CODES ANNUAL REPORT 2009

CODES
ARC CENTRE OF EXCELLENCE IN ORE DEPOSITS

ANNUAL REPORT 2009

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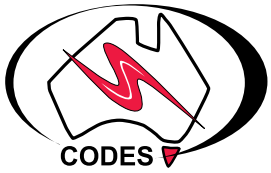

Australian Government

Australian Research Council

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CONTENTS

VISION

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

MISSION

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

CENTRE GOALS

- Undertake and publish high-quality research.
- Lead the global minerals industry in research on the exploration and recovery of new mineral resources.
- Equip the Australian minerals industry with world-class graduates.
- Communicate the Centre's research to the wider research, industry and general communities.

DIRECTOR'S REPORT

In 2009, CODES celebrated 20 years of operations as an ARC research centre. This significant milestone was recognised by a major international symposium in December and the release of *From the ground up* – a 150-page publication outlining the history of the Centre from the early days as a Key Centre through to its current status as a Centre of Excellence.

Numerous scientific achievements are highlighted in the book, but it is the statistics relating to the substantial growth of the Centre over this period that I believe encapsulate how far we have progressed. For example, at our inception in 1989 the entire research team consisted of just four academic staff, who were working on five projects confined entirely within Australia. This is in stark contrast to mid-2009 when academic staff numbers had risen to 42 researchers, working on over 50 projects, in 25 countries, on six continents.

The symposium, entitled CODES – *the First 20 Years*, was deliberately named to emphasise that although our anniversary provided an opportunity to celebrate the past, it was even more important to look to the future. I am pleased to report that 2009 has provided a number of highlights that indicate that CODES can look to its future with a great deal of optimism.

An integral part of our success has been how we have melded fundamental and applied research throughout our five programs. This has resulted in collaborations and partnerships with key players in the minerals industry, plus major national and international academic institutions. Some of the highlights of these collaborative initiatives over the past year include:

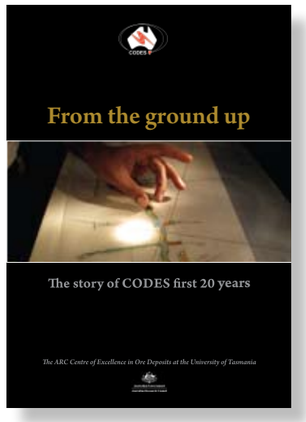
- The CODES-JKMRC-AMIRA P843 GeM[111] project was successfully completed in June, culminating with a final research meeting attended by over 70 industry sponsor representatives and academic researchers. Over the project's lifespan, nine sponsor-researcher meetings were held, and three technical volumes were produced – comprising 88 papers and 150 research presentations. Deliverables include nine hardware-based and seven software-based outcomes, which are currently undergoing technology transfer linked to benchmarking. Many of the methodologies from the project are currently in use at sponsor sites. Despite the global financial crisis, the industry support for the project has been overwhelming, which was demonstrated in July when the project was renewed for a further four-year period. The new project is entitled: AMIRA P843A, and has a new set of defined objectives and deliverables.
- The joint-funded Newcrest - ARC project on the evolution of the Cadia porphyry Cu-Au deposits in NSW has resulted in significant impacts on mine planning at Cadia East through detailed map interpretation and structural analysis. New target selection criteria were developed, which have contributed to a new breccia-hosted porphyry Au-Cu discovery. In July, Newcrest and CODES initiated a new collaborative project entitled Exploring the Porphyry Environment, which includes a targeted advanced education program, integrated with specific research objectives and deliverables.
- A collaborative project with BHP Billiton has generated a radically different view of the geological architecture of the giant Olympic Dam Cu-U deposit. This reopens the debate on the ore genesis and age of this deposit, and stimulates reconsideration of existing genetic models for similar IOCG deposits elsewhere. A project funded by OZ Minerals at Prominent Hill is having a similar dramatic influence on geological interpretation and timing of mineralisation in the Gawler Craton.
- Deliverables from CODES-AMIRA project P923 on trace element signatures in sediment-hosted gold deposits have been converted into four significant international publications. A landmark paper in *Economic Geology* in December showcased the first LA-ICPMS imaging of trace elements in pyrite in several gold deposits, showing the power of this revolutionary technique, which was developed in the CODES' laboratories. The impact and potential applications of this technique to ore targeting and mineral processing will be investigated in a new CODES-AMIRA project: P1041, starting early in 2010.
- CODES-AMIRA project P765A (Geochemical and geological halos in green rocks and lithocaps) continued to deliver significant results to sponsors involved in porphyry and epithermal exploration with the successful testing and implementation of a number of ore vectoring tools.
- Research on the fold belts and metallogenesis of South East Asia has gained considerable momentum, with ten companies now funding the research program. The focus is on the geochronology, tectonics and ore deposits of the Troung Son, Loei and Sukhotai fold belts and the Nan, Song, Phouc-Son-Tamky and Beotong Raub suture zones in Vietnam, Laos, Thailand, Cambodia, China and Malaysia. A new understanding of the tectonics of the region is being delivered to sponsors.
- A new model of sulphur solubility in silicate magmas was developed within the CODES-AMIRA P962 project. This research is being conducted in collaboration with the Russian Academy of Sciences with the aim of applying fundamental aspects of igneous petrology to the understanding of the Ni-PGE potential of mafic and ultramafic magmas. In a major breakthrough, it has been shown that nickel, despite its relatively low concentrations, has a pronounced negative effect on S solubility, causing an early onset of sulphide immiscibility. The new model is incorporated into COMAGMAT software, allowing quantitative simulations of sulphide-silicate assemblages, including changes in bulk sulphide-silicate ratios and sulphide compositions.

CODES has experienced exceptional growth over the past few years, and we realise that if we are to remain at the forefront of ore deposit research we need to invest in our infrastructure and facilities. Therefore, last year, with support from UTAS, our LA-ICPMS facility was expanded to cater for the rapidly increasing research requirements. An Excimer Resonetics M50 laser and new Agilent 7700 quadrupole ICPMS were acquired, which means that we now have two LA-ICPMS devoted to sulphide analyses and one to silicate analyses. One of the sulphide instruments will specialise in sulphide trace element imaging, with the second instrument used for quantitative sulphide multi-element analysis.

A vital part of our role as a Centre of Excellence is to provide a steady stream of quality geoscientists to the world. We place great emphasis on our graduate research and education programs, and we are very proud of the fact that so many of our alumni have gone on to take up senior positions in both commercial and academic fields. Therefore, I am pleased to report that our postgraduate program has continued its healthy growth and now has 56 enrolled PhD students, including 36 from overseas. In addition, the Master of Economic Geology program (part of the National Mineral Science Masters Program) had one of its most successful years with 13 new enrolments, which takes the total number of students to approximately 50.

Overall, our 20th anniversary year has been a good period for the Centre. It has resulted in a number of projects reaching a successful conclusion and exciting new projects being initiated. Our facilities have been significantly expanded, national and international collaborations have continued to grow, industry sponsors have reaffirmed support for our research – despite difficult economic conditions, and our postgraduate program has continued to go from strength to strength. With the minerals industry showing signs of recovery, particularly in Australia and China, the outlook is promising for another successful year in 2010. I am sure that with the continued valued support of the ARC, UTAS, collaborating institutions, industry partners and AMIRA International we can embrace future challenges and opportunities and look forward to the many anniversaries that lie ahead.

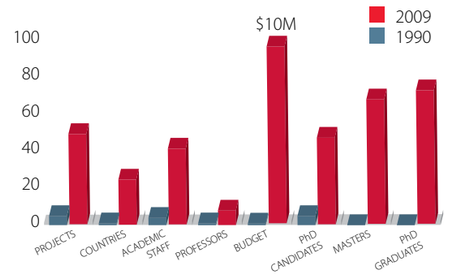
Ross R Large
Director and Chief Operations Officer



CODES' 20TH ANNIVERSARY

FROM THE GROUND UP

This year marked CODES' 20th anniversary. This landmark occasion was celebrated through a series of events and activities culminating in a major international symposium in December, which coincided with the release of a 150-page publication entitled *From the ground up*. This substantial publication covers the entire history of the Centre from the early days as a Key Centre through to its current status as a Centre of Excellence.



HIGHLIGHTS OF 20 YEARS OF GROWTH

The book highlights CODES' substantial growth over the years. For example, at its inception in 1989 the entire research team consisted of just four academic staff, who were working on five projects confined entirely within Australia. This is in stark contrast to 2009 when the academic staff had risen to 42 researchers, working on over 50 projects, in 25 countries, on six continents. The publication also tracks the remarkable growth in collaborations with industry and other academic institutions, a ten-fold increase in funding, a significant rise in higher research by degree (HDR) candidates and, more recently, the evolvement and expansion of the Centre into its current Hub and Nodes structure. In essence, it traces the story of CODES from being a small, Tasmanian research centre to becoming a truly international operation that is widely regarded as one of the world's foremost centres for ore deposit research.

Another notable achievement highlighted in *From the ground up* is the Centre's success in linking fundamental and applied research to deliver tangible benefits for the minerals industry. Three examples that underlined this success during this period were:

- Research that helped in the discovery of a 2.44 million tonne gold deposit at Newcrest's Gosowong gold field on Halmahera Island, Indonesia. This equates to 3.1 million ounces of refined gold.
- Research that assisted in the discovery of a major zinc, lead, copper, silver and gold ore deposit at Rosebery valued at over A$358 million.
- How the Centre has retained a balance of fundamental research, while evolving to meet industry needs by branching into new areas, such as geometallurgy.

SYMPOSIUM – CODES: *THE FIRST TWENTY YEARS*

A vital ingredient to CODES' success has undoubtedly been the high quality of people that have been involved with the Centre over the years. Although most of these people have now moved on, many to take up leading roles in industry and academia, they remain an integral part of the CODES family. The 20th anniversary symposium – CODES: *The First Twenty Years* – provided the ideal opportunity to bring these people back to the Centre with the aims of marking past achievements, covering the latest developments in the geosciences, and discussing future plans and trends – both for CODES and for the profession. Of course, it also provided the ideal opportunity for networking and catching up with old friends. Therefore, the symposium program was carefully crafted to include a number of social elements, while ensuring that the primary focus was to provide a world-class symposium covering topics at the forefront of the science.

The symposium was held over three days in early December at Hobart's Wrest Point conference centre, which is within walking distance of UTAS. Initially, it was planned to hold the event at CODES, but because of the high demand for places it had to be moved to a larger venue. In total, there were 38 national and international speakers who covered a range of topics relevant to CODES' activities – past, present and future. Key threads running throughout the presentations were the multidisciplinary team approach to major geoscientific challenges, the integration of fundamental and applied research, and the strong relationships developed with the global minerals industry.

At the end of the symposium, some delegates took advantage of the option of attending a four-day field trip that covered the full spectrum of mineralisation styles in Tasmania's geologically rich west coast region.

CODES' STRUCTURE & RESEARCH FRAMEWORK

ABOUT US

CODES is an Australian Research Council Centre of Excellence that is widely regarded as a global leader in ore deposit research. Formed in 1989, the Centre has grown substantially over the years and is now home to 68 highly qualified research staff and 127 postgraduate students, which makes it the largest university-based team of ore deposit researchers in the world.

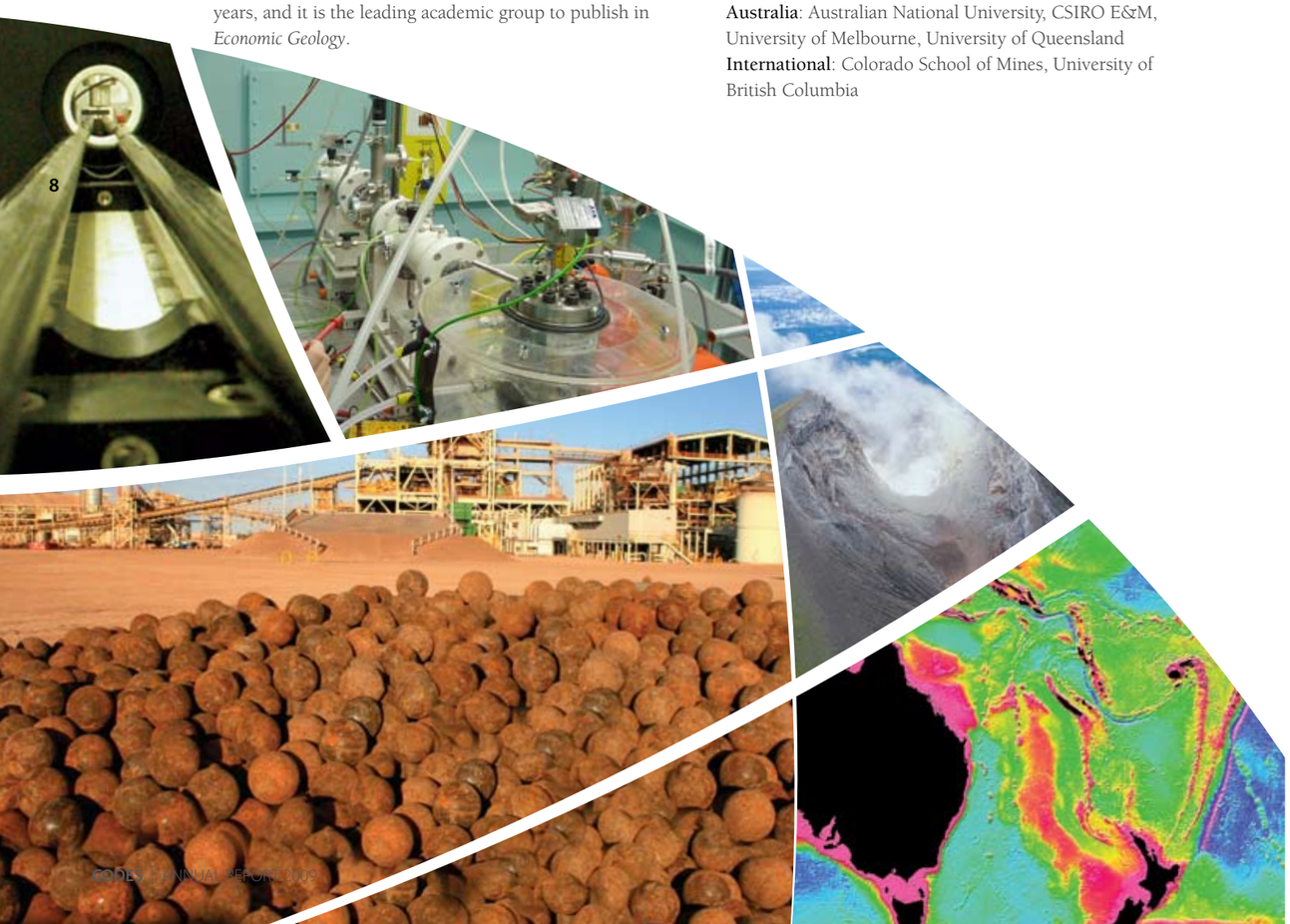
Highly productive worldwide collaborations have been developed with approximately 70 industry companies, plus a host of joint research initiatives with 79 institutes and universities – 18 in Australia and 61 overseas. It currently has 51 major research projects spanning 26 countries. Five hundred and seventy-three research reports have been issued to industry in the past four years, and it is the leading academic group to publish in *Economic Geology*.

CODES AT A GLANCE 2009

Academic research staff **68**
Postgraduate students **127**
Major research projects **51**
Publications in journals **58**
Research reports to industry **105**
Countries involved **26**
Industry funding **$4.5 million**
ARC funding **$3.7 million**
UTAS funding **$2 million**

Collaborating Nodes

Australia: Australian National University, CSIRO E&M, University of Melbourne, University of Queensland
International: Colorado School of Mines, University of British Columbia

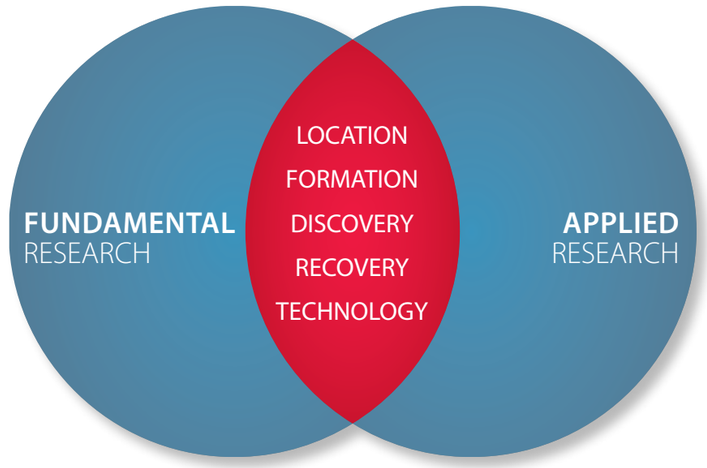


RESEARCH FRAMEWORK

CODES' research is built around five major programs that cover a wide spectrum of the geosciences including igneous petrology, geochemistry, melt/fluid inclusion research, volcanology, structural geology, tectonics, geophysics, ore petrology and geometallurgy.

The strategic focus of the Centre is based on a holistic, multidisciplinary approach that covers all elements of ore deposit research, from fundamental research through to applied research outcomes. Its modus operandi is to use advances in the fundamental research and technology programs to drive innovative team-based applied research, linked with industry. This is achieved through the five major research programs – Location, Formation, Discovery, Recovery and Technology.

- LOCATION builds on expertise in magmatic, volcanic and tectonic processes in diverse tectonic settings – includes groundbreaking research into magmas associated with nickel-PGE mineralisation. The program provides a better understanding of the links between tectonic setting, magmatism, basin evolution, and ore deposit formation in modern and ancient terrains.
- FORMATION develops practical, process-based ore genesis models to help explorers understand the formation of deposits. CODES has built a fine reputation for its research into process-based exploration models for hydrothermal and magmatic ore deposits. This research is enhanced by employing an integrated approach to solving metal source-transport-trap problems and utilising targeted collaborations with other leading research institutes.
- DISCOVERY focuses on the acquisition, processing and interpretation of scientific ore deposit data to assist in the discovery of minerals. CODES' 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 is an integrated, cross-disciplinary field that seeks to enhance mineral processing techniques and optimise mineral recovery rates. 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 uses a combination of traditional and cutting-edge technological developments to improve the understanding and, subsequently, advance the exploration and exploitation of minerals. CODES is at the forefront of advances in spatially resolved, inductively coupled plasma mass spectrometry (ICPMS), nuclear microprobe (NMP), and synchrotron-based non-destructive focused-beam spectroscopy and software development.



TEAMWORK

The Centre continues to place a great emphasis on teamwork. Co-operation and collaboration is openly encouraged, both within CODES and in its interactions with a host of national and international organisations. This team approach is inherent in the five research programs, which foster teamwork through an overlapping and interlinked process that follows a logical progression from area selection through to exploration, discovery and recovery.

HUB AND NODES

CODES is based at the University of Tasmania, with satellite facilities, known as nodes, at the University of Queensland, University of Melbourne, Australian National University, CSIRO Exploration and Mining, the University of British Columba (Canada) and the Colorado School of Mines (USA).

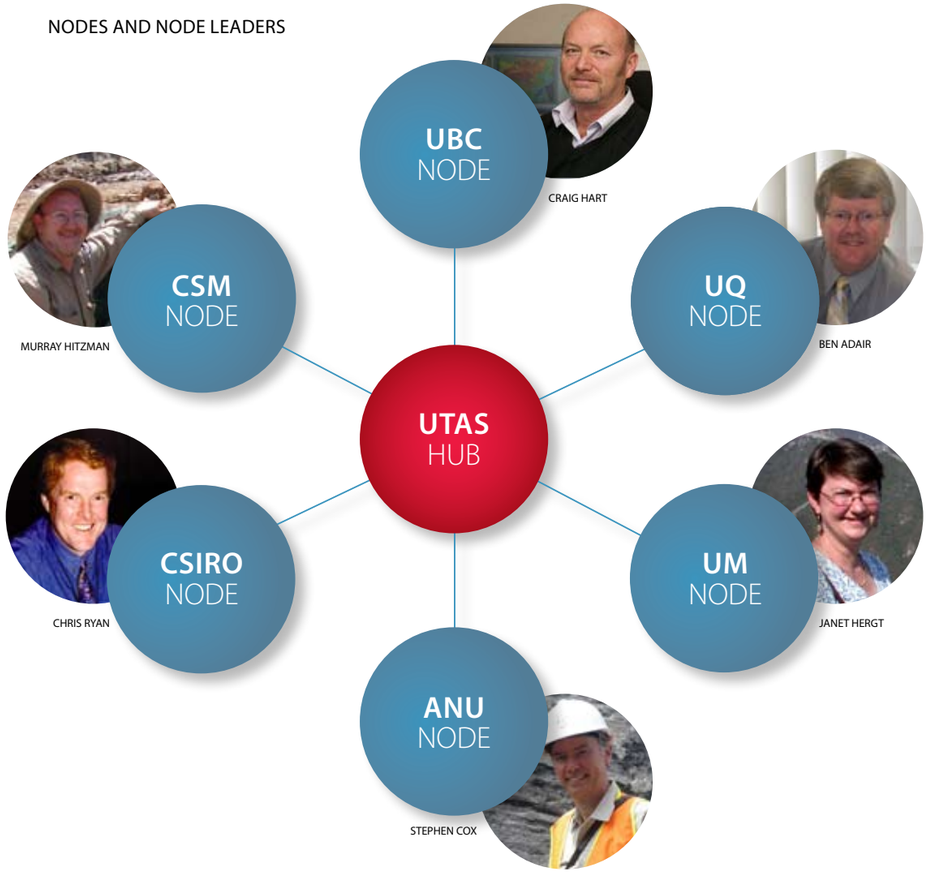
This structure provides an exceptionally strong mix of skills and facilities by combining the research strengths of CODES' UTAS Hub, with the diverse range of expertise available through the nodes. The nodes' strengths include:

- Metallurgy and mineral processing - JKMRC (University of Queensland).
- Structure of ore deposits (Australian National University).
- Isotope geochemistry (University of Melbourne).
- Micro-beam analytical techniques (CSIRO Exploration and Mining).

The strengths of these Australian nodes are complemented by the overseas nodes, which provide an ideal platform for international research projects and augment the Centre's access to the latest technology. Collaborations with international nodes include:

- Joint research projects in mineral deposits, geochronology and geophysics (University of British Columbia).
- Joint research projects with Murray Hitzman and his team (Colorado School of Mines).

NODES AND NODE LEADERS



STAFF & MANAGEMENT

CENTRE DIRECTOR

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

ADVISORY BOARD

The Advisory Board meets annually to review the progress of the Centre and to advise on future directions. The Board is composed of major industry partners, University of Tasmania senior management, and key national geoscience organisations. It 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 relating to the Centre's scientific research progress and to discuss potential new research projects. The membership is wider than that of the Advisory Board and includes a representative from all partner 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. It meets annually to discuss research progress, new research opportunities and particularly to focus on effective collaborative activities across all Centre partners.

EXECUTIVE COMMITTEE

The Executive Committee consists of the Centre Director, Deputy Director, five program leaders and administrative managers. It meets approximately six times a year, working closely with the Director to develop the Centre's goals, strategies and performance indicators.

STAFF APPOINTMENTS IN 2009

Kate Bromfield was appointed as a research assistant to study the microfossils recovered from samples relating to the Ore Deposits of SE Asia project. Kate completed her BSc Honours in Palaeontology at UTAS in 2003, and her PhD in Marine Palaeoecology at the Centre for Marine Studies, University of Queensland in 2009.

Leon Graham joined the ITsoil Help Desk team mid-year to provide geophysics IT support, working with Anya Reading. Towards the end of 2009 Leon was offered a position as a Research Fellow to undertake applied seismology research.

Marcel Guillong has joined CODES as a laboratory analyst, working with Leonid Danyushevsky and Sarah Gilbert within the laser ablation ICPMS facility. Marcel completed his PhD in the field of laser ablation at ETH, Zurich in 2004. He has also worked in a similar role at ETH.

Karen Mollross has joined the finance team as a Finance Officer. Karen has extensive experience in administration and customer service positions within a number of large organisations.

Ross Olsen has taken over the joint CODES/SES position of Geophysics Technician. Primary responsibilities include co-ordination of the geophysics laboratory and maintenance of geophysics field equipment. He also provides logistic and field support for research headed by Anya Reading, and ongoing support of the GeoTek MSCL (Multi Sensor Core Logger).

SYNERGY **TEAMWORK** COLLABORATION

CODES STAFF

(% IN CODES)

STAFF AND MANAGEMENT

NAME		%	NAME		%
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 Au-Ag	50

ACADEMIC/RESEARCH STAFF AT UTAS

NAME		%	NAME		%
Dr Sharon Allen, BSc (Massey), MSc (Auckland), PhD (Monash)	Volcanic facies analysis	50	Dr Maya Kamenetsky, PhD (UTAS)	MLA-SEM, geometallurgy, petrology	100
Dr Mike Baker, BSc Hons (Sydney), PhD (UTAS)	Igneous petrology, mineral chemistry	100	Professor Vadim Kamenetsky, BSc Hons (Moscow), PhD (Vernadsky Inst.)	Petrology and geochemistry of melt inclusions	50
Associate Professor Ron Berry, BSc, PhD (Flinders)	Structure of mineralised provinces, CHIME dating, geometallurgy	50	Associate Professor Khin Zaw, BSc (Rangoon), MSc (Queen's), PhD (UTAS)	Fluid inclusions, SE Asian metallogenesis	100
Dr Stuart Bull, BSc Hons, PhD (Monash)	Clastic and carbonate sedimentology and volcanology	75	Dr Lyudmyla Koziy, PhD (UTAS)	Fluid flow modelling	100
Dr Isabelle Chambefort, MSc (Clermont-Ferrand), PhD (U Geneva)	Petrology	100	Dr Peter McGoldrick, BSc Hons, PhD (Melbourne)	Geochemistry of ore deposits and their halos	50
Dr Zhaoshan Chang, BSc (PKU), PhD (PKU, WSU)	Skarn, porphyry and epithermal deposits; LA-ICPMS zircon dating	100	Dr Andrew McNeill, BSc Hons, PhD (UTAS)	Petrology, VHMS deposits, mineral exploration	100
Dr Huayong Chen, BSc, MSc (PKU), PhD (Queen's)	IOCG, porphyry and epithermal deposits	100	Professor Jocelyn McPhie, BA Hons (Macquarie), PhD (UNE)	Volcanic facies architecture and volcanic textures	50
Professor David Cooke, BSc Hons (Latrobe), PhD (Monash)	Fluid-rock geochemistry, porphyry Cu-Au	50	Dr Sebastien Meffre, BSc Hons, PhD (Sydney)	Petrology and tectonics of the SW Pacific	50
Professor Tony Crawford, BSc Hons, PhD (Melbourne)	Petrology, geochemistry and tectonics of volcanic arcs	50	Dr Steven Micklethwaite, BSc, PhD (Leeds)	Structural geology	100
Professor Leonid Danyushevsky, PhD (Vernadsky Inst.)	Petrology, geochemistry, application of melt inclusions	50	Dr Karin Orth, BSc Hons (Monash), PhD (UTAS)	Volcanology	50
Dr Garry Davidson, BSc Hons (ANU), PhD (UTAS)	Sulphur isotope geo-chemistry and Cu-Au ores	50	Dr Anya Reading, BSc Hons (Edinburgh), PhD (Leeds)	Geophysics, seismology, computational methods	50
Dr Paul Davidson, BSc Hons, PhD (UTAS)	Melt and fluid inclusions	100	Dr Michael Roach, BSc Hons (Newcastle), PhD (UTAS)	Geophysical responses of ore deposits	50
Dr Trevor Falloon, BSc Hons (Canterbury), BTeaching, PhD (UTAS)	Marine geoscience, petrology	50	Dr Rob Scott, BSc Hons, PhD (Monash)	Structural geology, gold deposits	100
Dr Sandrin Feig, MSc, PhD (Hannover)	Petrology	100	Dr Dave Selley, BSc Hons (Adelaide), PhD (UTAS)	Structural geology/basin analysis, sedimentary Cu	100
Associate Professor Jeff Foster, BSc Hons (City), MSc (Leicester)	Magmatic ore deposits	100	Dr Michael Solomon, MSc, PhD (UTAS), DSc (London)	Geochemistry and genesis of mineral deposits	20
Dr Jacqui Halpin, BSc Hons (Melbourne), PhD (Sydney)	Metamorphic petrology, geochronology	100	Dr Helen Thomas, MSc (Leicester), PhD (Manchester)	Geochemistry, geochronology	100
Dr Anthony Harris, BSc Hons, PhD (UQ)	Ore deposit geology/ geochemistry	100	Professor Steve Walters, BSc Hons, PhD (Sheffield)	Geometallurgy, applied mineralogy, exploration technologies	50
Dr Julie Hunt, MSc (UBC), PhD (JCU)	Geometallurgy, IOCG deposits	100	Dr Tony Webster, BSc Hons (Latrobe), BA (UNE), MSc (JCU), PhD (UTAS)	MTEC Senior Lecturer and Masters Program Coordinator	50
Dr David Hutchinson, HND (Camborne, Sch of Mines), BSc Hons, PhD (Cardiff)	Ni-Cu/PGE mineralisation	100	Professor Jamie Wilkinson, BA Hons (Cambridge), PhD (Southampton)	Geochemistry and isotopes of ore fluids	100
Dr Emily Johnson, BSc (Michigan), PhD (Oregon)	Petrology, physical volcanology	100			

ACADEMIC/RESEARCH STAFF BASED AT COLLABORATIVE INSTITUTIONS

NAME	INSTITUTION	%	NAME	INSTITUTION	%
Professor Ben Adair	Node Leader: University of Queensland: JKMRC	10	Dr Weihua Liu	CSIRO Exploration & Mining	20
Dr Stacey Borg	CSIRO Exploration & Mining	100	Dr Roland Maas	University of Melbourne	15
Professor Deirdre Bradshaw	University of Queensland: JKMRC	43	Dr Angus McFarlane	University of Queensland: Parker	20
Professor Alan Bye	University of Queensland: BRC	25	Dr Simon Michaux	University of Queensland: JKMRC	75
Professor Stephen Cox	Node Leader: Australian National University	20	Dr Rob Morrison	University of Queensland: JKMRC	5
Dr Nenad Djordjevic	University of Queensland: JKMRC	5	Dr Khoi Ke Nguyen	University of Queensland: JKMRC	100
Professor Grant Garven	TUFTS	10	Dr Italo Onederra	University of Queensland: BRC	15
Dr Louisa Groves	University of Queensland: JKMRC	88	Dr Chad Paton	University of Melbourne	25
Dr Angela Halfpenny	Australian National University	100	Dr Bence Paul	University of Melbourne	75
Dr Craig Hart	UBC, MDRU	30	Dr Chris Ryan	Node Leader: CSIRO Exploration & Mining	30
Associate Professor Jeff Hedenquist	Colorado School of Mines	10	Miss Esther Soden	University of Queensland: JKMRC	80
Associate Professor Janet Hergt	Node Leader: University of Melbourne	10	Professor Steve Walters	University of Queensland: JKMRC	50
Professor Murray Hitzman	Node Leader: Colorado School of Mines	20	Dr Yicai Wang	University of Queensland: JKMRC	75
Dr Jamie Laird	CSIRO Exploration & Mining	100	Dr Jon Woodhead	University of Melbourne	15

TECHNICAL/ADMINISTRATIVE STAFF

NAME	TITLE	%	NAME	TITLE	%
Dr Kate Bromfield	Research Assistant	20	Dr Roman Leslie	Research Assistant	50
Mr Steve Calladine	Communications Manager	100	Mrs Katie McGoldrick	Laboratory Assistant	50
Mrs Michele Chapple-Smith	Lapidary Technician	40	Mrs Karen Mollross	Finance Officer	50
Mr Peter Cornish	Laboratory Manager	50	Ms Caroline Mordaunt, BA Hons (King's College London)	Administrative Assistant	50
Mr Alex Cuison	Laboratory Technician	80	Mr Ross Olsen	Geophysics Laboratory Technician	50
Ms Grace Cumming	Research Assistant	30	Ms June Pongratz	Publications and Media Resource Centre Manager	50
Ms Sarah Gilbert, BSc Hons (UTAS)	Senior Technician ICP-MS	100	Mr Philip Robinson, BSc Hons (Nottingham)	Analytical Services Manager	100
Dr Marcel Guillong	Laboratory Analyst ICP-MS	100	Miss Helen Scott, BSc Hons (UTAS), BEd (QUT)	Finance Officer	75
Ms Christine Higgins, Grad. Cert. Management (UTAS)	Finance Manager	50	Ms Dianne Steffens	Finance Officer	50
Mrs Nilar Hlaing, BSc (Rangoon)	Personal Assistant to the Director	100	Mr Simon Stephens, BSc (UTAS)	Lapidary Services Manager	50
Mr Shaun Inglis	Research Technician	100	Ms Isabella von Lichtan, BSc Hons (UTAS)	Curator/ MTEC Administrative Assistant	50
ITsoil Pty Ltd Help Desk	IT support	50			

ADVISORY BOARD

NAME		NAME	
Chair: John Dow	Consultant	John Hammond	Newmont Exploration
Ben Adair	Director, JKMRC	Janet Hergt	University of Melbourne
Paul Agnew	Rio Tinto	John Holliday	General Manager, Property Generation, Newcrest
Trevor Beardsmore	Barrick Gold	Ross Large	Director, CODES
Tony Brown	Executive Director, Mineral Resources Tasmania	Jo Laybourn-Parry	Pro Vice-Chancellor Research, UTAS
Graham Carr	CSIRO	Jocelyn McPhie	Co-ordinator Graduate Research, CODES
Stephen Cox	Australian National University	Jim Reid	Dean, Faculty of Science, Engineering and Technology, UTAS
Andrew Cuthbertson	AngloGold Ashanti	Ian Sandl	Teck Resources
Mihir Deb	University of Delhi	Steve Turner	Newmont Exploration
Kathy Ehrig	BHP Billiton	Steve Walters	Recovery Program Leader, CODES
Bruce Gemmell	Deputy Director, CODES	Noel White	Consultant
Alan Goode	Research Director, AMIRA International	Ian Willis	VP Exploration, Anglo American

EXECUTIVE COMMITTEE

NAME		NAME	
Chair: Ross Large	Director, CODES	Bruce Gemmell	Deputy Director, CODES
Steve Calladine	Communications Manager	Christine Higgins	Finance Manager
David Cooke	Formation (2) Program Leader	Nilar Hlaing	Personal Assistant to the Director
Tony Crawford	Location (1) Program Leader	Jocelyn McPhie	Co-ordinator Graduate Research
Leonid Danyushevsky	Technology (5) Program Leader	June Pongratz	Publications and Media Resource Centre Manager
Jeff Foster	Discovery (3) Program Leader	Steve Walters	Recovery (4) Program Leader

SCIENCE PLANNING PANEL

(also includes the Executive Committee and all CODES research staff and students)

NAME		NAME	
Chair: Ross Large	Director, CODES		
Ben Adair	JKMRC	Duncan Gibbs	AngloGold Ashanti
Stacey Borg	CSIRO	Alan Goode	AMIRA International
Tony Brown	Mineral Resources Tasmania	John Hammond	Newmont Exploration
Graham Carr	CSIRO	Paul Heithersey	PIRSA
Darryl Clark	Vale	Janet Hergt	University of Melbourne
Dean Collett	Newcrest Mining Limited	John Holliday	Newcrest Mining Limited
Stephen Cox	Australian National University	Adrian McArthur	St Barbara Limited
Andrew Cuthbertson	AngloGold Ashanti	Bence Paul	University of Melbourne
Kim Denwer	Bass Metals	Greg Shirtliff	Cameco
John Dow	Consultant	Jon Woodhead	Unviersity of Melbourne
David Green	Mineral Resources Tasmania	Noel White	Consultant
Geoff Green	Mineral Resources Tasmania	Ian Willis	Anglo American

CODES

the first 20 years

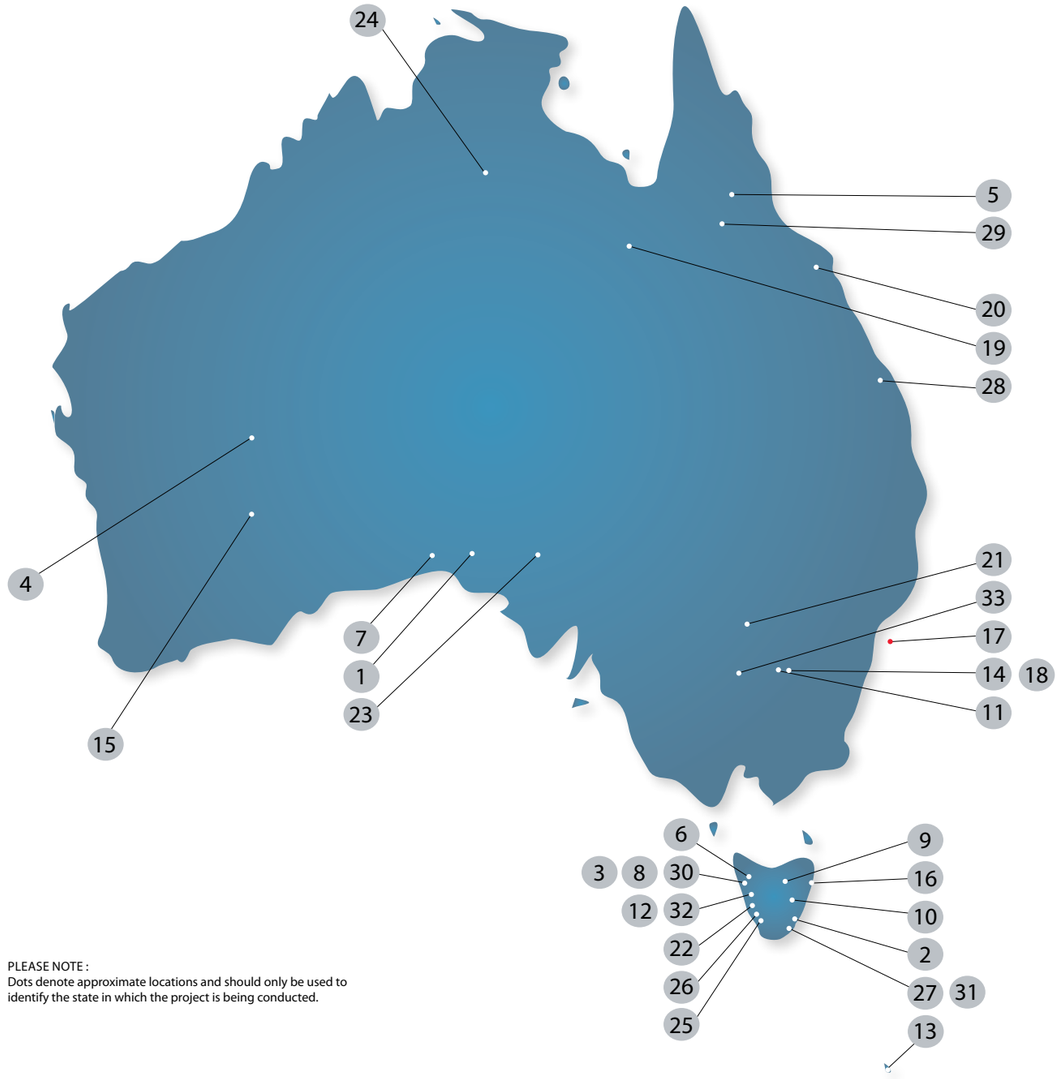
1989 to 2009

STUDENT PROJECTS

STUDENT PROJECTS IN AUSTRALIA

Project locations are shown in capitals. Unless marked otherwise, student projects shown here are field and lab-based Phd projects.

1. **Agangi, Andrea,** SA
   Magmatic and volcanic evolution of giant intraplate felsic igneous provinces: Gawler Range Volcanics and Hiltaba Suite, South Australia.
2. **Allen, Chris,** TAS (Hons)
   Characterisation and mapping of coastal acid sulphate soils in the Pitt Water Estuary, Tasmania.
3. **Andrews, Darren,** TAS
   Geophysical monitoring of acid mine drainage at Savage River Mine, Northwestern Tasmania.
4. **Belford, Susan,** WA
   Genetic and chemical characterisation of the Archaean Jaguar VHMS deposit.
5. **Best, Fiona,** QLD
   The petrogenesis of the Dido Tonalite, northern Queensland.
6. **Bold, Tiffany,** TAS (Hons)
   Stratigraphy of the Southwell Subgroup (above the Hellyer level), western Tasmania.
7. **Bowden, Bryan,** SA
   Geology, geochemistry and genesis of the Prominent Hill IOCG Deposit, South Australia.
8. **Braniff, Victoria,** TAS
   The structure and deformational history of the Savage River magnetite Orebodies, NW Tasmania.
9. **Chmielowski, Reia,** TAS
   The Cambrian metamorphic history of Tasmania.
10. **Cracknell, Matthew,** TAS (Hons)
    Application of Lidar technology to structural stratigraphic mapping in Tasmania.
11. **Cuison, Ana Liza,** NSW
    Geology and genesis of the Ridgeway porphyry Au-Cu deposit, NSW.
12. **Evans, Lee,** TAS
    Ground waters in wet, temperate sulphide mining districts: delineation of modern fluid flow and predictive modelling to improve management after mine closure (Rosebery, Tasmania).
13. **Ferguson, Paul,** TAS
    Origins of large negative anomalies in oceanic crust, Macquarie Island.
14. **Fox, Nathan,** NSW
    Controls on alteration and mineralisation in the Cadia East Au-Cu porphyry copper deposit, NSW, Australia.
15. **Heathcote, Jacob,** WA (Hons)
    Aspects of improvements to beneficiation of iron ores: Hamersley field area.
16. **Heckscher, Norman,** TAS (Grad.Dip.Sci)
    The ambient seismic wavefield of Eastern Tasmania.
17. **Howe, Stephanie,** NSW (Hons)
    Comparison of petrophysical properties derived from wireline well logs and measurements on rock core NSW, Sydney Basin.
18. **Keeney, Luke,** NSW (JKMRC)
    Integrated geometallurgical modelling of the Cadia East deposit.
19. **Kirkby, Patrick,** QLD (Hons)
    Origin of IOCG-style mineralisation in the Mt Dore deposit, Mt Isa Inlier.
20. **Kor, Ting,** QLD (Hons)
    Hydrothermal breccias at the Coalstoun porphyry Cu-Au-Mo deposit, SE Queensland.
21. **Kyne, Roisin,** NSW
    Structural controls on mineralisation, including sulphide mineralogy, at the CSA mine, Cobar NSW.
22. **Lygin, Alexey,** TAS
    The geology, geochemistry and genesis of the Avebury Ni deposit, Tasmania.
23. **Mackay, Wallace,** SA
    Sedimentology and structure of the Curdimurka Subgroup, Willouran Range, South Australia.
24. **Maier, Rodney,** NT
    Pyrite and base metal trace-element halos in the northern Australia Zn-Pb-Ag deposits.
25. **Pereira da Fonseca, Pedro,** TAS
    Strato-tectonic setting of massive sulphide deposits: Mount Read Volcanics (western Tasmania) and the Iberian Pyrite Belt (Portugal).
26. **Rast, Katrina,** TAS (Hons)
    Thermal characteristics of the Parmeener Supergroup, Tasmania.
27. **Shafaee, Maryam,** TAS (Grad. Dip. Sci)
    A geophysical investigation of the Coal Mines Historic Site, Saltwater River, Tasmania.
28. **Slater, Michelle,** QLD (Hons.)
    Geophysical surveying and modelling of geothermal plays, south-east Queensland.
29. **Vincent, Carla,** QLD (Hons)
    The Lynd: a nickel prospective system in North Queensland.
30. **Webb, Liam,** TAS (Hons)
    A geophysical study into the Savage River Iron Ore deposits.
31. **Whitfield, Alison,** TAS (Hons)
    Sedimentology of the Permo-Triassic transition in the northern Tasman Peninsula, Tasmania.
32. **Williams, Lucas,** TAS (Hons)
    Volcanology of the hangingwall volcaniclastics at Rosebery mine.
33. **Zukowski, Wojciech,** NSW
    Geology and mineralisation of the Endeavour 41 gold deposit, Cowal district NSW, Australia.



PLEASE NOTE :
Dots denote approximate locations and should only be used to identify the state in which the project is being conducted.

LAB-BASED PROJECTS – SINGLE OR MULTI-SITES

Bonnici, Natalee
Textural and mineralogical characterisation of Cu-Au systems in relation to process mineralogy.

Bychkov, Kirill
Numerical modelling of sulphide precipitation from mafic magmas with implications for the formation of layered intrusions.

Chauhan, Mitesh (JKMRC)
Application of small scale flotation testing.

Evans, Cathy (JKMRC)
The relationship between mineral characteristics of ores and the variation in their processing attributes.

Hoschke, Terry (MSc.Exp.Geo)
Geophysical signatures of gold-copper porphyry systems.

Leigh, George (JKMRC)
Multi-resolution image analysis for process mineralogy.

McMahon, Claire
Controls on the major and trace elements content of pyrite in hydrothermal alteration envelopes.

Parbhakar-Fox, Anita
Texture-based approaches to predictive geo-environmental modelling.

Schaa, Ralf
Rapid approximate 3D inversion of transient electromagnetic data.

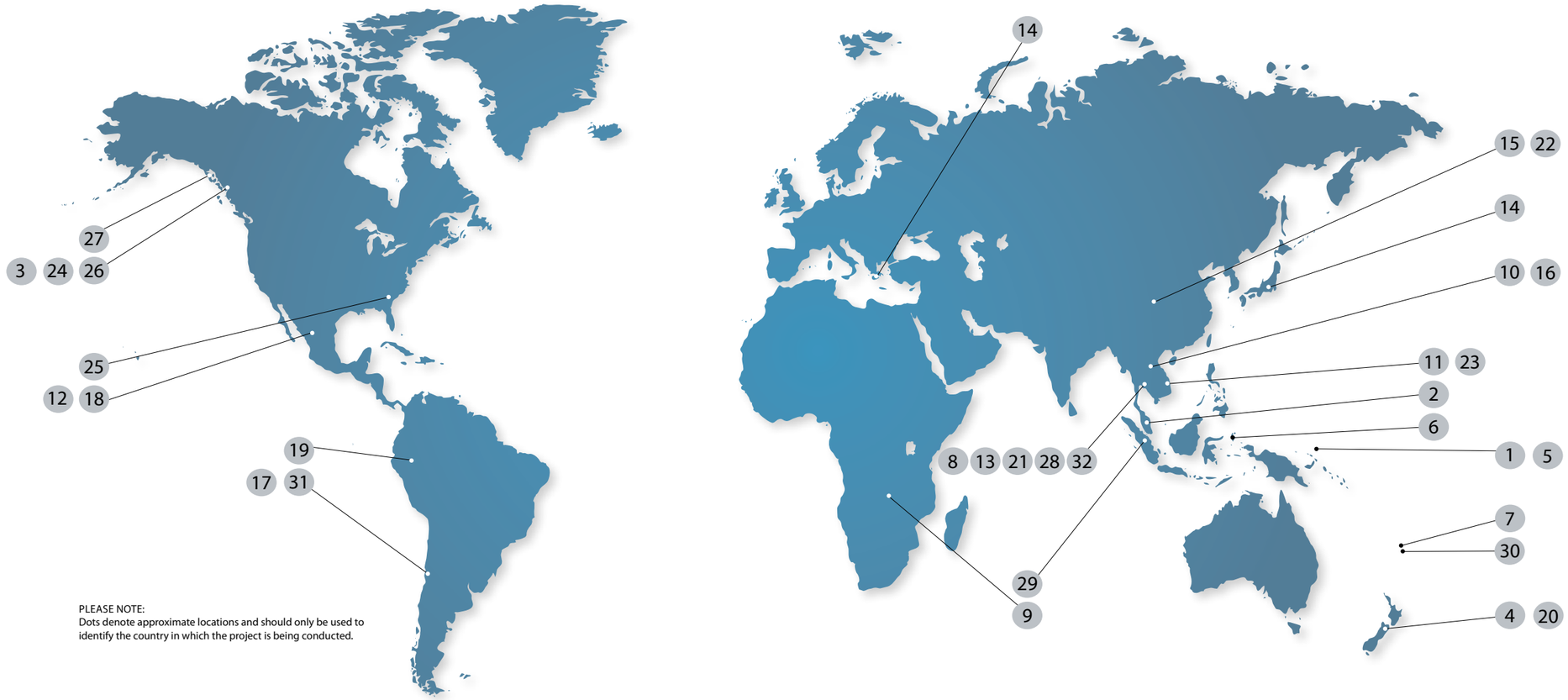
Singoyi, Blackwell
Controls on the geochemistry of magnetite in hydrothermal fluids.

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

Vatandoost Kohnehshahri, Adel
Automated petrophysical characterisation of drill core as a link to mineral processing attributes.

STUDENT PROJECTS OUTSIDE AUSTRALIA

Project locations are shown in capitals. Unless marked otherwise, student projects shown here are PhDs.



PLEASE NOTE:
Dots denote approximate locations and should only be used to identify the country in which the project is being conducted.

1. **Ageneau, Mathieu**, PAPUA NEW GUINEA
   Geology and geochemistry of the Kapit, Lienetz and Minifie ore zones, Ladolam gold deposit, Lihir Island, Papua New Guinea.
2. **Basori, Mohd Basril Iswada Bin**, MALAYSIA
   Geology of Volcanic Hosted Massive Sulphide (VHMS) deposits in Central Belt, Peninsular Malaysia.
3. **Bath, Adam**, CANADA
   Geology, geochronology and alteration of the Lower Main Zone, Lorraine, alkalic porphyry Cu-Au-Ag ± PGE deposit, north-central British Columbia.
4. **Berkenbosch, Heidi**, NEW ZEALAND
   Geochemistry of hydrothermal mineral chimneys from Brothers volcano, Kermadec arc.
5. **Blackwell, Jacqueline**, PAPUA NEW GUINEA
   Characteristics and origins of breccias in an alkalic epithermal gold deposit: Ladolam, Lihir Island, Papua New Guinea.
6. **Clark, Lindsey**, INDONESIA
   The geology and genesis of the Kencana epithermal Au-Ag deposit, Gosowong goldfield, Halmahera Island, Indonesia.
7. **Cobenas Benites, Gisela**, SW PACIFIC
   Metal and volatile contents of primitive subduction-related magmas (Hunter Ridge, SW Pacific): Assessing magmatic contributions to volcanic-hosted seafloor mineralisation.
8. **Cooper, Traci**, THAILAND (Hons)
   Geochemical and geochronological constraints on evolutional history of the Shan-Thai terrane, southern Thailand.
9. **Croaker, Mawson**, ZAMBIA
   Geology and genesis of the Nkana copper deposit, Zambia.
10. **Cromie, Paul**, LAOS
    Geological setting, geochemistry and genesis of the Sepon Mineral District, Laos PDR.
11. **Dinh, Quang Sang**, VIETNAM
    Geochronology and geological evolution of the northern margin of the Kontum massif, central Vietnam.
12. **Galvan-Guiterrez, Victor Hugo**, MEXICO
    Palmarejo carbonate base-metals silver-gold epithermal deposit, Trogan Project, Chihuahua, Mexico.
13. **Gibson, Luke**, THAILAND (Hons)
    Geology and geochronology of the northern Nan Suture, Thailand.
14. **Gordee, Sarah**, GREECE, JAPAN
    Characteristics of submarine volcanic facies in oceanic arc depocentres.
15. **Guan, JianXiang**, CHINA
    Origin of associated magnetite and sulphide mineralisation in large gabbroic intrusions: A LA-ICP-MS study of minerals and melt inclusions from the Panzhihua and Taihe intrusions in Emeishan LIP and Duluth Complex.
16. **Hotson, Mark**, LAOS (Hons)
    The geochronology and tectonic framework of Cu-Au prospects in the Phonsovan district, northern Laos.
17. **Ireland, Timothy**, CHILE
    Geological framework of the mineral deposits of the Collahuasi district, Tarapacá, Chile.
18. **Jansen, Nicholas**, MEXICO
    Geology and geochemistry of the Ixhuatan lithocap, and its relationships to porphyry and epithermal mineralisation.
19. **Jones, Benjamin**, PERU
    Tectonic setting and magmatic evolution of the Antapaccay porphyry copper-gold and skarn deposit, Peru.
20. **Jutzeler, Martin**, NEW ZEALAND
    Behaviour of submerged eruption plumes using data from facies analysis of a variety of submarine pyroclastic successions.
21. **Kamvong, Teera**, THAILAND
    Geology and genesis of porphyry-skarn Cu-Au deposits at the northern Loei Fold Belt, Northeast Thailand and Laos.
22. **Lai, Chun Kit**, CHINA
    Tectonics and metallogenesis of ophiolites and volcanics in southwestern Yunnan, China.
23. **Manaka, Takayuki**, VIETNAM
    Geology and mineralisation characteristics of the Phuoc Son goldfields, central Vietnam.
24. **Micko, Janina**, CANADA (MDRU)
    The hydrothermal genesis of the alkalic Cu-Au porphyry deposit Galore Creek, northwestern British Columbia.
25. **Moye Jr, Robert Josephus**, 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.
26. **Pass, Heidi**, CANADA
    Chemical and mineralogical zonation patterns in the breccia-hosted Mt Polley alkalic porphyry copper-gold deposit, British Columbia, Canada.
27. **Sack, Patrick**, UNITED STATES
    Characterisation of the footwall lithologies, Greens Creek VHMS deposit, Admiralty Island, southeast Alaska.
28. **Salam, Abhisit**, THAILAND
    Geology and genesis of the Chatree deposits, Phetchabun Province, central Thailand.
29. **Sutopo, Bronto**, INDONESIA
    The Martabe Au-Ag high-sulphidation epithermal mineralisation in the Tapanuli Selatan district, North Sumatra Province, Indonesia: Implications for ore genesis and exploration.
30. **Tetroeva, Sofia**, FIJI
    Petrology and geochemistry of adakites and related rocks from the Hunter Ridge, Southwest Pacific.
31. **Urzua, Felipe**, CHILE
    Regional geology of the Escondida district, northern Chile.
32. **Wilkinson, Alice**, THAILAND (Hons)
    Geological setting and mineralisation characteristics of sedimentary rock-hosted Langu Au deposit, Satun district, southern Thailand.

PROGRAM ONE
LOCATION

OBJECTIVE

To better understand the links between tectonic setting, magmatism, basin evolution and ore deposit formation in modern and ancient settings.

LEADER
Tony Crawford

TEAM MEMBERS
Sharon Allen, Mike Baker, Ron Berry, Stuart Bull, Isabelle Chambefort, Grace Cumming, Leonid Danyushevsky, Paul Davidson, Trevor Falloon, Sandrin Feig, Jeff Foster, Karsten Goemann, Jacqueline Halpin, Emily Johnson, Dima Kamenetsky, Maya Kamenetsky, Ross Large, Roman Leslie, Peter McGoldrick, Andrew McNeill, Jocelyn McPhie, Sebastien Meffre, Anya Reading, Khin Zaw.

PHD STUDENTS
Andrea Agangi, Adam Bath, Mohd Basril Iswadi Bin Basori, Susan Belford, Fiona Best, Jacqui Blackwell, Kirill Bychkov, Gisela Cobenas, Paul Cromie, Sang Quang Dinh, Pedro Fonseca, Hugo Galvan, Sarah Gordee, JianXiang Guan, Martin Jutzeler, Teera Kamvong, Chun Kit Lai, Rod Maier, Takayuki Manaka, Abhisit Salam, Ralf Schaa, Sofia Tetroeva, Olga Vasyukova

Tony Crawford
Program Leader

MASTERS STUDENT
You Jin Lee

HONOURS STUDENTS
Traci Cooper, Luke Gibson, Mark Hotson, Carla Vincent, Alice Wilkinson

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American Museum of Natural History, USA - James Webster
Anglo American Exploration - Paul Polito, Tony Donaghy, Allan Kneeshaw
AngloGold Ashanti - Mark Doyle
ANU, RSES - Hugh O'Neill, Greg Yaxley
Beadell Resources - Rob Watkins
BHP Billiton - Kathy Ehrig, Nick Green
British Columbia Geological Survey, Canada - Kirstie Simpson
Chiang Mai University, Thailand - Weerapan Srichan, Phisit Limtrakun, Sampan Singharajwarapan, Yuenyong Panjasawatwong
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FrogTech - Nick Direen
Fullager Geophysics - Peter Fullager
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Geological Survey of Denmark and Greenland - Troels Nielsen
Geological Survey of NSW - Barney Stevens
Geological Survey of Queensland - Ian Withnall
Geological Survey of Western Australia - Catherine Spaggiari, Ian Tyler
Geoscience Australia - Terry Mernagh, David Huston
Ghent University, Belgium - Marlina Elburg
Guangzhou Institute Geochemistry, China - Weidong Sun
Hanoi University of Geology and Mining, Vietnam - Hai Thanh Tran
Hebrew University, Israel - Oded Navon
Imperial College London, UK - Andrew Berry
Independence Group - Tim Kennedy
Institute for Frontier Research on Earth Evolution, Japan - Yoshi Tamura
Institute of Earth Sciences-Academia Sinica, Taiwan - Georg Zellmer
Institute of Experimental Mineralogy Chernogolovka, Russia - Eduard Konnikov and Oleg Safonov
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Institute of Geology and Mineralogy, Russia - Alexander Golovin, Victor Sharygin, Sergey Smirnov
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National Taiwan University - Sun-Lin Chung
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Smithsonian Institution, USA - Richard Fiske
State Key Laboratory in Ore Deposit Geochemistry, China - Xieyan Song
Triton Gold - Greg Hall, Marcus Wilson
United States Geological Survey - Poul Emsbo
Universiti Kebangsaan Malaysia - Wan Faud Wan Hassan
University College of Science, School of Geology, Iran - Mirsaleh Mirmohammadi
University of California Riverside, USA - Timothy Lyons
University of Central Missouri, Department of Earth Science, USA - John Nold and Mark Dudley
University of Lisbon, Portugal - Jorge Relvas
University of Malaya - Azman Ghandi
University of Manitoba, Canada - Anton Chakhmouradian
University of Melbourne - Roland Maas, Jon Woodhead, Mark Kendrick, David Phillips
University of Naples, Italy - Benedetto DeVivo
University of Oregon, USA - Ilya Bindeman, Kathy Cashman
University of Oulu, Finland - Eero Hanski
University of Queensland - Sue Golding, Paulo Vasconcelos
University of Science and Technology, China - Yuling Xie
University of Western Australia - Mark Barley, Derek Marshall
University of Wollongong - Chris Fergusson
Vernadsky Institute, Russia - Alexey Ariskin, Alex Sobolev, Vladimir Naumov

HIGHLIGHTS

- Successful completion of research voyage SS03/2009 on the Hunter Ridge in the SW Pacific, using the RV *Southern Surveyor* (Leonid Danyushevsky, Chief Scientist).
- ARC Discovery (non-core) project awarded to Dima Kamenetsky.
- Successful UTAS Fellowship application by Peter McGoldrick and Ross Large to support 2010 visit by Prof Tim Lyons (University of California Riverside).
- The project has generated a radically different view of the architecture of Olympic Dam, a world-famous supergiant ore deposit, that reopens the debate on ore genesis and age, and will stimulate reconsideration of existing genetic models for similar deposits elsewhere.

INTRODUCTION

The Location Program hosts the majority of fundamental research being carried out in CODES, with a strong emphasis on magmatic petrology and geochemistry, tectonics, and volcanology. Researchers within this program work across the scales from microscopic to mountain belt, and from laboratory- to field-based studies, attempting to better understand the major controls on the location, timing and size of key ore deposits, particularly those in arc-backarc settings and in continental rift basins. Current projects cover a diverse range of themes, from fundamental to more strategic in nature, and team members with a more fundamental science background are strongly encouraged to become involved in at least one industry- or mineralisation-related project.

OUTLOOK

- **Completion of project P1A4 (Ore deposits of SE Asia), and negotiations for new follow-on project.**
- **Completion of project P1B2 (Ni-PGE potential of mafic and ultramafic magmas – a combined melt inclusions and numerical modelling approach (AMIRA P962)) and negotiations for a continuation project building on outcomes of AMIRA P962.**
- **Completion of P1B1 Olympic Dam project and negotiation with BHP Billiton for an new project on the architecture of breccia facies at Olympic Dam.**
- **Commencement of fieldwork on new project P1A5 (Multi-disciplinary 4D study of an Archaean craton margin and mobile belt – the Albany Fraser Orogen).**
- **Visit by Prof Tim Lyons (University of California Riverside) on UTAS Fellowship, and CODES International Collaboration funding, to work with Peter McGoldrick and Stuart Bull on project P1A3 (global ocean chemistry, marine basins and mineralisation).**

CORE PROJECTS

Theme 1A Geodynamic controls on the fertility of foldbelts, cratons and sedimentary basins

P1A1 **Palaeoproterozoic magmatism and mineralisation**

P1A2 **Mafic magmatism in modern submarine SW Pacific settings**

P1A3 **Global ocean chemistry, marine basins and mineralisation**

P1A4 **Ore deposits of SE Asia**

P1A5 **Multi-disciplinary 4D study of an Archaean craton margin and mobile belt – the Albany Fraser Orogen**

P1A6 **Tectonic significance and mineralisation potential of volcano-plutonic belts and ophiolites at the northern end of the Tasman Line, N Queensland**

Theme 1B Magmas, volatiles and metals

P1B1 **Felsic magmas in volcanic arcs and intraplate volcanic provinces – eruption style, degassing processes, fluid evolution and links to mineralisation**

P1B2 **Ni-PGE potential of mafic and ultramafic magmas – a combined melt inclusions and numerical modelling approach**

P1B3 **Unmixing in magmas**:

P1B3A This project includes ARC Discovery Project and Australian Professorial Fellowship to Dima Kamenetsky (DP0555984): Unmixing in magmas: Melt and fluid inclusion constraints on the identity, timing and evolution of immiscible fluids, salt and sulphide melts

P1B3B This project focuses on melt-melt immiscibility and the origin of magnetite-apatite deposits

PROJECT SUMMARIES

P1A1
PALAEOPROTEROZOIC MAGMATISM AND MINERALISATION

LEADER: Tony Crawford

TEAM MEMBERS: Mike Baker, Roland Maas (University of Melbourne)

COLLABORATORS: Barney Stevens, Ian Withnall

This project, which is effectively completed, focused on Palaeoproterozoic mafic magmatic rocks occurring as widespread sills in the Broken Hill Block of western NSW, with the aim of better understanding their role in the genesis of the Broken Hill Pb-Zn-Ag mineralisation.

A new model has been proposed in which the giant Broken Hill deposit formed from fluids evolved during extended fractionation of rift tholeiitic magmas that formed widespread sills across the Broken Hill Block. Accumulation of these magmas along a major syn-rift extensional detachment led to strong syn-kinematic fractionation, generating remarkably Fe-rich ferrogabbros along this structure. Fluids evolved from deeper, highly fractionated magma batches contained the magmatic Pb budget, and reacted with the ilmenite-rich ferrogabbros, concentrating Mn (and probably Zn), and transporting metals to sites of ore lens formation sub-seafloor in the syn-rift sediments. A detailed Pb isotopic study of the mafic sills of the Broken Hill Block was completed, and supports the new model for the Broken Hill mineralisation (Crawford & Maas in prep.). Presentations of the new model were made as an Invited Paper at the SGA conference in Townsville, at the CODES 20th Anniversary Symposium, and in-house to several exploration groups, including Anglo American, Ivanhoe and Highlake Resources.

To complement the Broken Hill study, Mike Baker examined the geochemistry of mafic magmatism of Palaeoproterozoic age in the Georgetown Block of North Queensland. A paper based on Mike's study was accepted for publication in *Precambrian Research*, and will be published in the first half of 2010.

P1A2
MAFIC MAGMATISM IN MODERN SUBMARINE SW PACIFIC SETTINGS

LEADER: Leonid Danyushevsky

TEAM MEMBERS: Tony Crawford, Trevor Falloon

STUDENT: Gisela Cobenas

COLLABORATORS: Andrew Berry, Hugh O'Neill, Pavel Plechov, Jon Woodhead

This project aims to improve the understanding of magma generation and evolution processes in the complex region of convergent plate margins in the Southwest Pacific. This tectonic setting is considered to be the likely modern analogue of the geodynamic environments that existed during formation of palaeo-magmatic sequences in the orogenic volcanic belts along eastern Australia, which host numerous styles of ore deposits. Understanding the processes, products and key 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.

The project has four long-term, interrelated aims:

- Assess variations in the initial magma volatile and chalcophile element contents among closely spatially and temporarily associated arc magmas on the Hunter Ridge, whose geochemical signatures cover boninite-tholeiite-calc-alkaline-adakite spectrum.
- Understand the behaviour of volatile and chalcophile elements during differentiation (basalt-andesite-dacite-rhyolite) of a single geochemical magma type.
- Compare volatile and chalcophile element contents in the initial magmas erupted at backarc basin spreading centres, spatially and temporally associated with diverse arc magmatism.
- Evaluate the importance of magma generation conditions above subduction zones for the metal and volatile budget of magmas.

Highlights included:

- The successful completion of research voyage SS03/2009 (L. Danyushevsky, Chief Scientist) on board RV *Southern Surveyor*. During this voyage, 11,600 km^2 of the seafloor at the southern margin of the North Fiji Back-arc Basin was swath-mapped, revealing the highly deformed nature of the entire Hunter Ridge crust. Coupled with information from previous voyages, a better understanding of the tectonic structure of the Hunter Ridge was achieved. Numerous newly discovered active submarine volcanic centres along the entire southern margin of the basin suggest that it is currently undergoing extension. Thirty-two successful wax-coring stations, at intervals of one to two nautical miles along the southernmost propagating spreading centre of the basin, recovered sufficient glass at each station to enable full chemical analysis. At each station, water property measurements aimed at identifying hydrothermal plumes were also conducted, using MAPR sensors.
- Using the beamline 13-ID-C, GeoSoilEnviroCARS (GSECARS, University of Chicago), of the Advanced Photon Source (Argonne National Laboratory, Chicago, USA), over 50 melt inclusions in olivine from different types of subduction-related lavas from the Hunter Ridge area were analysed for their Fe oxidation state. These data are crucial for understanding of the magma generation conditions of different magma types in the area.
- Development work continued, in cooperation with Dr Thomas Rodemann from the CSL, to develop a technique for quantitative analysis of CO_2 in melt inclusion – using FTIR microscopes at the CSL and the Australian Synchrotron.
- Two applications for beam time on the Australian Synchrotron infrared beam line (96 hours of beam time in total in August and November) were successful, and allow a continuation of the analysis of fluid and melt inclusions for Cu, Fe and Mn, which started in 2008.

The large amount of primitive, high-magnesian samples recovered from the Hunter Ridge allows for assessment of magma generation conditions of all geochemical types sampled. This information can be used to understand the importance of magma generation conditions for the metal and volatile budget of subduction-related magmas.

Analysis continued on samples from the SS10/2004 and SS08/2006 voyages of RV *Southern Surveyor*. Samples were submitted for major, trace and isotope analyses, with the results expected early in 2010. Mineral compositions have been studied in detail in 35 samples representing different magma types within the study area. Data synthesis is currently underway.

PhD student Fiona Best left the project in January 2009, and in July 2009 Gisela Cobenas commenced her PhD studies within this project.

P1A3
GLOBAL OCEAN CHEMISTRY, MARINE BASINS AND MINERALISATION

LEADERS: Peter McGoldrick, Stuart Bull

STUDENTS: Rod Maier, Derek Marshall (UWA)

COLLABORATORS: Poul Emsbo, Timothy Lyons

The project aims are:

- Decipher processes that controlled the sulphur chemistry and redox state of oceans that existed in northern Australia approximately 1.65 billion years ago.
- Understand how coeval ocean water interacted with hydrothermal fluids responsible for forming the giant northern Australian Proterozoic SEDEX Zn-Pb-Ag deposits.

The main outcomes for 2009 were:

- A paper by Derek Marshall, Steffen Hageman and Peter McGoldrick on the Citronen Fjord sedimentary Zn deposit in Greenland was reviewed and accepted (subject to revision) by *Economic Geology* (a poster summarising this work was presented at SGA 2009 in Townsville).
- A further 30 carbonate-associated (CAS) sulphur isotope measurements from siltstones of Lady Loretta Formation near Lady Loretta mine were carried out; the results should yield new insight into why these deposits contain unusually large amounts of barite compared to other Australian Proterozoic sedimentary Zn deposits.
- Oral presentations detailing sulphur isotope results from Rod Maier's work on the Bluebush prospect were presented at Goldschmidt 2009 held in Davos, and SGA 2009 in Townsville. Peter McGoldrick also gave an invited presentation at Goethe Universitat, Frankfurt, as part of their regular seminar series.

Two short papers are nearing completion: 'Latest Paleoproterozoic ferruginous oceans: chemical and textural evidence from northern Australian basins', and 'Seawater evaporation and density-driven fluid flow: implications for SEDEX zinc models'. The latter is an invited contribution for *Economic Geology*.

P1A4
ORE DEPOSITS OF SE ASIA

LEADERS: Khin Zaw, Sebastien Meffre

TEAM MEMBERS: Tony Crawford, Grace Cumming, Jacqueline Halpin, Ross Large

STUDENTS: Mohd Basril Iswadi Bin Basori, Traci Cooper, Sang Quang Dinh, Luke Gibson, Mark Hotson, Teera Kamvong, Chun Kit Lai, You Jin Lee, Takayuki Manaka, Abhisit Salam, Alice Wilkinson

COLLABORATORS: Pol Chaodumrong, Wan Fuad Wan Hassan, Azman Ghandi, Sue Golding, Teh Guan Hoe, Somboon Khositanont , Phisit Limtrakun, Yuenyong Panjasawatwong, Sampan Singharajwarapan, Weerapan Srichan, Holly Stein, Hai Thanh Tran

This project investigates the mineralised foldbelts and suture zones of mainland SE Asia. It commenced in January 2008, building on the successful outcomes and results of the Loei ARC Linkage Project: 'Geochronology, metallogenesis and deposit styles of Loei Fold Belt (LFB) in Thailand and Laos PDR'. The primary aims are to study:

- The timing of formation of Cu, Au, Pb and Zn deposits relative to magmatic and tectonic events in mainland SE Asia.
- The style, and metal and hydrothermal fluids sources for the deposits in the region.

In 2009, the project team produced investigations of the following fold belts and suture zones, and their related ore deposits in SE Asia:

- Central Vietnam (Kontum Massif and Phuoc Son-Tamky Suture): a regional field sampling program on the Phouc Son-Tamky Suture Zone in central Vietnam, which included supervision of higher degree students (Taka Manaka, You Jin Lee) working on the Bong Mieu and Phouc Son orogenic Au deposits.
- Northern Vietnam (Song Ma/Song Da sutures).
- Northern part of the Loei Fold Belt in Laos: a detailed field sampling and core logging program undertaken in February on the Au and Cu-Au deposits in the Phonsavan District, which included supervision of Honours student Mark Hotson, and regional sampling in southern Lao PDR (Savhanakhet Province).
- Troung Son Fold Belt in Laos and Vietnam: further geochronological work and whole-rock analytical studies of mafic and granitic rocks along the northern margin of the Kontum Block form part of the PhD study of Sang Quang Dinh, currently in its third year.
- Thailand (Nan Suture Zone): Regional sampling and field work was undertaken along the northern section of the Nan Suture in Thailand as part of the study by Honours student Luke Gibson on the tectonic development of the Nan Suture.
- Bentong Raub Suture Zone in Malaysia: A detailed field program (including core logging and sampling), which included supervision of PhD student Mohd Basril Iswadi Bin Basori.
- Southern Yunnan: Regional sampling and field work were undertaken in May and December in southern Yunnan (China) as part of PhD student Chun Kit Lai's study on the tectonic development and metallogenesis of southern Yunnan.

The project provided comprehensive spatial and temporal relations of magmatic, volcanic and hydrothermal events, and improved conceptual and genetic models for the formation of Cu-Au, Pb-Zn and other mineral resources in mainland SE Asia. Deposit-scale studies characterised the Cu-Au skarn deposits (Phu He, Bohr Thong, KTL, Tharkaek, NNN) in Phonsavan District of Lao PDR, orogenic/mesothermal Au deposits at Selinsing (Malaysia) and Bong Mieu (Vietnam), and shale-hosted Phuoc Son Au deposits in Vietnam.

Four Honours student projects were completed:

- Alice Wilkinson: Geology and mineralisation characteristics of the Langu Au deposit, Satun Province, Thailand.
- Traci Cooper: Geochemistry and geochronology, evolution and history of the Sibumasu Terrane, southern Thailand.
- Mark Hotson: Geochronology and tectonic framework of Cu-Au deposits, Phonsavan District, northern Lao PDR.
- Luke Gibson: Geological and tectonic setting of the northern Nan Suture, Thailand.

P1A5
MULTI-DISCIPLINARY 4D STUDY OF AN ARCHAEAN CRATON MARGIN AND MOBILE BELT – THE ALBANY FRASER OROGEN

LEADERS: Tony Crawford, Jeff Foster

TEAM MEMBER: Jacqui Halpin

STUDENT: Ralf Schaa

COLLABORATORS: Mark Bennett, Sun-Lin Chung, Mark Doyle, Peter Fullager, Greg Hall,Tim Kennedy, Cath Spaggiari, Rob Watkins, Marcus Wilson

This project investigates the geological evolution and metallogenesis of the 1100–1200Ma Albany-Fraser Orogen in WA. As expected, new potential field data has demonstrated that, for this SW margin of the Yilgarn, three or possibly more terrains are strung out along this margin. Detailed sampling, geochronology and P-T-T studies of the metamorphic rocks in each terrain are required to better constrain their identity, extent and mineralisation potential. For example, a key part of the Albany Fraser Orogen is the aeromagnetically obvious Fraser Complex, a mafic granulite terrain for which there is minimal information on its composition, tectonic significance, origin, and mineralisation potential. Some mapping and sampling of one transect across this area by Andrew McNeill and Rob Lewis in 1992 provided a suite of immediately available, located samples for petrographic, whole-rock geochemical and geochronological studies. This work has commenced using the 2009 budget, along with some preliminary potential field data modelling by Ralf Schaa.

P1A6
TECTONIC SIGNIFICANCE AND MINERALISATION POTENTIAL OF VOLCANO PLUTONIC BELTS AND OPHIOLITES AT THE NORTHERN END OF THE TASMAN LINE, N QUEENSLAND

LEADER: Tony Crawford

TEAM MEMBERS: Jeff Foster, Sebastien Meffre

STUDENTS: Fiona Best, Carla Vincent

COLLABORATORS: Tony Donaghy, Chris Fergusson, Bob Henderson, Allan Kneeshaw, Paul Polito, Ian Withnall

This project builds on work, initiated with an ARC Small Grant (2004), aimed at better understanding the tectonic development and mineralisation potential of the north Queensland segment of the Tasman Line, the 'suture' between Palaeoproterozoic and Mesoproterozoic rocks of the Georgetown Block, and the Early Palaeozoic rocks of the northern Tasman Fold Belt System.

There are two key parts to the project:

- A detailed documentation of the structure and igneous petrology/geochemistry of the Greenvale region north of Charters Towers. Several fieldtrips by all collaborating researchers were completed and a large geochronological and geochemical database assembled, including extensive REE data for the widespread metavolcanic and intrusive igneous units. A draft manuscript was prepared for the *Australian Journal of Earth Sciences*, following a meeting held in Brisbane in early December (Crawford, Henderson, Fergusson). This paper will be submitted in early 2010.
- Geology, geochemistry and mineralisation potential of the Dido Batholith. This project encompasses the PhD project of Fiona Best, and the 2009 BSc (Hons) project of Carla Vincent, and is sponsored by Anglo American Exploration (Perth). Although the huge Silurian Dido Batholith is dominated by diorites and tonalites, potential field data supported by follow-up field work demonstrated the presence of layered mafic cumulates in the central part of the batholith. These layered mafic rocks are the focus of Fiona Best's PhD work, Carla Vincent's Honours project and Anglo American's drilling. Fiona and Carla completed four weeks mapping, delimiting the extent of the mafic sequences with the help of aircore drilling and nine diamond drill holes by Anglo American. Carla worked on the southern section of the mafic rocks, and Fiona concentrated on the main northern and central sections, as well as taking part in Carla's mapping exercise. Follow-up laboratory studies have included extensive XRF data for the mafic rocks and host Dido Tonalite, and electron microprobe analyses of all key cumulate minerals in a representative range of mafic rocks. An annual report on this work was presented to Anglo American in early December.

P1B1
FELSIC MAGMAS IN VOLCANIC ARCS AND INTRAPLATE VOLCANIC PROVINCES – ERUPTION STYLE, DEGASSING PROCESSES, FLUID EVOLUTION AND LINKS TO MINERALISATION

LEADERS: Dima Kamenetsky, Jocelyn McPhie

TEAM MEMBERS: Sharon Allen, Isabelle Chambefort, Karsten Goemann, Emily Johnson, Maya Kamenetsky, Sebastien Meffre

STUDENTS: Andrea Agangi, Sarah Gordee, Martin Jutzeler, Olga Vasyukova

COLLABORATORS: Kathy Cashman, Kathy Ehrig, Richard Fiske, Nick Green, Andrei Gurenko, Roland Maas, Terry Mernagh, Chris Ryan, Weidong Sun, Yoshi Tamura

This project examines the behaviour and evolution of volatiles and metals in felsic magmas by combining melt inclusion research and physical volcanology. This combination provides information on the stages, mechanisms and products of degassing events affecting felsic magmas. Two major felsic igneous provinces are being studied (Gawler Range Volcanics, South Australia; Taupo Volcanic Zone, New Zealand), as well as selected felsic porphyries and felsic pyroclastic successions in the circum-Pacific region.

Volcanological and geochemical research is underway on the Mesoproterozoic Gawler Range Volcanics in South Australia. This felsic igneous province covers a large area (~25,000 km^2) of the Gawler Craton and extends under cover to the east, where it hosts the Olympic Dam Cu-Au-U-REE deposit. Andrea Agangi's PhD research on the lower Gawler Range Volcanics revealed that the source magmas had high fluorine contents. However, F-bearing minerals, such as fluorite, topaz and REE fluorocarbonates, are ubiquitous in micro-miarolitic cavities and vesicles, and whole-rock and groundmass compositions have much lower fluorine contents. This relationship implies that fluorine, and some metals and REE, were preferentially partitioned into late-stage magmatic-hydrothermal fluids. Andrea has submitted one manuscript (*Chemical Geology*) and another will be submitted early 2010, together with his thesis.

A collaborative project with BHP Billiton is underway, aimed at a better understanding of the magmatic and hydrothermal events at the Olympic Dam Cu-Au-U-REE deposit. The research team includes Isabelle Chambefort, Dima Kamenetsky and Jocelyn McPhie from CODES, and Kathy Ehrig from BHP Billiton. Two progress reports and the first annual report were presented. The team also undertook further sampling and drill core logging on site. Preliminary results were presented at the SGA 10th Biennial Meeting (Townsville) and the Geological Society of America Annual Meeting (Portland, Oregon). The manuscripts for mafic igneous facies, the architecture of the host succession, and the role of fluorine in magmatic hydrothermal processes are all near completion.

Melt-inclusion research by Emily Johnson and Dima Kamenetsky on rhyolites in the Taupo Volcanic Zone has greatly advanced knowledge of magmatic volatile contents and changes in volatile and metal abundances during fractionation. Quartz-hosted melt inclusions have very high water contents (7–8 wt.%) and indicate depths of entrapment in the order of 12–15 km. Homogenisation temperatures are consistent with previous results (720–850°C). Emily presented the first stage of her research at the American Geophysical Union Fall Meeting (San Francisco) and has a manuscript in preparation.

Olga Vasyukova's PhD project involves a detailed geochemical and textural study of quartz in a number of circum-Pacific mineralised porphyry intrusions. Cathodoluminescence images of quartz crystals reveal distinct and complex zonation patterns that provide a framework for interpreting compositional data (principally chloride, metal and silica contents) on melt inclusions. Olga's thesis will be submitted in 2010.

Project P1B1 also examines explosive volatile outgassing events and the pyroclastic facies they produce, especially in submarine settings. Submarine pyroclastic facies are extremely common, but very difficult to study. The behaviour of submarine explosive eruption columns and that of the hot pumice that such eruptions produce has been clarified in two papers by Sharon Allen and colleagues.

Two PhD students are contributing to research on submarine explosive volcanism. Sarah Gordee is completing facies analysis of submarine pyroclastic units in the Shirahama Group in Japan and Milos, Greece. Sarah has demonstrated that the pyroclastic facies are largely density current deposits and define major depocentres that also include locally erupted domes and cryptodomes. Martin Jutzeler focused on eruption-fed Neptunian density current deposits and related facies in submarine settings, using field data from New Zealand, Japan and the USA. Martin has shown that a widely cited example of water-settled fall facies in fact comprises deposits from eruption-fed density currents.

P1B2
Ni-PGE POTENTIAL OF MAFIC AND ULTRAMAFIC MAGMAS – A COMBINED MELT INCLUSIONS AND NUMERICAL MODELLING APPROACH (AMIRA P962)

LEADER: Leonid Danyushevsky

TEAM MEMBERS: Tony Crawford, Sandrin Feig, Andrew McNeill

STUDENT: Kyrill Bychkov

COLLABORATORS: Alexey Ariskin, Eduard Konnikov

Main objectives of the project include:

- To gain a better understanding of:
  - the potential of various mafic/ultramafic magmas to form magmatic sulphide deposits
  - the S-saturation histories of mafic magmas and their effect on the ability of magmas to form deposits of economic grade and size
  - the processes during magma evolution responsible for the formation of sufficient mass of sulphide to form a deposit, if all other conditions are met
  - when, and why, sulphides are concentrated during magma evolution.

- Improved criteria for the Ni-PGE fertility of mafic/ultramafic complexes in different tectonic settings.

The project has three modules:

- The study of sulphide melt-inclusions in olivine phenocrysts in approximately 30 basalt samples from a range of tectonic settings.
- A field and laboratory (bulk rock geochemistry, mineralogy, isotopic, and silicate and sulphide micro-inclusion) study of well preserved volcanic-intrusive complexes with known Ni-Cu-PGE mineralisation (the Dovyren complex in eastern Siberia, and the Duluth complex in the USA).
- Numerical modelling of magma evolution. An existing software package (COMAGMAT) is being expanded to enable modelling of fertile mafic complexes with complex crystallisation histories.

Sixty-eight primitive samples from 31 magmatic suites worldwide have been examined within Module 1 for the presence of sulphide inclusions in olivine phenocrysts. Results will be submitted for publication at the end of 2010.

A new model of sulphide solubility in mafic magmas was developed within Module 3, and was presented at two international conferences. This model takes into account the effect of Ni on sulphide solubility, and was used to model sulphide-silicate cotectic crystallisation within the updated COMAGMAT software package. The model will be submitted for publication at the end of 2010.

The role of peritectic replacement of olivine by orthopyroxene during solidification of intrusive magma bodies, causing sulphide saturation of the interstitial melt, has been demonstrated within Module 2. This newly described mechanism leads to formation of Ni-rich sulphides. Also within Module 2, work continued on samples previously collected from the Dovyren and Duluth complexes.

Sponsors' meetings were held in Hobart in April and via teleconference in September. Two presentations describing non-confidential results of the project were made at the 2009 Xi'an Ni-Cu Symposium in China.

The final project meeting is scheduled for April 2010.

P1B3A
UNMIXING IN MAGMAS: MELT AND FLUID INCLUSION CONSTRAINTS ON IDENTITY, TIMING AND EVOLUTION OF IMMISCIBLE FLUIDS, SALT AND SULPHIDE MELTS

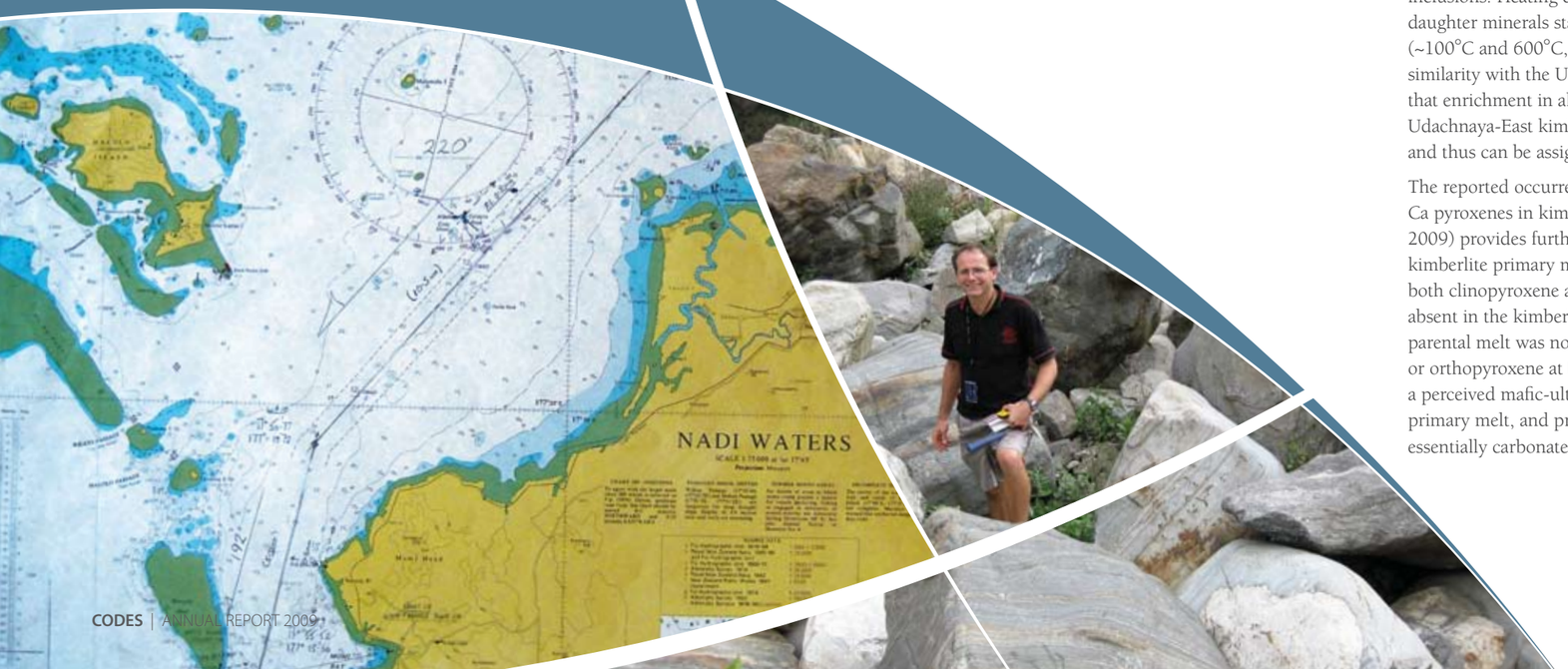
LEADER: Dima Kamenetsky

TEAM MEMBERS: Maya Kamenetsky, Roland Maas

STUDENT: Olga Vasyukova

COLLABORATORS: Ilya Bindeman, Anton Chakhmouradian, Sun-Lin Chung, Marlina Elburg, Alexander Golovin, Andrei Gurenko, Eero Hanski, Mark Kendrick, Dimitry Kuzmin, Terry Mernagh, Roger Mitchell, Vladimir Naumov, Oded Navon, Troels Nielsen, David Phillips, Oleg Safonov, Victor Sharygin, Sergey Smirnov, Alex Sobolev, Weidong Sun, Jon Woodhead, Greg Yaxley, Georg Zellmer

This project applies melt inclusion studies and modern microanalytical techniques to directly address the impact of melt/fluid unmixing on the chemical evolution of some typical magmatic systems.



The Udachnaya-East kimberlite pipe in Siberia contains an unusually high content of Na and Cl, far greater than other rocks of its kind. Even though this pipe appears fresh, there has been debate about whether the saltiness of the magma that fed it was inherited at the mantle source or imparted by the incorporation of sediments near the surface. New isotopic data (*Earth Planet. Sci. Lett*. 285, 96–104; 2009) seal the case in favour of a salty mantle source. Perovskite crystals occur with those of salt in the Udachnaya-East kimberlite. As perovskite forms directly from the parent magma of kimberlites, its isotopic composition is expected to reflect that of the kimberlite magma. The strontium isotopic composition of perovskite is very close to that expected for uncontaminated, primary magmas. Looked at in light of CODES' petrological and melt inclusion work on other kimberlites (*Lithos*, 112S, 334–346; 2009), it seems unlikely that the salt in this kimberlite could be attributed to the addition of crustal material. The explosive and rapid rise of kimberlite magmas to the surface is traditionally thought to be driven by large quantities of dissolved water. This contrasts with the very low H_2O in the Udachnaya-East parental magma. CODES' work suggests that it is the salty composition that imparts the high fluidity of kimberlite magmas and propensity to rise up so quickly that diamonds are preserved.

The idea of alkali and chlorine enrichment of the kimberlite parental melt was tested further by studying olivine-hosted melt inclusions and secondary serpentine in kimberlites from the Slave Craton, Canada and southern West Greenland (*Lithos*, 112S, 334–346; 2009). Host olivine phenocrysts closely resemble groundmass olivine from the Udachnaya-East kimberlite in morphology and compositions. Complex zoning melt inclusions in olivine consist of daughter phases represented by Na-K chlorides, calcite, dolomite, magnesite, Ca-Na, Ca-Na-K and Ca-Mg-Ba carbonates, monticellite, Cr-spinel and Fe-Ti oxides, and other unusual minerals. High abundances of Na, K, and incompatible trace elements in the melt inclusions, were confirmed by LA-ICPMS analysis of individual inclusions. Heating experiments showed that melting of daughter minerals starts and finishes at low temperatures (~100°C and 600°C, respectively), further reinforcing the similarity with the Udachnaya-East kimberlite. It appears that enrichment in alkalis and Cl, as seen in unaltered Udachnaya-East kimberlites, is shared by other kimberlites, and thus can be assigned a deep mantle origin.

The reported occurrence of inclusions of low-Ca and high-Ca pyroxenes in kimberlite olivine (*Lithos*, 112S, 213–222; 2009) provides further insights into the composition of kimberlite primary melts. Therefore, it was concluded that both clinopyroxene and orthopyroxene are completely absent in the kimberlite groundmass, and thus the parental melt was not saturated in either clinopyroxene or orthopyroxene at low pressure. This argues against a perceived mafic-ultramafic lineage of the kimberlite primary melt, and provides additional support for its essentially carbonate-chloride composition.

P1B3B
MELT-MELT IMMISCIBILITY AND THE ORIGIN OF MAGNETITE-APATITE DEPOSITS

LEADER: Paul Davidson

TEAM MEMBER: Leonid Danyushevsky

COLLABORATORS: Mark Dudley, Neng Jiang, Mirsaleh Mirmohammadi, John Nold, Rainer Thomas, James Webster, Yuling Xie

Melt/melt immiscibility has been investigated as a laboratory phenomenon for a long time, but whether it is a geologically important process in crustal differentiation and ore-deposit formation remains controversial. This study addresses this problem by examining selected ore deposits, particularly magnetite-apatite ore deposits, to determine if melt/melt immiscibility occurred during deposit formation. It also establishes petrographic and other criteria that can be used to identify the former existence of melt/melt immiscibility.

Although there are numerous possible forms of melt/melt immiscibility, Fe-Ti oxide-silicate and carbonate-silicate melt/melt immiscibility will be examined directly, and the work will be linked with the studies by Rainer Thomas and James Webster into silicate-silicate melt/melt immiscibility in the origin of pegmatites. The pegmatite work has resulted in two papers published this year, and two more currently submitted and under review.

The first study has successfully identified Fe-Ti oxide immiscible melts in the formation of Fe-Ti-P-rich rocks in the Qareaghaj mafic-ultramafic intrusion, NW Iran. The existence of Fe-Ti oxide melt inclusions in olivine has been demonstrated, which constitutes the first identification of Fe-Ti oxide melt inclusions in crustal rocks. Petrographic criteria for the identification of oxide melt inclusions, as opposed to co-trapped oxide crystals, have been established and the results are approaching publication.

A second study, involving the Fanshan magnetite-apatite deposit in northern China, has discovered carbonatite-like melt inclusions in apatite. Since the deposits occur in a large layered mafic-ultramafic complex, the apparent carbonatite association is unexpected, and requires explanation. In a related study, magmatic carbonate pods in a magnetite-bearing sill at Pilot Knob in Missouri, USA, are being examined. These carbonate pods are very similar to the contents of the melt inclusions in Fanshan apatite crystals. This is another case of an enigmatic carbonatite association, which implies the former occurrence of carbonate-silicate melt/melt immiscibility.

PROGRAM TWO
FORMATION

OBJECTIVE

To develop practical, process-based models for the formation of hydrothermal and magmatic ore deposits that will help increase discovery rates for Australia's deep earth resources.

LEADER

David Cooke

TEAM MEMBERS

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Pat Kirkby, Ting Kor, Roisin Kyne (Lakehead University)

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Colorado School of Mines, USA - Murray Hitzman
Geological Survey of Canada - Jan Peter, John Chapman
Geoscience Australia - Geoff Fraser, Roger Skirrow, Terry Mernagh
Geoscience BC, Canada - Kirstie Simpson
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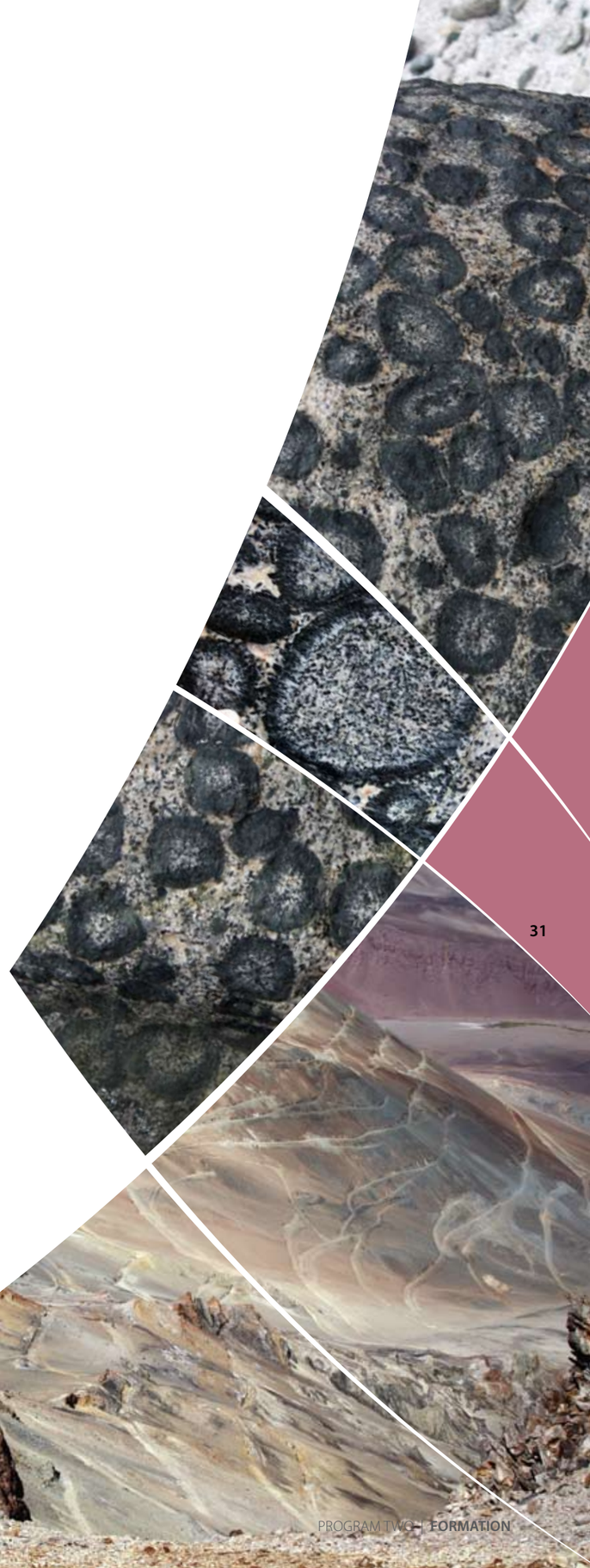


HIGHLIGHTS

- Completion of the Cadia Valley research project and initiation of a new project entitled 'Exploring the porphyry environment' – both projects supported by Newcrest Mining Ltd.
- Publication of a geology manuscript detailing numerical modelling results for fluid flow in the Zambian Copperbelt.
- Initiation of a new CAMIRO-funded research project: Hydrothermal event recognition and target vectoring in sedimentary strata for volcanic-hosted and SEDEX massive sulphide deposits.
- New geochronological evidence for syn-collisional porphyry and skarn-style mineralisation in the Gangdese belt, China.
- The world's oldest known epithermal vein systems shown to be associated with early Archean life forms.

INTRODUCTION

Ore deposits form when chemical and physical processes cause dramatic changes in metal solubilities in hydrothermal fluids or magmas. These processes vary between deposit classes, and also between individual deposits. Evaluating the relative and absolute effectiveness of different ore-forming processes is essential for the development of new, process-based exploration models.

The (ore deposit) Formation Program has two major research themes. Ore-Forming Processes investigates fundamental problems in ore genesis, taking advantage of CODES' unparalleled access to world-class ore deposits, well-constrained sample suites and data sets, and cutting-edge technologies. These technologies are accessed via Program 5, the nodes, and international collaborators. This theme aims to generate high profile publications, targeting high impact journals such as *Science, Nature, EPSL, Geology* and *Geochimica et Cosmochimica Acta*.

The second research theme is Ore Deposit Models. In order to understand how ore deposits form, it is essential that alteration and mineralisation features are carefully documented, both in the field and in the laboratory. This applied research activity generates essential data for understanding deposit formation and refining mineral exploration models, which makes this theme strongly linked to Program 3. Key papers and special issues describing and interpreting world-class ore deposits will be published in *Economic Geology* and *Mineralium Deposita*.

OUTLOOK

During the coming year, research will be instigated into the sources of metals for the Proterozoic base metal deposits of northern Australia. There will also be an intensification of research efforts into magmatic-hydrothermal ore deposits of the SW Pacific, most likely with a focus on porphyry systems in PNG and Fiji. Plans are in place to develop new research initiatives involving skarns and IOCG deposits, and to expand research activities in China. A special publication on alkalic mineral deposits will be finalised late in 2010.

CORE PROJECTS

Theme 2A Ore-forming processes

P2.A1 **Sources of ore-forming components**

P2.A2 **Metal fluxes and fluid flow**

P2.A3 **Efficiency of ore-forming processes**

Theme 2B Ore deposit characterisation

P2.B1 **Magmatic-hydrothermal ore deposits**

P2.B2 **Sediment-hosted base and precious metal deposits**

P2.B3 **Volcanic-hosted massive sulphide deposits**

P2.B4 **Fe-oxide Cu-Au deposits**

New Initiatives

P2.A2B **Determination of gold and other metal in fluid inclusions**

P2.A2C **Modelling fluid flow in the Irish orefield**

Note: The new initiatives listed above are sub-projects linked to projects in themes 2A and 2B.

PROJECT SUMMARIES

P2.A1
SOURCES OF ORE-FORMING COMPONENTS

LEADER: Jamie Wilkinson

TEAM MEMBERS: David Cooke, Bruce Gemmell, Ross Large

COLLABORATORS: Jamie Laird, Brian Rusk, Chris Ryan, Dominik Weiss

This project currently has one sub-project:

P2.A1A **Transition metal speciation and isotope systematics of source rocks for sediment- and volcanic-hosted ores.**

The sub-project objectives are to:

- Determine the composition of whole rock samples from putative source rocks.
- Identify mineral hosts and quantify concentration of trace metals using combined SEM, PIXE and LA-ICP-MS analysis.
- Measure transition metal isotope composition of whole rocks, partial extractions and mineral separates.
- Prepare and submit a paper and present results internationally.

The key achievements in 2009 include:

- The identification of principal hosts for metals in greywackes, sourcing metals to hydrothermal fluids in the Irish Zn-Pb orefield.
- A preliminary quantitative apportioning of the metal budget of these rocks between the mineral phases based on PIXE modal mineralogy and whole-rock chemistry reconciliation.
- Development of SEM-MLA automated mineral mapping to more accurately quantify mineral proportions, including production of detailed mineral maps. These results were presented as a plenary address at the SGA meeting in Townsville, as a research seminar at CODES and as part of a CODES 20th Anniversary Symposium presentation.

P2.A2
METAL FLUXES AND FLUID FLOW

LEADERS: Stephen Cox, David Cooke

TEAM MEMBERS: Angela Halfpenny

This project had one sub-project during 2009:

P2.A2A **Fracture arrays in intrusion-related ore systems – controls on the dynamics of fluid flow, vein formation and the generation of giant deposits**.

The sub-project aims are to:

- Document geometries and styles of vein systems and their overprinting relationships around mineralised intrusive complexes.
- Explore how stress states, stress field orientations and fluid pressures evolve during development of the hydrothermal systems.
- Explore the implications of these results for understanding the evolution of fracture-controlled hydrothermal fluid pathways and reactions.

The major focus in 2009 has been on the Porgera gold deposit (PNG). Work also commenced on the Cu-Au porphyry systems at North Parkes. Two major gold-bearing vein stages occur at Porgera. The richest veins (Stage 2) formed during the growth of several low-displacement faults, which exhibit a complex kinematic evolution involving both dextral and normal slip histories during mineralisation. Earlier (Stage 1) mineralisation comprises distributed veins that are not spatially associated with faults. The transition from Stage 1 to Stage 2 was contemporaneous with the development of several faults (including the Roamane Fault) that appear to have grown across the active hydrothermal system and provided a short-circuit fluid pathway between a deep magmatic fluid reservoir and shallow crustal levels. Large, transient hydraulic gradients promoted rapid flow and chemical disequilibrium.

Like Porgera, North Parkes is a multistage vein system with strong evidence for fluctuations in the orientation of the stress field during hydrothermal activity. The narrow, closely spaced vein arrays are interpreted to have formed because vein sealing produced veins with higher tensile strengths than the adjacent host rocks. This inhibited re-opening of previous veins and dispersed subsequent fracture episodes within intact wallrock.

P2.A3
EFFICIENCY OF ORE-FORMING PROCESSES

LEADER: Zhaoshan Chang

TEAM MEMBERS: David Cooke, Anthony Harris, Dima Kamenetsky, Ross Large, Noel White, Clara Wilkinson, Jamie Wilkinson

COLLABORATORS: Joey Garcia, Jeff Hedenquist, Valeriy Maslennikov, Chris Ryan, Jim Webster, Zhiming Yang

This project has several sub-projects that aim to test the efficiency of ore-forming processes through textural, analytical and modelling studies of various magmatic-hydrothermal and sediment-hosted ore types. Brine vs. vapour metal transport is being investigated in the Mankayan district, Philippines. In contrast to many of the more recently published models, research indicates that it is likely that the metals in the Lepanto HS deposit and the FSE porphyry deposit were transported by brines rather than vapours. A modified version of the White (1991) model is being advocated to explain the mineralisation processes in the Mankayan district.

A new study of the role of boron in alteration and Sn mineralisation in granite-related ore deposits of western Tasmania has been initiated in collaboration with Dr Jim Webster from the American Museum of Natural History. Three days of field work in February were followed by petrography, geochronology and fluid inclusion studies. Preliminary findings were presented at SGA 2009 in Townsville.

Unidirectional solidification textures and Au mineralisation are being investigated at the Bilihe Au deposit, China, in collaboration with Dr Zhiming Yang from the Chinese Academy of Geological Sciences. Numerous microprobe, LA-ICPMS and SWIR spectral analyses were completed, together with cathodoluminescence images and LA-ICPMS maps. Geochronological studies were also initiated.

P2.B1
MAGMATIC-HYDROTHERMAL ORE DEPOSITS

LEADERS: David Cooke, Bruce Gemmell, Anthony Harris

TEAM MEMBERS: Zhaoshan Chang, Ron Berry, Leonid Danyushevsky, Garry Davidson, Dima Kamenetsky, Jocelyn McPhie, Sebastien Meffre, Richard Tosdal

STUDENTS: Jinsong Bai, Adam Bath, Jacqueline Blackwell, Kevin Byrne, Ana Liza Cuison, Chao Duan, Nathan Fox, Amber Henry, Meghan Jackson, Paul Jago, Ting Kor, Yingxu Li, Liang Ma, Janina Micko, Heidi Pass, Bing Qian, Minghui Tang, Lejun Zhang, Wojciech Zukowski

COLLABORATORS: Charlotte Allen, Ian Campbell, Dean Collett, Robert Creaser, Yu Fan, Kevin Faure, John Holliday, Zengqian Hou, Jamie Laird, Guangming Li, Ian Percival, Chris Ryan, Kirstie Simpson, Zhiming Yang, Feng Yuan

This project has four sub-projects:

Sub-project P2.B1A **Exploring the porphyry environment**

In June, the five-year project with Newcrest Mining to achieve a better understanding of the architecture of Australia's premier porphyry district at Cadia Valley (central New South Wales) came to an end. Key technical outcomes include:

- The discovery of the Holman breccia body (300 m @ 0.54g/t Au, 0.49 wt.% Cu and 0.02 wt.% Mo).
- Positive impacts on mine planning at Cadia East through detailed mapping and structural analysis.
- New structural models emphasising thrust-related geometries that have resulted in juxtaposition of ore-bearing and barren alteration assemblages.
- New exploration targets and target selection criteria defined for ongoing exploration.

In July, CODES and Newcrest initiated a new project titled 'Exploring the Porphyry Environment'. To maximise opportunities for the discovery of new porphyry-related gold resources, Newcrest's technical staff will undergo training that is underpinned by targeted research activities designed to advance conceptual models and exploration techniques. A combination of in-house training and university-based research will ensure that the staff will be at the forefront in their understanding of genetic and exploration models for porphyry and epithermal deposits.

Sub-project P2.B1B **Polymetallic mineralisation and associated magmatic and volcanic activity in Cretaceous volcano-sedimentary basins of eastern China**

This project improves the understanding of the volcanic and intrusive evolution of the Luzong and Ningwu volcanic basins in China. The aim is to resolve relationships between alkalic magmatism (both intrusive and extrusive), porphyry Cu-Au deposits, iron deposits (skarns and IOCG) and massive polymetallic sulphide mineralisation in the basin, and into the controlling geodynamic processes.

Lejun Zhang gained funding from China's State Scholarship Fund, which enables him to visit CODES for one year to undertake collaborative research. Lejun is expected to arrive early 2010, pending visa approval.

In October / November, Taofa Zhou, Zhaoshan Chang, David Cooke and Lejun Zhang conducted field work in the Luzong basin, collecting material for analysis. Taofa visited CODES in early December, when research activities for 2010 were planned.

Publications during the year included an article in *Earth Science Frontiers* (in press) and a conference presentation at Goldschmidt 2009, in Switzerland. An additional manuscript is in preparation for *Economic Geology*.

Sub-project P2.B1C **Collision-related REE-bearing carbonatites, porphyries, skarns and gold deposits of Sichuan and Tibet, China**

During Yuling Xie's six-month visit, the characteristics of fluorite-hosted melt and fluid inclusions from REE-enriched carbonatites in the collisional-related Mianning-Dechang REE metallogenic belt (China) were investigated in detail. Technical difficulties were encountered during attempts to analyse fluorite-hosted melt and fluid inclusions from this deposit. Therefore, the work program was expanded to include research into the collisional-related porphyries, skarns and gold deposits of the nearby Gangdese Belt (Tibet).

The Maoniuping REE deposit is associated with Himalayan carbonatite-alkalic complexes in the eastern Indo-Asian collisional zone, China. LA-ICPMS and PIXE analyses of melt and fluid inclusions confirmed that the carbonatite-derived fluids are SO_4^{2-} - and CO_2-rich, and are not a simple NaCl (KCl)-H_2O system. Sulphate minerals are particularly common in melt and fluid inclusions hosted by fluorite, quartz and bastnasite.

The Qiagong iron skarn is located in the middle of the Gangdese Belt. New mapping has shown that this iron skarn is part of a larger, previously unrecognised porphyry-style system. Dating of the porphyry has revealed a new mineralising event in the Gangdese Belt (68.8 ± 2.2 Ma and 64.6 ± 1.6 Ma), much older than previously documented. These age determinations imply that Qiagong formed either immediately prior to, or during, the onset of collision in the Gangdese Belt.

The Nongruri gold deposit, located in the eastern Gangdese Belt, is related to a Himalayan-age porphyry intrusion. Gold occurs as native gold together with clay minerals, and also as 'invisible' gold in pyrite and arsenopyrite. LA-ICPMS and SEM/EDS analyses of pyrite, arsenopyrite, realgar, stibnite and illite from Nongruri were completed.

Sub-project P2.B1D **Shallow and deep-level alkalic mineral deposits**

The alkalic project is divided into 'porphyry' and 'epithermal' modules, with the research aiming to understand the characteristics and genesis of the alkalic porphyry deposits of British Columbia and alkalic epithermal deposits of PNG and Australia. The project involves collaboration with UBC and is supported by nine industry sponsors: Amarc Resources Ltd., AngloGold Ashanti Limited, Barrick Gold Corporation, Imperial Metals Corporation, Lysander Minerals Corporation, Newcrest Mining Limited, Newmont Mining Corporation, Novagold Resources Inc. and Teck Resources Limited. Additional financial support derives from grants from the Natural Sciences and Engineering Research Council of Canada (NSERC) and Geoscience BC.

After the completion of industry funding in 2008, the past year has seen the submission of theses by Kevin Byrne (MSc – MDRU) and Wojciech Zukowski (PhD – CODES). Jacqueline Blackwell and Adam Bath will both submit their PhD theses in January 2010, with Heidi Pass and Janina Micko (MDRU) also scheduled for thesis completion in the first quarter of the new year. Wojciech presented his research results at the SGA meeting in Townsville, and David Cooke gave a keynote address at the Geodynamics of the Australian Plate symposium at Monash University in June. Considerable progress has been made on manuscripts for an *Economic Geology* special issue in 2010, with several papers submitted and reviewed.

P2.B2
SEDIMENT-HOSTED BASE AND PRECIOUS METAL DEPOSITS

LEADER: Stuart Bull

TEAM MEMBERS: David Cooke, Lyudmyla Koziy, Ross Large, Peter McGoldrick, David Selley, Jamie Wilkinson

COLLABORATORS: Poul Emsbo, Grant Garven, Murray Hitzman

The main objectives for 2009 were to publish the results of the modelling on stratiform sediment-hosted Cu systems as part of ARC/AMIRA project P872. A manuscript on the original work on the Zambian Copperbelt was published in the December issue of *Geology*. A first draft of the second manuscript on the extended geological section, which includes the Democratic Republic of Congo, was also completed and will be submitted to an appropriate journal early in 2010.

P2.B3
VOLCANIC-HOSTED MASSIVE SULPHIDE DEPOSITS

LEADERS: Bruce Gemmell, Mike Solomon

TEAM MEMBERS: Garry Davidson, Ross Large, Andrew McNeill, Khin Zaw

STUDENTS: Susan Belford, Heidi Berkenbosch, Jo Condon, Russell Fulton, Margy Hawke, Patrick Sack

COLLABORATORS: A Ferreira, John Foden, O C Gaspar, Azman Ghandi, Lianxing Gu, Teh Guan Hoe, Mark, Hannington, Zengqian Hou, Carlos Inverno, Dan Layton-Matthews, Valeriy Maslennikov, Svetlana Maslennikova, Terry Mernagh, Thomas Monecke, Jim Mortensen, Fardin Mousivand, Nelson Pacheco, Jan Peter, Sven Petersen, Steve Piercey, Chris Ryan, Reinaldo Saéz, Manuel Toscano, John Walshe

This project encompasses four sub-projects:

P2.B3A **Fluids that form high-salinity, volcanic-hosted massive sulphide deposits**

Sulphur isotopes are being used to investigate the deposition mode and origin of the Lombador orebody, Neves Corvo, Portugal. Following the death of Mike Solomon in May, John Walshe (CSIRO) is continuing this research.

P2.B3B **Genesis of volcanic-hosted copper-lead-zinc-silver-gold massive sulphide deposits**

Research was undertaken on the genesis of the following VHMS deposits in 2009: Jaguar (Western Australia), Doolgunna (Western Australia), Greens Creek (USA), Yaman-Kasy (Russia), Baiyinchang (China), Tasik Chini (Malaysia) and Chahgaz (Iran). Patrick Sack completed his PhD study of Greens Creek. A paper on the genetic significance of trace element zonation in sulphide chimneys in the Yaman-Kasy was published in the December issue of *Economic Geology*.

P2.B3C **Hydrothermal event recognition and target vectoring in sedimentary strata**

This sub-project investigates the sulphide-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 CAMIRO (Canadian Mining Industry Research Organization-Exploration Division) project began in mid-2009. Jan Peter and John Chapman from the GSC, Ottawa, Canada spent a week at CODES doing LA-ICPMS analyses on pyrite to test the vectoring capacity of sulfidic black shales in the vicinity of the Archean Kidd Creek volcanogenic massive sulphide mine, Ontario.

P2.B3D **Active base- and precious-metal-rich massive sulphide depositions**

Bruce Gemmell and Robina Sharpe (consultant) continued to analyse the mineral chemistry and sulphur isotope characteristics of pyrite from seafloor massive sulphide mineralisation at Palinuro Seamount in the Tyrrhenian Sea, Italy. Oxidised conditions prevailed during sulphide deposition and are likely related to the presence of magmatic volatiles in the mineralising fluids that were derived from a degassing magma chamber below the Palinuro volcanic complex.

A new PhD project at Brothers volcano, in the Tonga-Kermadec arc was started by Heidi Berkenbosh in 2009. This is a collaborative project between GNS Science, New Zealand (Cornel de Ronde) and CODES. This project will be investigating the ore and gangue mineralogy, textures, paragenesis, mineral chemistry and sulphur isotopes of the sulphide-sulphate chimneys.

P2.B4
IRON OXIDE COPPER-GOLD AND RELATED DEPOSIT TYPES

LEADER: Garry Davidson

TEAM MEMBERS: Huayong Chen, Janet Hergt, Julie Hunt, Jamie Laird, Ross Large, Sebastien Meffre, Bence Paul, Khin Zaw

STUDENTS: Pat Kirkby, Claire McMahon, Blackwell Singoyi

COLLABORATORS: Zahra Bonyadi, Geoff Fraser, Paul Hiethersay, B Mehrabi, Roger Skirrow, Derek Thorkelson

The aim of this project is to improve the understanding of the origin of this puzzling ore deposit type and related systems. Research on formation and discovery aspects occurred via Honours fieldwork and PhD studies.

Achievements during the year include:

- Merlin deposit (sponsor: Ivanhoe) - completion of Honours thesis, which included some major improvements in understanding of the origin of the Mo-rich mineralisation that overprints the Mt Dore Cu-Au IOCG deposit.
- Prominent Hill - revision of Ar-Ar dates, in collaboration with Geoscience Australia. A publication is in preparation on the timing of phyllic alteration.
- Wernecke Breccias, Alaska - revision of stable isotope and fluid inclusion paper, and resubmission of accepted paper.
- Tennant Creek: recommencement of PhD write-up after a prolonged suspension.
- Se-Chahun, Iran: Resubmission of paper on CODES' research after first review (*Chemical Geology*).
- Nico Mine: collaboration with CSIRO on electrochemical influences on Au uptake in sulphide minerals.

PROGRAM THREE
DISCOVERY

OBJECTIVE

To develop techniques for the acquisition 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
Mike Baker, Stuart Bull, Zhaoshan Chang, Huayong Chen, Dave Cooke, Tony Crawford, Leonid Danyushevsky, Bruce Gemmell, Sarah Gilbert, Leon Graham, Jacqueline Halpin, Anthony Harris, Murray Hitzman, Dave Hutchinson, Shaun Inglis, Lyudmyla Koziy, Ross Large, Peter McGoldrick, Andrew McNeill, Sebastien Meffre, Steve Micklethwaite, Ross Olsen, Anya Reading, Mike Roach, Rob Scott, David Selley, Helen Thomas, Noel White, Jamie Wilkinson, Clara Wilkinson

Jeff Foster
Program Leader

PHD STUDENTS
Mathieu Ageneau, Adam Bath, Jacqueline Blackwell, Lindsey Clark, Mawson Croaker, Paul Cromie, Ana Liza Cuison, Nathan Fox, Hugo Galvan, Tim Ireland, Nic Jansen, Ben Jones, Alexey Lygin, Wallace Mackay, Joe Moye, Heidi Pass, Ralf Schaa, Bronto Sutopo, Gabe Sweet, Wojciech Zukowski

MASTERS STUDENTS
J Bigelow, Corrie Chamberlain, N Macalalad, Daud Silitonga, L Subang

HONOURS STUDENT
Ting Kor

COLLABORATORS
Australian National University - Nicholas Rawlinson, Malcolm Sambridge
CSIRO - Steve Barnes, Belinda Godel
Colorado School of Mines, USA - Murray Hitzman, Nick Harris, Jeff Hedenquist
Fullagar Geophysics - Peter Fullagar
Geoscience Australia - Erdinc Saygin
Lakehead University, Canada - Peter Hollings
Monash University - Reid Keays
Otago University, New Zealand - Dave Craw
Russian Academy of Science, Urals Branch - Valeriy Maslennikov
Scientific Computing and Applications - John Paine
University of British Columbia, Canada - Richard Freidman
University Lubumbashi, Democratic Republic of Congo - Stanislas Sebagenzi
United States Geological Survey - Poul Emsbo

HIGHLIGHTS

- P872: The origin and setting of Congolese type copper deposits finished early in the year with a field trip attended by ~100 exploration, mining and research geologists.
- P765A: Geochemical and geological halos in green rocks and lithocaps continued to deliver significant results with the successful testing and implementation of a number of vectoring tools.
- The fast TEM algorithms developed by Ralf Schaa were successfully applied to a significant deposit in southern Africa.
- High data recovery rates were achieved for the ASET array.
- Anya Reading was awarded ARC linkage funding for computational geophysics.
- A new model was developed for the formation of the Merensky Reef.
- A new model was developed for the behaviour of Pt in the presence of trace and semi-metals.
- The GeoTek core logger was successfully recommissioned and new measurement and standardisation protocols were developed.
- P1022: The rapid inversion of TEM data was released in November.
- Detailed sampling of the Kumtor Au deposit was carried out.

INTRODUCTION

The Discovery Program leverages off CODES' extensive, broad-based research expertise to enhance the development of geophysical, geochemical and geological models for specific world-class ore deposits. The program is now structured around two key themes: innovative techniques for discovery, and integrated exploration models for discovery.

CODES has built on its traditional strengths in ore deposit geology and geochemistry by expanding its geophysics capability, which now employs a comprehensive suite of geophysical and mathematical techniques in a diverse mix of projects around the world.

OUTLOOK

New Projects

- **Scale based inversion of Western Tasmania ore deposits (P3A1B).**
- **P1022 The rapid inversion of TEM data (P3A1C).**
- **An inversion based transect of the Albany Fraser Orogen, WA (P3A1D).**
- **Data inference techniques applied to diverse geoscientific datasets (P3A3A).**
- **Copper, uranium and precious metals in sedimentary basins: ore formation and location (P3B2B new developments from P872).**
- **The Ni deposits of the Circum - Superior, Canada: A passive margin or plume related phenomena (in development).**
- **Commencement of AMIRA P1041 - A new gold project.**

CORE PROJECTS

Theme P3A Innovative techniques for discovery

- P3A1A **The petrophysical characterisation of ore deposits**
- P3A1C **The rapid approximate inversion of TEM data**
- P3A2A **Ambient seismic energy techniques**

Theme P3B Integrated exploration models for discovery

- P3B1A **Geochemical and geological halos in green rocks and lithocaps** (P765A)
- P3B1C **Low- and high- sulphidation epithermal mineral deposits**
- P3B2A **Sediment - hosted Au-As deposits: Genesis and exploration models**
- P3B2B **Origin and setting of Congolese-type copper deposits** (P872)
- P3B3A **Shales and carbonates - improved vectors for Rosebery and Hercules style VHMS**
- P3B5A **The Tweefontein Sector of the Platreef, South Africa**
- P3B5B **The characterisation of magmatic sulphide systems**
- P3B5C **The geology and genesis of the Avebury Ni deposit. Implications for exploration.**

PROJECT SUMMARIES

P3A1A
THE PETROPHYSICAL CHARACTERISATION OF ORE DEPOSITS

LEADERS: Jeff Foster, Mike Roach

TEAM MEMBERS: Ross Olsen

STUDENT: Alexey Lygin

COLLABORATOR: Peter Fullagar

Petrophysical information is the key to relating the geology of an ore deposit to its geophysical expression. Because public-domain petrophysical data is limited or non-existent for many important ore systems, this project seeks to acquire and compile this information for use as constraints on conceptual geophysical models of ore systems.

The focus for the initial demonstration stage of the project is western Tasmania, where new data will be acquired from a number of mines, including Rosebery and Avebury, and integrated with existing data compiled primarily from company exploration reports. A spatial database structure has been created in ArcGIS to house the petrophysical information. New data will be collected by a combination of in-situ measurements, conventional laboratory measurements and the GeoTek multi-sensor core logger, which has been recommissioned following its use for the GeM[111] project. New logging protocols, calibration procedures and quality assurance processes have been developed for routine petrophysical logging. The GeoTek logger has recently been successfully used, in conjunction with PIRSA staff, for logging a number of regional 'stratigraphic' drill holes from the Gawler Craton.

P3A1C
THE RAPID APPROXIMATE INVERSION OF TEM DATA

LEADER: Peter Fullagar

TEAM MEMBER: Mike Roach

STUDENT: Ralf Schaa

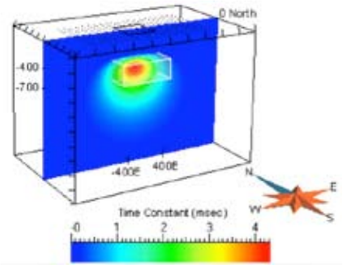
COLLABORATOR: John Paine

A fast, approximate 3-D TEM modelling and inversion algorithm, VPem3D, was developed based on the concept of TEM moments, in which the ground is divided into cubic cells, and electromagnetic interaction between volume elements is ignored. Linear combination of the moments from the individual cubic cells is an acceptable approximation at late times within the resistive limit.

The transformation from multi-channel, time-domain EM data into the moment-domain effectively converts the problem from one associated with 3-D TEM inversion into one involving 3-D magnetic inversion. Depth resolution, as provided by multi-channel TEM data, is lost during the process of time-integration. However, conductivity-depth imaging (CDI) sections, which convert time to depth implicitly, can be used to generate starting models for inversion.

The key result is that 3-D TEM inversions, utilising the VPmg inversion framework, can be performed in minutes, rather than hours. The method is suitable for moving loop (including airborne) and fixed loop TEM and was successfully field tested at a number of significant sites in Australia and overseas.

Ralf Schaa submitted his PhD thesis in November.



TEM time constant inversion for a synthetic prismatic conductor derived using the new rapid approximate inversion technique developed by Ralf Schaa in his PhD study.

P3A2A
AMBIENT SEISMIC ENERGY TECHNIQUES (ASET)

LEADER: Anya Reading

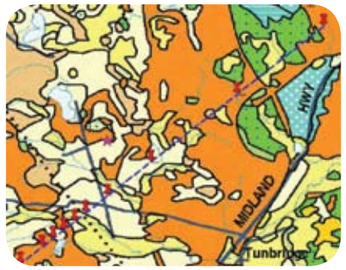
TEAM MEMBER: Leon Graham

STUDENT: Norman Heckscher

COLLABORATORS: Nicholas Rawlinson, Malcolm Sambridge

Ambient seismic energy techniques are new methods that use natural and man-made background or 'ambient' energy.

Anya Reading led a pilot study that pushed ambient techniques with the goal of high-resolution imaging of the Earth's upper crust. Ten stations were deployed in central-eastern Tasmania, producing good data returns that helped to characterise the ambient seismic wavefield of the area. The study also enabled station deployment and recording protocols to be established in similar locations, which will be of great benefit in optimising future data acquisition. Determination of the structure using the ambient energy is in progress.



The ten stations of the ASET1 seismic deployment spread across several contrasting lithologies - Jurassic dolerite in orange, sandstone in green and later sediments in yellow and orange colours.

P3B1A
GEOCHEMICAL AND GEOLOGICAL HALOS IN GREEN ROCKS AND LITHOCAPS – THE EXPLORERS TOOLBOX FOR PORPHYRY AND EPITHERMAL DISTRICTS (P765A)

LEADERS: David Cooke, Bruce Gemmell, Zhaoshan Chang

TEAM MEMBERS: Mike Baker, Huayong Chen, Shaun Inglis, Jamie Wilkinson, Noel White, Clara Wilkinson

STUDENTS: Nic Jansen, Gabe Sweet

COLLABORATORS: Richard Friedman, Jeff Hedenquist, Pete Hollings

Porphyry-related mineral districts host many major ore deposits of diverse styles and metal associations. Exploration in these districts can be complicated by shallow-level alteration systems (e.g. lithocaps) and structural complexities. At deeper erosion levels, it can be difficult to identify the locations of productive ore zones that are interspersed between barren gaps of weakly developed hydrothermal alteration (green rocks). It can also be difficult to evaluate and appreciate the significance of unmineralised veins that occur in these environments. Porphyry-epithermal mineral districts are typically zoned, and zoning has been an important tool for exploration. However, the various mineral assemblages and textures that characterise each zone can be produced by barren hydrothermal systems or by non-mineralising processes such as regional metamorphism. Discriminating mineralised and barren systems, being able to locate well mineralised hydrothermal centres and recognising the distal footprints of mineralisation continue to be great challenges to explorers.

This AMIRA-funded research project aims to provide tools that help to extend the detection of the geochemical footprints of porphyry and epithermal deposits, and help to focus exploration activity in the altered domains that enclose and obscure mineralisation. It is being sponsored by 18 mining and exploration companies: Anglo American Exploration, AngloGold Ashanti, Barrick Gold, CODELCO, Compania de Minas Buenaventura, Dundee Precious Metals, Equinox Resources NL, Freeport-McMoran Exploration Corporation, Gold Fields International Services, Kinross Gold Corporation, Minerals and Metals Group, Newcrest Mining, Newmont USA, Rio Tinto Exploration, St Barbara, Teck, Vale and Xstrata Copper.

Major field campaigns were undertaken at Cerro Casale, El Teniente and Collahuasi (Chile); Yanacocha, Perol and Tantahuatay (Peru); and Ixhuatan (Mexico). Existing sample suites from Baguio, Mankayan, Batu Hijau, Collahuasi and El Teniente were subjected to further geochemical analyses. U-Pb dating of samples from Baguio was completed by Richard Friedman at UBC. Sponsor meetings were held at CODES in late June and early December. One blind site test was completed in June, and three in December. Considerable progress was made in developing and testing new tools for exploration in porphyry and epithermal districts, particularly in the propylitic halos, where it appears that giant porphyry copper deposits can be detected from subtle geochemical signals as far as 10 km from the deposit centre.

P3B1C
LOW- AND HIGH-SULPHIDATION EPITHERMAL MINERAL DEPOSITS, AUSTRALIA AND PACIFIC REGION

LEADERS: David Cooke, Bruce Gemmell

TEAM MEMBERS: Anthony Harris, Steven Micklethwaite

STUDENTS: Mathieu Ageneau, Corrie Chamberlain, Lindsey Clark, Hugo Galvan, Daud Silitonga, Bronto Sutopo, Wojciech Zukowski

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

Low-sulphidation systems:

- Research fellow, Steven Micklethwaite, is investigating structural characteristics of the Gosowong goldfield to develop vectors to sites of further resource discovery.
- Lindsey Clark's PhD project is investigating the geology and genesis of the Kencana epithermal Au-Ag deposit, providing the first detailed study of this deposit via geological, structural, mineralogical and geochemical investigations.
- Masters of Economic Geology student, Daud Silitonga, is investigating the Toguraci epithermal veins that cross-cut the low grade Bora porphyry Cu-Au prospect in the district.
- Corrie Chamberlain, also a Master of Economic Geology student, is investigating the Kilkenny vein deposit within the Cracow epithermal system in Queensland. The aim is to compare the Kilkenny deposit to other deposits in the Cracow goldfield to gain a better understanding of the features and controls on mineralisation that can be applied to mineral exploration in the district.
- Hugo Galvan's PhD project investigates the geological and geochemical evolution of carbonate-base-metal Ag-Au epithermal veins in the Palmarejo district, Chuihuahua, Mexico. Funded by Coeur d'Alene, aim to develop a more detailed understanding of the geological evolution of the district by investigating the mineralisation history, geochemistry and relationships to grade distribution. The vein stratigraphy, paragenesis, spatial and temporal distribution of alteration assemblages and geochemistry of the mineralising fluids will also be documented. Much of the research effort in 2009 has been devoted to constraining sulphide chemistries using LA-ICPMS, and fluid compositions through fluid inclusion and stable isotope studies.
- The Ladolam gold deposit on Lihir Island has been the subject of several PhD-level research studies. Despite this intensive effort, the local geology continues to provide significant challenges. With this in mind, a new PhD study was initiated in February, supported by Lihir Gold. Mathieu Ageneau, is researching the geology of the Kapit ore zone to help resolve its evolution and genesis of gold mineralisation. To advance the research, new and existing samples suites from the Lienetz and Minifie ore deposits will be used to further constrain the mineral chemistry, stable isotopic and fluid inclusion compositions at Ladolam.
- The Ares silver-gold mine is situated 4900 metres above sea level in the Andes Mountains in southern Peru. A six-month study is being undertaken by postdoctoral research fellow, Wojciech Zukowski, with a focus on the development of geochemical and mineralogical vectoring tools.

High-sulphidation systems:

- PhD student, Bronto Sutopo, continues to study the high- and low-sulphidation mineralisation in the Matrabe district, Indonesia with the aim of understanding ore genesis and further developing criteria for enhanced exploration in the district.

P3B2A
SEDIMENT-HOSTED GOLD-ARSENIC DEPOSITS: GENESIS AND EXPLORATION MODELS

LEADERS: Ross Large, Stuart Bull

TEAM MEMBERS: Zhaoshan Chang, Leonid Danyushevsky, Sarah Gilbert, Shaun Inglis, Sebastien Meffre, Rob Scott, Helen Thomas

COLLABORATORS: Valeriy Maslennikov, Dave Craw

This project utilises the laser ablation ICPMS technology developed at CODES to understand the mechanisms and timing of gold, arsenic and tellurium concentrations in sediment-hosted, volcanic-hosted and orogenic gold deposits. Laser spot and trace element imaging of sulphides, using the LA-ICPMS at CODES, enables the precise timing of gold relative to the sulphide pargenesis in ores and host rocks to be determined – for the first time. This research has demonstrated in several major gold provinces that gold has been initially concentrated in organic-rich sediments, where it is incorporated into diagenetic pyrite. It shows that later tectonic and hydrothermal events lead to remobilisation and upgrading of the early pre-concentrated gold in the sediments to form structurally controlled deposits related to folds and shears. The gold provinces include Carlin (Nevada), Bendigo (Victoria), Sukhoi Log (Siberia) and Spanish Mountain (British Columbia).

In collaboration with Bendigo Mining, studies of pyrite chemistry and sediment lithogeochemistry in the Bendigo goldfield have enabled criteria to be developed to distinguish shale units with the potential to host productive gold reefs. Helen Thomas presented her findings at the SGA Conference in Townsville.

In the Otago Goldfield, research in collaboration with Otago University and Glass Earth Gold has characterised the nature and composition of gold-bearing pyrite, both within the ores and within the sedimentary and metamorphic host rocks.

Kumtor, a world-class gold deposit in the Tien Shan belt of Kyrgyzstan, was selected for detailed study to follow-up on the theories developed at Sukhoi Log, Carlin and Bendigo. Cennterra Gold provided access and logistical support for a sampling trip late in the year.

The first paper to outline the new pyrite and gold trace element imaging technique, developed in the CODES LA-ICPMS laboratory, was published in *Economic Geology*. An invited paper, which builds on these concepts and focuses on the two stages in sediment-hosted gold-ore genesis, will be published in a volume on Gold Metallogeny of India, edited by Mihir Deb and Rich Goldfarb.

A new three-year AMIRA project (P1041) has been established to investigate the diversity of gold mineralogy, textures and trace element associations for a range of sponsor initiated case study sites. The aim is to develop gold mineralogy and halo models applicable to both exploration and gold recovery.

P3B2B
ORIGIN AND SETTING OF CONGOLESE-TYPE COPPER DEPOSITS (P872)

LEADERS: David Selley, Stuart Bull, Murray Hitzman

TEAM MEMBERS: Jacqueline Halpin, Lyudmyla Koziy, Peter McGoldrick, Robert Scott

STUDENTS: Mawson Croaker, Wallace Mackay

COLLABORATORS: Poul Emsbo, Stanislas Sebagenzi

Principal goals of the project were to:

- Develop holistic models for the structural, sedimentological, and hydrological evolution of the Katangan Basin.
- Develop pragmatic exploration tools for sediment-hosted Cu ores, applicable in central African and similar geological environments worldwide.

These goals were largely achieved and reported in last year's annual report and at the project's final meeting, held in the Democratic Republic of Congo in late 2008. However, construction of serial cross-sections of the Katangan Basin remained an outstanding deliverable and was the focus of continuing work in the early part of the year. Four sections were produced. One of these sections, projecting through the supergiant Tenke-Fungurume ore district, was restored to its pre-orogenic structrural configuration. The sections revealed a basin that experienced relatively minor dismemberment during inversion, and containing classical stratiform copper ores, systematically partitioned into its condensed peripheries. Many of the high-level structural slices that characterise the outer parts of the basin, previously interpreted to represent allochthonous thrust sheets, appear to have formed in response to the collapse of an extensive salt stock canopy during late stages of basin growth. These interpretations not only revolutionise structural and tectonic concepts for the evolution of the Katangan Basin, but also provide a powerful tool for ground selection.

The results of structural analysis were incorporated into refined numerical fluid flow models. The new models demonstrate that the mechanism of salt withdrawal is less important in allowing metal-bearing fluids to be episodically expelled to upper levels of the basin fill (c.f. our previous models) than dramatically increasing the vigour of long-lived, laterally elongate convective cells, centred on salt layers. The modelling also indicates the great potential for a largely unrecognised copperbelt, positioned immediately out-board of the classical copper arc. The evolution of ideas on the hydrological evolution of the Katangan Basin is being presented in a series of publications. The first of which, dealing specifically with the Zambian arm of the copperbelt, was published in *Geology* in December 2009. A second paper that will examine modelling results and implications for regional exploration of the entire Central African Copperbelt is currently being prepared.

Additional highlights of the year have been the submission of two PhD theses (Mawson Croaker and Wallace Mackay) for examination, and the publication of an invited paper in *Economic Geology* dealing with major periods of sediment-hosted Cu ore formation in Earth's history.

A final technical report to sponsors has been partially issued via AMIRA as instalments. The entire volume will be submitted in February 2010.

P3B3A
IMPROVED VECTORS FOR ROSEBERY–HERCULES STYLE VHMS IN THE CENTRAL MOUNT READ VOLCANICS, TASMANIA

LEADERS: Andrew McNeill, Bruce Gemmell

Exploration for VHMS deposits in the Mt Read Volcanics (MRV) is based on the concepts that all economic mineralisation occurs at a particular time horizon and that this horizon has been adequately tested to a depth of 150-200 m.

Therefore, from the exploration perspective, it is important to define the location and down-dip extent of the prospective horizon and to locate alteration envelopes that may be associated with VHMS mineralisation.

This project addresses these problems by using the geochemistry of shales to define the prospective horizon, and the mineralogy and chemistry of shales and carbonates associated with the Rosebery and Hercules orebodies to develop vectors to mineralisation.

Studies of trace-element chemistry of pyrite and pyrrhotite in shales at the Rosebery VHMS were completed, and confirmed the previously reported trends. However, a review of existing geological and geochemical results from previous studies of carbonates indicated that they were unlikely to provide the 'medial' vectors required and the studies have been redirected to better defining and understanding the Tl and Sb 'envelope' around the Rosebery and Hercules ore bodies. Results to date indicate that, in contrast to previous studies, the anomalous envelope is relatively narrow in both the hanging- and foot-wall, and that minerals in addition to pyrite and sericite may be important in controlling the Tl distribution.

P3B5A
THE TWEEFONTEIN SECTOR OF THE PLATREEF, SOUTH AFRICA

LEADER: Jeff Foster

TEAM MEMBER: Dave Hutchinson

The principal aim of this project is to investigate the mechanisms and processes that lead to the formation of Ni-Cu-Platinum-Group Element (PGE) mineralisation in the Tweefontein Sector of the Platreef, in the northern limb of the Bushveld Complex, South Africa.

Two field seasons have been completed, with the aim of examining drill core (logging) and collecting samples for geochemical analysis and detailed petrological work at CODES.

The geochemical data for the first year was assessed and recognisable zones have been found that can be traced across adjacent drill holes. These zones correlate with features observed in thin-sections made from a large number of samples from one drill hole. In addition, microprobe analyses of minerals and SEM observations further support the presence of broadly defined zones that can be traced from hole to hole. These broad zones define 'packages' with varying degrees of metamorphic and metasomatic overprinting, and a unit that appears to host a large number of altered ultramafic xenoliths. The overprinting event resulted in the modification of the original host rock and the sulphide-PGE assemblages contained within it.

To test these findings, and to further expand the project, a series of drill holes are being studied in order to develop a 3D view of the mineralogical and geochemical variability of the Platreef in the Tweefontein Sector.

P3B5B
THE CHARACTERISATION OF MAGMATIC SULPHIDE ORES

LEADER: Jeff Foster

TEAM MEMBER: Dave Hutchinson

COLLABORATORS: Steve Barnes, Belinda Godel

The principal aim of this project is to investigate the mechanisms and processes that lead to the formation of Ni-Cu-Platinum-Group Element (PGE) mineralisation.

A key sample from the lower portion of the Merensky Reef was studied in detail. This stratiform and stratabound horizon forms part of a cyclic sequence within the world's largest layered mafic-ultramafic intrusion, the Bushveld Complex, South Africa. Many models and mechanisms have been proposed to explain the formation of the Merensky reef. However, most have focused on a limited number of aspects in what now appears to have been a complex ore forming and depositional magmatic system. Project P3B5B has confirmed the presence of multiple chromitite layers along the contact to the footwall rocks that, together, appear to form a single layer. A number of petrologically distinctive zones can be recognized, some on a mm to cm scale, and each hosts a distinctive sulphide and platinum-group mineral assemblage.

New data has recently emerged from the use of CODES' laser ablation ICP-MS system, which has been developed to produce high quality 2D surface multi-element maps. Pt and Pd are expected to behave similarly and reside in one or other of the sulphide mineral phases present in the rock. However, the laser mapping revealed only the presence of Pd, hosted by the Ni-rich sulphide component. Pt does not appear to be hosted within any of the sulphides. This part of the study has been applied to other locations and has consistently shown there is a significant problem with the current understanding of the behaviour of these elements. These observations cannot adequately be explained by the current models for the formation of the Merensky Reef and other Ni-Cu-PGE ore-bearing systems, such as Noril'sk – Talnakh. New models have been devised that more accurately fit these new and exciting observations.

P3B5C
THE GEOLOGY, GEOCHEMISTRY AND GENESIS OF THE AVEBURY NI DEPOSIT, TASMANIA: IMPLICATIONS FOR EXPLORATION

LEADER: Jeff Foster

TEAM MEMBER: Dave Hutchinson

STUDENT: Alexey Lygin

The Avebury nickel sulphide deposit is hosted by serpentinised ultramafic rocks of the McIvor Hill ultramafic complex, western Tasmania. This complex is one of 15 mapped Eocambrian-Cambrian ultramafic complexes found within metasediments of the Crimson Creek Formation. The deposit was discovered by CRA in 1997 and further developed by Allegiance Mining NL.

The mineralisation is atypical for a NiS deposit and initial research focused on reconnaissance style geology, lithogeochemistry and mineral chemistry. Preliminary results based on a combination of mineralogy, mineral compositions, textures, incompatible trace element and chalcophile-element geochemistry are consistent with the formation or significant modification of the Avebury Ni deposit by hydrothermal fluids, likely derived from the Heemskirk granite as it was emplaced during the middle Devonian age.

PROGRAM FOUR
RECOVERY

OBJECTIVES

- 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.
- 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.
- Deliver new, cross-discipline geometallurgical education, training and awareness.

LEADER
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TEAM MEMBERS
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Parker Centre CRC [CSIRO] - Byron Benvie, Matthew Jeffrey, Laura Kuhar, Angus McFarlane, Dave Robinson
WH Bryan Centre (BRC) - Alan Bye, Italo Onederra

Steve Walters
Program Leader

HIGHLIGHTS

The AMIRA P843 GeM[III] project, the centrepiece of the CODES Recovery Program, was completed in June 2009. The project grew to be the one of the world's largest research projects addressing the emerging multi-disciplinary area of geometallurgy, attracting over $6 million from 21 industry sponsors in addition to $2 million ARC Centre of Excellence funding. The project is in the top three AMIRA projects across all application areas, with the fastest growing start-up.

The final meeting was attended by over 70 sponsors and researchers. The life of the project produced a total of nine meetings, three technical volumes comprising 88 papers, and 150 PowerPoint presentations. Due to the highly confidential nature of the research, there are strict confidentiality arrangements in place with AMIRA that limit opportunities for publication. However, despite these restrictions, 21 conference papers, two keynote presentations at international conferences and one refereed journal publication have been produced.

A total of nine defined hardware-based and seven software-based outcomes were identified as direct deliverables from the P843 research, and these are currently undergoing technology transfer linked to benchmarking. Many of the methodologies from the project are already in use on sponsor sites.

The high degree of sponsor support for the initiative was demonstrated in July when the project was renewed for a further four-year term, under the project number P843A. This extension was achieved despite the effects of the global financial crisis, which resulted in companies carefully assessing their research portfolios. Thirteen companies have already sponsored the P843A core research program, with many other companies expressing strong interest. This represents over $4 million of financial support from industry, which will be combined with $2 million of Centre of Excellence funding.

A feature of P843A is the extension of geometallurgical integration into the areas of environmental characterisation, blasting and predictive leaching attributes. This involves new collaborations with UQ's Centre for Mined Land Rehabilitation (CMLR) – a leader in environmental aspects of mining; UQ's WH Bryan Mining and Geology Research Centre (BRC) – a leader in the areas of mass mining, geotechnical engineering, optimisation in mine design and planning; and the Perth-based Parker Centre CRC [CSIRO] – a recognised world leader in the area of integrated hydrometallurgy.

In addition to core program support, 12 sites have been nominated for case studies with an emphasis on implementation and validation of project outcomes. This will involve additional industry funding based on individually scoped projects that will be closely linked with technology transfer and commercialisation.

INTRODUCTION

The minerals industry continues to strive for greater efficiency, lower operating costs and reduced risk. This requires the treatment of lower grade, higher volume and more complex ores, together with the need to meet community expectations of social measures such as reduced energy, carbon and water footprints. The emerging field of geometallurgy is becoming recognised as a high-value activity that can deliver these outcomes through enhanced mine planning for more effective and sustainable mine site operations, and subsequent better utilisation of the resource.

Geometallurgy involves a quantitative and comprehensive approach to ore characterisation in terms of critical processing attributes. These include blasting, crushing, grinding, liberation, recovery, product quality and environmental effects.

Key benefits of improved geometallurgical knowledge are:

- Improved forecasting.
- Reduced technical risk.
- Enhanced economic optimisation of mineral production.
- More efficient use of the resource.

Detailed geometallurgical models that reflect inherent geological variability aim to reduce the technical risk associated with the design and operation of mines. This approach is particularly important in feasibility studies, as a precursor to design, where physical access to and knowledge of an ore deposit is limited and evolving.

Geometallurgical information provides an essential input into flow sheet design and equipment sizing. It also provides improved forecasting and optimisation of plant performance over the life of the project, as knowledge of the ore body evolves. Incorporation of predictive geometallurgical parameters into resource modelling supplements traditional geology and grade-based attributes, enabling a more holistic approach to maximising economic returns and managing risk.

The GeM[III] vision is collaborative development of a new cross-discipline research platform to support the emerging role of geometallurgy in providing predictive inputs into mine planning, economic optimisation and sustainability. Although many companies have already begun this process, the project is designed to accelerate the significant changes in culture and technology required for successful establishment of industry best practice, by providing new tools and methodologies.

The research goals for the P843A extension project are:

- Deliver the next generation of practical geometallurgical tools and methods.
- Extend the research scope into environmental, blasting and leaching applications.
- Consolidate an integrated approach to predictive geometallurgical modelling.
- Conduct site-based validation of the methods and tools.
- Develop programs for geometallurgy training and further education.
- Establish a forum for industry best practice in geometallurgy.
- Support new technology transfer initiatives.
- Develop a technology road map to guide future research needs.

OUTLOOK

The major initiative for the Recovery Program in 2010 will be continued development of the AMIRA P843A extension project. While this commenced in July 2009, the project is still in a ramp-up phase involving new research collaborations, generation of additional industry sponsorship, and development of an extensive portfolio of case studies.

P384a will be split into two components, part of which is core business to CODES and the other part core business to the planned CRC COREX which has a planned start date of July 2010.

The research scope involves additional areas of geometallurgical integration and research collaborations not covered in the original P843 project. These are mainly in the areas of early predictive environmental characterisation, more sophisticated inputs into blast modelling, and development of geometallurgical leaching indices. Five research institutions are involved in P843A:

- **CODES, the ARC Centre of Excellence in Ore Deposits at the University of Tasmania, a world-leader in research related to economic geology.**
- **Julius Kruttschnitt Mineral Research Centre (JKMRC) at the University of Queensland, a world-leader in mining and mineral processing research.**
- **WH Bryan Mining and Geology Research Centre (BRC) at the University of Queensland, a leader in the areas of mass mining, geotechnical engineering, optimisation in mine design and planning.**
- **The Parker Centre CRC [CSIRO] based in Perth a recognised world-leader in the area of integrated hydrometallurgy.**
- **The Centre for Mined Land Rehabilitation (CMLR) at the University of Queensland a leader in environmental aspects of mining.**

A feature of the research is a balance between generating fundamental knowledge and delivery of practical tools. This is evident in the project's structure, which is divided into core research and applied case studies. The core research is designed to undertake fundamental method development with a focus on enabling tools. Method development will proceed as far as proof of concept and then be made available for validation and benchmarking through site-based case studies. Twelve case study sites have been nominated with individually scoped work programs under development related to specific geometallurgical issues and opportunities identified in consultation with each site.

The successful extension of the GeM[III] project enables consolidation of world-class geometallurgical research involving the CODES Centre of Excellence in Ore Deposits, based on high-profile cross discipline research collaborations. Significant initiatives are also underway to provide technology transfer and commercialization support for GeM[III] outcomes in close consultation with industry. This is being done through JKTech (the technology transfer arm of the Sustainable Minerals Institute at UQ) and P843A supplier sponsors.

CORE PROJECTS

Project P4.L1 (AMIRA P843A) GeM^{III} project (Geometallurgical Mapping and Mine Modelling).

This is currently the only active project within Recovery. However, it is equivalent in size and funding to research activities within other Programs.

At the end of 2009, P843A was sponsored by 13 companies. Major sponsors are Anglo American, Anglo Gold Ashanti, BHP Billiton, Codelco, Newcrest, OZ Minerals, Rio Tinto, Teck, Vale Inco and Xstrata. Supplier sponsors are ALS Chemex, IoGlobal and Metso Minerals.

The project is based on six themes:

- P4.L1.1 **Predictive environmental indices**
- P4.L1.2 **Integrated blast modelling**
- P4.L1.3 **Deterministic comminution modellin**
- P4.L1.4 **Texture-based liberation and recovery modelling**
- P4.L1.5 **Predictive leaching indices**
- P4.L1.6 **Specialist analytical and software support.**

(L denotes industry-linked theme.)

PROJECT SUMMARIES

P4.L1.1
PREDICTIVE ENVIRONMENTAL INDICES

LEADER: Mansour Edraki (CMLR)

TEAM MEMBERS: Ron Berry, Barry Noller, Steve Walters

STUDENT: Anita Parbhakar-Fox

This is a new collaboration that is still under development and scoping. The aim is development of more cost-efficient small-scale testing and modelling to provide predictive indices for environmental attributes, mainly in the areas of propensity for dust generation and speciation; characterisation of texture-related acid-base reactions; and provision of new and more effective micro-analytical technologies to map deportment of deleterious and harmful trace elements, with an emphasis on secondary mobility and bioavailability. This will involve a new collaboration with the Centre for Mined Land Rehabilitation. A senior appointment in environmental geochemistry is envisaged within the School of Earth Sciences at UTAS to support this work.

Although a new research theme within GeM^{III}, many of the existing tools and methodologies developed in P843 will be modified and adapted for environmental characterisation. This particularly applies to automated mineralogy and texture analysis tools, which can be used to more effectively predict acid-base reactions. Prediction of the potential for fugitive dust emissions can also be linked, for example, to fines generation as part of comminution testing.

P4.L1.2
INTEGRATED BLAST MODELLING

LEADERS: Italo Onederra (BRC), Simon Michaux (JKMRC)

TEAM MEMBERS: Ron Berry, Toni Kojovic, Steve Walters

A wide range of blasting models is used in current practice, or is being researched by other projects. While aspects such as detonics and stress modelling are relatively advanced, fundamental bulk rock properties are typically represented by limited measurements or proxies, with poor representation of inherent geological variability. The main rock-based inputs involve distribution of discontinuity sets, such as joints or bedding planes. The aim is to optimise and integrate measurement of bulk rock properties, using technology suites already developed in P843, into current and emerging blasting models. A key aspect is an assessment of the sensitivity of blast modelling outcomes using data that more accurately represents inherent geological variability. Given that many of the component parts already exist, it is anticipated that this module will generate rapid outcomes. This will create opportunities for integration of improved blasting models into site-based case studies.

P4.L1.3
DETERMINISTIC COMMINUTION MODELLING

LEADERS: Louisa Groves (JKMRC), Toni Kojovic (JKMRC)

TEAM MEMBERS: Julie Hunt, Simon Michaux, Pat Walters, Steve Walters

STUDENTS: Luke Keeney, Adel Vatandoost

Significant progress was made in the development of comminution modelling methodologies in P843. This was supported by an extensive suite of integrated small-scale tests e.g. EQUOtip, Comminution Index, and JK RBT. An important outcome was the demonstration of a deterministic approach to generating predictive comminution indices. This involved integration of bulk mineralogy and texture attributes into class-based modelling.

While some further development of comminution testing and modelling methodologies is required, this work will be relatively minor compared to other core modules. The main opportunity is to undertake large-scale validation trials though site-based case studies. This will involve partnerships with suitable data-rich sites, or sites willing to support commercial technology transfer.

P4.L1.4
TEXTURE-BASED LIBERATION AND RECOVERY MODELLING

LEADER: Dee Bradshaw

TEAM MEMBERS: Ron Berry, Julie Hunt, Maya Kamentesky, Khoi Nguyen, Steve Walters

STUDENTS: Natalee Bonnici, Cathy Evans, Mitesh Chauhan

Current practice for determining flotation recovery is based predominantly on physical testing linked to grade recovery modelling. This is increasingly supported by SEM-based mineralogy of tails, and products to quantify liberation and locking. However, the approach is not predictive and is also relatively high cost. This discourages analysis of the large data sets required for assessing inherent geological variability. A common outcome is a universal grade-recovery curve or a single recovery adjustment factor embedded into the block model.

An alternative approach developed in P843 involves texture-based predictive modelling of liberation as a proxy for flotation recovery. This is based on analysis of intact meso-scale ore textures. The aim is to provide early recognition of differences in mineral separability potential. The approach involves a combination of sophisticated textural analysis and multi-component particle simulation calibrated against physical testing outcomes. This can also be supported through development of lower-cost comparative flotation testing.

The approach is not designed to address the complex physical and chemical interactions involved in froth flotation. The intent is to provide early indication of changes in ore textures predicted to result in significant changes to flotation feed properties. This information can be used to optimise feed and more effectively manage the recovery process. The ultimate goal is to develop effective methods to map deposit-scale, texture-based domains that incorporate predictive liberation indices. This will be used to guide sample selection for more rigorous or precise test work, such as batch or pilot scale tests.

Significant progress was made in P843 in developing the specialist tools and methods required to facilitate this approach. This included sophisticated image analysis software and provision of lower cost textural mapping methods, such as meso-scale core imaging and automated optical microscopy. However, the concept of linking intact texture analysis to predictive liberation potential, and ultimately to flotation recovery, is a major challenge. While proof of concept was demonstrated in P843, significant ongoing research is required to refine the method, consolidate tools and undertake large-scale validation.

P4.L1.5
PREDICTIVE LEACHING INDICES

LEADERS: Dave Robinson (Parker), Matthew Jeffrey (Parker)

TEAM MEMBER: Byron Benvie, Laura Kuhar, Angus McFarlane

The extension of GeM[III] into hydrometallurgy is designed to follow the principles established in other research themes and exploit many of the tools developed in P843. The aim is to develop predictive indices for selected aspects of leaching performance, with an emphasis on defining inherent geological variability and identifying fundamental controls. This will require development of enabling technologies to process larger numbers of small-volume physical tests analogous to the Comminution Index approach. While new physical tests are required, many of the mineralogical and textural analysis tools developed in P843 can be readily adapted to provide support for modelling.

This theme will be carried out in collaboration with the Parker Cooperative Research Centre [CSIRO] for Integrated Hydrometallurgy Solutions based in Perth. The Parker Centre has four Core Research Participants (CSIRO Minerals, Curtin University of Technology – including the Western Australian School of Mines, Murdoch University, and the University of Queensland). The Centre is one of the most successful CRCs and is recognised as a world-leader in the area of integrated hydrometallurgy research. It maintains close links to industry, working in both longer term fundamental and novel research while supporting incremental developmental activities.

The range of hydrometallurgy research being undertaken at the Parker Centre [CSIRO] includes mineralogical, chemical and physical characterisation of feed, intermediate and residue materials, leaching and solution chemistry, value(s) and impurity element separations, final metal, residue and effluent related processing steps, and a number of modelling techniques. With respect to leaching, there is a wide diversity of potential process routes linked to varying target commodities and different deposit types. Work is likely to focus on aspects of sulphide and oxide Cu-Au and Au leaching. Final selection of specific leaching routes and deposit types for investigation will be influenced by the case study opportunities provided by sponsors.

Although there are many generic similarities in the potential application of geometallurgical principles to predicting and optimising leaching performance, there are also a range of attributes more specific to leaching applications that need to be investigated. These include agglomeration characteristics, reagent consumption, rheology of slurries, reaction kinetics, and conditioning pre-treatments. As in all GeM[III] applications, the aim is not to simulate the precise outcomes of complex interactions but to provide comparative rankings and predictive indices suitable for early-stage geometallurgical mapping and domaining. This information can be incorporated into resource block models and used for more effective scheduling, optimisation and forecasting.

P4.L1.6
SPECIALIST ANALYTICAL AND SOFTWARE SUPPORT

LEADER: Ron Berry

TEAM MEMBERS: Alan Bye, Maya Kamenetsky, Khoi Nguyen, Steve Walters

GeM[III] research is supported by an extensive suite of analytical and testing facilities combined with software-based data analysis and modelling tools. This includes equipment specifically to support the project, such as two Leica DM600 optical microscopes, two GEOTEK automated core loggers, an EQUOtip hardness tester and a CAMSIZER optical sizer. This is augmented by shared access to a wide range of specialist equipment such as MLA, XRD, RBT and batch flotation devices.

The equipment support base will be expanded through new initiatives, such as the new Mineral Characterisation Research Facility (MCRF) laboratories at the JKMRC; access to leaching-related analytical facilities as part of the collaboration with the Parker Centre [CSIRO]; and potential application of advanced micro-analytical techniques being developed at CODES (e.g. micro-XRF and Laser Ablation ICP-MS).

Maintaining access to and supporting this equipment requires specialist technical input, which will be provided through a small team of technicians. The majority of support will involve providing inputs into site-based studies. A limited, focused program of new method development and identification of enabling technologies is planned.

A wide range of specialist software is required for data acquisition, processing, analysis and modelling. Limited software development will continue to be undertaken where gaps are identified in enabling software. The project will also provide specialist geostatistical and spatial modelling support through collaboration with the BRC and relationships with supplier sponsors.

PROGRAM FIVE
TECHNOLOGY

OBJECTIVES

Research activities within the program are aimed at developing new analytical techniques, ensuring that research is driven by innovative technology, and the Centre is at the cutting edge of analytical developments of relevance to ore deposit research.

The program also aims to provide CODES' research staff and students with access to state-of-the-art micro-analytical equipment within Australia and overseas, and maintain their awareness of new analytical developments.

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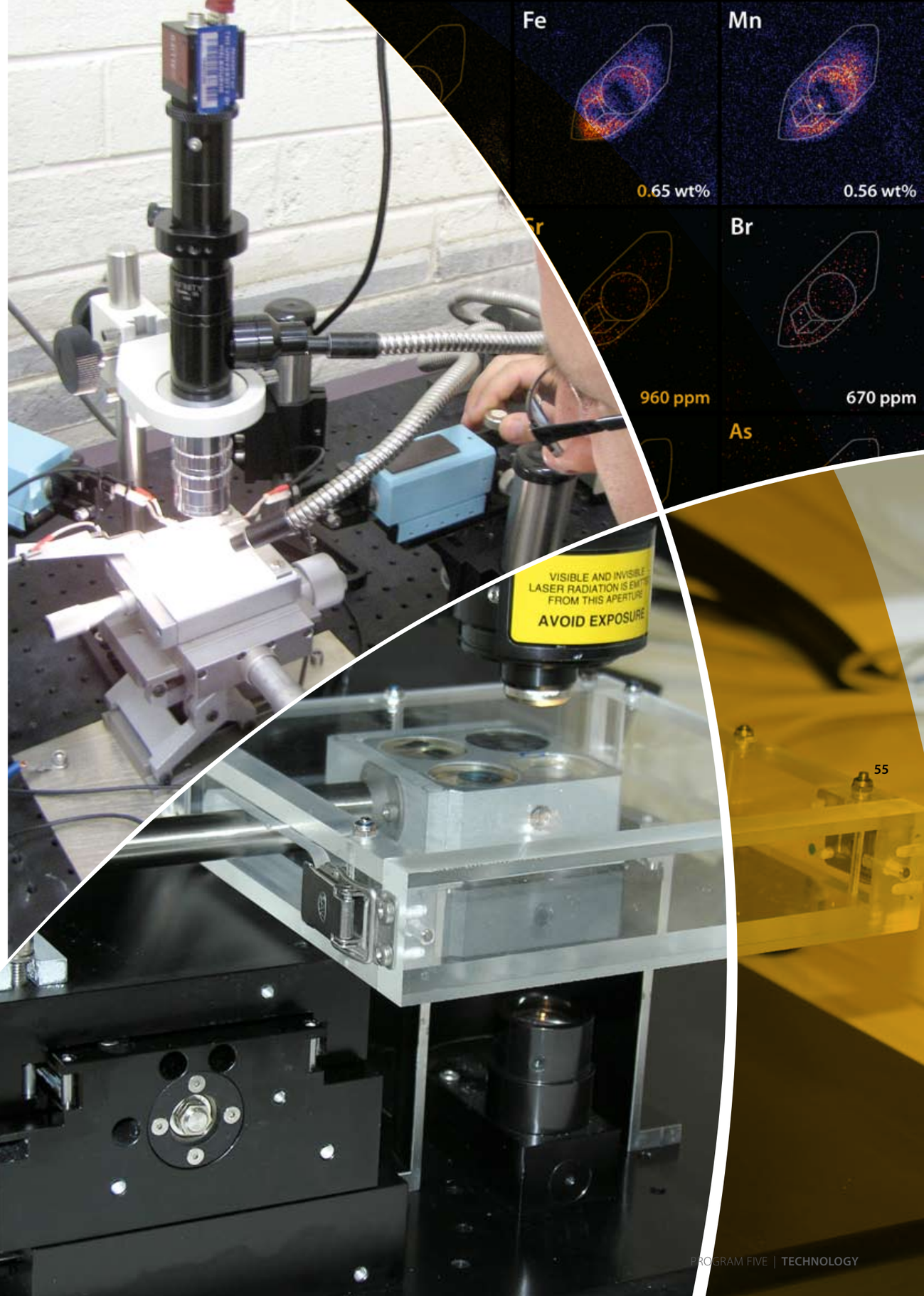


HIGHLIGHTS

- The CODES' LA-ICPMS facility was expanded by acquiring an excimer Resolution M50 laserprobe with a constant geometry ablation cell, and a new generation Agilent 7700 quadrupole mass-spectrometer, which is characterised by significantly improved sensitivity and detection limits for most trace elements.
- The high-TP mAESTRO (Australian Extreme SpecTROscopy) cell system for synchrotron XAS measurements was successfully commissioned at the Australian Synchrotron. The cell, which was developed in collaboration with the University of Adelaide, provides a capability for in-situ examination of the structure and composition of species in solutions under geologically relevant conditions.
- Developments commenced towards building a scanning electrochemical microscope (SECM) – in collaboration with the School of Physics, University of Melbourne. The new SECM will use a novel cell concept designed by Stacey Borg.
- A constant geometry cell for the NewWave UP platform laser probes has been successfully designed and built in-house.

INTRODUCTION

The Technology Program explores and develops novel analytical and data interpretation techniques based on the latest technological developments, such as a number of high spatial resolution microprobes. This helps in the understanding, exploration and exploitation of deep earth resources.

Current research projects focus mainly on expanding the capabilities of in-situ multi-element analysis by laser ablation (LA), inductively-coupled plasma mass-spectrometry (ICP-MS), in-situ isotope analysis by LA multi-collector (MC) ICPMS, non-destructive multi-element analysis using nuclear (PIXE) and synchrotron-based X-ray microprobes (XFM), and development of new stable-isotope solution-based analytical techniques. Research activities also develop data interpretation tools, such as new algorithms and user-friendly scientific software packages. These are used primarily for modelling the deep earth processes that lead to ore formation, and processing of analytical data. Many of the projects include close collaborations with Node partners, such as the University of Melbourne, CSIRO and ANU.

OUTLOOK

The main research focus in 2010 will be on:

- **Assessing possible applications of the mass-spectrometer collision cell technology for laser ablation ICPMS, aimed at increasing detection limits for a range of light elements and PGEs.**
- **Pushing the LA-ICPMS limits of detection to the maximum by examining the performance of quadrupole ICP mass-spectrometers under high plasma matrix load. These applications are designed for low-levels of Au and Pt in a wide range of rock types.**
- **Developing analytical protocols for the Mo isotope system and applying them to ore deposit studies.**
- **Developing a Scanning Electrochemical Microscope, and systems for charge injection mapping of pyrite to better constrain the electrochemical controls on Au deposition from hydrothermal solutions.**
- **Developing a standard procedure for extraction and analysis of XANES spectra from high resolution XRF images.**
- **Improving trace element distribution imaging techniques for LA-Q-ICPMS.**

CORE PROJECTS

Theme 5A Advancing Spatially-Resolved Mass-Spectrometry

P5A1 **LA-Q-ICPMS analysis development**

P5A2 **New LA-Q-ICPMS applications**

P5A3 **New LA-MC-ICPMS applications**

P5A4 **New stable isotope MS applications**

P5A4A **Cracking the sulphate isotopic composition problem in ancient hydrothermal systems: application of the Carbonate-Associated Sulphate (CAS) method**

Theme 5A Advancing Non-Destructive Focused-Beam Spectroscopy

P5B1 **Ion beam analysis development**

P5B2 **New ion beam applications**

P5B2A **Improved quantification of PIXE analyses of fluid inclusions using internal standardisation and accurate volumetric determination**

P5B2B **Application of PIXE technologies to hydrothermal processes: mineral trace element zoning and composition of single fluid inclusions**

P5B3 **Synchrotron X-ray probe development**

P5B4 **New synchrotron-based applications**

P5B4A **Developmental research into the use of synchrotron in ore deposit studies**

P5BN1 **X-ray microanalysis development.**

Theme 5c: Data Interpretation Tools

P5C1 **Improved data reduction algorithms for LA-ICPMS**

P5C2 **Improved image processing algorithms for LA-ICPMS**

P5C3 **Modelling of crystallisation and melting processes**

P5C4 **Combined database and data reduction software**

PROJECT SUMMARIES

P5A1

LA-Q-ICPMS ANALYSIS DEVELOPMENT

LEADERS: Sebastien Meffre, Leonid Danyushevsky

TEAM MEMBERS: Sarah Gilbert, Marcel Guillong

This project designs and develops new instrumentation to ensure continuing advances in geological LA-Q-ICPMS applications. Example developments include ablation cells, the interface between the laser and the mass-spectrometer, and testing of new types of laser microprobes and mass-spectrometers.

A total of four new in-house ablation cells were made for the NewWave UP platform laser probes. Manufacture was completed in collaboration with the UTAS Central Science Laboratory. The following improvements have been made to the initial prototype:

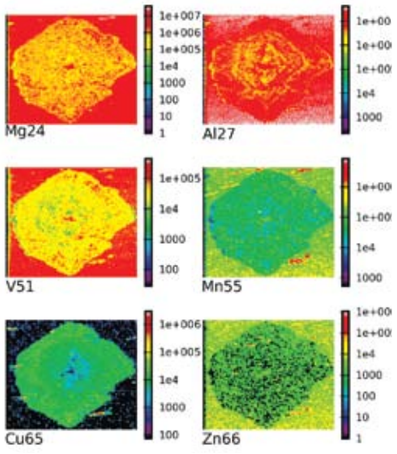
- The flow of He through the upper part of the cell has been reversed, which prevents the glass at the top of the chamber becoming rapidly coated by the aspirating aerosol and absorbing the laser beam energy.
- The reverse flow configuration allowed a modification to the flushing routine following sample exchange, which enables continuous flushing with a high Ar flow (20 l/min) while the cell is off-line. Flushing with Ar, instead of He, has substantially decreased the duration of the sample exchange routine to <10 min. The cell is now permanently filled with Ar through its entire volume, except immediately around the ablation site where He is injected from above. This configuration allows for ablation in a He atmosphere, with the He and ablated material being immediately mixed with Ar for efficient transport of the ablated aerosol to the mass spectrometer.
- Absorption of air during sample exchange has been prevented by using polyethylene-aluminium laminates in the construction of the bellows.
- A range of mixing devices has been acquired, developed and fitted between the laser and the mass-spectrometer to resolve the problem of harmonic interferences.

Trials of the final cell design suggest that the cell is robust and has a fast response time, with a much improved spot-

to-spot reproducibility compared to previous cells. The new cell takes four standard one-inch mounts, facilitating the use of the machine in fully automatic and overnight modes. This is highly advantageous for making maps and analysing Pb and U isotopic compositions because it enables the standards to be analysed continuously, giving better drift and mass bias correction.

The new excimer Resonetics M50 laser probe was thoroughly tested for U-Pb geochronology applications in the latter part of the year and a few teething problems were resolved. The laser was tested for precision, accuracy, down-hole elemental fractionation and drift. Overall, the performance of the system was excellent for U-Pb work. It is more robust than the New Wave 193 nm laser and its superior software enables faster sample throughput. The quality of U-Pb and Pb-Pb data was improved by introducing overnight gas flushing routines, which enhanced instrument stability by greatly reducing drift. All CODES geochronology is now performed on the M50 instrument.

A testament to the progress of this project since its inception in 2007 is the fact that approximately 10,000 U-Pb and Pb-Pb analyses were performed in 2009 on ~450 samples. The development work will continue to underpin many CODES' projects in 2010 and beyond.



LA-ICPMS pyrite maps, Bendigo gold-mine, Australia.

P5A2
NEW LA-Q-ICPMS APPLICATIONS

LEADERS: Marcel Guillong, Leonid Danyushevsky

TEAM MEMBERS: Sarah Gilbert, Sebastien Meffre

New geological LA-Q-ICPMS applications are being developed in the fields of ore deposit geology, igneous petrology, hydrothermal fluid chemistry, and U-Pb dating of zircons and other minerals.

Activities focused on transferring the existing application for analysis of sulphides and U-Pb dating to the new instruments. A report was prepared and submitted to Agilent on the optimisation of the new Agilent 7700 Q-ICPMS for laser ablation applications.

P5A3
NEW LA-MC-ICPMS APPLICATIONS

LEADERS: Bence Paul, Janet Hergt, Chad Paton

TEAM MEMBERS: Leonid Danyushevsky, Sebastien Meffre, Jon Woodhead

This project develops new analytical techniques for quantitative, in-situ analysis and imaging of isotopic compositions of a number of indicator elements including Pb and Sr, in sulphide, carbonate and silicate minerals. The aim is to provide new information on the nature of fluids involved in ore genesis for a variety of deposit types.

This past year, the focus was on developing techniques for imaging the Pb isotopic composition of pyrite and Sr isotopic composition of carbonates. Testing of Hg traps was performed at the University of Melbourne Node in an attempt to reduce interferences on ^{204}Pb. However, no improvements in ^{204}Pb data could be achieved. At present, imaging the distribution of ^{204}Pb-based Pb isotope ratios in pyrite on the multi-collector instrument requires the use of a large laser beam (>80 microns), which limits the application to large grains with elevated Pb contents. Parallel developments at the UTAS Hub resulted in the initial testing of a technique for imaging the distribution of ^{207}Pb/^{206}Pb and ^{208}Pb/^{206}Pb ratios in pyrite using a quadrupole instrument. As with MC-ICPMS, this technique can be applied to smaller grains with lower Pb contents. The technique can be used for understanding the complex Pb isotopic zonation common for high U deposits, and for identifying locations of the more precise spot analyses within complexly zoned grains.

The possibility of generating Sr-isotope data, via laser ablation of ore-stage carbonate, to interrogate the potential sources of Sr in hydrothermal fluids was examined at the University of Melbourne Node. Research indicates that carbonates would need to contain ~1,000 ppm Sr to allow use of a 50-micron laser beam.

P5A4
NEW STABLE ISOTOPE MS APPLICATIONS

LEADERS: Janet Hergt, Chad Paton, Bence Paul

TEAM MEMBERS: Zhaoshan Chang, Leonid Danyushevsky, Sebastien Meffre, Jon Woodhead

The aims are to:

- Develop micro-drilling-based, spatially resolved solution analysis of nonconventional stable isotopes (Cu, Zn, Li, Mo) that can be used as tracers of ore forming processes. This will be done on a multi-collector ICPMS instrument at the University of Melbourne Node.
- Develop in-situ UV laser ablation-based techniques for mapping the distribution of O, C and S isotopes in silicate and sulphide minerals, using a non-ICP mass-spectrometer at the UTAS Hub.

In 2009, the project focused on refining the Cu isotope technique and assessing the potential of Mo as an isotope tracer. Bulk analysis of Cu-rich deep marine sediments was completed. The samples from the OBS hydrothermal vent site (21°N on the East Pacific Rise) have high Cu isotope values compared with virtually all the chalcopyrite ores analysed previously, and are consistent with published data for similar sites on the Mid-Atlantic Ridge. Data reveal a zoning pattern in both Cu isotope composition and Cu content, which demonstrates the value of conducting detailed studies of single examples to gain an understanding of the causes of Cu isotope variations. Continuing development of the technique for analysis of Cu isotopic composition resulted in a modified elution procedure, the observation that Cu/Zn values need to be higher than 1 to avoid contaminating phases, and the use of an experimentally determined fractionation relationship between Cu and Zn for mass bias corrections.

The database of Cu isotope compositions now includes 40 chalcopyrite analyses from a wide range of ore deposits that all show little Cu isotope variation. Experimental work using Zn doping to simulate the presence of contaminating phases indicated that this can be a significant problem for measuring Cu isotope ratios and needs to be avoided by either microdrilling or crushing and separating chalcopyrite. Investigations also commenced into the establishment and application of the Mo isotope system to ore deposits. The strong fractionation in the marine environment, and long residence time, make Mo highly suitable to studies of changes in redox profiles, and possibly the source of Mo in ore systems. Preliminary column calibrations and mass spectrometry routines were established and a small number of molybdenite samples provided for testing.

P5A4A
CRACKING THE SULPHATE ISOTOPIC COMPOSITION PROBLEM IN ANCIENT HYDROTHERMAL SYSTEMS: APPLICATION OF THE CARBONATE-ASSOCIATED SULPHATE (CAS) METHOD

LEADERS: Garry Davidson, David Cooke

TEAM MEMBERS: Janet Hergt, Katie McGoldrick, Karin Orth

STUDENT: Heidi Pass

COLLABORATORS: RC Figueiredo e Silva, Steffen Hagemann

Commenced in 2006, this project is evaluating the concept of substituted sulphate in hydrothermal carbonate minerals. This subject is unexploited in hydrothermal research, and refinements to existing techniques are required to extract the isotopic information, and image the low level abundances of sulphate that appear to be typical of hydrothermal carbonate. These sulphur levels (mainly <100 ppm) lie below detection for in-situ stable isotope analytical techniques. Therefore, wet chemical extraction is currently the only method for isolation of sufficient sulphur for isotopic analysis.

In 2009, the case study involving epigenetic carbonate in upgraded Hamersley-style iron formations of the Carajas district progressed to submission of a manuscript. This multidisciplinary project has involved CAS analysis, microprobe S and trace element mapping, stable isotopes and Sr isotopes.

P5B1
ION BEAM ANALYSIS DEVELOPMENT

LEADER: Jamie Laird

TEAM MEMBERS: Stacey Borg, Garry Davidson, Chris Ryan

COLLABORATORS: Stephen Best, Kumar Ganesan, Brett Johnson, Jeff McCallum

Instrumentation is being developed that provides a better understanding of the role and fluid electrochemistry of semiconducting minerals, like pyrite, on gold ore genesis.

This requires analytical-type systems to be established for measuring the spatial variation in the electrical properties of minerals, which are used to select mineral zones for observation of electrically determined pathways. Techniques are then developed for imaging the likely seed spots for metal precipitation, based on the electro-chemical properties of the mineral.

A suite of techniques for mineral characterisation were developed in 2009, including:

- Thermoelectric probing using hot-cold probes (material type).
- Co-linear four point probing (resistivity).
- Van de Pauw probing (resistivity).
- Current and capacitance voltage (contact quality and activated impurity concentration).
- Hall-effect (carrier mobility).


Jamie Laird at the Nuclear Microprobe, University of Melbourne

These techniques and their associated analysis are non-trivial, and specially prepared calibrated pyrite samples have been used throughout the project.

Excellent progress has been made on developing systems for measuring electrical properties of minerals on the micron to mm scale, including several imaging techniques for better understanding the electrochemical controls on Au ore genesis. Cubic pyrite crystals were calibrated electrically, using both thermoelectric and resistivity probing. These were found to be n-type semiconductors with reasonably high levels of Co, as measured using PIXE microanalysis. These crystals were further characterised by synchrotron X-ray diffraction experiments in conjunction with the CSIRO, and have then been used for developing Schottky rectifying contacts, which simulate an electrolytic layer by forming a space-charge region at the surface. The difficulty in forming electrical contacts on pyrite was overcome by using Raman microscopy to identify surface treatments likely to result in good contacts. As a result, Au

and Pt based contacts have been formed and characterised at room and low-temperature (20K to 300K). Several reasonably good Pt-based devices, and one excellent Au-based device, have been fabricated for Charge Injection Mapping using the CSIRO proton microprobe. The system for mapping has been completed and tested on standard semiconducting devices based on Si, InGaAs and diamond. A number of publications have resulted from this work (see Publications section).

Development has commenced on building a Scanning Electrochemical Microscope (SECM). The project initially planned to incorporate an electrochemical stage onto the CSIRO proton microprobe, but this approach presented a number of insurmountable technical difficulties. However, the SECM is an established tool that, coupled with a focused laser beam, may offer more capabilities than the initial concept. Rapid progress has been made with the proto-type cell, and testing is planned for the first half of 2010.

P5B2
NEW ION BEAM APPLICATIONS

LEADER: Jamie Laird

TEAM MEMBERS: Chris Ryan, Jamie Wilkinson

The objective is to develop and implement Ion Beam Analysis (IBA) techniques that provide complementary information during PIXE analysis of Fluid Inclusion (FI) – in particular, accurate mineral phase and geometrical information to improve modelling of quantitative PIXE data. The two methods identified to meet this need are Ionoluminescence (IL) spectroscopy and Rutherford Back Scattering (RBS).

An optimal IL system for the CSIRO PIXE probe was purchased, and includes the Maya2000 spectrometer with a high efficiency to operate at minimal ion beam current to reduce damage effects. Optical fibre vacuum fittings were installed on the target chamber and LabVIEW-based control software has been written to scan the beam and collect hyper spectral luminescence spectra. The main spectrometer, which has a slightly customised design, is being built in the USA. A dose normalisation process, based on measuring charge integration on the sample as a function of position, is also being developed.

The technique will be tested initially on a set of inclusions with reasonably large daughter minerals. PIXE data on several of these inclusions have been collected to examine typical contents likely to be found in the final set chosen for IL spectroscopy. Eventual spectroscopic data will be compared to the mineral database at CSIRO for phase identification.

The Rutherford Back-Scattering Spectrometry aspect of the project is partially on hold, pending new target data acquisition and a target chamber for the CSIRO beam-line. However, modelling of Non-Rutherford Back Scattering, using the SIMNRA code, has ascertained the optimal detector configuration for sensitivity to the fluid location. This will partly feed into the new chamber design. Some materials for mounting detectors etc are currently being built at the CSIRO.

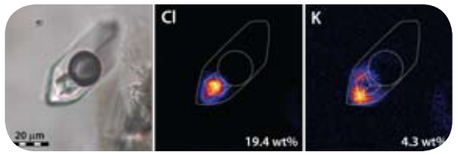
P5B2A
IMPROVED QUANTIFICATION OF PIXE ANALYSES OF FLUID INCLUSIONS USING INTERNAL STANDARDISATION AND ACCURATE VOLUMETRIC DETERMINATION

LEADER: Jamie Wilkinson

TEAM MEMBERS: Leonid Danyushevsky, Sarah Gilbert, Jamie Laird, Chris Ryan, Clara Wilkinson

A range of approaches is being tested to improve quantification of fluid inclusion measurements by nuclear microprobe (proton induced X-ray and gamma ray emission; PIXE and PIGE). Methods to be tested include internal standardisation using Cl and other elements (including Na derived from PIGE spectra), spindle stage and laser confocal microscopy for accurate volume quantification, and direct comparison of PIXE and LA-ICP-MS data. Preliminary PIGE spectra from synthetic and natural fluid inclusions are currently being processed. Processing of PIXE data from natural brine inclusions and comparison with LA-ICPMS results have shown that there is a systematic bias of a factor of 2–3 between the two techniques.

Modelling inclusion thickness and depth to the top surface as linked variables, using Cl as an internal standard, yields an improvement to PIXE data, which are only ~30% higher than LA-ICP-MS results. In both cases, derived concentrations are depth and inclusion mid-plane dependent, with convergence of the two datasets at increasing depths indicating the PIXE geometric correction requires adjustment.



An elemental image of a fluid inclusion showing distribution of chlorine (Cl) and potassium (K)

P5B2B
APPLICATION OF PIXE TECHNOLOGIES TO HYDROTHERMAL PROCESSES: MINERAL TRACE ELEMENT ZONING AND COMPOSITION OF SINGLE FLUID INCLUSIONS

LEADER: Zhaoshan Chang

TEAM MEMBERS: David Cooke, Leonid Danyushevsky, Dima Kamenetsky, Chris Ryan

COLLABORATOR: Taofa Zhou

As one of the most common minerals in lithocaps, alunite has attracted significant exploration attention. This initiative investigates the concentration of trace elements, their residence status, and relationship with major elements in this mineral. Recent empirical studies show that the trace element and SWIR spectral features of alunite may point towards the causative intrusive centre, where the potential for hosting epithermal and porphyry-style mineralisation is the highest (Chang et al., 2009). The objectives are to find more elements that may help exploration as vectors and evaluate the reliability of each vectoring element.

Ten alunite grains from seven samples from the Mankayan district were analysed using the CSIRO PIXE instrument at the University of Melbourne. There is a genetic relationship in this district between the lithocap hosting the Lepanto HS ores and the FSE porphyries with associated porphyry-style mineralisation. Zones of elevated Pb, Sr, Zn, As, Ga and/or Ba in alunite have been found.

Trace element concentrations of the whole grains, and the zones with various elevated trace elements, have been reduced from the imaging data. The major element concentrations of these zones will be analysed by microprobe to establish the correlations and constraints of the processes controlling the trace element distributions.

P5B3
SYNCHROTRON X-RAY PROBE DEVELOPMENT

LEADER: Chris Ryan

TEAM MEMBER: Stacey Borg

COLLABORATORS: Joel Brugger, Gianluigi De Geronimo, Martin de Jonge, Paul Dunn, Barbara Etschmann, Jean-Louis Hazemann, Daryl Howard, Murray Jensen, Robin Kirkham, Tony Kuczewski, Weihua Liu, Gareth Moorhead, David Paterson, Peter Siddons, Denis Testemale

Using the applications at the Australian Synchrotron, the objectives are to develop:

- An advanced fluorescence Maia detector for the XFM beamline, based on a series of successful prototypes developed between 2005 and 2008.
- A high pressure-temperature synchrotron spectroscopy cell for analysis of fluid inclusions at the XAS beamline.
- Simultaneous micro-XRD/XRF capability for quantitative identification and analysis of clay minerals.

Significant progress in the past year includes the completion and commissioning of the high-TP cell and extensive use of the Maia prototype – with the final Maia system close to finalisation.

The high-TP system, dubbed mAESTRO (Australian Extreme SpecTROscopy), provides a capability for in-situ examination of the structure and composition of species in solutions under geologically relevant conditions.

The first pilot test established that the cell geometry and dimensions were perfectly suited for the beamline, with no adjustments required from the initial specifications. In the second test, a full week's Ni K-edge data were collected at 400 bar pressure and temperatures up to 450ºC. The operation of the cell was very successful, with stability of pressure and temperature regulation at ±0.2 bar and ±1ºC respectively. This system enables examination of almost any solution, under conditions that are compatible with geological hydrothermal events. It is only the second XAS cell in the world capable of operation under these extreme conditions, and having this capability in Australia is invaluable.

Maia detector activities have focused on:

- Development of the full Maia 384 detector array and imaging system for installation at the XFM beamline of the Australian Synchrotron, in collaboration with Brookhaven National Laboratory, USA. Five major components were produced, and testing and commissioning will take place early in 2010.
- Use of the Maia 96 detector prototype as a test-bed for the new Maia system. It will also form a platform for development of XANES imaging capabilities (project P5B4), applied element mapping applications, and GeoPIXE analytical software – in anticipation of the larger Maia detector array. The GeoPIXE front-end applications will provide a common platform for real-time display of spectra, DA element maps and initial analysis.

P5B4
NEW SYNCHROTRON-BASED APPLICATIONS

LEADERS: Chris Ryan, Stacey Borg

COLLABORATORS: Joel Brugger, James Cleverly, Barbara Etschmann, Steve Fraser, Jean-Louis Hazemann, Rob Hough, Weihua Liu, Denis Testemale

Applications have been developed to probe the spatial distribution of the chemical states of As in geological samples and the nature of complexation of ore metals under conditions representative of ore forming systems.

The methods for collection and analysis of XANES spectra from 2D XRF maps are aimed at the display of spatial images of individual chemical species of an element. Activities include:

- Extraction of multiple beam-energy element maps from the Maia data stream.
- Evaluation using Dynamic Analysis (DA) methods to 'fit' species spectra in spatial XANES datasets.
- Successful beamtime proposal to the Australian Synchrotron to apply the methods to arsenic speciation in a regolith profile. The results of this work, which have been accepted for publication, demonstrate the extraction of contrasting spatial distributions of the AsIII and AsV components from high definition XANES datasets.

Successful synchrotron experiments include:

- Examination of Eu(III) speciation in brines and investigations of Eu(II) chemistry.
- Thermodynamics and speciation of Co(II) species in hydrothermal brine solutions at temperatures up to 440ºC.
- Implementation of the mAESTRO system on the Australian Synchrotron XAS beamline (see P5B3).
- Publication of the data for zinc-acetate, and copper-sulphur complexes.

P5B4A
DEVELOPMENTAL RESEARCH INTO THE USE OF SYNCHROTRON IN ORE DEPOSIT STUDIES

LEADER: Anthony Harris

TEAM MEMBERS: David Cooke, Chris Ryan, Clara Wilkinson, Jamie Wilkinson

COLLABORATORS: Andrew Berry, Ian Campbell, Terry Mernagh, Matthew Newville, Stephen Sutton

The aim of this project is to understand metal speciation in magmatic fluids at near-magmatic conditions (above 600°C).

Experimental studies show that significant amounts of metal and ligands (such as Cl and S) can be sourced during degassing and volatile exsolution from hot hydrous silicic magmas. However, little is known about metal speciation at near-magmatic conditions. Speciation controls metal solubility and melt-fluid partitioning, and is linked to when and where metals precipitate to form economic ore deposits, including those rich in Cu, Au, Mo, Sn and/or W. In addition, knowledge of metal speciation is critical to thermodynamic modelling of hydrothermal processes. Recently, CODES reported on in-situ, non-destructive, high-temperature spectroscopy experiments of natural fluid inclusions heated to 700°C.

XANES spectroscopic study revealed that Cu in a saline sulphur-poor ore solution is present as the linear $[CuCl_2]^-$-species at temperatures above ~200°C. Modelling of EXAFS spectra acquired at 530°C reveals the Cu-Cl bond length of 2.11(2) Å, consistent with that reported elsewhere for $[CuCl_2]^-$ at lower temperature (100-325°C) conditions. New high-temperature XANES and EXAFS spectroscopy also show that $[ZnCl_4]^{2-}$, $[FeCl_4]^{2-}$ and $[MnCl_4]^{2-}$ coexist with $[CuCl_2]^-$ at high temperature. Results extend the temperature range for speciation data of each of the elements studied beyond that determined previously and imply that Cu behaves differently from Zn and Mn, which may help to explain the distribution of metals in zoned mineral deposits and districts. Cu deposition from Cl-rich fluids will be less influenced by variations in chlorinity than other highly co-ordinated metals. The difference in speciation could also reflect general differences in bonding, which could make Cu more susceptible to forming Cu-S complexes and be the actual transporting agent of Cu.

P5BN1
X-RAY MICROANALYSIS DEVELOPMENT

LEADERS: Karsten Goemann, Leonid Danyushevsky

This new project commenced in 2009 and includes hardware, software and analytical developments in the Electron Microscopy & X-ray Microanalysis Facility of the UTAS Central Science Laboratory (CSL). Two developments of particular interest to CODES research projects are:

1. Actions that have contributed to a substantial increase in the Horiba MicroXRF sample throughput were:

- Design and manufacture of top-referencing multi-sample holders for geological samples – and matching holding brackets for these holders for use in the digitiser optical microscope.
- Programming Excel macros and spreadsheets for coordinate conversion and off-line calibration curves.
- Design of holders for 40 mm, 32 mm (pressed XRF pellets), and one-inch round mounts. The one-inch holder has been built. Coordinate file conversion programs are available and in use.

2. Automatic cathodoluminescence mapping of large sample areas on the MLA instrument.

Collection of CL mosaics of large sample areas can be performed automatically by the MLA software package, or through separate dedicated software. Using MLA requires an external switchbox for two detector signals. A two-in-one switchbox was designed and built by the CSL electronics workshop, which is now connected to the BSE port and used to switch between the BSE and CL detector. The CL detector output was adjusted to match the different channel requirements. Automated CL mapping, using the MLA software, is available and in use. The work done so far has shown that careful mounting and aligning of both detector and sample(s) are important to ensure adequate illumination and focus.

P5C1
IMPROVED DATA REDUCTION ALGORITHMS FOR LA-ICPMS

LEADER: Leonid Danyushevsky

TEAM MEMBERS: Sarah Gilbert, Marcel Guillong, Janet Hergt, Sebastien Meffre, Bence Paul, Jon Woodhead

The aim is to develop advanced algorithms for LA-ICPMS data reduction, and implementation within the existing data reduction software including Iolite, developed at the University of Melbourne, and Sills, developed at ETH in Zurich.

A new trace element data reduction scheme has been developed for Iolite that employs individual internal standard values for each sample, rather than a default value for all samples. The scheme also provides an indication of detection limits. However, problems were encountered with the detection limit calculations and substantial changes are needed before Iolite can be used for multi-element analysis data reduction on a routine basis. Sills software is reliable and user-friendly for routine multi-element applications, but proved difficult to use where particular interference corrections were required.

P5C2
IMPROVED IMAGE PROCESSING ALGORITHMS FOR LA-ICPMS

LEADER: Anya Reading, Bence Paul

TEAM MEMBERS: Leonid Danyushevsky, Marcel Guillong, Janet Hergt, Sebastien Meffre, Jon Woodhead

COLLABORATOR: Malcolm Sambridge

The aims are to improve the existing algorithms employed in processing image maps acquired by laser ablation and develop new approaches to image generation.

An initial exploration has been completed of the areas that geophysics-related time-series and image processing techniques can be applied to LA-ICPMS imaging of geological specimens. The three areas established were:

- Assistance with diagnostic tests to optimise data collection.
- Image pre-processing – removing the data collection history from the image.
- Image improvement – trialling approaches from information theory, plus statistical and mathematical techniques.

A collaboration with Malcolm Sambridge, a mathematical geophysicist from RSES/ANU, was established and will be developed in 2010.

Iolite software was upgraded to allow upload of data files generated by Agilent ICPMS, which enables 3D images to be produced at CODES. Work started on improving the display of background level concentrations and elements that have a large range of concentrations within an image, and on quantifying elemental concentrations from an image.

P5C3
MODELLING OF CRYSTALLISATION AND MELTING PROCESSES

LEADER: Leonid Danyushevsky

STUDENT: Kyrill Bychkov

COLLABORATOR: Pavel Plechov

The aims of the project are to:

- Develop model-independent algorithms for tracking the behaviour of trace elements during magma generation and evolution processes.
- Simulate mantle and crustal melting processes, with a view to implementation in future versions of Petrolog software.

Work focused on fine tuning mass-balance calculations in 'Petrolog 3', which were released in December 2008, and on revising a submitted manuscript that describes the latest version of the software.

P5C4
COMBINED DATABASE AND DATA REDUCTION SOFTWARE

LEADERS: Leonid Danyushevsky, Bence Paul

TEAM MEMBERS: Sarah Gilbert, Marcel Guillong, Sebastien Meffre

Development has been put on hold pending the outcome of planning for the CODES ICPMS database. Igor Pro licences were purchased to enable the use of Iolite at UTAS.

The project aim is to integrate Iolite software with the existing CODES ICPMS database – ensuring output can be imported directly into this database.

GRADUATE RESEARCH & TRAINING

HIGHER DEGREE BY RESEARCH PROGRAM

Students enrolled in the UTAS Higher Degree by Research (HDR) Program make a major contribution to CODES' research activities. Ninety per cent of HDR projects are integrated into the Centre's five research programs and about two thirds of the projects involve collaborations with industry. HDR students have access to all of the Centre's equipment and facilities and are encouraged to take advantage of the wide range of expertise and experience offered by academic staff.

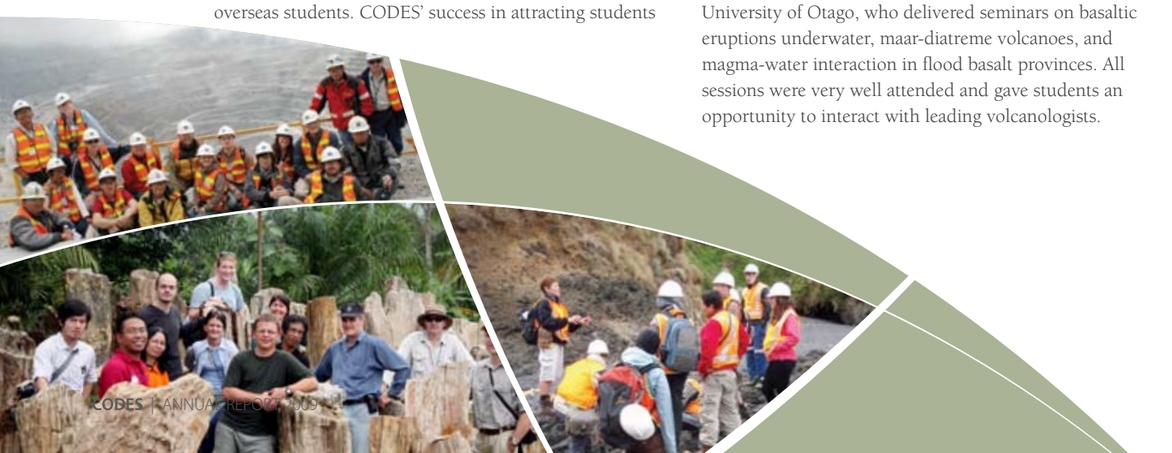
There were 53 students enrolled in the HDR program in 2009, including 11 new PhD students – Mathieu Ageneau, France; Heidi Berkenbosch and Roisin Kyne, Canada; Alexey Lygin, Russia; Victoria Braniff, UK; Gisela Cobenas Benites, Peru; JianXiang Guan, China; Taka Manaka, Japan; Pedro Fonseca, Portugal; Chun Kit Lai, Hong Kong and Basril Basori from Malaysia. Six PhD students and one MSc student submitted their theses for examination – Mawson Croaker, Paul Cromie, Tim Ireland, Wallace Mackay, Ralf Schaa and Wojciech Zukowski, and Terry Hoschke (MSc). Four PhD students graduated – Lee Evans, Felipe Urzua, Patrick Sack and Reia Chmielowski.

Eight PhD students suspended their candidature for part or all of the year, and another four chose part-time candidature, primarily to take high-paying positions in the minerals industry. Four PhD students withdrew from candidature. The withdrawals, suspensions and part-time enrolments have reduced the effective PhD workforce to 45, which is still above the target of 40 set for the UTAS Hub of the Centre of Excellence.

The 2009 HDR cohort included 36 international students representing 19 nationalities, nine of whom were at least partly funded by Centre of Excellence scholarships. All the new students were international, and most serious enquiries regarding 2010 enrolments have been from overseas students. CODES' success in attracting students from overseas is underpinned by its international reputation as a research training centre, and ability to invest ARC Centre funds in scholarships. The HDR program is also generously supported by UTAS in the form of international student fee waivers.

Many of CODES' HDR students are members of the UTAS Student Chapter of the Society of Economic Geologists. Chapter leaders Mathieu Ageneau and Takayuki Manaka organised a very popular series of professional events during the year, including short courses, lectures and field trips. These were complemented by a wide range of social events that featured barbecues, quiz nights, wine tastings, ice skating and ice hockey. The Chapter also played a key role in assisting with social events associated with CODES' twentieth anniversary celebrations. Four students – Lindsey Clark, Nathan Fox, Anita Parbhakar-Fox and Takayuki Manaka – were successful in winning SEG Research Grants that will help fund their PhD research.

CODES' HDR students with an interest in volcanology meet regularly for informal discussions of current research and to present reports on conferences or fieldwork. Although known as the 'Volcanology Group', a wide cross-section of the CODES community has been attending. Martin Jutzeler and Andrea Agangi organised a series of visits from interstate and international volcanologists, which were jointly funded by the SEG Student Chapter and CODES. Professor Ray Cas from Monash University presented a seminar on recent advances in understanding kimberlites. The second event was an ambitious week-long workshop on 'modern concepts in physical volcanology', presented by Professor Colin Wilson (Victoria University), Dr Darren Gravley (University of Canterbury) and CODES staff Dr Sharon Allen, Dr Emily Johnson and Professor Jocelyn McPhie. The workshop attracted more than 35 participants, including students from interstate and overseas universities. The final session of the series was a two-day presentation by Professor James White from the University of Otago, who delivered seminars on basaltic eruptions underwater, maar-diatreme volcanoes, and magma-water interaction in flood basalt provinces. All sessions were very well attended and gave students an opportunity to interact with leading volcanologists.



MASTERS OF ECONOMIC GEOLOGY PROGRAM

The Masters of Economic Geology (MEconGeol) program is managed by Dr Tony Webster and forms the CODES segment of the National Mineral Geoscience Masters Program, run in conjunction with the University of Western Australia, James Cook University and Curtin University. This unique collaboration provides industry-based postgraduate students with access to a broad range of specialised courses at all four universities.

The program had one of its most successful years, with 13 new enrolments and seven students completing the course – the largest single graduation group since 1995. With well over 40 UTAS students in the program, and a number of admissions still pending, there is no doubt that Masters of Economic Geology course is continuing to grow.

This year's graduates were César Aguirre Mascarelli, Benjamin Jones, Peter Pring, Budi Santoso, Kalem Wright, Yansan Jamyanbaatar, and Philip Smerchanski. While most graduates elected to complete the degree by coursework, Yansan Jamyanbaatar completed a research thesis on the Magmatic-hydrothermal evolution of the E48 Cu-Au Porphyry Deposit, NSW, under the supervision of Anthony Harris and David Cooke.

Two students elected to leave the program to undertake PhD research projects at other institutions. However, one of these students intends to complete the MEconGeol degree before getting too deeply involved in his new research.

Two short courses were presented. The first of these, Ore Deposit Geochemistry, Hydrology and Geochronology, attracted participants from as far afield as the USA, China, Mongolia, Indonesia, Philippines, Laos, Canada, and South Korea. In total, there were 17 Masters students, four industry participants and one PhD student in attendance. Many CODES/SES postdocs and postgrads also participated in all or part of the course, which covered a range of geochemical and geochronological techniques used to interpret environments of ore formation and the processes of ore genesis. Topics included Ar-Ar, U-Pb and Re-Os geochronology, whole rock and trace element chemistry of igneous rocks, sulphide trace element chemistry, stable and radiogenic isotopes, fluid inclusions and hydrothermal geochemistry. Course leader David Cooke was supported by an impressive line-up of 16 top national and international experts, including former CODES Research Fellow Peter Hollings, who is now with Lakehead University in Canada. The course initially focused on basic theoretical principles and then a series of practical case studies were introduced during the second week. Discussions ensued on the application of various geochemical, isotopic and dating techniques in relation to the genesis and exploration of three important styles of ore deposit.

A mix of MEconGeol students from UTAS, UWA and JCU completed the second short course, Ore Deposits of South America, at the end of March. Once again, the short course attracted widespread international interest with participants emanating from Australia, New Zealand, Indonesia, the Philippines, China, Mongolia, Zimbabwe, Canada, Switzerland and the United Kingdom. The field-based course, held in Chile and Peru, included visits to a total of 13 mines and exploration projects that included IOCG, porphyry, epithermal, skarn and MVT deposits. In addition, the students gained first-hand exposure to the remarkable regional geology and tectonic evolution of the Andes. The course was led by David Cooke and Bruce Gemmell, as well as Thomas Bissig (MDRU) – who also provided English translations for presentations given in Spanish.

CODES continued its close relationship with the Minerals Council of Australia through the Minerals Tertiary Education Consortium (MTEC). While the Masters program was not funded during 2009, MTEC restored significant funding that will commence in 2010.

HONOURS PROGRAM

Honours student numbers rose decisively in 2009, from 9 to 17. This figure is based on mid-year students counting in the year they finish, and includes two Graduate Diploma students. This is explained by a lull in the industry job market, which restored some balance to the number of third-year students who continued to an Honours year. However, although this number is now more in line with long-term statistics, it is not yet clear whether it indicates a move towards the belief that a final year thesis is essential for a complete education in the earth sciences. As was the case in the previous year, only one Honours student was sourced from a mainland university and, as in 2008, the student was attracted by a new subject relevant to a geothermal energy career.

Projects were spread across the disciplines in the following categories: economic geology (5), geothermal geophysics (3), resource geophysics (2), regional geophysics (2), volcanology (2), environmental geophysics (1), structure and geochronology (1), and igneous petrology (1). Five projects were Tasmanian based, with the others spread across Queensland, Western Australia and Thailand. A large number of externally supported projects were withdrawn by sponsors at the beginning of the year due to the global financial crisis. Nevertheless, projects were sponsored financially by Mineral Resources Tasmania, Granite Power, KUTh Energy, Anglo American, Newcrest, Grange Resources, MMG and Ivanhoe Australia. In addition, several CODES projects included industry sponsors, and in-kind sponsorships were provided by Bass Metals Ltd and Vale.

The Honours year was administered by Garry Davidson, with Peter McGoldrick supervising the coursework aspects.

OUTREACH

CODES continued its initiative to develop a greater knowledge and appreciation of the earth sciences within a wide cross-section of the local community. Working in conjunction with the UTAS School of Earth Sciences (SES), it delivered a broad mix of activities to demographic groups ranging from primary school children through to retirees. The key people driving most of the outreach activities throughout the year were Mike Roach and Anya Reading – both joint appointments between CODES and the SES.

For the younger age group, nine primary schools were visited and presentations were delivered on a range of geological topics, including an enticing overview of the many benefits of pursuing a career in the geosciences. In addition, a number of primary schools visited CODES and received presentations that mainly focused on seismology. Older students from schools and colleges were catered for via a series of similar visits. This demographic group was also targeted through participation in career exhibitions and open days at UTAS and local institutions. In addition, Anya Reading had an article promoting the benefits of geophysics as a career option published in a UTAS publication entitled *GETSET*, which is widely distributed to local teachers and career advisors.

A key part of this year's outreach activities was the participation in the Teacher Earth Science Education Program (TESEP). This excellent initiative operates under the auspices of the Australian Science Teachers, and provides a series of professional development workshops aimed at upper primary / lower secondary school teachers. Three workshops were held at the UTAS Hub during the year, with further workshops planned for 2010. The workshops were between one and two days in duration.

The Centre continued its ongoing participation in the Science Experience (for schools) program, with visiting Year 10 students taking part in activities related to the topics 'finding the age of rocks' and 'the rocks that make up Tasmania'. Participation was co-ordinated by Andrew McNeill. The National Youth Science Forum is a similar type of initiative that promotes science-based careers. This program targets high-achieving Year 11 students and gives them the chance to 'test-drive' a variety of universities and careers in the sciences. Participation was co-ordinated by Mike Roach.

At the top end of the demographic spectrum, a series of lectures was delivered to retirees during March, April and May. The series covered a range of geological topics and was presented as part of the University of the Third Age (U3A) program. The lectures were held at a local Adult Education Centre and delivered to an eclectic mix of mature-aged people, most with little knowledge of the principles of geology. U3A is an international program that has the aim of improving the quality of life of older people through a series of low-cost academic courses. It targets people that have entered a period of active retirement, known as the 'Third Age' – the first two ages being 'youth' and 'work/homemaking'. The lectures were delivered by a team comprised of Bruce Gemmell, Andrew McNeill, Peter McGoldrick, and Garry Davidson.

INDUSTRY LINKS & RESEACH COLLABORATIONS

OBJECTIVES

- To be a research focus for the national and international minerals industry.
- 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 research projects. Fostering and growing these national and international collaborations will continue to be a key strategic focus, which will strengthen CODES' position as a premier centre for ore deposit research.

INDUSTRY LINKS AND SYNERGIES

CODES has strong, enduring and mutually beneficial links with 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.

Nine Australian and international mining companies make up the group of CODES' industry partners: Anglo American, AngloGold Ashanti, Barrick Gold, BHP Billiton, Newcrest Mining, Newmont Mining, Rio Tinto, St Barbara Mines, and Teck. Each of the partner companies provides support of $20,000 to $80,000 in cash per year to the research budget of the Centre. A total of $1,775,000 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 of the CODES Science Planning Panel.
- Access to scholarships for staff undertaking Masters degree courses.
- Fee reductions on regular short courses and special in-house courses.

ROLE OF AMIRA INTERNATIONAL

AMIRA plays a vital role in facilitating 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 2009, AMIRA funded these major projects for CODES:

P765A (P3B1A) Geochemical and geological halos in green rocks and lithocaps – The explorer's toolbox for porphyry and epithermal districts

P843 / P843A (GeM^{III} project – P4.L1) Geometallurgical mapping and mine modelling

P872 (P3B2B) Sediment-hosted Cu-deposits of Congolese, Zambian & Central Australian basin systems

P962 (P1B2) Ni-PGE potential of mafic and ultramafic – a combined melt inclusion and numerical modelling approach.

RESEARCH COLLABORATIONS AND INTERNATIONAL VISITORS PROGRAM

CODES built on its reputation for cultivating research collaborations with other Australian and international research organisations. In 2009, collaborative research was conducted with 61 international and 18 national organisations.

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

Funding will continue to be used to support the International Visitors Program, which attracts high-profile researchers to CODES. In 2009, the following major international research collaborators were supported to visit CODES for more than three months each:

- Professors Alexei Ariskin (Vernadsky Institute of Geochemistry, Russia) and Eduard Konnikov (Institute of Experimental Mineralogy, Russia) – visited Leonid Danyushevsky from January to April to collaborate on the Ni-PGE potential of mafic and ultramafic magmas.
- Professor Valeriy Maslennikov and Dr Svetlana Maslennikova (both from the Russian Academy of Science) – visited Ross Large and Leonid Danyushevsky from March to June to work on trace element zonation in Phanerozoic black smoker chimneys and the theory of seafloor evolution in clastic sulphide deposits.
- Professor Yuling Xie (University of Science and Technology, China) – visited David Cooke and Dima Kamenetsky from January to June to work on carbonatite magma and fluid evolution.
- Professor Zhiming Yang (Institute of Geology, Chinese Academy of Geological Sciences) – visited Zhaoshan Chang for five months, starting in September, to collaborate on a porphyry deposit and unidirectional solidification textures (UST's) in China.

RESEARCHERS WHO WORK JOINTLY IN CODES AND OUR COLLABORATING ORGANISATIONS

INSTITUTION	COE ARC GRANT	NODE MATCHING FUNDS.	INDUSTRY/AMIRA FUNDS	UNIVERSITY/ CSIRO FUNDS
University of Queensland (incl. Julius Kruttschnitt Mineral Research Centre & WH Bryan Centre)	Steve Walters Simon Michaux Robert Morrison Alan Bye (8%) Italo Onederra Angus McFarlane (6%)	Ben Adair Angus McFarlane (15%)	Nenad Djordjevic Khoi Ke Nguyen Yicai Wang Deirdre Bradshaw Louisa Groves Alan Bye (17%)	
University of Melbourne	Chad Paton Bence Paul	Jon Woodhead Roland Maas		Janet Hergt
Australian National University	Angela Halfpenny			Stephen Cox
CSIRO Exploration and Mining	Jamie Laird (50%) Stacey Borg (50%)	Jamie Laird (50%) Stacey Borg (50%)		Chris Ryan Weihua Liu

TECHNOLOGY TRANSFER

OBJECTIVES

- Involve end-users (exploration and mining companies) in research planning, research evaluation and research adoption.
- Promote technology transfer so that innovative research outcomes are accessible to end-users.
- 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. These initiatives 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 2009, 105 research reports were presented to industry clients, and 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 246 copies in 2009).
- *New developments in Broken Hill-type deposits* (1996). CODES Special Publication 1. Editors: J Pongratz and G Davidson (sold 5 copies in 2009).
- *Basins, fluids and Zn-Pb ores* – CODES Special Publication 2 (1999). Editors: O Holm, J Pongratz and P McGoldrick (sold 20 copies in 2009).
- *Volcanic environments and massive sulphide deposits* (2000). Editors: JB Gemmell and J Pongratz (sold 19 copies in 2009).
- *The geology and origin of Australia's mineral deposits* (2000). Authors: M Solomon and D Groves (sold 7 copies in 2009).
- *Giant ore deposits: characteristics, genesis and exploration* (2002). CODES Special Publication 4. Editors: D Cooke and J Pongratz (sold 25 copies in 2009).
- *24ct Au workshop* (2004). CODES Special Publication 5. Editors: DR Cooke, C Deyell and J Pongratz (sold 30 copies in 2009).
- *Altered volcanic rocks: a guide to description and interpretation* (2005). Authors: C Gifkins, W Herrmann and R Large (sold 229 copies in 2009).
- *The geology of the Broken Hill Pb-Zn-Ag deposit, NSW, Australia* (2006). Author: A Webster (sold 20 copies in 2009).
- *Ore Geology Reviews – Special Issue* (April 2007): *mineral deposits of South China*. Editors: Khin Zaw, S Peters, N. Cook, Z. Hou (sold 9 copies in 2009).
- *Origin of Rocks and Mineral Deposits*. Author: J Elliston (sold 18 copies in 2009).

COMMERCIAL PRODUCTS AND PROCESSES

Geometallurgical research in Program 4, in collaboration with JKMRC at the 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

It has been another excellent year in terms of the number of short courses and workshops delivered by CODES staff. Twenty-six courses were held at various locations around the world including Italy, Sweden, Turkey, Canada, Peru, South Africa, China, Malaysia, Fiji, Papua New Guinea and Australia.

Total attendance by industry geologists, academic researchers and postgraduate students was over 760, with over 20 CODES' staff involved in delivering the lectures.

2009 SHORT COURSES/WORKSHOPS/CONFERENCES LED BY CODES

TITLE	PRESENTERS*	NO**.	LOCATION	DATE
Low and Intermediate sulphidation epithermal deposits, Hydrothermal Ore Deposits short course	**Bruce Gemmell**	100	University of Ottawa, Canada	18–19 Feb
Ore Deposits of South America short course	**David Cooke, Bruce Gemmell**	19	Chile, Peru	15–19 Mar
Exploration Skills Mapping Camp	**Tony Webster, Andrew McNeill** and **Dave Selley**	19	Tasmania	8–14 Mar
Fluid and Mineral Processes in Sedimentary Basins	**Ross Large, Stuart Bull**	12	Vale exploration, Johannesburg	Mar
Cadia Valley Porphyry Ore Deposits, NSW fundamental controls on system architecture	**Anthony Harris**	18	Newcrest Mining	3 Jun
Ore Deposit Models in SE Asia	**Khin Zaw,** Teh Guan Hoe, Somboon Khositanont, **Grace Cumming, Takayuki Manaka**	37	Mineral and Geoscience Department of Malaysia, Kuala Lumpur, Malaysia	11 Jun
Ore Deposit Geochemistry, Hydrology and Geochronology	**Ron Berry**, Phil Blevin, Graham Carr, David Carr, **Leonid Danyushevsky, Garry Davidson, Paul Davidson, Jeff Foster**, Scott Halley, **Anthony Harris**, Peter Hollings, **Ross Large**, Nick Oliver, **Jamie Wilkinson**, Leslie Wyborn and **Khin Zaw**	33	CODES, UTAS	July
Origin of the giant Broken Hill Ag-Pb-Zn deposit, and the use of lithogeochemistry in exploration	**Tony Crawford**	14	Ivanhoe Resources, Merlin Exploration Camp, N Qld	14 Aug
SWIR (Short Wavelength Infra-Red) Spectral Techniques Workshop	**Zhaoshan Chang**	7	CODES, UTAS	8 Sep
Porphyry copper and low and intermediate sulphidation epithermal gold-silver deposits workshop	**David Cooke, Bruce Gemmell**	20	Lihir Gold mine, PNG	12–13 Sep
Porphyry copper and low and intermediate sulphidation epithermal Au/Ag deposits course	**David Cooke, Bruce Gemmell**	40	University of Papua New Guinea	14 Sep
Porphyry ore deposits: describing their geology	**Anthony Harris**	5	Newcrest Mining, Wafi project, PNG	11 Oct
Tectonics, Fluids, Mineralisation – Gold	Stephen Cox	15	Vale SA, Lima, Peru	12–14 Oct
Modern Concepts in Physical Volcanology Workshop – An approach to the study of altered igneous rocks	**Tony Crawford**, **Jocelyn McPhie, Sharon Allen**, Colin Wilson, Darren Gravley	25	CODES, UTAS	26–30 Oct
Basin Hosted Ore Deposits of Zn-Pb, Cu and Au-As	**Ross Large, Stuart Bull**	25	Lulea University of Technology, Sweden	Nov
Geometallurgical Resource Modelling Workshop	**GeM team**	30	Hobart	Nov
Exploratory data analysis and visualisation using ioGeM	**GeM team**	30	Hobart	Nov
Introduction to advanced image analysis and textural classification software in GeM	**GeM team**	20	Hobart	Nov
Porphyry and skarn workshop	**David Cooke, Zhaoshan Chang**	40	Hefei University, China	4 Nov
Ore Deposit Models and Exploration Workshop	Steve Scott, Noel White, Kaihui Yang, David Leach, **David Cooke**, **Zhaoshan Chang**, Rich Goldfarb, Chusi Li	142	Beijing, China	5–8 Nov
Fluids in the Earth	**Leonid Danyushevsky**	15	University of Naples, Italy	9–13 Nov
Magmatic-hydrothermal ore deposits workshop	**David Cooke, Zhaoshan Chang**	50	Zijin Mine, Xiamen, China	11–12 Nov
Volcanoes and their products	**Jocelyn McPhie**	22	Tuprag Metal Madencilik, Kisladag, Turkey	18–22 Nov
Tectonics and metallogeny of Lachlan Fold Belt, and origin of the Broken Hill mineralisation	**Tony Crawford**	4	Highlake Resources, Melbourne	26 Nov
Porphyry ore deposits: describing their geology	**Anthony Harris**	6	Newcrest Mining, Namosi project, Fiji	5 Dec
Use of lithogeochemistry and igneous petrology in modern exploration	**Tony Crawford**	10	Anglo American Exploration, Perth	8–9 Dec
Porphyry ore deposits: describing their geology	**Anthony Harris**	8	Newcrest Mining, Namosi project, Fiji	8 Dec

* CODES presenters in bold

** Number of attendees

PERFORMANCE INDICATORS

RESEARCH FINDINGS

PERFORMANCE MEASURE	TARGET	2009
Publications in international journals	40 pa	58
Reports to industry collaborators	50 pa	105
Special issues and/or research monographs	1 per 2 years	0
Invitations to give keynote conference presentations	10 pa	19
Papers at national/international meetings	60 pa	117

INVESTIGATORS

PERFORMANCE MEASURE	TARGET	2009
Average % of CIs research in Centre	70%	74%
Average % of PIs research in Centre	20%	27%
Percentage of team-based projects	80%	82%
Percentage of Australian cross-institutional projects	30%	36%

RESEARCH TRAINING AND PROFESSIONAL EDUCATION

PERFORMANCE MEASURE	TARGET	2009
Percentage of HDR students attracted from interstate	40%	16%
Percentage of HDR students attracted from overseas	30%	62%
Honours students in Centre programs	10	17
HDR students in Centre programs	35	56 PhD, 2 MSc
Percentage of student in projects linked with industry	50%	75%
Professional short courses/workshops for industry	5 pa	25

INTERNATIONAL, NATIONAL AND REGIONAL LINKS AND NETWORKS

PERFORMANCE MEASURE	TARGET	2009
Centre national or international conferences/workshops	1 per 2 years	1
Registrants at Centre's conferences/workshops	50 pa	766
International and national visitors per year	30 pa	197
Collaborative projects with other global centres/groups	10	28
External collaborators using Centre's equipment	10 pa	14

END-USER LINKS

PERFORMANCE MEASURE	TARGET	2009
Frequency of meetings with industry representatives	10 pa	21
End-user representatives to Science Planning Panel and Advisory Board	20% / 50%	50% / 60%
Frequency of meetings with AMIRA Research Coordinator	10 pa	15
Number of industry visitors to Centre	50 pa	121

ORGANISATIONAL SUPPORT

PERFORMANCE MEASURE	TARGET	2009
Annual cash contributions from UTAS	$1,300,000	$ 2,019,881
Annual cash support from other collaborating Universities & CSIRO	$250,000	$237,500
Annual cash support from industry	$1,450,000	$4,450,795
Number of new organisations recruited to or involved in the Centre (Imperial College London)	1 pa	1
New annual cash support from industry	$200,00	$3,000,795

GOVERNANCE

PERFORMANCE MEASURE	TARGET	2009
Joint post-doctoral appointments between collaborating institutions/organisations	5	8 (2 CSIRO, 1 ANU, 3 JKMRC, 2 UMelb)
Balance and experience of Advisory Board members		Industry 50% Academic 42% Government 8%
Annual review of strategic and business plans		Yes
Effectiveness of Centre Research Committee		Yes
Effectiveness of Science Planning Panel		Yes
Public profile of Centre	High	High

NATIONAL BENEFIT

PERFORMANCE MEASURE	TARGET	2009
Centre research has input into a major mineral discovery	1 per 5 years	1
Employment of Centre's postgraduates by minerals industry	>65%	75%

FINANCES

ARC CONTRACT AND GOVERNANCE

CODES became the Australian Research Council (ARC) Centre of Excellence (CoE) in Ore Deposits on 1 July 2005. It was formerly an ARC Special Research Centre. The CoE contract with the Australian Government covers five years' funding from 2005 to 2010. At the mid-term review in November 2008 the ARC awarded an extension of funding for the period 2010 to 2013. However, the following statements refer to the current CoE agreement, not the extension.

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. CODES has a policy of assigning budget responsibility to Node and Program Leaders, which is overseen by the Finance Manager and the Director.

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 agreement, including funding allocations from the CoE to its nodes and agreed matching contributions made by those nodes.

The tables and figures presented in the following pages demonstrate the CoE is meeting the income and expenditure requirements of the current agreement.

2009 INCOME

Total CODES income was $10.8 million (see Table 1). This was derived principally from industry (41%), the ARC (31%) and UTAS (19%) (see Figure 1). The main income streams over time are compared in Figure 2, demonstrating that ARC funding is now being exceeded by other funding at a ratio of approximately 2:1 (the original CoE agreement with the ARC was 1:1). Therefore, non-ARC funding has consistently exceeded expectations since the start of the CoE, with industry funding showing the strongest growth.

THE COE COLLABORATOR/CONTRIBUTOR CASH INCOME AGREEMENT

The CoE funding agreement with the ARC requires that $3 million per annum ARC funding will be matched, dollar for dollar, with agreed core funding from collaborators/contributors. This combined cash income is used to fund core research projects. Table 2(A) tracks the original CoE agreement against cash received to date. Table 2(B) lists additional income received towards core and non-core projects. The right-hand 'difference' column in Table 2(A) demonstrates that all agreed cash funding from the collaborators/contributors (except that of UTAS, two of the nodes and one industry sponsor) was up to date at the end of 2009 (see explanations beneath the relevant tables regarding the current deficits). The grand total shows that CODES has currently received $15.8 million more towards all CoE projects than was specified in the original agreement. This is mainly due to:

- Annual indexation of the ARC CoE Grant
- Significantly increased industry and AMIRA International funding
- Income from book sales, short courses and laboratory analyses
- Pre-existing funding from UTAS, ARC and AMIRA, which has extended into the CoE period.

All collaborator/contributor funding is paid to CODES annually, in cash, with the exception of funding from the CoE nodes, which is treated differently, as detailed under the heading CoE Node Income.

In addition to the abovementioned cash income, the CoE receives a considerable amount of in-kind support from its collaborators/contributors, with UTAS providing the most substantial portion.

The following is a summary of the main income streams to the CoE in 2009:

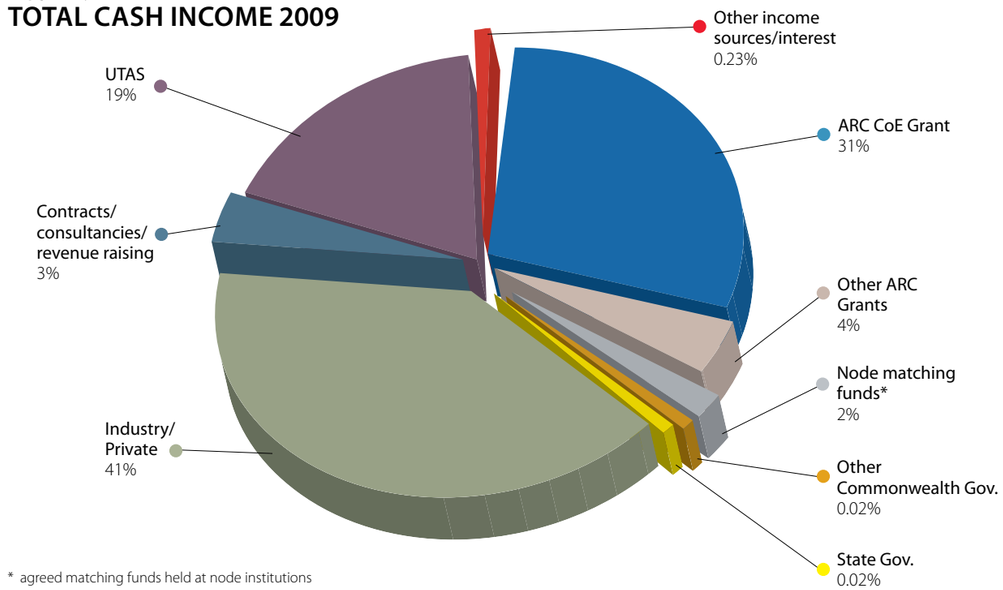
- **ARC INCOME:** In addition to the CoE ARC Grant ($3.3 million), CODES received an ARC Linkage Infrastructure, Equipment and Facilities Grant and one Discovery/Fellowship Grant (totalling $0.4 million). All other ARC grants previously held by CODES Chief Investigators were rolled into the CoE Grant in 2005.
- **COE NODE INCOME:** The CoE's Australian nodes comprise the University of Queensland, University of Melbourne, Australian National University and CSIRO Exploration and Mining. The CoE agreement requires that CODES transfers an agreed annual portion of its ARC CoE Grant income to each of the above nodes, to be expended at the node institutions. In return, the nodes agree to match this income with an agreed value of their own funds each year (see 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 institutions. Expenditure of both portions of node funding is reported annually to CODES. To date, all nodes have received their agreed ARC income from CODES and all have contributed their agreed matching funds, except University of Queensland and the Australian National University who are slightly down on matching fund contributions (see 'difference' columns of Table 3). Please see the notes beneath Table 3 for an explanation of this shortfall in matching funds, plus a statement indicating what proportion of these funds the nodes have spent to date.
- **STATE GOVERNMENT INCOME:** The agreed three-year funding from the State Government of Tasmania ceased at the end of 2007.
- **INDUSTRY INCOME:** Despite the economic downturn, industry funding increased by approximately 22%. This was due to some new research projects commencing and the successful extension of two very large pre-existing projects. This increase is contributing to the overall income surplus of $15.8 million, as shown in Table 2. Total industry funding (as shown in Table 1) was $4.5 million, of which the largest contribution (54%) was from AMIRA International for CoE core and non-core research projects.
- **HOST INSTITUTION SUPPORT:** UTAS provided $2 million cash funding, of which $1.4 million was its agreed core cash funding commitment to the ARC CoE. Its cash contribution increased by 26% in 2009, reversing its previous downward trend. This cash funding relates primarily to research salaries, PhD scholarships, equipment and income earned by the Centre from research output. In addition, UTAS provided over $2 million in in-kind support in 2009, which included $0.4 million cash expenditure on building renovations (key laboratory upgrades).

2010 INCOME ESTIMATES

During the reporting period, the recent world financial crisis made it difficult for CODES to get firm commitments on future funding from its usual external sources of income, such as mining companies. To an extent, uncertainty about commodity prices and their effect on income are impacting on the expenditure decisions of these companies. It was anticipated that this would cause a downturn in 2009 income, but this did not eventuate. However, we still remain conservative on future industry income estimates in the short term, because difficulty is still being experienced in attracting industry funding for some projects.

Although industry funding may decrease in 2010, all other income streams are expected to remain stable.

FIGURE 1:
TOTAL CASH INCOME 2009



* agreed matching funds held at node institutions

TABLE 1:
CASH INCOME FINANCIAL STATEMENT 2005–2009

	(HALF YR) 2005	2006	2007	2008	2009
ARC - CENTRE OF EXCELLENCE GRANT					
CoE agreed core funding* – 2005 grant indexation (not received until 2006)	0	31,500	0	0	0
CoE agreed core funding* – ARC grant	1,500,000	3,121,198	3,184,402	3,248,088	3,313,864
	1,500,000	**3,152,698**	**3,184,402**	**3,248,088**	**3,313,864**
COE NODES MATCHING FUNDS (agreed matching funds held at node institutions)					
CoE agreed core funding**	0	295,000	255,000	250,000	237,500
Additional funding (pre-existing or new)	0	0	0	0	0
	0	**295,000**	**255,000**	**250,000**	**237,500**
OTHER ARC GRANTS					
CoE agreed core funding*	0	0	0	0	0
Additional funding (pre-existing or new)	328,791	397,325	394,338	471,524	403,889
	328,791	**397,325**	**394,338**	**471,524**	**403,889**
OTHER COMMONWEALTH GOVERNMENT					
CoE agreed core funding*	0	0	0	0	0
Additional funding (pre-existing or new)	7,184	19,649	24,666	62,680	2,046
	7,184	**19,649**	**24,666**	**62,680**	**2,046**
STATE GOVERNMENT					
CoE agreed core funding*	200,000	200,000	200,000	0	0
Additional funding (pre-existing or new)	68,000	852	4,000	8,000	2,500
	268,000	**200,852**	**204,000**	**8,000**	**2,500**
LOCAL GOVERNMENT					
CoE agreed core funding*	0	0	0	0	0
Additional funding (pre-existing or new)	0	0	0	0	0
	0	**0**	**0**	**0**	**0**
INDUSTRY/PRIVATE					
CoE agreed core funding*	868,646	1,582,507	1,825,010	2,158,677	2,182,472
Additional funding (pre-existing or new)	444,803	909,552	938,913	1,487,935	2,268,323
	1,313,448	**2,492,059**	**2,763,923**	**3,646,611**	**4,450,795**
CONTRACTS/CONSULTANCIES/REVENUE RAISING					
CoE agreed core funding*	0	0	0	0	0
Additional funding (pre-existing or new)	143,787	286,675	306,743	368,160	383,012
	143,787	**286,675**	**306,743**	**368,160**	**383,012**
UNIVERSITY OF TASMANIA - HOST INSTITUTION SUPPORT					
CoE agreed core funding*	343,744	1,334,728	1,147,471	1,128,759	1,430,393
Additional funding (pre-existing or new)	383,623	678,064	566,682	468,267	589,489
	727,367	**2,012,792**	**1,714,152**	**1,597,026**	**2,019,881**
OTHER INCOME SOURCES/INTEREST					
CoE agreed core funding*	0	0	0	0	0
Additional funding (pre-existing or new)	4,348	60,006	53,000	131,585	25,147
	4,348	**60,006**	**53,000**	**131,585**	**25,147**
TOTAL ANNUAL INCOME	**4,292,926**	**8,917,056**	**8,900,226**	**9,783,674**	**10,838,635**
GRAND TOTAL OF ALL INCOME TO DATE					**42,732,517**

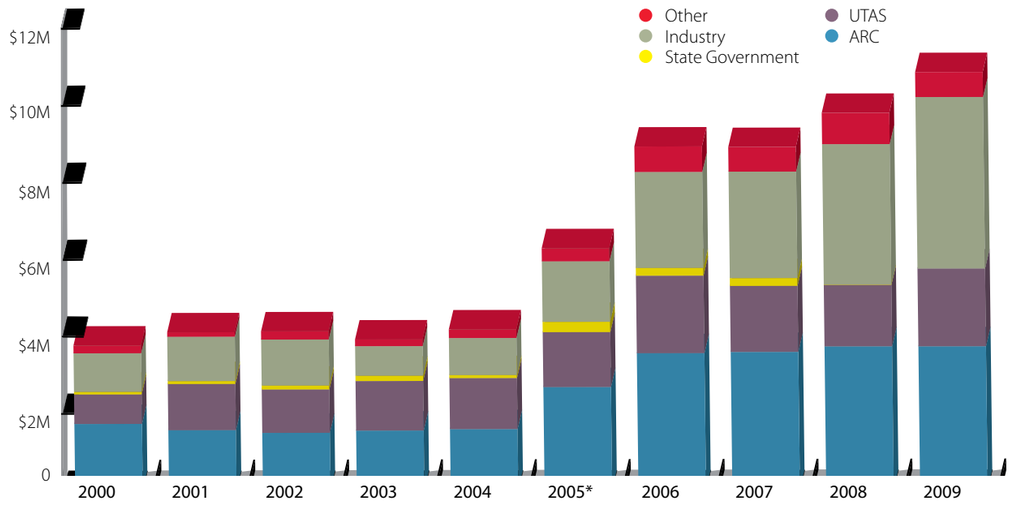
* see Table 2(A) for summary of the CoE agreed core funding agreement
** see Table 3 for summary of the node cash funding agreement

TABLE 2:
CURRENT STATUS OF THE COE'S CASH INCOME AGREEMENT WITH ITS CONTRIBUTORS – CASH PROMISED VERSUS CASH RECEIVED

(A) AGREED CORE CASH FUNDING RECEIVED TO DATE (AS PROMISED IN THE ORIGINAL COE AGREEMENT)	FROM THE CONTRIBUTORS TO THE COE		
	total promised and received to date (July 2005 – Dec 2009)		
Name of collaborator/contributor	**promised**	**received**	**difference**
University of Tasmania	6,122,000	5,385,095	(736,905)
CSIRO Exploration and Mining (CoE node)	400,000	400,000	0
University of Queensland (CoE node)	225,000	212,500	(12,500)
University of Melbourne (CoE node)	225,000	225,000	0
Australian National University (CoE node)	225,000	200,000	(25,000)
State Government of Tasmania	600,000	600,000	0
Minerals Council of Australia (MCA/MTEC)	280,000	515,732	235,732
AMIRA International	3,333,500	5,839,697	2,506,197
Industry partner - Anglo American	185,000	185,000	0
Industry partner - AngloGold Ashanti	115,000	115,000	0
Industry partner - Barrick Gold	115,000	115,000	0
Industry partner - BHP Billiton (includes WMC contribution from 2005 onwards)	300,000	300,000	0
Industry partner - Newcrest Mining	80,000	80,000	0
Industry partner - Newmont Mining	185,000	185,000	0
Industry partner - Rio Tinto	115,000	115,000	0
Industry partner - Teck Cominco (now Teck Resources)	115,000	115,000	0
Industry partner - Zinifex (now OZ Minerals)	185,000	135,000	(50,000)
Other Industry - Anglo American - Contrib. to Cooke student support	60,000	63,247	3,247
Other Industry - Newcrest Mining - Contrib. to Cadia project	600,000	853,636	253,636
ARC	13,500,000	14,399,052	899,052
TOTAL AGREED CASH INCOME	**26,965,500**	**30,038,958**	**3,073,458**
(B) ADDITIONAL CASH INCOME EARNED TO DATE (IN ADDITION TO THE ABOVE AGREEMENT)	**FROM THE CONTRIBUTORS TO THE COE**		
	total received to date (July 2005 – Dec 2009)		
	promised	**received**	**difference**
New Industry partner - St Barbara Mines	n/a	160,000	160,000
New Industry partner - Great South Land Minerals/Zeehan Zinc Tasmania	n/a	40,000	40,000
New AMIRA International - core CoE project (Danyushevsky P962 project)	n/a	283,840	283,840
New AMIRA International - core CoE project (Cooke P765A project)	n/a	845,000	845,000
Additional core funding - other industry	n/a	3,283,944	3,283,944
Additional core funding - other ARC grants	n/a	245,000	245,000
Additional core funding - other Commonwealth Government	n/a	116,225	116,225
Additional core funding - State Government	n/a	83,352	83,352
Additional core funding - Local Government	n/a	0	0
Additional core funding - contracts/revenue raising	n/a	1,488,378	1,488,378
Additional core funding - miscellaneous/other income	n/a	274,087	274,087
Pre-existing general support that continues into CoE period - UTAS	n/a	2,686,124	2,686,124
Pre-existing non-core - SRC industry partner (Goldfields) overlapped into CoE period	n/a	10,000	10,000
Pre-existing non-core - AMIRA projects	n/a	1,426,741	1,426,741
Pre-existing non-core - other ARC grants	n/a	1,750,867	1,750,867
TOTAL ADDITIONAL CASH INCOME	**0**	**12,693,559**	**12,693,559**
GRAND TOTAL OF ALL INCOME TO DATE	**26,965,500**	**42,732,517**	**15,767,017**

Explanation of deficits in Table 2(A) UTAS is down $0.7 million in agreed core cash funding, this is due to some cash income streams not eventuating as expected. However, Table 2(B) demonstrates that UTAS has contributed $2.7 million additional cash funds over the life of the Centre. UTAS provided over $2 million in-kind support in 2009, which included $0.4million cash expenditure on building renovations. The UQ and ANU nodes' total deficit of $37,500 relates to the late start-up of the project at ANU and a change of management at UQ/JKMRC. The nodes have advised that these shortfalls will be covered in 2010. The Zinifex shortfall is due to this company having been merged and taken over several times. It is now a much smaller company and has re-negotiated this agreement so that it now supports CODES at a similar annual value through direct sponsorship of research projects rather than as an industry partner.

FIGURE 2:
COMPARISON OF CODES MAIN INCOME STREAMS 2000–2009



*The CoE commenced mid-2005

TABLE 3:
CURRENT STATUS OF THE COE CASH FUNDING AGREEMENT WITH ITS NODES – CASH PROMISED VERSUS CASH PAID

AGREED FUNDS CONTRIBUTED	FROM THE COE TO ITS NODES			FROM THE NODES TO THE COE*		
	total CoE ARC Grant income promised and transferred to the nodes to date (July 2005 – Dec 2009)			total node matching funds promised and contributed at the node institution to date (July 2005 – Dec 2009)		
Nodes	promised	paid	difference	promised	paid	difference
CSIRO Exploration and Mining	400,000	400,000	0	400,000	400,000	0
University of Queensland	1,450,000	1,450,000	0	225,000	212,500	(12,500)
University of Melbourne	450,000	450,000	0	225,000	225,000	0
Australian National University	450,000	450,000	0	225,000	200,000	(25,000)
University of British Columbia (Canada)	0	0	0	0	0	0
Colorado School of Mines (USA)	0	0	0	0	0	0
Johns Hopkins University (USA)	0	40,020	40,020	0	0	0
TOTALS	2,750,000	2,790,020	40,020	1,075,000	1,037,500	(37,500)**

* This section reflects total matching funds contributed by each node and held at their institution. However, it does not include expenditure of these funds. To date, the CSIRO Node has expended considerably more than its required contribution, demonstrating very strong project support. UQ and UMelb have expended 90% of their matching funds, while ANU has spent only 70% due to very late project start-up (ANU's ARC funds are also underspent an equivalent percentage). All unspent node matching funds are carried forward to future years and it is anticipated all agreed funds will be expended by the end of the CoE extension period (December 2013).
** The $37,500 shortfall in node matching funds relates to payment schedules being revised due to the late start-up of the project at ANU and a recent change of management at UQ/JKMRC. The nodes have advised that these shortfalls will be covered in 2010.

2009 EXPENDITURE OF ARC COE GRANT

Summaries are provided in Table 4 and Figure 3 to show how CODES and its nodes have expended the ARC CoE Grant funds to date. The major areas of expenditure in 2009 were salaries, research and field travel, student scholarships and laboratory analyses. Salary expenditure on the CoE ARC grant was not as high as predicted in 2009 due to the fact that several academic salaries were able to be moved from the ARC CoE Grant into new industry projects.

The 2009 combined ARC CoE income and carry-forward of $3.4 million was offset by expenditure of $3.5 million, leaving a carry-forward deficit of $145,268.

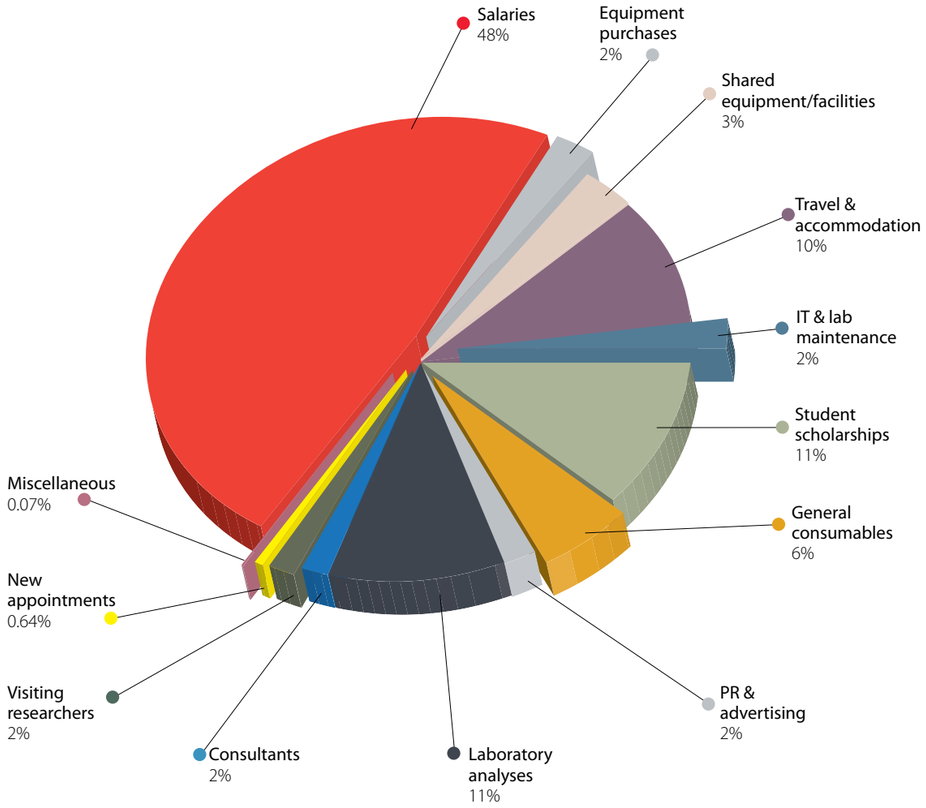
2010 EXPENDITURE ESTIMATES

Salary expenditure is expected to be lower in 2010 because several short-term research positions are likely to be terminated in 2010, due to project completions. Other expenditure areas are predicted to be slightly lower than previous years due to the reduction in research staff numbers.

TABLE 4:
EXPENDITURE OF ARC CENTRE OF EXCELLENCE GRANT 2005–2009
(CODES PLUS ITS NODES)

	(HALF YR) 2005	2006	2007	2008	2009
Income					
Balance brought forward from previous year	0	954,886	1,345,188	711,979	55,741
Miscellaneous income (refund of expenses)	0	8,497	29,589	43,155	0
ARC income	1,500,000	3,152,698	3,184,402	3,248,088	3,313,864
	1,500,000	**4,116,081**	**4,559,179**	**4,003,222**	**3,369,605**
Expenditure					
Salaries	(348,511)	(1,237,351)	(1,833,309)	(2,335,312)	(1,705,835)
Equipment purchases	(890)	(83,645)	(305,991)	(70,624)	(85,292)
Equipment leased/hired	(362)	(22,635)	(6,894)	0	0
Shared equipment/facilities	(1,119)	(21,900)	(46,750)	(58,188)	(109,407)
Travel and accommodation (research)	(52,363)	(354,349)	(314,206)	(282,161)	(364,065)
IT and lab maintenance	(1,866)	(91,292)	(208,688)	(145,441)	(82,620)
Student scholarships	(31,856)	(297,768)	(349,671)	(346,311)	(384,141)
General consumables/maintenance	(67,517)	(244,347)	(217,941)	(246,561)	(199,512)
Public relations and advertising	(9,289)	(105,160)	(119,364)	(53,466)	(66,299)
Laboratory analyses	(29,900)	(212,256)	(307,733)	(288,411)	(369,447)
Consultants	0	(90,290)	(108,075)	(68,962)	(62,186)
Visiting academics	(9,002)	(9,900)	(19,311)	(41,665)	(61,221)
New appointment expenses	0	0	(9,267)	(10,381)	(22,523)
Unspent node funds returned to CODES	0	0	0	0	0
Miscellaneous	7,561	0	0	0	(2,323)
	(545,114)	**(2,770,893)**	**(3,847,200)**	**(3,947,481)**	**(3,514,872)**
BALANCE REMAINING AT END OF YEAR	**954,886**	**1,345,188**	**711,979**	**55,741**	**(145,268)**

FIGURE 3:
EXPENDITURE OF ARC CENTRE OF EXCELLENCE GRANT 2009



NOTES TO, AND FORMING PART OF, THE FINANCIAL STATEMENTS FOR 2009

The financial pages of this Annual Report were prepared by Christine Higgins, CODES Finance Manager. Data for the financial statements was extracted from the UTAS Financial Management Information System and CODES' financial databases. All reports shown here have been audited by UTAS.

INCOME STATEMENT EXPLANATIONS

The income figures in Table 1 represent actual income recorded in the University's finance system or transferred internally from UTAS to CODES during 2009, with the following exception:

- The CoE node matching funds (approximately $250,000 per annum) are listed as cash income in the income statement (Table 1), but are not actually received as cash by the Centre. These matching funds, contributed by the nodes, are held and expended at the node institutions and reported annually to the CoE. They are listed as cash income in Table 1 to demonstrate that the nodes are providing their agreed annual contribution to the CoE.

In Table 1, sub-categories labelled 'CoE agreed core funding' are used to isolate core funding from other general funds. This is in accordance with the ARC requirement that the Centre demonstrates that these agreed core funds have been received each year.

Because of the six-month delay to the establishment of CODES as a CoE, very few agreed cash payments between the CoE and its nodes/collaborators were contributed in 2005. As a result, the payments for this six-month delay period were made during 2006. This has artificially inflated 2006 income figures by approx $400,000 (i.e. node income +$50,000, UTAS +$200,000, Industry Partners +$130,000). Therefore, any comparison between 2006 and 2007 income figures needs to take this into account.

In 2008 there was a minor retrospective amendment made to the 2005 industry/private income figure which has increased the 2005 income total by $20,000. This relates to $20,000 of CoE agreed 2005 income, which was paid in advance by Teck Cominco (now Teck Resources) in 2004. It has already been counted in the 2004 income statement of the SRC, but it is now listed again in the CoE's 2005 data (in the year that it was due) to clearly demonstrate to the ARC that Teck Cominco has met its CoE funding obligations within the five-year CoE agreement period. This amendment ensures that Table 1 data matches Table 2. Without this amendment an anomaly between the two tables would exist.

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) include the following:

- CODES expenditure of ARC CoE Grant funds (administered by UTAS)
- The nodes' expenditure of ARC CoE Grant funds (administered by the node institutions and reported annually to UTAS)

CODES' PUBLICATIONS 2009

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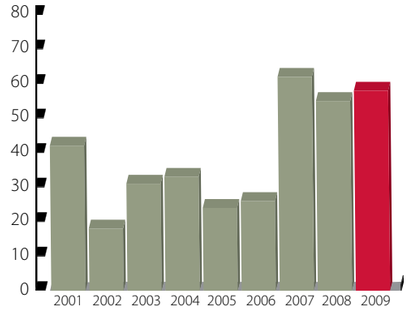

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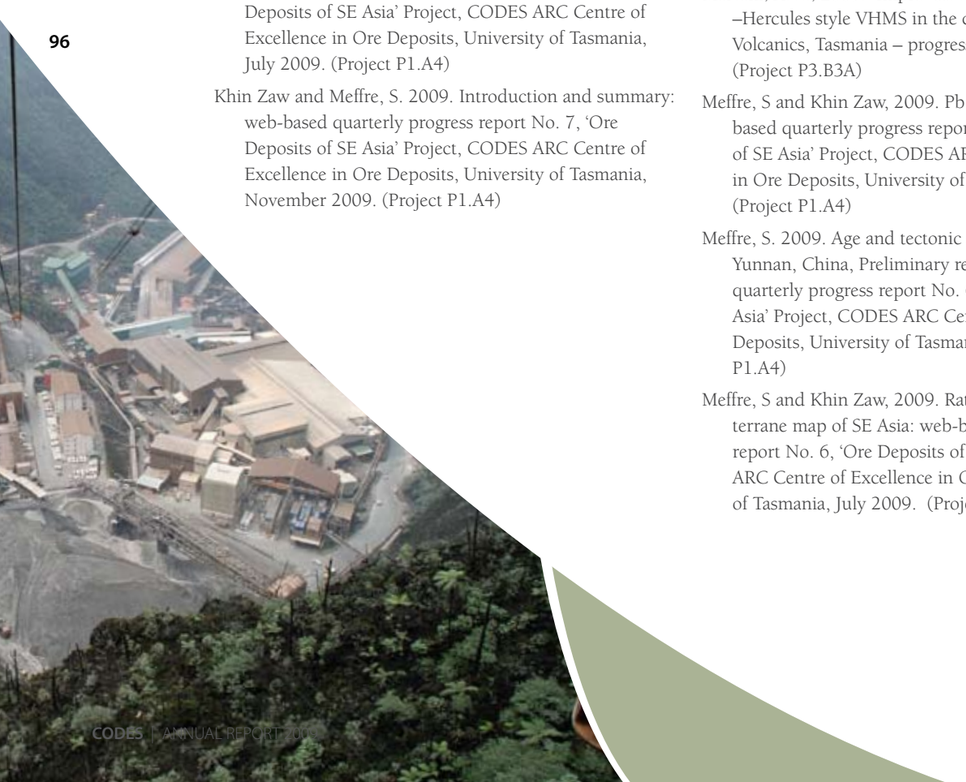

APPENDICES

CODES POSTGRADUATE STUDENTS 2009

GRADUATE DIPLOMA OF SCIENCE (2)

STUDENT	SUPERVISORS	PROJECT	SUPPORT
Norman Heckscher	Reading	The ambient seismic wavefield of eastern Tasmania	UTAS
Maryam Shafaee	Roach	A geophysical investigation of the Coal Mines historic site, Saltwater River, Tasmania	TGMS, Port Arthur HSMA

BACHELOR OF SCIENCE (HONOURS) (17)

STUDENT	SUPERVISORS	PROJECT	SUPPORT
Chris Allen	Roach, Direen	Gravity-magnetic interpretation of the Mt Arrowsmith nickel prospect, Koonenberry, NSW	Vale
Tiffany Bold*	McPhie, McNeill	Stratigraphy of the Southwell Subgroup (above the Hellyer level), western Tasmania	Bass Metals, School of Earth Sciences
Traci Cooper^	Khin Zaw, Meffre	Geochemical and geochronological constraints on evolutional history of the Shan-Thai terrane, southern Thailand	Ore Deposits of SE Asia project
Matthew Cracknell^	Roach, Lucier (Geog)	Application of Lidar technology to structural stratigraphic mapping in Tasmania	MRT
Luke Gibson*	Crawford, Meffre, Khin Zaw	Geology and geochronology of the northern Nan Suture, Thailand	Ore Deposits of SE Asia project
Jacob Heathcote*	Berry, Davidson	Aspects of improvements to beneficiation of iron ores: Hamersley field area	TGMS relocation, School of Earth Sciences
Mark Hotson*	Khin Zaw, Meffre	The geochronology and tectonic framework of Cu-Au prospects in the Phonsovan district, northern Laos	Ore Deposits of SE Asia project, PanAustralian Ltd, Phu Bia Mining- Phonsavan
Stephanie Howe*	Reading, Roach	Comparison of petrophysical properties derived from wireline well logs and measurements on rock core	Granite Power Ltd
Patrick Kirkby*	Davidson, Cooke	Origin of IOCG-style mineralisation in the Mt Dore deposit, Mt Isa Inlier	Ivanhoe Australia
Ting Kor	Harris, Cooke, Chang	Hydrothermal breccias at the Coalstoun porphyry Cu-Au-Mo deposit, SE Queensland	Newcrest
Katrina Rast*	Reading, Roach, Davidson	Thermal characteristics of the Parmeener Supergroup, Tasmania	KUTh Energy
Michelle Slater*	Reading, Roach	Geophysical surveying and modelling of geothermal plays	Granite Power Ltd
Carla Vincent^	Crawford, Foster, Danyushevsky	The Lynd: a nickel prospective system in North Queensland	Anglo American Exploration (Aust)
Liam Webb	Roach, Reading	Increased ore-grade control at Savage River using downhole geophysical techniques	Grange Resources
Alison Whitfield	Bull, Davidson	Sedimentology of the Permo-Triassic transition in the northern Tasman Peninsula, Tasmania	TGMS
Alice Wilkinson^	Khin Zaw, Meffre	Geological setting and mineralisation characteristics of sedimentary rock-hosted Langu Au deposit, Satun district, southern Thailand	Ore Deposits of SE Asia project
Lucas Williams*	McPhie, McNeill	Volcanology of the hangingwall volcaniclastics at Rosebery mine	MMG

MASTER OF ECONOMIC GEOLOGY (50)

STUDENT	SUPERVISORS	PROJECT	SUPPORT
César Eduardo Aguirre Mascarelli^		coursework only	Newcrest Resources Inc.
Abdul Gafar Arbi		coursework only	Ivanhoe Mines Mongolia Inc
Paluku Batsotsi		coursework only	African Mining Consultants
John Bedi		coursework only	Newcrest
John Brewster		coursework only	Newcrest Mining Limited (Cracow GM JV)
Mark Burdett		coursework only	Exco Resources Ltd
Colin Carter		coursework only	Bluestone Tin (Renison Mine)
Jenny Catoc		coursework only	unknown
Joanna Condon	Gemmell	Mineralisation characterisation of the Doolgunna Prospect: implications for mining, milling, and exploration	Sandfire Resources NL
Richard Cotton	Berry, Webster	The geology of the Ross Alluvial Gold Deposit and its implications for gold sourcing on the west coast, South Island, New Zealand	Solid Energy New Zealand Ltd
Corrie Chamberlain		Geology, Geochemistry and Genesis of the Kilkenny Low Sulphidation Epithermal Deposit, Cracow, Queensland	Newcrest Resources Inc
Martin De La Cueva Torres	Cooke	Characterisation of the Mineralising Fluids and Mineralogical and Geochemical Zoning of the Pucuy and Sausa Au Deposits and their relation with the Chimpo Deposit, Orcopampa-Arequipa, Peru	Compania de Minas Buenaventura
Glen Diemar		To be decided	BHPB Olympic Dam
Mike Everitt	Webster	An aspect of the grade distribution of the Savage River magnetite Deposit	Grange Resources Ltd
David Freeman		coursework only	AngloGold Ashanti Australia Limited
Margy Hawke	Gemmell	Geology of DeGrussa Prospect, WA: implications for ore genesis and exploration	Sandfire Resources NL
Darren Hicks		coursework only	Oz Minerals
Yansan Jamyanbaatar^	Harris, Cooke	Magmatic-hydrothermal evolution of the E48 Cu-Au porphyry deposit, New South Wales, Australia	Rio Tinto Gobi Expl JV
Alex Johnston		coursework only	Private Contracter
Ben Jones^		coursework only	Jabiru Metals
Brian Kay	Foster	Combined economic and geologic evaluation of eastern Australian gold projects - selection of acquisition targets	Northgate Australian Ventures
Martin Kent	Webster	An aspect of Broken Hill geology (to be dediced)	Perilya Broken Hill Ltd
You Jin Lee	Zaw, Meffre	A study of the mineralogy, alteration and ore genesis of the Bong Mieu Gold Mine, central Vietnam.	Korea Resources Corporation
Neil Macalalad		coursework only	Anglo American Exploration Philippines Inc
Ador Makuei		coursework only	Geoscience Australia
Kane Maxwelll	Webster	A review of the grade control drilling processes at Poitrel Coal Mine and their application in mine planning.	BMA
Mannie Mehu		coursework only	Rio Tinto Iron Ore Expansion Projects
Phillip Micale		coursework only	Beaconsfield Mine JV
Miguel Miranda Trinidad	Cooke, Chang	Thesis topic not yet known	Buenaventura
Noah Muzuva		coursework only	CMT
Mathew O'Neill		coursework only	unknown
Olufolajimi Ogunleye		coursework only	unknown
Katie Perrin		coursework only	Neptune Minerals Plc
Anna Price		coursework only	unknown

STUDENT	SUPERVISORS	PROJECT	SUPPORT
Peter Pring^		coursework only	Newmont Asia Pacific
Anthony Raimondo		coursework only	not known
Scott Randall		coursework only	AngloGold Ashanti Beijing Rep Office
Steven Richardson		The Fossey Zone, Hellyer Mine	Bass Metals
Alan Riles		coursework only	Riles Integrated Resource Management Pty Ltd
Jonathan Robbeson	Webster	An aspect of Broken Hill resource estimation	Perilya Broken Hill Ltd
Budi Santoso^		coursework only	Phelps Dodge
Daud Silitonga		coursework only	PT.Nusa Halmahera Minerals (Newcrest Mining Group)
Philip Smerchanski^		coursework only	Anglo American plc
Linda Sprigg		coursework only	Oz Minerals
Leo Subang		coursework only	Freeport McMoran Exploration Corp
Pearse Sweeny		coursework only	Moultrie Geology
Jason Triffit		coursework only	unknown
Kalem Wright^		coursework only	Perilya/BHP Billiton
Bruce Whittaker		coursework only	Oz Minerals
Zhang Yong		coursework only	Anglo Gold Ashanti

MASTER OF EXPLORATION GEOSCIENCE (1)

STUDENT	SUPERVISOR	PROJECT	SUPPORT
Terence Hoschke*	Large, Roach	Geophysical signatures of gold-copper porphyry systems	

MASTER OF SCIENCE (1)

STUDENT	SUPERVISOR	PROJECT	SUPPORT
Paul Ferguson	Davidson, Roach	Origins of large negative anomalies in oceanic crust, Macquarie Island	SEG

DOCTOR OF PHILOSOPHY (56)

STUDENT	SUPERVISOR	PROJECT	SUPPORT
Andrea Agangi	Kamenetsky, McPhie, Allen	Magmatic and volcanic evolution of giant intraplate felsic igneous provinces: Gawler Range Volcanics and Hiltaba Suite, South Australia	TPRS co-fund Scholarship, CoE, PIRSA
Mathieu Ageneau	Cooke, Gemmell, Danyushevsky	Geology of the Kapit ore zone and comparative geochemistry with Minifie and Lienetz ore zones, Ladolam gold deposit, Lihir Island, Papua New Guinea	Lihir Gold Ltd, CoE
Darren Andrews	Reid, Berry	Geophysical monitoring of acid mine drainage at Savage River Mine, Northwestern Tasmania	Australian Bulk Minerals, APA-I
Mohd Basril Iswadi Bin Basori	Khin Zaw, Large	Geology of Volcanic Hosted Massive Sulphide (VHMS) deposits in Central Belt, Peninsular Malaysia	Ore Deposits of SE Asia project, Malaysian Govt
Adam Bath	Kamenetsky, Crawford, Cooke	The geochemistry of melt inclusions and mineral phases from the Mount Polley and Lorraine (Canada) 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, Jabiru Metals Ltd
Heidi Berkenbosch	Gemmell, McNeill, de Ronde	Geochemistry of hydrothermal mineral chimneys from Brothers volcano, Kermadec arc	CoE, GNS Science
Fiona Best	Crawford, Foster	The petrogenesis of the Dido Tonalite, northern Queensland	CoE, Anglo American
Jacqueline Blackwell	Cooke, McPhie	Characteristics and origins of breccias in an alkalic epithermal gold deposit: Ladolam, Lihir Island, Papua New Guinea	CoE, Alkalic project, SEG/ Newmont, SEG Canada, TPRS co-fund Scholarship, LGL Gold

STUDENT	SUPERVISORS	PROJECT	SUPPORT
Natalee Bonnici	Walters, Berry	Textural and mineralogical characterisation of Cu-Au systems in relation to process mineralogy	GeM project, TGRS Scholarship
Bryan Bowden	Davidson	Geology, geochemistry and genesis of the Prominent Hill IOCG Deposit, South Australia	CODES, AGSO, Minotaur Resources, Goldstream Mining NL, PIRSA
Victoria Braniff	Webster, Berry	The Structure and Deformational History of the Savage River Magnetite Orebodies, NW Tasmania	Grange Resources Ltd
Kirill Bychkov	Danyushevsky, Falloon	Numerical modelling of sulphide precipitation from mafic magmas with implications for the formation of layered intrusions	CoE
Mitesh Chauhan (JKMRC)	Bradshaw (UQ)	Application of small scale flotation testing	GeM project
Reia Chmielowski^	Berry	The metamorphic history of Tasmania	TGMS, TPRS co-fund Scholarship
Lindsey Clark	Gemmell	The geology and genesis of the Kencana epithermal Au-Ag deposit, Gosowong goldfield, Halmahera Island, Indonesia	Newcrest
Gisela Cobenas Benites	Danyushevsky	Metal and volatile contents of primitive subduction-related magmas (Hunter Ridge, SW Pacific): Assessing magmatic contributions to volcanic-hosted seafloor mineralisation	UTAS
Mawson Croaker*	Selley, McGoldrick, Bull	Geology and genesis of the Nkana copper deposit, Zambia	AMIRA, TPRS Scholarship
Paul Cromie*	Khin 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, SEG
Sang Quang Dinh	Crawford, Berry	Geochronology and geological evolution of the northern margin of the Kontum massif, central Vietnam	Vietnamese Govt., CODES
Lee Evans^	Davidson, Cooke	Ground waters in wet, temperate sulphide mining districts: delineation of modern fluid flow and predictive modelling to improve management after mine closure (Rosebery, Tasmania)	Pasminco, APA-I
Cathy Evans (JKMRC)	Walters, Johnson (UQ), Manlapig (UQ), Kojovic (UQ)	The relationship between mineral characteristics of ores and the variation in their processing attributes	GeM project
Nathan Fox	Cooke, Harris	Controls on alteration and mineralisation in the Cadia East Au-Cu porphyry copper deposit, NSW, Australia	Newcrest
Victor Hugo Galvan-Guiterrez	Cooke, Gemmell, McPhie	Palmarejo carbonate base-metals silver-gold epithermal deposit, Trogan Project, Chihuahua, Mexico	IPRS, Bolnisi Gold NL
Sarah Gordee	McPhie, Allen	Characteristics of submarine volcanic facies in oceanic arc depocentres	TPRS co-fund Scholarship, CoE
JianXiang Guan	Danyushevsky, Crawford	Origin of associated magnetite and sulphide mineralisation in large gabbroic intrusions: A LA-ICP-MS study of minerals and melt inclusions from the Panzhihua and Taihe intrusions in Emeishan LIP and Duluth Complex	CoE, UTAS
Timothy Ireland*	Cooke, Berry	Geological framework of porphyry and epithermal mineralisation in the Collahuasi District, Tarapacá, Chile	APA Scholarship, AMIRA (P765), SEG (McKinstry Fund), Newmont Mining Corporation
Nicholas Jansen	Gemmell, Chang	Geology and geochemistry of the Ixhuatan lithocap, and its relationships to porphyry and epithermal mineralisation	AMIRA P765a, Kinross
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	Khin Zaw, Meffre	Geology and genesis of porphyry-skarn Cu-Au deposits at the northern Loei Fold Belt, Northeast Thailand and Laos	IPRS, ARC Linkage, CoE, SEG, Pan Australian
Luke Keeney (JKMRC)	Walters, Morrison (UQ)	Integrated geometallurgical modelling of the Cadia East deposit	GeM project
Roisin Kyne	Berry, Gemmell, Selley, Webb	Structural controls on mineralisation, including sulphide mineralogy, at the CSA mine, Cobar NSW	UTAS, Cobar Management Ltd
Chun Kit Lai	Crawford, Meffre, Khin Zaw	Tectonics and metallogenesis of ophiolites and volcanics in southwestern Yunnan, China	CoE, Ore Deposits of SE Asia project

STUDENT	SUPERVISORS	PROJECT	SUPPORT
George Leigh (JKMRC)*	Gay (UQ), Morrison (UQ)	Multi-resolution image analysis for process mineralogy	GeM project
Alexey Lygin	Foster, Crawford	The geology, geochemistry and genesis of the Avebury Ni deposit, Tasmania	CoE, MMG
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
Takayuki Manaka	Khin Zaw, Meffre	Geology and mineralisation characteristics of the Phuoc Son goldfields, central Vietnam	CoE, UTAS, Ore Deposits of SE Asia project, SEG, Olympus Pacific Minerals
Claire McMahon	Davidson	Controls on the major and trace elements content of pyrite in hydrothermal alteration envelopes	ARC
Janina Micko (MDRU)	Tosdal (MDRU), 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
Anita Parbhakar-Fox	Walters, Edraki (UQ)	Texture-based approaches to predictive geo-environmental modelling.	SEG, 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
Pedro Pereira da Fonseca	McPhie, McNeill	Strato-tectonic setting of massive sulphide deposits: Mount Read Volcanics (western Tasmania) and the Iberian Pyrite Belt (Portugal)	Portuguese Govt, CoE
Patrick Sack^	Gemmell, Berry	Characterisation of the footwall lithologies, Greens Creek VHMS deposit, Admiralty Island, southeast Alaska	Greens Creek Mining, SEG, IPRS
Abhisit Salam	Khin Zaw, Meffre, McPhie	Geology and genesis of the Chatree deposits, Phetchabun Province, central Thailand	Kingsgate Consolidated Ltd, IPRS, SEG, 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, Khin Zaw, Large	Controls on the geochemistry of magnetite in hydrothermal fluids	IPRS, CODES, TGMS, SEG
Bronto Sutopo	Gemmell, Cooke	The Martabe Au-Ag high-sulphidation 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 (now fee waiver), CODES
Felipe Urzua^	Cooke	Geology, geochronology and structural evolution of La Escondida Copper District, Northern Chile	BHP Chile
Olga Vasyukova	Kamenetsky, Davidson, Danyushevsky	The origin of quartz and fluid inclusions in mineralised porphyries	CoE, IPRS
Adel Vatandoost Kohnehshahri	Roach, Walters, 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

* Degree Completed But Not Yet Graduated
^ Graduated

RESEARCH COLLABORATIONS WITH CODES 2009

INTERNATIONAL COLLABORATIONS (IN ADDITION TO CENTRE PARTNERS)

INSTITUTION	RESEARCHER	CODES COLLABORATORS	PROJECT
American Museum of Natural History, Dept of Earth and Planetary Sciences, USA	J Webster	P Davidson	Melt-melt immiscibility and the origin of magnetite-apatite deposits
American Museum of Natural History, Dept of Earth and Planetary Sciences, USA	J Webster	Z Chang	Efficiency of ore-forming processes
Brookhaven National Laboratory, USA	P Siddons, T Kuczewski, G de Geronimo	C Ryan	Synchrotron X-ray probe development
Chengdu Institute of Geology and Mineral Resource, China	G Li	D Cooke	Collision-related REE-bearing carbontites, porphyries, skarns and gold deposits of Sichuan and Tibet, China
Chiang Mai University, Dept of Geological Sciences, Thailand	W Srichan, P Limtrakun, S Singharajwarapan	Khin Zaw, A Crawford	Ore Deposits of SE Asia
Chinese Academy of Geological Sciences, China	Zengqian Hou	Khin Zaw	VHMS deposits in China
Chinese Academy of Geological Sciences, China	Zengqian Hou, Zhiming Yang	D Cooke	Collison-related REE-bearing carbontites, porphyries, skarns and gold deposits of Sichuan and Tibet, China
Chinese Academy of Sciences, Institute of Geology and Geophysics, China	N Jiang	P Davidson	Melt-melt immiscibility and the origin of magnetite-apatite deposits
Colorado School of Mines, USA	M Hitzman	D Selley, S Bull, J Halpin, L Koziy, P McGoldrick, R Scott, G Davidson, S Micklethwaite	AMIRA P872: Origin and setting of Congolese-type copper deposits
Colorado School of Mines, USA	M Hitzman	S Bull	Base metal and gold mineralisation in sedimentary basins
Colorado School of Mines, USA	R Duncan, S Romberger	D Selley, S Bull, G Davidson, L Koziy, S Micklethwaite, R Scott	Copper, uranium, and precious metals in oxidising sedimentary basins: ore formation and location
Colorado School of Mines, USA	T Monecke	B Gemmell	VHMS deposits, exploration criteria
Colorado State University, Dept of Geosciences, USA	H Stein	Khin Zaw	Ore Deposits of SE Asia
Consultant, Canada	R Tosdal	D Cooke	Shallow and deep-level alkalic mineral deposits
Consultants, Portugal	O Gaspar, A Ferreira	B Gemmell	VHMS deposits
Department of Mineral Resources, Thailand	S Khositanont	Khin Zaw, S Meffre	Ore Deposits of SE Asia
Department of Mineral Resources, Thailand	Pol Chaodumrong	Khin Zaw	Ore Deposits of SE Asia
Dept Earth and Atmospheric Sciences, University of Alberta, Canada	R Creaser	A Harris	Exploring the porphyry environment
Dept Earth and Atmospheric Sciences, University of Alberta, Canada	R Creaser	R Large	Sediment-hosted gold
GeoForschungsZentrum Potsdam, Germany	R Thomas	P Davidson	Melt-melt immiscibility and the origin of magnetite-apatite deposits
Geolgical Survey of Canada	J Peter	B Gemmell	VHMS deposits, exploration criteria
Geolgical Survey of Denmark and Greenland	T Nielsen	D Kamenetsky	Unmixing in magmas: Melt and fluid Inclusion constraints on identity, timing and evolution of immiscible fluids, salt and sulphide melts
Geoscience BC, Canada	K Simpson	D Cooke	Shallow and deep-level alkalic mineral deposits
GNS, New Zealand	K Faure	A Harris	Exploring the porphyry environment
GNS, New Zealand	C de Ronde	B Gemmell	Modern seafloor black smokers
Ghent University, Belgium	E Elburg	D Kamenetsky	Unmixing in magmas: Melt and fluid Inclusion constraints on identity, timing and evolution of immiscible fluids, salt and sulphide melts

INSTITUTION	RESEARCHER	CODES COLLABORATORS	PROJECT
Guangzhou Institute Geochemistry, China	W Sun	D Kamenetsky	Unmixing in magmas: Melt and fluid Inclusion constraints on identity, timing and evolution of immiscible fluids, salt and sulphide melts
Guangzhou Institute Geochemistry, China	W Sun	D Kamenetsky, J McPhie	Felsic magmas in volcanic arcs and intraplate volcanic provinces - eruption style, degassing processes, fluid evolution and links to mineralisation
Hanoi University of Mining and Geology, Dept of Geology, Vietnam	H Tran	Khin Zaw, J Halpin	Ore Deposits of SE Asia
Hebrew University, Israel	O Navon	D Kamenetsky	Unmixing in Magmas: Melt and fluid Inclusion constraints on Identity, timing and evolution of immiscible fluids, salt and sulphide melts
Hefei University of Technology, China	T Zhou, F Yuan, Y Fan	D Cooke, Z Chang	Polymetallic mineralisation and associated magmatic and volcanic activity in the Luzong basin, middle and lower Yangtze River, eastern China
Hefei University of Technology, China	T Zhou	Z Chang	Application of PIXE technologies on hydrothermal processes: mineral trace element zoning and composition of single fluid inclusions
IFM-GEOMAR, Germany	S Petersen	B Gemmell	Modern seafloor hydrothermal systems
IGM, Portugal	C Inverno	B Gemmell	VHMS deposits
Imperial College London, UK	A Berry	L Danyushevsky	Mafic magmatism in modern submarine SW Pacific settings
Imperial College London, UK	A Berry	A Harris	Developmental research into the use of synchrotron in ore deposit studies
Imperial College London, UK	A Muxworthy	J Wilkinson	Plaeomagnetism of Lower Carboniferous rocks in the Irish Midlands Basin
Imperial College London, UK	D Weiss	J Wilkinson	Transition metal speciation and isotope systematics of source rocks for sediment and volcanic-hosted ores
Institut Neel and European Synchrotron Radiation Faility, France	D Testemale, J Hazemann	C Ryan	Synchrotron X-ray probe development
Institut Neel and European Synchrotron Radiation Facility, France	D Testemale, J Hazemann	C Ryan, S Borg	New synchrotron-based applications
Institute of Earth Sciences-Academia Sinica, Taiwan	G Zellmer	D Kamenetsky	Unmixing in magmas: Melt and fluid Inclusion constraints on identity, timing and evolution of immiscible fluids, salt and sulphide melts
Institute of Experimental Mineralogy, Russia	O Safonov	D Kamenetsky	Unmixing in magmas: melt and fluid Inclusion constraints on identity, timing and evolution of immiscible fluids, salt and sulphide melts
Institute of Experimental Mineralogy, Russia	E Konnikov	L Danyushevsky	AMIRA P962: Ni-PGE potential of mafic and ultramafic magmas - a combined melt inclusions and numerical modelling approach
Institute for Frontier Research on Earth Evolution, Japan	Y Tamura	D Kamenetsky, J McPhie	Felsic magmas in volcanic arcs and intraplate volcanic provinces - eruption style, degassing processes, fluid evolution and links to mineralisation
Institute of Geology, Chinese Academy of Geological Sciences	Z Yang	Z Chang	UST and porphyry Au mineralisation at the Bilihe deposit, China
Institute of Geology, Chinese Academy of Geological Sciences	Z Yang	Z Chang	Efficiency of ore-forming processes
Institute of Geology and Mineralogy, Russia	A Golovin, V Sharygin, S Smirnov	D Kamenetsky	Unmixing in magmas: Melt and fluid Inclusion constraints on identity, timing and evolution of immiscible fluids, salt and sulphide melts
Kunming University of Science and Technology, China	C Xue	A Crawford, S Meffre, Khin Zaw	Tectonics and mineral resources of Yunnan
Lakehead University, Canada	R Mitchell	D Kamenetsky	Unmixing in magmas: Melt and fluid inclusion constraints on identity, timing and evolution of immiscible fluids, salt and sulphide melts
Lakehead University, Canada	P Hollings, G Sweet, R Kyne	D Cooke, B Gemmell, Z Chang	AMIRA P765A: Geochemical and geological halos in green rocks and lithocaps - The explorer's toolbox for porphyry and epithermal districts
Laurentian University, Canada	S Piercey	B Gemmell	VHMS deposits, exploration criteria
Max Planck Institute, Germany	A Gurenko	D Kamenetsky, J McPhie	Felsic magmas in volcanic arcs and intraplate volcanic provinces - eruption style, degassing processes, fluid evolution and links to mineralisation

INSTITUTION	RESEARCHER	CODES COLLABORATORS	PROJECT
Max Planck Institute, Germany	D Kuzmin	D Kamenetsky	Unmixing in magmas: Melt and fluid Inclusion constraints on identity, timing and evolution of immiscible fluids, salt and sulphide melts
Moscow State University, Russia	P Plechov	L Danyushevsky	Modelling of crystallisation and melting processes
Moscow State University, Russia	P Plechov	L Danyushevsky	Mafic magmatism in modern submarine SW Pacific settings
National Taiwan University	Sun-Lin Chung	D Kamenetsky	Unmixing in magmas: Melt and fluid inclusion constraints on identity, timing and evolution of immiscible fluids, salt and sulphide melts
Otago University, New Zealand	D Craw	R Large	Sediment-hosted gold
Quebec Geological Survey, Canada	J Bedard	L Danyushevsky, A McNeill	AMIRA P962: Ni-PGE potential of mafic and ultramafic magmas-a combined melt inclusions and numerical modelling approach
Queens University, Canada	D Layton-Matthews	B Gemmell	VHMS deposits, exploration criteria
Russian Academy of Science	V Maslennikov, S Maslennikova	R Large	Sediment-hosted gold
Russian Academy of Science	V Maslennikov	Z Chang	Efficiency of ore-forming processes
Smith College, USA	L Meinert	Z Chang	Zonation in skarns and the skarn chapter for the v. 12 geochemistry of mineral resoures of Elsevier's Treatise of Geochemistry series
Smithsonian Institution, USA	R Fiske	D Kamenetsky, J McPhie	Felsic magmas in volcanic arcs and intraplate volcanic provinces - eruption style, degassing processes, fluid evolution and links to mineralisation
Smithsonian Institution, USA	R Fiske	S Allen, J McPhie	Submarine explosive eruptions
State Key Laboratory in Ore Deposit Geochemistry, Chinese Academy of Sciences	X Song	L Danyushevsky, A Crawford,	Layered intrusions in the Emeishan LIP, China
Tarbiat Modares, Iran	F Mousivand	B Gemmell	VHMS deposits
TUFTS, USA	G Garven	S Bull	Base metal and gold mineralisation in sedimentary basins
United States Geological Survey	P Emsbo	D Selley, S Bull, J Halpin, L Koziy, P McGoldrick, R Scott, G Davidson, S Micklethwaite	AMIRA P872: Origin and setting of Congolese-type copper deposits
United States Geological Survey	P Emsbo	D Selley, S Bull, J Halpin, L Koziy, P McGoldrick, R Scott	Copper, uranium, and precious metals in oxidising sedimentary basins: ore formation and location
United States Geological Survey	P Emsbo	S Bull	Base metal and gold mineralisation in sedimentary basins.
United States Geological Survey	P Emsbo,	P McGoldrick	Global ocean chemistry, marine basins and mineralisation
Universidade Federal de Minas Gerais, Brazil	R Figueiredo de Silva	G Davidson, D Cooke	Cracking the sulphate isotopic composition problem in ancient hydrothermal systems: application of the Carbonate-Associated Sulphate (CAS) method
Universite Catolica Norte, Chile	H Niemeyer	S Meffre	General research collaboration
Universite d' Orleans, France	P Trap, B Wang	S Meffre	Ore Deposits of SE Asia
Universiti Kebangsaan Malaysia, School of Environmental Science and Natural Resources	Wan Faud Wan Hassan, M Umor	Khin Zaw	Ore Deposits of SE Asia
University of British Columbia, MDRU, Canada	R Friedman	D Cooke, Bruce Gemmell, Z Chang	AMIRA P765A: Geochemical and geological halos in green rocks and lithocaps - The explorer's toolbox for porphyry and epithermal districts
University of British Columbia, MDRU, Canada	K Hickey	J Wilkinson	Fission track thermal analysis of the Irish Midlands Basin
University of British Columbia, MDRU, Canada	A Muxworthy	J Wilkinson	Paleomagnetism of lower carboniferous rocks in the Irish Midlands Basin
University of British Columbia, MDRU, Canada	T Bissig	D Cooke	Shallow and deep-level alkalic mineral deposits

INSTITUTION	RESEARCHER	CODES COLLABORATORS	PROJECT
University of British Columbia, MDRU, Canada	J Mortensen	B Gemmell	VHMS deposits, exploration criteria
University of California, Riverside, USA	T Lyons	P McGoldrick, S Bull	Global ocean chemistry, marine basins and mineralisation
University College of Science, School of Geology, Iran	M Mirmohammadi	P Davidson	Melt-melt immiscibility and the origin of magnetite-apatite deposits
University of Central Missouri, Dept of Earth Science, USA	J Nold, M Dudley	P Davidson	Melt-melt immiscibility and the origin of magnetite-apatite deposits
University of Chicago, USA	M Newville, S Sutton	A Harris	Developmental research into the use of synchrotron inore deposit studies
University of Delhi, India	M Deb, S. Deol	R Large, A Crawford	Sediment-hosted gold
University of Huelva, Spain	R Saez, M Toscano	B Gemmell	VHMS deposits
University of Lisbon, Portugal	M Gaspar	Z Chang	Zonation in skarns and the skarn chapter for the v. 12 geochemistry of mineral resoures of Elsevier's Treatise of Geochemistry series
University of Lisbon, Portugal	J Relvas	Khin Zaw	VHMS deposits
University of Lubumbashi, Democratic Republic of Congo	S Sebagenzi	D Selley, S Bull, J Halpin, L Koziy, P McGoldrick, R Scott	AMIRA P872:Origin and setting of Congolese-type copper deposits
University of Malaya, Geology Dept, Malaysia	A Ghandi, T Guan Hoe	Khin Zaw	Ore Deposits of SE Asia
University of Malaya, Geology Dept, Malaysia	T Guan Hoe	Khin Zaw	Volcanic-hosted massive sulphide deposits in Malaysia
University of Manitoba, Canada	A Chakhmouradian	D Kamenetsky	Unmixing in magmas: Melt and fluid Inclusion constraints on identity, timing and evolution of immiscible fluids, salt and sulphide melts
University of Naples, Italy	B DeVivo	L Danyushevsky	AMIRA P962: Ni-PGE potential of mafic and ultramafic magmas - a combined melt inclusions and numerical modelling approach
University of Oregon, USA	I Bindeman	D Kamenetsky	Unmixing in magmas: Melt and fluid Inclusion constraints on identity, timing and evolution of immiscible fluids, salt and sulphide melts
University of Oregon, USA	K Cashman	D Kamenetsky, J McPhie	Felsic magmas in volcanic arcs and intraplate volcanic provinces - eruption style, degassing processes, fluid evolution and links to mineralisation
University of Oregon, USA	K Cashman	S Allen	Origin and behaviour of submarine pumice
University of Oregon, USA	P Wallace	E Johnson, D Kamenetsky	Volatiles in felsic magmas
University of Ottawa, Canada	J Hedenquist	D Cooke, B Gemmell, Z Chang	AMIRA P765A: Geochemical and geological halos in green rocks and lithocaps - The explorer's toolbox for porphyry and epithermal districts
University of Ottawa, Canada	J Hedenquist	Z Chang	Efficiency of ore-forming processes
University of Ottawa, Canada	M Hannington	B Gemmell	VHMS deposits, exploration criteria
University of Oulu, Finland	E Hanski	D Kamenetsky	Unmixing in magmas: Melt and fluid inclusion constraints on identity, timing and evolution of immiscible fluids, salt and sulphide melts
University of Science and Technology, Civil and Environmental Engineering School, China	Y Xie	D Cooke	Collision-related REE-bearing carbontites, porphyries, skarns and gold deposits of Sichuan and Tibet, China
University of Science and Technology, Civil and Environmental Engineering School, China	Y Xie	P Davidson	Melt-melt immiscibility and the origin of magnetite-apatite deposits
Vernadsky Institute, Russia	V Naumov, A Sobolev	D Kamenetsky	Unmixing in magmas: Melt and fluid inclusion constraints on identity, timing and evolution of immiscible fluids, salt and sulphide melts
Vernadsky Institute, Russia	A Ariskin	L Danyushevsky	AMIRA P962: Ni-PGE potential of mafic and ultramafic magmas - a combined melt inclusions and numerical modelling approach
Woods Hole Oceanographic Institute, USA	A Gurenko	D Kamenetsky	Unmixing in magmas: Melt and fluid Inclusion constraints on identity, timing and evolution of immiscible fluids, salt and sulphide melts

NATIONAL COLLABORATIONS (IN ADDITION TO CENTRE PARTNERS)

INSTITUTION	RESEARCHER	CODES COLLABORATORS	PROJECT
Australian Museum, Sydney	L Sutherland	Khin Zaw	Ore Deposits of SE Asia
Australian National University	N Rawlinson, M Sambridge	A Reading	Ambient seismic energy techniques and computational geophysics
Australian National University	M Sambridge	A Reading, B Paul	Improved image processing alogorithms for LA-ICPMS
Australian National University	H O'Neill	L Danyushevsky	Mafic magmatism in modern submarine SW Pacific settings
Australian National University	C Allen, I Campbell	A Harris, D Cooke	Exploring the porphyry environment
Australian National University	I Campbell	A Harris	Developmental research into the use of synchrotron in ore deposit studies
Australian National University	G Yaxley	D Kamenetsky	Unmixing in magmas: Melt and fluid Inclusion constraints on identity, timing and evolution of immiscible fluids, salt and sulphide melts
Australian Synchrotron	D Paterson, M de Jonge, D Howard	C Ryan	Synchrotron X-ray probe development
Consultant	N White	D Cooke, B Gemmell, Z Chang, H Chen, M Baker	AMIRA P765A: Geochemical and geological halos in green rocks and lithocaps - The explorer's toolbox for porphyry and epithermal districts
CSIRO	W Liu, R Kirkham, G Moorhead, P Dunn, M Jensen,	C Ryan	Synchrotron X-ray probe development
CSIRO	W Liu, J Cleverly, R Hough, S Fraser	C Ryan, S Borg	New synchrotron-based applications
CSIRO	J Walshe	B Gemmell	VHMS deposits
CSIRO	S Barnes	J Foster, D Hutchinson	Characterisation of magmatic sulphide ores
Curtin University	F Jourdan	Z Chang	Ar-Ar dating for P765A
Geoscience Australia	D Huston, T Mernagh	Khin Zaw	VHMS deposits
Geoscience Australia	T Mernagh	A Harris	Developmental research into the use of synchrotron in ore deposit studies
Geoscience Australia	T Mernagh	D Kamenetsky, J McPhie	Felsic magmas in volcanic arcs and intraplate volcanic provinces - eruption style, degassing processes, fluid evolution and links to mineralisation
Geoscience Australia	T Mernagh	D Kamenetsky	Unmixing in magmas: Melt and fluid inclusion constraints on identity, timing and evolution of immiscible fluids, salt and sulphide melts
Geological Survey of NSW	B Stevens	T Crawford	Palaeoproterozoic magmatism and mineralisation
Geological Survey of NSW	I Percival	A Harris	Exploring the porphyry environment
Geological Survey of Queensland	I Withnall	T Crawford	Palaeoproterozoic magmatism and mineralisation
Geological Survey of Queensland	I Withnall	T Crawford	Tectonic significance and mineralisation potential of volcano-plutonic belts and ophiolites at the northern end of the Tasman Line, N Queensland
James Cook University	B Henderson	A Crawford	Tectonics of the N Tasman orogenic zone
James Cook University	B Rusk	J Wilkinson	Transition metal speciation and isotope systematics of source rocks for sediment and volcanic-hosted ores
James Cook University	B Henderson	A Crawford	Tectonic significance and mineralisation potential of volcano-plutonic belts and ophiolites at the northern end of the Tasman Line, N Queensland
Primary Industry and Resources South Australia	M Fairclough	J McPhie	Gawler Range volcanics
University of Adelaide	B Etschmann, J Brugger	C Ryan, S Borg	New synchrotron-based applications
University of Adelaide	B Etschmann, J Brugger	C Ryan	Synchrotron X-ray probe development
University of Adelaide	J Foden	B Gemmell	VHMS deposits

INSTITUTION	RESEARCHER	CODES COLLABORATORS	PROJECT
University of Ballarat	S McKnight	Z Chang	Clay QXRD analysis for P765A
University of Melbourne	J Woodhead	L Danyushevsky	Mafic magmatism in modern submarine SW Pacific settings
University of Melbourne	J Woodhead, M Kendrick, D Phillips	D Kamenetsky	Unmixing in magmas: Melt and fluid inclusion constraints on identity, timing and evolution of immiscible fluids, salt and sulphide melts
Monash University	R Keays	A Crawford	PGE in Lachlan Fold Belt greenstones and modern boninites
Monash University	R Keays	L Danyushevsky	AMIRA P765A: Geochemical and geological halos in green rocks and lithocaps - The explorer's toolbox for porphyry and epithermal districts
University of Melbourne	B Johnson, K Ganesan, J McCallum, S Best	J Laird, G Davidson	Ion Beam analysis development
University of Melbourne	R Mass	A Crawford	Origin of the supergiant Broken Hill Pb-zn-au deposit
University of Melbourne	R Mass	D Kamenetsky, J McPhie	Mafic igneous facies at Olympic Dam
University of Melbourne	R Mass	D Kamenetsky, J McPhie	Felsic magmas in volcanic arcs and intraplate volcanic provinces - eruption style, degassing processes, fluid evolution and links to mineralisation
University of Queensland	P Vasconcelos, S Golding,	Khin Zaw	Ore Deposits of SE Asia
University of Tasmania, Central Science Laboratory	K Goemann	D Kamenetsky, J McPhie	Felsic magmas in volcanic arcs and intraplate volcanic provinces - eruption style, degassing processes, fluid evolution and links to mineralisation
University of Western Australia	M Barley	Khin Zaw	Ore Deposits of SE Asia
University of Western Australia	S Haggeman	G Davidson, D Cooke	Cracking the sulphate isotopic composition problem in ancient hydrothermal systems: application of the Carbonate-Associated Sulphate (CAS) method
University of Woolongong	C Fergusson	A Crawford	N Tasman Orogenic zone
University of Woolongong	C Fergusson	A Crawford	Tectonic significance and mineralisation potential of volcano-plutonic belts and ophiolites at the northern end of the Tasman Line, N Queensland

VISITORS TO CODES 2009

INDUSTRY VISITOR

NAME	SURNAME	INSTITUTION
Paul	Agnew	Rio Tinto
Mark	Allen	OZ Minerals
Mark	Arundell	Copper Range
Ed	Baltis	Gold Fields
Robert	Barr	Newmont
Trevor	Beardsmore	Barrick Gold
Nick	Beaton	Datamine Australia
Jeff	Bigelow	Newmont
Victoria	Braniff	Grange Resources
Dave	Braxton	Anglo American
Jared	Broome	OZ Minerals
Lachlan	Brown	Copper Mines of Tasmania
Mac	Canby	Freeport-McMoran
James	Cannell	Minerals and Metals Group
Pedro	Carrasco	Codelco Chile
Chris	Chambers	Newcrest
Darryl	Clark	Vale
Dean	Collett	Newcrest Mining Ltd
John	Cooke	Equinox Minerals
Paul	Cromie	Tiger Realm Group
Andrew	Cuthbertson	AngloGold Ashanti
Elisabeth	da Fonseca	Vale
Lynda	Daley	Newmont
Adrian	Dance	Metso Minerals Process Technology Asia-Pacific
Carlos	Delgado	BHP Billiton, Minera Escondida Ltda
Fernando	Della Pasqua	GHD Mining & Resources
Kim	Denwer	Bass Metals
Jaime	Diaz	Codelco Chile
John	Dow	Consultant
Mark	Doyle	AngloGold Ashanti
David	Duncan	McPherson Duncan & Associates
Kathy	Ehrig	BHP Billiton
Trevor	Ellice	OZ Minerals
Steve	Enders	Renaissance Resource Partners
Ed	Eshuys	Resource Surveys
David	First	Freeport-McMoran
Hamish	Freeman	OZ Minerals
Roberto	Freraut	Codelco Chile
Stefan	Gawlinski	China MinMetals
Baris	Gazanfer Yildirim	Teck Resources Ltd
Duncan	Gibbs	AngloGold Ashanti
Aidan	Gilett	Newmont Asia Pacific Pty Ltd
Michael	Glinksy	BHP Billiton
Rene	Gonzales	Anglo American
Alan	Goode	AMIRA
Jonathan	Graham	Datamine Corporate Limited
Elliot	Grant	Venture Minerals
Nick	Green	BHP Billiton
John	Hammond	Newmont Exploration
David	Hartman	BHP Billiton
Wally	Herrmann	Walter Herrmann Geoscience
John	Holliday	Newcrest
Kirsty	Hollis	Newmont Asia Pacific Pty Ltd
Russell	Hooper	OZ Minerals
Tony	Hope	Indochine Resources, Consultant
Terry	Hoschke	Newmont
Keith	Kenny	AngloGold Ashanti
Paul	Kittler	BHP Billiton
Carl	Jackman	BMT
Thomas	James	Rio Tinto
Tamal	Lal	Ivanhoe Resources
Geoff	Lane	Rio Tinto
Andy	Lapworth	Datamine Corporate Limited
Chris	Large	Cam Bow
Penny	Large	A-Cap Resources
David	Lawie	ioGlobal
Greg	Lear	Tasmanian Geoventures
Steve	Liddell	BHP Billiton
Vanessa	Liebezeit	BHP Billiton, Olympic Dam Expansion
Neil	Macalalad	Anglo American
Grant	MacDonald	Bass Metals
Neil	Martin	Jabiru Metals
Stuart	Masters	OZ Minerals
Adrian	McArthur	St Barbara
Brendan	McGee	Copper Mines Tasmania
Nichola	McKay	Teck Resources
Ken	Morrison	K C Morrison
Peter	Muhling	CSA Global
Travis	Murphy	Bass Metals
Belinda	Moss	BHP Billiton
Malcolm	Newton	Datamine Corporate Limited
Shauna	Nichol	Anglo Platinum RPM
Roger	Norris	Rio Tinto
Justin	Osborne	Gold Fields
Marnie	Pasco	BHP Billiton Nickel West
Aubrey	Paverd	Buenaventura
James	Pinakis	ioGlobal
Paul	Polito	Anglo American Exploration
Celeste	Queiroz	Vale
Rowdy	Rawlings	Toro Energy
Mike	Richards	Equinox Minerals
Geoff	Richmond	OZ Minerals
Ian	Sandl	Teck
Robert	Schouwstra	Anglo Platinum RPM
Donna	Sewell	AngloGold Ashanti
Robina	Sharpe	Contract Geologist
Greg	Shirtliff	Cameco
Puru	Shrestha	BHP Billiton
Daud	Silitonga	Newcrest
Dale	Sims	Newcrest Mining Ltd
Stuart	Smith	G-Resources
Andrew	Somers	Innovx Systems
Andy	Stewart	Vale Exploration
Larry	Stewart	China MinMetals
Leonardo	Subang	Freeport-McMoran
Jillian	Terry	BHP Billiton
Andrew	Tunks	A-Cap Resources
Steve	Turner	Newmont
Felipe	Urzua	BHP Billiton
Alida	Van Der Merwe	Grange Resources
Rob	Wall	ioGlobal
David	Wallace	China MinMetals
Anthony	Wesson	BHP Billiton
Andy	West	Greens Creek Mining, Alaska
MJ	Westman	BHP Billiton
Matt	White	Nautilus Minerals
Noel	White	Consultant
Ian	Willis	Anglo American
Steve	Wilson	Teck Resources
Rohan	Wolfe	Ivanhoe Australia
Andy	Wurst	Gold Fields

NATIONAL ACADEMIC AND GOVERNMENT VISITORS

NAME	SURNAME	INSTITUTION
Ben	Adair	JKMRC
Tim	Baker	PIRSA
Mark	Barley	University of Western Australia
Stacey	Borg	CSIRO
Tony	Brown	MRT
Alan	Bye	BRC
Graham	Carr	CSIRO
Ray	Cas	Monash University
Cristiana	Ciobanu	University of Adelaide
Richard	Coleman	ARC
Nigel	Cook	University of Adelaide
Stephen	Cox	Australian National University
Nathan	Daczko	Macquarie University
Mark	Duffett	Mineral Resources Tasmania
Cathy	Evans	JKMRC
George	Gibson	Geoscience Australia
David	Green	Mineral Resources of Tasmania
Geoff	Green	Mineral Resources of Tasmania
David	Groves	UWA
Ying	Gu	JKMRC
Galen	Halverson	University of Adelaide
Richard	Hartner	JKMRC
Paul	Heithersay	PIRSA
Janet	Hergt	University of Melbourne
Jon	Huntington	CSIRO
David	Huston	Geoscience Australia
Reid	Keays	Monash University
Luke	Keeney	JKMRC
Toni	Kojovic	JKMRC
George	Leigh	JKMRC
Roland	Maas	University of Melbourne
Simon	Michaux	JKMRC
Khoi	Nguyen	JKMRC
Bence	Paul	University of Melbourne
Chris	Ryan	CSIRO
Malcolm	Sambridge	Australian National University
Margaret	Sheil	ARC
Richard	Stanton	ANU
Phil	Symonds	Geoscience Australia
John	Walshe	CSIRO
Pat	Walters	JKMRC
Yicai	Wang	JKMRC
Jon	Woodhead	University of Melbourne
Heather	Wright	Monash University
Leslie	Wyborn	Geoscience Australia
Greg	Yaxley	Australian National University

INTERNATIONAL ACADEMIC AND GOVERNMENT VISITORS

NAME	SURNAME	INSTITUTION
Rod	Allen	Lulea University of Technology / Boliden Mineral
Alexei	Ariskin	Vernadksy Institute of Geochemistry, Moscow, Russia
John	Chapman	GSC, Ottawa, Canada
Mike	Coffin	National Ocenography Institute, Southampton
Cornel	de Ronde	GNS Science, New Zealand
Mihir	Deb	University of New Delhi
Swati	Deol	University of New Delhi
Poul	Emsbo	United States Geological Survey
Grant	Garven	TUFTS
Darren	Gravley	University of Canterbury, Christchurch, New Zealand
Jeff	Hedenquist	University of Ottawa, Canada
Peter	Hollings	Lakehead University, Canada
Eduard	Konnikov	Institute of Experimental Mineralogy, Chernogolovka, Russia
Somboon	Khositanont	Dept of Mineral Resources Thailand
Tim	Lyons	University of California, Riverside
Valeriy	Maslennikov	Russian Academy of Science
Svetlana	Maslennikova	Russian Academy of Science
Larry	Meinert	Smith College
Jim	Natland	Rosentiel School of Marine & Atmospheric Science, University of Miami
Jan	Peter	GSC, Ottawa, Canada
Pavel	Plechov	Moscow State University, Russia
Ana	Rieger	Maximilians Universitat, Munich, Germany
Sampan	Singharajwarapan	Chiang Mai University, Dept of Geological Sciences, Thailand
Xieyan	Song	State Key Laboratory of Ore Deposit Geochemistry, China Academy of Sciences, Guiyang, China
Peter	Sorjonen-Ward	Geological Survey of Finland
Jim	Webster	American Museum of Natural History
Colin	Wilson	Victoria University, Wellington, New Zealand
Yuling	Xie	University of Science and Technology, Beijing
Zhiming	Yang	Institute of Geology, Chinese Academy of Geological Sciences
Taofa	Zhou	Hefei University of Technology, China

MAJOR EXTERNALLY FUNDED RESEARCH PROJECTS*

AMIRA-ARC CENTRE OF EXCELLENCE PROJECTS 2009†

INVESTIGATORS	PROJECT	INDUSTRY PARTNERS	PERIOD	COE-ARC FUNDING FOR 2009	AMIRA FUNDING FOR 2009[1]	MISC FUNDING FOR 2010	ADD'L AMIRA FUNDING FOR 2009
Cooke, Gemmell, Chang, Baker, Chen	AMIRA P765A. Geological and geochemical halos in green rocks and lithocaps	Anglo American, AngloGold Ashanti, Barrick Gold, Cia De Minas Buenaventura, Codelco, CVRD, Dundee Precious Metals, Equinox Resources, Freeport McMoran, Gold Fields, Kinross Gold, Newcrest Mining, Newmont Mining, Oxiana, Rio Tinto, St Barbara, Teck Resources	2008 - 2011	$120,000	$845,000	$0	$33,200 (Lakehead University)
Danyushevsky, McNeill, Feig, Ariskin (Vernadsky), Konnikov (IEM)	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	$107,852	$122,920^^	$0	$30,000 (Ariskin) $10,000 (Konnikov)
Walters, Berry, Djordjevic, Fullagar (Fullagar Geophysics), Hunt, Huntington, Kojovic, Bye	AMIRA P843. GeM Geometallurgical Mapping and Mine Modelling	Newmont, Rio Tinto, Teck Resources, XStrata, Newcrest, Inco, AngloGold Ashanti, Anglo Platinum, Barrick, Vale Inco, WMC, Zinifex, BHP Billiton, Datamine, GeoTek, Golder Associates, Codelco, Metso Minerals, Oxiana, ioGlobal	2005 - June 2009	$281,337	$1,265,929	$3,120	$0
Walters, Edraki, Berry, Kojovic, Michaux, Groves, Onederra, Bradshaw, Robinson, Jeffrey	AMIRA P843A. GeM Geometallurgical Mapping and Mine Modelling (extension)	Anglo American, AngloGold Ashanti, Barrick Gold, Codelco, BHP Billiton, ioGlobal, Metso, Newcrest Mining, OZ Minerals, Rio Tinto, Teck, Vale Inco, Xstrata	July 2009 - 2013	$250,000	$264,450	$0	$0

AMIRA-ARC LINKAGE PROJECTS 2009^

INVESTIGATORS	PROJECT	INDUSTRY PARTNERS	PERIOD	ARC FUNDING FOR 2009	AMIRA FUNDING FOR 2009[1]	MISC FUNDING FOR 2010	ADD'L FUNDING TO COLLAB-ORATORS
Selley, Bull, McGoldrick, Hitzman (CSM)	AMIRA P872. Sediment-hosted Cu-deposits of Congolese, Zambian & Central Australian basin systems	Anglo American, Anvil Mining, BHP Billiton, Vale Inco, Entreprise Generale Malta Forrest, Equinox Minerals, First Quantum, Gecamines, Phelps Dodge, Rio Tinto, Teal Mining	2005 - 2010	$0	$169,336^^	$0	$0

ARC DISCOVERY GRANTS 2009^

INVESTIGATORS	PROJECT	PERIOD	ARC FUNDING FOR 2009	MISC FUNDING FOR 2009
Allen	Discovery Grant: Submarine explosive eruptions of silicic magma: constraints on products and processes from modern sea-floor examples, ancient successions and experiments	2004 - 2012	**	$0
Kamenetsky	APF and Discovery Grant: Unmixing in magmas: Melt and fluid inclusion constraints on identity, timing and evolution of immiscible fluids, salt and sulphide melts	2005 - 2009	$158,889	$0

INDUSTRY AND OTHER EXTERNALLY FUNDED RESEARCH GRANTS 2009

INVESTIGATORS	PROJECT	FUNDING BODY	PERIOD	FUNDING FOR 2009	MISC FUNDING FOR 2009
Berry, Kyne (student)	Structural controls on mineralisation, including sulphide mineralogy, at the CSA mine, Cobar NSW	Cobar Management Pty Ltd	2009 - 2013	‡	$0
Chang, Cooke, White	Caijiaying Zn-Au deposit: Geological characteristics and their implications to exploration	Hebei Hua Ao Mining	2007 - 2009	$12,500	$0
Cooke, Gemmell, Ageneau (student)	Geology of the Kapit ore zone and comparative geochemistry with Minifie and Lienetz ore zones, Ladolam gold deposit, Lihir Island, Papua New Guinea	Lihir Gold Ltd	2009 - 2011	$10,000	$0
Cooke, Gemmell, Chang, Zukowski	Geological and geochemical vectors to epithermal silver-gold mineralisation, Ares mine, Araquepa, Peru	Compania Minera Area S.A.C.	2009 - 2010	‡	$0
Davidson, Cooke, Kirkby (student)	Origin of IOCG-style mineralisation in the Mt Dore deposit, Mt Isa Inlier	Ivanhoe Australia Limited	2009	$6,000	$0
Foster, Hutchinson	Tenor variation in the Tweefontein Sector of the Platreef, South Africa	Anglo American Exploration Luxembourg SARL	2008 - 2010	$150,308	$0
Fox (student)	Hugh E. McKinstry Fund	Society of Economic Geologists Foundation	2009	$3,169	$0
Gemmell, Micklethwaite	Deposit to district-scale study of the Gosowong Goldfield	Newcrest Mining Limited	2007 - 2010	$148,309	$1,720
Harris, Cooke, Berry	District- to deposit-scale structural and geochemical study of the Cadia porphyry Au-Cu deposits	Newcrest Mining Limited	2005 - June 2009	$47,935	$10,570
Harris, Cooke, Tosdal (UBC)	Exploring the porphyry environment	Newcrest Mining Limited	July 2009 - 2013	$243,998	$0
Harris, Cooke, Chang, Kor (student)	Hydrothermal breccias at the Coalstoun porphyry Cu-Au-Mo deposit, SE Queensland	Newcrest Mining Limited	2009 - 2010	$16,500	$0
Khin Zaw, Meffre	Ore Deposits of SE Asia	Indochine Resources Ltd, Newmont Asia Pacific, Barrick Gold, OZ Minerals, Pan Australian Resources, Kingsgate Consolidated Ltd/ Issara Ltd, Southern Gold Ltd, MMG, Monument Mining	2008 - 2010	$374,500	$0
Large, Bull, Thomas	Geochemistry of shales & LQ veins at Bendigo: A new approach to assist selection of drill targets	Bendigo Mining	2008 - 2009	$86,240	$0
Large, Thomas, Craw	Investigation of pyrite geochemistry, Otago Goldfield, NZ	Glass Earth Gold Limited	2009 - 2010	$8,256	$0
Manaka (student)	Newmont Mining Corporation Fund	Society of Economic Geologists Foundation	2009	$4,153	$0
McPhie, Kamenetsky, Chambefort	Mafic igneous facies at Olympic Dam	BHP Billiton	2008 - 2010	$395,096 ‡‡	$0
McPhie, McNeill, Williams (student)	Volcanology of the hangingwall volcaniclastics at Rosebery mine	Mines & Metals Group Rosebery Mine	2009	$5,000	$0
Micklethwaite	Targeting fault-related permeability and mineralisation around the Getchell Fault System	Barrick Gold	2009	$15,383	$0
Parbhakar-Fox (student)	Hugh E. McKinstry Fund	Society of Economic Geologists Foundation	2009	$2,337	$0
Reading, Roach, Howe (student)	Comparison of petrophysical properties derived from wireline well logs and measurements on rock core	Granite Power Limited	2009	$5,000	$2,355
Reading, Roach, Davidson, Rast (student)	Thermal characteristics of the Parmeener Supergroup, Tasmania	KUTh Energy Limited	2009	$2,000	$0
Reading, Roach, Slater (student)	Geophysical surveying and modelling of geothermal plays	Granite Power Limited	2009	$5,000	$1,443
Roach, Lucier (Geog), Cracknell (student)	Application of Lidar technology to structural stratigraphic mapping in Tasmania	Mineral Resources Tasmania	2009	$2,500	$0
Roach, Reading, Webb (student)	Increased ore-grade control at Savage River using downhole geophysical techniques	Grange Resources	2009	$11,000	$4,500
Webster, Braniff (student)	The structure & deformational history of the Savage River Magnetite orebodies	Grange Resources (formerly Australian Bulk Minerals)	2008 - 2011	$24,000	$0

* projects with greater than $2,000 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
[1] AMIRA funding invoiced in 2009 for retrospective quarters unless stated otherwise
^^ Funding still outstanding, to be invoiced at a later date
** All project funding received, project still active
‡ project started, funding not yet received
‡‡ full project funding received in one year

ACTIVITY PLAN 2010

PROGRAM 1

PROJECT	TEAM LEADER(S)	ACTIVITY PLAN
P1.A1	Tony Crawford	A paper on the Palaeoproterozoic mafic magmatism of the Georgetown Block (Baker, Crawford & Withnall) is in press in *Precambrian Research*. Paper proposing a new model for the giant Broken Hill Pb-Zn-Ag deposit (Crawford and Mass) is ready for submission to *Geology*. Project concluded at the end of 2009.
P1.A2	Leonid Danyushevsky	Trevor Falloon to continue to gather data on the new suites of rocks dredged during Cruise SS03/09 of the RV *Southern Surveyor.* Gisela Cobenas will continue her PhD project on a strongly fractionated suite from the Hunter Ridge.
P1.A3	Peter McGoldrick, Stuart Bull	Four-month visit of Prof Tim Lyons (U California Riverside), on a UTAS Fellowship, to work on stable isotope signatures in the N Australian Palaeoproterozoic basins. Develop of an improved seawater S isotope curve for the period 1650 to 1590 Ma and new insights into the redox state and S chemistry of seawater at this time. Establish a database of sulphide and sulphate isotopic and geochemical analyses from the northern Australian Proterozoic sequence.
P1.A4	Kin Zaw, Sebastien Meffre	Hold sponsors' meeting in Chiang Mai (Thailand) in February. Project concludes in late 2010. Plan and implement a follow-on project for SE Asia.
P1.A5	Tony Crawford, Jeff Foster	Logistical support for fieldwork will be available from April. Commence modelling of potential field data (Ralf Schaa). Start geochemical and geochronological studies on a suite of mafic granulites collected from the Fraser Complex by Andrew McNeill in 1992, and in the SES rock collection.
P1.A6	Tony Crawford	Fiona Best to continue study of mafic to felsic rocks comprising the huge Dido Batholith at the eastern margin of the Georgetown Block.
P1.B1	Dima Kamenetsky, Jocelyn McPhie	Taupo Volcanic Zone rhyolite project to be completed by mid-2010. Submit papers on volatiles in quartz-hosted melt inclusions in Taupo rhyolites for publication. Complete BHPB-sponsored Olympic Dam project by mid-2010; including submission of a final report. Present proposal (at final meeting of current project) for a new BHPB-funded project on the architecture of breccia facies at Olympic Dam PhD theses by Sarah Gordee, Andrea Agangi and Olga Vasyukova to be submitted. Continue work on a number of manuscripts deriving from these studies. Commence new pilot study on Chon Aike SLIP samples from Argentina, with collaborator Marcelo Marquez (Universidad Nacional de la Patagonia). This work will be compared with data deriving from ongoing work on Gawler SLIP rhyolites.
P1.B2	Leonid Danyushevsky	Project will conclude mid-2010, and a follow-up project proposal will be presented to the same sponsor groups. Several papers will be prepared for publication.
P1.B3A	Dima Kamenetsky	P1B3A and P1B3B are part of P1B3. The aim is to bring each of these sub-projects to completion with a paper on each in an A* journal. Project completed at the end of 2009. A new, non-core ARC Discovery Project DP1092823 Kimberlites and flood basalts: Linking primary melts with mantle and crustal sources, to commence in 2010. A second new project, The distribution of volatile and metallic elements in oceanic glasses and melt inclusions: Implications for fractional crystallisation and degassing during seafloor basaltic magmatism has been proposed for CODES funding, and will focus initially on Macquarie Island glasses.
P1.B3B	Paul Davidson	Continue work on melt-melt immiscibility in several key suites of mafic rocks (from Iran, China and USA).

PROGRAM 2

PROJECT	TEAM LEADER(S)	ACTIVITY PLAN
P2.A1	Jamie Wilkinson	Identify possible new sample suites for analysis, including McArthur Basin samples archived at CODES. Sample drillcore representing sedimentary source rocks from McArthur Basin. Prepare samples for geochemical and isotopic analysis and mineral separation (at Imperial College London). SEM backscatter imaging and SEM-MLA analysis, including development of EDS library for improved mineral identification, and microprobe analysis. LA-ICPMS analysis of individual mineral grains and mapping. PIXE element mapping and analysis of selected samples. Whole rock geochemical analysis (at Imperial College London). Transition metal isotope analysis of partial extractions and whole rocks, plus mineral separates (at Imperial College London). Review literature and prepare paper.
P2.A2	David Cooke, Stephen Cox	Complete a 3D analysis of the orientations, distributions and overprinting relationships of veins and their associated alteration halos. Emphasis will be placed on using microstructures and isotopic compositions of stage 2 veins to characterise the episodic flow regime and explore the implications of episodic flow and associated fluid pressure fluctuations for mineralisation processes. Use the 3D analysis to explore how evolving fluid pressure states and the orientations and magnitudes of stresses have influenced the styles of mineralisation, the development of fluid pathways, and the distribution of ore grades in the North Parkes Cu-Au system. Use microstructural studies (optical, cathodoluminescence and SEM) to resolve the processes controlling contrasting vein styles and hence the pervasiveness of fracturing and flow in hydrothermal systems – specifically at Porgera and North Parkes. P2.A2A Complete a 3D analysis of the orientations, distributions and overprinting relationships of veins and their associated alteration halos. Emphasis will be placed on using microstructures and isotopic compositions of stage 2 veins to characterise the episodic flow regime and explore the implications of episodic flow and associated fluid pressure fluctuations for mineralisation processes. Use the 3D analysis to explore how evolving fluid pressure states and the orientations and magnitudes of stresses have influenced the styles of mineralisation, the development of fluid pathways, and the distribution of ore grades in the North Parkes Cu-Au system. Use microstructural studies (optical, cathodoluminescence and SEM) to resolve the processes controlling contrasting vein styles and hence the pervasiveness of fracturing and flow in hydrothermal systems – specifically at Porgera and North Parkes. P2.A2B Preparation of new synthetic fluid inclusions containing gold at Imperial College, and analysis at CODES using LA-ICP-MS, varying acquisition parameters to optimise quantification. Additional analysis of synthetic fluid inclusions using PIXE and assess inclusion geometric correction for gold quantification. Analysis of selected natural inclusions from copper-gold porphyry ore systems, including Boyongan and Bajo de la Alumbrera (+Ladolam?). Synthesis of results and paper preparation. Presentation of results at an international conference.. P2.A2C Review of relevant literature and compilation of model parameters. Preparation of modelling sections, including meshing of sections. Complete first modelling phase; review initial results and revise approach as required. Complete second modelling phase. Preparation of manuscript, and powerpoint animations for conference presentation.
P2.A3	Zhaoshan Chang	P2.A3A Write and submit a manuscript. P2.A3B Attract a PhD student to undertake a systematic study of selected magmatic-hydrothermal systems in western Tasmania. P2.A3C Constrain the spatial and timing relationship between UST quartz internal textures and Au grain trails. Investigate metals coexisting with Au and assess likely Au transportation and deposition mechanisms. Synthesize data and either report results at a meeting or write a manuscript.

P2.B1	David Cooke, Bruce Gemmell, Anthony Harris	P2.B1A Appoint an additional research fellow (full-time) and at least one higher degree research student (PhD working on Au in the Wafi porphyry-epithermal district). Undertake field-based research and training at Newcrest sites in PNG and Fiji. Commence microanalysis of field samples. Construct the first of several field manuals. Compile literature review and present results to Newcrest. Undertake a field-based study tour of porphyry ore deposits of the SW Pacific. P2.B1B Lejun Zhang to arrive at CODES in Feb to initiate major analytical program on Luzong basin, including an investigation of S isotope compositional variations in pyrite grains. Refine the understanding on the evolution of S isotope signatures and its relationship with Au. Synthesize the data and report results at a meeting or write a manuscript. Taofa Zhou and Yu Fan to attend the IAGOD conference in April and CODES in September. P2.B1C Complete zircon dating of 20 samples from the Gangdese belt and publish results in Geology or another A* journal. P2.B1D PhD theses to be submitted by Heidi Pass, Adam Bath and Jacqueline Blackwell from CODES, and Janina Micko from MDRU. Publication of alkalic special issue for *Economic Geology* (edited by Bissig and Cooke).
P2.B2	Stuart Bull	Submit the second manuscript on Central African Copperbelt for publication. This updated version now includes the DRC.
P2.B3	Bruce Gemmell, Mike Solomon	P2.B3A Following the death of Mike Solomon, this researrch is continuing under John Walshe at CSIRO. P2.B3B Continue dating of Mount Read Volcanic belt lithologies in collaboration with Jim Mortensen (UBC). Continue investigating VHMS deposits at Jaguar, Doolgunna, Que-Hellyer Volcanics area, Yaman-Kasy (Russia), Baiyinchang (China) Tasik Chini (Malaysia) and Chahgaz, Iran. P2.B3C Continue research on the CAMIRO project. P2.B3D Continue LA-ICPMS and LA-sulphur studies on PACMANUS, Palinuro and Panerea samples. Continue PhD research on Brothers Volcano chimney samples.
P2.B4	Garry Davidson	Nico Mine: Collaborate with CSIRO to evaluate electrochemical effects on element enrichment in cobalt-gold-rich ores. Prominent Hill: Complete write-up of the PH dating paper. Iran: Plan follow-up work on the fluid composition of fluid inclusions in the magnetite-apatite system, dependent on completion of Zahra Bonyadi's PhD studies.

PROGRAM 3

PROJECT	TEAM LEADER(S)	ACTIVITY PLAN
P3A1A	Jeff Foster, Mike Roach	Finalise measurement and standardisation protocols. Perform full petrophysical measurements on a suite of materials from significant Australian ore bodies.
P3A1C	Peter Fullagar (Fullagar Geophysics)	Finalise sponsors for AMIRA P1022 and commence constrained inversion site studies. Active research to focus on conductivity gradients.
P3A2A	Anya Reading	Complete processing and analysis of data from the ASET pilot deployment
P3B1A	David Cooke, Bruce Gemmell, Zhaoshan Chang	Sixth sponsors meeting report – 13 May. Four quarterly reports – Feb, May, August, November. Sponsors update meeting report, Chile. Sponsors update meeting report, Philippines – late May. AMIRA P765B project proposal – August. Final sponsors meeting – 8–9 December.
P3B1C	David Cooke, Bruce Gemmell	Completion of Bronto Sutopo's PhD thesis. Completion of Corrie Chamberlain's Master of Economic Geology thesis. Completion of Hugo Galvan's PhD thesis. Continuation of Gosowong and Kencana projects. More fieldwork and research meetings with Newcrest. Continuation of Mathieu Ageneau's PhD study of Lihir, including a second field season (May 2010). Submit hydrothermal alteration associated with epithermal Au-Ag deposits and Kencana discovery papers for publication.
P3B2A	Ross Large, Stuart Bull, Valeriy Maslennikov	Commence AMIRA Project P923A with three case study sites (Newmont, Newcrest, AngloGold). Complete and write-up pyrite gold study of the Otago goldfield. Complete and write-up pyrite gold sulphur isotope study at Bendigo. Undertake LA-ICPMS research on samples collected from Kumtor Mine.
P3B2B	David Selley, Stuart Bull, Murray Hitzman	Complete final summary report for AMIRA P872. Develop new or continuation project that builds on the outcomes of P872 and focuses on a whole basin approach to fluid flow and metals zonation in an economic context. Circulate a formal proposal to potential industry sponsors in the first quarter. A total operating budget of ~$1.5M is estimated for the 3-year life of the project, approximately 2/3 of which will be sought via industry sponsorship, and the remainder via government sponsorship.
P3B3A	Andrew McNeill, Bruce Gemmell	Complete assessment of geochemical data in a spatial context and finalise reporting.
P3B5A	Jeff Foster	Complete sampling and finalise geology and lithgeochemistry database. Develop and confirm proxies for PGE distribution and mineralogical association. Develop 3D model for the Tweefontein Hill deposit.
P3B5B	Jeff Foster	Finalise LA-ICPMS mapping of Noril'sk sulphide globules and massive ores. Initiate LA-ICPMS program for selected magmatic sulphide-bearing samples from Jinchuan and Pechenga.
P3B5C	Jeff Foster	Perform systematic observations and sampling on controlled drill sections and outcrop. Continue to build the observation and lithogeochemistry database. Complete microprobe and S isotope analyses. Initiate LA-ICPMS mapping of sulphides. Sample and analyse a suite of weakly mineralized and barren ultramafic rocks.

PROGRAM 4

PROJECT	TEAM LEADER(S)	ACTIVITY PLAN
P4.L1	Steve Walters	Maintain progress of overall research project against plan. Develop case study validation programs and funding to supplement core research. Prepare P843 outcomes for a potential thematic issue of *Economic Geology*. Coordinate relationships with planned new COREx CRC due for a mid 2010 start-up.
P4.L1.1	Mansour Edraki	Develop new tools for texture-based acid base accounting. Assessment of new tests for predicting dust generation. Undertake a scoping program for trace element speciation and deportment.
P4.L1.2	Simon Michaux, Italo Onederra	Completion of Luke Keeney's and Adel Vatandoost's PhD theses. Integration of rock properties into new blasting models. Assessment of small-scale testing devices as bulk strength indicators. Develop software for more automated core-scale logging of rock mass discontinuities.
P4.L1.3	Louisa Groves, Toni Kojovic	Develop improvements of current GeM Comminution Index testing. Demonstrate use of non-core drilling products for routine comminution testing. Undertake a comminution blend response testing program initially for Bond Mill Work index.
P4.L1.4	Dee Bradshaw	Completion of Natalee Bonnici's and Cathy Evans PhD theses. Development of small scale physical testing device to deliver a mineral separability index. Integrate and evaluate GeM software tools for advanced textural analysis. Apply outcomes to delivering a methodology to track and predict textural convergence and liberation across particle size.
P4.L1.5	Dave Robinson, Matthew Jeffrey	Develop a suite of small scales test to predict rheology, agglomeration, and leaching performance for a range of ore types. Design software for texture-based leaching simulation. Investigate blasting as pre-conditioning for more effective leaching outcomes.
P4.L1.6	Ron Berry	Support other programs with analytical and software capabilities. Develop specification for integrated core imaging hardware and analytical software. Continue development of specialised software to support multivariate visualisation and data analysis. Provide support for geostatistical modelling.

PROGRAM 5

PROJECT	TEAM LEADER(S)	ACTIVITY PLAN
P5A1	Sebastien Meffre, Leonid Danyushevsky	Test the performance of the new Agilent 7700 mass-spectrometer when coupled to the new excimer Resolution M50 laser probe. Assess possible applications of the mass-spectrometer collision cell technology for laser ablation ICPMS aimed at increasing detection limits for a range of light elements and PGE. Assess the performance of different materials used in the interface between the laser and the mass-spectrometer. Continue improvements to the gas flow configuration of the excimer Resolution M50 laserprobe.

P5A2	Marcel Guillong, Leonid Danyushevsky	Investigate fluid inclusion in zircons from porphyry deposits. Improve inclusion analysis and data reduction. Investigate partition coefficients for metals, between fluids and framboidal pyrite. Push the limit of detection of LA-ICPMS to the extreme. Continue to improve on the U-Pb isotopic analysis. A comparative study of sulphide PGE standards. Assess the feasibility of S isotope measurements by LA-Q-ICPMS.
P5A3	Bence Paul, Janet Hergt, Chad Paton	Continue to apply in-situ Pb isotope analysis to geological problems and initiate development of the in-situ Mo isotope analysis.
P5A4	Janet Hergt, Chad Paton, Bence Paul	Develop and apply the Mo isotope system.
P5A4A	Garry Davidson, David Cooke	Finalise chemical separations method development. Complete and submit a paper on chemical separation methods. Submit paper on sulphur transfer during carbonate evolution at Mt Polley. Evaluate the CAS technique for lode gold deposits.
P5B1	Jamie Laird	Complete Charge Injection mapping on the established pyrite samples. Develop the SECM apparatus in collaboration with the University of Melbourne. Develop a better understanding of how to prepare pyrite surface for contact formation and electrochemical experiments. Artificially fabricate a pyrite trap for investigating micro-galvanic reduction of Au in solution by low-energy ion implantation - in collaboration with ANU. Improve understanding of defect structures in pyrite, using electrical techniques such as Deep Level Transient Spectroscopy (DLTS) - in collaboration with Brett Johnson.
P5B2	Jamie Laird	Investigate fluid inclusions using both hyper-spectral Ionoluminescence (IL) imaging and Rutherford Back Scattering. With the added information from both these techniques, improve algorithms for recalculating PIXE data.
P5B2A	Jamie Wilkinson	Produce a new quantification strategy for fluid inclusion analysis by PIXE. Assess the use of PIGE spectra for quantification of Na and other light elements. Fully evaluate and synthesise all results into a publication.
P5B3	Chris Ryan	*mAESTRO high P-T cell* Test and install the Be windows capable of higher pressure (~600 bar). Improve pressure and temperature control units (from semi automatic to full auto). *Maia detector* Complete the installation of Maia-384 at the XFM beamline at the Australian Synchrotron including implementation of the real-time DA image display and real-time GeoPIXE user interface. Complete real-time Maia interface for real-time imaging in GeoPIXE. Develop parallel algorithms for GeoPIXE to accelerate processing of the huge Maia datasets, which currently take up to 3 hours to process. Implement XANES point analysis and imaging into GeoPIXE package. Explore 3D fluorescence tomography as a complement to 2D SXRF mapping of complex structures (e.g. complex melt inclusions).
P5B4	Chris Ryan, Stacey Borg	*XANES imaging* Develop standard procedure for extraction and analysis of XANES spectra from high resolution XRF images. Evaluate statistical approaches to the extraction of observable chemical state component spectra in XANES image datasets. Investigate Fe, As, Cr and V redox state, using XANES from XRF images of pyrite, biotite and ilmenite samples. Facilitate access for CODES researchers to XFM and Maia for CODES applications. *EXAFS experiments* Study the speciation of Mo in hydrothermal aqueous chloride fluids. Probe the speciation of Ni in hydrothermal chloride fluids and extend the study to sulphur-rich solutions. Develop a method to probe metal speciation in ammonia solutions. Perform preliminary experiments on the role of CO2 in metal transport and deposition.
P5B4A	Anthony Harris	Use Zircon chemistry to improve the understanding of the 'hot source' involved in the formation of giant porphyry Cu deposits, and of rhenium mobility in molybdenite.
P5C1	Leonid Danyushevsky	Assess three alternative LA-ICPMS data reduction applications (CODES in-house, Iolite and Sills). Improve algorithms for analytical error calculations.
P5C2	Anya Reading, Bence Paul	Undertake image improvement in the following areas: 1. Assistance with diagnostic tests to optimise data collection. 2. Image pre-processing - removing data collection 'history' from image. 3. Image improvement trialling approaches from information theory, statistical and mathematical techniques. Work will also continue on improving the imaging capabilities of Iolite v. 2.
P5C3	Leonid Danyushevsky	Improve the algorithms for modelling of trace element behaviour during crystallisation.
P5C4	Leonid Danyushevsky, Bence Paul	Depending on the future of the CODES' ICPMS database, this project will look at the prospect of combining Iolite capabilities for data reduction with the database interface.

IMAGE DETAILS

SEQUENCE OF IMAGES ARE FROM TOP TO BOTTOM, LEFT TO RIGHT ON INDICATED PAGE

COVER

Front: Toromocho porphyry Cu-Mo and skarn deposit, Central Peru.

Back: Dee Bradshaw and Julie Hunt examining core with site geologists, Prominent Hill, Australia.

Sebastien Meffre examining a Tertiary metamorphic complex in Ailoshan, Yunnan, China.

Cretaceous granodiorite, Atacama Desert, Northern Chile.

Quartz-pyrite-tourmaline-cemented granodiorite clast breccia, Sierra Corda porphyry Cu-Mo deposit, Northern Chile.

DIRECTOR'S REPORT

Pg 5: Director, Ross Large.

Pedro Fonseca and Zhiming Yang in the core shed at the Henty mine, looking for gold in rock samples.

Dave Selley at the Savage River mine, looking at host rocks.

20TH ANNIVERSARY

Pg 6: Alan Goode, Research Director, AMIRA International.

One of the first research teams. L to R, David Huston, Richard Wedekind, Khin Zaw, Mark Rattenbury, Ross Large, Bruce Gemmell, Greg Jenkins and Garry Davidson.

Participants in the 20th anniversary symposium field trip at Mt Lyell mine.

Dave Selley in colourful attire talks with fellow delegates at the 20th anniversary symposium.

Ross Large (L) and Bruce Gemmell (R) in discussion with UTAS Vice-Chancellor, Daryl Le Grew, at the 20th anniversary symposium.

Tim Callaghan directing field trip activities at the Avebury mine.

STAFF & MANAGEMENT

Page 11: Delegates at the Science Planning Panel meeting.

Bruce Gemmell addresses the Science Planning Panel.

The CODES team of 2009 – not all team members were available.

Page 15: Gisela Cobenas working on board RV *Southern Surveyor*.

The Advisory Board.

PROGRAM ONE: LOCATION

Page 21: Sebastien Meffre examining a Tertiary metamorphic complex in Ailoshan, Yunnan, China.

Recovering deep-sea dredge samples aboard the RV *Southern Surveyor.*

RV *Southern Surveyor* birthed in Lautoka, Fiji.

Page 22: Taka Manaka (foreground) and Khin Zaw ford a creek at the Pac Lang Au deposit, Vietnam.

Page 25: Jacqueline Halpin examining an outcrop along the road from Sapa to Lao Cai, Vietnam.

Montage of images from aboard the RV *Southern Surveyor.*

Page 28: Sebastien Meffre examining a Teritiary metamorphic complex in Dali, Yunnan, China.

PROGRAM TWO: FORMATION

Page 31: Orbicular granite, Northern Chile.

Cerro Casale porphyry Cu-Au deposit, Maricunga belt, Chile.

Page 32: Zhaoshan Chang and Jamie Wilkinson investigating compositional variations in tourmaline orbicules that have accumulated in the roof zone of a tin granite - Heemskirk Granite, western Tasmania.

Page 35: Taofa Zhou, David Cooke and colleagues debating the significance of magnetite - actinolite alteration. Fe-oxide Cu-Au mineralisation - Luzong basin, China.

Bruce Gemmell sampling at Lihir gold mine, Papua New Guinea.

Cocanes lithocap and Perol porphyry Cu-Au deposit, Cajamarca, Peru.

Page 36: Montage of images from the Ore Deposits of South America short course led by David Cooke.

PROGRAM THREE: DISCOVERY

Page 39: Exploration drill rig in the snow-covered Tien Shan Mountains along strike from Kumtor, Kyrgyzstan.

Kumtor gold mining camp, Tien Shan Mountains, Kyrgyzstan.

Page 40: Top and Centre: GeoTek logging equipment operated by Ross Olsen.

Page 45: Drilling blast holes on the Platreef, South Africa.

Lennartz 3D-lite portable seismometers being used to find subsurface structures through combining waveforms (on loan from the ANSIR national research facility for Earth Sounding).

PROGRAM FOUR: RECOVERY

Page 47: Steve Walters at the Kennecott Bingham mine, Utah, USA.

Page 50: Toni Kojovic examining blast hole cuttings, Bingham Mine, Utah, USA.

The Big Nickel, Sudbury, Canada.

Aqqualuk mill, Canada.

Dee Bradshaw and Julie Hunt examining core with site geologists, Prominent Hill, Australia.

Page 52: Kennecott Bingham mine, Utah, USA.

Page 53: Prominent Hill processing mill, Australia.

Processing operations at Prominent Hill, Australia.

Steve Walters, Luke Keeney and Pat Walters with EQUOtip testing devices, Ernest Henry Mine.

PROGRAM FIVE: TECHNOLOGY

Page 56: Multiphase fluid inclusion from the Boyangan porphyry copper-gold deposit, Philippines (54 x 38 microns in size). Sample courtesy of David Braxton.

Stacey Borg and Joel Brugger set-up and test the mAESTRO cell online at the XAS beamline at the Australian Synchrotron.

Page 63: Installation of the new LA-ICPMS at CODES.

Sarah Gilbert in one of three LA-ICPMS facilities at CODES.

A multiphase fluid inclusion.

GRADUATE RESEARCH & TRAINING

Page 64: Top and bottom, left: SEG Student Chapter field trip to Indonesia.

Graduate Research Co-ordinator, Jocelyn McPhie, leading the CODES Volcanology Group field course in Cape Grim, Tasmania.

OUTREACH

Page 67: Rob Kirk (consultant) generating seismic waves during a TESEP workshop.

Bruce Gemmell presenting to retirees as part of the University of the Third Age (U3A) program.

Teachers taking part in a TESEP workshop at CODES.

A student from Herdsmans Cove Primary School is keen to ask a question during a visit to the Centre.

PUBLICATIONS

Page 84: Mike Roach leads a TESEP workshop.

Attendees at the Science Planning Panel meeting.

Page 91: Montage of images from various field trips to Indonesia, China, Chile and PNG.

Page 96: Aerial view of the processing plant at Grasberg.

PLEASE NOTE:

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