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.

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.

Contents
Director’s Report 4
Fundamental Research to Applied Outcomes 6
Staff & Management 9
Student Projects 13
Program One / Location 18
Program Two / Formation 26
Program Three / Discovery 36
Program Four / Recovery 46
Program Five / Technology 54
Graduate Research & Training 62
Outreach 64
Industry Links & Research Collaborations 66
Technology Transfer 68
Performance Indicators 70
Finances 72
2010 CODES’ Publications 78
Appendices 93
Activity Plan 2011 108
Image Details 112
The past year has seen our Centre build on its strengths, and continue to deliver successful outcomes across a broad range of areas, from fundamental and applied research, through to education, outreach, and technology transfer. It has also been a time when CoDes reached a crossroads and was presented with an opportunity to take another major step in its evolution, which I will cover later in this report.

Major research highlights included three high-profile projects coming to a successful conclusion:

- The Deposits of SE Asia ended in December, with the final meeting being held at the CODES’ UTAS Hub. The 3-year project has substantially enhanced the knowledge of the geology of the region. Outcomes include a new tectonic model for the area, based to a large extent on a new geochemical, geochronological and core deposits database developed within the project. A proposal to extend the project will be presented to the Science Planning Panel in April.
- AMiRA project P765A – Geochemical and geological halos in green rocks and ultramafics – was successfully concluded, on time and within budget, at a final meeting in Hobart during December. This has been a breakthrough project in the development of mineral chemical vectors that predict the likely direction and distance to porphyry-style mineralised centres. By using advances in LA-ICP-MS, the research team established that subtle hypogene geochemical dispersion halos can be detected several kilometres beyond the limits of geochemical anomalies that are detected by conventional rock-chip sampling techniques; thereby extending the detectable geochemical footprint of porphyry mineralised centres.
- AMiRA project P962 - Ni-PGE potential of mafic and ultramafic magmas – was finalised at a meeting in Hobart in April. Important achievements included the development of a new model of sulfur saturation in mafic magmas, which (for the first time) takes into account the effect of melt Ni content.

Our researchers also continued to break new ground in other areas, challenging long standing theories and pioneering new models for some of the world’s major ore bodies. For example, research conducted by Jeff Foster and Dave Hutchinson, making extensive use of CODES’ LA-ICP-MS facilities, has led to a new model for the formation of the Merensky Reef in South Africa’s Bushveld Complex – the world’s richest source of platinum group metals.

A statistic that stands out in this year’s report is the figure of 197 reports delivered to industry. This compares to 105 in 2009, and represents the highest total since CODES was formed over 20 years ago. The figure is high partly because a number of major projects drew to a close, but it is also indicative of increasingly strong links with industry, and our focus on technology transfer that delivers tangible outcomes.

Although this figure is pleasing, there is no doubt that this level of output has had an impact on our production of refereed journal articles, which has dropped below target. Quality journal output is increasingly important due to the ERA benchmarking program of the ARC. Therefore, we have made a firm commitment to improve our A and A* outputs to reach the higher levels that were achieved in recent years.

Staff maintained their record of regularly receiving top accolades. This year it was the turn of Research Fellow, Jacqueline Halpin, who was awarded one of only two Research Excellence Awards presented to Early-Career Researchers. We have also continued to attract top geoscientists to add to our pool of world-class researchers. Late in the year, we were successful in securing the services of renowned environmental geochemist, Bernd Luttermerzer, who has joined the team on the Recovery Program. This is a key appointment in helping us achieve our objective of building on our research activities in the field of environmental geosciences. Bernd is employed under the UTAS New Stars Program and will commence duties in January 2011.

Over the past two years, we have been very fortunate to have Jamie and Clara Wilkinson from ‘Imperial College London on the CODES’ team. They have contributed in a number of areas, particularly the AMiRA porphyry project P765A. We plan for this collaboration to continue to bear fruit into the future.

It was an exceptional year for our graduate research activities with 15 PhD students having theirses under examination, nine of whom graduated. Fifty-four students were enrolled on the HDR program, which included 37 international students representing 18 nationalities. Fourteen of these students were at least partly funded by CODES’ scholarships. The Centre has built a strong reputation for attracting international students, but it was pleasing to note that of the seven new students in this year’s cohort three were from Australia, the first in a number of years to be recruited nationally.

The Master of Economic Geology Program, co-ordinated by Tony Webster, also continued to go from strength to strength. For the first time, the number of students topped the 50 mark, a figure that represents over 60% of enrolments on the national program. Three major short courses were held during the year and all were full to capacity.

Our outreach activities continued to grow and included a mix of activities across a broad range of demographic groups, from pre-schoolers through to retirees. Teachers, and particularly career advisors, were also important target groups. A highlight was the introduction of the ‘Geminarium’, which is a large bed of brightly polished rocks from around the world. This new feature is particularly popular with the younger age groups, who love fossicking through the colourful stones. The rocks are also mounted on display boards and used in a variety of educational tools that teach the children about geology while they are having fun.

It has been a mixed year in terms of finance. There was a significant dip in industry funding, but there were a number of mitigating factors, which are covered in detail in the financial section of this report. Many of these factors will fall away in the future; therefore, the forecast is more promising in the longer term. On a positive note, we were pleased to announce that MMG has joined our list of Industry Partners, which now consist of ten major mining companies.

Overall, it has been a good year that has resulted in success in a wide range of areas; but it has also been a year that I believe will prove pivotal for our continued growth and evolution. Although CODES has secured an extension of its Centre of Excellence funding until 2013, there is no provision under current ARC rules for a further extension beyond that date. Therefore, management decided that it was important to start planning for our future beyond 2013. That process included meetings with all our key stakeholders, including our Advisory Board, the ARC, industry, and collaborating institutions. As a result of these consultations, it was decided that CODES would start an application process for becoming a CRC.

This is seen as a natural progression for the Centre, which started out as a Key Centre in 1989, became a Special Research Centre in 1997, and progressed to its current status as Centre of Excellence in 2005. Although CODES can still pride itself on its success in merging fundamental and applied research, there is no doubt that our links with industry, which have always been strong, have increased even further over the years. For example, the ratio of industry funding has continued to grow, and has been our largest source of income for the past few years. Not surprisingly, there has been a corresponding increase in the number of industry-related projects over the same period. The large increase in industry reports that I mentioned earlier bears testament to that trend, which has also led to research outcomes that are in high demand by industry, and provided us with the opportunity to become more involved in the commercialisation of our research.

As a CRC adopts a more commercial, industry-focused model, I believe (along with the majority of our stakeholders) that this application is a logical step in our development. Therefore, I ask everyone associated with CODES to embrace the opportunities that this presents and look forward, as I do, to the next chapter in our story.
In Brief /
CODES is the Australian Research Council Centre of Excellence in Ore Deposits, based at the University of Tasmania. Formed in 1989, the Centre has grown substantially over the years and is now widely regarded as a global leader in ore deposit research. In 2010, it was home to 64 highly qualified research staff and 116 postgraduate students, further cementing its position as 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 – 19 in Australia and 60 overseas. It currently has 51 major research projects spanning 28 countries, and is the leading academic group to publish in Economic Geology. In 2010, its reports to industry almost doubled to reach a total of 197, helping to strengthen the Centre’s reputation for delivering excellence in terms of technology transfer.

2010 Key Statistics /
- 64 Academic research staff
- 116 Postgraduate students
- 51 Major research projects
- 40 Publications in journals
- 197 Research reports to industry
- 28 Countries involved
- Industry funding $3.4 million
- ARC funding $3.1 million
- UTAS funding $2.1 million
- Worldwide collaborations:
  - 70 Industry (approximately)
  - 79 Institutes and universities

Framework for Leading Research /
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 (ICP-MS), 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 are 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, Nodes and International Partners / 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, and CSIRO Exploration and Mining. 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 two strong partnerships with the University of British Columbia and the Colorado School of Mines, which provide an ideal platform for international research projects and augment the Centre’s access to the latest technology. Collaborations with these two international partners include:

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

In addition to these international partnerships, CODES collaborates with 79 universities and institutes, plus approximately 70 industry companies worldwide.

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, Graduate Research Co-ordinator 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 2010 Ian Little was appointed as Research Technician in the ICP-MS laboratory, where his main role is the preparation and analysis of geological digests.

Janina Micko has joined the team on the Formation program, after completing her PhD at UBC (MDRU) earlier in the year. Janina is working on a collaborative project with Newcrest Mining entitled: exploring the porphyry environment.

Ralf Schaa completed his PhD at UTAS (CODES) in 2010, and was appointed as a Research Fellow to continue his work in the Discovery Program on project P3A1C (AMRA P1002) - Rapid approximate inversion of TEM data.

Andy Wakefield has been appointed to the position of Geophysics Technician, responsible for field assistance and the maintenance of geophysics equipment. In collaboration with ANU, Andy will be involved in the set-up and deployment of a passive seismic recording network throughout northern Tasmania, Bass Strait and southern Victoria.
## CODES Staff

**Deputy Director, Professor I. Bruce Gammel, BSc (Sydney), MA, PhD (Darmouth)**  
WHMS deposits and epithermal Au-Ag.

<table>
<thead>
<tr>
<th>Title</th>
<th>Name</th>
<th>Affiliation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Director, Professor Ross Large, BSc Hons (UTAS), PhD (UNE)</td>
<td>Dr. Mike Baker, BSc Hons (Sydney), PhD (UTAS)</td>
<td>Volcanic facies analysis</td>
</tr>
<tr>
<td>Associate Professor Ron Barry, BSc, PhD (Flinders)</td>
<td>Dr. Stuart Bell, BSc, Hons (Monash)</td>
<td>Genetic and carbonatite sedimentology and volcanology</td>
</tr>
<tr>
<td>Associate Professor Isabelle Chambefort, MSc (Grenoble), PhD (Sydney)</td>
<td>Dr. Isabelle Cambefort, MSc (Grenoble), PhD (Sydney)</td>
<td>Petrology</td>
</tr>
<tr>
<td>Associate Professor Dr. Marcel Guillong, PhD (ETH Zurich)</td>
<td>Dr. Desiree Bouilliez, BSc Hons (Sydney)</td>
<td>Structural and Crustal Geophysics and Metamorphic Petrology</td>
</tr>
<tr>
<td>Associate Professor Dr. David Cockey, BSc Hons (Cambridge), MA, PhD (Darmouth)</td>
<td>Dr. Bruce Gemmell, BSc (UBC), MA, PhD (UTAS)</td>
<td>Marine Geoscience, Petrology</td>
</tr>
<tr>
<td>Associate Professor Dr. David Jacobs, MSc (Glasgow), PhD (UTAS)</td>
<td>Dr. David Jacobs, MSc (Glasgow), PhD (UTAS)</td>
<td>Sedimentary Petrology and Geochemistry</td>
</tr>
<tr>
<td>Associate Professor Dr. Scott Armitage, BSc Hons (Sydney)</td>
<td>Dr. Scott Armitage, BSc Hons (Sydney)</td>
<td>Sedimentary Petrology and Geochemistry</td>
</tr>
<tr>
<td>Associate Professor Dr. Travis Falconer, BSc Hons (Canterbury), BA (Sydney)</td>
<td>Dr. Travis Falconer, BSc Hons (Canterbury), BA (Sydney)</td>
<td>Sedimentary Petrology and Geochemistry</td>
</tr>
<tr>
<td>Associate Professor Dr. Gérard Pons, MSc (Montpellier), PhD (Bordeaux)</td>
<td>Dr. Gérard Pons, MSc (Montpellier), PhD (Bordeaux)</td>
<td>Sedimentary Petrology and Geochemistry</td>
</tr>
<tr>
<td>Associate Professor Dr. Peter Tropper, BSc Hons (Sydney)</td>
<td>Dr. Peter Tropper, BSc Hons (Sydney)</td>
<td>Sedimentary Petrology and Geochemistry</td>
</tr>
</tbody>
</table>

### ACADEMIC/RESEARCH STAFF AT UTAS

**Dr. Mayra Kamenetska, PhD (UTAS)**  
MLA-SEM, geochemistry, petrology

**Dr. Yadvinder Kamenetsky, PhD (Monash)**  
Geochemistry of major and minor elements

**Dr. Associate Professor Dr. Maxime Patrice, BSc Hons (Monash)**  
Geochemistry of minor elements

**Dr. Dr. Sebastian Meffre, BSc Hons (Sydney)**  
Volumetric facies architecture and volcanic textures

**Dr. Associate Professor Dr. Steve Mole, BSc Hons (Leeds)**  
Structural geology

**Dr. Associate Professor Dr. Janeta Miles, MSc (Birmingham), PhD (Leeds)**  
Geology and genesis of hydrothermal ore deposits

**Dr. Associate Professor Dr. Ken O’Toole, BSc Hons (Monash), PhD (UTAS)**  
Volcanology

**Dr. Dr. Andy Reading, BSc Hons (Edinburgh), PhD (Leeds)**  
Geophysics, seismology, computational methods

**Dr. Associate Professor Dr. Michael Rich, BSc Hons (Newcastle, PhD (UTAS)**  
Geophysical responses of ore deposits

**Dr. Associate Professor Dr. Rob Scott, BSc Hons, PhD (Monash)**  
Structural geology, gold deposits

**Dr. Associate Professor Dr. David Selley, BSc Hons (Adelaide, PhD (UTAS)**  
Structural geology, basin analysis, sedimentary Cu

**Dr. Associate Professor Dr. Helen Thomas, MSc (Leicester), PhD (Manchester)**  
Geochemistry, geochronology

**Dr. Associate Professor Dr. Associate Professor Steve Walters, BSc Hons, PhD (Sheffield)**  
Geochemistry, applied mineralogy, exploration technologies

**Dr. Associate Professor Dr. Tony Wood, BSc Hons (Exeter, BA (Sydney), MSc (LCU), PhD (UTAS)**  
MTEC Senior Lecturer and Manager Program Coordinator

**Dr. Associate Professor Dr. James Williams, BSc Hons (Cardiff)**  
Ni-Fe-PGE mineralisation

**Dr. Associate Professor Dr. Emily Johnson, BSc (Michigan), PhD (Oregon)**  
Petrology, physical volcanology

### ACADEMIC/RESEARCH STAFF BASED AT COLLABORATIVE INSTITUTIONS

**Dr. Steve Calladine**  
Communications Manager

**Mrs. Michelle Chapple-Smith**  
Lapidary Technician

**Mr. Peter Corriss**  
Laboratory Manager

**Mr. Alex Cusson**  
Lapidary Technician

**Ms. Grace Cumming**  
Research Assistant

**Ms. Sarah Gillett, BSc Hons (UTAS)**  
Senior Technician (IO-MS)

**Ms. Christine Higgins, GradCert Management (UTAS)**  
Finance Manager

**Ms. Nina Hlávčíková, BSc (Rangon)**  
Personal Assistant to the Director

**Ms. Shauna Inghs**  
Research Technician

**Dr. Stanney Bird**  
CSIRO Exploration & Mining

**Professor Dee Bradshaw**  
JUMP, Queensland University

**Professor Alan Bye**  
WH Bryan Mining Geology Research Centre, University of Queensland

**Professor Stephen Cox**  
Node Leader, Australian National University

**Professor Grant Gearen**  
TUFTS

**Dr. Louise Groves**  
JUMP, Queensland University

**Dr. Angela Hallpenny**  
Australian National University

**Associate Professor Jeff Hedinquist**  
Colorado School of Mines

**Associate Professor Janet Hergt**  
Node Leader, University of Melbourne

**Professor Murray Hitzman**  
JUMP, Queensland University

**Dr. Luke Kenny**  
JUMP, Queensland University

### TECHNICAL/ADMINISTRATIVE STAFF

**Mr. Chris Allen**  
Geophysics Laboratory Technician

**Dr. Kate Bromfield**  
Research Assistant

**Mr. Steve Calladine**  
Communications Manager

**Mrs. Michelle Chapple-Smith**  
Lapidary Technician

**Mr. Peter Corriss**  
Laboratory Manager

**Mr. Alex Cusson**  
Lapidary Technician

**Ms. Grace Cumming**  
Research Assistant

**Ms. Sarah Gillett, BSc Hons (UTAS)**  
Senior Technician (IO-MS)

**Ms. Christine Higgins, GradCert Management (UTAS)**  
Finance Manager

**Ms. Nina Hlávčíková, BSc (Rangon)**  
Personal Assistant to the Director

**Ms. Shauna Inghs**  
Research Technician

**Dr. Roman Leslie**  
Research Assistant

**Mr. Ian Little**  
Lab Technician

**Mrs. Katie McGoldrick**  
Lab Technician

**Mrs. Karen Molfresh**  
Finance Officer

**Ms. Caroline Moedant, BA Hons (King’s College London)**  
Administrative Assistant

**Mr. Ross Allen**  
Geophysics Laboratory Technician

**Ms. Jane Pongratz**  
Publications and Media Resource Centre Manager

**Mr. Phil Rodriques, BSc Hons (Nottingham)**  
Analytical Services Manager

**Mrs. Helen Scott, BSc Hons (UTAS)**  
Biologist (CF)

**Ms. Isabella von Lichtan, BSc (UTAS)**  
Curator MTEC Administrative Assistant

**Mr. Andy Wakefield**  
Geophysics Technician
**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. **Belford, Susan, WA**
   Genetic and chemical characterisation of the Archaean Jaguar VHMS deposit.

3. **Best, Fiona, QLD**
   The petrogenesis of the Dido tonalite, northern Queensland.

4. **Braniff, Victoria, TAS**
   The structure and deformational history of the Savage River magnetite ore bodies, NW Tasmania.

5. **Cuison, Ana Liza, NSW**
   Geology and genesis of the Ridgeway porphyry Au-Cu deposit, NSW.

6. **Donaldson, Paul, TAS (Hons)**
   Facies architecture and radar stratigraphy of the Seven Mile Spit, Tasmania.

7. **Ferguson, Paul, TAS (Masters)**
   Origins of large negative anomalies in oceanic crust, Macquarie Island.

8. **Fox, Nathan, NSW**
   Controls on alteration and mineralisation in the Cadia East Au-Cu porphyry copper deposit, NSW.

9. **Gregory, Daniel, WA**
   Pyrite Black Shales: a source of gold for orogenic gold deposits, St Ives district, W. Kambalda, WA.

10. **Guillims, Josh, QLD**
    Early Mississippian microbial vent communities from the Century deposit, NW Queensland.

11. **Hey, Ben, TAS (Hons)**
    A geophysical reconnaissance of archaeological sites on Maria Island, Tasmania.

12. **Jervis-Bardy, Nicholas, WA (Hons)**
    Geophysical investigation of Enaabbba geothermal prospect, WA.

13. **Johns, Hamish, NT (Hons)**
    Characterisation of the Northern Star uranium mineralisation, Northern Territory, with special emphasis on IOCG relationships.
   Integrated geometallurgical modelling of the Cadia East deposit.

15. Knight, Kyen. TAS (Hons)
   Geophysical characterisation of Rosebery ore body and host environment.

16. Kor, Ting. QLD (Hons)
   Hydrothermal breccias at the Coalstoun porphyry: Cu-Au-Mo deposit, SE Queensland.

17. Kyne, Ruxin. NSW
   Structural controls on mineralisation, including sulfide mineralogy, at the CSA mine, Cobar NSW.

18. Lygin, Alexey. TAS
   The geology, geochemistry and genesis of the Avebury Ni deposit, Tasmania.

19. Mackay, Wallace. SA
   Sedimentology and structure of the Curdimurka Subgroup, Willouran Range, South Australia.

20. Macklin, Daniel. WA (Hons)
   Alteration at the Teutonic Bore (THMS) deposit Western Australia.

21. Maier, Rodney. NT
   Pyrite trace element halos to northern Australian SEDEX deposits.

22. Pereira da Fonseca, Pedro. TAS
   Strato-tectonic setting of massive sulfide deposits. Mount Read Volcanics (western Tasmania) and the Iberian Pyrite Belt (Portugal).

23. Sargent, Brendan. TAS (Hons)
   Geophysical characterisation of the Roaring 41 South Prospect, Balfour.

24. Staubmann, Markus. WA (Hons)
   The petrogenesis and economic potential of the Southern Cavenagh Range Intrusion (west Musgraves), Western Australia.

25. Stubley, Tim. TAS (Hons)
   The structure and stratigraphy of the Ironbound Group, Southwest Tasmania.

26. Tomlin, Michael. TAS (Hons)
   Optimised gravity survey design.

27. Webb, Katherine. VIC (Hons)
   The Boorahman intrusive complex, Victoria - geology, geochemistry, geochronology.

28. Whifflet, Allison. TAS (Hons)
   Sedimentology and denitrification geochronology of the Permo-Triassic transition in the northern Tasman Peninsula, Tasmania.

29. Wu, Selina. TAS
   Volcanic hosted massive sulfide deposits of the Que-Hellyer Volcanics, western Tasmania.

30. Zulkowski, Wojciech. NSW
   Geology and mineralisation of the Endeavour 41 gold deposit, Cowal District, NSW.

Lab-Based Projects – Single or Multi-Sites /

Bonnci, Natalee
The mineralogical and textual characteristics of Cu-Au deposits related to mineral processing attributes.

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

Chauhan, Mitesh [JKMRC]
Application of small-scale flotation testing.

Cracknell, Matthew
Innovative data inference from spatial datasets in earth science.

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

Gilbert, Sarah
Development of analytical methods and standard reference materials for determination of trace element concentrations and isotopic ratios in sulfur-rich minerals and silicate glasses.

Hoschie, Terence [Masters]
Geophysical signatures of gold-copper porphyry systems.

Leigh, George [JKMRC]
Multi-resolution image analysis for process mineralogy.

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

Palen, Siddarth [UMelb]
Spatial systematics of copper isotope fractionation in the Rainbow hydrothermal vent field, 36°14’N, Mid-Atlantic Ridge.

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

Parra Galvez, Hector Ivan [BRC]
Quantifying the impact of blast-induced fragment conditioning on leaching performance.

Pieterson, Kevin [JKMRC]
Geological and geometallurgical texture discrimination.

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 Kohneshahv, Adel
Automated petrophysical characterisation of drill core as a link to mineral processing attributes.
Outside Australia /

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

1. Ageneau, Mathieu. PAPUA NEW GUINEA
   Geology of the Kapit ore zone and comparative geochemistry with the Minife and Lennett ore zones, Liddell gold deposit, Lithi Island, Papua New Guinea.

2. Basori, Mohd Basil Iswadi Bin. MALAYSIA
   Geology of volcanic-hosted massive sulphide (VHMS) deposits in Central Belt, Peninsular Malaysia.

3. Barth, Adam. CANADA
   The geochemistry of melt inclusions and mineral phases from the Mount Polley and Lorraine (Canada) alkaline Cu-Au porphyry deposits: implications for the formation of ore deposits.

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, Gossowong goldfield, Halmahera Island, Indonesia.

6. Brown, Emma. NEW ZEALAND (Hons)
   Pumice vesicles of the 15.8ka Rotorua eruptive episode, new Zealand: implications for eruptive dynamics and conduit processes.

7. Clark, Lindsey. INDONESIA
   The geology and genesis of the Kencana epithermal Au-Ag deposit, Central Belt, Java, Indonesia.

8. Cobenas Benites, Gisela. NEW ZEALAND (Hons)
   Characteristics and origins of breccias in an alkalic epithermal gold deposit, Gossowong goldfield, Halmahera Island, Indonesia.

9. Croaker, Mawson. ZAMBIA
   Geology and genesis of the Nikana copper deposit, Zambia.

10. Cromie, Paul. LAOS PDR
    Geological setting, geochemistry and genesis of the Sepon copper deposit, Sepon District, Laos.

11. Dinh, Quang Sang. VIETNAM
    Geochemistry and field relationships of the V在上海 Cu-Au porphyry system, the Huong LienCu-Au skarn deposit, Ha Giang, Vietnam.

12. Galvan Gutierrez, Victor Hugo. MEXICO
    Geochronology and geological evolution of the northern margin of the Kontum massif, central Vietnam.

13. Gonder, Sarah. GREECE, JAPAN
    Characteristics of submarine volcanic facies in oceanic arc depocentres.

14. Guan, JianXiang. CHINA, USA
    Origin of associated magnetite and sulfide mineralisation in large gabbroic intrusions. A LA-ICP-MS study of minerals and melt inclusions from the Paozhihua and Taihe intrusions in Emshou LP and Duluth Complex.

15. Ireland, Timothy. CHILE
    Geological framework of porphyry and epithermal mineralisation in the Collahuasi district, Tarapacá, Chile.

16. Jansen, Nicholas. MEXICO
    Geology and geochemistry of the Ixtlihuatl-Ixtocap, and its relationship to porphyry and epithermal mineralisation.

17. Jones, Benjamin. PERU
    Tectonic setting and magmatic evolution of the Antapaccay porphyry copper-gold deposit, Peru.

18. Justizler, Martin. NEW ZEALAND, JAPAN, USA
    Behaviour of submerged eruption plumes: using data from facies analysis of a variety of submarine pyroclastic successions.

19. Kamvong, Teera. THAILAND, LAOS PDR
    Geology and genesis of porphyry-skarn Cu-Au deposits at the northern Loei Fold Belt, Northeast Thailand and Laos.

20. Lai, Chun Kit. CHINA
    Tectonics and metallogeny of ophiolites and volcanics in southwestern Yunnan, China.

21. Manaka, Takayuki. VIETNAM
    Geology and mineralisation characteristics of the Phuc Son goldfields, central Vietnam.

22. McGee, Brendan. ALGERIA
    The geology and mineralisation of the Talha Hamza Pb-Zn deposit, Algeria.

23. Mickov, Janina. CANADA (MCRU)
    The geology and mineralisation of the Central Zone alkali copper-gold deposit, Galore Creek district, northwestern British Columbia, Canada.

24. Moye Jr, Robert Josephus. USA
    Genesis and chemical and kinematic evolution of the late Proterozoic Ridgeview gold deposit in the Carolina Terrane of the central South Carolina piedmont, USA.

25. Pass, Heidi. CANADA
    Breccia-hosted chemical and mineralogical zonation patterns of the Northeast Zone, Mt. Polley Cu-Au-Ag alkaline porphyry deposit, British Columbia, Canada.

26. Pereira da Fonseca, Pedro. PORTUGAL
    Strato-tectonic setting of massive sulfide deposits. Mount Read Volcanics (western Tasmania) and the Iberian Pyrite Belt (Portugal).

27. Rinne, Marc. PAPUA NEW GUINEA
    Characteristics and relationships of the contrasting Vat-golgo Cu-Au porphyry-epithermal system, Papua New Guinea.

28. Salam, Abhisit. THAILAND
    Geology and genesis of the Chatree deposits, Phetchabun Province, central Thailand.

29. Steadman, Jeffrey. USA, CANADA
    The source of Au in banded iron formation (BIF) - hosted gold deposits.

30. Sutopo, Bronto. INDONESIA
    The Martabu Au-Ag high-sulfidation epithermal mineralisation in the Tapakul Selatan District, North Sumatra Province, Indonesia: Implications for ore genesis and exploration.

31. Tetereva, Sofia. SW PACIFIC
    Petrology and geochemistry of adakites and related rocks from the Hunter Ridge, Southwest Pacific.
Objective /
To better understand the links between tectonic setting, magmatism, basin evolution and ore deposit formation in modern and ancient settings.

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.

Highlights /
- Successful completion of Project P1A4: Ore Deposits of SE Asia, including meetings in Chiang Mai (Thailand) and Hobart.
- Successful completion of the Olympic Dam P1B1 project, which was being conducted in collaboration with BHP Billiton. A follow-up project has commenced.
- Research outcomes in P1B1 led to the first public presentations of a challenging new model for the Olympic Dam Cu-Au-U-REE deposit – one of the world's largest ore deposits.
- Successful completion of project P1B2 (AMiRA project P962): Ni-PGE potential of mafic and ultramafic magmas – a combined melt inclusions and numerical modelling approach.
- Jacqui Halpin awarded one of only two UTAS Research Excellence Awards presented to Early Career Researchers.
HANU UNIVERSITY OF GEOLOGY AND MINING, VIETNAM – Hai Thanh Tran
FM-GEOSAR, GERMANY – Jirin Freudent
IMPERIAL COLLEGE LONDON – Andrew Berry
INSTITUTE FOR FRONTIER RESEARCH ON EARTH EVOLUTION, JAPAN – Yoshikazu Tamura
INSTITUTE OF EARTH SCIENCES-ACADEMIA SINICA, TAIWAN – Gesell Zoller
INSTITUTE OF EXPERIMENTAL MINERALOGY, RUSSIA – Eduard Komninov, Oleg Safonov
INSTITUTE OF GEOLOGY & GEOPHYSICS, CHINESE ACADEMY OF SCIENCES – Neng Jiang
INSTITUTE OF GEOLOGY OF ORE DEPOSITS, PETROGRAPHY, MINERALOGY AND GEODESY, RUSSIA – Alexandre Borisov
INSTITUTE OF OCEANOGRAPHY, UK – Mike Coffin
JAMES COOK UNIVERSITY – Bob Henderson
KUNming UNIVERSITY OF SCIENCE AND TECHNOLOGY, CHINA – Chuan Dong Xue
LAURIN TECHNIK – Michael Shelley
MACQUARIE UNIVERSITY – Norm Pearson, Elena Belousova
MONASH UNIVERSITY – Reid Kayes, Massimo Raugei
MOSCOW STATE UNIVERSITY, RUSSIA – Pavel Plechov
MURIDIAN UNIVERSITY, JAPAN – Yoshi Goto
NATIONAL LABORATORY OF ENERGY AND GEOLgy, PORTUGAL – Carlos Rosa
NIAGATA UNIVERSITY, JAPAN – Katsuki Kusukawa
PRIMARY INDUSTRIES AND RESOURCES, SOUTH AUSTRALIA – Martin Fairebough
SURLIS RESOURCES – Tim Craske, Mark Bennett
SMITHSONIAN INSTITUTION, USA – Richard Fiske
STATE KEY LABORATORY IN ORE DEPOSIT GEOCHEMISTRY, CHINA – Xieyan Song, Ruohong Bu, Xi Xianwu
UNITED STATES GEOLOGICAL SURVEY – Paul Emmo
UNIVERSIDAD NACIONAL DE LA PATAGONIA, ARGENTINA – Marcelo Marquez
UNIVERSITET KEBANGSAAN MALAYSIA – Wan Faed Wan Hassan, Mohd Rashid Umor
UNIVERSITY COLLEGE OF SCIENCE, SCHOOL OF GEOLOGY, IRAN – Mirelah Mirmohammadi
UNIVERSITY OF BERN, SWITZERLAND – Thomas Pettke
UNIVERSITY OF CALIFORNIA BERKELEY, USA – Rebecca Carey
UNIVERSITY OF CALIFORNIA RIVERSIDE, USA – Tim Lyons
UNIVERSITY OF CENTRAL MISSOURI, USA – John Nold, Mark Dudley
UNIVERSITY OF FLORIDA AT GAINESVILLE, USA – Mike Perfit
UNIVERSITY OF LISBON, PORTUGAL – Jorge Revas
UNIVERSITY OF MALAYA – Azman Ghandi, Teh Guan Hoe
UNIVERSITY OF MELBOURNE – Jon Woodhead
UNIVERSITY OF NAPLES, ITALY – Beneditto De Vivo
UNIVERSITY OF NEW SOUTH WALES – Ian Graham
UNIVERSITY OF OREGON, USA – Kathy Cashman, Ilya Bindeman, Paul Wallace
UNIVERSITY OF QUEENSLAND, AUSTRALIA – Sue Golding, Paul vanconcelos, Ben Cohen
UNIVERSITY OF SCIENCE & TECHNOLOGY, CHINA – Yuling Xie
UNIVERSITY OF TAIWAN – Donna Sattensward
UNIVERSITY OF THE WITWATERLANDS, SOUTH AFRICA – Allan Wilson
UNIVERSITY OF WESTERN AUSTRALIA – Mark Bailey
UNIVERSITY OF WOLLONGONG – Chris Fergusson
VEROvsky INSTITUTE, RUSSIA – Alexey Arskin, Galina Barmina
VIRGINIA POLYTECHNIC INSTITUTE & STATE UNIVERSITY, USA – Robert Bodnar
WOODS HOLE OCEANOGRAPHIC INSTITUTE, USA – Andrey Gurevko
HAN University of GeoLogy and Mining, VIETNAM – Hai Thanh Tran
FM-Geosar, Germany – Jirin Freudent
Imperial CoLlege London – Andrew Berry
Institute for Frontier Research on Earth Evolution, Japan – Yoshikazu Tamura
Institute of Earth Sciences-Academia Sinica, Taiwan – Gesell Zoller
Institute of Experimental Mineralogy, Russia – Eduard Komninov, Oleg Safonov
Institute of Geology & Geophysics, Chinese Academy of Sciences – Neng Jiang
Institute of Geology of Ore Deposits, Petrography, Mineralogy and Geodesy, Russia – Alexandre Borisov
Institute of Oceanography, UK – Mike Coffin
James Cook University – Bob Henderson
Kunming University of Science and Technology, China – Chuan Dong Xue
Laurin Technik – Michael Shelley
Macquarie University – Norm Pearson, Elena Belousova
Monash University – Reid Kayes, Massimo Raugei
Moscow State University, Russia – Pavel Plechov
Muridian University, Japan – Yoshi Goto
National Laboratory of Energy and Geology, Portugal – Carlos Rosa
NiaGata University, Japan – Katsuki Kusukawa
Primary Industries and Resources, South Australia – Martin Fairebough
Surlis Resources – Tim Craske, Mark Bennett
Smithsonian Institution, USA – Richard Fiske
State Key Laboratory in Ore Deposit Geochemistry, China – Xieyan Song, Ruohong Bu, Xi Xianwu
United States Geological Survey – Paul Emmo
Universidad Nacional de la Patagonia, Argentina – Marcelo Marquez
Universitet Kebangsaan Malaysia – Wan Faed Wan Hassan, Mohd Rashid Umor
University College of Science, School of Geology, Iran – Mirelah Mirmohammadi
University of Bern, Switzerland – Thomas Pettke
University of California Berkeley, USA – Rebecca Carey
University of California Riverside, USA – Tim Lyons
University of Central Missouri, USA – John Nold, Mark Dudley
University of Florida at Gainesville, USA – Mike Perfit
University of Lisbon, Portugal – Jorge Revas
University of Malaya – Azman Ghandi, Teh Guan Hoe
University of Melbourne – Jon Woodhead
University of Naples, Italy – Beneditto De Vivo
University of New South Wales – Ian Graham
University of Oregon, USA – Kathy Cashman, Ilya Bindeman, Paul Wallace
University of Queensland, Australia – Sue Golding, Paul vanconcelos, Ben Cohen
University of Science & Technology, China – Yuling Xie
University of Tasmania – Donna Sattensward
University of the Witwatersrand, South Africa – Allan Wilson
University of Western Australia – Mark Bailey
University of Wollongong – Chris Fergusson
VeroVsky Institute, Russia – Alexey Arskin, Galina Barmina
Virginia Polytechnic Institute & State University, USA – Robert Bodnar
Woods Hole Oceanographic Institute, USA – Andrey Gurevko

Team Members / Sharon Allen, Mike Baker, Ron Berry, Stuart Bull, Isabelle Chamberlin, Grace Cumming, Leonid Danyushevsky, Paul Davidson, Trevor Falconon, Sandin Feng, Kesten Goemans, Jacqueline Halpin, Emily Johnson, Vadim Kamenetsky, Maya Kamenetsky, Ross Large, Roman Leslie, Roland Maas, Charles Makumand, Peter McGlode, Andrew McKeil, Jaceyl McPhee, Sebastien Mefro, Anya Reading, Phil Robinson, Chris Ryan, Kin Zaw
PhD Students / Andrea Agangi, Mohd Baird Iswadi Bin Basori, Fiona Best, Kirill Bythkos, Grasta Cobenas, Paul Cromie, Quang Sang Dinh, Fedes Fonotcia, Hugo Galvan, Sarah Goddard, JinXiang Guan, Martin Jatulizer, Teena Kammang, Chun Khi Lai, Rodney Maier, Takanuki Manaka, Abhisit Salam, Sofia Tetroeva, Olga Vasyukova
Masters Students / Glen Dieram, You Lin Lee
Honours Students / Emma Brown, Josh Guilliamse, Markus Staubmann, Glen Diemar, You Jin Lee
Masters Students / Andrea Agangi, Mohd Baird Iswadi Bin Basori, Fiona Best, Kirill Bythkos, Grasta Cobenas, Paul Cromie, Quang Sang Dinh, Fedes Fonotcia, Hugo Galvan, Sarah Goddard, JinXiang Guan, Martin Jatulizer, Teena Kammang, Chun Khi Lai, Rodney Maier, Takanuki Manaka, Abhisit Salam, Sofia Tetroeva, Olga Vasyukova
Collaborators / Emma Brown, Josh Guilliamse, Markus Staubmann, Glen Diemar, You Jin Lee.

Core Projects / Theme 1A – Geodynamic Controls on the Fertility of Foldbelts, Cratons and Sedimentary Basins
PA1A Palaeoproterozoic magmatism and mineralisation
PA1B Mafic magmatism in modern submarine SW Pacific settings
PA1C Global ocean chemistry, marine basins and mineralisation
PA1D Ore deposits of SE Asia
PA1E Tectonic significance and mineralisation potential of volcano-plutonic belts and ophiolites at the northern end of the eastern Tai, N Queensland
Theme 1B – Magmas, Volutiles and Metals
PB1A Felsic magmas in volcanic arcs and intraplate volcanic provinces – eruption style, degassing processes, fluid evolution and links to mineralisation
PB1B NI-PGE potential of mafic and ultrafelsic magmas – a combined melt inclusions and numerical modelling approach (JAMRA, IAG) PB1B Metalf-immiscibility and the origin of magmatite-spilit deposits

The above list represents active projects in 2010

Project Summaries / PA1A Palaeoproterozoic Magmatism and Mineralisation
Leader / Tony Crawford
Team Members / Mike Baker, Ronald Maas
Collaborators / Reid Koenig, Barney Stevens, Ian Withnall
A paper in Precambrian Research was published in 2010, recording a study of the Palaeoproterozoic magmatism in the Broken Hill Block. The aim is to understand the behaviour of base metals during evolution of arc magmas.

In collaboration with Hugh O'Neill and Andrew Berry, the oxidation state of Fe in a range of BAB glasses was determined, using the BeAmount 118 at the Diamond Light Source Synchrotron in the UK. Preliminary results indicate a significantly more oxidised nature of BAB and arc magmas. This has important implications for the compositions and generation conditions of subduction-related parental melts, and for interpretation of data obtained from studies of melt inclusions in phenocrysts.

In collaboration with Beneditto De Vivo and Robert Bodnar, a study of melt inclusions in olivine phenocrysts from modern volcanic rock in southern Italy has revealed the importance of polybaric crystallisation during explosive eruption. A paper has been submitted for publication in the Journal of Petrology.

PA1A2 Mafic Magmatism in Modern Submarine SW Pacific Settings
Leader / Leonid Danyushevsky
Team Members / Tony Crawford, Trevor Falconon
Student / Giota Cobenas
Collaborators / Andrew Berry, Robert Bodnar, Beneditto De Vivo, Hugh O'Neill, Pavel Plechov, Jon Woodhead

This project aims at improving the understanding of magma generation and evolution processes in the complex region of convergent plate margins in the Southwest Pacific; focusing largely on the Hunter Ridge, a submarine bathymetric high that extends between the southern Vanuatu arc and Fiji.

Activities in 2010 included:

- Over 120 samples of volcanic and plutonic rocks collected in 2009 along the entire length of the Hunter Ridge have been crushed, milled and submitted for major and trace element analysis by XRF and solution ICP-MS. The full results are expected in the first half of 2011.

- Zircons from plutonic rocks dredged from the central parts of the Hunter Ridge have been dated at CODES by LA-ICP-MS, yielding ages of 10 and 5 Ma, corresponding to the age of the substrate and rift, respectively. This first information on the age of the substrate, now proven to be a deformed block of old arc crust from the proto-Vitiaz arc, has important implications for the geodynamic reconstructions of this region of the SW Pacific.

- PhD student, Giota Cobenas, began to analyse major and trace element compositions (including base metals) of phenocrysts (olivine, plagioclase, clinopyroxene, orthopyroxene, amphibole) from a number of volcanic series from the Hunter Ridge. The aim is to understand the behaviour of base metals during evolution of arc magmas.
GLOBAL OCEAN CHEMISTRY, MARINE BASINS AND MINERALISATION

The aims are to decipher processes that controlled the sulfur chemistry and redox history of oceans that existed in northern Australia approximately 1.65 billion years ago, understand how coral ocean water interacted with hydrothermal fluids responsible for forming the giant northern Australian Proterozoic SEDEX Zn-Pb-Ag deposits, and elucidate the role played by (Im不起) organisms during seafloor venting of fluids responsible for forming Proterozoic sedimentary Zn mineralisation.

International collaboration, Tim Lyons, spent four months at CDIOES supported by a USGS visiting fellowship. He contributed to a paper entitled ‘Widespread ferruginous conditions in mid-Proterozoic oceans’, which has been submitted to a paper entitled ‘Widespread ferruginous conditions in mid-Proterozoic oceans’. This paper presents Fe speciation data from a suite of mid-Proterozoic marine mudstones, including a large number from the McArthur and Mt Isa Basins. The results indicate that ferruginous (anoxic and Fe-rich) conditions were both spatially and temporally extensive across diverse palaeogeographic settings in the mid-Proterozoic oceans, confirming the use of new views on the temporal distribution of iron formations, the availability of bio-trace element traces, and the formation of primary geochemical dispersions around ancient submarine hydrothermal vents.

Peter McGoldrick presented an invited keynote talk at the SEG meeting in Keystone, USA, during October. This talk was published as a peer-reviewed contribution to the conference volume.

Rodney Maier’s PhD thesis – ‘Pyrite trace element halos to mineralisation’ – was active during the formation of massive sulfide deposits in the Iberian Pyrite Belt and the Mount Read Volcanics. For volcanoes on the ocean floor, the mechanisms and products of degassing events that affect Felsic magmas are being documented through a portfolio of projects based on modern and ancient, submarine and subaerial, mineralised and unmineralised volcanic and sub-volcanic successions.

CDIOES’s research on young rhyolitic volcanics in the Taio-Bonin arc focuses on the outgassing of H2O and H2S on eruption style. High hydrostatic pressure on the seafloor reduces the explosivity of eruptions, but does not prevent the formation of pumice. In fact, giant pumice is a characteristic product of eruptions in this setting. These volcanoes provide models for similar felsic volcanoes that are active during the formation of massive sulfide deposits in the Iberian Pyrite Belt and the Mount Read Volcanics.

District, Laos, sediment-hosted Au deposits at Selining, Tensang and Penjamy (Malaysia); and intrusion-hosted Cu-Mo and Au-base metal deposits in eastern Cambodia. Deposit summaries highlighting mineralisation characteristics of 40 key ore deposits were produced as an atlas of ore deposits of SE Asia. A new tectonic reconstruction model for SE Asia has been developed, based on the existing literature and a new geochemical, geochronological and ore deposits database for this project.

Tectonic significance and mineralisation potential of volcanic-plutonic belts and ophiolites at the northern end of the Tasman line, N Queensland

This project includes two overlapping strands. The first strand covers the geology, geochemistry and geochronology of diverse Early Palaeozoic units at the northern end of the Tasman line in the area around Greenvale, N Queensland, along the eastern margin of the Pakea- and Mesoproterozoic Geocentre Block.

Key outcomes include a study covering the geochronology, geochemistry and geological mapping of volcanic units east of Greenvale that sits astride the Tasman line, and contains unusually felsic cumulates in its core.

Mapping, and all mineral chemical and geochemical data have been collected, including lidar topographic and GIS data, indicating considerable complexity in the magmatic history of this composite intrusion. Among the mafic and ultramafic rocks occurring in the core, two distinct suites have been defined – one Fe-rich, the other relatively Fe-poor. Fiona is working to synthesise the data into a model for the petrogenesis of this important, and unusual, batholith.

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

This project examines volcanites and metals in felsic magmas, using a combination of melt inclusion research and physical volcanology. The mechanisms and products of degassing events that affect felsic magmas are being documented through a portfolio of projects based on modern and ancient, submarine and subaerial, mineralised and unmineralised volcanic and sub-volcanic successions.

A new tectonic reconstruction model for SE Asia has been developed, based on the existing literature and a new geochemical, geochronological and ore deposits database for this project.

Tectonic significance and mineralisation potential of volcanic-plutonic belts and ophiolites at the northern end of the Tasman line, N Queensland

This project includes two overlapping strands. The first strand covers the geology, geochemistry and geochronology of diverse Early Palaeozoic units at the northern end of the Tasman line in the area around Greenvale, N Queensland, along the eastern margin of the Pakea- and Mesoproterozoic Geocentre Block.

Key outcomes include a study covering the geochronology, geochemistry and geological mapping of volcanic units east of Greenvale that sits astride the Tasman line, and contains unusually felsic cumulates in its core.

Mapping, and all mineral chemical and geochemical data have been collected, including lidar topographic and GIS data, indicating considerable complexity in the magmatic history of this composite intrusion. Among the mafic and ultramafic rocks occurring in the core, two distinct suites have been defined – one Fe-rich, the other relatively Fe-poor. Fiona is working to synthesise the data into a model for the petrogenesis of this important, and unusual, batholith.

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

This project examines volcanites and metals in felsic magmas, using a combination of melt inclusion research and physical volcanology. The mechanisms and products of degassing events that affect felsic magmas are being documented through a portfolio of projects based on modern and ancient, submarine and subaerial, mineralised and unmineralised volcanic and sub-volcanic successions.

A new tectonic reconstruction model for SE Asia has been developed, based on the existing literature and a new geochemical, geochronological and ore deposits database for this project.

Tectonic significance and mineralisation potential of volcanic-plutonic belts and ophiolites at the northern end of the Tasman line, N Queensland

This project includes two overlapping strands. The first strand covers the geology, geochemistry and geochronology of diverse Early Palaeozoic units at the northern end of the Tasman line in the area around Greenvale, N Queensland, along the eastern margin of the Pakea- and Mesoproterozoic Geocentre Block.

Key outcomes include a study covering the geochronology, geochemistry and geological mapping of volcanic units east of Greenvale that sits astride the Tasman line, and contains unusually felsic cumulates in its core.

Mapping, and all mineral chemical and geochemical data have been collected, including lidar topographic and GIS data, indicating considerable complexity in the magmatic history of this composite intrusion. Among the mafic and ultramafic rocks occurring in the core, two distinct suites have been defined – one Fe-rich, the other relatively Fe-poor. Fiona is working to synthesise the data into a model for the petrogenesis of this important, and unusual, batholith.

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

This project examines volcanites and metals in felsic magmas, using a combination of melt inclusion research and physical volcanology. The mechanisms and products of degassing events that affect felsic magmas are being documented through a portfolio of projects based on modern and ancient, submarine and subaerial, mineralised and unmineralised volcanic and sub-volcanic successions.

A new tectonic reconstruction model for SE Asia has been developed, based on the existing literature and a new geochemical, geochronological and ore deposits database for this project.

Tectonic significance and mineralisation potential of volcanic-plutonic belts and ophiolites at the northern end of the Tasman line, N Queensland

This project includes two overlapping strands. The first strand covers the geology, geochemistry and geochronology of diverse Early Palaeozoic units at the northern end of the Tasman line in the area around Greenvale, N Queensland, along the eastern margin of the Pakea- and Mesoproterozoic Geocentre Block.

Key outcomes include a study covering the geochronology, geochemistry and geological mapping of volcanic units east of Greenvale that sits astride the Tasman line, and contains unusually felsic cumulates in its core.

Mapping, and all mineral chemical and geochemical data have been collected, including lidar topographic and GIS data, indicating considerable complexity in the magmatic history of this composite intrusion. Among the mafic and ultramafic rocks occurring in the core, two distinct suites have been defined – one Fe-rich, the other relatively Fe-poor. Fiona is working to synthesise the data into a model for the petrogenesis of this important, and unusual, batholith.
Outcomes were:

- Olympic Dam.
- Sources of the metals, and better constrain the regional context of the first time) takes into account the effect of melt Ni content.
- A demonstration of the role of changes in melt Ni content at the late stages of melt solidification (due to peritectic replacement of olivine by pyroxenes), was highlighted as a cause of secondary in-situ sulfide saturation.
- Research focused on understanding the interplay between magma and sulfide crystallisation during solidification of large gabbroic intrusions. This work is part of JianXiang Guan’s PhD project, focusing on the Panzhihua Intrusion in China - one of the world’s largest magmatic magnetite reserves. Major and trace element contents in magnetite, sulfide and major silicate rock-forming minerals were analysed in 40 samples collected from two vertical cross-sections through the intrusion. A major finding was that there is very little variation in mineral chemistry across the intrusion, despite very significant changes in mineral proportions — from magnetite-rich ores, through to wehrlite, gabbronorite, and olivine-gabbro. This indicates that the intrusion was an open magma chamber, with minerals deposited from passing melts of similar compositions. Data collection will be completed in 2011.

A collaborative study with Alexander Borisov on understanding the mechanism of PGE solubility in silicate melts was completed. A paper is in press.

A project was initiated in collaboration with Allan Wilson from the University of the Witwatersrand, South Africa, on the nature of primitive melts for the Bushveld and Great Dyke intrusions in southern Africa. The project focuses on drill-core samples from the bottom sections of both intrusions that contain abundant high-Mg olivine phenocrysts, likely formed during the earliest stages of the parental melt evolution. Data collection is expected to be completed in 2011.

**P1B2 (AMIRA 962)**

**Ni-PGE POTENTIAL OF MAFIC AND ULTRAMAFIC MAGMAS — A COMBINED MELT INCLUSIONS AND NUMERICAL MODELLING APPROACH**

**Leader /**

Leonid Danyushevsky

**Team Members /**

Tony Crawford, Sandrin Feig, Andrew McNeill

**Students /**

Kirill Bychkov, Jianxiang Guan

**Collaborators /**

Alexey Ariskin, Alexander Borisov, Eduard Konnikov, Allan Wilson

This project was completed successfully in 2010. The main outcomes were:

- A new model of sulfur saturation in mafic magmas, which (for the first time) takes into account the effect of melt Ni content.
- A demonstration of the role of changes in melt Ni content at the late stages of melt solidification (due to peritectic replacement of olivine by pyroxenes), was highlighted as a cause of secondary in-situ sulfide saturation.

Research focused on understanding the interplay between magmatite and sulfide crystallisation during solidification of large gabbroic intrusions. This work is part of JianXiang Guan’s PhD project, focusing on the Panzhihua Intrusion in China - one of the world’s largest magmatic magnetite reserves. Major and trace element contents in magnetite, sulfide and major silicate rock-forming minerals were analysed in 40 samples collected from two vertical cross-sections through the intrusion. A major finding was that there is very little variation in mineral chemistry across the intrusion, despite very significant changes in mineral proportions — from magnetite-rich ores, through to wehrlite, gabbronorite, and olivine-gabbro. This indicates that the intrusion was an open magma chamber, with minerals deposited from passing melts of similar compositions. Data collection will be completed in 2011.

A collaborative study with Alexander Borisov on understanding the mechanism of PGE solubility in silicate melts was completed. A paper is in press.

A project was initiated in collaboration with Allan Wilson from the University of the Witwatersrand, South Africa, on the nature of primitive melts for the Bushveld and Great Dyke intrusions in southern Africa. The project focuses on drill-core samples from the bottom sections of both intrusions that contain abundant high-Mg olivine phenocrysts, likely formed during the earliest stages of the parental melt evolution. Data collection is expected to be completed in 2011.

**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, Yukung Xue

Whether melt/melt immiscibility is a geologically important process in crustal differentiation, and ore-deposit formation, remains controversial. This study addresses this problem by examining selected ore deposits to determine if melt/melt immiscibility occurred during deposit formation, and establishing criteria that can be used to identify its former existence. Fe-Ti oxide melt/melt immiscibility will be examined directly, and silicate-silicate melt/melt immiscibility in the origin of pegmatites will be researched via collaborative studies.

Samples from the zoned alkaline intrusion at Fanshan, China, contain abundant melt inclusions in apatite from the magnetite-apatite ore layers, but unfortunately rather less so in the mafic-ultramafic units. On the basis of microprobe analyses of crystallised inclusions, they appear to be either a peculiar mixed silicate/carbonate melt that has unmixed during cooling, or possibly involving co-trapping of immiscible silicate and carbonate melt fractions. The former seems more likely, but without homogenisation data this is speculative. This carbonatic melt(s) appears to be common to all the magnetite-apatite ores at Fanshan, but is quite different to the mafic-ultramafic bulk composition of the enclosing Fanshan large layered intrusion. The carbonate association is intriguing because the magnetite-apatite ore at Fanshan has a similar structural and stratigraphic relationship to the magnetitite and chromitite ore-layers in the Bushveld intrusion. Despite the presence of abundant, apparently pristine melt inclusions, preliminary attempts at homogenisation of these inclusions have not succeeded, possibly due to the presence of abundant calcite in the crystallised inclusions. However, alternative methods are being investigated.

A paper was submitted to Economic Geology (Mineralogy, Texture, Chemistry and Origin of the Pilot Knob Magnetite Deposit, St. Francois Mountains Terrane, southeast Missouri’ by John L. Nold, Paul Davidson, & Mark A. Dudley), which brings the Pilot Knob study to a conclusion.

Three co-authored papers have been accepted for publication relating to melt/melt immiscibility in pegmatite areas, and one is in review. In addition, a review paper has been requested by Mineralium Deposita.

**Outlook /**

- A new SE Asia-based project to commence, which will build on the successes of the Ore Deposits of SE Asia project.
- A new extension project to continue at BHP Billiton’s Olympic Dam site, researching the architecture of breccia facies at the deposit.
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.

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 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, GCA, EPSL, and Geology.

The second research theme is Ore Deposit Characterisation. 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.

Highlights / 
- P2A1: Combined Pd and Zn isotope data suggest that source rock mineralogy controls the generation of fertile hydrothermal fluids for sediment-hosted Zn-Pb ore deposits.
- P2A2: Optical cathodoluminescence and microscopy studies, along with microanalytical studies of the stage 2 veins at Porgera, have demonstrated substantial fluctuations on Al content of quartz during vein growth.
- P2A2: High concentrations of ore metals are transported by a hydrosilicate liquid in the barren Las Pampas system, part of the Bajo de la Alumbrera complex, Argentina.
- P2A2C: First regional fluid flow models incorporating interaction of variable-salinity fluids in the Irish ore field completed.
- P2B1A: New postdoctoral research fellow (Dr Janina Micko) and PhD candidate (Marc Rinne) appointed. Embedded research activities have led to the utilisation of CoDes’ research in ongoing exploration activities.
- P2B1B: Through U-Pb dating of zircons from 15 intrusive complexes, two phases of Jurassic intrusive activity related to Fe-Cu-Au mineralisation have been constrained in the Luzong volcanic basin, China.
- P2B1D: All five PhD students working on the alkalic project (Adam Bath, Jacqueline Blackwell, Heidi Pass, Janina Micko (MORU) and Wojciech Zukowski) completed their theses.
- P2B1B: Susan Belford completed her PhD on the Jaguar VHMS deposit in Western Australia.
INSTITUTE OF GEOLOGY, CHINESE ACADEMY OF GEOLOGICAL SCIENCES, CHINA – Zhyiming Yang
NANKHUE AUSTRALIA – Flaviana Laoa, Rohan Wolfe
LAURENTIAN UNIVERSITY, CANADA – Steve Percey
MCGILL UNIVERSITY, CANADA – Jeanne Paquette
MORINE MINING JOINT VENTURE, PNG – Dave Finn, Chris Muller, Simon Shalenby, Betty Tekeve
NEWCREST MINING – Dean Collett, John Holliday
NEWCREST MINING, PNG – Jon Rutter
NORTHERN TERRITORY GEOLOGICAL SURVEY – Massod Ahmad
OZ MINERALS – Hamish Freeman
QUEENS UNIVERSITY, CANADA – Dan Layton-Williams
SIMON FRASER UNIVERSITY, CANADA – Derek Thorkelson
TABIT NOAILLE UNIVERSITY, IRAN – Zahra Bonyadi, Behzad Mehrabi
UNIVERSITY KEBANGSAAN, MALAYSIA – Wan Fudzi Wan Hassan
UNIVERSITY OF ALBERTA, CANADA – Robert Creaser
UNIVERSITY OF BRITISH COLUMBIA, CANADA – Greg Dipple, Jim Montgomery
UNIVERSITY OF LISBON, PORTUGAL – Miguel Gaspar
UNIVERSITY OF MALAIA – Azman Ghani, Teh Guan Hoe
UNIVERSITY OF OTTAWA, CANADA – Mark Hannington
UNIVERSITY OF WESTERN AUSTRALIA – Marco Fiorentini

Project Summaries /
P2A1A
TRANSITION METAL SPECIATION AND ISOTOPE SYSTEMATICS OF SOURCE ROCKS FOR SEDIMENT AND VOLCANIC-HOSTED ORES
Leader / Jamie Wilkinson
Team Members / David Cooke, Bruce Gemmell, Jamie Laird, Ross Large, Chris Ryan
Collaborator / Dominik Weiss

Core Projects /
Theme 2A – Ore-forming Processes
P2A1A Transition metal speciation and isotope systematics of source rocks for sediment and volcanic-hosted ores
P2A2A Fracture arrays in intrusion-related ore systems – controls on the dynamics of fluid flow, vein formation and the generation of giant deposits
P2A2B Determination of gold and other metals in fluid inclusions
P2A2C Modelling fluid flow in the Irish Zn-Pb ore field
P2A3A Efficiency of ore-forming processes

Theme 2B – Ore Deposit Characterisation
P2B1A Exploring the porphyry environment
P2B1B Polymetallic mineralisation and associated magmatic and volcanic activity in Cretaceous sedimentary-basins of eastern China
P2B1C Genesis of volcanic-hosted Cu-Pb-Zn-Ag-Au massive sulfide deposits
P2B1D Shallow and deep-level alkalic mineral deposits
P2B3A Fluids that form high-salinity, volcanic-hosted massive sulfide deposits
P2B3B Hydrothermal event recognition and target vectoring in sedimentary strata
P2B3D Active base- and precious-metal-rich massive sulfide deposits
P2B4 Iron oxide copper-gold and related deposit types

THE ABOVE LIST REPRESENTS ACTIVE PROJECTS IN 2010
network. Textural and compositional banding in stage 2 veins indicates multiple episodes of vein growth and sealing. Each cycle of vein growth is marked by deposition of an initial zone rich in roscoelite and pyrite, together with Al-rich quartz. The early Au-rich phase of each cycle is overgrown by a quartz-rich zone with low Au grades and marked oscillatory zoning in quartz’s Al contents. Individual veins may contain several of these gold-rich to gold-poor cycles of vein growth. Each cycle of vein growth is interpreted to be triggered by breaching of the magmatic-hydrothermal fluid reservoir.

P2A2B
DETERMINATION OF GOLD AND OTHER METALS IN FLUID INCLUSIONS
Leader / Jamie Wilkinson
Team Members / David Cooke, Leonid Danyushevsky, Marcel Guillong, Vadim Kamensky
Student / Sarah Gilbert
Collaborator / David Braxton
Two Cu-Au porphyry systems were studied: the Boyongan deposit in the Philippines, and Las Pampas in Argentina - a barren satellite of the Bajo de la Alumbrera deposit. Brine inclusions are abundant in a quartz stockwork vein sample hosted by the inter-mineral diorite porphyry at Boyongan. LA-I CP-MS analyses confirmed the cation predominance Na>K>Fe, with an average ratio of 57:27:16. Gold was not detected, despite detection limits down to 0.11 ppm, but silver was determined at 5-20 ppm. In Las Pampas quartz-magnetite veins, the most common inclusion type are unusual vapour-solid inclusions in which the vapour typically fills ~50% of the inclusion volume and forms a planar or irregular contact with the principal transparent phase. Gold was only detected in one inclusion at the ppm level. Overall, the inclusions have bulk compositions similar to aqueous brines from Bajo de la Alumbrera, but differ in the concentrations of salt and (probably) silicate components.

P2A2C
MODELLING FLUID FLOW IN THE IRISH Zn-Pb ORE FIELD
Leaders / Jamie Wilkinson, Stuart Bull
Team Member / Lyudmyla Kazty
This project aims to produce the first model for fluid flow in the Irish Midlands Basin that incorporates interaction of variable salinity fluids. Objectives are to assess the variables that allow extensive basement flow; evaluate the competition between halite-saturated and gypsum-saturated brines; and understand the controls of the flow patterns, in particular the depth of fluid penetration. During the year, a finite element mesh has been constructed of a schematic cross section of the basin, and modelling of various scenarios commenced. Initial results suggest an important role for an upper crustal detachment for focusing lateral flow of brines (particularly southward-directed) and the significance of this mechanism for controlling discharge from faults. Although flow patterns and pathways indicated by the initial model scenarios are appropriate for ore formation, fluid velocity and temperature are both lower than expected. Model parameters are currently being adjusted to address this issue.

FLOW MODELS FOR THE IRISH MIDLANDS BASIN SHOWING SALTIVITY DISTRIBUTION AFTER 15 My, ILLUSTRATING DOWNWARD MOVEMENTS OF BRINES SOURCED FROM SUBAERIAL OR SHALLOW WATER HYDROTHERMAL ENVIRONMENTS NEARBY THE CAUSATIVE O Bowen INTRUSION AT THE RIGHT HAND SIDE OF THE MODEL. DARK LINES REPRESENT FAULTS.

P2A3
EFFICIENCY OF ORE-FORMING PROCESSES
Leaders / Zhaoshan Chang, David Cooke, Jamie Wilkinson
Team Member / Chris Ryan
Collaborators / Joey Garcia, Miguel Gaspar, Larry Meinert, Jeanne Paquette, Zhiming Yang
The following topics are currently being investigated:

- High-sulfidation epithermal deposits generally form in two stages. While the genesis of early stage silicic and advanced argillic alteration is well understood, late stage mineralisation processes are still debated. Many models have been proposed, including the recent vapour contraction model. This project is developing a new model to explain the mineralisation process, based on research into the Lepanto deposit, Philippines.

- Trails of regularly spaced Au grains with 8 or 6-sided shapes occur in dendritic quartz, UST quartz, and vein dykes in intrusive rocks at the Bilihe Au deposit, China. Geochemical analyses and crystallographical modelling are ongoing, but it is tentatively proposed that the Au grains were deposited from an Au-dominant melt.

- Garnet colours change systematically with distance from the causative intrusion in skarn deposits – a powerful tool in exploration. The relationship between garnet colours and chemical compositions is being investigated, using microprobe and LA-ICP-MS analyses.
Galore porphyry Au deposit. Marc Rinne commenced his PhD on who joined CoDes from MDRu after completion of her PhD on the techniques, including mineral chemistry determined by SWiR and the application of conventional and advanced geochemical field programs apply a multipronged approach that considers describing hydrothermal alteration - so critical in the exploration to the revision of logging procedures and revised methods of conceptual models and exploration techniques. This approach has led to improved understanding of Newcrest’s porphyry and epithermal deposits in Australia (Cadia), PNG (Golpu-Wafi), and Fiji (Waiwai-Waivaka). Ongoing field-based research has led to the revision of logging procedures and revised methods of describing hydrothermal alteration - so critical in the exploration of large porphyry systems in the southwest Pacific. Exploration field programs apply a multipronged approach that considers the application of conventional and advanced geochronological techniques, including mineral chemistry determined by SIMS and LA-ICP-MS. The research team has grown to include Janina Micko, who joined CODES from Monash after completion of her PhD on the Galore porphyry Au deposit. Marc Rinne commenced his PhD on the Galore porphyry during the year.

**P2B1A**

**EXPLORING THE PORPHYRY ENVIRONMENT**

*Leaders /*  
Anthony Harris, David Cooke

*Team Member /*  
Janina Micko

*Students /*  
Ana Liza Cusun, Nathan Fox, Ting Kor, Marc Rinne

*Collaborators /*  
Charlotte Allen, Ian Campbell, Dean Collett, Robert Creaser, Kevin Faure, Dave Finn, John Holiday, Chris Muller, Ian Percival, Simon Shakesby, Ben Tokuyasu

CODES and Newcrest are working together to maximise opportunities for the discovery of new porphyry-related gold resources. This is being achieved through ongoing training, which is underpinned by targeted research activities designed to advance conceptual models and exploration techniques. This approach has led to improved understanding of Newcrest’s porphyry and epithermal deposits in Australia (Cadia), PNG (Golpu-Wafi), and Fiji (Waiwai-Waivaka). Ongoing field-based research has led to the revision of logging procedures and revised methods of describing hydrothermal alteration - so critical in the exploration of large porphyry systems in the southwest Pacific. Exploration field programs apply a multipronged approach that considers the application of conventional and advanced geochronological techniques, including mineral chemistry determined by SIMS and LA-ICP-MS. The research team has grown to include Janina Micko, who joined CODES from Monash after completion of her PhD on the Galore porphyry Au deposit. Marc Rinne commenced his PhD on the Galore porphyry during the year.

**P2B1B**

**POLYMETALLIC MINERALISATION AND ASSOCIATED MAGMATIC AND VOLCANIC ACTIVITY IN CRETACEOUS VOLCANO-SEDIMENTARY BASINS OF EASTERN CHINA**

*Leaders /*  
Taozi Zhou, David Cooke

*Team Members /*  
Zhaoqian Cheng, Sebastian Meffre

*Students /*  
Jun Yang, Bin Qian, Lijuan Zhang

*Collaborators /*  
Yu Fan, Fang Yuan

Significant progress has been made in attaining a better understanding of the polymetallic mineralisation and associated magmatic and volcanic activity in the Luzong basin, middle and lower Yangtze River, eastern China. There are at least 34 plutons in the basin. LA-ICP-MS zircon U-Pb dating of 15 of the plutons has shown that intrusive activity occurred between 134 and 123 Ma. The intrusive rocks can be divided into two stages. Early stage (134–130 Ma) monzonite-diorite plutons crop out in the northern part of the basin - their emplacement was controlled by NNW-trending structures. Late stage plutons (129–123 Ma) include several syenites that crop out in the southern part of the basin, and A-type granites (126–123 Ma) that crop out on its southeast margin.

**P2B1D**

**SHALLOW AND DEEP-LEVEL ALKALIC MINERAL DEPOSITS**

*Leaders /*  
David Cooke, Richard Tosdal

*Team Members /*  
Thomas Bisig, Joselyn McPhee

*Students /*  
Adam Bath, Jacqueline Blackwell, Heidi Pass, Janina Micko, Wojciech Zukowski

*Collaborators /*  
Greg Dopple, Patrick McAndless, Paul McNines, Chris Rees, Jon Rutter

The aims are to document the characteristics and determine the genesis of alkalic porphyry deposits in British Columbia, and alkalic epithermal deposits of PNG and Australia. The project involves collaboration with UBC and is supported by four industry sponsors. Additional financial support derives from grants from the Natural Sciences and Engineering Research Council of Canada (NSERC) and Geoscience BC. All five PhD students working on the alkalic project successfully completed their theses and were awarded their degrees during the year. All team members made significant progress towards finalising their manuscripts for a special issue of Economic Geology summarising project results.

**P2B3A**

**FLUIDS THAT FORM HIGH-SALINITY, VOLCANIC-HOSTED MASSIVE SULFIDE DEPOSITS**

*Leader /*  
Bruce Gemmell

*Team Members /*  
Garry Davidson, Ross Large, Andrew Michell, Khin Zaw

*Collaborators /*  
Mohd Basril Iswadi Bin Basori, Susan Belford, Jo Condon, Paul Ferguson, Margy Hawke, Brendan McGee, Nathan Stevens, Selina Wu

This project is investigating the spectrum of massive sulfide deposit types. Research was undertaken in the past year on deposits at Kosse-Vel-Hey-Que River-Mt Charter (Tasmania), Jaugar (Western Australia), DeGrussa (Western Australia), Palmer (Alaska), Baynichang (China), Duc Bo (Vietnam), Tasik Chini (Malaysia) and Tala Hansza (Algeria). In addition, a detailed geochemical study of the host successions in the Mount Read Volcanic Belt continued.

**P2B3B**

**GENESIS OF VOLCANIC-HOSTED Cu-Pb-Zn-Ag-Au MASSIVE SULFIDE DEPOSITS**

*Leader /*  
Bruce Gemmell

*Team Members /*  
Gary Davidson, Ross Large, Andrew Michell, Khin Zaw

*Collaborators /*  
Mohd Basril Iswadi Bin Basori, Susan Belford, Jo Condon, Paul Ferguson, Margy Hawke, Brendan McGee, Nathan Stevens, Selina Wu

This project is investigating the spectrum of massive sulfide deposit types. Research was undertaken in the past year on deposits at Kosse-Vel-Hey-Que River-Mt Charter (Tasmania), Jaugar (Western Australia), DeGrussa (Western Australia), Palmer (Alaska), Baynichang (China), Duc Bo (Vietnam), Tasik Chini (Malaysia) and Tala Hansza (Algeria). In addition, a detailed geochemical study of the host successions in the Mount Read Volcanic Belt continued.

**P2B3C**

**HYDROTHERMAL EVENT RECOGNITION AND TARGET VECTORING IN SEDIMENTARY STRATA**

*Leader /*  
Bruce Gemmell

*Collaborators /*  
Wayne Goodfellow, Mark Hannington, Dan Layton-Matthews, Thomas Moreeke, Jan Peter, Steve Penney

This CANIRO (Canadian Mining Industry Research Organization - Exploration Division)–funded project is developing an improved understanding of the concentrations and behaviour of trace metals associated with volcanic-hydrothermal processes in marine sedimentary and volcanic-sedimentary successions. Research is progressing, which includes the development of new mineralogical, geochemical, and isotopic tools to discriminate potentially mineralised versus unmineralised horizons in many mineralised districts. A successful sponsoring meeting was held in Keystone, Colorado, in October.
Outlook /

P2A1A Submission of paper to Nature Geoscience.
P2A2A Submission of two papers dealing with the Porgera gold deposit.
P2A2B Submission of paper to Nature Geoscience.
P2A2C Submission of paper to Geology.
P2B1A Publication of research results from CODES-Newcrest collaborative research. Initiation of PhD study of Namosi, Fiji.
P2B1B A short course to be held at Hefei University. SEG student Chapter field trip to Luzong, and other areas in the middle and lower reaches of the Yangtze metallogenic province, China, is planned for May 2011.
P2B1D Publication of the Alkalic project special issue in Economic Geology.
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.

Introduction / The Discovery Program leverages 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.

Highlights /

- AMIRA Project P1022, the rapid approximate inversion of TEM data, commenced and the method has been implemented for airborne TEM (moving loop) data.
- Seismic wave speed structure tomographic sections were determined along a pilot transect of the upper crust using ambient seismic energy.
- Successful completion of Geochemical and Geological Halos in Green-Rocks and Lithocaps (AMIRA project P761A).
- Development and publication of a new genetic model for sediment-hosted gold deposits.
- The development of new models for Ni-Cu-PGE mineralisation, involving multi-stage processes leading to ‘sedimentary-style’ deposition of pre-formed chromite, sulfide and platinum group metals (PGM) grains under magmatic conditions.
Leader / Andrew McNeill

**Core Projects /**

**Theme 3A – Innovative Techniques for Discovery**

**P3A1C** (AMIRA P1022) – THE RAPID APPROXIMATE INVERSION OF TEM DATA

**Leaders /**
Jeff Foster, Peter Fullagar

**Team Members /**
Mike Baker, Ron Berry, Stuart Bull, Zhaohuan Chang, Huayong Chen, David Cooke, Tony Crawford, Leonid Danyushevsky, Garry Davidson, Jeff Foster, Bruce Gemmell, Leon Graham, Norman Hedscher, Dave Hutchinson, Shaun Inglis, Vadim Kamenetsky, Ross Large, Sebastien Mefitra, Steve Micklethwaite, Ross Olsen, Anya Reading, Michael Roach, Ralf Schaa, Rob Scott, David Selley, Helen Thomas, Tony Webster, Wojciech Zukowski

**PhD Students /**
Matthieu Agenaou, Victoria Banifaff, Lindsey Clark, Matt Cracknell, Sarah Gilbert, Rosim Kyns, Hugo Galvan, Dan Gregory, Nic Iansen, Alexey Lygin, Jeff Steedman, Bronco Sutopo

**Masters Students /**
Gabe Sweet (Lakehead University, Canada), Daud Siltonga

**Honours Student /**
Ryan Knight

**Collaborators /**
ANU – Nicholas Rawlinson, Malcolm Sambridge
CONSULTANT – Noel White
CSIRO – Rob Hough, John Walse
FULLAGAR GEOPHYSICS – Peter Fullagar
IMPERIAL COLLEGE LONDON – Clara Wilkinson, Jamie Wilkinson
JAMES COOK UNIVERSITY – Tom Blinkinsop
LAKEHEAD UNIVERSITY, CANADA – Peter Hollings
MINERAL RESOURCES TASMANIA – Ralph Bottrell, Jafar Taheri
OTAGO UNIVERSITY, NEW ZEALAND – Dave Craw
OZ MINERALS – Mark Allen, Jorge Benavides, Hamish Freeman
RUSSIAN ACADEMY OF SCIENCE, URAL’S BRANCH – Valery Maslenkov
SOUTH DAKOTA SCHOOL OF MINES & TECHNOLOGY, USA – Colin Paterson
UNIVERSITY OF OTTAWA – Jeff Hedenquist
UNIVERSITY OF SYDNEY – Patrice Rey

**Theme 3B – Integrated Exploration Models for Discovery**

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

**P3B1C** – Low- and high-sulfidation epithermal mineral deposits

**P3B2A** – Sediment- and volcanic-hosted gold-arsenic deposits: genesis & exploration models

**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 sulfide systems

**P3B5C** – The geology, geochemistry and genesis of the Avebury Ni deposit - implications for exploration

**P3B6A** – Shale and formation of the Savage River magnetite deposit

**P3B7A** – Iron oxide copper-gold and related deposit types

**Team Members /**
Mike Baker, Ron Berry, Stuart Bull, Zhaohuan Chang, Huayong Chen, David Cooke, Tony Crawford, Leonid Danyushevsky, Garry Davidson, Jeff Foster, Bruce Gemmell, Leon Graham, Norman Hedscher, Dave Hutchinson, Shaun Inglis, Vadim Kamenetsky, Ross Large, Sebastien Mefitra, Steve Micklethwaite, Ross Olsen, Anya Reading, Michael Roach, Ralf Schaa, Rob Scott, David Selley, Helen Thomas, Tony Webster, Wojciech Zukowski

**PhD Students /**
Matthieu Agenaou, Victoria Banifaff, Lindsey Clark, Matt Cracknell, Sarah Gilbert, Rosim Kyns, Hugo Galvan, Dan Gregory, Nic Iansen, Alexey Lygin, Jeff Steedman, Bronco Sutopo

**Masters Students /**
Gabe Sweet (Lakehead University, Canada), Daud Siltonga

**Honours Student /**
Ryan Knight

**Collaborators /**
ANU – Nicholas Rawlinson, Malcolm Sambridge
CONSULTANT – Noel White
CSIRO – Rob Hough, John Walse
FULLAGAR GEOPHYSICS – Peter Fullagar
IMPERIAL COLLEGE LONDON – Clara Wilkinson, Jamie Wilkinson
JAMES COOK UNIVERSITY – Tom Blinkinsop
LAKEHEAD UNIVERSITY, CANADA – Peter Hollings
MINERAL RESOURCES TASMANIA – Ralph Bottrell, Jafar Taheri
OTAGO UNIVERSITY, NEW ZEALAND – Dave Craw
OZ MINERALS – Mark Allen, Jorge Benavides, Hamish Freeman
RUSSIAN ACADEMY OF SCIENCE, URAL’S BRANCH – Valery Maslenkov
SOUTH DAKOTA SCHOOL OF MINES & TECHNOLOGY, USA – Colin Paterson
UNIVERSITY OF OTTAWA – Jeff Hedenquist
UNIVERSITY OF SYDNEY – Patrice Rey

**Project Summaries /**

**P3A1C** (AMIRA P1022) – THE RAPID APPROXIMATE INVERSION OF TEM DATA

**Leaders /**
Jeff Foster, Peter Fullagar

**Team Members /**
Mike Baker, Ron Berry, Stuart Bull, Zhaohuan Chang, Huayong Chen, David Cooke, Tony Crawford, Leonid Danyushevsky, Garry Davidson, Jeff Foster, Bruce Gemmell, Leon Graham, Norman Hedscher, Dave Hutchinson, Shaun Inglis, Vadim Kamenetsky, Ross Large, Sebastien Mefitra, Steve Micklethwaite, Ross Olsen, Anya Reading, Michael Roach, Ralf Schaa, Rob Scott, David Selley, Helen Thomas, Tony Webster, Wojciech Zukowski

**PhD Students /**
Matthieu Agenaou, Victoria Banifaff, Lindsey Clark, Matt Cracknell, Sarah Gilbert, Rosim Kyns, Hugo Galvan, Dan Gregory, Nic Iansen, Alexey Lygin, Jeff Steedman, Bronco Sutopo

**Masters Students /**
Gabe Sweet (Lakehead University, Canada), Daud Siltonga

**Honours Student /**
Ryan Knight

**Collaborators /**
ANU – Nicholas Rawlinson, Malcolm Sambridge
CONSULTANT – Noel White
CSIRO – Rob Hough, John Walse
FULLAGAR GEOPHYSICS – Peter Fullagar
IMPERIAL COLLEGE LONDON – Clara Wilkinson, Jamie Wilkinson
JAMES COOK UNIVERSITY – Tom Blinkinsop
LAKEHEAD UNIVERSITY, CANADA – Peter Hollings
MINERAL RESOURCES TASMANIA – Ralph Bottrell, Jafar Taheri
OTAGO UNIVERSITY, NEW ZEALAND – Dave Craw
OZ MINERALS – Mark Allen, Jorge Benavides, Hamish Freeman
RUSSIAN ACADEMY OF SCIENCE, URAL’S BRANCH – Valery Maslenkov
SOUTH DAKOTA SCHOOL OF MINES & TECHNOLOGY, USA – Colin Paterson
UNIVERSITY OF OTTAWA – Jeff Hedenquist
UNIVERSITY OF SYDNEY – Patrice Rey

**Leaders /**
Jeff Foster, Peter Fullagar

**Team Members /**
Mike Baker, Ron Berry, Stuart Bull, Zhaohuan Chang, Huayong Chen, David Cooke, Tony Crawford, Leonid Danyushevsky, Garry Davidson, Jeff Foster, Bruce Gemmell, Leon Graham, Norman Hedscher, Dave Hutchinson, Shaun Inglis, Vadim Kamenetsky, Ross Large, Sebastien Mefitra, Steve Micklethwaite, Ross Olsen, Anya Reading, Michael Roach, Ralf Schaa, Rob Scott, David Selley, Helen Thomas, Tony Webster, Wojciech Zukowski
A significant new 3D ambient seismic dataset (ASET2) was also obtained in collaboration with a geothermal exploration company. The deployment had a core of 16 stations in an irregular diamond pattern. A further six stations deployed in the latter part of the experiment were at wider station spacings to resolve deeper parts of the exploration prospect. Processing for 3D seismic wave speed structure is underway.

DATA INFEERENCE TECHNIQUES APPLIED TO DIVERSE GEOSCIENCE DATASETS

Leader / Anya Reading

Team Members / Jeff Foster, Michael Roach

Student / Matt Cracknell

Collaborator / Malcolm Sambridge

Inference refers to the process of extracting robust results, or gaining knowledge from a dataset or observed information. This process is implicit in most scientific endeavours, but this project aims to explicitly investigate the application of innovative mathematical, geophysical and statistical approaches to diverse geoscience datasets. In addition to necessary background work, two major activities occurred during the year:

1. A major conference session - Innovations in Geophysical Inversion – was convened by Reading and Sambridge at the ASEG meeting in Sydney during August. The presentations generated heated discussion and resulted in an invitation to write a feature article on the new approaches.

2. Machine learning style computational approaches to data inference were investigated, based on the PhD research of Matt Cracknell. This project began in July.

P3B1A (AMIRA P765A) GEOCHEMICAL AND GEOLOGICAL HALOS IN GREEN ROCKS AND LITHOCAPS - THE EXPLORER'S TOOLBOX FOR PORPHYRY AND EPITHERMAL DISTRICTS

Leaders / David Cooke, Bruce Gemmell, Zhaochuan Chang

Team Members / Mike Baker, Huayong Chen, Jeff Hedenquist, Peter Hollings, Shaun Inglis, Noel White, Clara Wilkinson, Jamie Wilkinson

Students / Nic Jansen, Rosin Kyne, Gabe Sweet

This project was completed on time and within budget in December. The research team developed and validated new geochemical techniques that help predict the likely direction and distance to porphyry-style mineralised centres, either in the deeply eroded green rock environment, where porphyric alteration predominates, or in the intensely clay-altered ‘lithocap’ environment, where porphyry or high sulfidation-style epithermal mineralisation may be hidden in intense clay and silicic alteration. Using advances in LA-ICP-MS, the team established that subtle hypogene geochemical dispersion halos can be detected several kilometres beyond the limits of geochemical anomalies that are detected by conventional rock-chip sampling techniques, thereby extending the detectable geochemical footprint of porphyry mineralised centres. The team also developed geochemical tools that discriminate between environments (porphyry, epithermal, metasomatism), and made significant progress towards developing and testing fertility indicators (i.e., discriminating large, small and barren systems).

P3B1C LOW- AND HIGH-SULFIDATION EPITHERMAL MINERAL DEPOSITS

Leaders / Bruce Gemmell, David Cooke

Team Members / Steve Micklethwaite, Wojciech Zukowski

Students / Mathieu Ageneau, Lindsey Clark, Hugo Galvan, Daud Silitonga, Bronto Sutopo

Collaborators / Tom Blenkinsop, Patricia Rey

The geology and genesis of low- and high-sulfidation epithermal mineral 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 these deposits, which will lead to improved genetic and exploration models.

Low sulfidation deposits

Research continued on the Newcrest-funded deposit to district-scale study of the Gosowong goldfield, Halmahera Island, Indonesia. Steve Micklethwaite finished his investigation of the structural characteristics of Gosowong, which led to the initiation of a new post-doctoral study entitled "Enabling Blind Exploration - Identifying Hidden Structure with Faults, Fractals and Geomorphology." This project utilizes quantitative geomorphological technology to identify the location of mineralised faults and veins from subtle landscape signatures. The research combines these methods with analyses of the fractal behaviour of fault-vein networks to provide geometric vectors to potentially mineralised structures.

Lindsey Clark’s PhD project, investigating the geology and genesis of the Kencana epithermal Au-Ag deposit at Gosowong, is providing the first detailed study of the deposit via geological, structural, mineralogical and geochemical investigations. Masters of Economic Geology student, Daud Silitonga, is investigating the Toqucari epithermal veins that crosstcut the low grade Bora porphyry Cu-Au prospect in the Gosowong district.

Hugo Galvan’s PhD project is investigating the geological and geochemical evolution of carbonate-base-metal Ag-Au epithermal veins in the Palmarejo District, Chihuahua, Mexico. The study is being funded by Coeur d’Alene and aims to develop a more detailed understanding of the geological evolution of the district. This will be achieved by investigating the mineralisation history, geochemistry and relationships to grade distribution, plus documenting the vein stratigraphy, paragenesis, spatial and temporal distribution of the alteration assemblages and geochemistry of the mineralising fluids.

PHD student, Mathieu Ageneau, continues to study the low-sulfidation Lladomír Au deposit in Papua New Guinea, supported by Newcrest. During 2010, the research focused on the mineralogy of the Lienetz and Minifie ore bodies and, more specifically, the geochemistry of the ore minerals and the refractory pyrite. The study is also investigating the geology, alteration, and metal zoning of the Kapit ore body.

Following a short-term postdoctoral study in 2009, Wojciech Zukowski completed a six-month study of the Ares intermediate and low-sulfidation epithermal silver-gold deposit in southern Peru. The project, funded by Hochstichl Mining, focused on developing geological, mineralogical and lithogeochemical indicators to epithermal veins that will help exploration activities in the Ares district. The study was completed mid-year, and comprised four months’ field work at the site, followed by laboratory analyses and report writing at CODES.

High sulfidation deposits

Bronto Sutopo is close to completing his PhD research on the high- and low-sulfidation mineralisation in the Martabe district, Indonesia. His thesis will significantly improve the understanding of the geologic setting and ore genesis, as well as developing criteria for enhanced exploration in the district. His thesis is expected to be submitted early in 2011.
P382A SEDIMENT- AND VOLCANIC-HOSTED GOLD-ARSENIC DEPOSITS: GENESIS & EXPLORATION MODELS

Leaders / Ross Large, Stuart Bull

Team Members / Leonid Danyushevsky, Garry Davidson, Shaun Inglis, Sebastien Ross Large, Stuart Bull

Collaborators / Sarah Gilbert, Dan Gregory, Jeff Steadman

This project focuses on pyrite textures, geochemistry and isotopes in a wide range of gold deposits to elucidate the origin, sources and timing of pyrite and gold. The new LA-ICP-MS pyrite mapping technology developed at CODES is a key tool in this study, which enables the trace element and gold hydrothermal history of deposits to be determined. A portion of this work forms part of ANRA project P1041. The application of new technologies to gold deposits sponsored by AngloGold Ashanti, Newcrest, Newmont, G/Resources, Spa and Issara.

The following deposits were studied in 2010:

- Wai high sulphidation epithermal gold deposit, PNG - Focusing on the pyrite textures, mineralogy and timing of gold, and the geochemical fingerprint of the gold event.
- Mt Olympus sediment-hosted gold deposit in Western Australia - This study involves a comparison of textures and gold mineral associations with the Carlin system in Nevada.
- McPhilemy's volcanic-sedimentary-hosted disseminated gold deposit in New South Wales - The aim is to determine the pyrite-gold geochemistry, timing of gold, S & Pb isotopic characteristics of pyrite, and the alteration/geochemistry.
- Witwatersrand Carboniferous Reef in the Witwatersrand, South Africa - Focus is on the textures and chemistry of pyrite and relationships to gold and uranium mineralisation. The research addresses the question: "What are the potential sources of the various pyrite types and related gold?"
- Kurnur gold deposit in the Tan Shan Belt, Central Asia - In this collaboration with Valery Maslennikov, RAS, the pyrite in black shale wall rocks and the ore zones have been studied. Nickel diagenetic pyrite in the carbonaceous shale host sequence are enriched in gold and tellurium, which may be the original source of these elements in the ores. S & Pb isotopes are being used to constrain sources and timing.
- Otogo Gold Province, New Zealand - Pyrite from the Maackesi deposit, and from schists throughout the province, has been studied to shed light on the hydrothermal history and relative timing of gold input. A geochemical fingerprint of ore-related pyrite has been established and can be used in exploration.
- St Ives gold camp, Yilgarn, WA - Research is focused on the Kapa Slate to determine if there is evidence of early concentration of gold in organic-rich, sedimentary facies of the greenstone belt. This is part of a PhD study by Dan Gregory, conducted in collaboration with the CSIRO MDU flagship and Gold Fields.
- Homestake Gold Mine, USA - PhD student, Jeff Steadman, is studying the footwall lithologies (Poorman Formation) to the Homestake BIF in collaboration with South Dakota School of Mines & Technology. Research is focused on understanding the metamorphic transition from pyrite to pyrrhotite in the footwall shales, and how this may relate to the concentration of gold in the overlying carbonate. This research involves a collaboration with Peter Hollings from Lakehead University.

This research on sediment-hosted gold has resulted in a new genetic model for Carlin Type and orogenic gold deposits, which has major relevance for mineral exploration. Ross Large presented keynote talks on this topic at the Goldschmidt Conference in Jerusalem and the International Mineralogical Association Conference in Budapest.

P383 SHALES AND CARBONATES - IMPROVED VECTORS FOR ROSEBERY AND HERCULES STYLE VHMS

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 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. In the past year, work has focused on developing a detailed understanding of the Ti and Sn envelope around the Rosebery and Hercules orebodies. Results indicate that although the contents of primitive pyrite and galena may have elevated, to 100 ppm Ti and the bulk of the Ti (x>80%) is hosted by phyllosilicates. Furthermore, mass balance calculations suggest that, in contrast to some other hydrothermal systems, the Ti contents of K-feldspars in the Rosebery system are negligible.

P384 THE TWEETFEINSTEIN SECTOR OF THE PLATREEF, SOUTH AFRICA

Leader / Jeff Foster

Team Member / Dave Hutchinson

This industry-sponsored project was designed to investigate the mechanisms and processes that led to the formation of Ni-Cu-PGE mineralisation in the Tweetfeinstein Sector of the Platreef, 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. The geometric data revealed the presence of recognisable zones that can be traced across adjacent drill holes. These zones correlate with features observed in thin-sections, and SEM observations for the location, distribution and identification of platinum-bearing minerals. Microprobe analyses of the main minerals further support the presence of broadly defined zones that can be traced from hole to hole. These broad zones define intrusive packages with varying degrees of metamorphic and metasomatic overprinting, together with a unit that appears to host a large number of altered ultramafic xenoliths. The overprinting event resulted in modification of the original host rock and the sulphide-PGE assemblages contained within it.

Comparison of cores across the area has led to a new understanding of the construction and genesis of the Platreef.

P385 THE CHARACTERISATION OF MAGMATIC SULFIDE SYSTEMS

Leader / Jeff Foster

Team Member / Dave Hutchinson

The principal aim is to investigate the mechanisms and processes that lead to the formation of Ni-Cu-Platinum Group Element (PGE) mineralisation. A sample encompassing the main mineralised portion of the Merensky Reef has been studied in detail together with samples from the Platreef (both part of the Bushveld Complex, South Africa, plus samples of disseminated, globular and massive ore from Noril'sk-Talnakh, Russia. 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 system. CODES' research has confirmed the presence of multiple chromite layers along the contact to the footwall rocks that, together, appear to form a single-layer. A number of petrologically distinctive zones, on a mm to cm scale, can be recognised, and each hosts a distinctive sulphide and platinum group mineral assemblage. Pt and Pd are expected to behave similarly and, together with the other PGE (Os, Ir, Ru & Rh), reside in one or other of the sulphide mineral phases. LA-ICP-MS mapping has consistently revealed the presence of all PGEs, except Pt, from the Merensky and Platreef samples. Pt does not appear to be hosted within the sulphides. Conversely, Pt is present in some, but not all, of the sulphides in different portions of the Noril'sk-Talnakh intrusions. This part of the study shows there are significant problems with the current understanding of the behaviour of these elements. In the Merensky Reef, Pt minerals are abundant and appear to be associated with sulphides throughout the chromite and overlying silicate portions. Likewise, Pt minerals are spatially associated with sulphides in the Platreef and Noril'sk-Talnakh samples. The new observations cannot adequately be explained by current models for the formation of the Merensky Reef and other Ni-Cu-PGE ore-bearing systems. Consequently, new models have been devised that more accurately fit these new and unexpected observations. The cumulative evidence for the Bushveld strongly supports multiple-stage processes where magmas ponded in one or more chambers en route to the crust. In the case of the Merensky, the main mineralising events involved sedimentary-style mechanical processes that resulted in the deposition of chromitites, sulphides and platinum-group minerals under magmatic conditions.
P3B6A
STRUCTURE AND FORMATION OF THE SAVAGE RIVER MAGNETITE DEPOSIT
Leader /
Tony Webster
Team Member /
Ron Berry
Student /
Victoria Braniff
Collaborators /
Ralph Bottrill, Jafar Taheri
After 45 years of mining, the geology of the Savage River magnetite deposit is still very poorly understood, despite it being the largest metallicferous deposit in Tasmania. With the support of Grange Resources, a project was developed with the primary aim of understanding the structure of the highly strained rocks at the mine, and the application of this knowledge to problems of slope stability management, resource definition and near-mine exploration.
Key findings, to date, include:
» The main host assemblage and adjacent, less deformed, Omah Formation metaassemblages preserve extensive evidence of all phases of the deformation and metamorphism recognised in the Arthur Lineament. Despite the very high strain, bedding is well-preserved in most of the important rock packages of the mine area.
» Models, developed using Leapfrog software, have revealed that the internal structure of the North Lens is composed of several shallow, southerly-plunging pipe-like shoots (folds) within a lower-grade halo. The shoots preserve the remnants of iron-rich layers formed in high-magnesium sediments and metamorphosed to serpentine and magnetite during deep burial.
» Ore textures indicate that all magnetite is metamorphic and mostly formed pre-CaD2 (Cambrian deformation), with continued formation syn- and post- CaD2. The ore lenses have the same
deformational history as their wall rocks, and the present geometry of the ore bodies is the result of tectonic processes. The magnetite ores were not formed by post-tectonic replacement.
» The generally low temperature, brittle and unhealed Devonian structures have had the most impact on the geotechnical properties of the pit wall rocks.

P3B7A
IRON OXIDE COPPER-GOLD AND RELATED DEPOSIT TYPES
Leader /
Stuart Bull
Team Members /
Garry Davidson, Sebastien Meffre
Collaborators /
Mark Allen, Jorge Benavides, Hamish Freeman
A new research project on the volcano-sedimentary and chrono-stratigraphic architecture of the host rock succession at Prominent Hill commenced during the year. The aims are to:
» Confirm the broad scale volcano-sedimentary architecture/ environments of the host rock succession by graphic core logging, with follow-up petrographic analysis of key samples.
» Test the viability of using LA-ICP-MS analysis of U-bearing phases within this framework to establish a provisional chrono-stratigraphy.
Although the details of the project outcomes remain confidential to OZ Minerals, it can be reported that a basin framework for the mineralised interval has been constructed by integrating the sedimentary facies analysis and chrono-stratigraphic data. This framework differs substantially from what has previously been published, and has implications for both near mine and regional exploration.

Outlook /
» Secure funding and commence AMIRA P1031 – Copper, Uranium, and Precious Metals in Oxidising Sedimentary Basins: Ore Formation and Location.
» Commence project to investigate the application of near-mine ambient seismic methods to brownfields mineral exploration and in-mine seismic rock mass characterisation.
» Develop computing techniques focussing on spatial data structures.
» Expand studies at Savage River to encompass a geological interpretation of the Centre Pit and South Pit deposits.
» Hugo Galvan, Lindsey Clark and Bronto Sutopo to complete PhD theses.
» New post-doctoral study at Gosowong will switch the research focus from landscape to drainage, and develop new techniques for the identification of potentially mineralised structures in underlying bedrock.
Objective /  
To create and develop a series of small-scale, low-cost practical geometallurgical tools, protocols, proxies and processing indices for the purpose of ore-body domaining and whole mine optimisation.

Introduction /  
Geometallurgy is an exciting, cross-disciplinary activity that is having a significant economic impact on the mining industry. The ability to create and calibrate a geometallurgical ‘toolkit’ for an ore deposit at different stages in its life cycle leads to improved decision making and early recognition of processing options. The three broad variables that control the economic viability and performance of an ore deposit are the amount of CAPEX required to put a deposit into production; cost per unit metal produced; and metals pricing. Of these variables, only CAPEX and C1 costs can be controlled.

The geometallurgical approach developed in AMIRA P843 and P843A utilises calibrated, small-scale tests to create proxies, which are used to define optimal processing domains within an economic envelope. The definition of an economic envelope is directly related to the conversion of resources to reserves, based on a series of modifying factors as defined by the JORC code or equivalent. This early detailed understanding of an ore body represents a significant leap forward from previous methods, which often relied on statistically insignificant bulk tests within a resource, defined on the basis of conventional grade-tonnage distribution.

The geometallurgical approach can be applied at a number of stages in the development of a mine, with maximum returns generated in relation to feasibility studies that precede development of new ore bodies or major expansions. The continuous application of geometallurgical protocols to extant ore bodies leads to performance optimisation and reduced C1 costs. The combination of reduced C1 costs and optimised CAPEX leads to superior economic performance.

The six principal themes of P843A, coupled with the case-study modules, effectively cover many of the major risk areas of mining and minerals recovery. Furthermore, the combined presence of Themes 1, 2 and 5 greatly enhances the probability of optimal cost curve solutions. As we move into a future further constrained by ever-rising energy and environmental costs, recognition of processing domains and routes can be used to more accurately and reliably establish the reserve base and, therefore, the amount of CAPEX required for a specific production rate.
Highlights /

Theme 1 – Predictive Environmental Indices
- Bernd Lottermoser appointed as Professor in Environmental Geochemistry under the USGS New Star program. Bernd will join the team in January 2011.
- Preliminary results from long-term column leach experiments are encouraging.

Theme 2 – Integrated Blast Modelling
- A new tool developed (iFragx) that creates links between blastability and geometallurgical domains defined by the DomAin software.

Theme 3 – Deterministic Comminution Modelling
- Introduction of a simple power meter during CI crushing has shown a consistent improvement in the A*b prediction, particularly in the case of harder samples. This evaluation also confirmed the utility of the A*b Express test as a rapid means of quantifying the impact resistance of core samples, using only one test at a single low RBt energy.

Theme 4 – Texture-based Liberation and Recovery Modelling
- The Julius Kruttschnitt Mineral separability index (JKMsi) test is being further investigated as a potential method to obtain information on flotation variability.
- Software developed to simulate textures found within rocks.
- Research from a test site indicates the analysis of mineral maps is a viable way of rapidly and inexpensively producing data that can be used to rank samples for liberation potential, and hence recovery.

Theme 5 – Predictive Leaching Indices
- New, small-scale approach for determining relative sample rheology, using compressive yield stress measurements, has been applied to samples from a calcrete-hosted uranium deposit with promising outcomes.
- Agglomeration of a standard ore and a variety of ore blends has established confidence levels for repeat tests, and identified pellet porosity and moisture content as key variables affecting agglomerate strength.
- Completion of development and initial testing of the overview level diagnostic leach methodology.
- Preliminary copper sulfide speciation leaching protocol determined for analysis of chalcocite, covellite, chalcopyrite and bornite.
- Texture-based leaching simulation method updated to incorporate specific mineral leaching rates and compared with a ‘simple’ dissolution test data.
- Prototype synthetic samples produced for blast-to-leach test work.

Theme 6 – Specialist Analytical and Software Support
- Two software applications suitable for generating more value from core imaging are in development, with stoRC being close to release.

Case Studies and Technology Transfer
- Final scoping completed for 11 of the 12 sites nominated by sponsors, leading to submission of a fully costed proposal. Five case studies have commenced.
Project P4A (WAAM P843A) – GeM³ Geometallurgical Mapping and Mine Modelling – is split into the following six themes, plus a sub-project covering case studies:

- Theme 1: Predictive environmental indices
- Theme 2: Integrated blast modelling
- Theme 3: Deterministic comminution modelling
- Theme 4: Texture-based liberation and recovery modelling
- Theme 5: Predictive leaching indices
- Theme 6: Specialist analytical and software support

Case Studies and Technology Transfer

**Project Summaries**

**P4A1 PREDICTIVE ENVIRONMENTAL INDICES**

**Leader:** Mansour Edraki

**Team Members:**
Ron Berry, Barry Noller, Steve Walters

**Student:** Anita Parbhakar-Fox

Mineralogical and textural data can be combined with geochemical assays for more realistic characterisation of rocks in regard to acid generation, particularly at the very early stages of the mine life cycle. Samples from an abandoned Au mine in Queensland were subject to an ongoing column leaching experiment, and mineral surface analysis (BIAL-SEM and LA-ICP-MS) supports the geochemistry-mineralogy-texture (GtM) approach to environmental rock characterisation. The kinetic test results broadly follow the mineralogy and the onset of acid generation is correctly predicted, which would not be possible with static leach tests. The element concentrations in leachates, although at very low levels (ppb), are also consistent with the mineralogy. The combination of element and mineral mapping results shows an emerging pattern that could be used to predict the release of detrimental elements based on the solubility of host minerals. For example, primary pyrite mineral grains have a core enriched in Au and As and are surrounded by secondary sulfates and iron oxhydroxides with high Ni and Co content.

Professor Bernd Lottermoser was appointed late in the year under the UTAS new stars program. He will join the team in January 2011.

Professor Bernd Lottermoser was appointed late in the year under the UTAS new stars program. He will join the team in January 2011.

The overall aim is to generate spatially-located, post-blast, run-of-mine (ROM) size distributions in a mine planning and GeM³ context. The project will integrate measurements of bulk rock properties into advanced blast fragmentation models, using technologies and procedures developed in the initial P843 project. This will provide more appropriate inputs into advanced comminution and leaching performance models.

The potential interaction between the current iFrag modelling framework and sources of spatially-resolved data has been explored. At this stage, the focus has been on exploring the use of Measure While Drilling (MWD) data. To distinguish logical rock units on the basis of blastability in the MWD data, a variant of the DomAn software being developed within GeM³ was evaluated and subsequently linked to the iFrag interface. This extension is undergoing further development and testing, and validation will continue over the next six months. In addition, further evaluation of the Blastability Index and proxy-based data inputs will continue in 2011.

**P4A2 INTEGRATED BLAST MODELLING**

**Leaders:** Italo Onederra, Simon Michaux

**Team Members:**
Ron Berry, Alan Cocker, Toni Kojovic, Steve Walters

**Student:** Hector Parra

The overall aim is to generate spatially-located, post-blast, run-of-mine (ROM) size distributions in a mine planning and GeM³ context. The project will integrate measurements of bulk rock properties into advanced blast fragmentation models, using technologies and procedures developed in the initial P843 project. This will provide more appropriate inputs into advanced comminution and leaching performance models.

The potential interaction between the current iFrag modelling framework and sources of spatially-resolved data has been explored. At this stage, the focus has been on exploring the use of Measure While Drilling (MWD) data. To distinguish logical rock units on the basis of blastability in the MWD data, a variant of the DomAn software being developed within GeM³ was evaluated and subsequently linked to the iFrag interface. This extension is undergoing further development and testing, and validation will continue over the next six months. In addition, further evaluation of the Blastability Index and proxy-based data inputs will continue in 2011.

**P4A3 DETERMINISTIC COMMINUTION MODELLING**

**Leader:** Toni Kojovic

**Team Members:**
Julie Hunt, Simon Michaux, Pat Walters, Steve Walters

**Students:**
Luke Keeney, Adel Vatandoost

In 2010, the team has been involved in technology transfer activities with JTech, providing support to its new Summer Park facility, which aims to offer sponsors access to GeM³ tests as part of the case studies. The work at Summer Park has integrated further development of Theme 3 topics, while providing training using over 100 intervals of intact HQ and HQ diamond drill core from two significant Australian ore deposits.

Two principal outcomes have been achieved. The first is the continuation of the G* power meter evaluation, following the preliminary trials using jet black granite slabs, which indicated the specific energy required to crush the samples could be used to estimate the A*b index. Recent work focused on a selection of 138 samples with a wide range of impact hardness, sourced from two significant Australian Au-Au deposits, and select development materials.

The second area of investigation looked at the potential use of modelling to quantify the blend response of AG and SAG mills when treating two ore components with different impact resistance, or A*b hardness indices. The approach is based on a conceptualised model of the AG/SAG process, calibrated to a set milling configuration and blend of ore types of known hardness. The model can then be applied to estimate the response to other blends of the same ore types in a given mill configuration.

**P4A4 TEXTURE-BASED LIBERATION AND RECOVERY MODELLING**

**Leader:** Dee Bradshaw

**Team Members:**
Ron Berry, Julie Hunt, Maya Kamenev, Xi Hung, Kevin Petersen

**Students:**
Natalie Bonnici, Mitesh Chauhan, Cathy Evans, Kevin Petersen

The focus is on developing an appropriate methodology to populate deposit block models with recovery predictions that incorporate inherent geological variability. For this to be effective, it is necessary to understand and characterise the contribution of mineral texture and composition to the breakage and separation of ore minerals during flotation. Several research streams are being investigated in order to achieve this objective.

The major part of an Australian-based case study falls within this theme. This study is developing a recovery predictor for the block model, using an appropriate small-scale test that has potential applications in various projects. Phase 1 test work at JKRC is complete and will be assessed in parallel with the mineralogical characterisation obtained from MLA analysis. This phase compared the response of 24 ores to JKMI and batch flotation tests. Phase 2, mineralogical characterisation, is approximately two-thirds complete.

An error model has been developed to identify the number of repeat tests required for a particular sample. The equipment and methodology used for the test are being developed outside the GeM³ project at JKRC. However, its application to geometallurgical characterisation is being developed within the project as part of Mitesh Chauhan’s PhD study. Using samples from an Australian Cu-Au deposit, a preliminary protocol has been created that links batch flotation test recoveries to JKMI recoveries. This includes models based on mass and Cu recoveries, and compensates for the error associated with these models.

An analysis is also being carried out to determine relationships between mineralogy and JKMI recoveries.

PhD student, Kevin Petersen, has developed a set of tools to compare a range of image types (raw, processed, and sub-sampled). A tool to create texture has been completed. A key project aims to design a comprehensive experiment linking image processing and image analysis. A combination of artificial and natural rock textures will be used to evaluate the Phase 1 tools.
P4A5
PREDICTIVE LEACHING INDICES
Leaders / Dave Robinson, Matthew Jeffrey
Team Members / Byron Benvie, Nicole Botis, Gautam Dau, Dave Kelly, Nick Kelly, Laura Kuhar, Nicole Turner, Angus McFarlane

Researchers at the Parker Centre are responsible for the development of predictive leaching indices within GeM®. Key outcomes included:

- The new proposed small-scale approach for determining relative sample rheology, using compressive yield stress measurements, has been applied to samples from a calcrete-hosted uranium deposit in Western Australia with promising outcomes.
- Agglomeration of a standard ore and a variety of ore blends has established confidence levels for repeat tests, and identified pellet porosity and moisture content as key variables affecting agglomerate strength.
- Completion of development and initial testing of the overview level diagnostic leach methodology.
- Determination of a preliminary copper sulfide operation leaching protocol for analysis of chalcocite, covellite, chalcopyrite and bornite.

Outlook /

- Develop a research team around Bernd Lottermoser, with a focus on environmental indices.
- Improve quality and understanding of inputs into iFragX, with the aim of developing robust, domain-based, blast-to-sort models.
- Continue to develop GeM® and A*b indices through a combination of core research and case studies.
- Attract a postdoctoral research fellow to accelerate small scale physical flotation testing and texture based modelling.
- Select a case study site to trial the diagnostic leach protocol.
- Expand capabilities in dump and heap leach, fluid-flow and metal liberation modelling.
- Create sequential and simultaneous analytical functions in DomAln software.
- Investigate alternate models for the development of SimLeach.
Objective / 
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.

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) ICP-MS, non-destructive multi-element analysis using nuclear (PIXE) and synchrotron-based X-ray microprobes (XFMI), and development of new stable-isotope solution-based analytical techniques. Research activities also develop data interpretation tools, such as new algorithms and new 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 the Australian National University.

Highlights / 
- New uraniumite and sphene standards were developed for U-Pb dating of these minerals, leading to significant improvements in accuracy of their age determinations.
- Development of a new technique for creating images from LA-ICP-MS data that enables researchers to analyse irregularly shaped domains, and merge these results with sample images to display the data in a precise spatial context.
- Development of a mapping technique for Large-scale Electric Field Distribution in sulfide minerals.
- Development of Hyper-spectral Ionoluminescence analysis mapping on the CSIRO nuclear microprobe.
- The first XANES mapping experiments were performed on the XFMI beamline using Misa-384 detector, looking at As and Fe redox state and chemical speciation.
Core Projects /
Theme 5A – Advancing Spatially Resolved Mass Spectrometry
PS01 LA-Q-ICP-MS analysis development
PS02 New LA-Q-ICP-MS applications
PS03 New LA-Q/MC-ICP-MS applications
PS04 New stable isotope Ms applications
PS04A Cracking the sulfate isotopic composition problem in ancient hydrothermal systems: application of the Carbonate-Associated Sulfate (CAS) method

Theme 5B – Advancing Non-Destructive Focused-Beam Spectroscopy
PSB1 Ion beam analysis development
PSB2 New ion beam applications
PSB2A Improved quantification of PIXE analyses of fluid inclusions using internal standardisation and accurate volumetric determination
PSB3 Synchrotron X-ray probe development
PSB4 New synchrotron-based applications

Theme 5C – Data Interpretation Tools
PS02 Improved image processing algorithms for LA-iCp-Ms
PS03 Modelling of crystallisation and melting processes

The above list represents active projects in 2010

Project Summaries /
PSA1 LA-Q-ICP-MS ANALYSIS DEVELOPMENT
Leaders / Sebastien Meffre, Leonid Danyushevsky
Team Member / Marcel Guillong
Students / Sarah Gilbert, Dan Gregory
Collaborators / Fred Fryer, Terry Mernagh, Bill Papas, Michael Shelley, Naoki Sugiyama
This project designs and develops new instrumentation to ensure continuing advances in geological LA-Q-ICP-MS applications. Example developments include ablation cells, the interface between the laser and the mass-spectrometer, and testing new types of laser microprobes and mass-spectrometers. The focus during the year was on improving the sensitivity, reliability and versatility of the LA-Q-ICP-MS instrumental set-ups at the CODES analytical facility. Activities included:

- An optimal combination of the three laser microprobes and three mass-spectrometers was determined, which maximises the effectiveness of the facility and the quality of the output.
- The performance of the new collision cell design, installed in the Agilent 7700x mass-spectrometer, was assessed for a range of laser ablation and bulk solution applications. Collision cell technology was found to provide significant benefits for in-situ measurements of S isotopic compositions in sulfides by LA-Q-ICP-MS, and for bulk solution ICP-MS of geological samples.
- FEP (fluorinated ethylene propylene) tubing was found to be superior when various types of plastic tubing were tested for their suitability as an interface between the laser-probe and the mass-spectrometer in relation to minimising background levels and instrument drift. It was demonstrated that instrument drift is largely related to absorbed air and moisture on the surfaces of the samples, ablation cells and the interface tubing.
- Significant improvement to the software and hardware of the Resolution 530 laser probe was achieved in close co-operation with the manufacturers (Laurn, Technic and Resonetics).
PSA2 NEW LA-Q-ICP-MS APPLICATIONS

Leaders / Marcel Guillong, Leonid Danyushevsky

Team Members / Sebastien Meffre

Student / Sarah Gilbert

Collaborators / Kathy Bhong, Rich Friedman, Jung Hun Seo, Roland Maas, Thomas Pertke, Massimo Raveggi, Markus Waelse

New geological LA-Q-ICP-MS 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. The main outcomes in the past year were:

- The ablation cell design for the Resolution M50 Laser Microprobe resulted in less than 2% error over the entire ablation space of the cell, thus allowing for development of highly accurate LA-ICP-MS applications.
- Using the Resolution M50 Laser Microprobe, the detection limits in the single digit ppt region were achievable with a laser beam size of 180 microns, opening opportunities for in-situ determination of ultra-low elemental concentrations in minerals.
- New analytical techniques are being developed for quantitative, in-situ analysis and the imaging of isotopic compositions of key elements in a range of geological materials. This will provide new spatially resolved information to help unravel processes involved in ore formation.

Further in-situ Pb isotope work on pyrite was conducted; however, the most important new advance was the development of a new technique for creating images from LA-ICP-MS data according to the y,z position in the laser cell, rather than time (as in the case with existing protocols). Instead of being restricted to rectangular domains, this new approach allows images to be created from irregular shapes and enables the analyst to follow non-linear features (e.g. crystal growth zones). This also allows laser ablation results to be merged with referenced images of the sample, illustrating the analytical results in a precise spatial context.

PSA3 NEW LA-MC-ICP-MS APPLICATIONS

Leaders / Janet Hergt, Bence Paul

Team Members / Leonid Danyushevsky, Sebastien Meffre, Jon Woodhead

Student / Sid Palen

Collaborators / Chris German, Daryl Green

The aim is to develop new analytical protocols for the measurement of non-conventional stable isotope compositions (e.g., Cu, Mo) that can be used to explore ore-forming processes. Progress includes the re-development of robust Cu separation protocols that can be applied to a broad range of geological matrices (e.g., to sulfide and silicate samples). This technique has been tested using in-house reference materials and demonstrated to generate data that is similar or higher in quality compared to data produced by other laboratories, worldwide. The method is currently being applied to hydrothermal sediment samples from the Rainbow vent field on the Mid-Atlantic Ridge, as part of an MSc project conducted by Sid Palen.

PSA4 NEW STABLE ISOTOPE MS APPLICATIONS

Leaders / Janet Hergt, Bence Paul

Team Members / Leonid Danyushevsky, Sebastien Meffre, Jon Woodhead

Student / Sid Palen

Collaborators / Chris German, Daryl Green

The aim is to develop new analytical protocols for the measurement of non-conventional stable isotope compositions (e.g., Cu, Mo) that can be used to explore ore-forming processes. Progress includes the re-development of robust Cu separation protocols that can be applied to a broad range of geological matrices (e.g., to sulfide and silicate samples). This technique has been tested using in-house reference materials and demonstrated to generate data that is similar or higher in quality compared to data produced by other laboratories, worldwide. The method is currently being applied to hydrothermal sediment samples from the Rainbow vent field on the Mid-Atlantic Ridge, as part of an MSc project conducted by Sid Palen.

Protocols for molybdenum isotope analysis have also progressed using reference materials supplied from other laboratories, including those at Bristol, Bern and Curtin universities. An isotope spike has been prepared and characterised to facilitate the precise analysis of sample solutions. Preliminary work has commenced on molybdenite ore samples.

PSA4A CRACKING THE SULFATE ISOTOPE COMPOSITION PROBLEM IN ANCIENT HYDROTHERMAL SYSTEMS: APPLICATION OF THE CARBONATE-ASSOCIATED SULFATE (CAS) METHOD

Leader / Garry Davidson

Team Members / David Cooke, Sandrin Feig, Janet Hergt

Collaborators / Rosa Figueredo e Silva, Steffen Hagemann

This project evaluates the use of carbonate-hosted sulfate as a tool for determining the composition of oxidised sulfur in ore systems, where no sulfate minerals are available. The substitution of SO_4 into carbonate has been well-established for sedimentary carbonates, but the levels that substitute into hydrothermal carbonates are far lower (commonly <100 ppm). Modern beam-based isotopic measurement techniques cannot determine the isotopic composition of sulfate at such low concentrations. Furthermore, use of elemental analysers, which are increasingly being adopted for whole-rock sulfur determination, is not useful for samples with several forms of sulfur (i.e., sulfides, sulfates, etc.). Consequently, an important objective is to refine a chemical means of extracting and measuring the isotopic composition of carbonate-hosted sulfate at low levels.

The extraction facility was moved and refurbished during 2010, which took most of the year. However, the facility is now complete and ready for substantial activity in 2011.

PSB1 ION BEAM ANALYSIS DEVELOPMENT

Leader / Jamie Laird

Team Members / Chris Ryan, Stacey Borg

Collaborators / Brett Johnson, Jeff McCaulm

The aim is to better understand the role of metal sulfide semiconduction on the deposition of precious metals, such as gold. The major outcome of the work this year was the completion of the technique for laser mapping of electric fields in sulfides, and its illustration on pyrite, galena and chalcopyrite assemblages. This is an important step in correlating growth with surface properties and, in particular, the role of defects and impurities. In parallel with this research, the Scanning Electrochemical Microscope is nearing completion and will provide the means to directly grow gold on the regions characterised by high electric fields, as identified by the laser mapping technique.

PSB2 NEW ION BEAM APPLICATIONS

Leader / Jamie Laird

Team Members / Chris Ryan, Jamie Wilkinson

The aim is to introduce new ion beam techniques developed by the community to better characterise geological materials, in particular fluid inclusions.

The major outcome was the completion and illustration of hyperspectral ionoluminescence mapping on the CSIRO nuclear microprobe. Maps of intrinsic defects in epidote and quartz have been collected and correlated with similar measurements made with cathodoluminescence (CL). The method, when combined with PIXE analysis, allows both elemental and chemical information to be extracted simultaneously when performing fluid inclusion analysis.

PSB2A IMPROVED QUANTIFICATION OF PIXE ANALYSES OF FLUID INCLUSIONS USING INTERNAL STANDARDISATION AND ACCURATE VOLUMETRIC DETERMINATION

Leader / Jamie Wilkinson

Team Members / Leonid Danyushevsky, Marcel Guillong, Jamie Laird, Chris Ryan, Clara Wilkinson

Student / Sarah Gilbert

PIXE data acquisition was completed for three principal sample sets: synthetic fluid inclusions; natural halite-saturated inclusions from the San Pedro porphyry-skarn deposit, New Mexico, and dilute CO_2-bearing inclusions from the Butte porphyry Cu-Mo deposit, Montana.
Comparison of the San Pedro data between LA-ICP-MS analysis and PIXE shows that there are marked inclusion depth- and mass-dependent deviations in the PIXE, resulting from an imperfect correction for inclusion geometry and depth effects. Modelling depth effects shows that current data reduction protocol underestimates light elements (Cl) at shallow depths (less than ~20 microns), and overestimates them at greater depths in an approximately exponential relationship. For intermediate masses (e.g., Zn), the geometric model is fairly accurate across the depth range, but data require a geometric correction. For higher masses, there is an increasing tendency to underestimate concentration. Using a “known” Cl concentration to model the depth, improved quantification is obtained for most elements at relatively shallow depths. Initial PIXE data have been obtained on a set of Blute inclusions for which PIXE data suggest low Cl concentrations of 0.2-0.8 wt% Cl, significantly below those assumed from microthermometry. Na peaks were clearly identified in a number of spectra, and quantification gave Na concentrations mainly between 0.1-0.6 wt%, broadly consistent with the pixe data. These results indicate that Cl is unlikely to be the only anion present in inclusions for which pixe data suggest low Cl concentrations from microthermometry.

The aims are to:
- Develop model-independent algorithms for tracking the behaviour of trace elements during magma generation and evolution processes.
- Modelling of post-entrapment modifications in melt inclusions in minerals.
- Simulation of processes of mantle and crustal melting, and melt crystallisation.
- Develop a range of general petrological tools. These algorithms are continuously implemented in the future versions of the Petrolab software package.

Petrolab v.1.1 was released during the year (http://petrolab.web.ru/), which contained enhanced algorithms for modelling melt crystallisation accompanied by H₂O degassing during magma ascent to the surface, and improvements to algorithms for modelling post-entrapment modifications to melt inclusions in olivine phenocrysts.

**Outlook**

- Development of sample preparation and handling techniques for LA-ICP-MS to improve precision and accuracy of the analysis.
- Improving accuracy of fluid inclusion analysis by LA-ICP-MS, through quantification of depth-dependent elemental fractionation.
- Developing new protocols for the in-situ analysis of Mo isotope compositions in molybdenite.
- Correlation of electric field mapping and in-situ gold growth on sulfide minerals using the laser mapping and scanning electrochemical microscope.
- Integration of PIXE, non-Rutherford backscattering spectrometry and LA analysis on quartz-hosted fluid inclusions within the new CSIRO nuclear microprobe chamber.
- Implementation of XANES data cube analysis within GeoPIXE software.
- Technique development for computer-corrected and enhanced images.
- Release of Petrolab v.3.2, which contains a range of general petrological tools.
Students enrolled in the UTAS Higher Degree by Research (HDR) Program make a major contribution to the research activities of the Centre of Excellence. 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 54 students enrolled in the program during 2010, which included seven new PhD students – Jeff Steadman, USA; Daniel Gregor, Selina Wu and Marc Rinnie, Canada; plus Matthew Cracknell, Sarah Gibert and Brendan McGee from Australia. Fifteen PhD students and one MSc student had their theses under examination, nine of whom graduated: Ralf Schaa, Paul Cromie, Jacqueline Walker, Blackwell, Adam Bath, Wojciech Zukowski, Anna Liza Cuisin, Heidi Pass, Susan Belford, and Tim Ireland.

Ten PhD students suspended their candidature for part or all of the year, two chose to study part-time, and another two withdrew. This reduced the effective PhD workforce to around 45, which was lowered further to 35 by the larger-than-usual number of thesis failures and got around the problem by hiring two helicopters. However, ‘the class of 2010’ were not daunted by previous failures and got around the problem by hiring two helicopters. They were given an introduction to geophysical modelling. These were presented by two highly respected industry consultants, Scott Halley and Jun Cowan. In addition, Michael Roach from UTAS/CoDES presented an introduction to geophysical techniques and GIS. One Deposit Models course was presented by a broad cross-section of CoDES researchers and included a presentation on uranium deposits by Roger Skirrow of Geoscientific Australia. As an example, in the ore Deposit Models course most students were from outside UTAS.

Part of the program’s success is that it is continually being updated and enhanced to meet the needs of the students. For instance, Brownfield Exploration incorporated a new format of intensive two and three-day workshops, including geochronological and 3D modelling. These were presented by two highly respected industry consultants, Scott Halley and Jun Cowan. In addition, Michael Roach from UTAS/CoDES presented an introduction to geophysical techniques and GIS. One Deposit Models course was presented by a broad cross-section of CoDES researchers and included a presentation on uranium deposits by Roger Skirrow of Geoscientific Australia. The course attracted many industry participants from as far afield as the Middle East, North America, South America, and Africa.

The program continued to be supported by the Minerals Council of Australia, through the Minerals Tertiary Education Council, which has played a significant role in its increasing success.

Honours Program /

Honours enrolments had risen decisively the previous year, and this high level was maintained in 2010 with a total of 15 students, which is around the current capacity for the program. This figure includes two students that graduated mid-year, and three that were sourced from outside institutions - University of Newcastle, University of Adelaide, and the University of Canterbury, New Zealand.

Projects were spread across the disciplines in the following categories: economic geology (4), geothermal geophysics, resource geophysics (3), sedimentology and sedimentological geophysics (3), archaeological geophysics, volcanology, structure and geochronology, and igneous petrology. Six projects were based in Tasmania and one in New Zealand, with the remainder spread throughout Australia. Projects were sponsored by Mineral Resources Tasmania, Grange Power, Anglo American, Emmerd Resources, Pacific Davide, MMG, Jabiru Metals, ASEG, and the University of Sydney.

Many of CoDES/UTAS students are members of the UTAS Student Chapter of the Society of Economic Geologists. Jeff Steadman and Pedro Fonseca took over as co-presidents of the Chapter in 2010 and, together with the new committee, continued on the path of their predecessors by organizing a wide range of events, both for professional development and recreation. A highlight of the program continued to be supported by the Minerals Council of Australia, through the Minerals Tertiary Education Council, which has played a significant role in its increasing success.

Twenty-two Honours students from UTAS, Melbourne University, ANU, Curtin and ICU completed the long-established Exploration Skills Mapping Course, led by Tony Webster and Andrew McNeill. The increasing popularity of this course with mainland universities resulted in it being full to capacity this year, with several people on the waiting list failing to gain a place. As a result, it has been decided to present the course twice in 2011. The Honours year was administered by Garry Davidson, with Peter McGoldrick supervising the coursework aspects. Principal supervision was undertaken by Michael Roach (4), Anya Reading (2), Garry Davidson (2), Andrew McNeill, Tony Crawford, David Cooke, Anthony Harris, Emily Johnson, Stuart Bull, and Peter McGoldrick. Additional co-supervision was provided by Jocelyn McPhee, Sharon Allen, Jeff Foster, David Selley and Mike Baker, plus Mark Dunett from Mineral Resources Tasmania. Components of the internal MTCG and HEPS Honours courses were taught by Tony Webster, Andrew McNeill, Garry Davidson, Leonid Danyushevsky, Jeff Foster, David Cooke, Bruce Gemmill, Rob Scott, Anya Reading, Michael Roach and Peter McGoldrick.
OUTREACH

The Centre has developed a comprehensive strategy to bring a greater awareness of the earth sciences to the broader community. Key components of this strategy include a commitment to communicate across the full spectrum of demographic groups, and to include a mix of activities aimed at teachers and career advisors in the program.

Activities started with children as young as three and four years old. Sharon Allen visited the local Lady Gowrie Child Centre in June, where she introduced a large group of pre-schoolers to the wonders of volcanoes - demonstrating a 'pretend' eruption using vinegar and baking powder. Earlier in the year, CODES introduced the 'Gemnasium', which is a large bed of brightly polished rocks from around the world. This new feature is popular with all age groups, but is a particular favourite with the very young. Children love to fossick through the myriad of coloured stones searching for the most exotic looking 'gem'. The stones are also mounted on display boards and used in a variety of educational tools that teach the children about geology while they are also having fun. This feature has also proven popular with local community groups, such as the local Taroona Cubs, who were one of a number of ad hoc visitors during the year.

Primary schools, high schools and colleges were once again a major focus of the program in 2010, with over ten visits to CODES spread throughout the year. These visits were mostly supervised by Michael Roach, who provided entertaining and educational presentations on seismology, with a high level of audience participation. Other visits were hosted by Ross Large, Andrew McNell and Karin Orth. CODES' staff also visited a number of these educational institutions. As an example, Rob Scott has committed to a series of visits to a local primary school to introduce students to the wonders of rocks and fossils.

The Centre continued its ongoing participation in the Science Experience initiative by hosting a workshop for Year-11 students early in the year. The program aims to inspire students to continue their science studies, and is supported by the Science Schools Foundation, Rotary and the Australian Science Teachers Association.

Twenty-one teachers and career advisors from secondary schools in Tasmania, Victoria and NSW visited the Centre in January as part of the annual UTAS Career Advisor Symposium. The visit was hosted by Bruce Gemmell and Michael Roach and included a presentation, a full tour of the facilities and a number of scientific demonstrations.

Support continued for the Teacher Earth Science Education Program (TESEP). This national program 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. A further three workshops were held at the UTAS Hub during the year, which mixed interactive classroom and laboratory sessions with off-site field activities at local sites of geological interest.

For the older age groups, further lectures were held as part of the University of the Third Age (U3A) program, which seeks to improve the quality of life of mature-age people through a range of low-cost academic courses. Another initiative aimed at this demographic was a series of presentations to the School for Seniors. This group falls under the umbrella of the local Adult Education program, but operates in a less formal way than U3A. The main aims of the group are to mix companionship, fun and learning through a variety of educational and social events. In keeping with the format, Andrew McNell delivered talks that covered an insight into the world of geology, interspersed with amusing anecdotes from his much-travelled career.

Primary sources of information and data were used to support the text, including records from the Centre and interviews with staff and visitors.
Industry Links and Collaborations

Objective

- 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.

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 2010, AMIRA funded these major projects for CODES:

- P765A - Geochemical and geological halos in green rocks and lithocaps – The explorer’s toolbox for porphyry and epithermal districts
- P843A - (GeM® project) Geometallurgical mapping and mine modelling
- PK62 - NPFGe potential of mafic and ultramafic – a combined melt inclusion and numerical modelling approach
- P1022 - The rapid approximate inversion of TEM data
- P1041 - Application of new technologies to gold deposits

Researchers Who Work Jointly in CODES and the Collaborating Organisations

<table>
<thead>
<tr>
<th>INSTITUTION</th>
<th>CODE ARC GRANT</th>
<th>NODE MATCHING FUNDS</th>
<th>INDUSTRY / AMIRA FUNDS</th>
<th>UNIVERSITY / CSIRO FUNDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>University of Queensland (incl. Julia Krutscher) Mineral Research Centre &amp; WH Bryan Centre</td>
<td>Steve Walters (20%), Simon Murchie, Dave Bradshaw (11%), Alan Bye (11%), Italo Ondederra (12%), Angus McFarlane (20%)</td>
<td>Angus McFarlane (20%), Steve Walters (11%)</td>
<td>Angus McFarlane (6%), Kerri Keeney, Italo Ondederra (12%), Dave Bradshaw (14%), Steve Walters (50%), Louisa Groves, Alan Bye (11%)</td>
<td></td>
</tr>
<tr>
<td>University of Melbourne</td>
<td>Bence Paul</td>
<td>Roland Maas</td>
<td>Janet Hirst</td>
<td></td>
</tr>
<tr>
<td>Australian National University</td>
<td>Angela Halfpenry</td>
<td></td>
<td>Stephen Cox</td>
<td></td>
</tr>
<tr>
<td>CURO Exploration and Mining</td>
<td>Jamie Lard (50%), Stacey Berg (50%)</td>
<td>Jamie Lard (50%), Stacey Berg (50%)</td>
<td>Chris Ryan, WeiHua Liu</td>
<td></td>
</tr>
<tr>
<td>CSIRO Exploration and Mining</td>
<td>Weihua Liu</td>
<td>Chris Ryan, WeiHua Liu</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

PhD student Hossein Kouhestani from Tarbiat Modares University, Iran, visited Khin Zaw for six months, starting in July, to collaborate on epithelial deposits in Iran.

Tim Lyons, from the University of California Riverside, visited Peter McGoldrick from March to June to collaborate on northern Australian Proterozoic Basin REDOX history.

Thomas Pettke, from the University of Bern, visited Vladimir Kamenevskiy to collaborate on seafloor alteration of basaltic glass and fluid inclusions.

PhD student Francisco Jose Testa from Universidad del Sur, Argentina, visited David Cooke for just over three months, starting in October, to collaborate on the Bi-Au-Cu San Francisco de los Andes breccia pipe deposit, San Juan Province, Argentina.

PhD student, Lejun Zhang, from Hefei University, China, visited David Cooke for one year, starting in March, to collaborate on alteration and mineralisation of the Nihe-Fe deposit, Anhui province, China.
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 2010, 197 research reports were presented to industry clients, and meetings were held to present and discuss progress and adoption of research results.

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 /  
Short courses and workshops continued to play a key role in the Centre’s technology transfer activities. Throughout the year, a total of 27 courses were held at various locations around the world including Chile, China, Indonesia, Italy, Myanmar, New Zealand, Peru, Philippines and the USA.

Total attendance by industry geologists, academic researchers and postgraduate students was 811, with 20 presenters from the CODES’ UFAS. Hubs, plus a number of students, involved in delivering the lectures.
## Performance Indicators

### Performance Measures

#### Research Findings

<table>
<thead>
<tr>
<th>Performance Measure</th>
<th>Target</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Publications in international journals</td>
<td>50%</td>
<td>40%</td>
</tr>
<tr>
<td>% of publications in A/A* journals</td>
<td>70%</td>
<td>68%</td>
</tr>
<tr>
<td>Reports to industry collaborators</td>
<td>80%</td>
<td>197</td>
</tr>
<tr>
<td>Special issues and/or research monographs</td>
<td>1 per 2 years</td>
<td>0</td>
</tr>
<tr>
<td>Invitations to give keynote conference presentations</td>
<td>10%</td>
<td>16</td>
</tr>
<tr>
<td>Papers at national/international meetings</td>
<td>70%</td>
<td>103</td>
</tr>
</tbody>
</table>

#### Investigators

<table>
<thead>
<tr>
<th>Performance Measure</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average % of CI research in Centre</td>
<td>70%</td>
</tr>
<tr>
<td>Average % of PI research in Centre</td>
<td>15%</td>
</tr>
<tr>
<td>Percentage of team-based projects</td>
<td>80%</td>
</tr>
<tr>
<td>Percentage of Australian cross-institutional projects</td>
<td>30%</td>
</tr>
</tbody>
</table>

#### Research and Professional Education

<table>
<thead>
<tr>
<th>Performance Measure</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of RHD students attracted from interstate</td>
<td>40%</td>
</tr>
<tr>
<td>Percentage of RHD students attracted from overseas</td>
<td>40%</td>
</tr>
<tr>
<td>Honours students in Centre programs</td>
<td>10</td>
</tr>
<tr>
<td>RHD students in Centre programs</td>
<td>44</td>
</tr>
<tr>
<td>Percentage of students in projects linked with industry</td>
<td>50%</td>
</tr>
<tr>
<td>Professional short courses/workshops for industry</td>
<td>10%</td>
</tr>
</tbody>
</table>

#### International, National and Regional Links and Networks

<table>
<thead>
<tr>
<th>Performance Measure</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centre national or international conferences/workshops</td>
<td>1 per 2 years</td>
</tr>
<tr>
<td>Registrants at Centre's conferences/workshops</td>
<td>100%</td>
</tr>
<tr>
<td>International and national visitors per year</td>
<td>50%</td>
</tr>
<tr>
<td>Collaborative projects with other global centres/groups</td>
<td>10%</td>
</tr>
<tr>
<td>External collaborators using Centre's equipment</td>
<td>10%</td>
</tr>
</tbody>
</table>

#### Organisational Support

<table>
<thead>
<tr>
<th>Performance Measure</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual cash contributions from USAS</td>
<td>$1,800,000</td>
</tr>
<tr>
<td>Annual cash support from other collaborating universities &amp; CSIRO</td>
<td>$205,000</td>
</tr>
<tr>
<td>Annual cash support from industry</td>
<td>$2,000,000</td>
</tr>
<tr>
<td>Number of new organisations recruited to or involved in the Centre</td>
<td>1pa</td>
</tr>
</tbody>
</table>

#### Governance

<table>
<thead>
<tr>
<th>Performance Measure</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joint post-doctoral appointments between collaborating institutions/organisations</td>
<td>5</td>
</tr>
<tr>
<td>Balance and experience of Advisory Board members</td>
<td>Excellent balance</td>
</tr>
<tr>
<td>Annual review of strategic and business plans</td>
<td>Yes</td>
</tr>
<tr>
<td>Effectiveness of Centre Research Committee</td>
<td>High</td>
</tr>
<tr>
<td>Effectiveness of Science Planning Panel</td>
<td>High</td>
</tr>
<tr>
<td>Public profile of Centre</td>
<td>High</td>
</tr>
</tbody>
</table>

#### National Benefit

<table>
<thead>
<tr>
<th>Performance Measure</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centre research has input into a major mineral discovery</td>
<td>1 per 5 years</td>
</tr>
<tr>
<td>Employment of Centre's postgraduates by minerals industry</td>
<td>&gt;65%</td>
</tr>
</tbody>
</table>

### End-User Links

- Frequency of meetings with industry representatives: 15pa
- End-user representatives to Science Planning Panel and Advisory Board: 20% / 20%
- Frequency of meetings with AMIRA Research Coordinator: 10pa
- Number of industry visitors to Centre: 180pa
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. 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.

2010 Income /

Total CODES income was $9.5 million (see Table 1). This was derived principally from industry (36%), the ARC (33%) and UTAS (22%) (Figure 1). The main income streams over time are compared in Figure 2, demonstrating that ARC funding continues to be 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 approximately $3 million per annum ARC funding be matched, dollar for dollar, with agreed core funding from collaborators/contributors (N.B. annual ARC funding was reduced from $3 million pa to $2.7 million pa for the extension period, 1.7.2010 to 31.12.2013). This combined cash income is used to fund core research projects at the Centre. All agreed cash funding from the collaborators/contributors (except that of UQ and ANU nodes and some of the Industry Partners) was up to date at the end of 2010 (see explanation in the ‘CoE node income’ and ‘Industry income’ sections on page 73 regarding this deficit). It should be noted that, in total, CODES has received $14.5 million more to-date towards 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/contribution, with UTAS providing the most substantial portion. The following is a summary of the main income streams to the CoE in 2010:

- ARC income: The only ARC income received in 2010 was the CoE’s ARC Grant ($3 million). Total ARC funding decreased by $300k due to the following factors:
  - The CoE ARC Grant has been reduced by approximately 20% during the extension period
  - A previous Discovery Grant finished in 2010
  - There were no LIEF Grant funds awarded to CODES in 2010.

- CoE node income: The CoE’s Australian nodes comprise the University of Queensland (UQ), University of Melbourne (uMelb), Australian National University (ANU) and CSIRO Exploration and Mining (CSIRO E&M). 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. Although these matching funds are counted as income to the CoE (Table 1), they are actually held and expended at the node institutions. Expenditure of both portions of node funding is reported annually to CODES. The UMelb node has received all of their agreed 2010 ARC income from CODES and contributed their matching funds to the Centre. In the case of the UQ, ANU and CSIRO E&M nodes, not all of these reciprocal transactions were able to take place for the July to December period because the CoE Extension Agreement had not been finalised. It is anticipated that the Agreement will be finalised shortly and these transactions will be included in the 2011 accounts.


- Industry income: Total industry funding in 2010 was $3.4 million, of which the largest contribution (43%) was from AMiRA International for CoE core and non-core research projects. Industry funding decreased by 23% ($1 million) in 2010. This was mainly due to the following factors:
  - Completion of a large AMiRA project in mid 2010
  - Reduced funding to an extended AMiRA project
  - A temporary $160,000 shortfall in Industry Partner income for the second half of the year, due to late finalisation of the CoE Extension Agreement – this will be rectified in 2011
  - Industry income payments for a two-year period were made in 2009. This anomaly had the double effect of making last year’s figure artificially high ($200k higher) and this year’s income abnormally low.

- $253k of funds from the AMiRA GeM Project were transferred to UQ and will be counted as income to UQ (see Notes to Financial Statements)

- $118k income from UQ’s CRC GRE could not be listed as income to CODES because it had already been counted as income to the CRC.

As demonstrated by the abovementioned points, there are a number of mitigating factors for this year’s decrease in industry funding. However, over the life of the Centre, this funding remains well above the CoE Agreement target of $700k to $1.5 million per year.

Host institution support: UTAS increased its core cash funding by 4% to $2.1 million, continuing an upward trend. This funding relates primarily to research salaries, PhD scholarships, equipment purchases and income earned by the Centre from research output. UTAS also provided over $1.8 million in in-kind support in 2010.

2011 Income Estimates /

Despite Australia escaping the worst effects of the global financial crisis, there is no doubt that it had a negative impact on income from industry in 2010. Although the outlook for the minerals industry is now more positive, a conservative view has been taken on industry funding for 2011 because companies are still taking a cautious approach to investment in research.

Although industry funding may decrease in 2011, and ARC funding will decrease due to a 20% funding reduction for the CoE extension period, all other income streams are expected to remain stable.
### Table 1

#### CASH INCOME FINANCIAL STATEMENT 2005–2010

<table>
<thead>
<tr>
<th></th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ARC - Centre of Excellence Grant</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CoE agreed core funding* - 2005 grant indexation (not received until 2006)</td>
<td>0</td>
<td>31,500</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>CoE agreed core funding* - ARC grant</td>
<td>1,500,000</td>
<td>3,121,198</td>
<td>3,184,402</td>
<td>3,248,088</td>
<td>3,313,864</td>
<td>3,097,230</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1,500,000</td>
<td>3,152,698</td>
<td>3,184,402</td>
<td>3,248,088</td>
<td>3,313,864</td>
<td>3,097,230</td>
</tr>
<tr>
<td><strong>CoE nodes matching funds</strong> (agreed matching funds held at node institutions)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CoE agreed core funding*</td>
<td>0</td>
<td>295,000</td>
<td>255,000</td>
<td>250,000</td>
<td>257,580</td>
<td>242,500</td>
</tr>
<tr>
<td>Additional funding (pre-existing or new)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>0</td>
<td>295,000</td>
<td>255,000</td>
<td>250,000</td>
<td>257,580</td>
<td>242,500</td>
</tr>
<tr>
<td><strong>Other ARC grants</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CoE agreed core funding*</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Additional funding (pre-existing or new)</td>
<td>328,791</td>
<td>397,325</td>
<td>394,338</td>
<td>471,524</td>
<td>403,889</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>328,791</td>
<td>397,325</td>
<td>394,338</td>
<td>471,524</td>
<td>403,889</td>
<td>0</td>
</tr>
<tr>
<td><strong>Other Commonwealth Government</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CoE agreed core funding*</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Additional funding (pre-existing or new)</td>
<td>7,184</td>
<td>19,649</td>
<td>24,666</td>
<td>62,680</td>
<td>2,046</td>
<td>87,856</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>7,184</td>
<td>19,649</td>
<td>24,666</td>
<td>62,680</td>
<td>2,046</td>
<td>87,856</td>
</tr>
<tr>
<td><strong>State Government</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CoE agreed core funding*</td>
<td>200,000</td>
<td>200,000</td>
<td>200,000</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Additional funding (pre-existing or new)</td>
<td>68,000</td>
<td>852</td>
<td>4,000</td>
<td>8,000</td>
<td>2,500</td>
<td>2,396</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>268,000</td>
<td>200,852</td>
<td>204,000</td>
<td>8,000</td>
<td>2,500</td>
<td>2,396</td>
</tr>
<tr>
<td><strong>Local Government</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CoE agreed core funding*</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Additional funding (pre-existing or new)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Industry/private</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CoE agreed core funding*</td>
<td>886,646</td>
<td>1,582,537</td>
<td>1,825,010</td>
<td>2,158,677</td>
<td>2,182,472</td>
<td>1,298,919</td>
</tr>
<tr>
<td>Additional funding (pre-existing or new)</td>
<td>444,803</td>
<td>909,052</td>
<td>938,913</td>
<td>1,487,995</td>
<td>2,268,323</td>
<td>2,117,721</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1,313,448</td>
<td>2,492,059</td>
<td>2,763,923</td>
<td>3,646,671</td>
<td>4,450,795</td>
<td>3,416,640</td>
</tr>
<tr>
<td><strong>Contracts/consultancies/revenue raising</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CoE agreed core funding*</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Additional funding (pre-existing or new)</td>
<td>143,767</td>
<td>286,675</td>
<td>305,743</td>
<td>368,160</td>
<td>383,012</td>
<td>411,097</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>143,767</td>
<td>286,675</td>
<td>305,743</td>
<td>368,160</td>
<td>383,012</td>
<td>411,097</td>
</tr>
<tr>
<td><strong>University of Tasmania</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CoE agreed core funding*</td>
<td>341,744</td>
<td>1,334,728</td>
<td>1,147,471</td>
<td>1,128,759</td>
<td>1,493,319</td>
<td>2,107,854</td>
</tr>
<tr>
<td>Additional funding (pre-existing or new)</td>
<td>98,623</td>
<td>678,084</td>
<td>566,682</td>
<td>468,257</td>
<td>589,469</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>437,367</td>
<td>2,012,812</td>
<td>1,714,153</td>
<td>1,597,026</td>
<td>2,082,788</td>
<td>2,107,854</td>
</tr>
<tr>
<td><strong>Other income sources/interest</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CoE agreed core funding*</td>
<td>4,348</td>
<td>60,006</td>
<td>53,000</td>
<td>131,585</td>
<td>25,147</td>
<td>84,795</td>
</tr>
<tr>
<td>Additional funding (pre-existing or new)</td>
<td>4,348</td>
<td>60,006</td>
<td>53,000</td>
<td>131,585</td>
<td>25,147</td>
<td>84,795</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>8,696</td>
<td>120,012</td>
<td>106,000</td>
<td>263,170</td>
<td>50,303</td>
<td>169,590</td>
</tr>
<tr>
<td><strong>Total annual income</strong></td>
<td>4,292,926</td>
<td>8,917,056</td>
<td>8,900,226</td>
<td>9,783,674</td>
<td>10,838,635</td>
<td>9,450,368</td>
</tr>
<tr>
<td>Grand total of all income to date</td>
<td>52,182,885</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Core funding listed in the CoE Agreement and matched to the ARC funds

---

### Figure 1

**TOTAL CASH INCOME 2010**

- University of Tasmania: 22%
- Other income sources/interest: 1%
- ARC CoE Grant: 33%
- Node matching funds*: 3%
- State Government: 0.1%
- Other Commonwealth Government: 1%
- Industry/private: 36%
- Contracts/consultancies/revenue raising: 4%

* AGREED MATCHING FUNDS HELD AT NODE INSTITUTIONS

---

### Figure 2

**COMPARISON OF CODES’ MAIN INCOME STREAMS 2003 – 2010**

- Other
- Industry
- State Government
- University of Tasmania
- ARC

* NOTE: THE COE COMMENCED MID 2005
2010 Expenditure of ARC CoE Grant / ARC CoE Grant / 2011 Expenditure Estimates / All expenditure in 2011 is expected to be lower than 2010 due to the reduction in ARC CoE Grant funding.

Summaries are provided in Table 2 and Figure 3 to show how CODES 5 and its nodes have expended the ARC CoE Grant funds to date. In past years, the major areas of expenditure in 2010 were salaries, research and field travel, student scholarships and laboratory analyses. However, most expenditure was lower than previous years due to decreased ARC funding.

The 2010 combined ARC CoE income and carry-forward of $3.1 million was offset by expenditure of $2.6 million, leaving a carry-forward surplus of $573k. However, it should be noted that the CoE Centre currently owes $465k of 2010 funds to two of its nodes (UQ and CSIRO E&M). This amount was not able to be paid in 2010 due to late finalisation of the CoE Extension Agreement between UQ and the nodes. If this had been paid in the year that it was due, the 2010 carry-forward balance would have been a deficit of $93k.

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 2009. 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 $530,000, UTAS $230,000, Industry Partners $110,000). 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 income/ 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 CRC, 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.

Expenditure statements

All expenditure categories are consistent with last year’s reports, except for the following change:

- From 2010 onwards, ‘visiting academic’ expenditure is no longer itemised separately. This expenditure is now included in the appropriate other categories (e.g. travel, analyses, consumables, etc).

The expenditure financial statement and pie chart (Table 2 and Figure 3) include the following:

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

Notes to, and Forming Part of, the Financial Statements for 2010 / 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 TeckOne Financial System and CODES’ financial databases. All Financial Statements shown here have been reviewed and audited by UTAS.

### Table 2

<table>
<thead>
<tr>
<th>Income</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balance brought forward from previous year</td>
<td>0</td>
<td>954,886</td>
<td>1,345,188</td>
<td>711,979</td>
<td>55,741</td>
<td>145,268</td>
</tr>
<tr>
<td>Miscellaneous income (refund of expenses)</td>
<td>0</td>
<td>8,497</td>
<td>29,839</td>
<td>43,155</td>
<td>0</td>
<td>18,704</td>
</tr>
<tr>
<td>ARC income</td>
<td>1,500,000</td>
<td>3,152,698</td>
<td>3,184,402</td>
<td>3,248,088</td>
<td>3,313,864</td>
<td>3,097,230</td>
</tr>
<tr>
<td><strong>Total Income</strong></td>
<td>1,500,000</td>
<td>4,116,081</td>
<td>4,559,179</td>
<td>4,003,222</td>
<td>3,369,605</td>
<td>2,970,667</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Expenditure</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salaries</td>
<td>(348,511)</td>
<td>(1,237,351)</td>
<td>(1,833,309)</td>
<td>(2,315,312)</td>
<td>(3,708,835)</td>
<td>(3,332,826)</td>
</tr>
<tr>
<td>Equipment purchases</td>
<td>(890)</td>
<td>(83,645)</td>
<td>(305,991)</td>
<td>(70,264)</td>
<td>(85,292)</td>
<td>(35,992)</td>
</tr>
<tr>
<td>Equipment leased/ hired</td>
<td>(262)</td>
<td>(22,835)</td>
<td>(6,994)</td>
<td>0</td>
<td>0</td>
<td>(500)</td>
</tr>
<tr>
<td>Shared equipment/facilities</td>
<td>(1,119)</td>
<td>(21,000)</td>
<td>(46,750)</td>
<td>(70,367)</td>
<td>(104,407)</td>
<td>(54,407)</td>
</tr>
<tr>
<td>Travel and accommodation [research]</td>
<td>(52,363)</td>
<td>(304,946)</td>
<td>(274,206)</td>
<td>(282,976)</td>
<td>(364,665)</td>
<td>(227,765)</td>
</tr>
<tr>
<td>IT and lab maintenance</td>
<td>(1,866)</td>
<td>(91,292)</td>
<td>(208,688)</td>
<td>(145,441)</td>
<td>(82,620)</td>
<td>(16,334)</td>
</tr>
<tr>
<td>Student scholarships</td>
<td>(31,856)</td>
<td>(297,768)</td>
<td>(346,311)</td>
<td>(384,141)</td>
<td>(401,617)</td>
<td>(401,617)</td>
</tr>
<tr>
<td>Public relations and advertising</td>
<td>(9,289)</td>
<td>(105,160)</td>
<td>(119,504)</td>
<td>(53,466)</td>
<td>(85,292)</td>
<td>(36,158)</td>
</tr>
<tr>
<td>Laboratory analyses</td>
<td>(26,000)</td>
<td>(212,256)</td>
<td>(307,738)</td>
<td>(288,411)</td>
<td>(369,647)</td>
<td>(247,365)</td>
</tr>
<tr>
<td>Consultants</td>
<td>0</td>
<td>(92,240)</td>
<td>(108,636)</td>
<td>(68,962)</td>
<td>(82,196)</td>
<td>(117,203)</td>
</tr>
<tr>
<td>Visiting academics *</td>
<td>(9,062)</td>
<td>(9,060)</td>
<td>(19,011)</td>
<td>(41,665)</td>
<td>(61,217)</td>
<td>(0)</td>
</tr>
<tr>
<td>New appointment expenses</td>
<td>0</td>
<td>(9,267)</td>
<td>(10,886)</td>
<td>(22,520)</td>
<td>(5,864)</td>
<td>(0)</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>(451,114)</td>
<td>(2,770,890)</td>
<td>(3,847,200)</td>
<td>(3,947,481)</td>
<td>(3,514,872)</td>
<td>(2,598,343)</td>
</tr>
</tbody>
</table>

**Balance remaining at end of year**

954,886 1,345,188 711,979 55,741 145,268 372,323

* From 2010 onwards, ‘visiting academic’ expenditure is no longer itemised separately.


## CODES Postgraduate Students 2010 /

### MASTER OF ECONOMIC GEOLOGY (54)

<table>
<thead>
<tr>
<th>STUDENT</th>
<th>SUPERVISOR(S)</th>
<th>PROJECT</th>
<th>SUPPORT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pakalu Bititosi</td>
<td>coursework only</td>
<td>Sedimentary and detrital arc geochemistry of the Permo-Triassic transition in the northern Tasman Peninsula, Tasmania</td>
<td>CoDes, TGMs, SES</td>
</tr>
<tr>
<td>Lynelle Binen</td>
<td>coursework only</td>
<td>Grinding and milling of the savage River magnetite deposit</td>
<td>Grange Resources Ltd</td>
</tr>
<tr>
<td>Jeffrey Bigelow</td>
<td>coursework only</td>
<td>The geology of the Koonenberry Belt, NSW</td>
<td>Geological Survey of NSW</td>
</tr>
<tr>
<td>John Borrow</td>
<td>coursework only</td>
<td>Combined economic and geologic evaluation of eastern Australian gold projects - selection of acquisition targets</td>
<td>Northgate Australian Ventures</td>
</tr>
<tr>
<td>Mark Butsett</td>
<td>coursework only</td>
<td>A review of the grade control drilling processes at Poitrel coal mine and their application in mine planning</td>
<td>BMA</td>
</tr>
</tbody>
</table>
| Adrian Byass | coursework only | Geochronology of hydrothermal REE minerals and their relationships with economic mineralisation at the Olympic Dam breccia complex, South Australia | Compania de Minas Buenaventura,
BP Billiton Olympic Dam |
| Cesar Calderon Tipari | coursework only | Characterisation of the mineralising fluids and mineralogical and geochemostratigraphic characteristics of the Pucuy and Sausa Au deposits and their relation with the Chirimaco deposit, Chopoampa-Aiquapa, Peru | Compania de Minas Buenaventura,
BP Billiton Olympic Dam |
| Colin Carter | coursework only | Geology, geochemistry and genetics of the Kidd-McIntyre Cu-Au deposit, central New South Wales, Australia | Anglogold Ashanti Australia Limited |
| Conner Chamberlain | coursework only | Geology, geochemistry and geochronology of the Olympic Dam breccia complex, South Australia | Geoscience Australia,
Anglogold Ashanti Australia Limited |
| Mathew Chatenet | coursework only | Various aspects of the grade control drilling processes at Poitrel coal mine and their application in mine planning | BMA |
| Jo Cordian | coursework only | Geology, geochemistry and geochronology of the Olympic Dam breccia complex, South Australia | Geoscience Australia,
Anglogold Ashanti Australia Limited |
| Richard Cotton | coursework only | Geology of the Ross Alluvial gold deposit and its implications for gold mining on the West Coast, South Island, New Zealand | Rio Tinto |
| Monica Davis | coursework only | Various aspects of the grade control drilling processes at Poitrel coal mine and their application in mine planning | BMA |

### BACHELOR OF SCIENCE (HONOURS) (15)

<table>
<thead>
<tr>
<th>STUDENT</th>
<th>SUPERVISOR(S)</th>
<th>PROJECT</th>
<th>SUPPORT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emma Bigg</td>
<td>coursework only</td>
<td>Late-stage mineralisation of the Timmins supergene gold deposit, Ontario, Canada</td>
<td>University of Toronto</td>
</tr>
<tr>
<td>Paul Donaldson</td>
<td>coursework only</td>
<td>Early Mesoproterozoic microbial vent communities from the Century deposit, Nh West Australia</td>
<td>Western Australian Geological Survey</td>
</tr>
<tr>
<td>Josh Goatman</td>
<td>coursework only</td>
<td>The geology of the Ross Alluvial gold deposit and its implications for gold mining on the West Coast, South Island, New Zealand</td>
<td>Rio Tinto</td>
</tr>
<tr>
<td>Ben Hey</td>
<td>coursework only</td>
<td>Determining the geochemical halo around intermediate sulfurized pahoehoe flows, New Zealand</td>
<td>University of Tasmania</td>
</tr>
<tr>
<td>Nicholas Jarvis</td>
<td>coursework only</td>
<td>The geology of the Ross Alluvial gold deposit and its implications for gold mining on the West Coast, South Island, New Zealand</td>
<td>University of Tasmania</td>
</tr>
<tr>
<td>Hamish John</td>
<td>coursework only</td>
<td>The geology of the Ross Alluvial gold deposit and its implications for gold mining on the West Coast, South Island, New Zealand</td>
<td>University of Tasmania</td>
</tr>
<tr>
<td>Kyren Knight</td>
<td>coursework only</td>
<td>Geophysical characterisation of the Roaring 41 prospect, Balfour Pleiades Resources</td>
<td>University of Tasmania</td>
</tr>
<tr>
<td>Ting Kor</td>
<td>coursework only</td>
<td>Geophysical characterisation of the Roaring 41 prospect, Balfour Pleiades Resources</td>
<td>University of Tasmania</td>
</tr>
<tr>
<td>Daniel Macklin</td>
<td>coursework only</td>
<td>Geophysical characterisation of the Roaring 41 prospect, Balfour Pleiades Resources</td>
<td>University of Tasmania</td>
</tr>
<tr>
<td>Breandan Sargent</td>
<td>coursework only</td>
<td>Geophysical characterisation of the Roaring 41 prospect, Balfour Pleiades Resources</td>
<td>University of Tasmania</td>
</tr>
<tr>
<td>Markus Staudmann</td>
<td>coursework only</td>
<td>Geological setting and mineralisation characteristics of the Bong Mieu mine, Central Vietnam</td>
<td>Korea Resources Corporation</td>
</tr>
<tr>
<td>Tim Stubley</td>
<td>coursework only</td>
<td>Geophysical characterisation of the Roaring 41 prospect, Balfour Pleiades Resources</td>
<td>University of Tasmania</td>
</tr>
<tr>
<td>Mark Tomlin</td>
<td>coursework only</td>
<td>Geophysical characterisation of the Roaring 41 prospect, Balfour Pleiades Resources</td>
<td>University of Tasmania</td>
</tr>
<tr>
<td>Katherine Webb</td>
<td>coursework only</td>
<td>Geophysical characterisation of the Roaring 41 prospect, Balfour Pleiades Resources</td>
<td>University of Tasmania</td>
</tr>
<tr>
<td>Allison Whitelaw</td>
<td>coursework only</td>
<td>Geophysical characterisation of the Roaring 41 prospect, Balfour Pleiades Resources</td>
<td>University of Tasmania</td>
</tr>
<tr>
<td>Ben Ulrich</td>
<td>coursework only</td>
<td>Geophysical characterisation of the Roaring 41 prospect, Balfour Pleiades Resources</td>
<td>University of Tasmania</td>
</tr>
</tbody>
</table>
## MASTER OF EXPLORATION GEOSCIENCES (1)

<table>
<thead>
<tr>
<th>Student</th>
<th>Supervisor(s)</th>
<th>Project</th>
<th>Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serence Houshe*</td>
<td>Large, Roach</td>
<td>Geophysical signatures of gold-copper porphyry systems</td>
<td></td>
</tr>
</tbody>
</table>

## MASTER OF SCIENCE (2)

<table>
<thead>
<tr>
<th>Student</th>
<th>Supervisor(s)</th>
<th>Project</th>
<th>Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paul Ferguson</td>
<td>G. Davidson, Roach</td>
<td>Origins of large negative anomalies in oceanic crust, Macquarie Island</td>
<td>SEG</td>
</tr>
</tbody>
</table>
### Research Collaborations with CODES 2010 /

<table>
<thead>
<tr>
<th>INSTITUTION</th>
<th>RESEARCHER(S)</th>
<th>CODES COLLABORATOR(S)</th>
<th>PROJECT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australian National University</td>
<td>Steve Enggs</td>
<td>Vadim Kamenetsky</td>
<td>Unmixing in magmas</td>
</tr>
<tr>
<td>Australian Synchrotron</td>
<td>David Paterson, Dary Howard</td>
<td>Chris Ryan</td>
<td>Synchrotron K-xray probe development</td>
</tr>
<tr>
<td>CSIRO, Perth</td>
<td>John Valente</td>
<td>Ross Large, Dan Gregory</td>
<td>Relationship between gold and organic matter in orogenic gold deposits</td>
</tr>
<tr>
<td>CSIRO, Perth</td>
<td>John Valente</td>
<td>Ross Large</td>
<td>Fluids that form high-valency, volcanic-hosted massive sulfide</td>
</tr>
<tr>
<td>CSIRO</td>
<td>Murray Jensen, Robin Kehlhamer, Gérald Montheaud, Paul Dunn</td>
<td>Chris Ryan</td>
<td>Synchrotron K-xray probe development</td>
</tr>
<tr>
<td>Geological Survey of New South Wales</td>
<td>James Cleverly, Steve Friend, Bob Hough</td>
<td>Chris Ryan</td>
<td>Next generation-based applications</td>
</tr>
<tr>
<td>Geological Survey of Queensland</td>
<td>Ian Pecsell</td>
<td>Anthony Han</td>
<td>Exploring the porphyry environment</td>
</tr>
<tr>
<td>Geosciences Australia</td>
<td>David Hutton, Terry Meraghi</td>
<td>Khin Zaw</td>
<td>VHMS deposits</td>
</tr>
<tr>
<td>Geosciences Australia</td>
<td>Terry Meraghi, Bill Paspas</td>
<td>Sebastian Melffe</td>
<td>LA-QCP-MS analysis development</td>
</tr>
<tr>
<td>James Cook University</td>
<td>Bob Henderson</td>
<td>Tony Crawford</td>
<td>Taran Line tectonics and mineralisation potential</td>
</tr>
<tr>
<td>James Cook University</td>
<td>Thomas Blankensop</td>
<td>Steve McEachern</td>
<td>Identifying hidden structure with faults, fractals and geomorphology</td>
</tr>
<tr>
<td>Macquarie University</td>
<td>Elena Belousova</td>
<td>Jocelyn Mulhees, Vadim Kamenetsky</td>
<td>Setting of Olympic Dam</td>
</tr>
<tr>
<td>Mineral Resources Tasmania</td>
<td>Rajbir Bhat, Jalen Taheri, Braxil Ron Berry</td>
<td>Tony Webber, Victoria Black</td>
<td>Savage River magmatic deposit</td>
</tr>
<tr>
<td>Monash University</td>
<td>Massimo Raveggi</td>
<td>Leonid Danyushevsky</td>
<td>New LA-QCP-MS applications</td>
</tr>
<tr>
<td>Monash University</td>
<td>Reid Kaays</td>
<td>Tony Crawford</td>
<td>Paleopetrogenesis, magmatism and mineralisation</td>
</tr>
<tr>
<td>Murdoch University</td>
<td>Sean Stevens</td>
<td>Martin Farrant</td>
<td>Jocelyn Mulhees, Vadim Kamenetsky</td>
</tr>
<tr>
<td>University of Adelaide</td>
<td>Joel Bruggen, Barbara Eschmann</td>
<td>Chris Ryan</td>
<td>Synchrotron K-xray probe development and new synchrotron-based applications</td>
</tr>
<tr>
<td>University of Melbourne</td>
<td>Brett Johnson, Jeff McGaw</td>
<td>Jamie Lard</td>
<td>Ion beam analysis development</td>
</tr>
<tr>
<td>University of Melbourne</td>
<td>Jon Woodhead</td>
<td>Leonid Danyushevsky</td>
<td>Mafic magnatism in modern subaerial SW Pacific settings</td>
</tr>
<tr>
<td>University of Melbourne</td>
<td>Mark Kendrick</td>
<td>Vadim Kamenetsky</td>
<td>Unmixing in magmas</td>
</tr>
<tr>
<td>University of Melbourne</td>
<td>Roland Nies</td>
<td>Sebastien Melffe</td>
<td>New LA-QCP-MS applications</td>
</tr>
<tr>
<td>University of Melbourne</td>
<td>Roland Nies</td>
<td>Tony Crawford, Jocelyn Mulhees, Vadim Kamenetsky</td>
<td>Paleopetrogenesis, magmatism and mineralisation, Olympic Dam</td>
</tr>
<tr>
<td>University of New South Wales</td>
<td>Ian Graham</td>
<td>Khin Zaw</td>
<td>One deposits of SE Asia</td>
</tr>
<tr>
<td>University of Sydney</td>
<td>Patrick Ray</td>
<td>Steve McEachern</td>
<td>Subduction polarity switches</td>
</tr>
<tr>
<td>University of Queensland</td>
<td>Paul Vasconcelos, Sue Golding</td>
<td>Khin Zaw</td>
<td>One deposits of SE Asia</td>
</tr>
<tr>
<td>University of Western Australia</td>
<td>Mark Bailey</td>
<td>Khin Zaw</td>
<td>One deposits of SE Asia</td>
</tr>
</tbody>
</table>

### NATIONAL COLLABORATIONS (IN ADDITION TO CENTRE PARTNERS)

<table>
<thead>
<tr>
<th>INSTITUTION</th>
<th>RESEARCHER(S)</th>
<th>CODES COLLABORATOR(S)</th>
<th>PROJECT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australian Museum, Sydney</td>
<td>Lin Letherald</td>
<td>Khin Zaw</td>
<td>One deposits of SE Asia</td>
</tr>
<tr>
<td>Australian National University</td>
<td>Charlotte Allen, Ian Campbell</td>
<td>Anthony Han</td>
<td>Exploring the porphyry environment</td>
</tr>
<tr>
<td>Australian National University</td>
<td>Hugh O'Neill</td>
<td>Leonid Danyushevsky</td>
<td>Mafic magnatism in modern subaerial SW Pacific settings</td>
</tr>
<tr>
<td>Australian National University</td>
<td>Malcolm Sambidge, Anya Reading, Jeff Foster, Matt Craswell</td>
<td>Data inference techniques</td>
<td>New LA-QCP-MS applications</td>
</tr>
<tr>
<td>Australian National University</td>
<td>Marc Norman</td>
<td>Leonid Danyushevsky</td>
<td>Ambient seismic energy techniques</td>
</tr>
</tbody>
</table>

---
### INTERNATIONAL COLLABORATIONS (IN ADDITION TO CENTRE PARTNERS)

<table>
<thead>
<tr>
<th>INSTITUTION</th>
<th>RESEARCHER(S)</th>
<th>CODEX COLLABORATOR(S)</th>
<th>PROJECT</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAAS, GSA/UGSS, USA</td>
<td>Larry Memeret</td>
<td>Zhaoxuan Zong</td>
<td>Efficiency of one-forming processes</td>
</tr>
<tr>
<td>American Museum of Natural History, USA</td>
<td>James Webster</td>
<td>Paul Davidson</td>
<td>Melt-melt immiscibility and the origin of mafic-ultramafic deposits</td>
</tr>
<tr>
<td>Brookhaven National Laboratory, USA</td>
<td>Gianluigi De Geronimo, Tony Kuczenski, Jan Peter</td>
<td>Chris Ryan</td>
<td>Synchrotron X-ray probe development</td>
</tr>
<tr>
<td>Chiang Mai University, Thailand</td>
<td>Prin Lerttrakul, Sampan Singhaninsirikun, Wipatarn Sirichan</td>
<td>Khim Zaw, Tony Crawford</td>
<td>One-deposits of SE Asia</td>
</tr>
<tr>
<td>Chinese Academy of Geological Science, China</td>
<td>Zengjian Huo</td>
<td>Khim Zaw</td>
<td>VHMS deposits</td>
</tr>
<tr>
<td>Colorado School of Mines, USA</td>
<td>Thomas Mondeke</td>
<td>Bruce Gemmell</td>
<td>Hydrothermal event recognition and targeting in volcano-sedimentary setting</td>
</tr>
<tr>
<td>Colorado State University, USA</td>
<td>Holly Steen</td>
<td>Khim Zaw</td>
<td>One-deposits of SE Asia</td>
</tr>
<tr>
<td>Consultant</td>
<td>Joyce Garcia</td>
<td>Zhaoxuan Zong</td>
<td>Efficiency of one-forming processes</td>
</tr>
<tr>
<td>Department of Mineral Resources, Thailand</td>
<td>Pol Cha USumong</td>
<td>Khim Zaw</td>
<td>One-deposits of SE Asia</td>
</tr>
<tr>
<td>Department of Mineral Resources, Thailand</td>
<td>Somboon Khousathan</td>
<td>Khim Zaw, Sebastien Maftei</td>
<td>One-deposits of SE Asia</td>
</tr>
<tr>
<td>ETHZ, Zurich, Switzerland</td>
<td>Jang Hun Seo, Markus Wadde</td>
<td>Manuel Guibourg</td>
<td>New LA-Q-ICP-MS applications</td>
</tr>
<tr>
<td>Geological Survey of Canada</td>
<td>Wayne Goodfellow, Ian Peter</td>
<td>Bruce Gemmell</td>
<td>Hydrothermal event recognition and targeting in volcano-sedimentary setting</td>
</tr>
<tr>
<td>GFZ German Research Centre for Geosciences, Germany</td>
<td>Ryo Wakisaka</td>
<td>Vadim Kamenetsky</td>
<td>Unmixing in magmas</td>
</tr>
<tr>
<td>GFZ German Research Centre for Geosciences, Germany</td>
<td>Rainer Thomas</td>
<td>Paul Davidson</td>
<td>Melt-melt immiscibility and the origin of mafite-ultramafic deposits</td>
</tr>
<tr>
<td>Ghent University, Belgium</td>
<td>Mafera Elburg</td>
<td>Vadim Kamenetsky</td>
<td>Unmixing in magmas</td>
</tr>
<tr>
<td>Hanoi University of Mining and Geology, Dept of Geology, Vietnam</td>
<td>Hai Thanh Tran</td>
<td>Khim Zaw</td>
<td>Genesis of volcanic-hosted copper-lead-zinc-silver-gold massive sulfide deposits</td>
</tr>
<tr>
<td>Hanoi University of Mining and Geology, Dept of Geology, Vietnam</td>
<td>Hai Thanh Tran</td>
<td>Khim Zaw, Jacob Maklin</td>
<td>One-deposits of SE Asia</td>
</tr>
<tr>
<td>Hebei University of Technology, China</td>
<td>Taoa Zhou, Yu Fan, Feng Yuan</td>
<td>David Cooks, Zhaoxuan Zong, Huayong Chen</td>
<td>Polymetallic mineralisation and associated magmatic and volcanic activity in Cretaceous volcano-sedimentary basin of eastern China</td>
</tr>
<tr>
<td>IFG-GEOFAR, Germany</td>
<td>Armin Freundt</td>
<td>Sharon Allen, Joelyn McPhie</td>
<td>Explosive degassing of subaqueous felsic magmas</td>
</tr>
<tr>
<td>IJAG-MESTEC, Japan</td>
<td>Yoshiko Tamura</td>
<td>Sharon Allen, Joelyn McPhie</td>
<td>Explosive degassing of subaqueous felsic magmas</td>
</tr>
<tr>
<td>Imperial College London, UK</td>
<td>Andrew Berry</td>
<td>Anthony Harris</td>
<td>Exploring the porphyry environment</td>
</tr>
<tr>
<td>Imperial College London, UK</td>
<td>Andrew Berry</td>
<td>Leonid Danyshevsky</td>
<td>Magmatic massif in modern submarine SW Pacific settings</td>
</tr>
<tr>
<td>Imperial College London, UK</td>
<td>Doreen Weis</td>
<td>James Wilhelm</td>
<td>Transition metal speciation and isotope systematics of source rocks for sedimentary-volcanic-hosted ore deposits</td>
</tr>
<tr>
<td>Imperial College London, UK</td>
<td>James Wilkinson, Clara Wilkinson</td>
<td>David Cooks, Bruce Gemmell, Zhaoxuan Zong</td>
<td>AMB RDAHA: Geochemical and geological halos in green rocks and host rocks - The explorer's toolbox for porphyry and epithermal districts</td>
</tr>
<tr>
<td>Institute of Nuclear and Energy Synchrotron Radiation Facility, France</td>
<td>Denis Testemale, Jean-Louis Haarmann, Chris Ryan</td>
<td>Leonid Danyshevsky</td>
<td>Synchrotron X-ray probe development and new synchrotron-based applications</td>
</tr>
<tr>
<td>Institute of Experimental Mineralogy, Russia</td>
<td>Eduard Korenkov</td>
<td>Leonid Danyshevsky</td>
<td>No-PGE potential of mafic and ultramafic magmas - a combined melt inclusions and numerical modelling approach</td>
</tr>
<tr>
<td>Institute of Geological and Nuclear Sciences, New Zealand</td>
<td>Kevin Faure</td>
<td>Anthony Harris</td>
<td>Exploring the porphyry environment</td>
</tr>
<tr>
<td>INSTITUTION</td>
<td>RESEARCHER(S)</td>
<td>CODES COLLABORATOR(S)</td>
<td>PROJECT</td>
</tr>
<tr>
<td>-------------</td>
<td>---------------</td>
<td>------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>University of British Columbia, Canada</td>
<td>Richard Tosick</td>
<td>Anthony Harris, Larissa Mirkus, David Cooke</td>
<td>Exploring the porphyry environment</td>
</tr>
<tr>
<td>University of California Berkeley, USA</td>
<td>Rebecca Cary</td>
<td>Sharon Allen, Jocelyn McPhee</td>
<td>Expensive degassing of submarine felsic magmas</td>
</tr>
<tr>
<td>University of California Riverside, USA</td>
<td>Tim Lyons</td>
<td>Peter McGintyck</td>
<td>Global ocean chemistry, marine basins and mineralisation</td>
</tr>
<tr>
<td>University of Central Missouri, Dept of Earth Science, USA</td>
<td>John Nold, Mark Dudley</td>
<td>Paul Davidson</td>
<td>Meltil-melt immiscibility and the origin of magnetite-apatite deposits</td>
</tr>
<tr>
<td>University College of Science, Iran</td>
<td>Mirsaleh Memomahmoud</td>
<td>Paul Davidson, Leonid Danyshevskiy</td>
<td>Meltil-melt immiscibility and the origin of magnetite-apatite deposits</td>
</tr>
<tr>
<td>University of Hannover, Germany</td>
<td>Roman Butashevska</td>
<td>Vadim Kamenetsky</td>
<td>Unmixing in magmas</td>
</tr>
<tr>
<td>University of Lisbon, Portugal</td>
<td>Jorge Rekas</td>
<td>Jocelyn McPhee</td>
<td>Submarine volcanism and the Borean Pyrite Belt</td>
</tr>
<tr>
<td>University of Lisbon, Portugal</td>
<td>Miguel Geasar</td>
<td>Zhaochun Zhang</td>
<td>Efficiency of ore-forming processes</td>
</tr>
<tr>
<td>University of Malaysia</td>
<td>Teh Guan Hoe, Azman Ghani</td>
<td>Kim Zaw</td>
<td>Genesis of volcanic-hosted copper–lead-zinc massive sulphide deposits</td>
</tr>
<tr>
<td>University of Malaysia</td>
<td>Teh Guan Hoe</td>
<td>Kim Zaw</td>
<td>One deposits of SE Asia</td>
</tr>
<tr>
<td>University of Naples, Italy</td>
<td>Benedetta De Vito</td>
<td>Leonid Danyshevskiy</td>
<td>Mafic magmas in modern submarine SW Pacific settings</td>
</tr>
<tr>
<td>University of Oregon, USA</td>
<td>Rya Bredenam</td>
<td>Vadim Kamenetsky, Marcel Guiot</td>
<td>Unmixing in magmas</td>
</tr>
<tr>
<td>University of Oregon, USA</td>
<td>Kathy Cashman</td>
<td>Sharon Allen, Jocelyn McPhee</td>
<td>Expensive degassing of felsic magmas</td>
</tr>
<tr>
<td>University of Oregon, USA</td>
<td>Paul Wallace</td>
<td>Emily Johnson, Vadim Kamenetsky, Jocelyn McPhee</td>
<td>Vitrates in felsic magmas</td>
</tr>
<tr>
<td>University of Otago, New Zealand</td>
<td>David Craw</td>
<td>Ross Large, Helen Thomas</td>
<td>Sediments and volcanic-hosted gold</td>
</tr>
<tr>
<td>University of Ontario, Canada</td>
<td>Mark Harrington</td>
<td>Bruce Gemmell</td>
<td>Hydrothermal event recognition and targeting in volcanic-sedimentary reservoirs</td>
</tr>
<tr>
<td>University of Ontario, Canada</td>
<td>Jeff Hedenquist</td>
<td>David Cooke, Bruce Gemmell, Zhaochun Zhang</td>
<td>AMIRA P765A: Geochemical and geological halos in green rocks and lithocaps - The explorer’s toolbox for porphyry and epithermal districts</td>
</tr>
<tr>
<td>University of Pisa, Italy</td>
<td>Paolo Fuglinati, Paolo Matanelli, Alessandro Storaro</td>
<td>Vadim Kamenetsky</td>
<td>Unmixing in magmas</td>
</tr>
<tr>
<td>University of Science and Technology, China</td>
<td>Yuling Xie</td>
<td>Paul Davidson</td>
<td>Meltil-melt immiscibility and the origin of magnetite-apatite deposits</td>
</tr>
<tr>
<td>University of the Witwatersrand, South Africa</td>
<td>Allan Wilson</td>
<td>Leonid Danyshevskiy</td>
<td>No-FGE potential of mafic and ultra mafic magmas – a combined melt inclusions and numerical modelling approach</td>
</tr>
<tr>
<td>Vernadsky Institute, Russia</td>
<td>Alexei Aksenov</td>
<td>Leonid Danyshevskiy</td>
<td>No-FGE potential of mafic and ultra mafic magmas – a combined melt inclusions and numerical modelling approach</td>
</tr>
<tr>
<td>Virginia Polytechnic, USA</td>
<td>Robert Bodnar</td>
<td>Leonid Danyshevskiy</td>
<td>Mafic magmas in modern submarine SW Pacific settings</td>
</tr>
<tr>
<td>Woods Hole Oceanographic Institution, USA</td>
<td>Chris German</td>
<td>Janet Hergt</td>
<td>New stable isotope MS applications</td>
</tr>
</tbody>
</table>

**Visitors to CODES 2010**

**INDUSTRY VISITORS**

<table>
<thead>
<tr>
<th>Name</th>
<th>Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paul Agnew</td>
<td>Rio Tinto</td>
</tr>
<tr>
<td>Zsolt Arpait</td>
<td>Aurox</td>
</tr>
<tr>
<td>Emmanuel Bash-Danso</td>
<td>Newmont</td>
</tr>
<tr>
<td>Bradley Baker</td>
<td>BHP Billiton</td>
</tr>
<tr>
<td>Fabian Baker</td>
<td>Lydian International</td>
</tr>
<tr>
<td>Ed Ballis</td>
<td>Gold Fields</td>
</tr>
<tr>
<td>Pakulu Batsutso</td>
<td>African Minerals (Barbados)</td>
</tr>
<tr>
<td>Lynelle Berrie</td>
<td>Heathgate Resources</td>
</tr>
<tr>
<td>Steve Beresford</td>
<td>MMG</td>
</tr>
<tr>
<td>Gabriele Bressan</td>
<td>BHP Billiton</td>
</tr>
<tr>
<td>David Brown</td>
<td>Anglo American</td>
</tr>
<tr>
<td>Matt Briggs</td>
<td>St Ives Gold Mining</td>
</tr>
<tr>
<td>Graeme Broadbent</td>
<td>Rio Tinto</td>
</tr>
<tr>
<td>Rex Brommacker</td>
<td>Barrick</td>
</tr>
<tr>
<td>David Cameron-Smith</td>
<td>Bass Metals</td>
</tr>
<tr>
<td>Keith Cameron-Smith</td>
<td>Pan Australian Resources</td>
</tr>
<tr>
<td>Chris Campbell</td>
<td>Newmont Asia Pacific</td>
</tr>
<tr>
<td>Gemina Circosta</td>
<td>Incoamining</td>
</tr>
<tr>
<td>Dean Collett</td>
<td>Newcrest</td>
</tr>
<tr>
<td>Jon Cowan</td>
<td>Pentalogic</td>
</tr>
<tr>
<td>John Cooke</td>
<td>Equinox Minerals</td>
</tr>
<tr>
<td>Paul Croome</td>
<td>Tiger Realm Group</td>
</tr>
<tr>
<td>Matthew Croome</td>
<td>BHP Billiton</td>
</tr>
<tr>
<td>Lynda Daley</td>
<td>Newmont Asia Pacific</td>
</tr>
<tr>
<td>Graeme Davis</td>
<td>Kinross Gold</td>
</tr>
<tr>
<td>Kim Dennew</td>
<td>Bass Metals</td>
</tr>
<tr>
<td>Cathy Dickens</td>
<td>St Barbara</td>
</tr>
<tr>
<td>Glen Deemer</td>
<td>BHP Billiton</td>
</tr>
<tr>
<td>Nick Dreen</td>
<td>FROGtech</td>
</tr>
<tr>
<td>John Dor</td>
<td>Domegold</td>
</tr>
<tr>
<td>John Dolber</td>
<td>Barrick</td>
</tr>
<tr>
<td>Kathy Ehrig</td>
<td>BHP Billiton</td>
</tr>
<tr>
<td>Doug Ellinger</td>
<td>OZ Minerals</td>
</tr>
<tr>
<td>David Frist</td>
<td>Floatport McMillan</td>
</tr>
<tr>
<td>David Freeman</td>
<td>Minotaur Exploration</td>
</tr>
<tr>
<td>Fach Fryer</td>
<td>AgiLabs</td>
</tr>
<tr>
<td>Alan Goodle</td>
<td>AMIRA International</td>
</tr>
<tr>
<td>Dave Gibson</td>
<td>Orange Resources</td>
</tr>
<tr>
<td>Scott Halley</td>
<td>Mineral Mapping</td>
</tr>
<tr>
<td>Emam Hannon</td>
<td>Forensic Metals Group</td>
</tr>
<tr>
<td>Ben Happer</td>
<td>GoldFields</td>
</tr>
<tr>
<td>Zaidi Harun</td>
<td>Monument</td>
</tr>
<tr>
<td>Nick Hayward</td>
<td>Sack</td>
</tr>
<tr>
<td>Daryl Hendrasan</td>
<td>Rio Tinto</td>
</tr>
<tr>
<td>John Holloway</td>
<td>Newmont Mining</td>
</tr>
<tr>
<td>Ben Holmes</td>
<td>EarthData</td>
</tr>
<tr>
<td>Terry Horschel</td>
<td>Newmont Asia Pacific</td>
</tr>
<tr>
<td>Noel Hughes</td>
<td>MMG</td>
</tr>
<tr>
<td>Bruce Hutchinson</td>
<td>Orange Resources</td>
</tr>
<tr>
<td>Teena Kamrong</td>
<td>Barrick Gold</td>
</tr>
<tr>
<td>Sung Yong Huang</td>
<td>Koresan Resources Corporation</td>
</tr>
<tr>
<td>Peter Langley</td>
<td>Kamek</td>
</tr>
<tr>
<td>Chris Large</td>
<td>Gam Bow</td>
</tr>
<tr>
<td>Mark Lindsay</td>
<td>Newmont</td>
</tr>
<tr>
<td>Steve Loach</td>
<td>BHP Billiton</td>
</tr>
</tbody>
</table>
INTERNATIONAL ACADEMIC AND GOVERNMENT VISITORS

- Alexey Ariskin, Vernadsky Institute, Russia
- Therese Bejgarn, Luleå University of Technology, Sweden
- Anthony Chappaz, University of California Riverside, USA
- Milco Coifin, UK Oceanography Centre, UK
- Maxim Gavrilenko, Institute of Volcanology and Seismology, Russia
- Heinrich Hartli, King Abdullah University, Saudi Arabia
- Jeff Hedinquist, University of Ottawa, Canada
- Peter Hollings, Lakehead University, Canada
- Eduard Kornikov, Institute of Experimental Mineralogy, Russia
- Hirswen Kouhestani, Taktur Modane University, Iran
- Tim Lyons, University of California Riverside, USA
- Marcelo Marquez, University of Patagonia, Argentina
- Thomas Pettke, University of Bern, Switzerland
- Peter Sorjonen-Ward, Geological Survey of Finland
- Hai Thanh Tran, Hanoi University of Mining and Geology, Vietnam
- James White, University of Otago, New Zealand
- Jamie Wilkinson, Imperial College London, UK
- Clara Wilkinson, Natural History Museum, London, UK
- Liyun Zhang, Heil University of Technology, China
- Zhirong Yang, Institute of Geology, Chinese Academy of Geological Sciences, China

NATIONAL ACADEMIC AND GOVERNMENT VISITORS

- Richard Aculis, Australian National University
- Stacey Borg, CSIRO
- Tony Brown, Mineral Resources Tasmania
- Cristina Conibear, University of Adelaide
- Nigel Cooke, University of Adelaide
- Stephen Cox, Australian National University
- Philip Gámez, Geological Survey, NEM
- Andrea Giuliani, University of Melbourne
- Dave Green, Mineral Resources Tasmania
- Geoff Green, Mineral Resources Tasmania
- Angela Halfpenny, Australian National University
- Richard Hartner, University of Queensland
- Paul Hetherway, Department of Primary Industries and Resources of South Australia
- Janet Hergt, University of Melbourne
- Jon Huntington, AusScope
- Kate Keeva, CSIRO

Angela Lorrigan, Bendigo Mining
Neil Macalalad, Anglo American
Grant Macdonald, Bass Metals
John MacDonald, BHP Billiton
Michael Macdonald, Rio Tinto
Glen Masterman, Kinross Gold
David Meade, Indoshine
Cheryl Morton, African Explorer
Jorma Mota e Silva, Visetanitim Metals
Tim Mueller, SPW Resources
Ashley Norris, Resoretics
Matthew O’Neill, NSW Coal Company
James Pattison, MMG
Audrey Pavend, Compania de Minas Buenaventura
Annette Piccock, AngloGold
Paul Plockie, Anglo American
Mike Richards, Equinox Minerals
Alan Riles, Riles Consulting/AMC
Steven Richardson, Bass Metals
Nic Rosengren, BHP Billiton
Dean Rossell, Rio Tinto
David Royle, EMX Exploration

Travis Schweinfeger, Corvette Resources
Lee Sampson, Bannick Gold
Denna Sewell, AngloGold Ashanti
Robina Sharpie, MMG
Michael Shelly, Laun Technic
David Sillitonga, PT Nusa Halfmahena Minerals
Jim Sinclair, AngloGold Ashanti
Larry Stewart, MMG
Leonardo Subang, Freeport McMoRan
Naoki Sugiyama, Agilent
Brenton Sutopo, Newmont
John Thompson, Teck
Stephen Turner, Newmont Asia Pacific
Lisa Jane Vella, Teck Australia
David Wallace, MMG
Edward Ward, Exploration Geologist
Michael Whitbread, Newcrest Mining
Ian Wills, Anglo American
Peter Winterburn, Vale
Andy Wust, Gold Fields
Yong Zhang, Longton Minerals

Tom Kopacic, JKMRC
Laura Kuchar, CSIRO
Roland Maks, University of Melbourne
Terry Menagh, Geoscience Australia
Simon Michaux, JKMRC
Bill Papas, Geoscience Australia
Bence Paul, University of Melbourne

Brasil Pilands, Australian National University
Roger Skirrow, Geoscience Australia
John Waliche, CSIRO
Steve Watters, JKMRC
Jon Woodhead, University of Melbourne
Greg Yaxley, Australian National University

Marcelo Marquez, University of Patagonia, Argentina
Thomas Pettke, University of Bern, Switzerland
Peter Sorjonen-Ward, Geological Survey of Finland
Francisco Testa, Universidad Nacional del Sur, Argentina
Hai Thanh Tran, Hanoi University of Mining and Geology, Vietnam
James White, University of Otago, New Zealand
Jamie Wilkinson, Imperial College London, UK
Clara Wilkinson, Natural History Museum, London, UK
Liyun Zhang, Heil University of Technology, China
Zhirong Yang, Institute of Geology, Chinese Academy of Geological Sciences, China
Major Externally Funded Research Projects

**AMIRA-ARC CENTRE OF EXCELLENCE PROJECTS 2010**

<table>
<thead>
<tr>
<th>INVESTIGATOR(S)</th>
<th>PROJECT</th>
<th>INDUSTRY PARTNERS</th>
<th>PERIOD</th>
<th>CODE-ARC FUNDING FOR 2010</th>
<th>AMIRA FUNDING FOR 2010</th>
<th>MISC FUNDING FOR 2010</th>
<th>ADDITIONAL AMIRA FUNDING FOR 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foster, Walker, Edralin,quirer, Moen, Overdev, Bradshaw, Robinson, Jeffrey</td>
<td>AMIRA P3848A, GollG</td>
<td>Geomorphological Mapping and Mine Modelling (extension)</td>
<td>July 2009 - 2013</td>
<td>$500,000 ($772,259)</td>
<td>$1,346 ($411,189 ARC)</td>
<td>$471,228 (Foster Centre)</td>
<td>$118,950 (CIC One-UC)</td>
</tr>
<tr>
<td>Chiarie, Glemmer, Chang, Baker, Chen</td>
<td>AMIRA P7164A, Geophysical and geochemical studies in green rocks and mafic volcanoes: The exposer's toolbox for prophyllitic and epithermal districts</td>
<td>AngloAmerican, AngloGold Ashanti, Barrick Gold, Global Minerals, Gold Fields Australia, StGibral, Metio, Minares LamitGold, Newmont Mining, OZ Minerals, Quantitative Geoscience, Rio Tinto, Tenke, Vale, Xintai Copper</td>
<td>2008 - 2011</td>
<td>$114,000 ($676,000)</td>
<td>$42,160 ($13,200)</td>
<td>(Lakehead University)</td>
<td></td>
</tr>
<tr>
<td>Large, Thomas, Baile, Danyushievsky, Scott</td>
<td>AMIRA P1041, Application of new technologies to gold deposits</td>
<td>AngloGold Ashanti, Newmont Mining, Newmont Mining, Newmont Mining, OZ Minerals, Xinhua Exploration, Sipa Exploration, Xintai Copper</td>
<td>2010 - 2013</td>
<td>$45,000 ($118,300)</td>
<td>$0 ($0)</td>
<td>$50 ($50)</td>
<td></td>
</tr>
<tr>
<td>Foster, Schau, Danyushievsky, Scott</td>
<td>AMIRA P1022, The applied rapid approximate inversion of TEM data: AMIRA p962, ni-pGe</td>
<td>AngloGold Ashanti, Gold Fields Australia, Rio Tinto, Xintai Geoscience</td>
<td>2010 - 2013</td>
<td>$50,000 ($36,000)</td>
<td>$0 ($0)</td>
<td>$50 ($50)</td>
<td></td>
</tr>
<tr>
<td>Danyushievsky, Michael, Feng, Arinik (Vernadsky), Kembello (BIM)</td>
<td>AMIRA P062, NB-IPE potential of mafic and ultramafic magmas: a combined model inclusion and numerical modellling approach</td>
<td>AngloAmerican, BHP Billiton, Ijomtomum Metals</td>
<td>2007 - 2010</td>
<td>$43,673 ($28,963)</td>
<td>$17,000 ($5,000)</td>
<td>(Kemterm)</td>
<td></td>
</tr>
</tbody>
</table>

**ARC DISCOVERY GRANTS 2010**

<table>
<thead>
<tr>
<th>INVESTIGATOR(S)</th>
<th>PROJECT</th>
<th>PERIOD</th>
<th>ARC FUNDING FOR 2010</th>
<th>MISC FUNDING FOR 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allen</td>
<td>Discovery Grant: Submarine explosive eruptions of silicic magma: constraints on products and processes from modern sea-floor examples, ancient successions and experiments</td>
<td>2004 - 2012</td>
<td>**</td>
<td>50</td>
</tr>
</tbody>
</table>

**INDUSTRY AND OTHER EXTERNALLY FUNDED RESEARCH GRANTS 2010**

<table>
<thead>
<tr>
<th>INVESTIGATOR(S)</th>
<th>PROJECT</th>
<th>FUNDING BODY</th>
<th>PERIOD</th>
<th>MISC FUNDING FOR 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harris, Cooke, McKie, Toddal (MRC)</td>
<td>Exploring the prophyllitic environment</td>
<td>Newmont Mining Limited</td>
<td>July 2009 - 2013</td>
<td>$352,679 ($50)</td>
</tr>
<tr>
<td>Khin Zaep, Mafeie</td>
<td>One Deposit of SE Asia</td>
<td>Insolucine Resources Ltd</td>
<td>2008 - 2010</td>
<td>$340,000 ($50)</td>
</tr>
<tr>
<td>Micklethwaite, Glemmer, Cooke, Baroni (CSI)</td>
<td>Enabling blind exploration: identifying hidden structure with faults, fractures and geophysics</td>
<td>Newmont Mining Limited</td>
<td>2010</td>
<td>$207,015 ($50)</td>
</tr>
<tr>
<td>Micklethwaite</td>
<td>Deposit to district-scale study of the Groote Eylandt Goldfield</td>
<td>Newmont Mining Limited</td>
<td>2007 - 2010</td>
<td>$548,909 ($1,990)</td>
</tr>
<tr>
<td>Foster, Hutchinson</td>
<td>Total variation in the Tswatson Sector of the Platreef, South Africa</td>
<td>AngloAmerican Exploration Luxembourg SRL</td>
<td>2008</td>
<td>$112,310 ($26)</td>
</tr>
<tr>
<td>McPhie, V. Kamenetsky, Chamblofort</td>
<td>Malic spousos facies at Olympic Dam</td>
<td>BHP Billiton</td>
<td>2008</td>
<td>$27</td>
</tr>
</tbody>
</table>

**PROJECTS WITH Greater Than $1,200,000 External ARC FUNDING PER YEAR**

- **ARC FUNDING FOR THESE PROJECTS COMES DIRECTLY FROM THE ARC DISCOVERY OR LINKAGE PROGRAMS**
- **ALL OTHER PROJECTS ARE FUNDING FROM NON-ARC SOURCES**
- **FULL PROJECT FUNDING RECEIVED IN ONE YEAR**
continued work on the Panzhihua Intrusion in China, as part of Jianxiang Guan’s PhD project.

Tony Crawford publication in Australian Journal of Earth Sciences – explain why some Sedex systems make supergiant stratiform Zn-anomalous pyrite deposits, whereas others make various deposits in the Hunter Ridge, SW Pacific – collected during the voyage of RV Southern Surveyor in 2009.

Peter McGoldrick produce second paper with the University of California Riverside group, using mid-proterozoic ferruginous ocean sediments to elucidate the ‘way up’ of the ore bodies.

P1A1 Tony Crawford Complete Phillips study of the Broken Hill mafic-silicic rocks with Rockkeys of Monash University. In collaboration with Barry Stevens of GNS-NSC, complete the study of the onion in the Broken Hill mafic-silicic rocks, aimed at elucidating the ‘way up’ of the one bodies.

P1A2 Leonid Danyushevsky Complete major and trace element bulk rock and main rock-forming mineral analysis of representative rocks from the Dido batholith in NSW.

P1A3 Peter McGoldrick Produce second paper with the University of California Riverside group, using mid-proterozoic ferruginous ocean sediments to elucidate the ‘way up’ of the ore bodies.

P1A4 Xin Zou, Sebastien Melle Produce complete proposal for an extension to the One Deposits of SE Asia Project, and present at the CODES Science Planning Meeting in April.

P1A5 Tony Crawford Jeff Foster Project discontinued.

P1A6 Tony Crawford Publication in Australian Journal of Earth Sciences – key findings of the N Tasmian Line – Greenvale project. Completion of Fiona Bell’s PhD, and preparation of paper describing the geology, geochronology and petrogenesis of the Dido Batholith in QLD.

P1B1 Jacek Mielicki, Vadim Kamenetsky Submit two more manuscripts from Andrea Angioli’s PhD thesis – quartz textures, melt inclusions and magma evolution.

P1B2 Leonid Danyushevsky Continue work on the Panzhihua Intrusion in China, as part of the Jianxiang Guan’s PhD project.

P1B3 Bruce Gemmell Continue research on the Fossey-Hellyer-Que River-Mt Charter (Tasmania), Lagoi (Western Australia), Doolguma (Western Australia), Palmer (Alaska), Bayschurch (China), Dus Bo (Vietnam), Taek Chiri (Malaysia), and Talara Homo (Algeria) deposits.

P1B4 Garry Davidson Complete final report for the Coronation Hill U-Pb Ge-Au system. Define Coronation Hill work program for AMIRA P103 project. Complete submission of Prominent Hill with Gossan Science Australia.
**PROJECT LEADER(S) ACTIVITY PLAN**

### PROGRAM 3

**P3A1C**
Jeff Foster, Peter Fuller

<table>
<thead>
<tr>
<th>ACTIVITY PLAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continue development of GiTa3D including, forward modelling with conductivity gradients, downhill and multicomponent TEM capability and optimise code. Nominate and commence work on site studies.</td>
</tr>
</tbody>
</table>

**P3A2A**
Anya Reading

<table>
<thead>
<tr>
<th>ACTIVITY PLAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Submit publication on pilot project (AEGS). Establish processing methodology for 3D ambient seismic structure and prepare publication(s). Begin new near-mine ambient seismic project; tentative agreement with G2 Minerals for work at Porrow Hill / Honour student support. Begin new in-mine seismic interferometry project: tentative agreement with IMS and Newcrest, Cadia / Honour student support.</td>
</tr>
</tbody>
</table>

**P3B1A**
David Cooke, Bruce Gemmell, Zhaochun Chang

<table>
<thead>
<tr>
<th>ACTIVITY PLAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distribute AMIRA proposal P1001 in February. Repeat final P1016 sponsors meeting in Santiago, Chile, on March 28th, for South American sponsors. Secure funding &amp; commence P1010 project with a start-up meeting in Hobart, during April. Sponsors field meeting in USA is tentatively scheduled for October 2011.</td>
</tr>
</tbody>
</table>

**P3B1C**
Bruce Gemmell, David Cooke

<table>
<thead>
<tr>
<th>ACTIVITY PLAN</th>
</tr>
</thead>
</table>

**P3B2A**
Ross Large, Stuart Bull

<table>
<thead>
<tr>
<th>ACTIVITY PLAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Report to AMIRA P1041: sponsors on results from pyrite-gold case studies at McPhilemy’s, NED West and Carbon Leader Reef, South Africa, and Chaiyaboon, Thailand. Undertake new pyrite-gold case studies at Mariboe, Indonesia, Hope Bay, Canada, and Geita, Tanzania. Write-up Kumtor and Otago research for publication.</td>
</tr>
</tbody>
</table>

**P3B3A**
Andrew Michael, Bruce Gemmell

<table>
<thead>
<tr>
<th>ACTIVITY PLAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finalise report. Prepare publication on results.</td>
</tr>
</tbody>
</table>

**P3B4A**
Andrew Michael, Bruce Gemmell

<table>
<thead>
<tr>
<th>ACTIVITY PLAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Develop computer-corrected enhanced images generated by lA-iCp-Ms.</td>
</tr>
</tbody>
</table>

**P3B5A**
Chris Ryan

<table>
<thead>
<tr>
<th>ACTIVITY PLAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test and implement the new coil heater system for mAestRo.</td>
</tr>
</tbody>
</table>

**P3B6A**
Jamie Laird

<table>
<thead>
<tr>
<th>ACTIVITY PLAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bring the new nuclear microprobe chamber and data collection system online.</td>
</tr>
</tbody>
</table>

**P3B7A**
Marcel Guillong, Leonid Bence Paul

<table>
<thead>
<tr>
<th>ACTIVITY PLAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Develop and test new protocols for the in-situ analysis of Mo isotope compositions in molybdenite grains. Complete analysis of the Rainbow vent field samples exploring the variation in Cu isotope compositions in fall-out plume sediments with increasing distance from the vents. Compare chimney material from Rainbow with samples from PACMANUS to examine what influence, if any, the composition of the basement lithology has on the Cu isotope composition of vent products. Conduct combined stable isotope analysis (Cu + Mo) on a suite of hydrothermal sediments from the East Pacific Rise and Juan de Fuca Ridge.</td>
</tr>
</tbody>
</table>

**P3B8A**
Garry Davidson

<table>
<thead>
<tr>
<th>ACTIVITY PLAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analyse several well understood synthetic compositions, using different acid digests and time periods of reaction, to establish the best procedure for the analysis of mixtures of mono-sulfides, di-sulfides, and low levels of sulfates in carbonate. Apply the technique to samples that are well characterised and imaged (MT Pilsley-Cu-Au and Sunnake Dam Au deposits, but were not included) until the technique modifications were proven.</td>
</tr>
</tbody>
</table>

**P3B9A**
Janet Hergt, Benoit Chenu

<table>
<thead>
<tr>
<th>ACTIVITY PLAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>In-situ growth of free gold on both real and synthetic junctions, after first selecting or generating likely seed locations, respectively. Submit several high-impact research papers on the main outcomes of the past two years.</td>
</tr>
</tbody>
</table>

**P3B10A**
Jalilu Nkongho, Janet Hergt

<table>
<thead>
<tr>
<th>ACTIVITY PLAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Further improve the accuracy of PXE and luminescence analysis of fluid inclusions and the surrounding host material.</td>
</tr>
</tbody>
</table>

**P3B11A**
Jamec Wilkinson

<table>
<thead>
<tr>
<th>ACTIVITY PLAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measure volume of inclusions using spindle stage and nanoCT scanning. Synthesize information and write-up for publication.</td>
</tr>
</tbody>
</table>

**P3B12A**
Chris Ryan

<table>
<thead>
<tr>
<th>ACTIVITY PLAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test and implement the new coil heater system for mAestRo. Install the mAestRo system into the second hutch at the xAS beamline, As. Develop routines for fully automatic operation, plus temperature and pressure control. Construct a new Maia-104 detector block for improved energy resolution. Conduct tests using a new silicon-drift detector (SDD) array prototype that provides a path to 2x better energy resolution and count-rate throughput. Implement XAINS imaging into GeoPXE package. Develop an adapted Maia-104 platform for the NNP for PXE imaging. Upgrade the NNP vacuum chamber to accommodate Maia plus a new stage. Demonstrate parallel processing of Maia data in the GeoPXE software.</td>
</tr>
</tbody>
</table>

**P3B13A**
Stacey Bong

<table>
<thead>
<tr>
<th>ACTIVITY PLAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>The following actions are planned via the Australian Synchrotron. Develop standard procedures for extraction and analysis of XANES spectra from high resolution XRF images. Investigate Fe, Cu, Cr and Mn resonance states using XANES from SRO images of pyrite, biotite and felsic metarimes. Integrate XANES using single- and multi-layer stacks. Analyse the solubility and chemistry of Au in bromide rich solutions at high pressure and temperatures (LEIFS and mAESTRO).</td>
</tr>
</tbody>
</table>

**P3C2A**
Anya Reading

<table>
<thead>
<tr>
<th>ACTIVITY PLAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Develop computer-corrected enhanced images generated by LA-ICP-MS.</td>
</tr>
</tbody>
</table>

**P3C3A**
Leonid Danyushkevich

<table>
<thead>
<tr>
<th>ACTIVITY PLAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Release Petrolog v.3.2, containing a range of petrological tools.</td>
</tr>
</tbody>
</table>
Cover

Drill core showing pyrite, sericite-hematite vein in porphyry.
Grange Resources’ Savage River operation.

Back

Drill core at BHP’s Escondida mine, Chile.
Outcrops of Cambrian sequences at the Ironbound Range, SW Tasmania – image continues to bottom, left corner of page.

Zhaoshan Chang and Jamie Wilkinson, sampling at Cerro Ironbound Range, SW Tasmania.

Student Projects

Dan Gregory collects core samples from the River Derwent, Hobart.

Introductory Pages

Page 2: Chris Allen on the coast near the Ironbound Range, SW Tasmania.
Stained potassium feldspar.
Zhaoshan Chang and Jamie Wilkinson, sampling at Cerro Cocos in the Yanacocha district, Peru.

Director’s Report

Page 5: Director, Ross Large.

Fundamental Research to Applied Outcomes

Page 9: Stephen Cox (right), ANU, leading a short course at CODES on fracture controlled hydrothermal systems. The student is Charles Makoundi.
Ironbound Range, SW Tasmania.
Bruce Gemmell (right) with John Thompson, Teck Resources, at the CODES booth, SEG Meeting, Keystone, Colorado.

Staff & Management

Page 8: The Advisory Board meeting in June.

Student Projects

Page 13: Paul Polito, Anglo American, with Fiona Best at the Phantom Creek tenement, north Queensland.

Program One / Location

Page 18: Matthew Island volcano in the south-eastern tip of the Quaternary volcanic chain of the New Hebrides island arc.
Group attending final meeting of the Ore Deposits of SE Asia project.

Page 24: Vadim Karnetsky, Jocelyn McPhee and Nick Green (BHP Billiton) inspecting drill core samples at Olympic Dam.
Dogashima coastal formation, Izu Peninsula, Japan.

Page 25: Laminated mudstone in the Olympic Dam breccia complex.
Takayuki Manaka inspecting granites in southern Myanmar.

Program Two / Formation

Page 35: Open pit at Newcrest Mining’s Cadia Hill site.
Yangshan iron deposit, Anhui province, China.

Page 31: Samples from Nihe iron deposit, Anhui province, China – two images.
David Cooke with Taoa Zhou (Hefei University), China.

Page 32: Core yard at OZ Minerals’ Prominent Hill site.
Shelter for core logging and sampling, Wafi camp, PNG.
Mike Baker looking at core samples at Newcrest’s Cadia Hill mine.
Rhizo-concretions and wind turbines, near Cape Bridgewater, Victoria.

Page 34: Biscuit Tumul, Wollareldale, Victoria.
Hematite-magnesium carbonates and limonite.
Series of lava flows with brecciated margins, Cape Bridgewater, Victoria.

Page 35: Stained potassium feldspar.

Program Three / Discovery

Page 36: Chris Allen on a field trip to SW Tasmania.
Huayong Chen in the Casale district, Chile.

Page 38: Gabe Sweet (Lakehead University) mapping the Black Mountain porphyry, Baguio district, Philippines.
Ironbound Range, SW Tasmania.

Page 41: Ross Olsen on ASET2 field deployment.
Aerial views of Grange Resources’ Savage River site.

Page 44: Ceno-Casale district, Chile.
Final meeting of AMIRA project P765A.

Page 45: Cathedral Peak, Ceno Casale.

Program Four / Recovery

Page 46: Drill core at BHP’s Escondida mine, Chile.
Angus McFarlane underground at Newcrest’s Telfer Au-Cu mine, Western Australia.

Page 50: Malachite stained rock.
Bucket shovel at BHP’s Escondida mine, Chile.

Page 52: SAG/AG mills at Wiluna Gold Mine, Western Australia.
Prominent Hill site – photo courtesy of OZ Minerals.

Page 53: Conveyors at Newcrest’s Telfer Au-Cu mine, Western Australia.

Program Five / Technology

Page 54: Marcel Guifong working with the new Agilent 7700 quadrupole mass spectrometer.
Map of Fe57 taken from a multi-element laser map of a pyrite mineral grain. Sample is from the epithermal Ag-Au deposit at Palmarito, Chihuahua, Mexico.
Dan Gregory collects core samples from the River Derwent, Hobart.
Ian Little using the new Resonetics Resolution M50 laser microprobe.

Page 57: Sarah Gilbert using the Agilent 7500 ICP-MS.

Page 61: CSIRO Nuclear Magnetic Resonance (NMR) laboratory in Melbourne.

Graduate Research & Training

Page 63: Graduate Research Co-ordinator, Jocelyn McPhee, aboard the two young cubs engrossed in an educational game with the UTAS Career Advisor Symposium.

Page 64: Andrew McNeiles addresses the school for seniors at Rosny Library.
A student from Calvin Christian School jumps and stomps on the floor to simulate the effects of an earthquake as part of a seismology demonstration.

Page 71: Coast near Ironbound Range, SW Tasmania.

Appendices

Page 93: David Cooke with Taoa Zhou (Hefei University) and Zhaoshan Chang examining the Longgasa iron, Anhui province, China.

Please note: in various places throughout this publication, imagery has been used for graphic purposes only. Captions have not been provided in these instances.

Outreach

Page 44: The new Garnissum, featuring rocks from around the world.
Taronga Cubs visit the lapidary facilities at CODES.
Two young cubs engrossed in an educational game with rocks.

Page 65: Andrew McNeiles addresses the School for Seniors at Rosny Library.
A student from Calvin Christian School jumps and stomps on the floor to simulate the effects of an earthquake as part of a seismology demonstration.
Rob Scott talks about rocks and fossils to a group from the Montagu Bay Primary School.
Teachers conduct experiments during a TESEP workshop.
Director, Ross Large, in the CODES’ rock garden ‘talking geology’ to a group from the Fahan School for girls.
Michael Roach explains some of the intricacies of seismology during the UTAS Career Advisor Symposium.

Performance Indicators

Page 71: Coast near Ironbound Range, SW Tasmania.

Appendices

Page 93: David Cooke with Taoa Zhou (Hefei University) and Zhaoshan Chang examining the Longgasa iron, Anhui province, China.

Please note: in various places throughout this publication, imagery has been used for graphic purposes only. Captions have not been provided in these instances.