CODES

ARC Centre of Excellence in Ore Deposits

Annual Report 2006

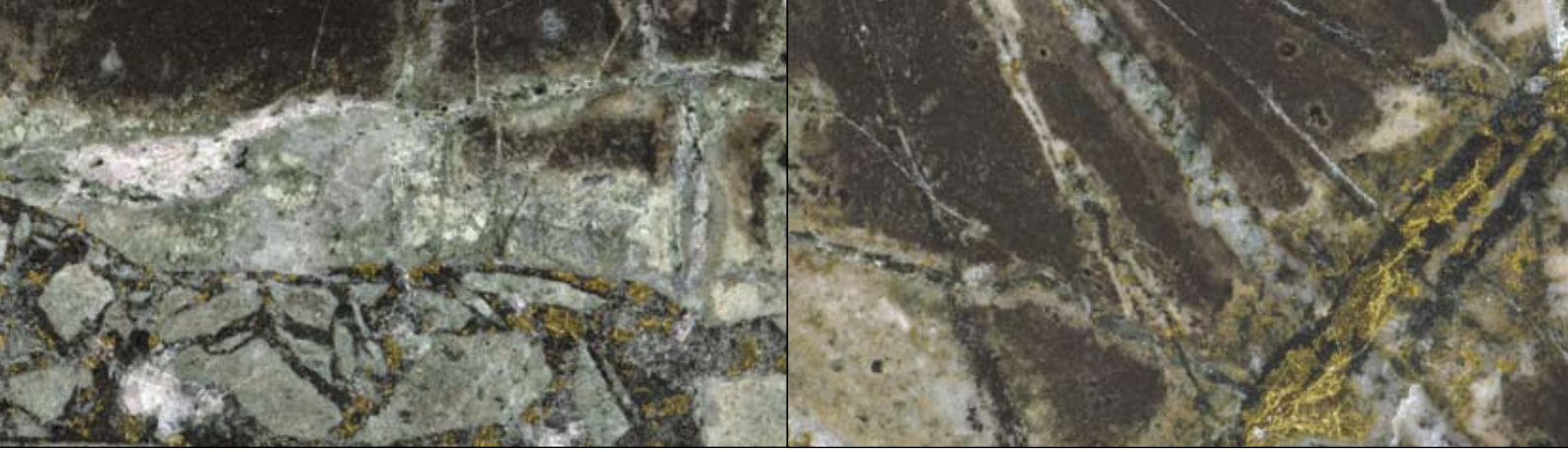
Australian Government

Australian Research Council

The Centre is supported by the Australian Research Council through its Centres of Excellence program.

It is a partnership between CODES, AMIRA International and industry: Anglo American, AngloGold Ashanti, Barrick Gold, BHP Billiton, Newcrest Mining Limited, Newmont Mining Corporation, Rio Tinto, St Barbara Mines, Teck Cominco and Zinifex Limited.

Collaborating institutions are the Australian National University, the Colorado School of Mines, CSIRO Exploration and Mining, Johns Hopkins University, the University of British Columbia, the University of Melbourne, the University of Queeensland and the University of Tasmania.



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CODES
ARC Centre of Excellence in Ore Deposits
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VISION

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

MISSION

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

CENTRE GOALS

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

CONTENTS

DIRECTOR'S REPORT

Since its establishment in mid-2005, the Centre of Excellence in Ore Deposits (CODES) has engaged in an exciting period of growth and consolidation. Our research is focused on five major programs: Location, Formation, Discovery, Recovery and Technology involving over 35 projects that include collaboration with a wide range of national and international research groups. CODES research strategy has been to build a world-class multidisciplinary team with the capacity to tackle major research problems anywhere in the world. We work in collaboration with other recognised global/regional research institutes and industry partners. Our education strategy, in collaboration with the UTAS School of Earth Sciences, is to run a high-quality integrated Honours, Masters and PhD program with a balance of Australian and international students working on projects relevant to the minerals industry. This program is facilitated by our active participation in the Minerals Council of Australia's national education initiative.

During our first 18 months we have put considerable effort into developing three new research directions in CODES. First, we have successfully initiated and commenced a major collaboration with the Julius Kruttschnitt Mineral Research Centre at University of Queensland in the area of geometallurgy. This globally significant research initiative addresses the cross-disciplinary divide between ore-deposit geology and metallurgy, with an aim to provide new tools and methodologies to support more efficient and sustainable metalliferous mineral extraction and mine planning. The project has rapidly developed into our largest research program. Led by Steve Walters, the program involves 14 research staff, five postgraduate students and total funding of $2 million by ARC and $4.5 million by 15 companies under the umbrella of AMIRA International. Even at this early stage of research it appears highly likely that this project will have a major impact on the geological and mineral processing practices of the minerals industry.

Our second initiative has been to develop critical mass in exploration geophysics at CODES, and to integrate geophysics into our other major research programs, especially Location, Discovery and Recovery. To this end, Peter Fullagar has joined CODES as an Adjunct Professor and has become strongly involved in our Recovery and Discovery programs. In addition, we have appointed Mark Duffett as a Research Fellow to work across our Location and Discovery programs, and in late 2005, Anya Reading accepted a 50/50 position in CODES and UTAS School of Earth Sciences to join Michael Roach in our geophysics teaching and research program. We now have one of the strongest geophysics groups in Australia to focus on ore deposit-related geophysics research.

The third initiative has been to expand our ore-genesis research to include magmatic nickel deposits and sediment-hosted gold deposits. Both objectives have been achieved. On the nickel front, during 2006 we negotiated a new AMIRA-funded research project on the application of our fundamental melt-inclusion research techniques to understanding magma evolution, sulfur saturation and Ni-PGE deposit genesis in mafic/ultramafic complexes. This project, to be led by Leonid Danyushevsky, will involve major collaboration with the Vernensky Institute of the Russian Academy of Sciences. On the gold front, our newly developed AMIRA research project on sediment-hosted gold deposits in the Carlin trend (USA), Fosterville and Bendigo (central Victoria, Australia), and the Lena Goldfield (Siberia), has made some exciting breakthroughs in understanding the protracted evolution of gold-rich sedimentary basins. Although only early days for this research, the results have major implications for future exploration of sediment-hosted gold systems.

Some other significant highlights for the year include:

- Researchers in our Location program have been the main contributors to four of the '50 most highly cited papers' published in the prestigious *Journal of Petrology* over the past five years.
- The new collaborative research project between CODES and MDRU (UBC) on ore-forming processes for alkalic porphyry copper-gold and epithermal gold deposits has received strong support from the Canadian and Australian minerals industry. This project has engaged nine new PhD and Masters students based at UBC and UTAS.
- The three-year AMIRA-ARC Linkage project on transition and zoning in porphyry-epithermal districts had a successful final research meeting in December 2006, with sponsors in strong agreement that some of the most exciting outcomes justified further focused research.
- Significant progress was achieved on a range of new

Federal Education Minister Julie Bishop, UTAS Vice Chancellor Daryl Le Grew (obscured), Chairman of the CODES Advisory Board John Dow and Director of CODES Ross Large at the opening of the ARC Centre of Excellence held in July 2006

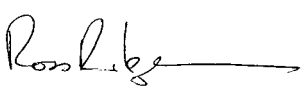
technology developments in geometallurgy, in particular, automated core logging, automated mineral textural data acquisition and analysis and small-scale comminution testing. A collaborative agreement was developed with CSIRO to integrate SWIR-based HyLogger instrumentation into the Recovery program.

- In collaboration with the University of Melbourne CODES has developed a rapid and cost-effective technique for LA-ICPMS lead isotope analysis on pyrite.
- We have expanded the CODES LA-ICPMS facility with installation of a new Agilent 7500 quadrupole mass spectrometer and a New Wave Research 193 nm solid-state Nd-YAG laser. This will enable sensitive geochronological and fluid/melt inclusion analysis to be undertaken separately from the sulfide and Pb-isotope analysis.
- Publication of a CODES monograph, 'The Geology of the Broken Hill Deposit', which is the first in a new series of publications on world-class ore deposits.
- Organisation of a successful workshop on 'Ores in Sediments: New Directions, New Developments' which was attended by more than 100 academic and industry geoscientists.

The CODES International Visitors Program made an excellent start this year with eleven international researchers making extended visits to work with our research staff: Professor Grant Garven (Johns Hopkins University, USA), Professors Sergey Smirnov and Victor Sharygin (Institute of Geology and Mineralogy, Russia), Dr Kirstie Simpson (Geological Survey of Canada), Dr Xieyan Song (Guangzhou Institute of Geochemistry, China), Professor Taofa Zhou (Hefei University, China), Professor Valeriy Maslennikov and Dr Svetlana Maslennikova (Institute of Mineralogy, Russia), Dr Somboom Khositanont (Department of Mineral Resources, Thailand), Dr Dan Layton-Matthews (Queens University, Canada) and Dr George Zellmer (Institute of Earth Sciences, Taiwan). In addition to these academic visitors, we had more than 80 industry visitors to CODES, for periods of from one day to a week, to review research progress and discuss new research initiatives.

Research output from CODES in 2006 can be reviewed in relation to the Research Quality Framework program currently being developed by DEST. In terms of academic quality, CODES researchers produced 27 publications in quality international journals including: *Economic Geology*, *Journal of Petrology*, *Chemical Geology*, *Mineralium Deposita*, *Geology*, *American Journal of Science*, *Bulletin of Volcanology* and *Terra Nova*. Eighty-three papers were presented by CODES researchers and students at national and international conferences, of which 15 were invited keynote papers. Michael Roach received a best paper award at the Australian Earth Sciences Convention for his research on geophysical characterisation and inversion of ore deposits. In terms of impact to the minerals industry, 139 separate individual research reports were presented to industry, of which 72% were reports to AMIRA International concerning results, interpretation and application of the research to the minerals industry. In addition to the reports, 15 meetings (each covering one to two days of scientific presentations) were held with industry representatives to facilitate technology transfer and adoption of the specific research findings. Between five and 30 industry representatives were present at each meeting. A further nine short courses/workshops were held for industry practitioners to aid the on-going technology transfer process of CODES research. These short courses/workshops were attended by 220 end-user geoscientists. In 2006 the impact of CODES research on industry was far reaching, including North and South America, South East Asia, and Central and Southern Africa.

In conclusion, I look forward to the exciting years ahead for CODES as the minerals industry continues to grow through this extended super-cycle. I particularly want to thank the exceptional team of researchers and support staff at CODES and our national/international collaborators and industry partners for their support in 2006.



Ross R Large
Director and Chief Operations Officer

STAFF & MANAGEMENT

Centre Director

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

Advisory Board

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

Science Planning Panel

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

Centre Research Committee

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

Executive Committee

The Executive Committee membership consists of the Centre's Director, five program leaders and administrative managers. This committee meets, on average, six times a year. The Executive Committee works closely with the Director to develop the Centre's goals, strategies and performance indicators.

Staff Appointments in 2006

Ruben Chan joined us as database and website manager at the beginning of June 2006. In conjunction with Leonid Danyushevsky, he is developing a data repository to provide CODES researchers with data management tools.

Mark Duffett has joined CODES as a research fellow in regional geophysics and tectonics. He will be working on geophysical interpretation and modelling aspects of projects in mineralised regions of Tasmania, mainland Australia and Africa.

Peter Fullagar joined CODES as an Adjunt Professor in 2006. He is currently Principal of Fullagar Geophysics Pty Ltd.

Julie Hunt moved from the Yukon Geological Survey to join CODES as a postdoctoral fellow at the beginning of May 2006. She is carrying out research for the Geometallurgical Mapping and Mine Modelling (GeM^{III}) project which is examining the interface between ore petrology and mineral beneficiation.

Andrew McNeill joined us in early May 2006 as a Senior Research Fellow. He moved from his former position as Senior Exploration Geologist, Rosebery, to take up this three-year position. Andrew's research will follow on from his PhD work, using melt inclusions to determine the origin of magmatic nickel deposits and develop models to be used for exploration. He will also work on Tasmanian projects, including investigating aspects of the Rosebery VHMS deposits to help with exploration in the area.

Tony Webster started with CODES in the second half of 2006 as the MTEC Senior Lecturer and Masters Program Coordinator. His career spans 18 years in the mining industry in production, resource definition, exploration, heritage assessment, environmental and research roles.

CODES staff 2006

Director, Professor Ross Large, BSc Hons (Tasmania), PhD (New England)	Volcanic-hosted and sediment-hosted base metal and gold ores	100% in CODES
Deputy Director, Assoc. Professor J Bruce Gemmell, MA, PhD (Dartmouth)	VHMS deposits and epithermal Au-Ag	50
Academic/research staff at UTAS		
Dr Sharon Allen, BSc (Massey), MSc (Auckland), PhD (Monash)	Volcanic facies analysis	50
Dr Ron Berry, BSc, PhD (Flinders)	Structure of mineralised provinces, CHIME dating, geometallurgy	50
Dr Stuart Bull, BScHons, PhD (Monash)	Clastic and carbonate sedimentology and volcanology	100
Dr Zhaoshan Chang, BSc, PhD (PKU, WSU)	Skarn, porphyry and epithermal deposits; LA-ICPMS zircon dating	100
Assoc. Professor David Cooke, BScHons (LaTrobe), PhD (Monash)	Fluid-rock geochemistry, porphyry Cu-Au	50
Professor Tony Crawford, BScHons, PhD (Melbourne)	Petrology, geochemistry and tectonics of volcanic arcs	50
Assoc. Professor Leonid Danyushevsky, PhD (Vernadsky Inst.)	Petrology, geochemistry, application of melt inclusions	50
Dr Garry Davidson, BScHons (ANU), PhD (Tasmania)	Sulfur isotope geochemistry and Cu-Au ores	50
Dr Paul Davidson, PhD (Tasmania)	Melt and fluid inclusions	100
Dr Cari Deyell, BSc (Queens) PhD (British Columbia)	Geochemistry and mineralogy of hydrothermal systems	100
Dr Mark Duffett, PhD (Tasmania)	Regional geophysics	100
Dr Anthony Harris, BScHons, PhD (Queensland)	Ore deposit geology/geochemistry	100
Mr Wally Herrmann, BScHons (Monash), MEconGeol (Tasmania)	Alteration and exploration in volcanic settings	100
Dr Julie Hunt, MSc (British Columbia), PhD (James Cook)	Geometallurgy, IOCG	100
Dr Maya Kamenetsky, PhD (Tasmania)	MLA-SEM, geometallurgy, petrology	50
Professor Vadim Kamenetsky, PhD (Vernadsky Inst.)	Petrology and geochemistry of melt inclusions	50
Dr Peter McGoldrick, BScHons, PhD (Melbourne)	Geochemistry of ore deposits and their halos	75
Professor Jocelyn McPhie, BAHons (Macquarie), PhD (New England)	Volcanic facies architecture and volcanic textures	50
Dr Sebastien Meffre, BScHons, PhD (Sydney)	Petrology and tectonics of the SW Pacific	50
Dr Andrew McNeill, PhD (Tasmania)	Petrology, VHMS deposit, mineral exploration	100
Dr James Reid, PhD (Macquarie)	Electrical geophysics	50
Dr Michael Roach, BScHons (Newcastle), PhD (Tasmania)	Geophysical responses of ore deposits	50
Dr Robert Scott, BScHons, PhD (Monash)	Structural geology, gold deposits	100
Dr David Selley, BScHons (Adelaide), PhD (Tasmania)	Structural geology/basin analysis, sedimentary Cu	100
Dr Michael Solomon, MSc, PhD (Tasmania), DSc (London)	Geochemistry and genesis of mineral deposits	25
Assoc. Professor Steve Walters, BScHons, PhD (Sheffield)	Node Leader: geometallurgy, applied mineralogy, exploration technologies	50
Dr Tony Webster, MSc (James Cook), PhD (Tasmania)	MTEC Senior Lecturer and Masters Program Coordinator	100
Dr Khin Zaw, BSc (Yangon), PhD (Tasmania)	Fluid inclusions, SE Asian metallogenesis	100
Academic/research staff based at collaborative institutions		
Dr David Belton	CSIRO Exploration & Mining	50
Professor Steve Cox	Node Leader; Australian National University	5
Dr Nenad Djordjevic	University of Queensland	30
Dr Peter Fullagar	Fullagar Geophysics Pty Ltd	30
Professor Grant Garven	Johns Hopkins University	20
Assoc. Professor Jeff Hedenquist	Colorado School of Mines	10
Assoc. Professor Janet Hergt	Node Leader, University of Melbourne	10
Professor Murray Hitzman	Colorado School of Mines	20
Dr Rob Morrison	University of Queensland	15
Dr Richard Tosdal	University of British Columbia	30
Assoc. Professor Steve Walters, BScHons, PhD (Sheffield)	Node leader, University of Queensland	50
Dr John Woodhead	University of Melbourne	30
Technical/administrative staff		
Mr Ruben Chan, BComp (Tasmania)	Database and website manager	100
Mr Peter Cornish	Laboratory manager	50
Ms Anisa Ghofrany	Personal assistant (March-Sept)	100
Ms Sarah Gilbert, BScHons (Tasmania)	Senior technician ICP-MS	100
Ms Christine Higgins, GradCertManagement (Tasmania)	Finance manager	50
Mrs Katrina Keep	Personal assistant (Jan-March, Sept-Dec)	100
Mrs Katie McGoldrick	Laboratory assistant	80
Ms June Pongratz	Publications manager	50
Mr Philip Robinson, BScHons (Nottingham)	Analytical services manager	70
Mrs Dianne Steffens	Finance assistant	100
Mr Simon Stephens, BSc (Tasmania)	Manager lapidary services	50
Ms Isabella von Lichtan, BScHons (Tasmania)	Curator	20

Advisory Board

Chair: John Dow	Consultant
Jim Reid	Dean, Faculty of Science Engineering and Technology, UTAS
Ross Large	Director, CODES
Bruce Gemmell	Deputy Director, CODES
Jocelyn McPhie	CODES
Steve Walters	Recovery Program Leader, CODES
Ben Adair	Director, JKMRC
Tony Brown	Executive Director, Mineral Resources Tasmania
Alan Goode	Research Director, AMIRA International
John Holliday	Principal Geologist – SE Australia, Newcrest Mining Limited
Graham Carr	CSIRO
Noel White	Consultant
Ian Willis	VP Exploration Anglo American
John Hammond	Chief Geologist, Newmont Exploration
John Larson	VP Exploration Zinifex
Steve Cox	Australian National University
Janet Hergt	University of Melbourne

Executive Committee

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

Science Planning Panel (includes the Executive Committee and all CODES research staff)

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

CODES executive committee 2006: L to R, Tony Crawford, Bruce Gemmell, Christine Higgins, Ross Large, Katrina Keep, Leonid Danyushevsky, June Pongratz, David Cooke. Insets: Jocelyn McPhie, Steve Walters

CODES technical and administrative staff 2006: L to R, Peter Cornish, Phil Robinson, Christine Higgins, CODES Director Ross Large, Simon Stephens, Sarah Gilbert, June Pongratz, Dianne Steffens and Katrina Keep

RESEARCH FRAMEWORK

The ARC Centre of Excellence in Ore Deposits (CODES) was established in 2005 to build upon the internationally recognised strengths of the ARC Special Research Centre for Ore Deposit Research, in order to create the nation's leading research centre in ore deposit genesis, mineral exploration and geometallurgy.

The Centre has embraced strategic and applied research into the formation, location, discovery and recovery of ore deposits and the development of innovative technologies to support this quest.

Background

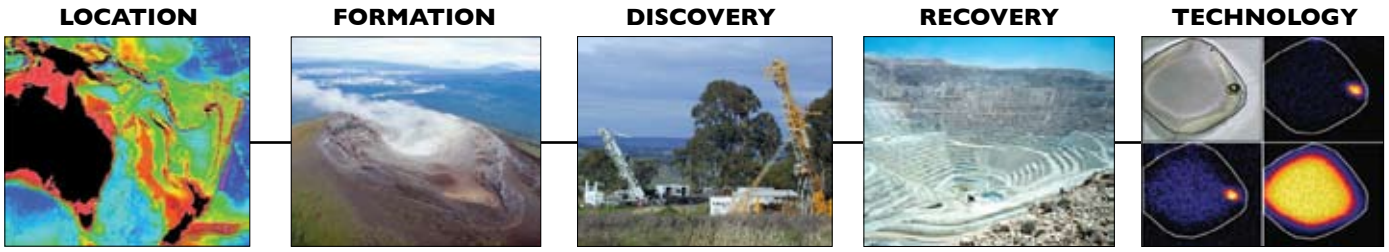
Australia has the world's third largest minerals sector, by value of production, after the USA and South Africa (E. Kuller, The global mining industry report for Austrade, May 2006). Our minerals sector generated exports of around $75 billion in 2005–06 (Minerals Council of Australia, 2005 Annual Report). In 2006, total Australian minerals exploration expenditure rose by 21% to $2.5 billion and new capital expenditure in the mining industry rose by 76% to $18.1 billion. In real terms, estimated expenditure in the 2005-06 period was the highest since 1997–98 and around 13% above average annual expenditure on minerals exploration over the past 25 years. New capital expenditure was the highest on record, more than double the average annual expenditure for the past 25 years ($8.3 billion) (Australian Bureau of Agricultural and Resource Economics, Australian commodities report, December quarter 2006). Securing maximum financial and environmental benefits from this investment in our ore resources requires a comprehensive understanding of a wide range of complexly interacting geodynamic processes that lead to their formation, location, discovery and recovery. CODES aims to lead the global minerals industry in these endeavours.

The paradigm underlying the Centre's research agenda is that tectonic setting and large-scale processes exert fundamental controls on the fertility and ore potential of volcano-plutonic fold belts and sedimentary basins. Tectonic setting influences magma composition, the nature and abundance of volatile and metal elements, and structure, all of which are key ingredients in the formation of mineralising hydrothermal systems. Tectonic setting also controls the architecture and evolution of sedimentary basins. In these settings, ore formation depends on a favourable conjunction of hydrological and chemical parameters that control the basin-scale hydrothermal systems. Hence, terrane-scale research on tectonic settings of fold belts and sedimentary basins underpins our ability to predict the LOCATION of different ore deposit types (Program 1).

Success in exploration for ore deposits in fertile provinces depends on accurate and practical scientific models of ore formation. These models are used by mining companies to decide where to explore and what methods to use. Hence, research focusing on the FORMATION of ore deposits (Program 2) provides a further predictive dimension that is critical in mineral exploration – only through a thorough understanding of the formation of ore deposits can the search for them be conducted efficiently. This understanding forms the basis for devising techniques aimed at finding new ore deposits.

Deep Earth resources by definition are covered – their DISCOVERY (Program 3) depends on 'seeing' through the cover using a combination of geophysical, geochemical and geological approaches. There is thus an urgent need for data on the physical, geochemical and mineralogical properties of ore deposits and their alteration halos. These integrated data can then be used, together with innovative 2D and 3D inversion modelling, to define the geophysical and geochemical responses of different ore deposit types, and to show how these responses relate to the surrounding geology or vary according to depth of burial.

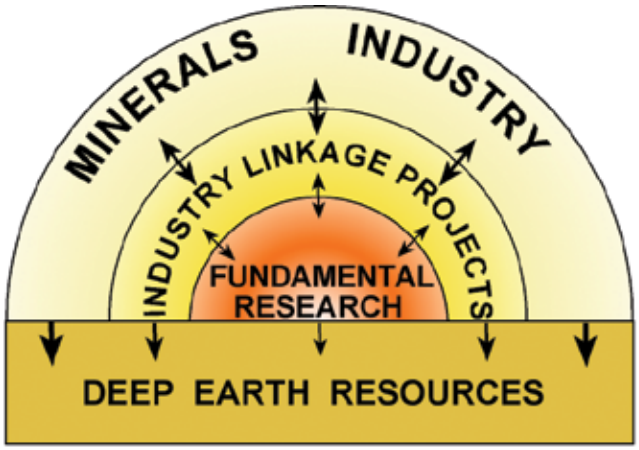
Transforming an ore deposit into a sustainable and profitable mining operation requires detailed information on the ore mineralogy, chemistry and texture. The challenge here is to bridge the gap that separates geologists and geophysicists who traditionally focus on location, formation and discovery of ore deposits, and metallurgists and mining engineers whose primary focus is on mineral extraction. Meeting that challenge demands new and radically different approaches to ore RECOVERY. This will be addressed in Program 4 through the creation of a formal collaboration between CODES and the Julius Kruttschnitt Mineral Research Centre (JKMRC), two of the top research groups worldwide in their respective fields. This collaboration, involving a bold step into the field of geometallurgy, has the



potential to revolutionise the way mining companies use ore characterisation to enhance mineral recoveries and manage downstream environmental impacts.

Research programs 1 to 4 are supported and augmented by developments in TECHNOLOGY (Program 5) that will routinely produce compositional and geochronological data of exceptional accuracy. The equipment and analytical developments in Program 5 will underpin the Centre's capacity to conduct research at the forefront of global Earth science.

These five research programs – LOCATION, FORMATION, DISCOVERY AND RECOVERY of ore deposits, and TECHNOLOGY – articulate the aims of the Centre of Excellence in Ore Deposits and, with more than 80 researchers including over 50 Honours, Masters and PhD students, we are leading the world in collaborative ore deposit research.

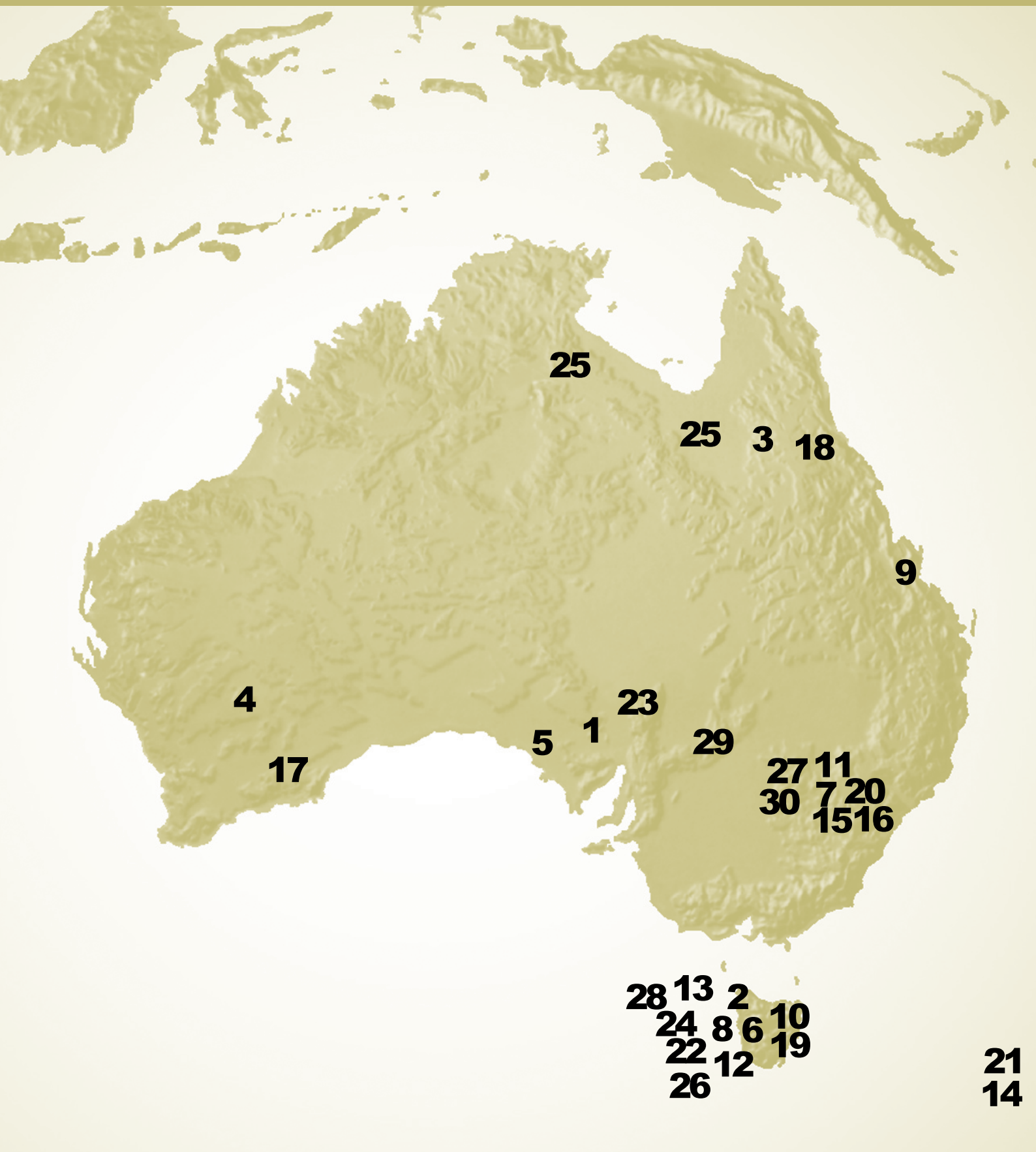


Framework

The Centre has an inner core of fundamental research programs that are linked to a portfolio of applied programs conducted in collaboration with the minerals industry. The research in the applied programs is built on the initiatives and innovations undertaken in our fundamental research projects. Fundamental projects ('F' projects) are funded by the ARC Centre of Excellence grant. Industry-linked projects ('L' projects) are jointly funded by industry and ARC Centre of Excellence funds. In 2006, new initiatives arising from fundamental and/or linked research projects ('N' projects) are identified.

The Centre conducts five linked and complementary research programs: Location, Formation, Discovery, Recovery and Technology. Program 1 (Location) builds on our existing expertise in magmatic, volcanic and tectonic processes but involves expansion into diverse tectonic settings and includes new research on magmas associated with nickel-PGE mineralisation. Program 2 (Formation) encompasses much of the internationally recognised research previously conducted by CODES, and will be strengthened and extended by adopting an integrated approach to solving metal source, transport, trap problems, and by targeted collaborations with other leading research institutes. Program 3 (Discovery) includes a new initiative in ore deposit geophysics that will complement our established expertise in ore deposit geology and geochemistry. This step is strongly supported by the mining industry and directly addresses the need to explore for concealed Deep Earth resources. Program 4 (Recovery) is both entirely new and radically innovative. Collaboration between two recognised world leaders in their respective fields – CODES in ore deposits and the JKMRC in metallurgy – has the potential to radically change current practices. Program 5 (Technology) also incorporates substantial expansion and new developments for the equipment and data-processing capacity of the Centre. That capacity will achieve the world-class status required to support the research effort by an up-grade of existing equipment at CODES, and establishing collaborations that provide access to key equipment elsewhere.

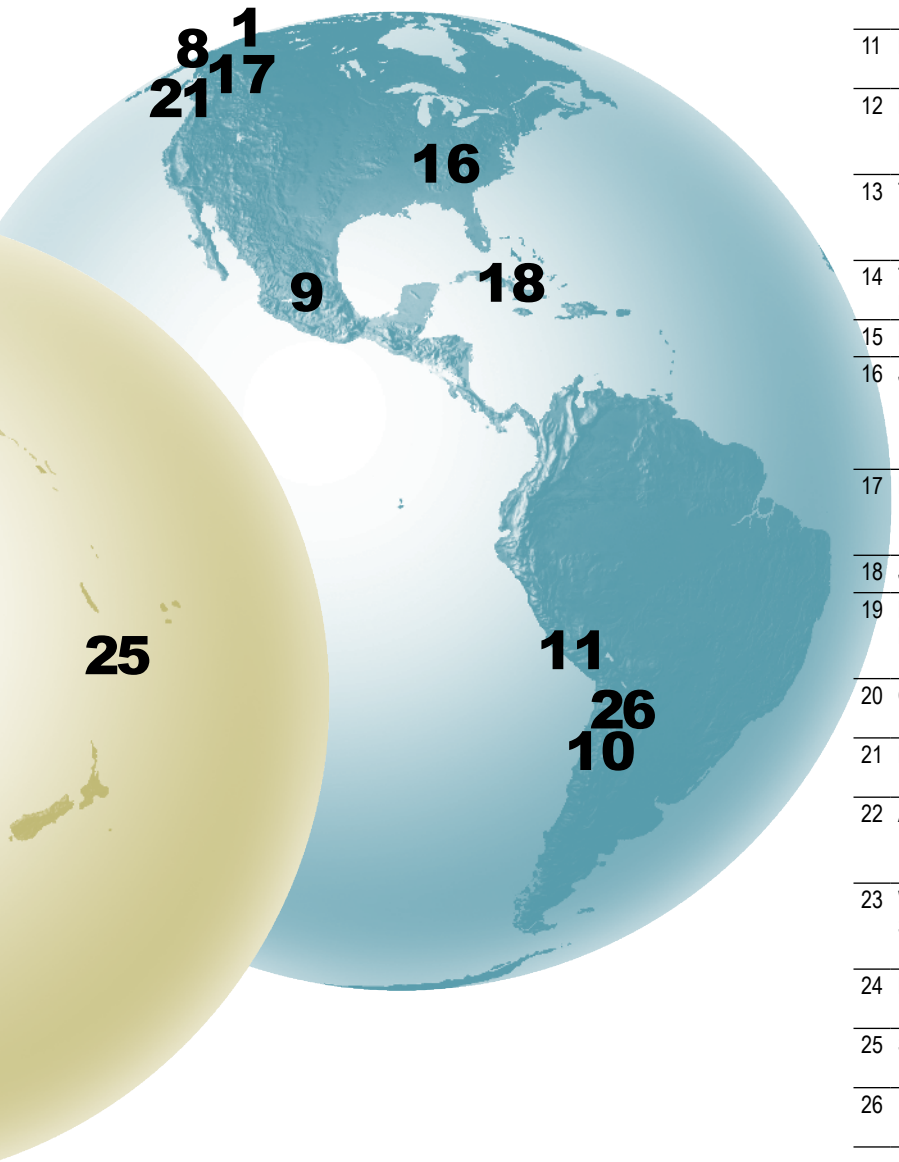
STUDENT PROJECTS IN AUSTRALIA



Un-numbered projects are laboratory-based

1	Andrea Agangi	Magmatic and volcanic evolution of giant intraplate felsic igneous provinces and associated ore deposits: Gawler Range Volcanics and Hiltaba Suite, South Australia
2	Darren Andrews	Geophysical monitoring of acid mine drainage at Savage River Mine, northwestern Tasmania
3	Michael Baker	Palaeoproterozoic magmatism in the Georgetown Block, North Queensland, and comparisons with the Broken Hill Block
4	Susan Belford	Genetic and chemical characterisation of the Archaean Jaguar VHMS deposit
	Natalee Bonnici	Textural and minerological characterisation of Cu-Au systems in relation to process mineralogy
5	Bryan Bowden	Iron oxide Cu-Au-related alteration history of the Mount Woods Inlier, South Australia, with special emphasis on the Prominent Hill prospect
6	Lachlan Brown	Geophysical investigation of tailings system integrity, Rosebery mine, Tasmania
7	Katharine Bull	Facies architecture of the Ural Volcanics, NSW
8	Colin Carter	An aspect of the CMT operations on the West Coast of Tasmania
9	Corrie Chamberlain	Geology, geochemistry and genesis of the Kilkenny low-sulfidation epithermal deposit, Cracow, Queensland
10	Reia Chmielowski	The metamorphic history of Tasmania
11	Ana-Leizl Cuison	Geology and genesis of the Ridgeway porphyry Au-Cu deposit, NSW
12	Kim Denwer	Mineralogical, geochemical and isotopic investigation of the Mount Lyell Cu-Au ore body and alteration system
	Cathy Evans	Texture-related flotation characteristics of ores
13	Lee Evans	Ground waters in wet, temperate sulfide mining districts: delineation of modern fluid flow and predictive modelling to improve management after mine closure (Rosebery, Tasmania)
14	Paul Ferguson	Origin of large negative magnetic anomalies in oceanic crust, Macquarie Island
15	David Finn	Late-stage mineralised faults in the Cadia district: their geological and exploration significance
16	Nathan Fox	Controls on mineralisation and alteration assemblages in the Cadia East gold-copper deposit, New South Wales
17	Laura Frankcombe	Geochemical and structural controls of gold mineralisation, Mars Mine, Western Australia
	Sarah Gordee	Characteristics of subaqueous pyroclastic facies in arc settings
18	Steven Groves	Geology and genesis of the Moonlight low-sulfidation epithermal prospect, Pajingo, Queensland
19	Katherine Harris	Characterisation and causes of dry land salinity in the Hamilton district, Tasmania
	Terence Hoschke	Geophysical signatures of gold-copper porphyry systems
20	Luke Keeney	Geometallurgical study of the big Cadia copper-gold skarn system
	Lyudmyla Koziy	Numerical simulation of fluid flow and fluid chemistry in sedimentary basins
	George Leigh	Wavelet analysis of texture parameters related to mineral processing
21	Steven Lewis	Sulfidic hydrothermal alteration in late brittle faults, Macquarie Island
22	Alexandra Lintner	Henty gold deposit, Mount Read Volcanics, western Tasmania
23	Wallace Mackay	Sedimentology and structure of the Curdimurka Subgroup, Willouran Range, South Australia.
24	Daniel MacIntyre	The Hollway Prospect; stratigraphy, regional correlations, alteration and mineralisation (west Tasmania)
25	Rodney Maier	Pyrite and base-metal trace-element halos in the northern Australian Zn-Pb-Ag deposits
	Richard Mazurek	GIS application to landslip prediction around major montane roadage infrastructure
	Claire McMahon	Controls on the geochemistry of hydrothermal pyrite in ore systems
26	Lee Robson	Application of remote sensing for geological mapping in western Tasmania
	Ralf Schaa	Rapid approximation imaging of electromagnetic data acquired using distributed multichannel data acquisition systems
	Blackwell Singoyi	Controls on the geochemistry of magnetite in hydrothermal fluids
27	Craig Stegman	Geochemistry and structure of gold-basemetal mineralisation in the Cobar Gold Field, NSW
28	Wijnand van Eijndthoven	Unravelling the southern extent and history of the Cambrian Rosebery Fault, western Tasmania
	Adel Vatandoost	Automated petrophysical characterisation of drillcore and potential relationships to mineral processing attributes
29	Kalem Wright	An aspect of the Broken Hill deposit
30	Wojciech Zukowski	Geology and mineralisation at Lake Cowal district, NSW, Australia

STUDENT PROJECTS OUTSIDE AUSTRALIA



1	Adam Bath	The geochemistry of inclusions and mineral phases from the Mount Polley and Lorraine alkalic Cu-Au porphyry deposits: implications for the formation of ore deposits
2	Paluku Batsotsi	An aspect of the geology of the Kinsevere Project, in the Katangan copperbelt, D R Congo
3	Jacqueline Blackwell	Characteristics and origins of breccias in an alkalic epithermal gold deposit: Ladolam, Lihir Island, PNG
4	David Braxton	Boyongan and Bayugo porphyry Cu-Au deposits, NE Mindanao, Philippines: geology, geochemistry, and tectonic evolution
5	Mawson Croaker	Geology and genesis of the Nkana copper deposit, Zambia.
6	Paul Cromie	Geological setting, geochemistry and genesis of the Sepon Mineral District, Laos PDR
7	Dinh, Quang Sang	Geochronology and geological evolution of the northern margin of the Kontum massif, central Vietnam
8	Russell Fulton	Geology and geochemistry of the hanging wall argillite, Greens Creek VHMS deposit, Alaska-Implications for ore genesis and exploration
9	Galván Gutiérrez	Palmarejo carbonate base-metal silver-gold epithermal deposit, Chihuahua, México
10	Tim Ireland	Geological evolution of the Collahuasi District, Tarapaca, Chile
11	Ben Jones	Genesis of the Antapaccay Cu-Au porphyry deposit, Peru
12	Maya Kamenetsky	Nature of primary melts in intracratonic settings: application of melt inclusions studies to kimberlites (Siberia)
13	Teera Kamvong	Geology and genesis of porphyry-skarn Cu-Au deposits at the northern Loei Fold Belt, Northeast Thailand and Laos
14	Takayuki Manaka	Epithermal low-sulfidation system at Ban Houyxai and LCT deposits, Laos PDR
15	Mannie Mehu	Lihir Island project
16	Joe Moye Jr	Genesis and chemical and kinematic evolution of the late Proterozoic Ridgeway gold deposit in the Carolina Terrane of the central South Carolina piedmont, USA
17	Heidi Pass	Chemical and mineralogical zonation patterns in alkalic mineral systems: implications for ore genesis and mineral exploration
18	Jose Polanco	District-scale mapping project around Pueblo Viejo
19	Nicole Pollington	Sedimentology, mineral paragenesis and geochemistry of the Konkola North copper deposit, Zambia
20	Carlos Rosa	Submarine volcanic successions in the Iberian Pyrite Belt, Portugal
21	Patrick Sack	Characterisation of the footwall lithologies, Greens Creek VHMS deposit, Admiralty Island, SE Alaska
22	Abhist Salam	Geological, paragenesis and geochronological relations of the Chatree area, Phetchabun Province, central Thailand
23	Weerapan Srichan	Petrochemistry, geochronology and tectonic implication of Chiang Khong-Lampang-Tak Volcanic Belts, Northern Thailand.
24	Bronto Sutopo	Geology and genesis of the Martabe deposit, Indonesia
25	Sofia Tetroeva	Petrology and geochemistry of adakites and related rocks from the Hunter Ridge, SW Pacific
26	Felipe Urzua	Regional geology of the Escondida district, northern Chile

PROGRAM 1: LOCATION

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

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Institute of Earth Sciences-Academia Sinica (Taiwan) – Georg Zellmer
Institute of Experimental Mineralogy (Russia) – Eduard Konnikov
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Institute of Geological and Nuclear Sciences (New Zealand) – Cornel de Ronde
Institute of Geology and Mineral Exploration (Greece) – Georgos Vougialakalis
Institute of Geology and Mineralogy (Russia) – Sergey Smirnov

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Monash University (Victoria) – Reid Keays
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Core projects in the Location Program

(F prefix denotes fundamental research project)

P1.F1 Geodynamic controls on fertility of fold belts and cratons
P1.F2 Modern magmatism in the Southwestern Pacific Ocean
P1.F3 Felsic magmas: volatile and metal budgets during magma evolution – a combined melt inclusion and volcanological approach
P1.F4 Nickel-PGE potential of mafic and ultramafic magmas – a combined melt inclusion and numerical modelling approach
P1.F5 Global ocean chemistry, marine basins and zinc-lead-silver mineralisation

(L prefix denotes industry-linked project)

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

HIGHLIGHTS

- **Successful proposal to commence a new AMIRA-supported project 'Nickel-PGE potential of mafic and ultramafic magmas – a combined melt inclusion and numerical modelling approach' in March 2007, involving Leonid Danyushevsky, Dima Kamenetsky, Andrew McNeill and Tony Crawford from CODES, Prof. Alexei Ariskin from the Vernadsky Institute of the Russian Academy of Sciences in Moscow and Prof. Eduard Konnikov of the Institute of Experimental Mineralogy (Russia).**

- **Four papers by CODES Program 1 researchers in 'Most cited 50 papers in past 5 years' compiled by high impact factor *Journal of Petrology*. This is more than any other group globally.**

- **Outstanding results from a National Facility vessel RV *Southern Surveyor* combined swath mapping and dredging cruise – 'Hot Subduction on the Hunter Ridge, Fiji-Vanuatu region'. The Chief Scientist was Leonid Danyushevsky.**

- **Launch of new cross-disciplinary project focusing on metal and volatile budgets of magmas that generate felsic volcanic provinces.**

- **Successful conclusion of comprehensive geochronological and metallogenic study of the highly prospective Loei Fold Belt in Thailand and Laos**

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

Project Leader: A Crawford
Project Members: R Berry, P Davidson, C Gifkins, A McNeill, J McPhie, S Meffre, J Woodhead
Students: M Baker, S Belford, QS Dinh, C Rosa, W Srichan
Collaborators: A Ariskin (Vernadsky Institute, Moscow), D Asthana (Indian School of Mines), N Direen (Frogtech), D Giles (University of Adelaide Centre for Exploration Under Cover), D Glen and B Stevens (Geological Survey of New South Wales), R Keays (Monash University), M Manly (Perilya Ltd),) N Martin (Jabiru Metals), J Penhall (Perilya Ltd), J Relvas (University of Lisbon), XY Song (Institute of Geochemistry and State Key Laboratory of Ore Deposit), I Withnall (Geological Survey of Queensland), MF Zhou (University of Hong Kong)

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

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

This project is the centrepiece of Project P1.F1, and has developed to the stage of demonstrating that the massive Broken Hill silver-lead-zinc deposit may well have formed from fluids exsolved from the widespread Palaeoproterozoic mafic magmas. By focusing on the concordant gabbroic (now amphibolite to granulite) sills in the Broken Hill Block, we have demonstrated that compositional variations due to in situ fractionation in the thicker sills (>~40 m thick) provide reliable and unambiguous 'way-up' indicators in regions where the high-grade metamorphism has obliterated other useful markers, and that gabbroic sills along the Broken Hill line of lode are significantly more iron-rich than regional Broken Hill Block mafic sills. Analytical data already available have been complemented by around 150 more wholerock analyses from across the Broken Hill Block.

Building on existing studies of the metabasic rocks in the Broken Hill Block, the team has shown that these are typical rift tholeiites, with a significant percentage of evolved ferrobasaltic compositions. The latter are ubiquitous along the line of lode, and we have demonstrated that this iron-enrichment, to striking levels (as much as 21% iron oxide in some sill chilled margins), is not due to pervasive iron-metasomatism as has been previously claimed. Major- and trace-element studies clearly demonstrate that advanced closed system crystal fractionation is responsible for the pronounced iron-enrichment.

Why should the iron-enriched magmas be dominant along the line of lode? We draw an analogy with gabbros drilled from the ultra-slow spreading centre at the Southwestern Indian Ridge at Ocean Drilling Program Site 735B. This 1500-m-deep drillhole sampled oceanic lower crust produced adjacent to a major extensional shear zone, and was characterised by remarkable amounts of oxide-rich gabbros that crystallised from exceptionally iron-rich magmas.

We propose that massive lead, zinc and water enrichment by synkinematic fractionation existed in oxide gabbros developed below the major extensional shear zone along which the line of lode now occurs, with much of the zinc located in ilmenite. Exsolution of late magmatic fluid provided the hydrothermal fluids responsible for the lead-zinc mineralisation, metals being leached from the lead-zinc enriched magmatic rocks along the shear zone. Sulfur isotope values of major Broken Hill lead-zinc ores cluster around zero, indicative of a magmatic source for the sulfur, and we believe also of the lead and zinc. Ilmenites in oxide gabbros typically have 1–2% manganese oxide, and their alteration by such hydrothermal fluids provided the abundant manganese and iron that characterises alteration assemblages around the ore bodies.

Complementing the Broken Hill study was research forming the core of Mike Baker's near-completed PhD thesis, which centred on the Palaeoproterozoic mafic magmatism of the Georgetown Block in northern Queensland. Striking age and compositional similarities exist between these rocks and the sills in the Broken Hill Block, except that the iron-rich sills of the Broken Hill line of lode are absent in the Georgetown Block, as is significant lead-zinc mineralisation. A paper presenting the results of this study is written, and will be submitted to *Precambrian Geology* as soon as the thesis is completed.

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

Closure on this large SPIRT-funded project will be the March-April 2007 publication of a two-volume thematic issue of *Australian Journal of Earth Sciences*. Of the 14 papers in press in this thematic issue, CODES staff and PhD students have senior-authored eight papers and they are co-authors of all but one paper. The volume represents one of the largest single additions of new knowledge to the geodynamic evolution and metallogenesis of the Lachlan Orogen in the past 40 years.

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

Three main study areas provide the database for research on the character and setting of submarine volcanic successions that host massive sulfide districts: the Cambrian Mount Read Volcanics in western Tasmania, the Archaean in Western Australia, and the Devonian-Carboniferous Iberian Pyrite Belt in Portugal.

Several linked projects, all well underway, are investigating key volcanic units within the Mount Read Volcanics to contribute to a better understanding of the tectonic and metallogenic evolution of this highly mineralised belt in western Tasmania. In particular, we are focusing on three areas: the Hellyer Basalt, the Sterling Valley Volcanics and the Henty Fault Wedge sequence, and the felsic rocks along the length of the belt. The latter rocks are being examined from a neodymium and hafnium isotope perspective, in an attempt to distinguish regional and temporal changes in the dominant felsic volcanic and intrusive rocks in the belt, and relate these to tectonic models. All field work and sampling are completed for this study, and analytical data for all suites are assembled (22 new wholerock analyses of Sterling Valley Volcanics), apart from one remaining set of rocks for neodymium-hafnium data, which are in progress.

Susan Belford's PhD research focuses on the recently discovered Archaean (2.6 Ga) Jaguar massive sulfide deposit in Western Australia. The Jaguar ore lenses occur along strike from the already mined Teutonic Bore massive sulfide deposit in a highly prospective and extensive greenstone belt. Susan's project will clarify the tectonic setting and volcanic architecture of the host succession using a combination of volcanic facies analysis and geochemical data. The succession consists mainly of andesitic and basaltic pillow lavas although fine sedimentary facies and felsic volcanic facies occur close to the massive sulfide. The project is funded by Garry Davidson's Linkage Grant and generously supported by Jabiru Metals Ltd.

Mount Read Volcanics at Lake Plimsoll, western Tasmania, the subject of on-going tectonic and volcanological research in Program 1

The first detailed study of the volcanology of the Iberian Pyrite Belt in Portugal was completed in 2006. The project involved collaboration with the University of Lisbon and was partly funded by the Portuguese Science and Technology Fund. CODES PhD student, Carlos Rosa, focused on three main locations in Portugal, one of which was the giant Neves Corvo massive sulfide ore deposit, and five sections in the Spanish part of the belt. Carlos produced detailed facies architecture reconstructions for the three main areas, and showed that two of the areas contain diverse submarine felsic pyroclastic and effusive facies whereas the third area is dominated by submarine felsic lavas. The Neves Corvo massive sulfide lenses accumulated close to a volcanic centre that produced felsic lava. Carlos showed that genuine peperite is uncommon in these successions, in contrast to the reported abundance of peperite elsewhere in the Iberian Pyrite Belt. He also assessed the character of the source felsic magmas and concluded that they are primarily crustal melts generated in a low-productivity, extensional sedimentary basin. Carlos has taken a post-doctoral position at the University of Lisbon and plans to extend his volcanological research in the Iberian Pyrite Belt.

Project P1.F1.4: Geological and tectonic evolution of the Greenvale region, northern Queensland

Field work on this northern extremity of the Palaeozoic Tasman Fold Belt System in northern Queensland was completed in 2005, and geochemical and geochronological data (LA-ICPMS on zircons) enabled the elucidation of the complex lithostratigraphy, and better constraints to be placed on the timing of major magmatic and metamorphic events. Only some CHIME monazite dating is required to complete this project, which will be then prepared for publication in the *Australian Journal of Earth Sciences.*

P1.F1.5: Geological evolution of southeast Asian terranes

This project encompasses two PhD projects. One (Weerapan Srichan) examines the geochemistry and geochronology of the extensive early Mesozoic volcanics in northern Thailand, to test and improve the numerous existing models for the geological evolution of mainland southeast Asia. All field and analytical work for this project is completed, and a preliminary report on the major results was presented at the December 2006 International Union of Geodesy and Geophysics meeting in Manila ('Geological Evolution of Eastern Asia').

The second PhD project in progress (Quang Sang Dinh) is focused on the northern margin of the poorly understood Kontum Massif in the Central Highlands of Vietnam. Previously considered by many workers to be a Precambrian crustal block, new data from this PhD study show that the oldest rocks are probably part of an Early Palaeozoic intra-oceanic island-arc backarc basin assemblage that has been intruded by at least three separate events of granitic magmatism. CHIME monazite work in progress is constraining the timing of the widespread metamorphic overprint on the basement rocks in the region.

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

This work, with Reid Keays at Monash University, attempts to demonstrate that the gold in the Victorian goldfields turbidite-hosted quartz reefs derives ultimately from unusually gold-rich mafic igneous rocks in the basement of central and western Victoria. Included in the latter are Neoproterozoic picrites of the 600 Ma volcanic passive margin succession, and boninitic lavas of the Cambrian ophiolite that were thrust over this volcanic passive margin around 510 Ma. We use PGE analyses to show that relative to modern, unaltered variants of these distinctive rock types, the old metamorphosed analogues have significantly reduced gold/palladium values, yet similar palladium to modern variants, indicating wholesale loss of gold during regional metamorphic degradation. All sampling and analytical work has been completed.

Project P1.F2: Modern magmatism in the Southwestern Pacific Ocean

Project Leaders: L Danyushevsky, A Crawford
Project Members: S Allen, T Falloon, S Meffre, J Woodhead
Student: Sofia Tetroeva
Collaborator: B Hayward (Geomarine Research)

This project aims to improve understanding of magma generation and evolution processes and products in the complex region of convergent plate margins in the Southwestern Pacific. This tectonic setting is considered to be the likely modern analog of the geodynamic environments that existed during formation of the orogenic volcanic belts in eastern Australia, which host numerous types of ore deposits. Understanding the processes, products and key elements involved in the construction of continental crust is fundamental to developing a better interpretation of where and why major ore deposits form, and devising smarter regional exploration strategies.

The project has five long-term inter-related aims: to assess variations in the initial magma volatile and chalcophile element contents among arc magmas on the Hunter Ridge; to understand the behaviour of volatile and chalcophile elements during differentiation (basalt-andesite-dacite-rhyolite); to compare volatile and chalcophile element contents in the initial magmas erupted at backarc basin spreading centres; to evaluate the importance of magma generation conditions above subduction zones for the metal and volatile budget of magmas; to develop volcanic facies models of key elements in the complex architecture of arc environments.

The highlight of 2006 was the successful research voyage SS08/2006 of the National Facility research vessel RV *Southern Surveyor* in August–September 2006 (Chief Scientist: Leonid Danyushevsky). The voyage focused on conducting multibeam and magnetics surveys and rock sampling in two areas along the Hunter Ridge. Four important questions were addressed: What is the lateral extent of adakites on the seafloor around Kadavu Island? What is the structural relationship between the northern Hunter Ridge and Kadavu Island? What is the distribution of different magma types within the rift zone at the southern end of the Hunter Ridge? What is the age and rate of southward propagation of the southernmost segment of the North Fiji Basin spreading centre?

The ship spent ~8 days swath mapping and dredging at the eastern end of the Hunter Ridge and around Kadavu Island and ~12 days swath mapping, magnetic surveying, wax coring and dredging within the rift zone at the western end of the Hunter Ridge and at the North Fiji Basin southernmost propagating spreading centre.

The seafloor structural data obtained during the two voyages will help to better understand tectonic processes that occur during oblique propagation of backarc spreading centres towards arc lithosphere. It appears that expansion of backarc basins occurs via rifting of arc lithosphere. This suggests that the oceanic crust of the backarc basin contains numerous blocks of arc lithosphere and thus has a different composition to that formed at the spreading centres. This has implications for our interpretation of ancient obducted terranes.

CODES is also using a young, well-exposed arc succession to better understand the architecture of arc crust. This aspect is strongly field-based, in contrast to other activities in this project, and uses detailed facies analysis to define the key facies associations characteristic of submarine clastic aprons around arc volcanoes. These aprons are typically the only long-term record of arc activity, and much more voluminous than the source volcanoes, so correct identification and interpretation are critical in fold belt research worldwide. Sharon Allen and Bruce Hayward (Geomarine Research) collaborated to produce a facies model for submarine volcaniclastic aprons in arc settings, using data from the Miocene Manukau Subgroup on the North Island of New Zealand. They provided field

criteria for distinguishing proximal, medial and distal parts of such aprons that can be applied in poorly exposed and/or deformed arc-related successions of all ages. This research was partly funded by Sharon Allen's ARC Research Fellowship.

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

Project Leaders: J McPhie, V Kamenetsky
Project Members: S Allen, R Arculus, P Davidson, M Kamenetsky
Students: A Agangi, S Gordee
Collaborators: O Bachmann (University of Geneva, Switzerland), G Bergantz (University of Washington, USA), K Cashman (University of Oregon, USA), S Curtis and M Fairclough (Primary Industries and Resources South Australia), C de Ronda (Institute of Geological and Nuclear Sciences, NZ), B De Vivo (University of Naples Federico II, Napoli, Italy), R Fiske (Smithsonian Institution, USA), A Freundt (Leibniz Institute of Marine Sciences, Germany), T Mernagh (Geoscience Australia, Canberra), R Mustard (James Cook University, Townsville, Australia), V Naumov (Vernadsky Institute of Geochemistry, Moscow, Russia), S Smirnov (Institute of Geology and Mineralogy, Novosibirsk, Russia), W Sun (Guangzhou Institute of Geochemistry, China), Y Tamura (Institute for Frontier Research on Earth Evolution, Japan), R Thomas (GeoForschungsZentrum, Potsdam, Germany), G Vougialakalis (Institute of Geology and Mineral Exploration, Athens, Greece), G Zellmer (Institute of Earth Sciences-Academia Sinica, Taipei, Taiwan)

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

A comprehensive review of studies of immiscible magmatic liquids and vapours trapped as melt and fluid inclusions in phenocrysts was presented in two papers 'Melt inclusion record of magmatic immiscibility in crustal and mantle magmas' and 'Examples from the Neapolitan area and Pontine Islands, Italy' (*Mineralogical Association of Canada Short Course Series*, volume 36). We demonstrated that such inclusions can be used as a natural experimental laboratory to model volatile phase exsolution from cooling and crystallising magmas (a proxy for some large-scale magma chamber processes, such as sequestering of metals and degassing), and thus quantify partitioning of metals and volatiles. Since magmatic immiscibility and consequent separation of a volatile-rich phase from a cooling silicate magma is a keystone of orthomagmatic models of ore formation, more insights into late magmatic-early hydrothermal processes and phases are required. By studying examples in which immiscibility does not go all the way to ore formation, it should be possible to use the melt/fluid inclusion approach to record consecutive snapshots of the immiscibility processes and production of immiscible phases. The first occurrence of immiscibility in magmas appears to be most important in the magmatic-hydrothermal transition, and thus our studies of magmatic immiscibility should be primarily directed towards recognition of coexisting silicate melt and essentially non-silicate melts or fluids. Similar methodology was applied to melt and fluid inclusions in minerals of granites, metasomatic rocks, and veins associated with tin ore at the Industrial'noe deposit in the Omsukchan Trough, northeastern Russia in collaboration with Vladimir Naumov (Vernadsky Institute of Geochemistry, Moscow, Russia).

We also studied melt inclusions containing bubbles of aqueous fluid (L, V and L + V) occurring in rhyolites from the Okataina Volcanic Centre, New Zealand, and the Río Blanco copper–molybdenum deposit, Chile.

Andrea Agangi and Stacey Curtis (Primary Industries and Resources South Australia) collecting data on the Glyde Hill Volcanic Complex in the Gawler Range Volcanics, the main field area for Andrea's PhD research

We have demonstrated that these aqueous fluids coexisted with silicate melts (magmas) and represent either post-trapping exsolution (in the case of Okataina), or co-trapping of phases already coexisting in the magma (in the case of Río Blanco). Microthermometry showed that some of the bubbles are a single-phase aqueous liquid, and all were shown by PIXE analysis to be metal-rich saline solutions. As such, these aqueous fluids provide the closest approximation to direct testing of the proposition that cooling magmas exsolve metal-rich aqueous fluid. In the case of pre-trapping exsolution at Río Blanco, we showed that some inclusions record and preserve magmatic emulsions (melt + aqueous fluid) that are the first stage in the evolution of hydrothermal fluids. We have demonstrated that heating experiments on volatile-rich melt inclusions can produce in situ exsolution of hypersaline metal-rich aqueous fluid bubbles, potentially permitting magma chamber processes to be experimentally modelled.

A similar study in collaboration with Roger Mustard (James Cook University), Thomas Ulrich (Australian National University) and Terry Mernagh (Geoscience Australia), in which the first quantitative microanalyses of gold in granitic silicate melt inclusions by LA-ICPMS was reported, tracked metal evolution in a composite granitic pluton hosting the Timbarra gold deposit, Australia. We showed that gold and other metals become enriched to economic levels during fractional crystallisation in a granite intrusion, implying that no gold-enriched precursor melt is required. The low content of accessory oxides and sulfides, the absence of early chlorine-bearing fluids, and prolonged crystallisation are all important factors for extensive metal enrichment during crystal fractionation of felsic magmas.

Several projects are now underway addressing the physical effects of exsolution of volatiles from felsic magmas and the influence of volatiles on eruption dynamics. All these projects have a field component in volcanic successions that are well constrained in terms of setting, age and facies characteristics.

A very precious suite of rhyolitic pumice samples was recovered from young lava domes of the Izu-Bonin Arc south of Japan during a research cruise of the RV *Natsushima* in 2004. Although erupted in seawater more than 600 m deep, and produced by effusive activity, these samples have vesicularity characteristics identical to those of subaerial pyroclastic pumice. Sharon Allen, Yoshi Tamura (Institute for Frontier Research on Earth Evolution), Richard Fiske (Smithsonian Institution) and Kathy Cashman (University of Oregon) have used the samples in a series of experiments designed to explore the behaviour of juvenile pumice delivered directly to the deep-sea environment. The dual aims are to cast light on the link between magma degassing processes and eruption style, and on the processes that accompany transport and deposition of submarine pumice.

In a related project, PhD student Sarah Gordee is producing detailed data on the facies characteristics of the Pliocene submarine rhyolitic pumice-rich succession that is very well exposed on Milos in the Southern Aegean Volcanic Arc, Greece. To date, Sarah has focused on two strongly contrasting units, one comprising tabular graded beds of pumice lapilli and ash, and the other comprising a bimodal association of giant (typically 3–5 m across) pumice clasts and laminated ash. Facies analysis and vesicularity studies will be the basis for interpreting the eruption styles, transport and depositional processes, vent setting and depositional setting. Such interpretations are conventionally based on (and limited by) empirical data, but there is a growing awareness of the value of

Sarah Gordee at work on the submarine pumice-rich Sarakiniko Formation on Milos, Greece

Sharon Allen and collaborators, George Bergantz (University of Washington) and Olivier Bachmann (University of Geneva) collecting samples from the Kos Plateau Tuff, Greece

experimental simulations that mimic the natural processes and allow firm links between cause and effect to be established. Sharon Allen has recently completed a series of such simulations, in collaboration with Armin Freundt (Leibniz Institute of Marine Sciences). Sharon and Armin designed an experiment that simulated the formation of submarine pumiceous gravity flows. They analysed samples of the gravity flow deposit for grain size, componentry and texture, and identified the principal down-current changes in deposit character. These projects build on previous CODES research into submarine pyroclastic successions and will significantly advance current understanding of the origin of the diverse pumice-rich facies that dominate many prospective submarine successions worldwide.

Felsic magmas are notorious as the drivers of the most powerful known explosive eruptions, those that form super-volcanoes (aka caldera volcanoes). The combination of high viscosity and moderate to high volatile content typically leads to explosive degassing on a scale which, though not yet witnessed and beyond imagination, must occur, given the abundance of voluminous ignimbrites in subaerial felsic igneous provinces of all ages. These eruptions involve catastrophic changes to magma volatile and metal budgets, with profound consequences for the 'fertility' of their volcanic and subvolcanic products. Sharon Allen and collaborators, Olivier Bachmann (University of Geneva) and George Bergantz (University of Washington) received a grant from the Swiss National Science Foundation to study the pre- and syn-eruptive volatile contents of the magma that fed the 161 ka Kos Plateau Tuff eruption at the eastern end of the Southern Aegean Volcanic Arc in Greece. This caldera-forming eruption produced a widespread subaerial rhyolitic pyroclastic unit that records marked changes in eruption dynamics. The project involves detailed measurement of pumice vesicularity and comparison with melt-inclusion data on magma volatile content to assess the efficiency of magma degassing throughout the eruption and provide constraints on magma fragmentation mechanisms, discharge rate and eruption column height.

View of the Manukau Subgroup outcrops, New Zealand, studied by Sharon Allen and Bruce Hayward (Geomarine Research) for their research on the architecture of volcaniclastic aprons

Some felsic volcanic provinces are far from conventional, diverging from the norm in being dominated by the products of effusive, rather than explosive, eruptions. The best-known of these provinces are in continental intraplate settings and amount to volumes comparable with their mafic counterparts (flood basalt provinces). Processes of magma genesis and magma evolution must differ markedly from the more conventional case, given that the eruption of voluminous felsic lavas requires special circumstances that substantially lower magma viscosity. With generous support from Primary Industries and Resources South Australia, we are exploring the differences through research on a very well preserved Mesoproterozoic felsic igneous province in South Australia, the Gawler Range Volcanics and co-magmatic granitoid plutons of the Hiltaba Suite. This province is particularly important being the host to the Olympic Dam Au-Cu-U deposit. Previous CODES research has established a sound understanding of the younger part of this province, demonstrating the existence of at least three very voluminous (>500 km^3) rhyolitic lavas. In a new project, we are examining one of the best exposed older parts of the succession, known as the Glyde Hill Volcanic Complex. Andrea Agangi is mapping and sampling the complex as part of his PhD project. The assemblage of subaerial volcanic facies is diverse, including conventional rhyolitic ignimbrites and lavas, accretionary lapilli tuff, extensive felsic lavas and small-volume mafic and intermediate units. Andrea will use melt inclusions in quartz phenocrysts to document the pre-eruption volatile contents of the magmas that produced the voluminous felsic lavas and compare the results with similar data for the ignimbrites. Our previous work on the younger part of the succession has revealed the presence of viscosity-lowering volatiles such as fluorine, as well as a wide variety of other components in melt and fluid inclusions. This research will have a bearing on models for the formation of the Olympic Dam mineralisation, as well as clarifying the influence of volatiles on eruption dynamics in these intraplate felsic igneous provinces.

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

Project Leader: L Danyushevsky
Project Members: A Crawford, V Kamenetsky, A McNeill
Collaborators: A Ariskin (Vernadsky Institute, Moscow), E Konnikov (Institute of Experimental Mineralogy, Moscow)

This project received seed funding in 2006 in order to develop an AMIRA/ARC-funded research project. In January–May 2006, a number of CODES researchers visited mining companies in Australia, Canada and the

USA, which are exploring for magmatic nickel deposits. The purpose of the visits was to discuss research directions of possible interest to the mining companies and address important unresolved questions on the origin of magmatic sulfide deposits. As a result of these visits, a three-year project has been developed with an annual budget of $350,000. The project is based on novel techniques developed at CODES, such as studies of melt and fluid inclusions in phenocrysts, and thermodynamic modelling of magma crystallisation developed by our collaborator Alexei Ariskin at the Vernadsky Institute of Geochemistry (Russia). The project was submitted to AMIRA in August 2006 and has received support from BHP Billiton, Anglo American and Votorantim for a total of $210,000 per annum. The project will start on 1 March 2007 with additional support from CODES.

The main objectives of the project for 2007 include: a better understanding of the potential of various mafic/ultramafic magmas to form magmatic sulfide deposits; an improved understanding of the sulfur-saturation histories of mafic magmas; a better understanding of the processes during magma evolution responsible for the formation of sufficient mass of sulfide to form a deposit, if all other conditions are met; a better understanding of when, and why, sulfides are concentrated during magma evolution; improved criteria for the nickel-PGE fertility of mafic/ultramafic complexes in different tectonic settings.

Investigating ancient oceans (CODES P1.F5) and coping with the dust at the Black Star Open Cut, Mount Isa – Tim Lyons, Poul Emsbo and Peter McGoldrick

Project P1.F5: Global ocean chemistry, marine basins and zinc-lead-silver mineralisation

Project Leader: P McGoldrick
Project Members: S Bull, R Maier
Collaborators: P Emsbo (US Geological Survey), T Lyons (University of California, Riverside)

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

The main outcomes from new work in 2006 were the completion of carbonate-associated sulfate (CAS) processing for 22 samples of drillcore from the Paradise Creek Formation, near Gunpowder mine, northwestern Queensland, collected during fieldwork in 2005; interpretation of pyrite laser-ablation trace-element investigations at McArthur River and Bluebush (presented at the Goldschmidt and CODES 'Ores in Sediments' meetings, respectively); refinement of a simple 'in-house' process for extracting CAS from sedimentary rock samples; and the publication of research by Tim Lyons and Peter McGoldrick (*Geological Society of America Memoir*) and presentations by Peter McGoldrick ('Microbes, siderophile oceans, sulfur-sources and SEDEX deposits or why was the end of the Palaeoproterozoic such a great time for sedimentary zinc deposits?') and Poul Emsbo ('Impact of exhalative hydrothermal systems on marine chemistry: applications for ore genesis and mineral assessment') at the CODES 'Ores in Sediments' meeting.

Project P1.L1: Geochronology, metallogenesis and deposit styles of Loei Fold Belt in Thailand and Laos PDR

Project Leader: K Zaw
Project Members: S Golding, S Meffre
Students: PhD – T Kamvong, A Salam; Masters – T Manaka
Collaborator: S Khositanont (Department of Mineral Resources, Bangkok, Thailand)

During the tenure of the project we have re-examined the geological framework of the Loei Fold Belt in Thailand and Laos. This belt is located between the Shan-Thai and Indochina terranes forming a north–south trending arcuate magmatic-volcanic belt. We studied the entire belt using modern geological/geochemical and analytical techniques, in particular with the accurate and low cost LA-ICPMS U-Pb zircon geochronology. We determined the age, geochemistry and lithological characteristics of around 140 samples collected from most of the geological units in the region of interest. The results showed that many of the geological units have incorrect ages on the current geological maps. The new data were then synthesised into a revised

At Phu Kham Cu-Au deposit in Laos PDR. L to R: Andrew Rowe (Panaustralian), Teera Kamvong (CODES PhD student), Laotian mine geologist, Aaron McLeod (Panaustralian), Takayuki Manaka (CODES MSc student), and Khin Zaw (CODES)

geological history for the area and an updated GIS package. The raw data were summarised into a 'geological atlas' of the Loei Fold detailing the textures, chemistry, affinity, location and age of each of the rocks analysed. The project also involved training of two PhD, two MSc and four Honours students. Deposit-specific characterisation studies along the Loei Belt also demonstrated that the fold belt hosts a variety of copper-gold styles such as epithermal gold deposits, mineralised copper-molybdenum porphyry, mesothermal/skarn and porphyry/skarn copper-gold systems.

The outcomes of this project will have a significant impact on the scientific understanding of the geology and plate tectonic history of the Loei Fold Belt and southeast Asia. We have formulated a new geological history of the area based on the robust and well-documented data. The outcome and results of this successful project provide a modern geological data set to help our sponsors with target selection and regional exploration as well as to add to the broader scientific understanding of southeast Asia.

PhD projects in the Location Program

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

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

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

Quang Sang Dinh: Geological evolution of the northern margin of the Kontum massif, Vietnam

Sarah Gordee: Characteristics of subaqueous pyroclastic facies in arc settings

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

Rodney Maier: Pyrite and base-metal trace-element halos in the northern Australian zinc-lead-silver deposits

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

Abhisit Salam: Geological, paragenesis and geochronological relations of the Chatree area, Phetchabun Province, central Thailand

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

Sofia Tetroeva: Petrology and geochemistry of adakites and related rocks from the Hunter Ridge, Southwest Pacific

PROGRAM 2: FORMATION

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

Team members

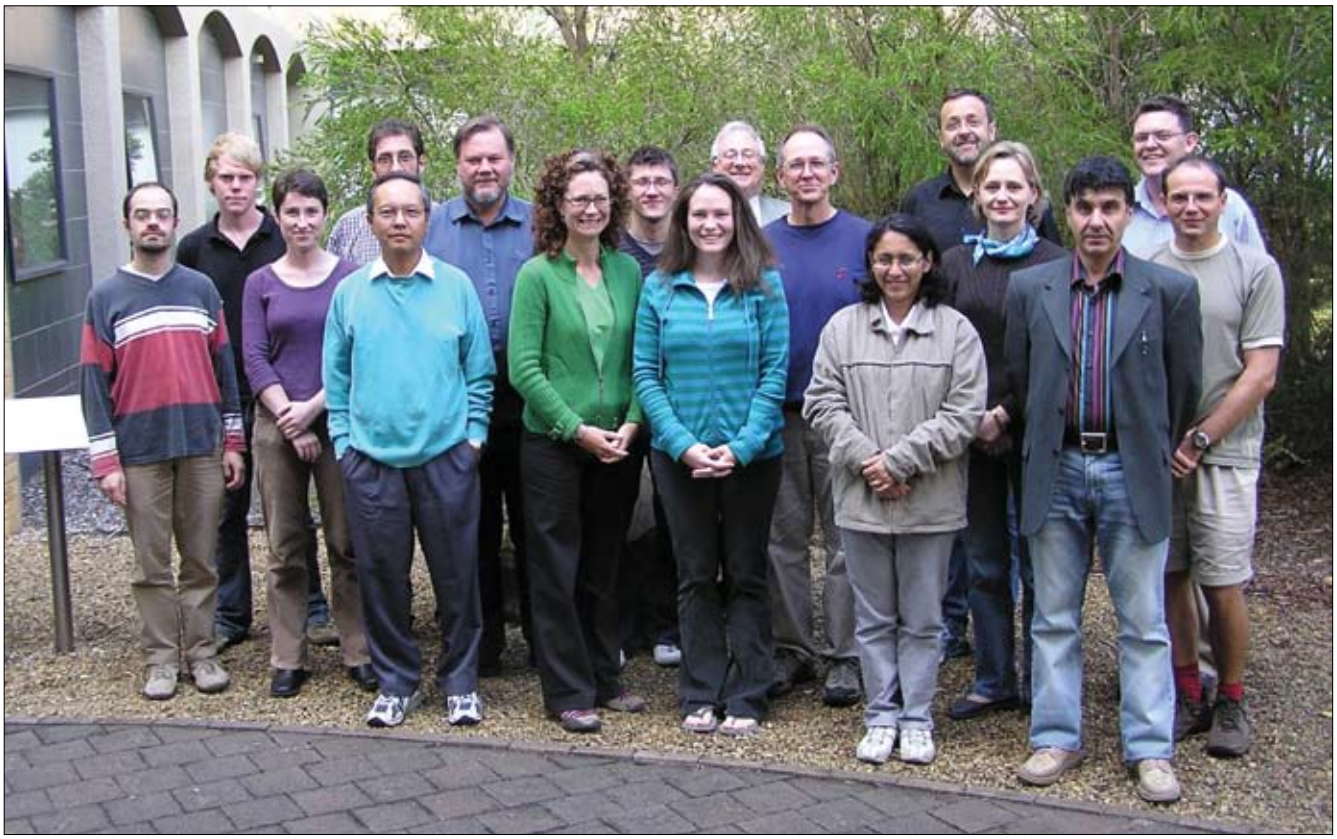
David Belton,* Ron Berry, Stuart Bull, Claire Chamberlain,* Zhaoshan Chang, Dean Collett, Stephen Cox,* Leonid Danyushevsky, Cari Deyell, Grant Garven,* Bruce Gemmell, Sarah Gilbert, Anthony Harris, Amber Henry, Walter Herrmann, Meghan Jackson, Paul Jago, Vadim Kamenetsky, Ross Large, Jocelyn McPhie, Sebastien Meffre, Janina Micko, Chris Ryan,* Christian Schardt, Rob Scott, Mike Solomon, Dick Tosdal,* Noel White, John Woodhead,* Khin Zaw
(* partner research organisation team member)

PhD students

Adam Bath, Jacqueline Blackwell, Ana-Liezl Cuison, Nathan Fox, Heidi Pass, Wojciech Zukowski

Collaborators

CSA Australia Pty Ltd – Rupert Crowe, Glenn Whalan, Nigel Wilson, Warren Woodhouse
Geological Survey of New South Wales – Ian Percival
Geological Survey of Canada – Wayne Goodfellow, Jan Peter, Kirstie Simpson
GeoForschungsZentrum (Germany) – Rainer Thomas
Geoscience Australia (Canberra) – Terry Mernagh
Hefei University (China) – Taofa Zhou



Program 2 team members: L to R, Andrea Agangi, Nathan Fox, Sarah Gilbert, Leonid Danyushevsky, Khin Zaw, Ron Berry, Heidi Pass, Wojciech Zukowski, Jacqueline Blackwell, Ross Large, Joe Moye, Ana-Leizl Cuison, David Cooke, Lyudmyla Koziy, Dima Kamenetsky, Anthony Harris, Sebastien Meffre

David Cooke: Team Leader

Institute of Geological and Nuclear Sciences (New Zealand) – Kevin Faure
Institute of Geology and Mineralogy (Russia) – Victor Sharygin, Sergey Smirnov
Institute of Mineralogy, Russian Academy of Science (Russia) – Valery Maslennikov
Newcrest Mining Limited – Dean Collett, John Holliday, Colin McMillian, Geoff Smart, Ian Tedder
Queens University (Canada) – Dan Layton-Matthews
United States Geological Survey (USA) – Poul Emsbo
University of Huelva (Spain) – Reinaldo Sáez, Manuel Toscano
University of Ottawa (Canada) – Mark Hannington

Core projects in the Formation Program

(F prefix denotes fundamental research project)
P2.F1 Fracture arrays in intrusion-related systems – controls on the dynamics of fluid flow, vein formation and the generation of giant deposits
P2.F2 Base-metal mineralisation in sedimentary basins
P2.F3 Volcanic-hosted massive sulfide deposits

(L prefix denotes industry-linked project)
P2.L1 District- to deposit-scale structural and geochemical study of the Cadia porphyry gold-copper deposits
P2.L2 Controls on the formation and sulfide trace-element signatures of sediment-hosted gold deposits (AMIRA P923)
P2.L3 Shallow and deep-level alkalic mineral deposits
P2.L4 Genesis of the giant Sukhoi Log gold deposit, Siberia

(N prefix denotes new initiative project)
P2.N1 Phase and chemical composition of high-temperature hydrothermal systems undergoing interaction between silicate rocks/magmas and aqueous fluid
P2.N2 Zinc and gold mineralisation in the Caijiaying deposit: geologic characteristics and genesis
P2.N3 Polymetallic mineralisation and associated magmatic and volcanic activity in the Luzong basin, middle and lower Yangtze River, eastern China

HIGHLIGHTS

- **New hydrological modelling of fluid flow in the Red Sea hydrothermal system providing insights into the formation of sediment-hosted base-metal deposits**
- **Improved understanding of the facies architecture and evolution of the Cadia Valley, NSW, helping to unravel the structural controls on emplacement of the Cadia porphyry gold-copper deposits**
- **Broad halos of sedimentary gold enrichment detected up to several kilometres away from major sediment-hosted gold deposits raise questions about the timing of gold mineralisation**
- **Nine PhD and masters students working on a collaborative research project between CODES and MDRU to define the 3D architecture and ore-forming processes within alkalic porphyry and epithermal deposits**
- **A two-stage process of gold enrichment (syngenetic and metamorphic) determined for the giant Sukhoi Log gold deposit, Siberia**

P2.F1: Fracture arrays in intrusion-related systems – controls on the dynamics of fluid flow, vein formation and the generation of giant deposits

Project Leaders: S Cox, D Cooke

In this project we aim to:

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

Effort this year has focused on assessing recent developments in understanding volcano deformation and volcano-tectonic seismicity, and applying these new developments to explore how inflation-deflation processes in magma chambers potentially influence evolution of stress states, fluid pressure regimes, and the development of vein systems in intrusive-related hydrothermal systems. We are currently seeking to recruit a post-doctoral fellow to work on this project for three years. The major focus will initially be on field studies of several well-documented intrusive-related systems in South America, North America, Papua New Guinea and Australia. Field studies will document the geometries and distribution of veins in these several case studies and use the geometry of vein systems to better understand the dynamics of changes in stress regimes in evolving, intrusion-related hydrothermal systems and which will lead to a better understanding of factors controlling vein abundance, size and spacing. The structural studies will be combined with studies of vein mineralogy, associated hydrothermal alteration and evolving fluid chemistry in these systems to explore how the dynamics of the evolution of fluid pathways and reactions can influence the generation of well-endowed intrusion-related ore systems.

P2.F2: Base-metal mineralisation in sedimentary basins

Project Leaders: C Schardt, G Garven
Project Members: S Bull, R Large

The aim of this project is to construct numerical models of the Red Sea rift to predict subsurface fluid and heat flow patterns and to predict differences in hydrothermal activity, which may explain the evolution and fluctuations of brine pool chemistry and associated metal deposition on the sea floor. Currently, several aspects of the Red Sea hydrothermal systems are poorly understood due to limited geological data and restricted access to the region, including the subsurface flow patterns and the hydrochemical conditions governing the formation and the evolution of Red Sea brine pools.

Finite-element models are under construction to investigate the Red Sea hydrothermal systems. Model 1 (pre-rift) will be used to investigate heat and fluid flow before the creation of oceanic crust. Model 2 (20 km long x 4 km deep profile of the Atlantis II Deep) examines hydrothermal fluid migration under modern conditions and comparison with results from Model 1 may yield information about changes in fluid flow pathways and salinity evolution. Model 3 will be a telescoped close-up of Model 2 (~6 km length) to investigate 2D reactive-coupled transport processes of fluid migration through evaporates and basalt, associated chemical changes, and discharge into the brine pool. The numerical models are based on published geologic, seismic, tectonic and heat-flow data.

P2.F3: Volcanic-hosted massive sulfide deposits

Project Leaders: B Gemmell, M Solomon,
Project Members: D Belton, A Harris, R Large, C Ryan, K Zaw
Collaborators: W Goodfellow (Geological Survey of Canada), M Hannington (University of Ottawa), D Layton-Matthews (Queens University), T Mernagh (Geoscience Australia), J Peter (Geological Survey of Canada), R Sáez (University of Huelva), M Toscano (University of Huelva)

This project aims to evaluate processes responsible for the formation of giant, high-grade VHMS deposits. Two sub-projects were undertaken in 2006:

- The nature and origin of fluids that form high-salinity volcanic-hosted massive sulfide deposits

A spindle stage for precise measurement of sizes and depth of fluid inclusions was constructed following the designs of Bodnar and Anderson.

Fluid inclusions in massive sulfide stockworks at Myra Falls, Rio Tinto, San Miguel, Neves Corvo, Feitais, Aznalcollar, Hokuroku Basin, Windy Craggy, Sellefte district, Hellyer, Rosebery and Mount Lyell were investigated directly by microscope or indirectly through the literature.

Samples from the quartz veins in stockworks of the Hellyer and Aznalcollar deposits contained aqueous inclusions of size potentially suitable for PIXE analysis. Homogenisation and freezing temperatures, and size measurements, of a number of inclusions have been made in preparation for PIXE analysis.

A comparative study of the geology and ores of the Bathurst mining camp and the Iberian pyrite belt were completed in September 2006.

- Trace-element chemistry of pyrite in the Que River Shale: exploration implications for the Hellyer deposit, Tasmania

Ten diamond drillholes were examined and sampled from the Hellyer-Que River area. Diamond drillholes comprised distal through proximal intersections of the Que River Shale in relation to the Hellyer ore bodies.

A total of 430 individual trace-element analyses were made on pyrite grains of varied morphology. Pyrite textures comprised primary sedimentary textures, which include framboidal, polyframboidal, detrital and biogenic forms, recrystallised sedimentary textures and deformational sedimentary textures.

Initial data reduction of 330 analyses indicates an average decrease in the order of trace-element abundance of nickel, arsenic, manganese, lead > cobalt, antimony, zinc, selenium, barium, titanium, molybdenum > silver, chromium, cadmium, thallium, tellurium, tin, vanadium > bismuth, zirconium, lanthanum, gold > thorium, tungsten, uranium, and platinum.

There appears to be a relationship of increased total trace-element contents of pyrite with relation to the Hellyer ore bodies. Additionally, the abundance of base-metal inclusions within individual pyrite grains also appears to correlate with proximity to the Hellyer ore body.

P2.L1: District- to deposit-scale structural and geochemical study of the Cadia porphyry gold-copper deposits

Project Leaders: A Harris, D Cooke, R Berry
Project Members: C Allen, R Berry, I Campbell, J McPhie, R Tosdal
Students: A-L Cuison, N Fox
Collaborators: D Collett (Newcrest Mining Limited), K Faure (IGNS), J Holliday (Newcrest Mining Limited), C McMillian (Newcrest Mining Limited), I Percival (GS NSW), G Smart (Newcrest Mining Limited), I Tedder (Newcrest Mining Limited)

CODES, with industry partner Newcrest Mining Limited, is working towards a better understanding of the architecture of Australia's premier porphyry districts. Newcrest's Cadia Valley Operations (central New South Wales) is one of this country's largest gold producers, several deposits (including the gold-rich Ridgeway alkalic-type porphyry deposit) having a combined in situ resource in excess of 28 million ounces of gold. CODES researchers are working together with Newcrest geologists to deconstruct the geometry of porphyry ore systems (both spatially and temporally) at the deposit- and district-scale of the Cadia Valley.

This year, Honours, Masters and PhD research is being undertaken for this project including collaborative student research projects with the MDRU at the University of British Columbia. Ana-Liezl Cuison's PhD research seeks to better constrain the fundamental controls on porphyry emplacement at Ridgeway. Nathan Fox began his PhD research late in 2006. Nathan will investigate the lithological and structural controls on alteration assemblages in the giant Cadia East deposit. Malissa Washburn (Masters student jointly supervised by MDRU-CODES) is mapping the architecture of the rocks covering the Ordovician porphyry ore deposits in the Cadia Valley. Such rocks cover up to 40% of the known hydrothermal alteration and mineralisation. Despite this, the cover sequence remains poorly documented. Detailed reconstruction of the Silurian succession, plus recognition of the hierarchy of faults, is considered vital to the on-going reconstruction of the syn-mineralisation Ordovician architecture. Richard Tosdal is now also part of the research team actively working on this problem.

Anthony Harris has been unravelling the district-scale architecture and evolution of the Cadia Valley. Anthony will use a multi-faceted approach to develop an improved understanding of the geometry of the deposits and the rocks that host them. In 2006 he has documented the valley-wide stratigraphy, including completing the reconstruction of the district's volcanic architecture. Collaborative geochronologic research (using LA-ICPMS), devoted to better constraining the timing of volcanism and magmatism of porphyry ore districts, is on-going with researchers at ANU. Research outcomes of this absolute age dating are being integrated with detailed palaeontologic studies (undertaken by Ian Percival at the Geological Survey of New South Wales). Limited collaborative stable isotopic studies have been undertaken with Kevin Faure at the Institute of Geological and Nuclear Sciences (New Zealand) and Sue Golding at the University of Queensland. Other research has included new compilations of district-scale geology, alteration assemblages and geochemistry. This work is made possible through on-going consultation with mine and exploration geologists and unprecedented access to the geology and data throughout the valley. Anthony's research will establish new constraints on the timing and positioning of events critical to the formation of these porphyry ore deposits.

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

Project Leaders: R Large, R Scott
Project Members: S Bull, Z Chang, L Danyushevsky, S Gilbert, S Meffre, W Herrmann
Collaborators: P Emsbo (United States Geological Survey), V Maslennikov (Russian Academy of Science)

This project uses advanced trace-element and isotopic analytical techniques to investigate the extent, timing and origin of gold enrichment in pyrite in the host rocks to major sediment-hosted gold deposits. Through this study, the three-year research project, which commenced in January 2005, aims to develop new approaches for terrane selection and deposit characterisation, as well as longer-range, more robust deposit proximity indicators for sediment-hosted gold deposits. The work is jointly funded by CODES and industry sponsors Barrick, Newcrest, Newmont, Perseverance and St Barbara Mines. Deposits being studied are Gold Quarry and the periphery to the giant Post-Betze-Screamer deposit in the Carlin District, Sukhoi Log in Siberia, Bendigo and Fosterville in central Victoria and Lefroy in northeast Tasmania.

The research is underpinned by the use of the CODES LA-ICPMS facility, which enables the low-level quantitative determination of over 40 trace elements in sulfides with a spatial resolution down to 8 microns, and lead-isotopic analysis of pyrite containing >100–200 ppm lead with a spatial resolution 55–110 microns. In 2006, significant progress was made in each of the study areas. The research has shown gold-enriched pyrite in the host rocks extends many tens of metres, and in some cases at least several kilometres, from the known deposits, and in most areas complex pyrite paragenetic sequences have been established. Pyrite trace-element characteristics and paragenetic, microstructural and lead-isotopic constraints on the timing of pyrite growth have been successfully used to determine whether gold-enriched pyrite in the wall rocks represents a halo or possible precursor to the adjacent epigenetic deposits (i.e. vein-hosted, replacement mineralisation). The study highlights the potential of detailed paragenetic, trace-element and lead-isotopic characterisation of pyrite for both increasing the size of exploration targets and for improving understanding of how these deposits form. Pyrite lead-isotopic and trace-element data have also been useful in helping to identify likely source areas for the fluids and metals involved in formation of the deposits, providing additional terrane-scale information that can be used by explorers to target regions with greater potential for hosting significant deposits of this type.

Results from the project (currently confidential) were presented to sponsors at three meetings in Hobart and one in Elko (Nevada, USA) in 2006.

P2.L3: Shallow and deep-level alkalic mineral deposits

Project Leaders: D Tosdal, D Cooke, C Chamberlain, K Simpson (Geological Survey of Canada)
Project Members: C Deyell, A Henry, M Jackson, P Jago, J Micko
Students: A Bath, J Blackwell, H Pass, W Zukowski

Alkalic gold-(copper) deposits include some of the world's highest grade and largest porphyry-related gold as well as

Stuart Bull photographing core in the Barrick Goldstrike core laydown, Carlin district, Nevada, USA

Angular unconformity between Pennsylvanian (U. Carboniferous) Ely and base Strathearn basin strata, Carlin Canyon, NE Nevada. These rocks form part of the Mississippian-Permian 'overlap' (foreland basin) succession deposited during east-directed thrusting along the former passive margin of the western USA

some of the largest gold accumulations in epithermal settings. The alkalic group of porphyry systems is an eclectic group, and styles of mineralisation in the Jurassic oceanic island arc alkalic provinces of British Columbia differ considerably from those discovered so far in New South Wales. The alkalic epithermal systems have features similar to the 'low sulfidation' family of calc-alkalic epithermal deposits. Discriminating features include the presence of roscoelite (e.g. Porgera, Emperor), and anhydrite (e.g. Lihir, Porgera), and negative sulfur isotopic compositions of sulfide minerals (e.g. Lihir). These features are indicative of oxidation states higher than expected for calc-alkalic LS systems, and potentially providing evidence of a greater magmatic contribution to the alkalic mineralising fluids.

Although the alkalic porphyry and epithermal deposits are known from various mineral provinces around the world, particularly in British Columbia and eastern Australia, the quality of individual deposit descriptions in the public domain varies markedly. Thus, there are considerable gaps in knowledge regarding this important deposit type. Filling the knowledge gaps is the aim of a collaborative project between CODES, the Mineral Deposit Research Unit at the University of British Columbia, Amarc Resources Ltd, AngloGold Ashanti Limited, Barrick Gold Corporation, Imperial Metals Corporation, Lysander Minerals Corporation, Newcrest Mining Limited, Newmont Mining Corporation, Novagold Resources Inc. and Teck Cominco Limited. Additional financial support derives from grants from the Natural Sciences and Engineering Research Council of Canada (NSERC) and Geoscience British Columbia. This project seeks to build an integrated model for these deposits, including the characteristics of various alteration styles that can develop in either a shallow or deep-level alkalic igneous setting.

This collaborative research project involves a significant component of higher degree research, which is providing important new insights into the 3D architecture, geology and geochemistry of alkalic porphyry and epithermal deposits. Four PhD students (Bath, Blackwell, Pass, Zukowski) are undertaking studies based at CODES, and there is one PhD student (Micko) and three masters students (Henry, Jackson, Jago) based at MDRU. Major results for 2006 have been presented to industry sponsors of the porphyry module in a one-day meeting in June at the University of British Columbia. The sponsors of the epithermal module were presented with research results for 2006 at a one-day meeting in West Wyalong (New South Wales), which was followed by a half-day field trip to the Cowal gold mine.

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

Project Leaders: R Large, V Maslennikov
Project Members: Z Chang, S Meffre, R Scott, J Woodhead
Collaborators: V Maslennikov (Institute of Mineralogy, Russian Academy of Science)

Sukhoi Log is a 30-million-ounce gold deposit hosted in Proterozoic black shales in the Lena Goldfield adjacent to the eastern margin of the Siberian craton. It is the largest undeveloped gold resource in the world. Controversy has surrounded its origin since its discovery in the 1960s. It is currently regarded as an orogenic gold deposit, with gold mineralisation of the black shales considered to take place during metamorphism and granite intrusion. However, our research provides clear evidence that there was an early stage of gold introduction into the organic-rich black shale host rocks during sedimentation and diagenesis.

Petrographic study of over 70 polished mounts of ores and host rocks at the Sukhoi Log and Vernensky deposits has revealed a multi-stage origin for both the pyrite and gold. The two earliest forms of pyrite, termed py1 and py2, are commonly aligned parallel to bedding, as clusters of micron-sized crystals, framboids and fine euhedra, which are interpreted as sedimentary to diagenetic in origin. Coarser grained, inclusion-rich pyrite, termed py3 and py4, overgrows the earlier pyrite, and the diagenetic/metamorphic fabric in the sediments, and is interpreted to have a syn-diagenetic to metamorphic timing. Late-stage pyrite, py5, overgrows and replaces earlier sulfides and is considered to be post-peak metamorphic and related to quartz vein development.

LA-ICPMS analyses of the various pyrite types indicate that the syn-sedimentary py1 contains the highest levels of lattice-bound gold, varying from 0.4 to 12.1 ppm, with a mean of 3.22 ppm gold and 1900 ppm arsenic. Later generations of pyrite, from py2 to py5, including pyrite in bedding-parallel quartz veins, contain progressively lower contents of lattice-bound gold and most other trace elements. However, these metamorphic and post-metamorphic pyrites contain micro-inclusions of free gold, pyrrhotite, sphalerite and chalcopyrite.

Based on our research we concluded that two key processes were critical to the formation of the Sukhoi Log deposit: (1) original syn-sedimentary concentration of gold, dissolved within diagenetic arsenian pyrite in organic-rich black shales, that produced a thick stratigraphic succession with a highly anomalous gold content of around 40–100 ppb, and (2) metamorphic processes that liberated gold from the diagenetic arsenian pyrite, to be concentrated as free gold within metamorphic pyrite and associated pyrite-quartz veins in the core of an overturned anticline. These ore-forming processes, defined at Sukhoi Log, may

also be important in the genesis of other 'orogenic-style' black-shale-hosted gold deposits (e.g. Kumtor, Muruntau, Zarmitan, Amantaitau, Natalka, Nezhdaninskoye, Bakyrichik, Alaska-Juneau, Macreas Flat). On-going research is planned to test the general applicability of this model to other black-shale-hosted gold ores.

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

Project Leader: V Kamenetsky
Project Member: R Large
Collaborators: V Sharygin, S Smirno (Institute of Geology and Mineralogy, Novosibirsk, Russia), R Thomas (GeoForschungsZentrum, Germany)

For a long time hydrosilicate liquids remained a subject of experimental mineralogy and mineral synthesis, but were missing from reconstructions of magmatic-hydrothermal evolution. Nevertheless, several workers have suggested the existence of such liquids in nature and emphasised their significance in the element transport and mineralisation. Our experiments excised the conditions of the magmatic-hydrothermal transition in the granite-pegmatite system, and the hydrosilicate liquid was formed at the expense of quartz and alkaline aqueous solution. The coexisting inclusions of essentially aqueous and essentially silicate liquids, trapped in regenerated quartz, confirm that the system was heterogeneous at the time and conditions of experiments. Quartz was forming in all runs, and silicate-tantalate of Na crystallising with quartz in the system Na_2O–SiO_2–H_2O±NaCl may indicate chemical affinity of tantalum with dissolved silica. Therefore, the system seems to be saturated with respect to silica, which is distributed between two liquids, quartz and silicate-tantalate of sodium.

The physical state of the silicate liquid in this study is of particular interest. We interpret shrinkage and cracking of the vitreous phase resulting from dehydration in the air; moreover, re-hydration and ionic exchange with distilled water are also possible for this phase. Thus, the hydrosilicate liquids in our experiments show common properties of a silica gel and support suggestions of their colloidal nature.

Our experiments confirmed formation of hydrosilicate liquids at the P–T conditions of the magmatic-hydrothermal transition in the systems corresponding to rare-metal granites and pegmatites. Using tantalum and molybdenum as examples we demonstrate that the hydrosilicate liquids, forming in the reaction between magmatic-derived aqueous fluids with earlier formed silicate minerals and residual silicate melt, are able to accumulate significant amounts of ore elements.

In view of the gel-like properties of the quenched products of experimental hydrosilicate liquids, we suggest that they can exchange some elements with coexisting aqueous fluids. Thus it is likely that high-temperature hydrosilicate liquids are a transitional reservoir controlling distribution of elements between coexisting silicate magmas and aqueous fluids. As such they represent a missing link in the orthomagmatic ore-forming systems.

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

Project Leaders: Z Chang, N White
Project Members: D Cooke, B Gemmell
Collaborators: R Crowe, G Whalan, N Wilson, W Woodhouse (CSA Australia Pty Ltd)

The Caijiaying deposit is located in the Zhangbei County, Hebei Province, China. It is the first new foreign-controlled (by Griffin Mining Ltd., UK) mine established in China and it is the first foreign exploration project to obtain a mining licence.

Caijiaying is a zinc-gold deposit and it is unusual in that it contains both significant amounts of zinc and gold. Current resource in zone III, one of the five known ore zones, is 23.6 Mt grading 8.1% zinc and 0.7 g/t gold; on-going exploration is expanding the resource. The ores are mostly hosted in the metamorphic rocks, with minor ores in the volcanic cover rocks. There is not much apparent alteration directly above the ores, but along a major northeast fault <1000 m southeast of zone III, banded chalcedony ± fluorite veins/breccias typical of low-sulfidation epithermal (LS) deposits are abundant. Previously the deposit was reported as 'mesothermal' in literatures (in Chinese) with the LS features not recognised. Some of the recent reports from consultants also classified Caijiaying as SEDEX or metamorphosed SEDEX deposit.

In 2006, we carried out 22 days of fieldwork during which nine drill holes were logged, 75 samples from drill holes and 71 samples from underground and surface were collected, and 1294 PIMA measurements were taken. Other work finished included 163 microprobe analyses, 39 LA-ICPMS analyses, 86 fluid inclusion thermometric measurements, and numerous photomicrographs, BSE and CL images.

The major progress in 2006 includes proving the origin of the deposit to be hydrothermal instead of metamorphosed; finding skarn minerals including hederbergitic pyroxene and ilvaite at depth; recognising a large alteration halo in the seemingly fresh volcanic cover rocks using a PIMA, which has the potential to be very helpful in exploration around Caijiaying; finding gold as electrum and as particles in the lattice of pyrite

and arsenopyrite; establishing paragenesis; constraining physiochemical conditions of the prograde skarn, retrograde alteration and zinc mineralisation by fluid inclusion thermometric data; and finding a way to check whether a seemingly fresh felsic dyke is pre-, syn- or post-mineralisation using PIMA.

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

Project Leader: T Zhou (Hefei University)
Project Members: Z Chang, D Cooke

This project started in late November 2006. So far, petrographic observations of intrusive rocks, volcanic rocks and ores from major deposits in the Luzong volcanic basin (east China) have been completed. A total of 30 samples have been analysed for their whole rock (major, trace and rare earth element) compositions and the data are currently being processed. LA-ICPMS zircon uranium-lead dating is being conducted and is planned to be completed by the end of January 2007. These data will be used to improve our understanding of the volcanic and intrusive evolution of the Luzong volcanic basin. Specifically, these data should provide new insights into the relationships between alkalic magmatism (both intrusive and extrusive), porphyry deposits and massive polymetallic sulfide mineralisation in this basin, and into related tectonic and geodynamic processes.

PhD projects in the Formation Program

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

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

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

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

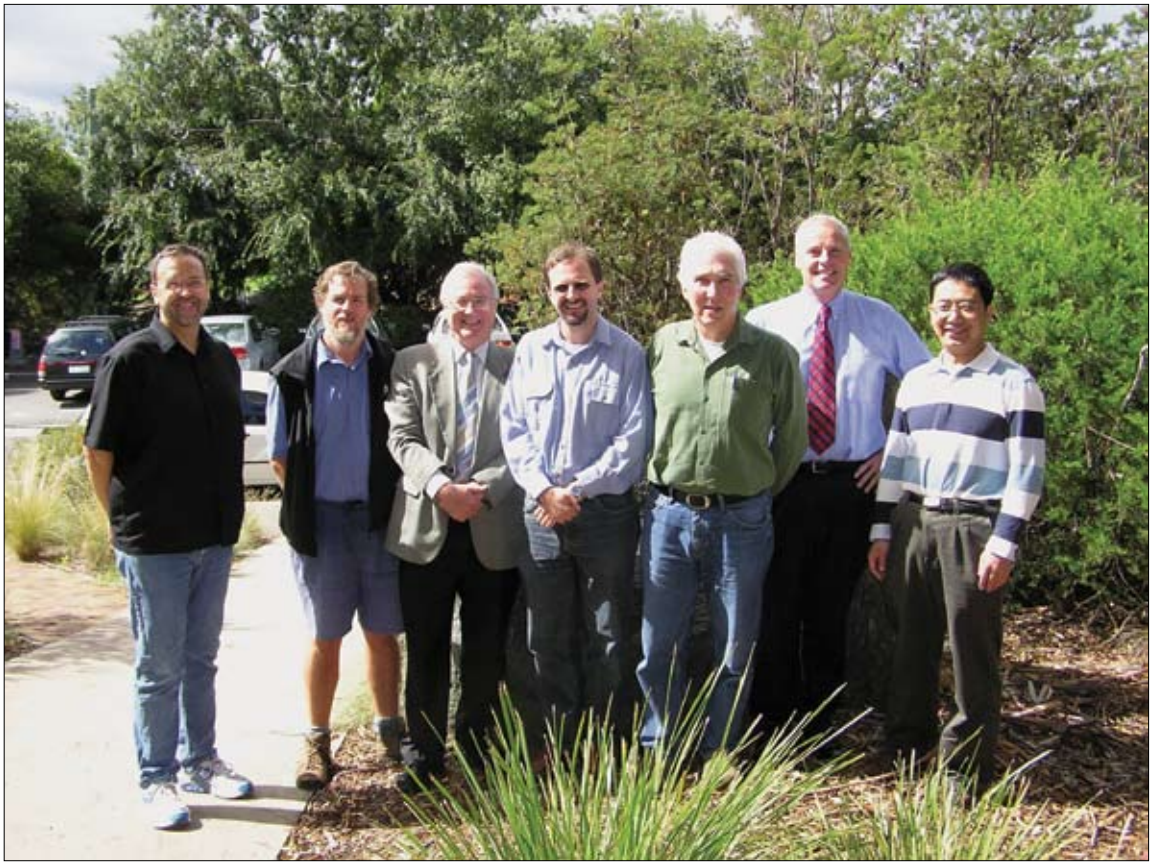
Heidi Pass: Chemical and mineralogical zonation patterns in alkalic mineral systems: implications for ore genesis and mineral exploration

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

Noel White (left) and Glenn Whalan (CSA Australia Pty Ltd) at the Caijiaying Zn-Au mine, Hebei Province, China

PROGRAM 3: DISCOVERY

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



Program 3 team members: L to R, David Cooke, Michael Roach, Ross Large, Mark Duffett, Peter McGoldrick, Bruce Gemmell, Zhaoshan Chang

Team members

David Broughton,* Stuart Bull, Zhaoshan Chang, David Cooke, Cari Deyell, Mark Duffett, Peter Fullagar,* Nick Harris,* Jeff Hedenquist,* Murray Hitzman,* James Macnae,* Peter McGoldrick, Andrew McNeill, Doug Oldenburg,* James Reid, Michael Roach, Robert Scott, David Selley, Noel White
(* partner research organisation team member)

PhD students

Tim Ireland, Lyudmyla Koziy, Ralf Schaa

Collaborators

University of Lubumbashi (Zaire) – Stanislas Sebagenzi
United States Geological Survey (USA) – Poul Emsbo
Lakehead University (Canada) – Peter Hollings
Hefei University (China) – Taofa Zhou

Bruce Gemmell: Team Leader

Highlights

- Successful completion of AMIRA P765 (Project P3.L2) on transitions and zoning in porphyry-epithermal mineral districts
- Best paper award at the Australian Earth Sciences Convention to Michael Roach for his research on 'Geophysical characterisation and inversion of ore deposits' (Project P3.F1)
- Development of a method for determination of unambiguous apparent conductivity from fixed loop transient electromagnetic data
- Completion of PhD research by Lyudmyla Koziy on fluid flow and salinity transfer related to formation of sedimentary copper deposits

Core projects in the Discovery Program

(F prefix denotes fundamental research project)

P3.F1 Geophysical characterisation and inversion of ore deposits

(L prefix denotes industry-linked project)

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

P3.L4 Quantitative 3D imaging of the electrical properties of ore deposits and their environment

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

Project P3.F1: Geophysical characterisation and inversion of ore deposits

Project Leader: M Roach
Project Members: M Duffett, P Fullagar, D Oldenburg

This project focuses on techniques for inversion of potential field geophysical datasets and in particular the relationships between measured rock properties and properties estimated from the inverse models. The application of classification techniques to interpretation of physical property volumes has been investigated for the Tennant Creek area in the Northern Territory. Soft classifiers that provide class membership scores for each model cell were found to be the most effective classification techniques. The output from a soft classification is a series of 'probability' volumes for each geological class that effectively incorporate the uncertainties associated with overlapping class signatures derived from petrophysical sampling or outcrop data.

An additional unexpected outcome of this project was development of a technique for optimisation of gravity data acquisition that utilises an unconstrained inversion of pre-existing data to locate priority regions for new data acquisition. This work was presented at the Australian Earth Sciences Convention in 2006 where it was awarded the 'Best Paper' award.

Postdoctoral and PhD positions to work on this project have been advertised but not filled and this has delayed further progress on this project.

Project P3.L1: Approximate 3D inversion of transient electromagnetic data

Project Leaders: P Fullagar, M Roach
Project Member: J Reid
Student: R Schaa

A method was developed for determination of unambiguous apparent conductivity from fixed loop transient electromagnetic (TEM) data. This approach has permitted stable conductivity-depth transformation for fixed loop TEM, which previously proved problematic.

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

Project Leaders: D Cooke, B Gemmell
Project Members: Z Chang, C Deyell, J Hedenquist, N White
Students: T Ireland, G Migley, J Polanco
Collaborators: P Hollings (Lakehead University), T Zhou (Hefei University)

Porphyry-related mineral districts host many major ore deposits of diverse styles and metal associations. These include the porphyry (copper-molybdenum-gold) deposits themselves, but also epithermal gold-silver deposits, skarn copper-gold deposits, carbonate replacement zinc-lead-silver, and sediment-hosted gold. These districts continue to be major targets for both copper and gold explorers. The purpose of P765 was to determine the links between the diverse deposit styles within porphyry-related mineral districts, and identify where the highest grade copper and gold accumulations are expected to occur. We aimed to improve exploration success in porphyry-epithermal districts by providing geological, geochemical and geophysical vectors towards major metal accumulations, and indicate the likely distance. Study areas include Lepanto and Baguio (Mankayan, Philippines), Batu Hijau (Indonesia), Collahuasi (Chile), Pueblo Viejo (Dominican Republic) and Colquijirca (Peru). This non-core project received ARC Linkage funding and industry funding through AMIRA (AngloGold Australia Limited, Placer Dome Inc, Teck-Cominco, Gold Fields Ltd, Newcrest Mining Ltd, Anglo American and Newmont).

This project began in mid-2003 and finished in December 2006. It has made major advances in our understanding and interpretation of transitions and zoning in both the 'lithocap' (high-level advanced argillic alteration) and 'green rock' (propylitic alteration) environments that occur above and around porphyry and epithermal systems. New techniques for vectoring in towards mineralised centres have been developed, and have been demonstrated to be effective in several well-mineralised porphyry-epithermal districts. The research team is now compiling a proposal for a project extension, to be distributed to potential sponsors in early 2007.

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

Project Leaders: D Selley, S Bull, M Hitzman
Project Members: D Broughton, M Duffett, N Harris, P McGoldrick, R Scott
Student: L Koziy
Collaborators: S Sebagenzi (University of Lubumbashi/ Gécamines), P Emsbo (US Geological Survey)

This project aims principally to progress understanding of geology and base-metal mineralisation processes within the regional framework of the Central African Copperbelt, and to develop practical exploration tools for sediment-hosted copper deposits in basins around the globe. We are grateful for the financial and logistical support provided by industry sponsors via AMIRA (African Rainbow Minerals, Anglo American, Anvil Mining, BHP Billiton, CVRD, Equinox, Gécamines, Phelps Dodge and Rio Tinto) and the ARC.

**** ARC Linkage Projects — non-core in the Centre of Excellence

A major focus of AMIRA-ARC P872 involves the development of evolutionary models for the Katangan basin system. The basis of this research includes drill core databases in both Zambia and the Democratic Republic of Congo, and the remarkably comprehensive geological and geophysical databases assembled by Union Minière and Gécamines over the past 80 years. Our research has identified several major basin compartments, and a systematic extensional fault network, that were moulded by a period of salt tectonism spanning ~740–600 Ma. We have also recognised close spatial associations between ore distribution and the fringes of basin compartments.

Links between the Congolese and Zambian arms of the Central African Copperbelt have been further elucidated by the development of a sequence stratigraphic framework for the lower Katangan Supergroup, led by Stuart Bull, and supported by CSM team members David Broughton and Nick Harris.

An integrated gravity and aeromagnetics study of the outer Congolese Copperbelt has commenced under the leadership of Mark Duffett. These data were contributed to the project by Dr Stanislas Sebagenzi, Gécamines, and Bureau Gravimétrique International. Preliminary investigations have revealed apparent differences between the basement to the Zambian and Congolese copperbelts, and several local anomalies within the latter that potentially record heterogenous basement, variation in stratal thicknesses of the Katangan succession, or preservation of Katangan salt bodies.

Basement mineralisation studies (Robert Scott and Murray Hitzman) have indicated a link with classical Zambian-style ores hosted in Katangan metasedimentary rocks, through a common spatial association with extensional, sub-basin-bounding fault zones. This relationship supports AMIRA ARC P544 and P872 numerical fluid-flow modelling, which indicated interaction of basin-derived brines with basement, via an extensional fault network.

Project P3.L4: Quantitative 3D imaging of the electrical properties of ore deposits and their environment

Project Leader: M Roach
Project Members: M Duffett, P Fullagar

This is a one-year project, commencing in January 2007. Work in 2006 was limited to preliminary geological and geophysical data compilation.

This project aims to evaluate alternative geophysical inversion methods through generation of constrained 3D petrophysical/geological models of a study area between Zeehan and Rosebery in western Tasmania. The field area contains numerous mineralised localities and was selected to encompass zones of significant geophysical anomalism associated with Cambrian mafic-ultramafic rock units and Devonian granitic rocks.

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

Project Leaders: A McNeill, B Gemmell

Exploration for VHMS deposits in the Mount Read Volcanics (MRV) is based on the concept that all economic mineralisation occurs at a particular time horizon (the 'Holy Host') and that this horizon has been adequately tested to a depth of 150–200 m. The major problems for VHMS exploration in the MRV are defining the location and down-dip extent of the 'Holy Host' and locating alteration envelopes and the hanging and footwall to the target VHMS mineralisation.

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

This 18-month project commenced in November 2006. Work in 2006 was limited to preliminary data compilation and sampling of shales.

PhD Projects in the Discovery Program

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

Ralf Schaa: Rapid approximation algorithms of TEM data

Lyudmyla Koziy: Numerical simulation of fluid flow and fluid chemistry in sedimentary basins

‘ORES IN SEDIMENTS’ WORKSHOP

Over three days in mid-November 2006 more than one hundred people gathered to attend the CODES ‘Ores in Sediments: New Directions, New Developments’ workshop. The meeting was convened by Peter McGoldrick from CODES and presented new information and the latest research results for several styles of ore deposits found in sedimentary basins. It was held at the Wrest Point Convention Centre and attended by industry, government and university geologists.

Over the three days, invited speakers from industry, international universities and CODES gave 26 individual presentations grouped into a series of commodity-focused sessions. The first morning began with an overview from Kurt Kyser (Queens University) of ore-related processes that occur in sedimentary basins. Kurt’s talk set the scene for a series of talks on uranium from Dave Thomas (Cameco), Paul Polito (Anglo American) and Kurt.

The famous Zambian Copperbelt was the topic for the first afternoon session. Research results of AMIRA Project P544 (CODES/CSM collaboration 2000–2003) were presented by Murray Hitzman (CSM) and CODES researchers (David Selley, Peter McGoldrick, Ross Large, Rob Scott, Lyudmyla Koziy and Stuart Bull).

The second day, largely devoted to sedimentary zinc deposits, kicked off with two reviews: northern Australian Proterozoic SEDEX Zn deposits (Ross Large), and ore fluid chemistry and sulfide precipitation controls (David Cooke, CODES). Peter McGoldrick then described evidence for a low-S Palaeoproterozoic ocean and the implications this has for SEDEX deposits. These overview talks were followed by a series of deposits case studies, with Rod Maier (CODES), Ken Chapple (Gold Aura Ltd), Mick Skirka (Zinifex) and Peter McGoldrick describing Bluebush, Mehdiabad, Duddar and Red Dog, respectively. The penultimate presentation on day two was from Poul Emsbo (USGS) who argued that major Phanerozoic SEDEX events had ocean-scale chemical effects, notably on coeval seawater Sr isotope signatures. Day two concluded with a provocative talk from David Rickard (Cardiff University) discussing the merits of equilibrium versus kinetic approaches to understanding pyrite formation.

Day three saw a second pyrite talk from David Rickard and two presentations from Ray Coveney (University of Missouri–Kansas City) describing nickeliferous black shales from central USA and southern China. The workshop ended with two gold talks. One from Poul Emsbo presented a Sedex model for the Rodeo deposit in Nevada and one from Ross Large describing new laser ablation and textural studies of the giant Sukhoi Log deposit in Russia.

Transcripts of the question and answer sessions will be included in a workshop proceedings volume to be published as a CODES Special Publication in 2007.

‘Ores in Sediments: New Directions, New Developments’ workshop session led by the Convenor, Peter McGoldrick

Attendees at the CODES 'Ores in Sediments: New Directions, New Developments' workshop held in Hobart in November 2006

PROGRAM 4: RECOVERY

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

Team members

Ron Berry, Nenad Djordjevic*, Peter Fullagar*, Stephen Gay*, Wally Herrmann, Julie Hunt, Jon Huntington*, Maya Kamenetsky, Toni Kojovic*, Gary McArthur, Simon Michaux*, Rob Morrison*, James Reid, Mike Roach
(* partner research organisation team member)

PhD students

Natalee Bonnici, Cathy Evans (JKMRC), Luke Keeney (JKMRC), George Leigh (JKMRC), Adel Vatandoost

Core projects in the Recovery Program

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

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

P4.L1.2 Integrated micro-analytical mineral mapping

P4.L1.3 Textural classification, simulation and modelling

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

P4.L1.5 Geostatistical attribution of processing performance attributes

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

Industry sponsorship and ARC funding for AMIRA P843

Fifteen companies support the AMIRA P843 GeM^{III} project with three levels of industry sponsorship – Level 1 involving a maximum of six significant site-based studies, Level 2 with no designated site-based studies and Level 3 'supplier' sponsors who provide specialist services, software or hardware relevant to the project.
Level 1 Sponsors: Inco, Newcrest, Newmont, Rio Tinto, Teck Cominco and Xstrata.
Level 2 Sponsors: AngloGold Ashanti, Anglo Platinum, Barrick, BHP Billiton, CVRD and Zinifex.
Level 3 Sponsors: Datamine, Golder Associates and GEOTEK.

This represents over $4.2 million of direct industry cash support over the life of the project with substantial in-kind support for site-based activities. A further $2 million of ARC funds will be provided through the Centre of Excellence.

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

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

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

Steve Walters: Team Leader

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

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

Ernest Henry copper-gold – mature open-pit iron-oxide-associated copper-gold system north of Cloncurry, NW Queensland, Australia; provided by Xstrata.

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

Highlights

- Significant progress on a range of new technology developments to support the research program in the areas of automated core logging, automated textural data acquisition and analysis, and small-scale comminution testing
- Site-deployment of automated petrophysical, imaging and SWIR-based logging instruments at Cadia East and Ernest Henry
- Collaborative research agreement with CSIRO to integrate SWIR-based HyLogger instrumentation into the program
- Development of a range of simulation and modelling techniques to support the program
- Continued growth in industry support and sponsorship for the program

Program 4 team

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

Project Leader: S Walters
Project Members: M Roach, P Fullagar, W Herrmann, J Reid
Student: A Vatandoost

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

In early 2006 the AMIRA P843 GeM^{III} project took delivery of a containerised automated multi-sensor core logger (MSCL) supplied by Geotek in the UK. Over 80 Geotek MSCL systems have been produced and are used mainly in oceanographic research and petroleum exploration applications. The MSCL involves linear feed of core through a series of mainly petrophysical and imaging sensors with automated collection of data at user-defined intervals. Sensor arrays can be customised – the initial configuration includes high-resolution digital imaging, gamma ray attenuation bulk density, magnetic susceptibility, P-wave velocity, and resistivity, with other sensor types and configurations under evaluation. Geotek has joined the project as a Level 3 sponsor and is providing specialist method development support.

The approach is a derivative of down-hole geophysical logging that involves bringing rock to the sensor rather than placing the sensor into the rock and provides synergies with other geophysical research in the Centre of Excellence. It allows use of the extensive archived core available at most sites, which is typically associated with historical processing performance information and ensures close correlation with other core-derived attributes such as assays. The majority of petrophysical attributes provide proxies for potential mineral processing performance such as derivates of P-wave velocity and sonic logs related to strength and elastic moduli.

The high-resolution imaging system is being used for sophisticated image analysis and classification to provide early information on potential textural groups that have relevance to processing attributes.

The containerised logger system was deployed at Cadia East in mid-2006 to provide detailed logging information for ~2000 m of archived half core carefully selected to provide representative sections through a range of alteration and mineralisation zones. The Geotek system will be conducting petrophysical logging of the Ernest Henry core in early 2007.

A collaborative research agreement was signed in 2006 with the CSIRO Division of Exploration and Mining to access the HyLogger short-wave-length infra-red logging system for application in the project. HyLogger is a highly automated logging system that provides systematic information on SWIR-responsive mineralogy such as clays, chlorites, carbonates and micas. In the context of mineral

Michael Roach operating the Geotek logger. Inset - containerised Geotek laboratory at Cadia

processing these phases can strongly influence comminution performance. The HyLogger system was deployed at Cadia East and Ernest Henry during 2006.

A range of other core-based logging techniques have also been implemented as part of these site deployments. This includes systematic hardness testing based on instrumentation developed primarily for concrete testing.

The underlying theme of this approach is the use of small-scale, spatially constrained samples (generally 2 m of half core) that can be used to identify fundamental processing behaviours and associations as inputs into modelling. This contrasts with the bulk sampling and testing approach typically used in current practice, and has required the development of a new suite of small-scale physical testing methods (P4.L1.4).

P4.L1.2: Integrated micro-analytical mineral mapping

Project Leader: R Berry
Project Members: J Hunt, G McArthur, S Walters, M Kamenetsky
Student: N Bonnici

In the past decade there have been major on-going advances in the field of automated micro-analytical mineral mapping mainly related to the development of automated SEM-based X-ray microscopy such as the JKTech MLA and Intellection QEMSCAN™ systems.

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

This module aims to develop an integrated automated microscopy facility at CODES to support the needs of the AMIRA P843 GeM^{III} project. This facility will focus more on mineral mapping of intact textures rather than comminuted products. The approach is based on a combination of new hardware linked to automation and advanced software applications for image classification and textural analysis.

The first phase of this system was implemented in mid-2005 with the installation of an MLA facility at the University of Tasmania based on an FEI Quanta 600 SEM. This represents the first dedicated university-based MLA research facility in Australia and one of the first such university-based facilities in the world. The system is now providing routine analytical support to the AMIRA P843 GeM^{III} project.

During 2006 the same approach of increased automation and software-based image analysis has been applied to optical microscopy. Significant advances have occurred in automated optical microscopy systems mainly driven by the needs of other sectors such as pathology. Similarly, advances in image analysis and classification have been driven by sectors such as remote sensing.

During 2006 a Leica DM600M computer-controlled microscopy system was installed at CODES to specifically serve the AMIRA P843 GeM^{III} project. In combination with novel application of the sophisticated eCognition image analysis software, this system is capable of routine digital image capture and classification of large area mineral maps.

The integrated combination of more automated MLA and optical microscopy provides new capabilities for mineral mapping and texture analysis that can be linked to simulation and modelling of processing performance (P4. L1.3).

PhD students Luke Keeney and Natalee Bonnici with Dean Collet of Newcrest Cadia Valley Operations

P4.L1.3: Textural classification, simulation and modelling

Project Leader: S Gay
Project Members: R Berry, G McArthur, S Walters, K Nguyen, J Hunt
Students: N Bonnici, G Leigh

The traditional textural classification and categorisation schemes used by geologists are poorly correlated with and calibrated against processing performance. At the hand specimen/core scale, traditional geological classification schemes are largely based on visual observation that can be subjective and experience-based.

The advent of automated digital mineral mapping outlined in P4.L1.2 presents new opportunities for a more systematic and reproducible approach to textural classification and categorisation based on quantified, statistical methods. However, automated mineral mapping techniques generate large volumes of increasingly complex measurements that can challenge even computer-based classification methods.

The aim of this module is to provide a range of more effective software-based methods for textural analysis, feature extraction and categorisation that have relevance to processing performance. Typical parameters include systematic measures of grain size, grain shape and association using classified mineral maps provided by P4.L1.2. Much of this involves in-house software development carried out as part of the AMIRA P843 GeM^{III} project at the JKMRC. Significant advances are being made in the application of wavelet functions to texture-based image analysis and automated feature extraction.

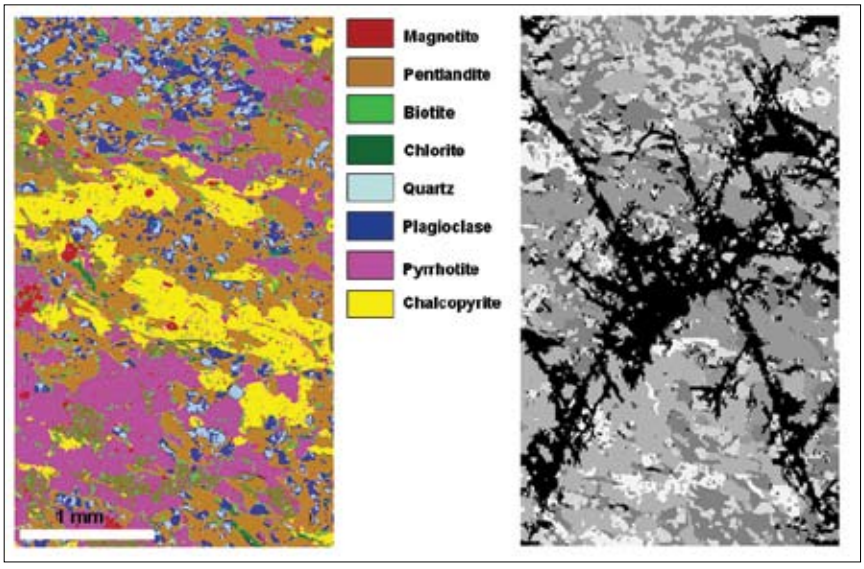
Another aspect of the research is the use of classified mineral maps of intact texture to simulate and predict potential processing performance. This involves use of sophisticated finite element modelling techniques to simulate fundamental mineral-based fracturing and liberation. The work is providing important insights into how rock textures behave and interact under processing conditions. The resulting models can be compared and validated against actual physical processing behaviour in P4.L1.4.

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

Project Leader: T Kojovic
Project Members: S Michaux, R Morrison, N Djordjevic, S Walters
Students: C Evans, L Keeney

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

Many of the physical tests currently in use are based on large sample volumes that require compositing of routine core samples over significant intervals, with a tendency to select sampling intervals based on grade or mining constraints. Combined with a high cost per sample for existing tests, this limits sampling density and often results in inappropriate compositing and blending. The 'noise' related to poorly constrained compositing typically generates poor comparative statistics based on small sample sets relative to ore body size, and can disguise natural geological variability.



Finite-element modelling simulation of rock microtexture breakage

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

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

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

P4.L1.5: Geostatistical attribution of processing performance attributes

Project Leader: C Alford
Project Member: G McArthur

A key objective of the Recovery Program and the AMIRA P843 GeM^{III} project is to provide improved attributes or indices of processing performance that can be embedded in block models to define processing domains, which can be exploited in more effective mine planning and optimisation. A key technical issue is effective geostatistical modelling of potentially non-additive, non-linearly averaging attributes such as grindability and texture on a variety of scales.

Attributes that are not intrinsic rock properties or reflect machine interactions are poorly understood with indications they behave differently to traditional attributes such as ore grade, and significant research challenges exist. This aspect is being addressed through collaboration with the WH Bryan Mining Geology Research Centre (BRC) at the University of Queensland.

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

An important outcome of the AMIRA P843 GeM^{III} project is training and formal education delivered by JKMRC, BRC and CODES. The project involves a significant number of postgraduate students closely linked to site-based activity that will assist with technology transfer. The ultimate aim is to educate and enthuse the next generation of practitioners to enter the industry with a focus on geometallurgical integration.

Relevant courses and training opportunities will be developed as the project progresses.

PhD projects in the Recovery Program

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

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

Luke Keeney (JKMRC): Geometallurgical study of the big Cadia copper gold skarn system

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

Adel Vatandoost: Automated petrophysical characterisation of drillcore and potential relationships to mineral processing attributes

Physical sample testing – JKMRC laboratories

PROGRAM 5: INNOVATIVE

Objectives … to develop new analytical techniques, ensuring that research in the Centre is driven by innovative technology, and that the Centre is at the cutting edge of analytical developments of relevance to ore deposit research … and to provide CODES research staff and students with access to state-of-the-art micro-analytical equipment within Australia and overseas, and to maintain their awareness of new analytical developments

Team members

David Belton,* Zhaoshan Chang, David Cooke, Garry Davidson, Cari Deyell, Sarah Gilbert, Anthony Harris, Kathryn Harris, Janet Hergt,* Vadim Kamanetsky, Ross Large, John Mavrogenes,* Katie McGoldrick, Peter McGoldrick, Sebastien Meffre, Phil Robinson, Chris Ryan,* David Selley, Mike Shelley,* Jon Woodhead
(* partner research organisation team member)

PhD Student

Heidi Pass

Collaborators

Imperial College (UK) – Andrew Berry
University of Western Australia (Western Australia) – Stefan Haggeman

Program 5 team members: L to R, Ross Large, Anthony Harris, Olga Vasyukova, Sebastien Meffre, Sarah Gilbert, Dima Kamenetsky, Leonid Danyushevsky, Katie McGoldrick, Phil Robinson, Peter McGoldrick

TECHNOLOGY

Leonid Danyushevsky: Team Leader

Core projects in the Innovative Technology Program

(F prefix denotes fundamental research project)

P5.F1 Developments in LA-ICPMS of sulfides, fluid inclusions and carbonates

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

P5.F3 Developmental research into the use of synchrotron in ore deposit studies

P5.F4 Nuclear microprobe analytical development

P5.F6 Lead isotopic analysis in the CODES LA-ICPMS facility

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

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

Highlights

- Expansion of CODES LA-ICPMS facility with installation of an Agilent 7500 quadrupole mass-spectrometer and a New Wave Research 193 nm solid state neodymium-YAG laser
- Analysis of lead isotopes in sulfide minerals and silicate melt inclusion in phenocrysts by LA-ICPMS at the University of Tasmania and the University of Melbourne
- Analysis of lithium, boron, fluorine, magnesium and sodium on the nuclear microprobe at CSIRO, Melbourne, using the phenomenon of proton induced gamma emission (PIGE)
- Improved precision of uranium-lead dating by LA-ICPMS at the CODES analytical facility

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

Project Leader: L Danyushevsky
Project Members: S Gilbert, V Kamenetsky, P McGoldrick, P Robinson, M Shelley

In 2006, the CODES LA-ICPMS facility was expanded. A new Agilent 7500cs quadrupole mass-spectrometer and a new New Wave Research 193nm solid state neodymium-YAG laserprobe were installed and are now operational.

The new equipment has been extensively tested for ablation of silicate minerals and glasses, zircons (see also P5.F6), and fluid inclusions and delivers vastly improved performance in spatial resolution, precision and sensitivity.

Work was also started on developing a new ablation cell for the new laserprobe which should further improve precision and sensitivity. Two different designs are being tested, one in cooperation with Michael Shelley from ANU and one in cooperation with Peter Dove from the UTAS CSL workshop.

Development of a standard for PGE and mercury analysis of sulfides was begun. The standard will be developed at CODES using a fire assay technique.

Work started successfully on the proposed fluid inclusion analytical developments with preliminary experiments on the multiphase fluid inclusions from miarolitic quartz of the Omsukchan granite and sanidine from the Mount Vesuvius endoskarn. The rationale behind this development work is that chlorine cannot be used for mass-balance calculations (assumption: all cations are bonded with chloride ions) because other anions are likely to be present. Among them, sulfur and fluorine are difficult to measure by LA-ICPMS of fluid inclusions due to high backgrounds, whereas measurement of boron is possible, but requires standardisation. The preliminary measurements of boron in fluid and melt inclusions in the pegmatitic quartz were performed in collaboration with Dr Sergey Smirnov, a visitor to CODES from the Institute of Geology and Mineralogy, Novosibirsk, Russia. The results on the sassolite (H_3BO_3)-bearing fluid inclusions demonstrate that boron can be quantified well.

Finally, work was also started on testing a natural calcite ('Iceland Spar') for use as a secondary standard for LA-ICPMS of carbonate minerals. The sample was analysed by LA-ICPMS (50 analyses) to check for homogeneity and by electron microprobe (also 50 analyses next to each laser hole) to compare the concentrations of strontium and manganese obtained by the two techniques.

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

Project Leaders: J Hergt, J Woodhead, S Meffre
Project Members: Z Chang, L Danyushevsky, V Kamanetsky, R Large

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

In the first strand, two new research projects were initiated using our recently developed methods for in situ analysis of melt inclusions. These investigated inclusion suites from the Hunter Ridge in the southwest Pacific and Emeshan flood basalt province in China, with a view to understanding both the processes of inclusion entrapment, and the nature of the processes recorded by the inclusions.

As part of the second strand, during 2006, extensive experimentation has refined our analytical methodologies for in situ lead-isotope analysis of sulfides (primarily pyrite at this stage) to the extent that routine analysis is possible and individual programs utilising this technology can begin.

Three potential standard reference materials were identified and characterised by solution analysis and, of these, one has proved particularly suitable with homogeneous lead-isotopic composition and concentration of lead; these will prove invaluable as matrix-matched calibration standards.

Dan Layton-Matthews operating the CODES LA-ICPMS facility

Two research projects were completed towards the end of 2006, using samples from the sediment-hosted Sukhoi Log deposit in Russia, and gold deposits from Laos. These proved valuable in highlighting both some 'real world' limitations on the technique but also its great potential utility for provenance studies.

F5.3: Developmental research into the use of synchrotron in ore deposit studies

Project Leader: A Harris
Project Members: D Cooke, J Mavrogenes, V Kamenetsky
Collaborator: A Berry (Imperial College)

Porphyry-copper deposits originate from huge volumes of metal-bearing hydrothermal fluid exsolved from specialised upper crustal magmas. This research seeks to better constrain the behaviour of important ore-forming elements during fluid exsolution and subsequent phase separation. High-temperature spectroscopy (using synchrotron light sources) of fluid inclusions is advancing the understanding of metal speciation during the evolution of a magmatic fluid. Despite this, the total copper content of aqueous liquid-rich fluid inclusions is below detection limit to obtain meaningful results. By contrast, salty fluid inclusions that contain percent levels of copper, can commonly contain numerous opaque daughter crystals that will not dissolve when heated. Our developmental work, employing new procedures and methods, is attempting to dissolve these solid phases, as dissolution of such phases on heating makes it possible to better establish the metal speciation of high-temperature magmatic-hydrothermal fluids.

Our investigations are focused on quartz from samples that span the magmatic-hydrothermal transition in several world-class porphyry copper-molybdenum (-gold) systems. We have selected metal-rich (up to several percent copper) fluid inclusions (as determined by PIXE and LA-ICPMS) crowded with daughter crystals (including those visibly rich in chalcopyrite). These samples will form the basis of hydrogen-infusion experiments in the high pressure cold-seal lab at Imperial College. In 2006 our collaborators at Imperial College successfully re-established the lab (three cold-seal hydrothermal vessels) for future synchrotron research.

Two applications for beam-time were made during 2006; one experiment proposal was successful at the Advance Photon Source, Chicago. This experiment will be undertaken in early 2007; we aim to run in situ high-temperature (up to several hundred degrees) spectroscopy on fluid inclusions already known to contain detectable soluble copper. XANES experiments using synchrotron radiation will focus on copper, iron and, for the first time, manganese. Three experimental days have been granted with a total in-kind value of AUS$45,000.

P5.F4: Nuclear microprobe analytical development

Project Leader: D Belton (joint appointment with CSIRO)
Project Members: L Danyushevsky, C Ryan

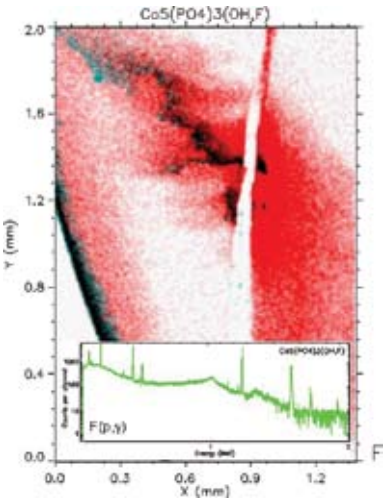
The CSIRO nuclear microprobe combines the excellent ion beam brightness and shape characteristics with multiple rastering mode capabilities to provide high sensitivity analysis of geological samples. The system complements the CODES LA-ICPMS facility by providing uniquely powerful trace-element imaging of traditional thin-sections and polished slabs, coupled with the non-destructive analysis of fluid inclusions in situ. Over the past year we have been working towards a number of our established goals and at the same time have been extending the research capabilities of this facility so as to maximise the probe's application in addressing ore research questions. These include:

- The introduction of improved image illumination and capture capabilities on the microprobe during the year now enables rapid matching of samples from other coordinate systems and is the first step towards opening the system to 'telepresence' technologies. We are also continuing to adapt our software control system to accommodate the integration of multiple analysis coordinate systems.
- Fitting the nuclear microprobe with a gamma-ray detector which expands the range of elements we can detect to include lithium, boron, fluorine, magnesium and sodium, using the phenomenon of proton induced gamma emission (PIGE). We have also conducted experiments utilising low energy beams of 1MeV (as opposed to 3MeV protons routinely used). While there remain some challenges with this approach, we have successfully captured PIGE-derived element images of light element distributions (e.g. phosphorus) in heavy matrices, using this technique. Subsequent efforts will focus on more precisely calibrating the fluorine and sodium output to cope with the analysis of fluid inclusions at depth in the substrate.
- As part of our experimental development, we have been trialling the application of PIXE in chemical age mapping. By exploiting the rapid collection of uranium, thorium and lead images using the nuclear microprobe, we are developing the capability to collect both the sample chemistry while simultaneously generating an age image of selected minerals including zircon and monazite. With the assistance and advice of Ron Berry and Sebastien Meffre, we are working to establish this technology as an added tool in the available suite of geochronology capabilities at CODES.

We have also conducted a program of continuous software development to optimise the new GeoPIXE™ software package which was installed during 2005. This package permits the user to sort list mode data and project quantitative elemental images from raw X-ray data. It also

enables extraction of concentration averages, line profiles and has a full suite of presentation capabilities for exporting the results. Thus it allows full quantitative analysis to be conducted by researchers on site.

Paralleling these software developments, we are in the process of migrating our database of PIXE/PIGE analyses across to hardware facilities at CODES. In the future, this will permit ready on-site access for CODES researchers to archives of data currently held in Melbourne.



Distribution of fluorine in hydroxyapatite using proton-induced gamma-ray emission (PIGE) on the nuclear microprobe. The image combines F (red component) and Pb (black component) and shows the close spatial relationship between the two elements. Both are concentrated at the curved boundary of the material (lower left) and within the irregular fracture (upper left).

P5.F6: Uranium–lead isotopic analysis in the CODES LA-ICPMS facility

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

Four main activities were undertaken in this project in 2006:

• Improving uranium-lead dating of minerals

Uranium-lead dating techniques were improved dramatically with the introduction of a new 193nm laser (see P5.F1). Average dating precision improved by a factor of 2 (halving errors) and average precision on low lead samples, young and low uranium zircons and other minerals improved by a factor of 4 (quartering errors).

• Lead isotope analysis of fluid inclusions

A technique for analysis of lead isotopes in fluid inclusions in quartz was successfully completed with the testing of fluid inclusion lead isotopic composition from four deposits ranging in age from the Proterozoic to the Quaternary.

The inclusions were analysed using a 213 nm solid-state neodymium-YAG laser connected to a quadrupole ICPMS at the CODES LA-ICPMS facility and a 193 nm excimer laser coupled with a MC-ICPMS at the University of Melbourne. The results were also compared to solution whole rock lead isotopic analyses from the same samples. All results were within error of the solution data from the same sample.

The results showed that analyses using a quadrupole ICPMS can be performed on inclusions with lower lead content, and that the shorter pulse width of the 213 nm solid state laser achieves much more controlled ablation of quartz than the 193 nm excimer laser, allowing for successful analysis of more inclusions. The ablation of quartz is further improved when using the 193 nm solid state laser. The results have also shown that analyses using a MC-ICPMS produce more precise values on inclusions with high lead contents.

• Lead isotope analysis of minerals

Lead isotopes compositions of magmatic K-feldspar, sphalerite and molybdenite were analysed using the 213 nm laser coupled with the Agilent 4500 quadrupole and compared to those derived from pyrite analyses from the same samples (see P5.F2). We found that lead isotopes can be analysed with a similar precision to pyrite analyses when lead contents are above 50 ppm. For analyses using the MC-ICPMS at the University of Melbourne, required lead content is above 200 ppm. Development has also started for LA-ICPMS analysis of lead isotopes in galena and this work will be continuing in 2007.

• Crystallisation temperature of zircon and rutile

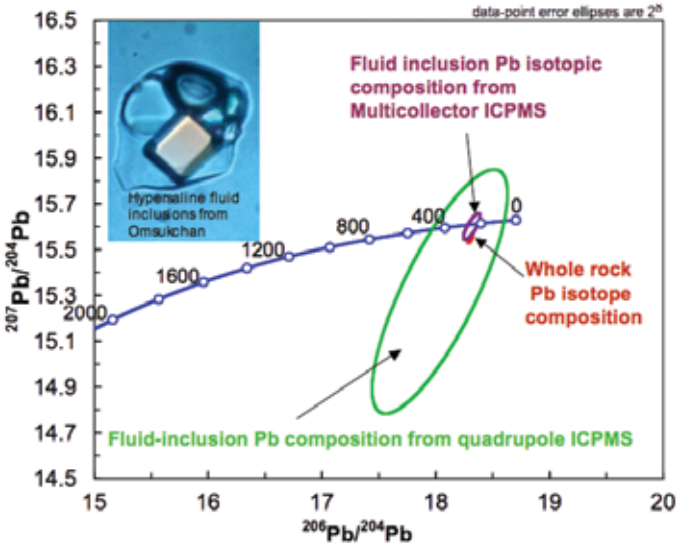
The concentration of titanium in zircons is thought to be correlated with their crystallisation temperature. Titanium contents were determined using NIST612 as a primary standard and tested on samples from the Antapaccay (Peru) copper-gold porphyry deposit which had been analysed previously at the Australian National University, and also on the 91500 standard zircon. The results obtained using the 213 nm laser and Agilent 4500 quadrupole are within error of the published values, showing that the temperature of crystallisation of zircon can be determined.

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

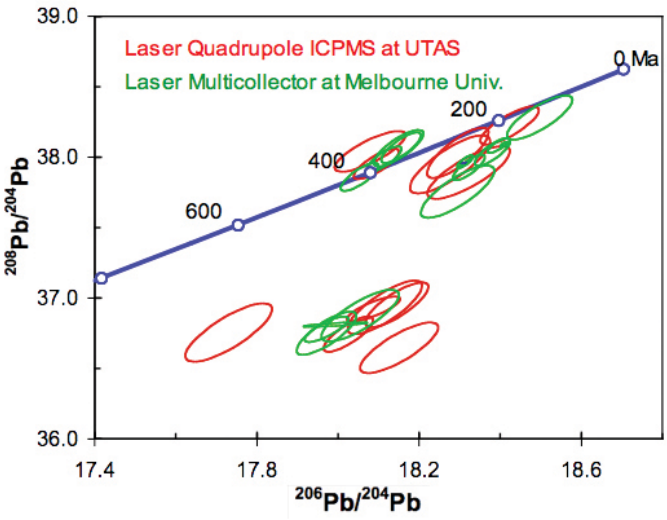
Project Leaders: G Davidson, D Cooke, C Deyell
Project Members: K Harris, J Hergt, K McGoldrick
Student: H Pass
Collaborator: S Haggeman (University of Western Australia)

In 2006, Heidi Pass completed a long field season at the Canadian Mount Polley porphyry as part of her PhD research, producing a large number of carbonate vein samples and substantial documentation. Trial samples from Mount Polley were run by the sulfate extraction technique, and results were consistent with expectations.

A study of sulfate compositions in Kelian carbonates has been completed. Kelian is a carbonate-rich epithermal deposit in Indonesia, for which CODES has a substantial sample base. The aim of this work was to undertake a



Comparison of Pb isotopic composition of fluid inclusions hosted in miarolitic quartz from the Omsukchan massif, northeastern Russia, analysed using different techniques and instruments



Comparison of the Pb isotopic composition of pyrite from the Sukhoi Log deposit determined using the MC-ICPMS at the University of Melbourne and the quadrupole ICPMS at the University of Tasmania

larger study of samples from a single deposit, rather than a few samples from a larger number of deposits, to examine isotopic variation. The work was successful in identifying the sulfate composition at the site, and H_2S/SO_4 ratio that operated during carbonate vein deposition.

Microprobe analysis was completed on variably deformed carbonates from Cadia, and the Mount Isa Eastern Succession, that have been previously studied via the CAS technique. This work also included the production of element maps (mainly sulfur, manganese, calcium, magnesium and iron).

Work has started on formulation of a hydrothermal carbonate database from the literature.

Steffen Haggemann (UWA lecturer) and his PhD students, Warren Thorne and Rosaline de Silva, provided samples of lower temperature carbonates from iron ore systems (Pilbara, Carajas). In addition to sampling these for sulfate in carbonate analysis, our project extended the geochemical understanding of these same carbonates with C-O analyses and strontium isotope analyses performed on the MC-ICPMS at the University of Melbourne.

In terms of technique development, progress was made towards a more robust technique for a wider range of vein sulfide-carbonate mixes. In the earlier work, samples mainly consisted of carbonate-pyrite-chalcopyrite mixes. These behaved well using the current chemical extraction, because disulfide reaction rates are relatively slow. However, in some Kelian samples containing sphalerite, reaction rates with acids were rapid, so rapid that attempts to maintain the gas composition in a reduced state were at times defeated, leading to the oxidation of the evolved H_2S in the reaction vessel, and the storage of some of this component ultimately as dissolved aqueous sulfate. This was not satisfactory in terms of separating the primary sulfate and sulfide isotope compositions. A modification of the technique will be trialled in 2007 to address this issue.

Other activities within the Innovative Technology Program

Work began on developing a database of chemical analyses produced at the CODES LA-ICPMS facility. Ruben Chan has been hired to design the structure of the database and oversee data accumulation. The database will become operational in May 2007.

PhD projects in the Innovative Technology Program

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

GRADUATE RESEARCH,

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

PhD program

CODES had 48 PhD candidates during 2006, up from 34 in 2005. This is the highest number of enrolments in our PhD program since the inception of CODES. Our increase in PhD numbers is an exceptional result, as it comes at a time when the minerals industry is booming, and graduate retention rates in the earth sciences are very low across Australia and in many overseas countries.

There were two PhD graduations in 2006 (Kate Bull and Maya Kamenetsky) and three theses were submitted late in the year (Lyudmyla Koziy, Steve Lewis and Carlos Rosa). Lyudmyla Koziy is continuing her research at CODES, Steve Lewis secured a position at Geoscience Australia and Carlos Rosa took up a position at the University of Lisbon (Portugal).

A total of 13 new PhD students enrolled in 2006, of which eight are international students.

Master of Economic Geology program

The CODES Master of Economic Geology program is part of the national Minerals Geoscience Masters Program that is supported by the Minerals Council of Australia.

It was a busy year in 2006, with three Masters short-course modules being presented by CODES: 'Volcanology and Mineralisation in Volcanic Terrains', 'Brownfields Exploration', and 'Ore Deposit Models and Exploration Strategies'.

Jocelyn McPhie, Bruce Gemmell and Wally Herrmann led 19 participants in the Volcanology Short Course (5–19 March) through a two-week examination of modern volcanic successions of the North Island of New Zealand and the more ancient Mount Read Volcanics of western Tasmania. Eight of the participants took part in the course as part of the MEconGeol program (one from UWA) and there were two industry participants.

Twenty-two participants took part in the Brownfields Exploration Short Course (12–23 June) led by Steve Walters (CODES/JKMRC), James Reid, Mike Roach, Simon Gatehouse and Vic Wall. Seven of the participants were MEconGeol students (including one from UWA) and four came from industry.

By far the largest turnout of Masters students was for the 'Ore Deposit Models and Exploration Strategies' short course held from 15–24 November. Nineteen students attended the course with three of them enrolling in the Masters program after originally starting as industry participants. Four of the students were from JCU and three were from UWA. The course was presented by Stuart Bull, Zhoashan Chang, David Cooke, Garry Davidson, Bruce Gemmell, Anthony Harris, Murray Hitzman (Colorado School of Mines), Julie Hunt, Ross Large, Peter McGoldrick, David Selley, Steve Walters (CODES/JKMRC) and Noel White.

The 'Ore Deposit Models and Exploration Strategies' short course was preceded by a three-day 'Ores in Sediments' workshop. Over 90 industry, government and academic geoscientists from all over the world attended the workshop and several stayed on for parts of the ore deposit models course. Two industry participants signed up for the Masters program in the first week of the course.

Tony Webster started as the new MTEC senior lecturer and the coordinator of the CODES Masters program in November. Tony spent a year teaching geology at the WA School of Mines in Kalgoorlie and prior to that was working as an exploration geologist in Broken Hill.

The Masters program has continued to attract new recruits, with seven new students joining the program in 2006. Continued strong interest from across the minerals industry indicates that 2007 should continue to be a good year for student recruitment.

Minerals Tertiary Education Consortium

CODES continued its close relationship with the Minerals Council of Australia through its Minerals Tertiary Education Consortium (MTEC). The support from MTEC is used to exchange students between universities both within the Honours and Masters programs. This gives CODES students access to specialised courses that would not normally be available at UTAS. It also allows students from mainland Australia to travel to Tasmania to experience courses offered by CODES.

CODES will play a leading role in planning the future direction of the Minerals Geoscience Masters Program.

TRAINING & OUTREACH

Jocelyn McPhie: Coordinator Graduate Research

Honours program

The program continued to be administered by Garry Davidson in 2006, with Peter McGoldrick being responsible for coursework matters. Nine CODES/Earth Sciences staff members were involved in supervision. The trend of falling Honours student numbers continued in 2006, with only eight students, down from 12 in 2005. We broadly attribute this to a combination of low student numbers in first-year cohorts three to four years ago, combined with an emerging and disturbing trend of students moving directly into the workforce after completion of their basic degree. Daniel MacIntyre came to us from Latrobe University, and we also proudly hosted our first Dutch student, Wijnand van Eijndthoven. Projects were split between economic geology (6), and environmental geology/geophysics (2). Only two non-Tasmania-based projects were undertaken: one at St Ives (continuing), and another in the Cadia district of NSW. Of results known at the end of 2006, two of eight students secured a first-class rating. Early indications are that student numbers in 2007 will increase from those in 2006, with 10 students already enrolled for next year.

Outreach program

In 2006, researchers and students from CODES contributed to activities that raised the Centre's profile: at local, national and international conferences (e.g. RoundUp 2006), through the Centre's newsletter, through visits to collaborating institutions and by hosting visitors to the Centre.

In 2007, the Centre will contribute significantly to outreach activities such as National Science Week and Earth Science Week and develop specific outreach strategies to further engage school students, educators, government, media and the general community.

Master of Economic Geology students on Mount Tarawera, New Zealand, March 2006

INDUSTRY LINKS AND RESEARCH COLLABORATIONS

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

Industry links

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

Role of AMIRA International

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

In 2006 AMIRA funded these major projects for CODES:

- P843 (GeM^{III} project – P4.L1) Geometallurgical mapping and mine modelling.
- P923 (P2.L2) Controls on the formation and sulfide trace-element signatures of sediment-hosted gold deposits
- P872 (P3.L3) Origin and setting of Congolese-type copper deposits
- P765 (P3.L2) Transitions and zoning in porphyry-epithermal mineral districts

A new project (P962) on magmatic nickel-PGE deposits has been negotiated for funding over three years starting in March 2007.

Role of industry partners

Ten Australian and international mining companies make up the group of CODES industry partners: Anglo American, AngloGold Ashanti, Barrick Gold, BHP Billiton, Newcrest Mining Limited, Newmont Mining Corporation, Rio Tinto, St Barbara Mines, Teck Cominco and Zinifex Limited. Each of our sponsor companies provides support of $20,000 to $120,000 in cash per year to the research budget of the Centre of Excellence. A total of $1,850,000 has been guaranteed over five years. Senior representatives of these companies sit on the Science Planning Panel, along with other government and university researchers. This panel meets annually to discuss the results of CODES research and the potential directions for new research.

CODES industry partners benefit from sponsorship by having:

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

Research collaborations and International Visitors Program

CODES also has a strong track record of research collaboration with other Australian and international universities and research organisations. In 2006 CODES undertook collaborative research with 27 international and 16 national organisations (see appendix).

International links were expanded and new collaborations developed, particularly through joint postdoctoral appointments. In 2006, CODES established a joint postdoctoral appointment with Johns Hopkins University (Christian Schardt) and a second is planned for 2007 with the University of British Columbia. An on-going appointment was continued with Colorado School of Mines.

In addition, funding will continue to be used to support the International Visitors Program which attracts high-profile ore deposit researchers to CODES. In 2006, the following major international research collaborators were supported to visit CODES for more than two months each:

- Dr Georg Zellmer (Institute of Earth Sciences-Academia Sinica, Taiwan)– visited Vadim Kamenetsky from

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

September to November 2006 to collaborate on Project P1.F3

- Professor Sergey Smirnov (Institute of Geology and Mineralogy, Russia) – visited Vadim Kamenetsky from November to December 2006 to collaborate on Project P1.F3
- Mr Victor Sharygin (Institute of Geology and Mineralogy, Russia) – visited Vadim Kamenetsky and Ross Large from November to December 2006 to collaborate on Project P2.N1
- Dr Kirstie Simpson (Geological Survey of Canada) – visited David Cooke from November to December 2006 to collaborate on Project P2.L3
- Dr Xieyan Song (Guangzhou Institute of Geochemistry, Chinese Academy of Sciences) – visited Tony Crawford in 2006 to collaborate on Project P1.F1
- Professor Grant Garven (Johns Hopkins University) – visited Ross Large and Stuart Bull in 2006 to collaborate on Project P2.F2
- Professor Taofa Zhou (Hefei University, China) – visited David Cooke in 2006 to collaborate on Project P2.N3 and P3.L2
- Professor Valery Maslennikov and Dr Svetlana Masslenikova (Institute of Mineralogy, Russia) – visited Ross Large and Leonid Danyushevsky in 2006 to collaborate on Project P2.L4
- Somboon Khositanont (Department of Mineral Resources, Thailand) visited Khin Zaw in 2006 to collaborate on Project P1.L1
- Dr Dan Layton-Matthews (Geological Survey of Canada) visited Bruce Gemmell from January to May 2006 to collaborate on Project P2.F3

Collaborative research between our Australian-based partners (Australian National University, CSIRO Exploration and Mining, University of Melbourne, University of Queensland and University of Tasmania) is also being facilitated by joint postdoctoral appointments. These postdoctoral researchers are based at our collaborating partner institutions and incorporate research visits to CODES throughout their fellowship.

The first joint postdoctoral appointment with CSIRO, David Belton, commenced in late 2005. In 2006 a joint appointment was made with the University of Queensland. Further appointments at the Australian National University and University of Melbourne will be made in 2007.

St Barbara Mines

TECHNOLOGY TRANSFER

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

Technology transfer activities

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

Research results and technical developments in the applied research programs are transferred to end-users via regular research meetings, research reports, monographs, books, digital presentations and software packages, where appropriate. In 2006, 139 research reports were presented to industry clients, and 15 meetings were held to present and discuss progress and adoption of research results.

Publications targeted at end-users

CODES also delivers knowledge and applications to end-users and the wider scientific community through a selection of special publications that represent the culmination of major research efforts by the Centre's staff. *The Geology of the Broken Hill Pb-Zn-Ag Deposit, NSW, Australia* was added in 2006, bringing the number of CODES publications for sale to a total of ten.

- *Volcanic textures: a guide to the interpretation of textures in volcanic rocks* (1993). Authors: J. McPhie, M. Doyle and R. Allen (sold 302 copies in 2006)
- *New developments in Broken Hill-type deposits* (1996) - CODES Special Publication 1. Editors: J. Pongratz and G.J. Davidson (sold 9 copies in 2006)
- *Basins, fluids and Zn-Pb ores* - CODES Special Publication 2 (1999). Editors: O. Holm, J. Pongratz and P. McGoldrick (sold 14 copies in 2006)
- *Volcanic environments and massive sulfide deposits* (2000) - CODES Special Publication 3. Editors: J. Bruce Gemmell and June Pongratz (sold 25 copies in 2006)
- *The geology and origin of Australia's mineral deposits* (2000). Authors: M. Solmon and D. I. Groves (sold 23 copies in 2006)
- *Giant ore deposits: Characteristics, genesis and exploration* (2002) - CODES Special Publication 4. Editors: D. Cooke and J. Pongratz (sold 27 copies in 2006)
- *24ct Au workshop* (2004) - CODES Special Publication 5. Editors: D. R. Cooke, C. Deyell and J. Pongratz (sold 29 copies in 2006)
- *Altered volcanic rocks: a guide to description and interpretation* (2005). Authors: C. Gifkins, W. Herrmann and R. Large (sold 292 copies in 2006)
- *The geology of the Broken Hill Pb-Zn-Ag deposit, NSW, Australia* (2006). Author: A. E. Webster (sold 6 copies in 2006)

Commercial products and processes

In 2005 the Centre commenced building high-temperature low-inertia microscope-based heating stages for experimental studies of melt inclusions in phenocrysts from magmatic rocks. This year, CODES sold two stages – one to Jim Webster from the American Museum of Natural History (New York, USA) and another to Adam Kent from Oregon State University (Corvalis, USA).

Due to the commercial-in-confidence nature of the research undertaken in some of the projects at CODES we are unable to detail all our plans for commercialisation and technology transfer at this time.

Jocelyn McPhie presenting the 'Volcanoes and their products' short course to Ivanhoe Mines personnel in Mongolia

Short courses, workshops and conferences for end-users

CODES runs a series of workshops, short courses and conferences to facilitate the on-going adoption of our research by industry. In 2006 we ran nine such events in various locations including Canada, Thailand, Mongolia, New Zealand and Tasmania. The courses are based on the results of our research programs and emphasise the application and adoption of our research to effect positive change in exploration practice and improve mineral exploration success rates.

2006 short courses/workshops

Short course/workshop	Presenters (CODES presenters in bold)	Number of participants	Location	Date
Volcanology and breccias for the explorationist! From description to interpretation	**Jocelyn McPhie, David Cooke, Bruce Gemmell**, Andrew Davies and Kirstie Simpson	50	Canada	20-22 January 2006
Introduction to physical volcanology	**Jocelyn McPhie**	56	Thailand (Kingsgate Mining)	7-9 February 2006
Volcanology and mineralisation in volcanic terrains	**Jocelyn McPhie, Bruce Gemmell** and **Wally Herrmann**	19	New Zealand and Tasmania	5-19 March 2006
Volcanoes and their products	**Jocelyn McPhie**	15	Mongolia (Ivanhoe Mines)	23-26 April 2006
Brownfields exploration	**Steve Walters, James Reid, Mike Roach**, Simon Gatehouse and Vic Wall	22	CODES, Hobart, Australia	12-23 June 2006
Volcanic facies analysis	**Jocelyn McPhie**	14	Thailand (Kingsgate Mining)	28-31 August 2006
Ore deposit models and exploration strategies	**Stuart Bull, Zhaoshan Chang, David Cooke, Garry Davidson, Bruce Gemmell, Anthony Harris**, Murray Hitzman, **Julie Hunt, Ross Large, Peter McGoldrick, David Selley, Steve Walters** and Noel White	30	CODES, Hobart, Australia	15-24 November 2006
Exploration for porphyry and epithermal deposits	**David Cooke, Bruce Gemmell**, Jeff Hedenquist and Noel White	3	CODES, Hobart, Australia	7-8 December 2006

2006 conferences

Conference	Presenters (CODES presenters in bold)	Number of participants	Location	Date
Ores in sediments	Murray Hitzman, **Peter McGoldrick**, Kurt Kyser, Dave Thomas, Paul Polito, Poul Emsbo, **David Selley**, **Ross Large**, **Robert Scott, Lyudmyla Koziy, Stuart Bull, Mike Solomon, David Cooke, Rod Maier**, Ken Chapple, Mick Skirka, David Rickard, Ray Coveney and **Bruce Gemmell**	95	Wrest Point Convention Centre, Hobart, Australia	12-14 November 2006

PERFORMANCE INDICATORS

Key result area	Performance measure	Target	2006
Research findings			
	Publications in international journals	40 pa	27
	Reports to industry collaborators	50 pa	139
	Special issues and/or research monographs	1 per 2 yrs	1 mongraph
	Invitations to give keynote conference presentations	10 pa	15
	Papers at national/international meetings	60 pa	84
Investigators			
	Average % of CIs research in Centre	70%	81%
	Average % of PIs research in Centre	20%	26%
	Percentage of team-based projects	80%	83%
	Percentage of Australian cross-institutional projects	30%	38%
Research training and professional education			
	Percentage of RHD students attracted from interstate	40%	50% PhD 50% Masters
	Percentage of RHD students attracted from overseas	30%	25% PhD, 25% Masters
	Honours students in Centre programs	10	8
	RHD students in Centre programs	35	48 PhD 27 Masters
	Percentage of student projects linked with industry	50%	70% PhD, 75% Masters
	Professional short courses/workshops for industry	5 pa	8
International, national and regional links and networks			
	Centre national or international conferences/workshops	1 per 2 yrs	1 ('Ores in Sediments')
	Registrants at Centre conferences/workshops	50 pa	95 at conferences 198 at workshops
	International and national visitors per year	30 pa	46
	Collaborative projects with other global centres/groups	10	27
	External collaborators using Centre equipment	10 pa	7
End-user links			
	Frequency of meetings with industry representatives	10 pa	15
	End-user representatives to Science Planning Panel and Advisory Board	20%/50%	20%/40%
	Frequency of meetings with AMIRA Research Coordinator	10 pa	12
	Number of industry visitors to Centre	50 pa	83

Key result area	Performance measure	Target	2006
Organisational support			
	Annual cash contributions from UTAS	$1,300,000	$1,334,728
	Annual cash support from other institutional collaborators	$250,000	$225,000
	Annual cash support from all industry contributors	$1, 450,000	$2,492,059
	Number of new organisations recruited to or involved in the Centre	1 pa	1 (St Barbara Mines)
	New annual cash support from industry	$200,000	$1,198,611
Governance			
	Joint post-doctoral appointments between collaborative institutions/organisations	5	1 CSIRO, 1 JHU, 3 JKMRC (UQ)
	Balance and experience of Advisory Board members		53% Academic, 41% Industry, 6% Government
	Annual review of strategic and business plans		Nil
	Effectiveness of Centre Research Committee		Met December 2005
	Effectiveness of Science Planning Panel		80%
	Public profile of Centre	High	Internationally – high Nationally – high Locally – low
National benefit			
	Centre research has input into a major mineral discovery	1 per 5 yrs	Not in 2006
	Employment of Centre's postgraduates by minerals industry	>65%	Only second year of Centre; employment details of postgraduates will follow from Centre graduations

FINANCES

ARC contract and governance

The Centre for Ore Deposit Research (CODES) commenced as a Centre of Excellence (CoE) on 1 June 2005, having formally concluded as a Special Research Centre after operating for eight years since 1997. The CoE contract with the Commonwealth covers five years of funding from 2005–2010. The Centre's financial affairs are conducted within the established procedures, controls and delegations of the relevant universities. To ensure that the ARC CoE requirements are met an Inter-Institutional Agreement was established by the University of Tasmania (UTAS) Research Office, formally binding all participating institutions to the ARC CoE requirements including funding allocations from the CoE to its Nodes and agreed matching contributions of the Nodes. The Centre has a policy of assigning budget responsibility to Node and Program Leaders, overseen by CODES Finance Manager and the Director.

2006 income

Total CODES income for 2006 was $8,917,056 (see Table 1 and Figure 1). This is derived principally from the Australian Research Council (36%), industry (28%) and UTAS (23%).

- ARC Income: In addition to the Centre of Excellence Grant ($3.15 million), CODES received four ARC Linkage grants and two Discovery/ Fellowship grants amounting to $400,000. Other ARC grants held by Chief Investigators were rolled-in to the Centre of Excellence grant.
- State Government income: As per the Centre of Excellence Agreement the State Government of Tasmania contributed $200,000 toward the Centre for research to support the Tasmanian minerals industry. The previous Tasmanian scholarship funding of $68,000 pa is now included in the $200,000 annual allocation. The State Government contribution is currently paid $100,000 in advance (see Table 2)
- Industry Funding: Total industry funding was $2.49 million, of which the largest contribution (57%) was from AMIRA International for Centre of Excellence core and non-core research projects. Although AMIRA International core funding was down slightly in the first 18 months (see Table 2) this will be rectified in future years, when their core funding is anticipated to be higher than the agreed annual totals in Table 2.
- Host Institution Support: UTAS provided $2.01 million of which $1.33 million was their core funding commitment to the ARC Centre of Excellence. This funding relates to research salaries, PhD scholarships, equipment and research quantum earned by the Centre.
- Centre of Excellence Node Funding: The Centre of Excellence Nodes are the University of Queensland, University of Melbourne, Australian National University and the CSIRO – Exploration and Mining.

These Nodes have all contributed their agreed cash matching fund contributions to-date in accordance with the CoE agreement (see Table 2), with the exception of Australian National University which is currently $30,000 under-contributed. This short-fall is due to an agreed late start to that project and a corresponding delayed new appointment. It is expected they will catch-up this short-fall in 2007.

Collaborator/contributor funding agreement

Table 2 tracks the Centre of Excellence agreed cash income from all collaborators/contributors, against cash received to date. Overall, most collaborator/contributor funding was up-to-date at the end of 2006. Two contributors have underpaid (mentioned in Node and industry funding sections above) and several others are in surplus. The result is that we are currently $239,000 in surplus compared to the original Centre of Excellence agreement.

2006 expenditure

UTAS and Node expenditure of the ARC Centre of Excellence grant is shown in Table 3 and Figure 2. This demonstrates the total ARC funds UTAS contributed to each of the Nodes and how they have expended their ARC funds. Due to the delayed start of the CoE, UTAS paid 18 months of agreed ARC contributions in 2006. Some Nodes are underspent due to this late start.

The major areas of UTAS expenditure were salaries, research travel/accommodation, laboratory analyses and other consumables. Payments to Nodes amounted to 30% of the UTAS expenditure.

Table 1 2006 Income

ARC - Centre of Excellence Grant		
2005 Grant indexation (not received until 2006)*	31,500.00	
2006 Grant	3,121,198.00	3,152,698
CoE Nodes (collaborators) matching funds (agreed matching funds held at Node institution)		
CSIRO - *CoE core funding (see Table 2)* *	100,000	
University of Queensland - *CoE core funding (see Table 2)* *	75,000	
University of Melbourne - *CoE core funding (see Table 2)* *	75,000	
Australian National University - *CoE core funding (see Table 2)* *	45,000	295,000
Other ARC Grants		
Linkage grants and collaboratives	220,042	
Discovery grants	177,283	397,325
Other Commonwealth Government Funds		
Miscellaneous	19,649	19,649
State Government funds		
Tasmanian State Govt. - *CoE core funding (see Table 2)*	200,000	
Tasmanian State Govt. - Scholarships	0	
Miscellaneous	852	200,852
Local government funds		0
Industry/private funds		
AMIRA International - *CoE core funding (see table 2)*	956,825	
AMIRA International - non-core projects	475,060	
Industry - Other Projects	271,000	
Industry - Other Projects - *CoE core funding (see table 2)*	115,082	
Industry - Student-funded projects	120,685	
CODES industry partners - *CoE core funding (see table 2)* *	402,500	
Minerals Council of Australia (MTEC) - *CoE core funding (see table 2)*	148,100	
Miscellaneous	2,807	2,492,059
Contracts/consultancies/revenue raising		
Short courses	65,011	
Book sales	96,111	
Consulting	39,285	
Miscellaneous	86,268	286,675
University of Tasmania – Host Institution Support		
University - *CoE core funding (see table 2)* *	1,334,728	
Additional support to salaries	572,953	
General operating grant	22,635	
Scholarships (non-core)	48,076	
Student fee income	32,400	
Miscellaneous	2,000	2,012,792
Other Income Sources/Interest		
Overseas government	0	
Society of Economic Geologists - student scholarships	10,559	
Student support	23,434	
Specific projects	15,877	
Miscellaneous	10,137	60,007
Total		**8,917,056**

* income relates to first 18-month period of the Centre of Excellence (CoE started 6 months late due to late signing of CoE agreement therefore there was a catch-up of some income in 2006)

The ARC CoE income of $3,152,698 was matched by total expenditure of $2,770,893 during 2006.

The overall ARC carry forward of $1,345,188 is due to two factors:

- The six-month delayed start of the Centre of Excellence due to late signing of the agreement and the resulting late ARC payment of $1.5 million in December 2005. This $1.5 million payment was largely carried forward into 2006.
- The delay in filling several key research appointments.

The carry forward will be significantly reduced in 2007 when it is anticipated several senior appointments will be finalised.

Table 4 lists the Centre of Excellence agreed annual contribution to its Nodes (to be paid from ARC CoE funds). It demonstrates that, as at the end of 2006, UTAS has paid these agreed contributions. Detail of the Nodes' agreed matching fund cash contributions paid to date is shown in Table 2.

Notes to and forming part of the financial statements for 2006

CODES financial data and reports for 2006 were prepared by Christine Higgins, CODES Finance Manager. Data was extracted from the University of Tasmania's Financial Management Information System and CODES finance databases. All reports shown here have been audited by the University of Tasmania.

Due to the six-month delayed start of the Centre of Excellence, very few agreed cash payments and matching funds were contributed in 2005. Instead, there was an 18-month catch-up in 2006. This has artificially inflated some of the 2006 UTAS income and expenditure figures in the financial statements (Tables 1 and 3).

Income statement explanations

Last year's 'Collaborator funds' category is now called 'CoE Nodes (collaborator) matching funds'. CODES 'Industry sponsors' are now called 'Industry partners.' All other income categories are consistent with previous years.

Under the main income headings, sub-categories labeled 'CoE core funding' have been added to isolate Centre of Excellence core funding from other general funds, as the ARC requires us to demonstrate these agreed core funds were actually received.

The income figures in Table 1 financial statement represent actual income deposited into the University's finance system or transferred from UTAS to CODES during 2006, apart from the following exceptions:

- $1,500,000 ARC CoE income received in 2006 has not been counted. This income was received early January 2006 but relates to the 2005 CoE period. As it has already been counted as 2005 ARC income, it cannot be counted in 2006 (the ARC required that it be counted in the year that it applied to rather than the year it was received).
- $295,000 Centre of Excellence Node income counted in Table 1 was not actually received as cash by UTAS. It was contributed by the Nodes but held at their own institutions to be expended there. The CoE agreement requires that the Nodes make these annual 'cash

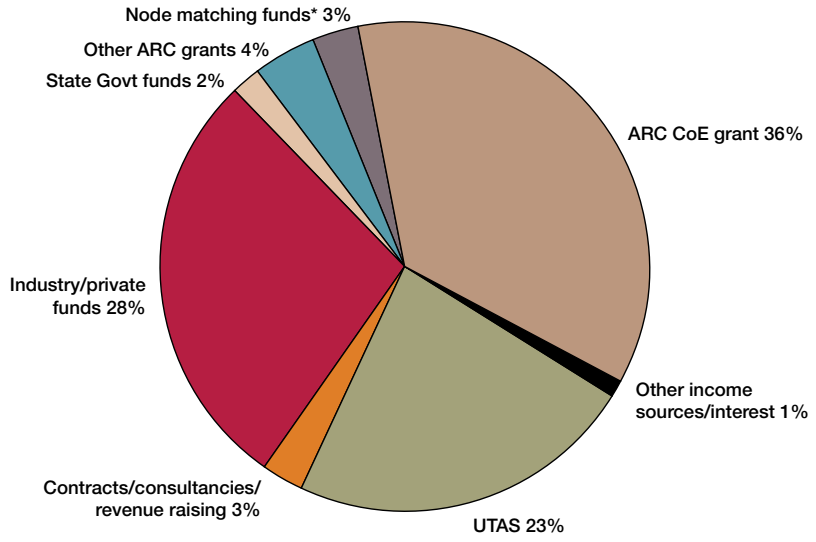


Figure 2 Total CODES income 2006

* Node (collaborator) matching funds (agreed matched funds held at Node).

Table 2 CoE agreed cash income – Summary of collaborators/contributors of the Centre of Excellence and their agreed cash contributions

		July–Dec 05	2006	2007	2008	2009	2010	Summary of agreed cash contributions owed and received to date (January 2005–Dec 2006)		
Collaborator/contributor		Agreed cash contri-bution	Agreed cash contri-bution	Agreed cash contri-bution	Agreed cash contri-bution	Agreed cash contri-bution	Agreed cash contri-bution	Agreed cash contri-bution	Paid to date	Over or under
University of Tasmania	Agreed Cash income table in the original Centre of Excellence Agreement	545,500	1,129,000	1,215,000	1,413,000	1,819,500	1,038,000	1,674,500	1,678,472	3,972
CSIRO - Exploration and Mining (CoE Node)		25,000	75,000	100,000	100,000	100,000	50,000	100,000	100,000	0
University of Qld (CoE Node)		25,000	50,000	50,000	50,000	50,000	25,000	75,000	75,000	0
University of Melbourne (CoE Node)		25,000	50,000	50,000	50,000	50,000	25,000	75,000	75,000	0
Australian National University (CoE Node)		25,000	50,000	50,000	50,000	50,000	25,000	75,000	45,000	(30,000)
AMIRA International		495,440	993,470	888,810	673,280	282,500	0	1,488,910	1,471,415	(17,495)
Minerals Council of Australia (MCA)		70,000	140,000	70,000	0	0	0	210,000	226,684	16,684
State Govt of Tasmania		100,000	200,000	200,000	100,000	0	0	300,000	400,000	100,000
Anglo American - Contrib to Cooke student support (Braxton, Ignacio, Gonzales)		20,000	30,000	10,000	0	0	0	50,000	63,247	13,247
Newcrest Mining - Contrib to Cadia project		192,224	115,082	126,613	118,147	47,935	0	307,306	307,307	1
Anglo American		15,000	35,000	40,000	45,000	50,000	25,000	50,000	50,000	0
Anglo Gold Ashanti		10,000	22,500	25,000	27,500	30,000	15,000	32,500	32,500	0
Barrick		10,000	22,500	25,000	27,500	30,000	15,000	32,500	32,500	0
BHP Billiton (includes WMC contribution from 2005 onward)		25,000	57,500	65,000	72,500	80,000	40,000	82,500	82,500	0
Newcrest Mining		0	20,000	20,000	20,000	20,000	20,000	20,000	20,000	0
Newmont Mining		15,000	35,000	40,000	45,000	50,000	25,000	50,000	50,000	0
Rio Tinto		10,000	22,500	25,000	27,500	30,000	15,000	32,500	32,500	0
Teck Cominco		10,000	22,500	25,000	27,500	30,000	15,000	32,500	32,500	0
WMC (taken over by BHP Billiton in 2005)		0	0	0	0	0	0	0	0	0
Zinifex		15,000	35,000	40,000	45,000	50,000	25,000	50,000	50,000	0
ARC		1,500,000	3,000,000	3,000,000	3,000,000	3,000,000	1,500,000	4,500,000	4,652,698	152,698
Total - collab and ARC cash listed in the CoE Agreement		3,133,164	6,105,052	6,065,423	5,891,927	5,769,935	2,858,000			
Additional new collab/contrib committed after orig CoE agreement										
St Barbara Ltd (new in 2006)	New contrib signed up		30,000	40,000	40,000			30,000	30,000	0
Great Southland Minerals and Zeehan Zinc Tasmania (new in 2007)				40,000	45,000	50,000		0	0	0
								0	0	0
Pre-existing SRC Sponsor that overlapped into CoE period										
Gold Fields Australiasia Ltd (old SRC sponsor that finishes in 2006)		5,000	5,000					10,000	10,000	0
								0	0	0
Revised total (CoE Agreement income plus new funding obtained)		3,138,164	6,140,052	6,145,423	5,976,927	5,819,935	2,858,000	9,278,216	9,517,323	239,107

Table 3 Expenditure of ARC COE Grant 2006

		Centre of Excellence collaborators (Nodes)					
	UTAS	CSIRO	U Qld	U Melb	ANU	JHU	Total UTAS plus Nodes
Balance brought fwd from 2005	1,145,642	(13,197)	(176,648)	0	(911)	0	954,886
Miscellaneous income (refund of expenses)	8,497						8,497
ARC income	3,152,698						3,152,698
Agreed payments to collaborators (for period 1 Jul 2005 to 31 Dec 2006) *	(965,020)	100,000	525,000	150,000	150,000	40,020	0
Salaries	(904,208)	(57,998)	(185,299)	(62,619)		(27,227)	(1,237,351)
Equipment purchases	(81,414)	(2,231)					(83,645)
Leased/hired equipment	(2,635)	(20,000)					(22,635)
Shared equipment/facilities	(3,000)			(18,900)			(21,900)
Travel and accommodation (research)	(334,948)	(17,973)		(861)	(567)		(354,349)
IT maintenance	(90,367)	(925)					(91,292)
General consumables/maintenance	(244,347)						(244,347)
Miscellaneous expenditure							0
PhD scholarships	(213,867)	(250)	(83,651)				(297,768)
Public relations and advertising	(105,160)						(105,160)
Laboratory analyses	(212,256)						(212,256)
Consultants	(12,116)		(78,174)				(90,290)
Visiting academics	(9,900)						(9,900)
Account balance at 31 Dec 2006	1,127,599	(12,574)	1,228	67,620	148,522	12,793	1,345,188
						Total expenditure	(2,770,893)

* 18-month period was paid in 2006. This catch-up of payments was required due to the six-month delayed start of the CoE (caused by late signing of the agreement)
Note: some Nodes started spending in 2005 in anticipation of receiving ARC funds in 2006 (hence their negative 2005 carry forwards).

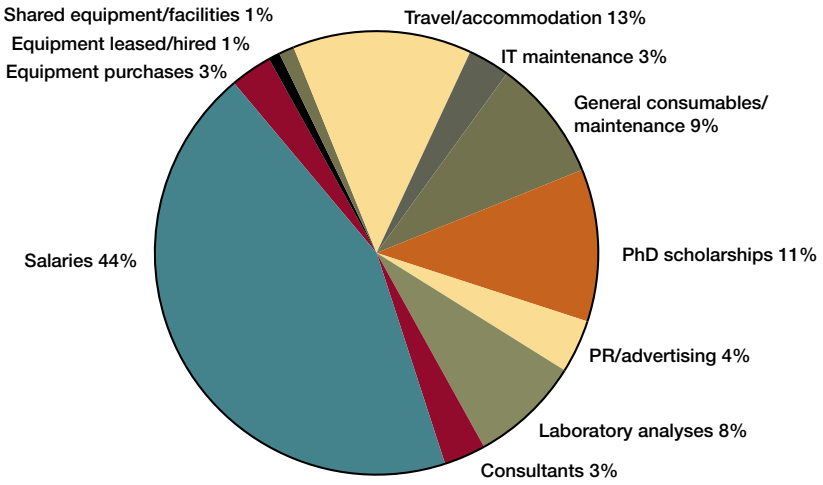
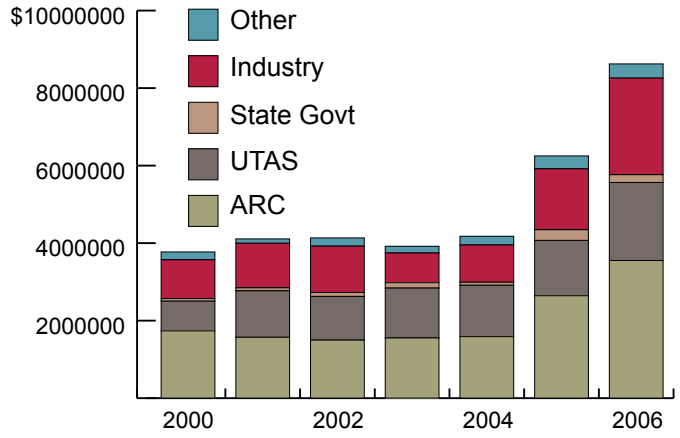


Figure 3 ARC/CoE Grant expenditure 2006

Table 4 Summary of CODES agreed ARC cash payments to collaborators/contributors (Nodes) and the agreed matching cash contributions of those collaborators/contributors

	Jul–Dec 2005		2006		2007		Summary of CODES payments owed and paid to date (18-month period)		
	CODES payment	Collab. matching contribution	CODES payment	Collab. matching contribution	CODES payment	Collab. matching contribution	Agreed CODES payments	PAID	over or under
CSIRO - Nuclear microprobe - starts CoE yr 1	25,000	25,000	50,000	50,000	50,000	50,000	75,000	75,000	0
CSIRO - Synchrotron Anal. Devel. - starts CoE yr 2	0	0	25,000	25,000	25,000	25,000	25,000	25,000	0
University of Qld	50,000	25,000	100,000	50,000	100,000	50,000	150,000	150,000	0
University of Melbourne	50,000	25,000	100,000	50,000	100,000	50,000	150,000	150,000	0
Australian National University	50,000	25,000	100,000	50,000	100,000	50,000	150,000	150,000	0
University of British Columbia	0	0		0	0	0	0	0	0
Colorado School of Mines	0	0	0	0	0	0	0	0	0
Johns Hopkins University	0	0	0	0	0	0	0	40,020	40,020
University of Qld (JKMRC)	125,000	0	250,000	0	250,000	0	375,000	375,000	0
Total agreed in CoE agreement	300,000	100,000	625,000	225,000	625,000	225,000	925,000	965,020	40,020

Note: see Table 2 for collaborator matching funds contributed to date.



Note: CoE commenced in mid-2005

Figure 4 CODES income 2000–2006

contributions' to the Centre in the form of matching funds (see Tables 2 and 4). Their contributions are therefore listed as income in Table 1, to demonstrate that they are meeting their agreed annual contribution to the Centre of Excellence. Financial statements have been obtained from the Nodes to demonstrate these agreed matching cash contributions have been made and to summarise how they are expending the funds.

Expenditure statement explanations

The expenditure financial statement and pie chart (Table 3 and Figure 2) now include Node expenditure, to demonstrate how the Nodes are expending the ARC funds paid to them by the Centre of Excellence.

The UTAS category 'Agreed payments to collaborators' is used to demonstrate that these agreed Centre of Excellence commitments have been met by UTAS (new ARC reporting requirement). Other expenditure categories are consistent with previous years.

CODES PUBLICATIONS 2006

** Publications from core projects in the Centre of Excellence. CODES authors in bold.*

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Chapters in books (3)

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*__Kamenetsky, V.S__. 2006. Melt inclusion record of magmatic immiscibility in crustal and mantle magmas. In: J.D. Webster (Ed.), Melt Inclusions in Plutonic Rocks. Mineralogical Association of Canada Short Course Series: 81–98. (Project P1.F3)

*Lyons, T.W., Gellatly, A.M., **McGoldrick, P.J**. and Kah, L.C. 2006. Proterozoic sedimentary exhalative (SEDEX) deposits and links to evolving global ocean chemistry. In: H. Ohmoto and S.E. Kesler (Eds), Evolution of the Early Earth's Atmosphere, Hydrosphere, and Biosphere – Constraints from Ore Deposits. Geological Society of America Memoir, 198: 169–184. (Project P1.F5)

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Allen, S.R. and Freundt, A. 2006. Resedimentation of cold pumiceous ignimbrite into water: facies transformations simulated in flume experiments. Sedimentology, 53: 717–734.

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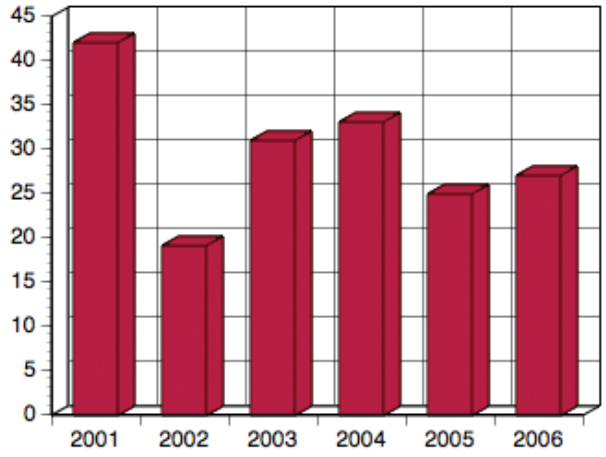

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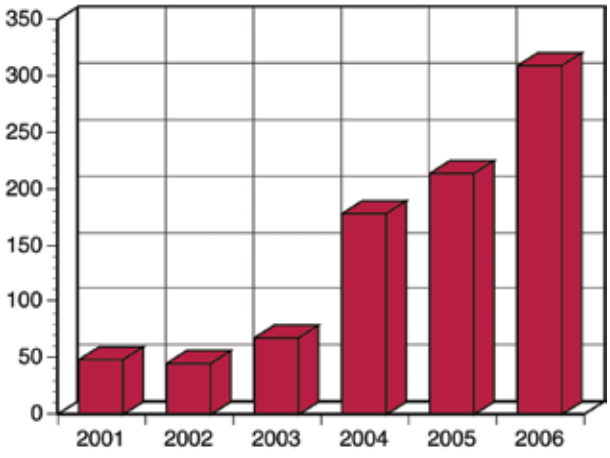

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APPENDICES

CODES postgraduate students 2006

Student	Project	Support
Bachelor of Science (Honours)		
Lachlan Brown	Geophysical investigation of tailings system integrity , Rosebery mine, Tasmania	Zinifex
Katherine Harris	Characterisation and causes of dry land salinity in the Hamilton district, Tasmania	TGMS, UTAS/MRT
David Finn	Late-stage mineralised faults in the Cadia district: their geological and exploration significance	Newcrest Mining
Laura Frankcombe	Geochemical and structural controls of gold mineralisation, Mars Mine, Western Australia	Goldfields Ltd
Daniel MacIntyre	The Hollway Prospect; stratigraphy, regional correlations, alteration and mineralisation (west Tasmania)	TGMS, Zinifex
Richard Mazurek	GIS application to landslip prediction around major montane roadage infrastructure	TGMS, Governor's Environmental Scholarship, MRT
Alexandra Lintner	Henty gold deposit, Mount Read Volcanics, western Tasmania	Barrick Gold
Wijnand van Eijndthoven	Unravelling the southern extent and history of the Cambrian Rosebery Fault, western Tasmania	TGMS, Zinifex, SGTSG Scholarship
Master of Economic Geology		
Cesar Eduardo Aguirre Mascarelli	Yet to be determined	Newcrest Resources Inc
Abdul Gafar Arbi	Course work only	Ivanhoe Mines Ltd
Paluku Batsotsi	An aspect of the geology of the Kinsevere Project, in the Katangan copperbelt, D R Congo	Anvil Mining
John Bedi	Yet to be determined	Newcrest Resources Inc
Steven Cancio-Newton	Yet to be determined	BHP Billiton
Colin Carter	An aspect of the CMT operations on the West Coast of Tasmania	Copper Mines of Tasmania
Corrie Chamberlain	Geology, geochemistry and genesis of the Kilkenny low-sulfidation epithermal deposit, Cracow, Queensland	Newcrest-Kracow,Qld
Hector Galam	Yet to be determined	
Ernie Gaspar	Yet to be determined	
Christopher Gaughan	Yet to be determined	
Christopher Gianatti	Yet to be determined	
Steven Groves	Geology and genesis of the Moonlight low-sulfidation epithermal prospect, Pajingo, Queensland	Newmont Mining
Benjamin Jones	Yet to be determined	Anglo American
Damian Jungmann	Yet to be determined	

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CODES postgraduate students (M Econ Geol) 2006 (cont.)

Student	Project	Support
Fiona Meaker	Course work only	
Mannie Mehu	Lihir Island project	Lihir Management Co
Jose Polanco	District-scale mapping project around Pueblo Viejo	
Anna Price	Yet to be determined	De Grey Mining Ltd
Peter Pring	Coursework only	
Budi Santoso	Coursework only	
Michael Skirka	Yet to be determined	
Simon van der Wielen	Yet to be determined	Geosciences Aust
Kalem Wright	An aspect of the Broken Hill deposit	Perilya Ltd
Master of Exploration Geoscience		
Terence Hoschke	Geophysical signatures of gold-copper porphyry systems	Newmont Mining
Bronto Sutopo	Geology and genesis of the Martabe deposit, Indonesia	Newmont Mining
Master of Science		
Paul Ferguson	Origin of large negative magnetic anomalies in oceanic crust, Macquarie Island	Australian Antarctic Division
Takayuki Manaka	Epithermal low-sulfidation system at Ban Houyxai and LCT deposits, Laos PDR	ARC Linkage Project, Pan Australian Resources

Student	Supervisors	Project	Support
Doctor of Philosophy			
Andrea Agangi	V Kamenetsky, J McPhie, S Allen	Magmatic and volcanic evolution of giant intraplate felsic igneous provinces and associated ore deposits: Gawler Range Volcanics and Hiltaba Suite, South Australia	CODES Scholarship
Darren Andrews	J Reid, M Roach	Geophysical monitoring of acid mine drainage at Savage River Mine, northwestern Tasmania	DPIWE, Aust Bulk Minerals
Michael Baker	A Crawford, R Berry	Palaeoproterozoic magmatism in the Georgetown Block, N Queensland, and comparisons with Broken Hill Block.	GSNSW, GSQ
Adam Bath	V Kamenetsky, A Crawford, D Cooke	The geochemistry of inclusions and mineral phases from the Mount Polley and Lorraine alkalic Cu-Au porphyry deposits: implications for the formation of ore deposits	BCGS, Uni of British Columbia MDRU
Susan Belford	J McPhie, G Davidson, R Large,	Genetic and chemical characterisation of the Archaean Jaguar VHMS deposit	APA-I
Jacqueline Blackwell	D Cooke, J McPhie	Characteristics and origins of breccias in an alkalic epithermal gold deposit: Ladolam, Lihir Island, Papua New Guinea	Lihir Gold Mine, Alkalic research project
Natalee Bonnici	S Walters, R Berry	Textural and minerological characterisation of Cu-Au systems in relation to process mineralogy	GeM^{III} project

CODES postgraduate students (PhD) 2006 (cont.)

Student	Supervisors	Project	Support
Bryan Bowden	G Davidson	Iron oxide Cu-Au-related alteration history of the Mount Woods inlier, South Australia, with special emphasis on the Prominent Hill prospect	PIRSA Minotaur Resources, Goldstream Mining, Geoscience Australia
David Braxton	D Cooke	Boyongan and Bayugo porphyry Cu-Au deposits, NE Mindanao, Philippines: geology, geochemistry, and tectonic evolution	Anglo American Exploration (Philippines), IPRS, SEG grant.
Katharine Bull *	J McPhie, A Crawford	Facies architecture of the ural volcanics, NSW	SEG, GSNW, ARC SRC
Reia Chmielowski	R Berry, D Cooke	The metamorphic history of Tasmania	Tas Govt
Mawson Croaker	D Selley, P McGoldrick, S Bull	Geology and genesis of the Nkana copper deposit, Zambia.	AMIRA ARC Linkage
Paul Cromie	K Zaw, D Cooke, N White	Geological setting, geochemistry and genesis of the Sepon Mineral District, Laos PDR	Oxiana Limited, APA Scholarship
Ana-Leizl Cuison	D Cooke, A Harris, R Berry	Geology and genesis of the Ridgeway porphyry Au-Cu deposit, NSW	Newcrest Mines Ltd
Kim Denwer	R Large	Mineralogical, geochemical and isotopic investigation of the Mount Lyell Cu-Au ore body and alteration system	MRT/TGMS, Copper Mines of Tasmania
Dinh, Quang Sang	A Crawford, R Berry	Geochronology and geological evolution of the northern margin of the Kontum massif, central Vietnam	Vietnamese Government
Cathy Evans	S Walters, E Manalapig	Texture-related flotation characteristics of ores	GeM^{III} Project
Lee Evans	G Davidson, D Cooke	Ground waters in wet, temperate sulfide mining districts: delineation of modern fluid flow and predictive modelling to improve management after mine closure (Rosebery, Tasmania)	Zinifex, ARC Linkage
Nathan Fox	D Cooke, A Harris	Controls on mineralisation and alteration assemblages in the Cadia East gold-copper deposit, New South Wales	Newcrest Mines Ltd
Russell Fulton	JB Gemmell, R Berry	Geology and geochemistry of the hanging wall argillite, Greens Creek VHMS deposit, Alaska: implications for ore genesis and exploration	Kennecott Greens Creek Mining
Sarah Gordee	J McPhie, S Allen	Characteristics of subaqueous pyroclastic facies in arc settings	CODES Program 1
Victor Hugo Galván Gutiérrez	D Cooke, JB Gemmell, J McPhie	Palmarejo carbonate base-metal silver-gold epithermal deposit, Chihuahua, México	IPRS, Bolnisi Gold NL
Tim Ireland	D Cooke, R Berry, JB Gemmell	Geological evolution of the Collahuasi District, Tarapaca, Chile	AMIRA P765, APA scholarship.
Ben Jones	A Crawford, R Large	Genesis of the Antapaccay Cu-Au porphyry deposit, Peru	BHP World Minerals
Maya Kamenetsky *	A Crawford, L Danyushevsky	Nature of primary melts in intracratonic settings: application of melt inclusions studies to kimberlites (Siberia)	ARC Discovery W. Paul project (A. von Humboldt Foundation)
Teera Kamvong	K Zaw, S Meffre	Geology and genesis of porphyry-skarn Cu-Au deposits at the northern Loei Fold Belt, Northeast Thailand and Laos	IPRS, ARC Linkage Project, Pan Australian Resources, SEG grant
Luke Keeney	S Walters, R Morrison	Geometallurgical study of the big Cadia copper gold skarn system	GeM project
Lyudmyla Koziy *	R Large, S Bull, D Selley	Numerical simulation of fluid flow and fluid chemistry in sedimentary basins	AMIRA P552
George Leigh	S Walters, S Gay	Wavelet analysis of texture parameters related to mineral processing	CODES GeM^{III} project
Steven Lewis *	G Davidson, R Berry	Sulfidic hydrothermal alteration in late brittle faults, Macquarie Island	Australian Antarctic Division, AusIMM , SEG
Wallace Mackay	D Selley, S Bull	Sedimentology and structure of the Curdimurka Subgroup, Willouran Range, South Australia	AMIRA/ ARC Linkage
Rodney Maier	P McGoldrick, R Large	Pyrite and base metal trace-element halos in the northern Australian Zn-Pb-Ag deposits	ARC SRC Anglo American
Claire McMahon	G Davidson	Controls on the geochemistry of hydrothermal pyrite in ore systems	ARC Linkage
Robert Josephus Moye Jr	D Cooke, J McPhie	Genesis and chemical and kinematic evolution of the late Proterozoic Ridgeway gold deposit in the Carolina Terrane of the central South Carolina piedmont, USA	CODES scholarship, Kennecott Mining Company, Kennecott Exploration Company, SEG
Heidi Pass	D Cooke, G Davidson	Chemical and mineralogical zonation patterns in alkalic mineral systems – Implications for ore genesis and mineral exploration	Imperial Metals (Mount Polley), Barrick Gold Corp (Cowal)

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CODES postgraduate students (PhD) 2006 (cont.)

Student	Supervisors	Project	Support
Carlos Jose Paulino Rosa *	J McPhie, JB Gemmell, J Relvas	Submarine volcanic successions in the Iberian Pyrite Belt, Portugal	Portuguese Science and Technology (FCT) fund, Mining and Geological Institute (IGM) of Portugal
Nicole Pollington	P McGoldrick, S Bull	Sedimentology, mineral paragenesis and geochemistry of the Konkola North copper deposit, Zambia	AMIRA/ ARC Linkage
Lee Robson	M Roach	Application of remote sensing for geological mapping in western Tasmania	MRT/ TGMS
Patrick Sack	JB Gemmell, R Berry	Characterisation of the footwall lithologies, Greens Creek VHMS deposit, Admiralty Island, southeast Alaska	Kennecott Greens Creek Mining Company, IPRS
Abhist Salam	K Zaw, S Meffre, J McPhie	Geological, paragenesis and geochronological relations of the Chatree area, Phetchabun Province, central Thailand	Kingsgate, IPRS, ARC Linkage Project
Ralph Schaa	P Fullagar, M Roach	Rapid approximate imaging of electromagnetic data acquired using distributed multichannel data acquisition systems	CODES
Blackwell Singoyi	G Davidson, K Zaw, R Large	Controls on the geochemistry of magnetite in hydrothermal fluids	MRT/ TGMS, Newcrest
Weerapan Srichan	A Crawford, R Berry	Petrochemistry, geochronology and tectonic implication of Chiang Khong-Lampang-Tak Volcanic Belts, Northern Thailand.	Royal Thai Government Scholarship
Craig Stegman	R Scott, R Large	Geochemistry and structure of gold-basemetal mineralisation in the Cobar Gold Field, NSW	Rio Tinto
Sofia Tetroeva	L Danyushevsky, A Crawford	Petrology and geochemistry of adakites and related rocks from the Hunter Ridge, Southwest Pacific	ARC, SRC
Felipe Urzua	D Cooke	Regional geology of the Escondida district, northern Chile	BHP Billiton
Adel Vatandoost	S Walters, M Roach	Automated petrophysical characterisation of drill core and potential relationships to mineral processing attributes	CODES GeM project
Wojciech Zukowski	D Cooke, A Crawford	Geology and mineralisation at Lake Cowal district NSW, Australia	Barrick Gold Ltd, Alkalic project

* thesis submitted in 2006

Outside research grants

AMIRA–ARC Linkage projects 2006

Investigators	Project	Industry Partners	Period	ARC Funding for 2006	AMIRA Funding for 2006
D Cooke, JB Gemmell, C Deyell, N White	AMIRA P765. Transitions and zoning in porphyry-epithermal districts: Indicators, discriminators, and vectors	Anglo American, AngloGold Ashanti, Goldfields, Newcrest, Newmont, Placer, Teck Cominco	2004-2006	$ 123,119	$131,760
D Selley, S Bull, M Hitzman, D Broughton, R Scott, R Large, P McGoldrick, M Roach	AMIRA P872. Sediment-hosted Cu-deposits of Congolese, Zambian & Central Australian basin systems	African Rainbow Minerals, Anvil Mining, CVRD, Equinox Minerals Limited, Anglo American, BHP Billiton, Entreprise Generale Malta Forrest, Phelps Dodge Exploration Corporation, Rio Tinto	2004-2007	$130,000	$291,666

AMIRA–ARC Centre of Excellence projects 2006

Investigators	Project	Industry Partners	Period	ARC Funding for 2006	AMIRA Funding for 2006
S Walters, R Berry, N Djordjevic, P Fullagar, S Gay, W Herrmann, J Hunt, J Huntington, M Kamenetsky, T Kojovic, G McArthur, S Michaux, R Morrison, J Reid, M Roach	AMIRA P483. GEM^{III} Geometallurgical Mapping and Mine Modelling	Newmont, Rio Tinto, Xstrata, Teck Cominco, Inco, Newcrest, Barrick,CVRD, Zinifex, BHP Billiton, AngloGold Ashanti, Anglo Platinum, Golder Associates, Geotek, Datamine	2006-2009	$500,000	$1,050,000
R Scott, R Large, W Herrmann, S Bull, L Danyushevsky, S Gilbert, V Maslennikov, P Emsbo	AMIRA P923. Controls on formation and sulfide trace-element signatures of sediment-hosted gold deposits	Barrick, Newcrest, Newmont, Perseverance, St Barbara Mines	2005-2007	$100,000	$130,000

ARC Discovery Grants 2006

Investigator	Project	Period	ARC Funding for 2006
S Allen	Discovery Grant: Submarine explosive eruptions of silicic magma: constraints on products and processes from modern sea-floor examples, ancient successions and experiments	2004-2008	$101,582
V Kamenetsky	APF and Discovery Grant: Unmixing in magmas: melt and fluid Inclusion constraints on identity, timing, and evolution of immiscible fluids, salt and sulfide melts.	2005–2009	$149,262

Major industry research grants 2006

Investigators	Project	Funding Body	Period	Industry Funding for 2006
JB Gemmell , R Berry	Geology and geochemistry of the footwall phyllite, Greens Creek VHMS deposit, Alaska: implications for ore genesis and exploration	Kennecott Greens Creek Mining Company	2004–2008	$40,262
D Cooke, JB Gemmell, J McPhie	Palmarejo carbonate base-metals silver-gold epithermal deposit, Chihuahua, México	Bolnisi Gold NL	2006–2008	$68,163
D Cooke, A Harris	District- to deposit-scale structure and geochemical study of the Cadia porphyry Au-Cu deposits	Newcrest Mining Limited	2005–2008	$115,082
A McNeill, JB Gemmell	Vectors to VHMS, Rosebery district	Zinifex	2006–2007	$40,804
K Zaw, S Meffre	Geochronology and metallogenesis of Loei Fold Belt, Thailand and Laos	Pan Australia, Kingsgate, Oxiana	2004–2007	$90,000
D Cooke, R Tosdal, C Chamberlain, K Simpson	Shallow and deep-level alkalic mineral deposits	Amark Resources Ltd, AngloGold Ashanti, Barrick Gold, Imperial Metals, Lysander, Newcrest, Newmont, Novagold, Teck Cominco, NSERC, GBC	2006-2008	$0

Institutional research collaborations with CODES 2006

International institution collaborations

Institution	Researcher	CODES collaborators	Project
Department of Mineral Resources, Thailand	S Khositanont	K Zaw, S Meffre	P1L1 Geochronology, metallogenesis and deposit styles of Loei Fold Belt in Thailand and Laos PDR
GeoForschungs Zentrum Potsdam, Germany	R Thomas	V Kamenetsky, P Davidson, M Kamenetsky	P1F3 Felsic magmas: volatile and metal budgets during magma evolution – a combined melt inclusion and volcanological approach
Geological Survey of Canada	J Peter W Goodfellow	JB Gemmell	P2F3 Volcanic-hosted massive sulfide deposits
Geological Survey of Canada	K Simpson	D Cooke, C Deyell	P2L3 Shallow and deep-level alkalic mineral deposits
Guangzhou Institute of Geochemistry, China	W Sun	V Kamenetsky	P1F3 Felsic magmas: volatile and metal budgets during magma evolution – a combined melt inclusion and volcanological approach
Hefei University, China	Taofa Zhou	D Cooke, Z Chang	P2N3 Polymetallic mineralisation and associated magmatic and volcanic activity in the Luzong basin, middle and lower Yangtze River, eastern China P3 L2 Transitions and zoning in porphyry-epithermal districts
Imperial College (UK)	A Berry	A Harris, D Cooke, V Kamenetsky	P5F3 Developmental research into the use of synchrotron in ore deposit studies
Indian School of Mines	D Asthana	A Crawford, A McNeill, P Davidson, S Meffre, R Berry	P1F1 Geodynamic controls on the fertility of fold belts and cratons
Institute of Earth Sciences-Academia Sinica, Taipei, Taiwan	G Zellmer	V Kamenetsky, M Kamenetsky	P1F3 Felsic magmas: volatile and metal budgets during magma evolution – a combined melt inclusion and volcanological approach
Institute of Experimental Mineralogy , Moscow	E Konnikov	L Danyushevsky, A Crawford, V Kamenetsky, A McNeill	P1F4 Ni-PGE potential of mafic and ultramafic magmas – a combined melt inclusion and numerical modelling approach
Institute of Geochemistry and State Key Laboratory of Ore Deposit Geochemistry, Chinese Academy of Sciences, Guiyang, China	XY Song	L Danyushevsky, V Kamenetsky A Crawford	P1F1 Geodynamic controls on the fertility of fold belts and cratons
Institute of Geological and Nuclear Sciences, NZ	C de Ronde	V Kamenetsky	P1F3 Felsic magmas: volatile and metal budgets during magma evolution – a combined melt inclusion and volcanological approach
Institute of Geological and Nuclear Sciences, NZ	K Faure	A Harris, D Cooke, R Berry, J McPhie	P2L1 District- to deposit-scale structural and geochemical study of the Cadia porphyry Au-Cu deposits
Institute of Geology and Mineralogy, Novosibirsk, Russia	S Smirnov	•V Kamenetsky, M Kamenetsky •V Kamenetsky, R Large	P1F3 Felsic magmas: volatile and metal budgets during magma evolution – a combined melt inclusion and volcanological approach P2N1 Phase and chemical composition of high-temperature hydrothermal systems undergoing interaction between silicate rocks/magmas and aqueous fluid
Institute of Geology and Mineralogy, Novosibirsk, Russia	V Thomas,	V Kamenetsky, R Large	P2N1 Phase and chemical composition of high-temperature hydrothermal systems undergoing interaction between silicate rocks/magmas and aqueous fluid
Kingston University, UK	S Bryan	A Harris	Volcanology
National Isotope Centre, GNS Science, NZ	K Faure	A Harris	Stable isotopes

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Institutional research collaborations with CODES (international) 2006 (cont.)

Institution	Researcher	CODES collaborators	Project
National Taiwan University, Taipei	SL Chung	V Kamenetsky	P1F4 Ni-PGE potential of mafic and ultramafic magmas – a combined melt inclusion and numerical modelling approach
Queens University, Canada	D Layton-Matthews	JB Gemmell, R Large	P2F3 Volcanic-hosted massive sulfide deposits
Russian Academy of Science	V Maslennikov	•R Large, R Scott, S Bull, W Herrmann, L Danyushevsky, S Gilbert, S Meffre, Z Chang •R Large, R Scott, S Meffre, Z Chang	P2L2 Controls on the formation and sulfide trace-element signatures of sediment-hosted gold deposits P2L4 Genesis of the giant Sukhoi Log gold deposit, Siberia
United States Geological Survey	P Emsbo	•S Bull, P McGoldrick •R Large, R Scott, S Bull, W Herrmann, L Danyushevsky, S Gilbert, S Meffre, Z Chang •D Selley, S Bull, R Scott, M Duffett, P McGoldrick, M Hitzman*	P1F5 Global ocean chemistry, marine basins and mineralisation P2L2 Controls on the formation and sulfide trace-element signatures of sediment-hosted gold deposits P3L3 Origin and setting of Congolese-type copper deposits
University of Arizona, USA	P Rieners	A Harris	Geochronology and thermochronology
University of California, USA	T Lyons	S Bull, P McGoldrick	P1F5 Global ocean chemistry, marine basins and mineralisation
University of Hong Kong	MF Zhou	A Crawford, A McNeill, J McPhie, P Davidson, S Meffre, R Berry	P1F1 Geodynamic controls on the fertility of fold belts and cratons
University of Huelva	R Saez, M Toscano	JB Gemmell, M Solomon, R Large, K Zaw, A Harris	P2F3 Volcanic-hosted massive sulfide deposits
University of Lisbon, Portugal	J Relvas	A Crawford, R Berry, P Davidson, A McNeill, J McPhie, S Meffre	P1F1 Geodynamic controls on the fertility of fold belts and cratons
University of Lubumbashi/ Gécamines, Zambia	S Sebagenzi	D Selley, S Bull, R Scott, M Duffett, P McGoldrick, M Hitzman*	P3L3 Origin and setting of Congolese-type copper deposits
University of Naples Federico II, Napoli, Italy	B De Vivo	V Kamenetsky, M Kamenetsky	P1F3 Felsic magmas: volatile and metal budgets during magma evolution – a combined melt inclusion and volcanological approach
University of Ottawa, Canada	M Hannington	JB Gemmell, M Solomon, R Large, K Zaw, A Harris	P2F3 Volcanic-hosted massive sulfide deposits
Vernadsky Institute, Moscow	A Ariskin	•A Crawford, A McNeill •A Crawford, L Danyushevsky, V Kamenetsky, A McNeill	P1F1 Geodynamic controls on the fertility of fold belts and cratons P1F4 Ni-PGE potential of mafic and ultramafic magmas – a combined melt inclusion and numerical modelling approach
Vernadsky Institute, Moscow	V Naumov	V Kamenetsky, P Davidson	P1F3 Felsic magmas: volatile and metal budgets during magma evolution – a combined melt inclusion and volcanological approach

National institution collaborations

Australian National University	R Arculus	V Kamenetsky	P1F3 Felsic magmas: volatile and metal budgets during magma evolution – a combined melt inclusion and volcanological approach
Australian National University	M Shelley	L Danyushevsky, V Kamenetsky, P McGoldrick, P Robinson, S Gilbert	P5F1 Developments in LA-ICPMS of sulphides, fluid inclusions and carbonates.
Australian National University	I Campbell, C Allen	A Harris, D Cooke. R Berry, J McPhie, R Tosdal*	P2L1 District-to-deposit-scale structural and geochemical study of the Cadia porphyry Au-Cu deposits
Australian National University	J Dunlap	A Harris	Geochronology and thermochronology
Consulting Economic Geologist	N White	Z Chang, D Cooke, JB Gemmell	P2N2 Zn and Au mineralisation in the Caijiaying deposit: geologic characteristics and genesis

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Institution	Researcher	CODES collaborators	Project
CSA Australia Pty Ltd	R Crowe, W Woodhouse, N Wilson, G Whalan	Z Chang, D Cooke, JB Gemmell	P2N2 Zn and Au mineralisation in the Caijiaying deposit: geologic characteristics and genesis
CSIRO Exploration & Mining	A Raiche G Wilson	J Reid	P3F2 Improved Electromagnetic methods for mineral exploration
CSIRO Exploration & Mining	M Quigley J Huntington	S Walters, R Berry, W Hermann, J Reid, M Roach, J Hunt, M Kamenetsky	P4L1 Geometallurgical mapping and mine modelling (GeM^{III})
Frogtech	N Direen	A Crawford, A McNeill, J McPhie, P Davidson, S Meffre, R Berry	P1F1 Geodynamic controls on the fertility of fold belts and cratons
Geological Survey of NSW	B Stevens D Glen	A Crawford	P1F1 Geodynamic controls on the fertility of fold belts and cratons
Geological Survey of Qld	I Withnall	A Crawford, R Berry	P1F1 Geodynamic controls on the fertility of fold belts and cratons
Geoscience Australia	T Mernagh	•V Kamenetsky , P Davidson •M Solomon, K Zaw, A Harris	P1F3 Felsic magmas: volatile and metal budgets during magma evolution – a combined melt inclusion and volcanological approach P2F3 Volcanic-hosted massive sulfide deposits
Jabiru Metals	N Martin	G Davidson, J McPhie	P1F1 Geodynamic controls on the fertility of fold belts and cratons
James Cook University	R Mustard	V Kamenetsky	P1F3 Felsic magmas: volatile and metal budgets during magma evolution – a combined melt inclusion and volcanological approach
McArthur Ore Deposit Assessments Pty	G McArthur	S Walters, R Berry, W Hermann, J Reid, M Roach, J Hunt, M Kamenetsky	P4L1 Geometallurgical mapping and mine modelling (GeM^{III})
Monash University	R Keays	A Crawford	P1F1 Geodynamic controls on the fertility of fold belts and cratons
Perilya Ltd	M Manly J Penhall	A Crawford	P1F1 Geodynamic controls on the fertility of fold belts and cratons
Primary Industries NSW	Ian Percival	A Harris, D Cooke. R Berry, J McPhie, R Tosdal*	P2L1 District- to deposit-scale structural and geochemical study of the Cadia porphyry Au-Cu deposits
University of Queensland, Dept of Earth Sciences	S Golding	K Zaw, S Meffre	P1L1 Geochronology, metallogenesis and deposit styles of Loei Fold Belt in Thailand and Laos PDR
University of Queensland, Earth Sciences	S Golding	A Harris	Stable isotopes
University of Western Australia	S Haggeman	G Davidson, D Cooke, C Deyell, K Harris, K McGoldrick	P5F8 Cracking the sulfate isotopic composition problem in ancient hydrothermal systems: application of the carbonate-associated sulfate (CAS) method

* Partner research organisation team member

Visitors to CODES 2006

International academic and government visitors

Grant Garven	Johns Hopkins University, USA	P2.F2 collaboration with Ross Large and Stuart Bull	July
Somboon Khositanont	Department of Mineral Resources Thailand	P1L1 Geochronology, Metallogenesis and Deposit Styles of Loei Foldbelt in Thailand and Laos PDR	Jan
Daniel Leyton-Matthews	Geological Survey of Canada	P2.F3 collaboration with Bruce Gemmell	Jan–May
Valery Masslenikov	Institute of Mineralogy, Russia	P2.L4 collaboration with Ross Large and Leonid Danyushevsky	Jan–Dec
Svetlana Masslenikova	Institute of Mineralogy, Russia	P2.L4 collaboration with Ross Large and Leonid Danyushevsky	Jan–Dec
Victor Sharygin	Russian Academy of Science Siberian Branch	Ross Large	Nov
Kirstie Simpson	Geological Survey of Canada	P2.L3 collaboration with David Cooke	Nov–Dec
Sergey Smirnov	Russian Academy of Science Siberian Branch	Ross Large	Nov
Xie-Yan Song	Chinese Academy of Sciences	P1.F1 Geodynamic controls on the fertility of fold belts and cratons	Dec
Georg Zellmer	Academia Sinica	Meeting with V Kamenetsky	Sept
Taofa Zhou	Hefei University of Tech, China	Postdoctoral Research Fellow – D Cooke	Feb

National academic and government visitors

Ben Adair	JKMRC	Science Planning Panel Advisory Board Meeting AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	July Feb Aug
Chris Alford	WH Bryan Centre	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Feb Aug
Kate Bailue	Latrobe University	MCA student, work with D Cooke	Sept
David Belton	CSIRO	Science Planning Panel, CODES CoE opening	Feb
Emma Briggs	Australian National University	MCA student, work with D Cooke	Sept
Mary Burton	ARC	UTAS and CoE familiarisation visit	Mar
Helen Byrne	Australian National University	MCA Student, work with D Cooke	Sept
Graham Carr	CSIRO	Science Planning Panel, Advisory Board Meeting, CODES CoE opening Meeting with R Large	July Dec
Nenad Djordjevic	JKMRC	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Feb, Aug
Cathy Evans	JKMRC	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Feb, Aug
Stephen Gay	JKMRC	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Aug
Sarah Hagerty	Latrobe University	MCA Student, work with D Cooke	Sept
Alex Hickey	Australian National University	MCA Student, work with D Cooke	Sept
Peter Høj	ARC	UTAS and CoE familiarisation visit	Mar
Sharon Hull	Monash University	MCA Student, work with D Cooke	Sept
Jon Huntington	CSIRO	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Aug
Reid Keays	Monash University	GSA Talk P1F1 Meeting	April Oct
Luke Keeney	JKMRC	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Aug
Penny Knox	ARC	UTAS and CoE familiarisation visit	Mar

Toni Kojovic	JKMRC	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Feb, Aug
Gabrielle Lafes	Australian National University – CRCLEME	MCA student, work with D Cooke	Sept
George Leigh	JKMRC	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Feb, Aug
Weihua Liu	CSIRO	Meeting with L Danyushevsky	Oct
Helen Lynch	Monash University	MCA Student, work with D Cooke	Sept
Simon Michaux	JKMRC	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Feb, Aug
Rob Morrison	JKMRC	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Feb
Khoi Nguyen	JKMRC	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Aug
Inengah Nuada	University of Melbourne	MCA student, work with D Cooke	Sept
Ryan Owens	Australian National University	MCA student, work with D Cooke	Sept
Anya Reading	Australian National University	Meeting with R Large	Sept
Rick Squire	Monash University	D Selley, P McGoldrick	Oct
Mandy Thomas	ARC	UTAS and CoE familiarisation visit	Mar
Rebecca Turnbull	Monash University	MCA student, work with D Cooke	Sept
John Walshe	CSIRO	Meeting with D Cooke	Sept
Erich Weigold	ARC	UTAS and CoE familiarisation visit	Mar
Marcia Zucchetti	University of Western Australia	PhD student	Feb

Industry visitors

Paul Agnew	Rio Tinto	Science Planning Panel, CODES CoE opening	July
Nilce Alves	CVRD	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Aug
Andrew Bailey	BHP Billiton	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Aug
Virgilio Baratang	Anglo American Phillipines	Meeting with D Cooke	Dec
Trevor Beardsmore	Barrick Gold	Science Planning panel, CODES CoE opening	July
Richard Brescianini	NTGS	Presentation on NTGS activities	Aug
Anthony Brown	Mineral Resources Tasmania	Science Planning Panel, Advisory Board Meeting, CODES CoE opening	July
Rob Burns	Rio Tinto	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Aug
Jennifer Catoc	Anglo American Phillipines	Meeting with D Cooke	Dec
Belinda Coates	AMIRA International	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Aug
Lynda Daley	Newmont Mining	AMIRA P765 Transitions and Zoning in Porphyry-Epithermal Districts AMIRA P923 Sediment-hosted gold meeting	Feb July, Dec
John Dow	Dowgold Consultants	Science Planning Panel, Advisory Board Meeting, CODES CoE opening	July
Scott Dunham	Newcrest	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Feb, Aug
Robert Dunne	Newmont	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Feb, Aug
Christine Edgoose	NTGS	Presentation on NTGS activities	Aug
Trevor Ellice	Zinifex	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Feb, Aug
Steve Ellis	Barrick Gold	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Feb, Aug

cont. over

Visitors to CODES 2006 (cont.)

John Elliston	Elliston & Associates	Meeting with V Kamenetsky and RLarge	Oct
Dean Fredericksen	Newcrest	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Feb, Aug
Kevin Gleeson	Newmont	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Feb, Aug
Alan Goode	AMIRA International	Science Planning Panel, Advisory Board Meeting, CODES CoE opening AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting AMIRA P765 Transitions and Zoning in Porphyry-Epithermal Districts	July Feb , Aug Feb
David Green	Mineral Resources Tasmania	Science Planning Panel, CODES CoE opening	July
Geoff Green	Minerals Resources Tasmania	Science Planning Panel, CODES CoE opening	July
Wang Hai-zhou	Jinchuan Group Ltd	Collaboration discussions	Dec
John Hammond	Newmont Mining	Science Planning Panel, Advisory Board Meeting, CODES CoE opening P923 Sediment-hosted gold meeting	July July
Andrew Harris	Newcrest Mining	AMIRA P765 Transitions and Zoning in Porphyry-Epithermal Districts	Feb
Nick Hawkes	Rio Tinto	AMIRA P872 Meeting	Jan
John Holliday	Newcrest Mining	Science Planning Panel, Advisory Board Meeting, CODES CoE opening	July
Terry Hoschke	Newmont Mining	AMIRA P765 Transitions and Zoning in Porphyry-Epithermal Districts	Feb
Rachael Jensen	AMIRA International	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting AMIRA P765 Transitions and Zoning in Porphyry-Epithermal Districts	Feb Feb
Zhang Jiaming	Jinchuan Group Ltd	Collaboration discussions	Dec
Keith Kenny	AngloGold Ashanti	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Feb
Tracey Kerr	Rio Doce Australia	AMIRA P872 Meeting	Jan
Sasa Krstic	Inco	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Feb, Aug
Billy Lamb	Rio Tinto	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Aug
John Larson	Zinifex	Science Planning Panel, Advisory Board Meeting, CODES CoE opening	July
Dewetia Latti	Rio Tinto	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Aug
Greg Lear	Lear Geoconsulting	Research discussions	Sept
Foy Leckie	Newcrest Mining	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Feb, Aug
Jonathon Lew	Rio Tinto	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Feb
Ian Lipton	Golder Associates	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Aug
Joshua Mazhakata	Newcrest Mining	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Feb
Nichola McKay	Teck Cominco	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Aug
Gem Midgley	Placer Dome (Barrick)	AMIRA P765 Transitions and Zoning in Porphyry-Epithermal Districts	Feb
Marian Moroney	Barrick Gold	P923 Sediment-hosted gold meeting	July
Robert Musgrave	NSW Geological Survey	Meeting with R Large	Sept
Alistair Nicholas	Creekco Mining	Research discussions	Sept
Neil Norris	Perseverance Corporation Limited	P923 Sediment-hosted gold meeting	Feb, July, Dec
Michael Nugus	AngloGold Ashanti (Boddington)	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Feb, Aug
Annette Pal	Rio Tinto	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Aug
Dwayne Povey	Ernest Henry Mining Pty Ltd	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Aug

Mike Richards	Equinox Minerals	AMIRA P872 Meeting	Jan
Andrew Richmond	Golder Associates	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Aug
Steve Riley	Ernest Henry Mines/Xstrata	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Feb, Aug
Esm'e Ryan	Rio Tinto	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Feb
Ian Sandl	Teck Cominco	Science Planning Panel, CODES CoE opening	July
Peter Schulthesis	GEOTEK	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Feb
Donna Sewell	AngloGold Ashanti	AMIRA P765 Transitions and Zoning in Porphyry-Epithermal Districts Science Planning Panel , CODES CoE opening	Feb July
Ma Shuping	Jinchuan Group Ltd	Collaboration discussions	Dec
Kirstie Simpson	Geo Survey Canada	Meeting with D Cooke	Nov/ Dec
Ian Scrimgeour	NTGS	Meeting with M Duffett	Aug
Xie Yan Song	Chinese Academy of Sciences	Collaborative research	Oct-Dec
Peter Sorjonen-Ward	Finnish Geological Survey	Presenting a seminar/workshop on Finnish metallogeny. Future research collaboration discussions	Dec
Michael Taylor	Teck Cominco	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting AMIRA P765 Transitions and Zoning in Porphyry-Epithermal Districts	Feb Feb
Edison Tazava	CVRD	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Feb
Ian Tedder	Newcrest Mining	AMIRA P765 Transitions and Zoning in Porphyry-Epithermal Districts P923 Sediment-hosted gold meeting	Feb July
Andrew Tew	Ernest Henry Mines/ Xstrata	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Feb
John Thompson	Teck Cominco	Science Planning Panel	July
Peter Thompson	St Barbara Ltd	Science Planning Panel P923 Sediment-hosted gold meeting	July
Kevin Tuckwell	Minerals Council of Australia	Science Planning Panel CODES CoE opening	July
Paddy Waters	Anglo American	AMIRA P765 Transitions and Zoning in Porphyry-Epithermal Districts	Feb
Aaron Wehrle	Gold Fields	AMIRA P765 Transitions and Zoning in Porphyry-Epithermal Districts	Feb
Noel White	Consulting economic geologist	Science Planning Panel, Advisory Board Meeting, CODES CoE opening	July
Ian Willis	Anglo American	Science Planning Panel, Advisory Board Meeting, CODES CoE opening	July
Alan Wilson	Anglo American	AMIRA P872 Meeting AMIRA P765 Transitions and Zoning in Porphyry-Epithermal Districts	Jan Feb
Dan Wood	Newcrest Mining	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Aug
Bao Xingwang	Jinchuan Group Ltd	Collaboration discussions	Dec
Gavin Yeates	BHP Billiton	AMIRA P843 Geometallurgical Mapping and Mine Modelling meeting	Feb
Zhang Yimin	Jinchuan Group Ltd Australia	Collaboration discussions	Dec
Li Yong-jun	Jinchuan Group Ltd	Collaboration discussions	Dec
Jiang Yongsheng	Jinchuan Group Ltd	Collaboration discussions	Dec
Liu Zhiliang	Jingshuan Group Ltd	Collaboration discussions	Dec

ACTIVITY PLAN 2007

Project	Team Leader(s)	Activity Plan
PROGRAM 1		
P1.F1	A Crawford	• Undertake fieldwork for Potosi, Indian palaeoproterozoic rocks, Mount Isa Eastern Succession and Sullivan projects and collect and interpret analytical data for Henty Fault Wedge and remaining Sterling Valley Volcanics project • Collect monazite CHIME via RFB data to constrain metamorphic story • Undertake fieldwork in, and linkage building with, Vietnam for geological evolution of southeast Asian terranes project • Commence 'Compositional variations and sulfur distribution in mafic sills' project using two Tasmanian Jurassic dolerites as test cases • Publish 13 papers in the March/April 2007 Thematic Issue of *Australian Journal of Earth Sciences*
P1.F2	L Danyushevsky A Crawford	• Assess variations in arc magmas on the Hunter Ridge and compare volatile and chalcophile element contents in lavas erupted at backarc basin spreading centres spatially and temporally associated with diverse arc magmatism • Complete initial sample analysis of rocks collected during SS08/2006 (thin sections, wholerock XRF), solution ICPMS, isotope MC-ICPMS analyses, electron microprobe analysis of mineral and volcanic glass compositions (major elements, chlorine, sulfur), FTIR analysis for water contents of volcanic glasses and LA-ICPMS of glasses • Begin melt inclusion studies of olivines from samples collected during SS10/2004 • Submit a paper for publication in *Chemical Geology*
P1.F3	J McPhie V Kamenetsky	• Research the colloidal nature of immiscible fluids/melts in felsic magmas and quantify silica present in fluid inclusions • Determine phase and chemical composition of high-temperature hydrothermal systems undergoing interaction between silicate rocks/magmas and aqueous fluid • Undertake melt inclusion study of primary aqueous fluids in rhyolitic magmas, including criteria for pre- and post-trapping exsolution • Determine effects of assimilation on the composition of primary MORB melts and coexistence of diverse silicate melts and research factors controlling the explosivity of volcanic eruptions • Submit research to peer-reviewed international journals • Negotiate project with BHP Billiton on Olympic Dam research
P1.F4	L Danyushevsky A McNeill V Kamenetsky A. Crawford	• Identify and analyse sulfide inclusions in phenocrysts from ten volcanic suites, focusing on mid-ocean ridge and intra-plate settings • Complete first field season on the Dovyren complex focusing on the Inyaptuk volcanics • Undertake bulk chemical analysis of collected samples and sample preparation for mineralogical and melt inclusion studies • Model FeS solubility in mafic/ultramafic systems as a function of P-T-fO_2 • Model the R factor and test software for optimisation of the new S-saturation model
P1.F5	P McGoldrick	• Complete Mount Isa Western Succession CAS work at Paradise Creek Formation, Lady Loretta Formation and Riversleigh Siltstone • Complete Century (sulfide) sulfur isotope study • Obtain additional samples from the Teena/Barney/Reward interval of the River Sequence, southern McArthur Basins • Prepare manuscripts on Century, Bluebush and siderophile Proterozoic oceans

P1.L1	K Zaw S Meffre	• Submit paper to *Geology* or *Terra Nova* on the Loei ARC Linkage Project: Geochronology, metallogenesis and deposit styles of the Loei Fold Belt in Thailand and Laos PDR • Embark on new project 'Tectonism, magmatism and mineralisation along the Phanerozoic plate boundaries in southeast Asia' as below • Undertake U-Pb zircon geochronological studies of the volcanic and magmatic rocks and sediments along the Chiang Mai-Chang Rai and Sukothai Fold Belts at the western margin of the Shan-Thai terrane and Troungson Fold Belt at the northern margin of Indochina Terrane • Unravel the pre-accretion geotectonic configuration of the mainland southeast Asia and develop a concise geotectonic history of Shan-Thai terranes • Develop a geotectonic and metallogenic model for the terrane evolution in relation to the origin of mineralised belts in mainland southeast Asia
PROGRAM 2		
P2.F1	S Cox D Cooke	• Recruit postdoctoral fellow for three-year project to focus on field studies of one or two of several well-documented intrusive-related systems in South America, North America, PNG and Australia • Recruit PhD student for fluid inclusion and isotopic research program • Solicit funding from industry • Gain permission for access to suitable mine sites for research • Initiate research program
P2.F3	B Gemmell M Solomon	• PIXE and Raman analyses of fluid inclusions from Hellyer and Aznacollar • Completion of mineralogical, textural and isotopic studies of the Lombador and Neves Norte orebodies, Neves Corvo mine and publication of results • Complete Que River Shale publications • Initiate new AMIRA project entitled 'Hydrothermal event recognition and target vectoring in sedimentary strata for volcanic-hosted and SEDEX massive sulfide deposits' • Undertake oceanographic cruise to investigate the Palinuro Seamount in the southeastern Tyrrhenian Sea, Mediterranean Ocean
P2.L1	A Harris D Cooke R Berry	• Liezl Cuison to complete third field season of underground mapping and core logging at Ridgeway, and to initiate geochemical research program; and Nathan Fox to complete first two field seasons at Cadia East, and to initiate petrographic and geochemical studies • Will Reynolds to undertake an Honours research project investigating the characteristics of peripheral alteration zones at Ridgeway • Malissa Washburn to continue mapping the Silurian cover sequence at Cadia Hill • Anthony Harris to undertake applied research on the district-scale architecture of the rocks hosting the Ridgeway, Cadia East and Cadia Hill, improve understanding of the geologic framework of porphyry-ore deposits via integrated field-based observations with geochronologic and geochemical studies, and to present selected results at the SGA conference (Dublin) and the 'Ores and Orogenesis' conference (Arizona) • Report research outcomes to industry sponsors
P2.L2	R Large R Scott	• Complete trace-element, Pb and S- isotopic characterisation of pyrite in the Northern Carlin Trend • Undertake analysis of pyrite from more distal drillholes through the prospective stratigraphy (or temporal/lateral equivalents) on the North Carlin trend • Collect samples in regional Central Victoria to better characterise background levels of gold in the Ordovician host rocks, and underlying Cambrian mafic volcanic and sedimentary rocks • Undertake S-isotopic analysis of pyrite from Sukhoi Log, Central Victoria and the North Carlin trend to improve constraints on fluid sources, pyrite paragenesis and conditions of formation in these areas • SynthesiSe data and present final report to industry sponsors

Activity Plans (cont.)

P2.L3	D Tosdal D Cooke C Chamberlain K Simpson	• Continue petrographic, geochemical and geological studies of Galore Creek, Mount Milligan, Mount Polley and Lorraine • Conduct field season at Lihir and undertake mapping in the Lienetz pit • Initiate detailed geochemical studies of the E41 gold deposit (Cowal) and continue structural analysis of the E42 gold deposit (Cowal) • Present student research results at Roundup (Vancouver), SGA (Dublin) and 'Ores and Orogenesis' (Arizona) • Report results of year 2 research activities at a sponsors' field meeting in Kamloops, British Columbia (October 2007)
P2.L4	R Large V Maslennikov	• Complete monazite dating and lead isotopes on pyrite • Commence conventional and laser S-isotope study of pyrite generations • Present at Structural and SGA Conferences • Publish research outcomes in *Mineralium Deposita*, *Geochemica et Cosmochimica* and others as appropriate
P2.N2	Z Chang N White	• Commence dating the intrusions and alteration/mineralisation • Commence isotopic geochemistry study (O, C, S, Pb) • Investigate the geochemistry halos • Submit a manuscript to *Economic Geology* or *Mineralium Deposita*
P2.N3	T Zhou	• Complete zircon dating work and construct a time framework of magmatic activity (both volcanic and intrusive) • Undertake field investigations of major mineral deposits in the basin (porphyry, massive sulphide polymetallic and HS deposits) • Elucidate mineralisation styles through geochemical study of the magmatic rocks and major ore deposits, including mineral chemistry, stable isotopes and fluid inclusion • Develop and refine a model for mineralisation in the Luzong basin • Attend one international meeting, submit annual and final project reports and two papers to international journals and 2-3 papers to top Chinese journals
PROGRAM 3		
P3.F1	M Roach	• Pursue the approach to petrophysical volume classification developed in 2005-2006 and concentrate on methods for effective incorporation of geological and petrophysical constraints into inverse models • Test the application of software packages such as Geomodeller and VPmg which employ different inversion methodologies to the UBC software in use currently (to be conducted in parallel with work on the western Tasmanian geophysical inversion project - P3.L4) • Develop projects with synergies to the AMIRA P843 GeM^{III} project • Appoint a research fellow and PhD students to work in this program
P3.L1	P Fullagar M Roach	• Develop approximate 3D inversion method for TEM data, based on magnetic moments • Test and refine technique in the Gocad 3D geological modelling environment • Present abstract on approximate 3D modelling for TEM data based on magnetic moments at ASEG meeting in Perth (November 2007)
P3.L2	D Cooke JB Gemmell Z Chang N White J Hedenquist P Hollings	• Present results of final sponsors' meeting to South American sponsors in Santiago (March) • Write project extension proposal and distribute to sponsors • Contingent on sponsor support, submit ARC Linkage grant application • Commence research on P765A once industry funding is committed • Prepare manuscripts from P765 for inclusion in special publication of *Economic Geology*
P3.L3	D Selley S Bull M Hitzman	• Undertake fieldwork at Kamoto, Dikulwe, KOV, Dikulwe, Tenke, Luputo, and Ruashi for April-May and September field seasons • Commence pilot project for chlorine-bromine, lead-isotope and sulphide trace-element studies prior to the April field season, undertake preliminary 2D basin modelling and design a new geophysical field program for April and May 2007, and undertake pilot petrophysical study during this field period, which, if successful, will be expanded during the September field season • Expand Kolwezi structural mapping program to include the Dikulwe and Mutoshi deposits and digitise the remainder of the Gécamines 1:20,000 geological mapping dataset • Host Dr Stanislas Sebagenzi to CODES for three weeks in January/February 2007, to work with Mark Duffett on regional gravity and aeromagnetics datasets • Prepare petrographic and geochemical data for laboratory work during second half of 2007 and report results to industry sponsors
P3.L4	M Roach	• Evaluate alternative geophysical inversion methods through generation of constrained 3D petrophysical/geological models of a study area between Zeehan and Rosebery in western Tasmania • Report to industry sponsors December 2007

P3.L7	A McNeill B Gemmell	• Attract one or two Honours students • Complete fieldwork relating to shale component of project in first six months of year • Commence fieldwork for carbonate component of project in second six months of year • Interim report to sponsors March 2007 and final report to sponsors November 2007
PROGRAM 4		
P4.L1	S Walters	• Complete Phase 1 automated core logging and create geometallurgical matrices for Ernest Henry and Boddington • Sample core for textural analysis, comminution testing and recovery testing and complete method development for textural analysis and new software • Finalise new suite of tools for small-scale comminution testing • Model new processing performance indicators • Host two major AMIRA industry sponsor meetings (February and August 2007), present research papers at three major international conferences and deliver technical reports on site-based outcomes to Ernest Henry (Xstrata) and Cadia East (Newcrest)
PROGRAM 5		
P5.F1	L Danyushevsky V Kamenetsky P McGoldrick	• Complete development of a PGE and mercury standard for analysis of sulfides • Continue development work on fluid inclusions, particularly quantifying the amount of silica in different types of fluid inclusions • Complete development of a secondary carbonate standard • Two papers will be submitted for publication in international peer-reviewed journals
P5.F2	J Hergt J Woodhead S Meffre	• Dr Jon Woodhead will step down from his role as one of the team leaders • Appoint new postdoctoral position to conduct CODES research using the MC-ICPMS facility at the University of Melbourne • Submit in situ pyrite analysis paper to peer-reviewed journal
P5.F3	A Harris	• Undertake in situ high-temperature (over 400°C) spectroscopy experiments using both treated (hydrogen-infused) and untreated fluid inclusions (on beam-line 13 GSE-CAR Advance Photon Source, Chicago) • Undertake collaborative synchrotron research between CODES, Imperial College and CSIRO (e.g. high-pressure and temperature spectroscopy of synthetic fluids versus analysis of natural fluid inclusions) • Research outcomes will be presented at the 2007 Goldschmidt Conference
P5.F4	D Belton A Harris C Ryan	• Continue development of integrated coordinate systems for nuclear microprobe, LA-ICPMS and SEM/EMPA and cross calibration of standards • Develop PIGE technology and focus on calibration of fluorine and sodium standards for quantitative application in fluid inclusion analysis • Develop analytical methods and numerical algorithms for treatment of uranium, thorium and lead results in the determination of age and error images for selected uranium/thorium-rich minerals • Evaluate minimum-penetration, low energy proton beam techniques in the detection and mapping of light elements such as lithium, boron, fluorine, sodium and phosphorus • Produce research reports where applicable for stakeholders
P5.F6	S Meffre	• Undertake development on lead and uranium systematics of galena and sulfur isotopes on the LA-ICPMS • Design a new ablation chamber for the 193 nm laser • Increase the analytical capabilities of CODES • Submit a methods based paper for U-Pb Laser ablation ICPMS zircon geochronology, comparing 213 nm with 193 nm lasers
P5.F8	G Davidson D Cooke C Deyell	• Undertake CAS separations and isotopic analysis of Heidi Pass's Mount Polley samples and develop a more robust CAS technique modification that deals with monosulphide minerals • Undertake fieldwork at Yellowstone National Park (e.g. Mammoth) to test the assertion that little fractionation occurs during the carbonate precipitation process • Continue microprobe analysis and element mapping of the carbonates that are also subjected to the isotopic technique • Embark on a new direction, to assess the hypothesis of sedimentary sulfate release from limestones during metamorphism, which could contribute to the sulfur content of ore-forming solutions • Submit results to *Chemical Geology* and present at Goldschmidt conference