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

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

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

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DIRECTOR’S REPORT

In my 2014 Director’s Report, I described how our first year since the cessation of ARC Centre of Excellence funding had been one of the most successful in our history. However, the key question with any success is always ‘can it be sustained?’. Although there were a number of reasons to be optimistic about 2015, there were also significant challenges that had the potential to make things go awry. While some of these challenges still remain, I am pleased to report that we came through our second year under the new funding scenarios and research models exceedingly well.

SEG-CODES 2015 CONFERENCE

Undoubtedly, one of the high points of the year was the Society of Economic Geologists (SEG) 2015 Conference held at Wrest Point. Despite the downturn in the minerals industry, 742 delegates from 43 countries converged on Hobart at the end of September for an event that has since been described by the SEG as ‘an unqualified success’. This statement was supported by extensive post-conference surveys, all of which revealed high satisfaction ratings. This was the first time that this major conference had been held in Tasmania, and also the first time that the SEG had partnered with a university-based research group to co-host the event. It was a once-in-a-lifetime opportunity for CODES to showcase the breadth of its research to the world, and our people certainly stepped up to the plate, providing 16 presenters, one panellist, six session chairs, 52 poster presentations, as well as leading two short courses and three field trips – to Indonesia, western Tasmania, and New South Wales. I was also very honoured to be asked to fill the role of Conference Chair.

By any criterion, this was a highly successful event and I wish to thank everyone at CODES for the immense contribution they made to this accomplishment. I also wish to thank the sponsors, the conference co-ordinators (Conference Design), the staff at Wrest Point, my colleagues on the organising committee, the delegates, and all the external speakers and course leaders. Lastly, a special thank you to Brian Hoal and his team at the SEG, not just for the essential part they played in this event, but also for their ongoing support for CODES, exemplified by appointing us as joint hosts.

THE TMVC

Another significant event was the start of the ARC Industrial Transformation Research Hub, Transforming the Mining Value Chain (TMVC). The research hub was officially launched at a VIP function in September, and has already made significant progress, including the commencement of the AMIRA P1153 project: Applying the explorers’ toolbox to discover porphyry and epithermal deposits, with field campaigns being initiated at new study sites in Sweden, the U.S.A. and Canada.

CRC ORE ||

I am very pleased to report that the Australian Government has approved the application by CRC ORE to extend its tenure as a Co-operative Research Centre (CRC) for a further six years. As CODES was included as an Essential Research Participant in this application, this outcome ensures that the status of geometallurgy as one of the Centre’s three research Modules has been considerably strengthened. The key challenge for the CRC is to address the declining productivity in the minerals industry, and our expertise in areas such as geometallurgy, ore deposit characterisation and modelling, and postgraduate training will play an essential role in achieving this objective over its extended tenure.

RESEARCH MODULES

The Ore Deposits: Characterisation and Context Module continued its development in 2015, with 13 new or expanded research projects. This takes the total number of projects in the Module to 26, many of which had outcomes that had a direct impact on the potential discovery of new economic ore bodies. For example, the Drummond Peak Gold project has successfully identified ten new exploration targets; a study by Karl Ort, in collaboration with the Geological Survey of Western Australia, has raised the prospectivity of the Hart Dolomite for titanium, vanadium and iron across northern Western Australia’s Kimberley district; and the Power of Pyrite project has led to potential vectors to ore being developed in at least four of the case study sites. It was a relatively quiet year for the Geometallurgy Module with research being undertaken by HDR projects, but activities are expected to pick up considerably once CRC ORE I operations come into full swing in the latter part of 2016. The Enabling Technologies Module continued to play an essential role in CODES operations, underpinning so many of our research initiatives. The laboratories, which already house some of the world’s finest laser ablation analytical facilities, ensured that they will remain leaders in their field with a successful application to the University of Tasmania (UTAS) for funding to purchase and install a new generation Time-Of-Flight ICP-MS instrument. This purchase will significantly enhance CODES’ capabilities in the rapidly developing field of imaging trace element distributions in minerals using LA-ICP-MS.

The team from this Module also co-hosted a central part in AMAS XIII, the 13th biennial Australian Microbeam Analysis Symposium, which was hosted by CODES in the early part of the year. This major event in the field of microanalysis and imaging attracted 118 delegates from all around Australia, and included talks by over 50 of the world’s leading experts. The symposium was led by Module Leader Leonid Danyushevsky, and Karsten Goermann from the UTAS Central Science Laboratory.

TRAINING

It was a good year for the Training Module, with 12 new enrolments for the HDR program, up from nine in 2014. This figure included a record high of nine Australian enrolments, which bettered the previous year’s high of seven. While this increase may be in part due to people seeking to further their education in a tight jobs market, it is pleasing to see this positive trend continuing.

The Master of Economic Geology Program enjoyed another strong year, with the number of UTAS-based students active in the program equaling an all-time high of 52, complemented by a good throughput of completions and graduations. There is no doubt that our students play an integral role in the success of our research projects, and particularly in disseminating our research outputs to audiences around the world. Their contribution to raising our profile on the world stage was once again evident in 2015, when they presented 29 papers and 30 poster presentations in Australia, Canada, Chile, the Czech Republic, France and Peru. A commendable achievement.

PUBLICATIONS, INDUSTRY REPORTS AND CONFERENCE ABSTRACTS

It was a record year for publications. Refereed journal articles totalled 65, up from 55 the previous year, and not far behind the record of 69 achieved in 2013. However, when 15 chapters in books and an edited book are added to this figure, the grand total is 81, compared with 71 in 2013. It is also worth noting that many of these publications were published in journals of particular importance to applied economic geology research, including Economic Geology, Mineralium Deposita and Ore Geology Reviews. What makes this record output particularly pleasing is that it was achieved while we maintained our high output of industry reports, which totalled 84, compared to 82 the previous year.

It was also a record year for conference abstracts, which totalled 147, which exceeds the previous best of 135 achieved in 2012.

AWARDS AND ACCOLADES

One of the most significant awards of the year was the announcement of the Government’s Excellence in Research for Australia (ERA) rankings, in which UTAS Geology and Geophysics received a top mark of 5 out of 5 – referred to as ‘well above world standard’ in the ERA report. In addition, Earth and Marine Sciences at UTAS were placed in the top 100 of universities in the world in the QS World University rankings – the only areas within UTAS to get into the top 100.
These results highlight the importance of the earth sciences within the university, and how we rank as one of the world’s leaders in this field.

From the moment he started his undergraduate studies, it was evident that Jacob Mulder had the potential to be an exceptional student. He has not disappointed. He has gone on to receive numerous awards, and attained the highest marks of any UTAS Earth Sciences Honours student on record, receiving the highly prized University Medal in the same year. Jacob has continued to build on this success as a postgraduate student. His achievements in the past year include two first author papers in high ranking journals (Geology and Australian Journal of Earth Sciences), and being awarded the prestigious Endeavour Postgraduate Scholarship by the Australian Government, which will result in him spending up to two years studying at the University of New Mexico under the guidance of the highly respected Professor Karl Karlstrom, starting in 2016.

Other notable achievements include PhD candidate Angela Escolme – best student presentation at the SEG 2015 Conference; Anya Reading – Fulbright Senior Scholar; Jay Thompson – the Dean’s Award for Professional Staff; and PhD student Laura Jackson – best paper at the AusIMM Conference: Tailings and Mine Waste Management for the 21st Century.

I am also pleased to report that I completed my guest professorship at the GEOMAR Helmholtz Centre for Ocean Research in Kiel, Germany, to the Centre over the best part of three decades. I am pleased to say a big thank you to Ross, on behalf of everyone at CODES, for the immense contribution he has made to the Centre over the best part of three decades. I am pleased to say that Ross has been retained in an honorary position, so long may his input continue; albeit in a reduced capacity.

**LOOKING FORWARD**

We have every reason to feel positive about the year ahead.

The TMVC research hub will gain momentum. CRC ORE II will come on stream, with a subsequent increase in collaborative research with CODES. The analytical laboratories will be further enhanced. We will also be pursuing a host of potential opportunities, including a partnership with Laurentian University in Canada for a high value research project named Metal Earth, an Industrial Transformation Training Centre in Mine Waste Characterisation, and a geoscience initiative in conjunction with Mineral Resources Tasmania and the Tasmanian Minerals and Energy Council. In addition, discussions are underway with Universitas Gadjah Maja, Indonesia, to run a joint Master of Economic Geology degree.

2016 promises to be an exciting year.

J. Bruce Gemmell
Director and Chief Operations Officer

**STATISTICS AT A GLANCE 2015**

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<th>Academic Research Staff</th>
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**WORLDWIDE COLLABORATIONS:**

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OVERVIEW AND RESEARCH STRUCTURE

IN SUMMARY
CODES was formed in 1989, and has been the Australian Research Council (ARC) Centre of Excellence in Ore Deposits since 2005. Based at the University of Tasmania, the Centre has grown substantially over the years and is now widely regarded as a global leader in ore deposit research and postgraduate training. It is home to 51 highly qualified research staff and 129 postgraduate students, further cementing its position as the largest university-based team of ore deposit researchers in the world.

Highly productive worldwide collaborations have been developed with 47 industry companies, plus a host of joint research initiatives with 61 institutions and universities – 19 in Australia and 42 overseas. It currently has 42 major research projects spanning 35 countries, and is the leading academic group to publish in leading academic journals spanning 35 countries, and is the largest university-based team of ore deposit researchers in the world.

The Training Module provides an ongoing supply of world-class geoscience graduates, and delivers a range of professional development short courses and workshops tailored to meet the needs of the minerals industry in terms of upskilling its workforce. The schedule for upskilling courses varies in line with demand. Typical courses include Geophysics for Geologists and Engineers, and Advances in Geo-logging.

Postgraduate courses are offered at the following levels:
- HONOURS – a one-year degree that will significantly increase employment options, or can be used as a stepping-stone to a PhD. Courses are available in Economic Geology, Geophysics and Geochemistry.
- MASTER OF ECONOMIC GEOLOGY – offers a series of intensive, two-week courses aimed at the working geologist. Available in coursework only and coursework/thesis (25%) options. The degree is part of the national Minerals Geoscience Masters program.
- PhD AND MSc – these higher degree by research programs enable students to complete their theses in an environment that provides access to state-of-the-art technology, exceptional links with industry, and supervisors that are international leaders in their field.

RESEARCH FACILITIES
CODES state-of-the-art facilities cover a wide range of applications encompassing the routine multi-element analysis of sulfide and oxide minerals, including the full range of platinum group elements; U/Pb dating of zircon and monazite; and multi-element analysis of silicates. These facilities include four laser ablation ICP-MS laboratories specialising in ore deposit applications, an XRF laboratory, solution ICP-MS and clean room, fluid’ melt inclusion laboratory, a lapisry department and sample preparation facilities. In addition, portable analytical techniques are provided, including shortwave infrared (SWIR) and portable XRF.

CODES also has reciprocal arrangements with the UTAS Central Science Laboratory, which has an extensive suite of complementary equipment, particularly in the areas of electron microscopy and mineral liberation analysis (MLA), X-ray microanalysis, laser Raman and FTIR spectroscopy, and ICP-MS.

OUTCOME-DRIVEN RESEARCH AND TRAINING
CODES has developed an integrated, four module research model, which provides a step-change in exploration techniques for metal discovery, new practices for sustainable mining, a steady supply of world-class geoscience graduates, and, as well as creating a platform to meet the training and upskilling needs of the minerals industry.

THE MODULES
The Ore Deposits: Characterisation and Context Module defines the geological, geochemical and geophysical features of ore deposits and their environments, in order to develop models that aid in the discovery of mineral resources at surface and under cover.

The Geometallurgy Module transforms how explorers and miners plan and predict mining and environmental activities, by providing new tools to guide these activities from the initial discovery through to end of mine life.

The Enabling Technologies Module utilizes a suite of cutting-edge instrumentation to develop analytical and computational techniques and tools to aid researchers with big data knowledge discovery, data reduction, modelling and interpretation.

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CODES’ leading edge is based on the development of a number of unique analytical techniques and calibration standards, combined with employing staff with extensive expertise in analytical protocols and the interpretation of results.

TRANSFORMING THE MINING VALUE CHAIN
an ARC Industrial Transformation Research Hub

CODES is home to an Australian Research Council Industrial Transformation Research Hub, entitled Transforming the Mining Value Chain (TMVC). The Hub encompasses a wide array of activities from exploration, discovery, ore deposit characterisation, and environmental assessment, through to mining, ore processing and waste rock disposal. The main objective is to improve efficiencies within the value chain, creating a focus on areas that will have a marked impact on the value of mineral resources. External organisations involved in the Hub are BHP Billiton, Corescan, Laurin Technic, Newcrest Mining, NICTA, and RWTH Aachen University, plus a consortium of national and international companies co-ordinated by AMIRA International.

TMVC commenced activities in mid-2015, which are covered later in this annual report.
CENTRE DIRECTOR
Centre Director, Professor Bruce Gemmell, is responsible for the scientific leadership and operational management of the Centre. He is supported in these duties by Professor David Cooke (Deputy Director), the Advisory Board and the Executive Committee.

ARC TMVC RESEARCH HUB DIRECTOR
Professor David Cooke is Director of the ARC Research Hub for Transforming the Mining Value Chain.

ADVISORY BOARD
The Advisory Board meets once a year to review the progress of the Centre and to advise on future directions. The Board is composed of representatives from major industry partners, University of Tasmania senior management, and key national geoscience organisations. It is chaired by Dr Paul Heithersay, from the Department of Resources, Tasmania senior management, industry partners, University of Tasmania, and key national geoscience organisations. It is chaired by Dr Paul Heithersay, from the Department of Resources, Tasmania senior management, industry partners, University of Tasmania, and key national geoscience organisations.

STAFF & MANAGEMENT
SCIENCE PLANNING PANEL
The Science Planning Panel meets annually for a one-day forum of presentations relating to the Centre’s scientific research progress and to discuss potential new research projects. The membership is wider than that of the Advisory Board and includes a representative from all partner companies. The Panel is designed to provide industry with an opportunity to influence future research directions of the Centre.

EXECUTIVE STAFF
Dr Dan Gregory has attained a position at the University of California, Riverside. Dr Jacqueline Halpin has moved to a position within the University at the Institute of Marine and Antarctic Studies (IMAS), but has been retained in an honorary position. Professor Ross Large retired at the end of 2015, but has been retained in an honorary position.

PROFESSIONAL STAFF
Caroline Mordaunt – Administrative Assistant (part-time).
Jennifer Thompson has stepped down from her position as Laboratory Analyst to pursue a PhD within the ARC TMVC Research Hub.

STAFF MOVEMENTS 2015
APPOINTMENTS
Helen Scott has been appointed Program Coordinator. From left: for Thames, with Bruce Gemmell; after receiving the Dean’s Award for Exceptional Performance by Professional Staff: Elena Loussouros taking to Mark Whittaker from MRE at the Science Planning Meeting.

STAFF AND MANAGEMENT
NAME % IN CODES TMVC
Director, Professor J Bruce Gemmell, BSc (UBC), MA, PhD (Dartmouth) 80
V-MIS deposits and epithermal Au-Ag 100
Deputy Director, Professor David Cooke, BSc (Hons) (Lutrol), PhD (Monash) 100
Porphyry Cu-Au, fluid-rock geochemistry 50

ACADEMIC/RESEARCH STAFF AT UTAS
NAME % IN CODES TMVC
Dr Sharon Allen, BSc (Massey), BSc (Auckland), PhD (Monash) 50
Volcanic facies analysis
Hon
Dr Mike Baker, BSc (Hons) (Sydney), PhD (UTAS) 100
Igneous petrology, mineral chemistry
Dr Associate Professor Ron Burrey, BSc, PhD (Finders) 50
Structure of mineralised provinces, CHIME dating, geostatistics
Hon
Dr Stuart Bull, BSc (Hons), PhD (Monash) 50
Clastic and carbonate sedimentology and volcanology
Hon
Dr Rebecca Carey, BSc (Hons) (UTAS), PhD (U-Hawaii) 100
Volcanology
Hon
Dr Matt Cracknall, BSc (Hons), PHD (UTAS) 100
Geophysics, machine learning and data mining
Professor Tony Crawford, BSc, PhD (Melbourne) 100
Porphyry, geochemistry and tectonics of volcanic arcs
Hon
Professor Leonid Danyushevsky, PhD (Vernadsky Inst.) 50
Petrology, geochemistry, LA-MC-MS analysis
Professor Dr Chun-kit Lai, BSc, MPhil (HKU), PhD (UTAS) 100
Petrology, geochemistry
Professor Dr Garry Davidson, BSc Hons (ANU), PhD (UTAS) 50
Sulfur isotope geochemistry and Cu-Au ores
Hon
Dr Paul Davidson, BSc Hons, PhD (UTAS) 100
Melt and fluid inclusions
Hon
Dr Trevor Faltone, BSc Hons (Canterbury), BTeaching, PhD (UTAS) 100
Marine geoscience, petrology
Hon
Professor David Green, BSc Hons, MSc, BSc, DLit Hon (UTAS), PhD (Canbridge) 100
Experimental petrology
Hon
Dr Jacqueline Halpin, BSc Hons (Melbourne), PhD (Sydney) 100
Metamorphic petrology, geochronology
Hon
Dr Maya Kamatani, PhD (UTAS) 100
MILA SIMA, geosmtakurgy, petrology
Professor Vadim Kamenetsky, BSc Hons (Moscow), PhD (Vernadsky Inst.) 100
Petrology and geochemistry of melt inclusions
Professor Dr Jacqueline Halpin, BSc Hons (Melbourne), PhD (Sydney) 100
Fluid inclusions, SE Asian metallogenesis
Hon
Professor Dr Chun-kit Lai, BSc, MPhil (HKU), PhD (UTAS) 100
Petrology, geochemistry and tectonics of SE Asia
Hon
Professor Ross Large, BSc (Hons) (UTAS), PhD (UNE) 100
Volcanic-hosted and sediment-hosted base metal and gold ores
Hon
Dr Peter McGoldrick, BSc Hons, PhD (Melbourne) 100
Ore deposits and their halos
Hon
Professor Jocelyn McPhie, BA Hons (Macquarie), PhD (UNE) 100
Volcanic facies architecture and volcanic textures
Hon
Professor Khin Zaw, BSc (Bangong), BSc (Queen’s), PhD (UTAS) 100
Volcanic-hosted and sediment-hosted base metal and gold ores
Hon
Associate Professor Dr Michael Roach, BSc Hons (Newcastle), PhD (UTAS) 100
Petrology and tectonics of the SW Pacific
Hon
Dr Karin Orth, BSc Hons (Monash), PhD (UTAS) 100
Volcanology
Hon
Dr Anna Parthakar-Fox, BSc Hons (London), PhD (UTAS) 100
Environmental geology, mineralogy, geochronology
Hon
Dr Associate Professor Anja Reading, BSc Hons (Edinburgh), PhD (Leeds) 50
Geophysics, seismology, computational methods
Hon
Dr Michael Roach, BSc Hons (Newcastle), PhD (UTAS) 20
Geophysical responses of ore deposits
Hon
Dr Robert Scott, BSc Hons, PhD (Monash) 100
Structural geology, gold deposits / MTEC Senior Lecturer and Masters Program Coordinator
Hon
Dr David Selley, BSc Hons (Adelaide), PhD (UTAS) 70
Structural geology, basin analysis, ore deposit modelling
Hon
Dr Jeff Staudman, BSc (Central Missouri), MSc (Iowa) 80
Ore and sedimentary-prise geochemistry; seawater composition through geologic time
Hon
Dr Aleksandar (Sasha) Stipanov, MSc (Novosibirsk), PhD (ANU) 100
Geochemistry of rare metals
Hon
Dr Lejun Zhang, BSc, PhD (IFUT) 100
Porphyry Cu-Au and HS epithermal
### ACADEMIC/RESEARCH STAFF BASED AT COLLABORATIVE INSTITUTIONS/INDUSTRY

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<td>Dr Tony Brown</td>
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<td>Professor Ray Cas</td>
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<td>Dr Kathy Ehrig</td>
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<td>Neil Goodey</td>
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<td>Dr Stephen Hardy</td>
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<td>Dr Anthony Harris</td>
<td>Newcrest Mining</td>
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<td>Professor Peter Hollings</td>
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<td>RWTH Aachen University</td>
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<td>Adele Saymon</td>
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<td>Michael Shelly</td>
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<tr>
<td>Dr Jamie Wilkinson</td>
<td>Natural History Museum, London</td>
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### TECHNICAL/ADMINISTRATIVE STAFF

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<tr>
<td>Mr Steve Calladine</td>
<td>Communications Manager</td>
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<tr>
<td>Mrs Michelle Chapple-Smith</td>
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<td>Mr Alex Cusson</td>
<td>Lapidary Technician</td>
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<tr>
<td>Dr Sarah Gilbert, PhD, BSc Hons (UTAS)</td>
<td>Laser Ablation Technician- ARC TMVC Research Hub</td>
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<td>Dr Jane Higgins, BIS, BA(Hons) Hons, PhD (UTAS)</td>
<td>Personal Assistant to the Director</td>
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<tr>
<td>Mr Ian Little, BSc Hons (UTAS)</td>
<td>Maintenance, Field Equipment, and Safety Officer</td>
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<td>Ms Elena Lounjewa</td>
<td>Laboratory Analyst</td>
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<td>Mrs Katie McColldrick</td>
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<td>Dr Paul Oliy, BA (SOU), MSc, PhD (WSU)</td>
<td>Laser Ablation Technician- ARC TMVC Research Hub</td>
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<tr>
<td>Ms Julia Pongratz</td>
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<tr>
<td>Mrs Claire Rutherford</td>
<td>Administrative Assistant</td>
<td>60</td>
</tr>
<tr>
<td>Ms Helen Scott, BSc Hons (UTAS), BEd (QUT)</td>
<td>Hub Manager- ARC TMVC Research Hub</td>
<td>100</td>
</tr>
<tr>
<td>Ms Jay Thompson, BSc Hons, MSc (U Iowa)</td>
<td>Laboratory Analyst</td>
<td>100</td>
</tr>
<tr>
<td>Ms Isabella von Lichten, BSc Hons (UTAS)</td>
<td>Curator</td>
<td>15</td>
</tr>
</tbody>
</table>

Staff and students in 2015 – or at least those that were around on the day.

### ADVISORY BOARD

<table>
<thead>
<tr>
<th>NAME</th>
<th>Department</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chair: Paul Holtersay</td>
<td>Department of State Development, South Australia</td>
</tr>
<tr>
<td>Vice Chair:</td>
<td></td>
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<tr>
<td>Rio Tinto Exploration</td>
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<tr>
<td>Acting Dean, Faculty of Science, Engineering and Technology, UTAS</td>
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<tr>
<td>Pro Vice-Chancellor, Research Training, UTAS</td>
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<td>CODES, UTAS</td>
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<td>Iain Dalrymple</td>
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### EXECUTIVE COMMITTEE

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<td>AMIRA International</td>
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### SCIENCE PLANNING PANEL

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**Committee member for part of year**

### ACADEMIC/RESEARCH STAFF AND STUDENTS

<table>
<thead>
<tr>
<th>NAME</th>
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<th>TMVC</th>
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<tbody>
<tr>
<td>Dr John Bishop</td>
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<td>Hon</td>
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<td>Dr Daniel Bombardieri</td>
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<tr>
<td>Associate Professor Jeff Foster</td>
<td>S2 Resources</td>
<td>Hon</td>
</tr>
<tr>
<td>Neil Goodey</td>
<td>Coriscan</td>
<td>*</td>
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<tr>
<td>Professor Mark Hannington</td>
<td>University of Ottawa</td>
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<tr>
<td>Dr Stephen Hardy</td>
<td>NICTA</td>
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<td>Dr Julie Hurt</td>
<td>University of Liege</td>
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<tr>
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<td>RWTH Aachen University</td>
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<tr>
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<td>University of Queensland</td>
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<tr>
<td>Dr Jamie Wilkinson</td>
<td>Natural History Museum, London</td>
<td>Hon</td>
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### FROM LEFT:
- Professor Ross Large receiving his Distinguished Service Medal from the Vice-Chancellor, Professor Peter Rathjen; Deputy Chair of the Advisory Board, Paul Agnew from Rio Tinto, addressing delegates at the SEG 2015 Conference.

### FROM LEFT:
- Professor Ross Large receiving his Distinguished Service Medal from the Vice-Chancellor, Professor Peter Rathjen; Deputy Chair of the Advisory Board, Paul Agnew from Rio Tinto, addressing delegates at the SEG 2015 Conference.
**CODES CO-HOSTS SEG 2015 CONFERENCE**

When the Premier of Tasmania, Will Hodgman, opened the SEG 2015 Conference at Wrest Point in Hobart on Sunday, September 27, it marked the first time that this major international event had been held in Tasmania, and only the second time it had come to Australia. It was also the first time that the Society of Economic Geologists (SEG) had entered into an equal partnership with a research organisation (CODES) for this annual conference, which is widely regarded by economic geologists as the most important event on the calendar.

Despite the current downturn in the minerals industry, and the long distances many people had to travel to reach Tasmania, the attendance exceeded all expectations with 742 delegates, from 43 countries, filling the conference facilities at the venue. The main conference ran for three days, but this was supplemented by two field trips and four short courses pre-conference, and three field trips and two short courses post-conference.

The main conference theme, World-Class Ore Deposits: Discovery to Recovery, combined the topics of exploration and discovery with a number of the geosciences, as well as ge metallurgy, to cover a range of deposit types and major mines and districts. Spread over twenty sessions, in nine theme sessions, the technical program was delivered by an outstanding line up of keynote and volunteer speakers from around the world, who covered a wide array of subjects, and didn’t shy away from tackling the important, and at times controversial, issues facing the minerals industry. To illustrate this point, the main conference was rounded off with a special Controverses Session, which included a typically assured and enthusiastic talk by Professor Ross Large, intriguingly titled ‘A neptunist’s view in a world of magmatists’.

An innovation at this year’s event was the introduction of a new style of keynote presentation, named the Trifecta talks. These highly popular presentations combined the discovery history, geology, and geometallurgy of four of the world’s finest ore bodies: the Red Dog and Pebble deposits in Alaska, Olympic Dam in South Australia, and Ladoxam in Papua New Guinea.

Student participation was actively encouraged by both the SEG and CODES, and the budding geoscientists certainly rose to the occasion with significant participation in the technical program, through both the oral and poster presentations. In addition, the CODES SEG Student Chapter organised a number of highly successful pre-conference activities, including a reception to welcome students from a diverse mix of cultural backgrounds.

In conjunction with the main technical program, the poster sessions attracted 262 entries – a record for an SEG Conference. There was also an extensive exhibition area that housed booths representing more than 40 mining companies and organisations. As co-host, CODES had a large booth in a prime position, which was manned by a host of staff and students, on a roster basis.

CODES staff and students also made major contributions to the overall conference proceedings, which included Bruce Gemmell as Conference Chair, plus 16 presenters and one panellist, six session chairs, 52 poster presentations, as well as leading two short courses and three field trips – to Indonesia, western Tasmania, and New South Wales. The conference received widespread local media coverage, including a substantial article in the Sunday Tasmanian and several interviews on ABC Radio.

CODES wishes to thank the following people and organisations for making this event such a success:

- The Chairman Bruce Gemmell’s colleagues on the organising committee: Noel White (consultant), Patrick Sack (Yukon Geological Survey), Zhaoshan Chang (CU), Garry Davidson (CODES), Dan Wood (consultant), and Brian Hoal and Christine Horrigan (SEG).
- The CODES SEG Student Chapter, and the all the staff at CODES that played a part in the event.
- Ben Theiss and his team at Conference Design – the conference co-ordinators.
- The staff and management at Wrest Point.
- The sponsors (see list on this page).
- All the presenters, short course and field trip leaders, and the 742 delegates who came from far and wide to participate.

**EVENT SPONSORS**

- **GOLD** Rio Tinto, Newcrest Mining Limited
- **SILVER** Barrick Gold Corporation, Newgold, Antofagasta plc

**2015 Event Sponsors**

- **Patron** BHP Billiton
- **Gold** Rio Tinto, Newcrest Mining Limited
- **Silver** Barrick Gold Corporation, Newgold, Antofagasta plc
OBJECTIVE
To describe the geological, geochemical and geophysical features of ore forming systems and terrains, and use this information to devise better means of discovering mineral resources at surface and under cover.

INTRODUCTION
The Ore Deposits: Characterisation and Context Module provides end-users with process-based models for the formation of high value metaliferous ore deposits and a framework to develop innovative new tools for determining the most prospective regions for exploration (fertility), and for targeting buried ore deposits (vectoring).

The Module was formed at the beginning of 2014 and is the result of the amalgamation of the Location, Formation and Discovery Programs, which had been in operation since 2006. This revised model retains CODES’ core research strengths, while establishing a platform that allows projects to be developed that meet the evolving needs of the minerals industry. This is achieved through six themes, which reflects CODES’ range of expertise and level of diversity in the field of hard-rock geology.

HIGHLIGHTS
In its second year since the transition from the Program structure, the Module continued to expand and develop, building on the solid and wide ranging research platform established in 2014. The total figure of 26 projects within this Module report is up slightly from 25 in the previous year, which has been achieved despite some projects being transferred to the Discipline of Earth Sciences and the new ARC TMVC Research Hub. The total also includes 13 new or expanded research initiatives, demonstrating how the Module has evolved significantly during the year. Many of these projects were created as a result of initiatives reaching maturity and outgrowing the scope of project titles, creating the need for new projects that better reflect the evolving nature of the research.

Other Highlights include:

PUBLICATIONS
It was another exceptional year for publications output, with researchers and students within the Module producing 61 published refereed journal articles, 15 chapters in books, and one edited book. It is worthwhile to note that many of these publications were published in journals of particular importance to applied economic geology research, including nine in Economic Geology, eight in Ore Geology Reviews, and two in Mineralium Deposita. It is also worth noting that the figures exclude publications affiliated to the Discipline of Earth Sciences.

One of the highlights of this output was a manuscript published in the high ranking journal, Geology, by PhD student Jacob Mulder. Jacob’s paper revealed that Tasmania was once linked to what we now recognise as North America and Antarctica during the time of the ancient supercontinent Nuna. The paper, and subsequent media release, received worldwide media attention, including a segment in the ABC TV’s popular science program Catalyst, which will air in 2016.

Nathan Fox and co-authors also published a paper in Geology in 2015, describing a fundamental crustal link between the locations of volcanosedimentary rift basins and Cu-Au porphyry deposits in the Cadia district, NSW.

REPORTS TO INDUSTRY/GOVERNMENT AGENCIES
In addition to the high number of publications produced during the reporting period, team members issued 38 reports to mining companies and government agencies, maintaining the Module’s excellent performance in terms of technology transfer.

RESEARCH OUTCOMES
It was also a good year for research outcomes, with many projects having direct impacts on the potential discovery of new economic ore bodies. For example:

• A study by Karin Orth, in collaboration with the Geological Survey of Western Australia, has raised the prospectivity of the Hart Dolomite for titanium, vanadium and iron across northern Western Australia's Kimberley district.

• David Selley’s research on the Gosowong low sulphidation epithermal gold system, Halmahera, Indonesia, has led to the construction of a district-scale 3-D tectono-stratigraphic model, which provides a robust geometric template for ongoing exploration targeting.

The work completed on the Power of Pynite project led to a better understanding of the nature of mineralisation at all studied sites, with potential vectors to ore developed for at least four of the case studies. Six companies, plus GA and the GSSA, are now funding this project, and a total of six case studies have commenced.

• The Drummond Peak Gold project successfully identified ten new exploration targets.

Other key research outputs and achievements include:

• Honours student Sally Mattner took advantage of the temporary draining of Tasmania’s Lake Rowallan to study Precambrian rock formations that had not been visible since the last Ice Age. The study is expected to shed light on the geological development of the whole of eastern Australia.

• Excellent progress has been made on recognising and answering major questions relating to the processes responsible for metal concentration and their duration in the formation of the supergiant Olympic Dam Cu-U-Au ore deposit.

AWARDS AND GRANTS
• PhD student Jacob Mulder was awarded the prestigious Endeavour Postgraduate Scholarship by the Australian Government, which will result in him spending up to two years studying at the University of New Mexico, under the guidance of Professor Karl Karlstrom.

• PhD candidate Angela Escolme was awarded the best student presentation at the SES 2015 Conference in Hobart.

• Bruce Gemmell completed his guest professorship at the GeoMAR Helmholtz Centre for Ocean Research in Kiel, Germany, as the recipient of the 2015 Research Excellence Professorship award from the Dr Werner Petersen Foundation.

OPPOSITE PAGE: Chrysocolla (light green to blue), and malachite (dark green) rimmed breccia from the copper mine, NW Zambia.
THE MODULE TEAM

LEADER: Gary Davidson

TEAM MEMBERS:
Sharon Allen, Ron Berry, Stuart Bull, Rebecca Carey, David Cooke, Matt Cracknell, Leonid Danilchuk, Paul Davison, Nathan Fox, Bruce Gennett, Dan Gregory, Jacqueline Halpin, Alastair Harvey, Nic Jansen, Maya Kamenskaya, Vadim Kamenskyy, Ross Large, Jocelyn McPhie, Sebastien Mefret, Karl Orth, Anya Reading, Michael Roach, Robert Scott, David Selley, Jeff Steadman, Jay Thompson, Selsia Wu, Wim Zaw, Lejun Zhang

MASTERS STUDENTS:
Billy Beas, Jo Condon, Xuan Truong Le, Saranya Nuantia-Ong, Irma Vejela

HONOURS STUDENTS:
Chris Hildrew, Travis Holmes, Sally Mattner, Jordan Sheppard, Jonathan Traynor

COLLABORATORS:
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AKITA UNIVERSITY, JAPAN
Akira Imai
ANGLOGOLD ASHANTI
Michael Nugus, Ross Pringle
ARGENT MINERALS
David Busch
BHP BILLITON
Kathy Ehrg, Danny Husman
BOLIDEN MINERAL AB
Rodney Allen
BRITISH GEOLOGICAL SURVEY
Mike Crow
CAMERO RESOURCES
Penny Sinclair
CHIANG MAI UNIVERSITY, THAILAND
Phiset Limtrakun
CHULALAKORN UNIVERSITY, THAILAND
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CLUMP MOUNTAIN GEOSCIENCE
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Cho Cho Aye
EMERSON RESOURCES
Hamish Johns, Grant Osborne
ENTERPRISE METALS
Frank Doeders, Dermot Ryan
FIRST QUANTUM MINERALS
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Rainer Thomas
GEOLOGICAL SURVEY OF JAPAN
Kazuo Sonomatsu
GEOLOGICAL SURVEY OF SOUTH AUSTRALIA
Rian Dutch, Adrian Fabris, Anthony Reid
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
Julie Holmes, David Maclennan, Christopher Phillips, Michael Wingate
GEOMAR, GERMANY
Sven Petersen
GEOSCIENCE AUSTRALIA
Gustav Nortje, Charlotte Seabrook
NORTHERN TERRITORY GEOLOGICAL SURVEY
Dorothy Close, Andrew Wygrafox
OZ MINERALS
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Robert Moritz
UNIVERSITY OF MELBOURNE
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UNIVERSITY OF OTTAWA, CANADA
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UNIVERSITY OF Padjajaran, INDONESIA
Mega Rosiana
UNIVERSITY OF SYDNEY
Detmar Muller, Simon Williams, Derek Wyman
UNIVERSITY OF TASMANIA
Mike Coffin, Karsten Goermann, Taryn Noble, Pat O’Fly, Thomas Rodemann, Joanne Whittaker

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NANYANG TECHNOLOGY UNIVERSITY, SINGAPORE
Yu Wang
NEWCREST MINING
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Mike Coffin, Karsten Goermann, Taryn Noble, Pat O’Fly, Thomas Rodemann, Joanne Whittaker
CORE PROJECTS

THEME 1
ORE FERTILITY OF THE CRUST AND MANTLE
• Melt-melt immiscibility and the origin of magnetite-apatite deposits
• Tectonic and Cu-Au and Au mineralisation of western Myanmar-Sumatra Terrane
• Architecture of the Birimian belts in Côte d’Ivoire

THEME 2
VOLCANISM, AND ITS EFFECT ON ORE FORMING PROCESSES
• VHMS research – modern
• VHMS research – ancient
• Volcanology related to ore deposits
• Paleoproterozoic mafic magmatism of the Kimberley Basin, Western Australia

THEME 3
MAGMATIC-HYDROTHERMAL PROCESSES AND ORES
• Exploring the porphyry environment
• Olympic Dam
• Magmatic-hydrotectonic volcanic exploration and mineralisation in Tasmanian Sn granites

THEME 4
BASE PROCESSING AND ORES
• McArthur Basin copper
• Kansanshi gold
• Uranium concentrations in basins

THEME 5
THE ORE-AFFECTED CRUST
• The power of pyrite
• Drummond peak gold
• DeGrussa VHMS vectoring
• Integrating geology and geophysics for resources targeting
• Metamorphic architecture of the western Gawler Craton
• Application of sulfide S and carbonate C-O isotopes to ore genesis and exploration
• Australian hydrothermal IOCG and related deposits
• The characteristics and role of colloidal silica fluids in the formation of the Gireses Sidling Pb-Zn prospect, western Tasmania
• The geology, geochemistry and genesis of the Avebury Ni deposit: Implications for exploration
• Geology and genesis of the Invincible gold deposit, St Ives

THEME 6
DATES AND PLATES
• Building Tasmania: The Cambrian and beyond
• Tectonic reconstruction of East Gondwana
• Structure of SE Australia using multiple geophysical methods

PROJECT SUMMARIES

THEME 1
ORE FERTILITY OF THE CRUST AND MANTLE
MELT-MELT IMMISCIBILITY AND THE ORIGIN OF MAGNETITE-APATITE DEPOSITS
Leader: Paul Davidson
Collaborators: Mark Dudley, Mrasaleh Mirmohammadi, John Nold, Rainier Thomas
Melt-melt immiscibility covers a group of related processes in which melts at specific TPX conditions may spontaneously split into two or more mutually immiscible phases. In contrast to fractionation, melt-melt immiscibility is a sudden, intense, step-wise change in magma composition, which may rank with fractionation as a significant, if subordinate, driver of magma evolution, and thus crustal evolution. There are numerous forms of melt-melt immiscibility, and this project began studying Fe-Ti oxide melt-silicate melt immiscibility (Kruna-type magnetite-apatite deposits) and has gone on to concentrate on silicate melt-silicate melt immiscibility (pegmatites) with a view to understanding the generation of economically valuable ore-deposits. It is intended to separate these streams in future, with pegmatite research being conducted under the title of ‘The origin of pegmatites and pegmatite-related ores’, with the research into Kruna-type deposits being reported under the revised ‘IOCG deposits and related deposits’ project.
During 2015, a paper by Rainer Thomas and Paul Davidson entitled ‘Revisiting complete miscibility between silicate melts and hydrous fluids, and the extreme enrichment of some elements in the supercritical state – consequences for the formation of pegmatite and ore deposits’ was accepted for publication in Ore Geology Reviews. A second paper is ready for submission.

TECTONIC AND Cu-Au AND Au MINERALISATION OF WESTERN MYANMAR-SUMATRA TERRANE
Leader: Khin Zaw
Team Members: Jacqueline Haislip, Ross Lange, Sebastien Meffre
Students: Mohd Basri Iswadi Bin Basori, Joseph Knight, Kuan Thuang Le, Charles Makound, Saranya Nuania-Ong, Jordan Sheppard, Jonathan Trajmar
This research commenced in 2015, building on the successful Ore Deposits of SE Asia project, which came to a conclusion at the end of 2014. While the SE Asia project focussed on the geochronology, metallogenesis and deposit styles of mainland areas of the region, this new initiative looks specifically at the tectonic, Cu-Au, and Au mineralisation of the western Myanmar-Sumatra Terrane. Highlights for 2015 include:
• Research by Honours student Jordan Sheppard in stratigraphically and palaeoecologically well-constrained Devonian shales exposed along the Mandalay-Pyin Oo Lwin tract in the Northern Shan State, Myanmar, indicates a clear mass extinction event in the Upper Devonian, and significant changes (oxic to dysoxic and anoxic) in palaeoredox conditions of the Devonian Ocean. The relativeness plots of the zircons suggest the source and provenance of the Devonian sequence in Myanmar has a Gondwana affinity, as the peaks of the zircons confirm an affinity with the Sibumasu Terrane.
• LA-ICP-MS analyses and imaging of three types of pyrites, and fluid studies of the Paleozoic shale/ sandstone-hosted Mo Taung orogenic gold deposit near Nay Pyi Taw, Central Myanmar, suggest at least two stages of enrichment of gold: both in the sedimentary environment and the late magmatic-metamorphic conditions, as evidenced by a change in fluid chemistry and hydrothermal source. Pb isotope analysis suggests that lead has been sourced from a crustal region and is likely to be attributed to post-collisional setting following the suture of the Sibumasu Terrane and the West Myanmar Terrane.
• Fieldwork and sampling conducted on major ore hosting lithologic volcanic/magmatic units. This sub-project, entitled ‘Geodynamic and metallogenic setting of Cu-Au mineralisation in Myanmar: Implications for mineral exploration’ was funded by a major Australian mining company. Laboratory analyses (XRF, LA-ICP-MS zircon dating) are in progress.

ARCHITECTURE OF THE BRIMIN BELTS IN CÔTE D’IVOIRE
Leader: David Selley
Team Member: Sebastien Meffre
Collaborators: Mathieu Agneau, Anthony Harris, Paul Kito, Dominic Murphy, Charlette Seabrook
This Newcrest-sponsored project, initiated in August 2015, aims to generate a country-wide geologic template for Côte d’Ivoire that can be used to facilitate basin and gold exploration at deposit to district scales. The work builds on major multidisciplinary research by the WAXI consortium, led by the University of Western Australia and the University of the Witwatersrand, that has focussed on countries surrounding Côte d’Ivoire. The successful multi-faceted approach employed by WAXI, including analysis of regional datasets, targeted field trianning, and the generation of petrographic, geochronologic, and geochemical datasets, is being replicated in this project.
A preliminary structural template has been produced largely on the basis of geophysical and topographic data, which projects Birimian belts
from Côte d’Ivoire’s peripheries into its interior. Complementary field mapping in the west and north of the country has provided a new complete composite section through the Palaeoproterozoic stratigraphy. Geochronological sampling of felsic and intermediate volcanic units from lower arc related sequences, coupled with detrital zircon dating of upper basin levels, will underpin a robust chronostratigraphic framework, relating stratigraphic growth to orogenic and magmatic events. Initial work has generated one crystallisation age for a lower felsic interval, indicating that sampling and analytical methods are viable. Detailed structural analysis reveals phases of N- to NW-directed arc accretion, associated granitic magmatism, and exhumation of mid-crustal levels. Each phase records components of locally intense orogen-parallel stretch, as individual belts are progressively anticlockwise orogen-parallel stretch, as individual components of locally intense accretion, associated granitic phases of N- to NW-directed arc orogen-parallel stretch, as individual components of locally intense accretion, associated granitic magmatism, and exhumation of mid-crustal levels. Each phase records components of locally intense orogen-parallel stretch, as individual belts are progressively anticlockwise

THEME 2

VOLCANISM, AND ITS EFFECT ON ORE FORMING PROCESSES

VHMS RESEARCH – MODERN

Leader: Bruce Gemmell
Student: Heidi Berkenbosch
Collaborators: Cornel de Ronde, Nathan Steeves, Sven Petersen
Heidi Berkenbosch’s PhD project at Brothers volcano, in the Tonga-Kermadec arc, commenced in 2015. This collaborative project with GNS, New Zealand (Cornel de Ronde) is investigating the ore and gangue mineralogy, textures, paragenesis, mineral chemistry, and copper isotopes of the sulfide-sulfate chimneys. A paper detailing the Cu isotopes geochemistry of the chimneys was published by Mineralium Deposita during the year.

Bruce Gemmell is continuing research on the Palaeo seaﬂoor mineralising system in the Tyrrhenian Sea, Italy, which is an evolving intermediate to high sulfidation massive sulfide. Bruce is using LA-ICP-MS analysis of the different paragenetic generations of pyrite to elucidate the evolving hydrothermal fluids responsible for the Palermo mineralised occurrence. This research is being conducted in collaboration with Sven Petersen at GEOMAR, Germany.

VHMS RESEARCH – ANCIENT

Leader: Bruce Gemmell
Team Members: Ron Berry, Garry Davidson, Ross Large, Khin Zaw
Students: Mohd Basril Iswadi Bin Basori, Jo Condon, Mandy Hawke, Brian McNulty, Nathan Steeves
Collaborators: Mark Hannington, Andrew McNeill, Jim Mortensen, Sven Petersen, Mike Vicary
The genesis of volcanic-hosted Cu-Pb-Zn-Au massive sulfide deposits is being investigated across the spectrum of massive sulfide deposit types, from typical seafloor VHMS to Cu-Au Au-Ag deposits, through sub-seafloor shallow-water, replacement gold-rich epithermal to deep sub-volcanic interstitial-related Cu-Au-rich styles. In 2015, research was undertaken on deposits at Fossey- Hellyer- Que-River-Mt Charter (Tasmania), DeGrussa and Jagutan (Western Australia), Greens Creek (Alaska), Myra Falls (Canada), Tasik Chiri (Malaysia) and Bawdwin (Myanmar).

Nathan Steeves continued his PhD investigation of the Greens Creek VHMS deposit in southeast Alaska. The Greens Creek deposit is the top silver producer in the U.S. and one of the most significant top silver producing mine in the world. The deposit occurs as sub-vertical pipes in a rhyolitic volcaniclastic pile of Cambro-Ordovician age. The ore bodies are localised in a major rift structure in which dome-shaped rhyolite intrusions were emplaced. Two student projects continued at Sandfire Resources’ VHMS deposit at DeGrussa, WA. The first, a PhD project by Mandy Hawke, is investigating the geologic, structural and geochronological setting of the deposits. Mandy’s work includes a paper in 2015 in Precambrian Research on the geochemistry of the DeGrussa VHMS deposit and associated mineralisation of the Yerrida, Bryah and Padbury Basins, Western Australia. She also presented results of her research at the SGA Conference in France, and the SEG Conference in Hobart. The second study is a Masters project by Jo Condon, which is concentrating on the ore and gangue mineralogy, textures, paragenesis, and mineral chemistry of two of the ore lenses at DeGrussa. Jo submitted her thesis in 2015 and it is currently undergoing its second review before, during and after the VHMS mineralising events at these locations. Former PhD student Susan Belford, in conjunction with Garry Davidson, Jocelyn McPhee and Ross Large, published the results of her investigation on the architecture of the Neoproterozoic Jagutan VHMS deposit, Western Australia: implications for prospectivity and the presence of depositional breaks in Precambrian Research. In addition, Susan and Garry contributed to another publication in Precambrian Research entitled ‘A review of volcanic-hosted massive sulfide (VHMS) mineralization in the Archaean Yilgarn Craton, Western Australia: Tectonic, stratigraphic and geochemical associations’. The first phase of a project aimed at improving the age and geochronological constraints on the development of the Mount Read Volcanic Belt (MRV) was completed, in collaboration with Jim Mortensen (UBC). Work included U-Pb dating of zircons, which produced many new dates that have helped to constrain the timing of the development of the MRV and associated VHMS mineralisation. A paper was published in Economic Geology in 2015, entitled ‘High-precision U-Pb zircon chronochronography of the Mount Read Volcanic Belt in Western Tasmania, Australia: Implications for VHMS deposit formation’. A second phase of age dating throughout the MRV is underway and results were presented at the SEG Conference in Hobart.

VOLCANOLOGY RELATED TO ORE DEPOSITS

Leader: Rebecca Carey
Team Members: Sharon Allen, Jocelyn McPhee
Students: Billy Beas, Pedro Fonseca, Chris Hindrew
Collaborator: Ray Cas

Pedro Fonseca’s PhD project is focussed on the internal stratigraphy and architecture of the Mount Read Volcanics in western Tasmania. The stratigraphic and facies analyses...
This project leads on from the Carson-Volcanics Hart Dolerite Large Igneous Province (LIP) research (2012-2014) in the Kimberley, Western Australia, and involves assessment of the Carson-Volcanics Hart Dolerite LIP for a variety of commodities. Ancient sills and dykes of the Hart Dolerite correlate with voluminous basalt of the Carson Volcanics to form the Hart-Carson LIP in the Kimberley. Two sedimentary basins host the LIP: The older Speewah Basin hosts sills and dykes, whereas the overlying lower Kimberley Basin is host to the volcanic unit. Stratigraphic mapping, volcanology and sampling for geochemistry and geochronology of the LIP have been completed across the region. At Speewah Dome, a Ti-V-Fe resource has been identified in a magnetite-enriched unit. The study identified similar magnetite-rich units exposed within the Hart Dolerite sills. The discovery raises the prospectivity of the Hart Dolerite for Ti-V-Fe across northern Western Australia’s Kimberley district. The prospectivity of the Hart Dolerite for Ti-V-Fe ore deposits was presented at the GSWA Open Conference in Hobart. The new assessment will form part of the final report for this project, which will be published as a Geological Society of Western Australia record.

**THEME 3**

**MACMAGMATISM OF THE KIMBERLEY BASIN, WESTERN AUSTRALIA**

**ORE DEPOSITS: CHARACTERISATION AND CONTEXT**

**EXPLORING THE PORPHYRY ENVIRONMENT**

**Leaders:** David Cooke, David Selley  
**Team Members:** Nathan Fox, Nic Jansen  
**Students:** Erin Lawlis, Evan Orovan, Marc Rinne, Stephanie Sykora  
**Collaborators:** Ben Ackerman, Chris Allickson, Nick Fitzpatrick, Karyn Gardner, Anthony Harris, Bridgette Henderson-Smith, John Holliday, Fiona Karaut, Fraser MacConquodale, Paul Napier

The team is working in close collaboration with Newcrest Mining in order to obtain new knowledge and maximise opportunities for the discovery of porphyry and epithermal related gold resources in the South West Pacific region. Research is being conducted that is advancing the conceptual models and exploration techniques at the relevant deposits and districts. This new knowledge is then passed directly to Newcrest geologists with onsite training. The close working relationship with Newcrest is facilitated by the company’s strong leadership in research, both logistically and financially.

Stephanie Sykora’s project at the Lihir gold deposit in Papua New Guinea aims to resolve the genesis of large porphyry and epithermal related gold systems, with findings published in the prestigious journal *Geology*. Research outcomes were presented at the SEG Conference in Hobart.

**OLYMPIC DAM**

**Leader:** Vadim Kamenetsky  
**Team Members:** Maya Kamenetsky, Jocelyn McPhie, Sebastien Mefret, Jay Thompson  
**Students:** Olga Apukhtina, Nathan Chapman, Alex Cherry, Matt Ferguson, Guiyue Huang, Ima Vejelyte  
**Collaborators:** Andrea Agangi, Elena Belousova, Kathy Emig, Maria Kirchenbaur, Roland Maas

Nathan Fox’s work on the Cadia Cu-Au district, NSW, culminated in a new understanding of the link between volcanosedimentary basin architecture and timing, and the formation of large porphyry Cu-Au systems, with findings published in the prestigious *Journal of Geology*.
Excellent progress has been made on recognising and answering major questions relating to the processes responsible for metal concentration and their duration in the formation of the supergiant Olympic Dam Cu-U-Au-Ag ore deposit. This deposit is one of the most enigmatic because it is polymetallic, and the economic elements and iron are concentrated within a breccia complex hosted by undeformed, weakly altered granite. Although the age of the granite is well established at ca. 1580 Ma, the timing of metal addition and accumulation is uncertain, largely because the context and textures of the ore are variable and indicative of several genetic processes. In addition to high-precision U-Pb ages of uraninite spreading over 1 Ga, the team is now confident that different rocks and mineral assemblages record post-1590 Ma tectonic, magmatic, sedimentary and hydrothermal events.

Major breakthroughs are identified below:

- **Zircon in clasts of quartz-rich sandstone in the hematite-rich breccia (RD2751, 855-914 m)** belong to three age populations (1612.9±9.1, 1732.7±5.5, 2485±30 Ma) that correspond to those of detrital zircon in the ca. 1425 Ma Pandurna Formation (Carilverloor Basin overlapping the Gawler LIP). The presence of Pandurna Formation in the breccia complex suggests brecciation and incorporation of sediments at <1425 Ma.

- **The Sm-Nd dates of step-leached ore samples are similar to published whole rock data and define a ~1300 Ma apparent age, which is broadly supported by Pb-Sr isochrons for the same fractions.** Garnet in ca. 1580 Ma basaltic dykes and picrite lavas at Olympic Dam has an age of 1128±19 Ma (2B-Sy). A similar age is suggested by Pb isotope systematics of authigenic pyrite in a mafic sandstone belonging to bedded sedimentary facies, and galena in some mineralised samples.

- **The Gairdner Dykes intruded the breccia complex at ca. 820 Ma, and are associated with coeval brecciation and circulation of syn- and post-magmatic fluids.** This research is now published in Precambrian Research (Huang et al) and Contributions to Mineralogy and Petrology (Apukhtina et al). The related hydrothermal alteration is characterised by re-distribution of Fe, Cu, Pb, Pb, REE etc., and precipitation of magnetite, apatite, ilmenite, pyrite, chalcopyrite and galena.

- **The youngest ages (Ordovician, ca. 440-480 Ma) are recorded by (1) authigenic apatite (U-Pb dating) in the bedded sedimentary facies, including ironstones, (2) hydrothermal apatite and monazite (U-Pb dating) in the sulfide-bearing mineralisation associated with basaltic dykes, and (3) fluorspar (Sm-Nd dating; Maas et al, 2011) from extensive fluorspar-barite-siderite veins cross-cutting the breccia complex.** Importantly, roughly Delamerian ages are reported for ‘massive’ uraninite (Eng et al., 2015).

- **The post-1590 Ma brecciation, alteration and mineralisation events coincided with tectonic and magmatic events that affected the Gawler Craton margin in response to amalgamation and/or breakup of three supercontinents – Columbia (breakup 1.6-1.3 Ga), Rodinia (amalgamation 1.3-1.1, breakup 0.95-0.6 Ga) and Gondwana (amalgamation 0.6-0.3 Ga).** The team attribute the extraordinary metal accumulation at Olympic Dam to a favourable position at the craton's margin, where multiple events of metal addition and redistribution can be linked to supercontinent cycles. A possibility of post-1590 Ma uranium addition will be advocated based on 207Pb/206Pb of bulk rocks and sulfides.

- **Concentrations of uranium (from 14 ppm to > 12 wt%)** and isotope compositions of U, Pb and Sm are studied across the entire deposit and reported in Geochimica et Cosmochimica Acta (Kirchenbaur et al). The U isotope composition of most investigated samples (δ234U = 0.56 to -0.04 ‰) overlap within analytical uncertainty with the δ234U of the possible U source, the ambient Rovby Downs granite (δ234U = -0.18 to -0.32‰).

The project has also not only generated a huge amount of geochemical and geochronological data within the deposit but also regionally. To date, the project outcomes are published in three papers and 17 conference proceedings (one keynote). A paper entitled ‘Characteristics, origin and significance of Mesoproterozoic breccia’ is accepted for publication in Precambrian Research.

**MAGMATIC-HYDROTHERMAL VOLATILE EXSOULUTION AND MINERALISATION IN TASMANIAN Sn GRANITES**

**Leader:** David Cooke

**Team Members:** Nathan Fox, Lejun Zhang

**Students:** Travis Holmes, Wei Hong

**Collaborators:** David Huston, Roland Maas

The key objectives of this project in NW Tasmania are to:

- Develop a mineralogical paragenesis model and determine if the mineral chemistry of tourmaline can be used as a useful vector to high-grade mineralisation.
- Resolve the sources of volatile components and depositional mechanisms associated with the formation of each type of hydrothermal phenomena in the roof zone of the Heemskirk Granite.

Paleozoic granitoids in Tasmania contain many textural features indicative of phenomena associated with the magmatic-hydrothermal transition, including world-class examples of UST textures and abundant tourmaline orbicules. These granitoids are associated with world-class tin and tungsten deposits and zoned Pb-Zn-Ag mineral districts. Based on detailed field geological mapping, it has been found that Sn-mineralised (Heemskirk) and barren (Pieman Heads) granites from western Tasmania have developed similar tourmaline-rich magmatic-hydrothermal features, including tourmaline patches, orbicules, cavities and veins. LA-ICP-MS analysis of tourmalines from both granites has revealed that tourmalines are preferentially enriched in Li, Be, Sn and transition elements compared to their granite host. Sn, Nb, Ta and REEs are more likely incorporated into tourmalines from the Heemskirk Granite, whereas the Pieman Heads tourmalines are characterised by enrichments of Zn, Co, Ga, Sr and Pb. Trace element ratios of Sn/Nb, Co/Nb, Sr/Ta, Co/La etc. versus Sn in tourmaline appear to be robust tools for discriminating Sn-mineralised from barren granites.

**THEME 4 BASIN PROCESSES AND ORES**

**McARTHUR BASIN COPPER**

**Leader:** Gary Davidson

**Team Members:** Stuart Bull, David Selley

**Student:** Larriana Morgan

**Collaborators:** Dorothy Close, Andrew Wygnanski

This project began in mid-late 2014, sponsored wholly by the NTGS. Its aims were to develop an improved understanding of copper ore formation processes in the central western McArthur Basin. There are several ‘camps’, each with a cluster of deposits that individually display largely structural control. Most sit lower in the stratigraphy than the main Zn-Pb occurrences (such as the HIC Zn-Pb-Ag Deposit), either in the Tawallah Group, or in the lowermost McArthur Group, with a particular concentration in the Amelia Dolomite and Mallapunyah Formation.

In the reporting period, six drill holes were extensively logged and sampled at the NTGS core store in Darwin. The focus was on the Coppermine Creek prospect, with several unmineralised regional holes sampled for comparison. However, PhD student Larriana Morgan elected to discontinue her studies in August, and the direction of the project has now been re-evaluated, with an agreement for the NTGS to sponsor the research for comparison. However, PhD student Larriana Morgan elected to discontinue her studies in August, and the direction of the project has now been re-evaluated, with an agreement for the NTGS to sponsor the research for comparison. However, PhD student Larriana Morgan elected to discontinue her studies in August, and the direction of the project has now been re-evaluated, with an agreement for the NTGS to sponsor the research for comparison. However, PhD student Larriana Morgan elected to discontinue her studies in August, and the direction of the project has now been re-evaluated, with an agreement for the NTGS to sponsor the research for comparison. However, PhD student Larriana Morgan elected to discontinue her studies in August, and the direction of the project has now been re-evaluated, with an agreement for the NTGS to sponsor the research for comparison. However, PhD student Larriana Morgan elected to discontinue her studies in August, and the direction of the project has now been re-evaluated, with an agreement for the NTGS to sponsor the research for comparison. However, PhD student Larriana Morgan elected to discontinue her studies in August, and the direction of the project has now been re-evaluated, with an agreement for the NTGS to sponsor the research for comparison. However, PhD student Larriana Morgan elected to discontinue her studies in August, and the direction of the project has now been re-evaluated, with an agreement for the NTGS to sponsor the research for comparison.
This project is focussed on researching the nature and causes of uranium concentration in sedimentary basins. Several basins were researched in 2015, with the following outcomes:

- A uranium forming link is being tested between the basement Tennant Creek intruder and the overlying rift packages of the Ooradidgee Basin. In this hypothesis, growth faults active at ~1852 Ma channelled basin brines through IOCG magnetite-hematite ironstones, resulting in U precipitation. The work commenced as an Honours project by Hamish Johns, supported by Emerson Resources, and continued through 2015 with internal funding.
- The previously reported Masters project on the Angauli U unconformity-style mineralisation of the McArthur Basin East Alligator Rivers Province did not progress in 2015. However, this initiative has been converted to a funded CODES-Cameco Resources collaborative research project that is testing a genetic model, and evaluating geochemical halo features of the province. The first samples were delivered in December.

**THEME 5**

**THE ORE AFFECTED CRUST**

The objectives of the Power of Pyrite project are to help explorers gain new insights into the textural, mineralogical and elemental paragenetic history of their respective deposits and alteration footprints using pyrite trace element geochemistry and, where possible, to also provide geochemical vectors toward new ore bodies.

It was a successful year for the Power of Pyrite project, with a number of positive outcomes:

- Seven research reports were produced for the case study sites, characterising pyrite chemistry and target signatures for a vast range of mineral systems.
- Six companies, plus GA, and the GGSA, are now funding the power of pyrite vector project, and six case studies have commenced.
- Statistical software techniques were successfully applied in a number of case studies to provide a statistical verification for the geochemical vector parameters. The work completed has led to a better understanding of the nature of mineralisation at all studied sites, with potential vectors to ore developed for at least four of the case studies.
- Preliminary work commenced on deposits belonging to two additional industry sponsors.

This approach to the project is proving to be very successful in that it combines information on metal paragenesis, textural paragenesis, and Pb isotope signatures with pyrite vector geochemistry, even in cases when only minor mineralisation has been intersected.

**DRUMMOND PEAK GOLD VECTORING**

**Leaders:** Ross Large, Dan Gregory, Matt Cracknell

Collaborators: Richard Beckley, Paul Hiltard

The objective of the DeGrussa vectoring project is to determine whether the trace element content of chalcopyrite, magnetite, hematitic sediments, and/or titanite can be used to extend the footprint and vector towards the Proterozoic DeGrussa VHMS deposit in Western Australia.

A total of 400 titanite, 916 chalcopyrite, 441 magnetite, 660 hematite and six sericite samples were analysed using LA-ICP-MS. All the analyses were processed using statistical software to determine if the trace element content of these minerals could be used to vector towards the ore body. Analyses were conducted on samples taken from drill holes at 190 m, 210 m, 515 m, 975 m, 1550 m, and 2105 m from known ore. A smaller number of samples were taken from sediments and mafic units in the foothall and hanging wall of the prospective stratigraphy to inform future research goals.

These results have increased the understanding of how the exhalative plume extended from the deposit, and what elements and minerals can be used to vector towards new deposits.
INTEGRATING GEOLOGY AND GEOPHYSICS FOR RESOURCES TARGETING

Leader: Anya Reading
Collaborators: Daniel Bombardieri, Mark Duffett

This project was formerly named ‘Integrated geology and geophysical modelling and exploration targeting in the Lyell-Rosebery region’. The name has been changed to better reflect the evolving scope of the research.

Daniel Bombardieri, from Mineral Resources Tasmania, continues his association with CODES through his development of 3D models of prospective regions of interest using the advanced GOCAD computing and visualization environment. In 2015, the Mt Lyell area model was further refined and geophysical work began on the northern region model. Daniel shares his valuable knowledge of several industry-standard software environments with staff, and PhD and Honours students.

METAMORPHIC ARCHITECTURE OF THE WESTERN GAWLER CRATON

Leader: Jacqueline Halpin
Collaborators: Ryan Dutch, Anthony Reid

The generation and preservation of hydrothermal or magmatic-related mineral systems is strongly depth dependent. This is because major changes in fluid pressure and composition occur as deeper magmatic or metasomatic fluids interact with other fluids and structures as they reach shallower crustal levels. These changes in fluid chemistry result in the precipitation of ore minerals. This project is aimed at expanding those applications, by combining mineral-specific C-O and S isotope data with spatial and paragenetic control, major and trace element analyses, and whole rock geochemical data.

The study site at the Sunrise Dam gold deposit in the Archean Yilgarn of Western Australia, solely funded by AngloGold Ashanti, is evaluating C-O isotope variation as a means of understanding the genesis of the orogenic ores, and its use as a halo tool. In 2015, a global database of C-O carbonate data in orogenic gold deposits was completed, which will be used to make comparisons with the results at Sunrise Dam. This work formed part of the preparation of the final report on the study site, which will be released in 2016.

A second activity in this project utilises sulfur isotopes to help constrain the genesis of the Paracatu gold deposit, Minas Gerais, Brazil, which is a slate belt orogenic deposit. The very uniform sulfur isotope compositions of all sulfides (18-22 permil) provided evidence that the source of sulfur was either reduced seawater or biogenic sulfur from an extremely starved basin setting, typical of many Neoproterozoic sequences; and that some mechanism resulted in efficient homogenisation of the sulfur inventory prior to deposition as ore sulfides. This research has been a collaboration with Nick Oliver, and with co-authors a paper on the work was published in Economic Geology during the year.

AUSTRALIAN HYDROTHERMAL IOCG AND RELATED DEPOSITS

Leader: Garry Davidson
Team Members: Stuart Bull, Paul Davidson, Sebastian Mefrite, Jay Thompson
Student: Subhraj Sharma
Collaborators: Bryan Bowden, Greg Clarke, Maxim S Croaker, Geoff Fraser, Harman Freeman, Thomas Rodemann, Roger Skirrow, Rob Smith, Pat Williams

IOCG research occurred on the Prominent Hill (SA), Vulcan (SA) and Mt Dore-Merlin (Qld) deposits during the year. A highlight was convening of an IOCG-focused session at Garry Davidson at the International SEG Conference in Hobart, with 13 presentations and 24 posters.

Prominent Hill and Vulcan South Abstracts on recent work at these sites was presented by Stuart Bull and Greg Clarke at the SEG Conference. Manuscripts for both presentations are in preparation.

Mt Dore-Merlin

Subhraj Sharma’s PhD work on graphite in the felsic to medium felsic ores at Merlin has culminated in submission of a paper to the 2016 IOCG conference focusing on the application of the Parram instrument to these materials. From 2016 onwards, research on iron oxide-apatite/Kuroko-style deposits will be reported in this project. The name of the project will also be shortened to ‘IOCG deposits and related deposits’. Research on Olympic Dam will continue to be reported under its own project heading.

THE CHARACTERISTICS AND ROLE OF COLOIDAL SILICA FLUIDS IN THE FORMATION OF THE GRIEVES SIDDING FO-Zn PROJECT, WESTERN TASMANIA

Leader: Vadim Karnenetsky
Student: Richelle Avid Pascual

Collaborators: Neil Allen, Karsten Goermann, Bernd Lottermoser, Taryn Noble, Thomas Rodemann

This research presents an alternative mechanism to the formation of sphalerite in carbonate-bearing, sediment-hosted base metal deposits. Widely accepted to form through direct crystallisation from an ore fluid, evidence is presented, and modelled, for the evolution of crystalline sphalerite from amorphous precursors within a Zn-rich phase at ambient conditions. The characteristics and role of precursors and the mechanisms related to a step-wise pathway to sphalerite formation have not been explored in natural samples, particularly in ore-hosting sedimentary environments. This research is of most interest to the student of ore genesis, as it expands the knowledge on early sulphide formation, particularly in low temperature base metal deposits. Furthermore, it is expected that the proposed formation mechanism will extend to other metallic or mineral systems that form in the near surface environment.

The coexistence of crystalline sphalerite and amorphous, non-stoichiometric Zn-rich phases in the metal-rich Gries Siding deposit in Tasmania, is inferred to represent a continuous evolution of metastable Zn-organic precursors to sphalerite. The research proposes possible mechanisms of the step-wise process occurring from the heterogeneous nucleation of precursor phases on, and/or within, a Zn-rich clay substrate; recurring growth and maturation by aggregation, coalescence and impurity expulsion; culminating in transformation to sphalerite. Each step is observed to be a progression towards crystallinity and homogeneity, tending to ZnS. Moreover, a significant microbiological influence is implicated in the mineralisation process. The outcomes of this research have been published in Contributions to Mineralogy and Petrology (Avid Pascual et al) and have been submitted for publication in Geology.

THE GEOLOGY, GEOCHEMISTRY AND GENESIS OF THE AVEBURY Ni DEPOSIT: IMPLICATIONS FOR EXPLORATION

Leader: Vadim Karnenetsky
Team Members: Maya Karnenetsky, Sebastien Mefrite
Collaborators: Steve Beresford, Jeff Foster, Karsten Goermann, Alexey Lygin, Roland Maas

The Avebury serpentinite-hosted Ni sulfide deposit in Tasmania is the largest known non-magmatic nickel deposit on Earth. A study to understand the sources of metals and fluids responsible for this style of economic mineralisation have been completed, and a paper on the research has been accepted for publication in American Mineralogist.

This work shows that serpentinisation of the Ni-bearing olivine in the Cambrian peridotites of the Mtovar Hill complex was followed by metasomatic transformation, assisted by heat and fluids supplied by a nearby Late Deccanian granitic intrusion. In the model, Ni was released from magmatic olivine during serpentinisation, rather than being remobilised from magmatic sulfides. The research confirms the viability of a new class of Ni sulfide deposits that are formed by metasomatic and/or hydrothermal modification of peridotites, rather than by magmatic processes.

This project has now concluded.

GEOLOGY AND GENESIS OF THE INVINCIBLE GOLD DEPOSIT, ST IVES

Leader: Robert Scott
Student: David Douch
Collaborators: Ray Cas

In 2015, David Douch commenced a PhD study, funded by Gold Fields, investigating the geology and genesis of the recently discovered >1 Moz Au Invincible deposit in the St Ives Goldfield, Kambalda, W.A. The Invincible deposit is located in a NW trending structural corridor known as the Speedwell fault zone, and is hosted by black shale and underlying anesitic volcanics.
at the top of the Black Flag Group; a 2680 – 2665 Ma package of predominantly felsic to intermediate volcano-sedimentary rocks. The Black Flag Group is overlain by the 2665 Ma Merougil sequence, which consists of arkosic/lithic sandstone, poorly sorted, polymict, pebble to boulder conglomerate, conglomeratic sandstone, and forms the immediate hanging wall of the Invincible deposit. Until the discovery of Invincible, the majority of the more than 12 M ounces of gold produced at St Ives was derived from the older (2720 – 2680 Ma) mafic Kambalda Sequence.

Major goals of this study are to:
- Refine and interpret the internal stratigraphy of the Black Flag and Merougil groups in the vicinity of the Invincible deposit.
- Determine the mineralogy and paragenesis of auriferous veins and altered wall rocks.
- Determine the structural setting, age and controls on gold mineralisation.
- Characterise the geochemical footprint of the deposit.
- Undertake comparisons with gold deposits hosted by mafic rocks (principally dolerites) of the Kambalda Sequence.
- Develop criteria for future exploration based on the results of this study. Of particular interest will be the interplay between structure and host-rock characteristics in controlling the locations of deposits within the goldfield.

Excellent progress has been made in the first year of the project, which focussed on field work and analysis of Gold Fields’ existing geochemical database for the deposit and surrounds. Approximately 23 km of drill core was logged, accessible exposures in open pits mapped, and samples for petrography, geochemistry, geochronology and microstructural studies collected and prepared. A major highlight was the completion of a provenance analysis based on clast types in conglomerates from the Black Flag and Merougil sequences at Invincible. The results of this study aid stratigraphic delineation and have important implications for late basin development in this area and first unroofing of the 2602 Ma Kambalda Granodiorite.

**THEME 6: DATES AND PLATES**

**BUILDING TASMANIA: THE CAMBIAN AND BEYOND**

**Leaders:** Jacqueline Halpin, Robert Scott, Sebastian Melge

**Team Member:** Fon Berry

**Students:** Sally Mattner, Jacob Mulder

**Collaborators:** Clive Calver, Grace Cummings, Nathan Daczko, John Evenard, Mike Hall

This research draws together a number of themes around the early (Precambrian to Cambrian) geological evolution of Tasmania, including the age, affinity and paleo-significance of the cryptic basement and overlying Proterozoic successions, to the accretion of the Tasmanian microcontinent onto the Gondwanan paleo-Pacific margin.

The project was previously named ‘Age, affinity and provenance of Tasmanian Proterozoic metasedimentary successions’. The name has changed to better reflect the wider range of sub-projects that now fall within this research. It was an exceptional year for PhD student Jacob Mulder. Highlights included:
- A paper published in Geology on research that uses U-Pb-Hf isotopes in zircon combined with palaeocurrent data to identify the provenance of the lower-middle Rocky Cape Group of NW Tasmania. This work demonstrates sediments were derived from a combination of source terranes in SW Laurentia and East Antarctica that, along with NW Tasmania, were juxtaposed in the Proterozoic supercontinent Nuna. Jacob showed, through a comprehensive compilation of detrital zircon data, that the Australian mainland was unlikely to have been a prominent source region, supporting a paleo-position of NW Tasmania that differs from its location within Gondwana.
- As a result of the abovementioned research, a team from the ABC’s Catalyst program visited COOBES late in the year to film Jacob, and Jacqueline Halpin, for a segment to be aired in 2016. The team also filmed the researchers on location at Rocky Cape. The paper in Geology attracted widespread national and international media coverage, in addition to the Catalyst program.
- A paper published in the Australian Journal of Earth Sciences entitled ‘The structure and metamorphism of the Red Point Metamorphic Complex–A newly discovered high-pressure metamorphic complex from the south coast of Tasmania’, which was based on his 2013 Honours project.
- A paper ‘in press’ in Gondwana Research that examines the Cambrian tectonic evolution of Tasmania, and specifically the orogenic metamorphic sole rocks exposed in western Tasmania, which record the accretion of Tasmania to the margin of Gondwana in the Cambrian.
- Two presentations by Jacob (and co-authors) at the Geological Society of Australia Specialist Group in Tectonics and Structural Geology conference in Caloundra, Queensland.
- Jacob was awarded the prestigious Endeavour Postgraduate Scholarship by the Australian Government to spend up to two years studying for his PhD overseas at his nominated host institution. As a result, Jacob will spend much of 2016 at the University of New Mexico, under the guidance of Prof. Karl Karstrom, where he will further investigate the ancient links between Tasmania and SW Laurentia.

Other project highlights included:
- Sally Mattner’s Honours project on the structure and metamorphism of the Mersey River metamorphic complex was thrust into the spotlight when a major lake within the complex was drained to allow for the upgrade to a power station. The temporary draining of Lake Rowallan exposed Precambrian rock formations that had not been visible since the last ice Age. This provided Sally with a small, but invaluable window of opportunity to study the formations that are expected to shed light on the geological development of the whole of eastern Australia. The event was supported by a media release, which garnered widespread publicity.
- Jacqueline Halpin presented a talk at the American Geophysical Union Fall Meeting in San Francisco, USA, entitled ‘Tasmania in Nuna: Witness to a ~1.4 Ga East Antarctica–Laurentia Connection’.

**TECTONIC RECONSTRUCTION OF EAST GONDWANA**

**Leader:** Jacqueline Halpin

**Students:** Sally Watson, Toban Wild

**Collaborators:** Mike Coffin, Nathan Daczko, Ian Fitzsimons, Andy Gleadow, Fred Jourdan, Barry Kohn, Luke Milan, Dietmar Müller, Pat Quilty, Jeff Sliver, Joanne Whittaker, Simon Williams, Derek Wyman

The overall aim of this project is to integrate both onshore and offshore geological and geophysical data to produce holistic tectonic reconstructions for both the amalgamation and break up of East Gondwana. In 2015, the scope of this project expanded from the Perth Abyssal Plan, where research was first focussed after a very successful 2011 RV Southern Surveyor cruise, into the previously contiguous parts of Antarctica. This expansion was made possible through three new research grants from UTAS, the University of New England and the Australian Antarctic Division.

Major progress was made on understanding the tectonic evolution of the Perth Abyssal Plan, with two papers submitted for publication. The first by PhD student Sally Watson et al to Gondwana Research on the Dick Hartog Ridge, and the second by Joanne Whittaker et al to Earth and Planetary Science Letters on Microcontinent formation driven by plate motion changes. Whole rock geochemical and isotope results for basaltic from the Perth Abyssal Plan were also generated and a paper is in progress. New geochronological results on basement samples from East Antarctica, combined with plate modelling, have set the scene for a radical rethink of the amalgamation of East Gondwana, with two papers currently in preparation.

Other highlights in 2015 included:
- Two presentations by collaborator Nathan Daczko at the Geological Society of Australia Specialist Group in Tectonics and Structural Geology conference in Caloundra in November.
Collaborator, Andy Wakefield, from Mineral Resources Tasmania, installing passive seismic array equipment.

Collaborators: Daniel Bombardieri, Mark Duffett, Andy Wakefield

This project seeks to improve the understanding of the broad-scale structure of SE Australia, and is being conducted in collaboration with Mineral Resources Tasmania (MRT).

During 2015, further petrophysical data were collected from deep drill core samples housed in MRT’s core store, to constrain geophysical modelling. Using multiple techniques, broad-scale modelling was carried out for eastern Australia, particularly the Moho depth constrained by magnetic Curie point. This work was presented at the Australian Society for Exploration Geophysicists meeting in Perth early in the year.

Further significant progress was made in building detailed models for Tasmania, working closely with geologists from MRT. The challenges of modelling potential fields in the offshore-shore transition, and over large regional scales across this transition, were addressed.

Looking Forward

The Module will continue its evolution in 2016, with a number of projects either commencing, coming to a natural conclusion, moving to other areas, or progressing in new directions of research.

One of the projects coming to a conclusion is ‘Exploring the porphyry environment’, which has been running since 2009. This highly successful project has been operating in collaboration with Newcrest Mining to maximise opportunities for the discovery of porphyry and epithermal related gold resources in the South West Pacific region.

Stephanie Sykora’s PhD project on anhydrite zones at the Lihir gold deposit, PNG, which was being conducted within this project, will continue under the TMVC.

The Module will maintain its presence in Africa through projects in Côte d’Ivoire and Zambia. The Architecture of the Birimian Belts project will be developing a chronostratigraphic framework using whole rock geochemical analyses, building a petrophysical dataset to aid interpretation of geophysics, and refining the tectonostratigraphic model for Côte d’Ivoire and neighbouring countries.

In addition to the work in Africa, the Module will also maintain its truly global footprint through projects in Australia, North America, South America, Europe, and Asia – where Khin Zaw will be conducting further negotiations with potential sponsors to continue and expand research activities in the SE Asian region.

It is also expected to be a milestone year for many of the students within the Module. Highlights of the year will include:

- PhD students Heidi Berkenbosch, Margy Hawke, Erin Lawlis, Evan Orovan and Subira Sharma are all expected to complete their theses, and Charles Makoundi will graduate.
- Master of Economic Geology student Jo Condon will also be graduating, as will Master of Science student Irma Vejelyte.
- Jacob Mulder (PhD) will commence his Endeavour Postgraduate Scholarship at the University of New Mexico, under the guidance of Professor Karl Karlstrom, where he will continue his groundbreaking research into the provenance and age of the upper Rocky Cape Group and Clark Group, and the relationship to source terranes in Laurentia.
OBJECTIVE
To transform how explorers and miners plan and predict mining and environmental activities, by providing new tools to guide these activities from the initial discovery stage through the life of the project.

INTRODUCTION
Geometallurgy is the integration and utilisation of geological, metallurgical, environmental and economic information to maximise the value of an ore body, while minimising technical and operational risk. Through a holistic approach, it identifies attributes that contribute to the realised value of a resource, and enables ore variability to be factored into the flowsheet, infrastructure design, and the production and quality forecasts over the life-of-mine. This includes traditional attributes, such as grade, as well as less traditional factors such as concentration of deleterious elements, hardness (crushability, grindability), mineral species and abundance, mineral liberation, metallurgical recovery, acid generating potential, neutralising potential and smelter enabling characteristics.

Geometallurgy uses integrated tools, methods and knowledge, with an emphasis on ore body knowledge, which can be utilised in mining and mineral processing. A key component is linking geology and mineral processing as inputs into mine planning, optimisation and ultimately valuation.

Over the past decade, the extent of research related to geometallurgy has significantly increased, spurred mainly by an increased interest in the discipline by the minerals industry. This increase in industry involvement led to the large AMIRA P843 and P843A (GeMIII) collaborative projects that ran from 2005 to 2013 and were successful in developing an array of geometallurgical methods and protocols in the areas of mineralogy, comminution and flotation – which were subsequently tested on case study sites in active mines.

Although the GeM project has come to a successful conclusion, this work is continuing to be developed within the Geometallurgy Module. A large part of this research is also being carried out under the Optimising Geometallurgical Prediction Theme, which is one of the three themes established within the new Industrial Transformation Research Hub – Transforming the Mining Value Chain (TMVC).

HIGHLIGHTS
• The new ARC TMVC Research Hub commences operations, with a focus on geometallurgical and geoenvironmental research in two of the three Theme areas.
• Successful CRC ORE II application, which includes CODES as an Essential Partner.
• Anita Parbhakar-Fox appointed as Acting Module Leader.
• Former Module Leader, Julie Hunt, moves to the University of Liege in Belgium, but is retained as a University Associate and a collaborator.
• Technology transfer of GeM research continued, including presentations in Australia, Chile, France and Sweden.
• PhD student Cassady Harraden joins the new TMVC research team.
THE MODULE TEAM

TEAM MEMBERS:
Ron Berry, Leonid Danyushevsky, Sarah Gilbert, Sebastien Mettre

PHD STUDENT:
Angela Escolme

COLLABORATORS:
COPPER MINES OF TASMANIA
Lachlan Brown, Brendan McGee

CRC ORE
Nathan Fox, Taryn Noble

CRC ORE II
Ben Adair, Steve Walters

CSIRO
Louise Fisher

GRANGE RESOURCES
Tony Ferguson, Roger Hill

HOT CHILI
Melanie Leighton

JKMRC/UQ
Khoi Nguyen

MINERAL RESOURCES TASMANIA
David Green

SPECIM LTD.
Rainer Bärts, Kati Laakso

UNIVERSITY OF EXETER, UK / RWTH AACHEN, GERMANY
Ely van Veen, Bernd Lottermoser

UNIVERSITY OF LIEGE, BELGIUM
Julie Hunt

UNIVERSITY OF TASMANIA, CENTRAL SCIENCE LABORATORY
Karsten Goemann

ACTING LEADER:
Anita Parbhakar-Fox

THE YEAR IN REVIEW

KEYSTONES IN PLACE
Two significant events occurred in 2015, which ensure the continued development of geometallurgical and geoenvironmental research within CODES over a sustained period.

TMVC
As foreshadowed in the previous annual report, the ARC TMVC Research Hub came on stream in mid-2015 and included geometallurgical and geoenvironmental research as two of its three focus areas, known as Themes. Theme Two, entitled Optimising Geometallurgical Prediction, includes the geometallurgical characterisation of ores through automated core logging and spectral analysis of drill core, which is enabling 3-D exploration, mining and geometallurgical models to be developed that are continually updated as the exploration or resource drilling program continues. The TMVC is also funding research that builds on the work that had been initiated in the previous GeM project, which fell within the old CODES’ Recovery Program up to the end of 2013.

Theme Three is entitled Minimising Geoenvironmental Risks, and focuses on improving geoenvironmental characterisation practices across the whole life-of-mine chain.

Projects include using hyperspectral data to predict geo-environmental characteristics during mineral exploration, to geometallurgical characterisation of mine wastes to evaluate resource potential.

CRC ORE II
The second key event was the announcement by the Australian Government in May that the application, this outcome ensures that the status of geometallurgy as one of the Centre’s three research Modules has been considerably strengthened.

The key challenge for CRC ORE II is to address the declining productivity in the minerals industry, which is partly due to the propensity for mining companies to focus on quantity over quality during the previous mining boom. CODES expertise in areas such as ore deposit modelling, postgraduate training and ore characterisation will play a key role in the outputs of the CRC over its extended tenure.

The research performed by CRC ORE II is split into five programs: Define, Separate, Extract, Control and Operate, with CODES working within the Define Program, which has the main objective of improving feed quality. There were still one or two administrative processes to be worked through at the end of 2015, but it is expected that these will be completed early in 2016, with CODES involvement in the CRC increasing as the year progresses.

TECHNOLOGY TRANSFER
Although the GeM project ended in mid-2013, the process of transferring the knowledge and expertise developed during the project’s long life cycle continued in 2014 and into 2015.

Examples of this knowledge transfer in 2015 included:

- PhD student Angela Escolme presented papers on her thesis studies, involving ore characterisation and geometallurgical modelling at the Productora copper-gold-molybdenum deposit in Chile, at the SGA Conference in Nancy, France, and the SEG Conference in Hobart, Australia.

- Anita Parbhakar-Fox delivered a presentation on behalf of Ron Berry, entitled ‘Prediction of acid rock drainage (ARD) from calculated mineralogy’, at the 10th ICAFR/ IMWA – the 10th International Conference on Acid Rock Drainage, held in Santiago, Chile.

A number of confidential research reports were presented to industry, including those related to waste rock management and characterisation of tailings, and the research on the ore characterisation and geometallurgical modelling at the Productora Cu-Au-Mo deposit in Chile.

SHORT COURSES
The Geometallurgy Module members provided significant inputs to two short courses during the year. In September, Julie Hunt, supported by Ron Berry, led a post-SEG 2015 Conference short course, entitled ‘Drill core measurements and domaining for geometallurgy’. In the following month, Julie and Ron, together with Acting Module leader Anita Parbhakar-Fox, led the Master of Economic Geology Geometallurgy short course, which included a three-day field trip to northeast and western Tasmania. Invited presenters were Dee Bradshaw (University of Queensland) and Melissa Humphries (School of Physical Sciences, UTAS). This course is covered in more detail in the Training Module section of this Annual Report.

POSTGRADUATE RESEARCH
PhD student Angela Escolme continued with her project entitled: Ore characterisation and geometallurgical modelling at the Productora Cu-Au-Mo deposit, Chile, which aims to determine relationships between ore textures, alteration and geochemical zonation patterns, and assess their impact on liberation behaviour and recovery response at the deposit.

Quantitative and predictive geometallurgical models of processing behaviour have now been developed, which integrate the existing 33 element ICP-AES database. In 2015, calculations of modal mineralogy from assay data were finalised and validated, and deposit-wide data for predicted ore classifications was modelled in 3D. Models were also developed to predict comminution parameters and copper recovery using the calculated modal mineralogy and geochemical database. Sample preparation for geochemical analysis is currently underway in order to develop a revised geological model. Oral presentations on the geometallurgy and geology of Productora were given at both the SEG and SGA conferences.

PhD student Cassidy Harraden was transferred to the TMVC team during the year, and her research is reported within the TMVC’s section of this report.
LOOKING FORWARD

It is anticipated that the final administrative processes for CODES’ participation in CRC ORE II will be finalised early in 2016, which will signal the start of a significant increase in Module activities in the years ahead.

As activities within the new TMVC start to gather pace, collaborations between the two areas will further develop, specifically in relation to geometallurgical and geoenvironmental research.

Anita Parbhakar-Fox will continue as Acting Module Leader, with applications for the position expected to be considered in the latter half of the year.

Anita will help pursue geometallurgical and geoenvironmental AMIRA proposals, and one-on-one collaborations with industry and local stakeholders in 2016.

A highlight of 2016 will be the AusIMM GeoMet 2016 Conference at Perth’s Pan Pacific Hotel in June. As a member of the Organising Committee, Anita has played a key role in securing speakers for the event, which include team members from both the Geometallurgy Module and the TMVC: Angela Escolme, Laura Jackson, Nathan Fox, and Cassady Harraden – plus Anita, who will also be co-leading a geoenvironmental workshop at the conference.

Angela Escolme’s PhD study at the Productora deposit in Chile will be transferred to the TMVC from the beginning of the year. A key development in this project in 2016 will be the acquisition and interpretation of geochemical data (including radiogenic and stable isotopes, and mineral chemistry) to support a revised deposit model.
OBJECTIVES
Research activities within the Module are aimed at developing new analytical techniques and new computational algorithms for big data knowledge discovery, the modelling of crystallisation and melting processes, and analytical data reduction; thereby ensuring that the research is driven by innovative technology and CODES is at the cutting edge of analytical and computational developments of relevance to ore deposit research.

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

INTRODUCTION
The Enabling Technologies Module explores and develops novel analytical and data interpretation techniques based on the latest technological and algorithmic developments, such as a number of high spatial resolution microprobes and big data knowledge discovery techniques. This helps in the understanding, exploration and exploitation of deep earth resources.

Current research projects focus predominantly on expanding the capabilities of laser ablation inductively-coupled plasma mass-spectrometry (LA-ICP-MS) for geological applications, development of algorithms for big data knowledge discovery, modelling of geological processes, analytical data reduction, and the development of new, user-friendly software packages. In 2015, a significant proportion of research activities were focused on projects that underpin the research occurring within the ARC TMVC Research Hub.

The analytical projects using LA-ICP-MS include in-situ multi-element analysis and imaging of element distribution within minerals; in-situ isotope analysis, focussing on a range of U-Pb dating applications and Pb isotope measurements; development of calibration standards; and technological developments aimed at improving the capabilities of the laser microprobes. The computational projects include target generation from data-driven computations, computational knowledge discovery from high-dimensional (high-D) data, modelling of melting and crystallisation, and geodata visualisation.

Many of the projects involve close collaborations with national and international research groups and equipment manufacturers.

HIGHLIGHTS
NEW EQUIPMENT
In 2015, CODES made a successful application to the University of Tasmania (UTAS) for funding to purchase and install a new generation Time-Of-Flight ICP-MS instrument, from TOFWERK, which is capable of the simultaneous detection of virtually the entire periodic table, including all the elements applicable to this application. This will be the first TOFWERK instrument to be installed in Australia, and its addition to the technology facilities will significantly enhance CODES’ capabilities in the rapidly developing field of imaging trace element distributions in minerals using LA-ICP-MS.

CODES was also successful with its application for funding to the Australian Research Council and UTAS for a new generation field-emission gun sub-micron resolution electron microprobe, which will provide for new capabilities for imaging and identification of micro-inclusions in minerals.

RESEARCH
The main research focus during the year centred on understanding the fundamentals of H₂O-free inductively-coupled plasma and refining algorithms for big data knowledge discovery. Analytical and computational developments included:

ANALYTICAL DEVELOPMENTS

• Investigation of ion energy in the ICP-MS has improved understanding of the instrumentation for laser ablation in geological materials.

• The installation of two new types of excimer laser ablation systems, 193nm ATL ArF and 248nm ATL KrF, has further expanded CODES’ research and analytical capabilities.

• Changes to the operating procedures have resulted in a decrease of the matrix effects during Pb/U dating, leading to improved accuracy.

COMPUTATIONAL DEVELOPMENTS

• Development of robust and intuitive workflows in open source software for supervised and unsupervised learning approaches to geological modelling.

• Release of “Tagger” — an application that enables interactive data analytics for geoscience.

• Foundation work continued on changepoint detection applied to spatial data.

AWARD
Jay Thompson was presented with the UTAS Faculty of Science Engineering and Technology Dean’s Award for professional staff. Jay received the award for his contribution to the ongoing operations of the LA-ICP-MS and XRF facilities, and the overall R&D program within the CODES Analytical Laboratories.

AMAS XIII
CODES hosted AMAS XIII, the 13th biennial Australian Microbeam Analysis Symposium, in the early part of the year. The program commenced with two days of Pre-Meeting Workshops on February 9 and 10, which were immediately followed by the main symposium from February 11 to 13.

This major event in the field of microanalysis and imaging attracted 118 delegates from all around Australia, and included talks by over 50 of the world’s leading experts.

The symposium was led by Leonid Danyushhevsky and Karsten Goemann (UTAS Central Science Laboratory). Leonid also conducted a Pre-Meeting Workshop on LA-ICP-MS, and team members Sarah Gilbert, Sebastien Meffre and Jay Thompson each gave talks during the main symposium.
THE MODULE TEAM

LEADER: Leonid Danyushevsky

TEAM MEMBERS:
- Ivan Belousov, Matt Cracknell, Sarah Gilbert, Elena Lounejeva, Sebastien Meffre, Paul Olin, Anya Reading, Sava Stepanov, Jay Thompson

PHD STUDENTS:
- Stephen Kuhn, Peter Morse, Sarah Gilbert, Paul Olin, Jay Thompson

COLLABORATORS:
- AGILENT TECHNOLOGIES
  - Fred Fryer
- BHP BILLITON
  - Kathy Ehrg
- ETH ZURICH, SWITZERLAND
  - Detlef Gunther, Joachim Koch
- FIRST QUANTUM MINERALS
  - Tim Ireland, Chris Wijns
- UNIVERSITY OF MELBOURNE
  - Roland Maas
- UNIVERSITY OF WAIKATO, NEW ZEALAND
  - Shaun Barker
- QUEENSLAND UNIVERSITY OF TECHNOLOGY
  - Charlotte Allen
- RIO TINTO
  - Paul Agnew, Alan Kobussen

NEWCREST MINING
- Anthony Harris

NORRIS SOFTWARE
- Ashley Norris

UNIVERSITY OF TASMANIA
- Christopher Lueg

UNIVERSITY OF MELBOURNE
- Roland Maas

UNIVERSITY OF WAIKATO, NEW ZEALAND
- Shaun Barker

UNIVERSITY OF MELBOURNE
- Roland Maas

RIO TINTO
- Paul Agnew, Alan Kobussen

PROJECT SUMMARIES

THEME 1 ANALYTICAL DEVELOPMENTS

- Fundamentals of ICP-MS
- Fundamentals of laser ablation
- Element mapping by LA-ICP-MS
- Calibration standards for LA-ICP-MS
- LA-ICP-MS instrumentation development
- U-Pb dating

THEME 2 ALGORITHMS AND SOFTWARE FOR GEOCHEMICAL MODELLING AND ANALYTICAL DATA PROCESSING

- LA-ICP-MS data reduction software
- Modeling of crystallisation and melting processes

THEME 3 COMPUTATIONAL KNOWLEDGE DISCOVERY FOR GEOSCIENCE

- Target generation and geology map refinement from data-driven computation
- Technique development in computational knowledge discovery from high-Q data
- Geodata analytics, visualisation and decisions

THEME 4 FOR GEOSCIENCE KNOWLEDGE DISCOVERY

- Enabling Technologies

FUNDAMENTALS OF LASER ABLATION

LEADERS: Sarah Gilbert, Leonid Danyushevsky

TEAM MEMBERS: Sebastien Meffre, Paul Olin, Jay Thompson

COLLABORATORS: Charlotte Allen, Shaun Barker, Kathy Ehrg, Fred Fryer, Detlef Gunther, Joachim Koch, Ric Russo, Michael Shelley

This project aims to gain a better understanding of laser ablation processes, leading to improved analysis of geological materials, especially sulfide.

In 2015, two new 4 ns pulse-width laser ablation systems (ArF 193 nm and KrF 248 nm excimer lasers) were installed, thus expanding the range of laser microprobes within the CODES Analytical Laboratories. Research was mainly focussed on understanding the impact of laser beam frequency, pulse width, and energy on the ablation of a range of sulfide minerals with small spot sizes. The main outcomes included:

- Improved capabilities for analysis of trace elements in copper-rich sulfide minerals by using the 248 nm 4 ns excimer laser, which reduces signal drop for small spot size analyses (beam size < 25 μm). Morphologies of ablation craters in sulfide minerals, produced by different laser microprobes, were compared using a high-resolution FE-SEM at the UTAS Central Science Laboratory, revealing variations in the amount and distribution of melted material.
- Ablation characteristics of pyrite are dependent on the amount and range of trace elements present as micro-inclusions. Pyrites with a large concentration of micro inclusions are characterised by a more regular ablation, leading to a different behaviour of sulfur.
- Demonstration of the ability of the high sensitivity 248 nm LA-ICP-MS system to characterise micron-scale gold rims on pyrite grains by utilising a small beam size (~4 μm).
U-Pb DATING

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Key objectives are to develop new analytical procedures and algorithms for mapping the distribution of trace elements in geological materials by LA-ICP-MS. In 2016, the main focus was on conducting an initial assessment of the requirements for the integration of data from digital cameras, short wave infrared spectrometers, Raman spectrometry, handheld pXRF spectrometers and LA-ICP-MS. Once integrated, this data will be used for extracting information on element deportment, mineral chemistry, and mineral association. It will also be used to acquire other important mineral-based information. For example, it will provide the ability to automatically distinguish between gold in solid solution, and gold in particles. These activities underpin several projects that will be occurring within the ARC TMVC Research Hub. In 2016, the team will continue testing and refining the methods for:
• Automated mineral identification from images of elemental distributions in geological samples.
• Matrix correction algorithms during data reduction.

CALIBRATION STANDARDS FOR LA-ICP-MS

Leaders: Ivan Belousov, Leonid Danyushesvsky

This project is aimed at the development and characterisation of new calibration standards for LA-ICP-MS analysis of various geological materials. During the year, a new calibration standard (STDLG3) for the analysis of sulfides was developed and its homogeneity tested. The relative standard deviations (RSDs) at 50 µm spatial resolution were within 5% for Au and Pt, 7% for Se, and 3% for most other elements.

Work has commenced on assessing matrix-dependent fractionation when using STDLG3 for the analysis of sulfides. The chosen approach is to use pressed pellets of finely ground sulfide mix (0.5 micron) of known composition as proxies for sulfide crystals, which involves determining the correction factors that will be applied to quantified results based on STDLG3. Currently, the testing involves a range of nanosecond pulse width laser ablation systems: 193 nm excimer lasers with variable pulse widths, a 213 nm Nd:YAG laser, and a 248 nm excimer laser.

The focus was on quantifying fractionation between metals and sulfur, and between volatile and refractory metals (e.g., Zn, Cd, W relative to Fe).

LA-ICP-MS INSTRUMENTATION DEVELOPMENT

Leader: Leonid Danyushesvsky

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

The main activities during the year were related to understanding the effect of the design and configuration of the gas mixing tunnel of the S-155 ablation cell, in combination with the length and configuration of the interface between the laser probe and ICP-MS, on the instrumentation wash-out times, aimed at improving imaging capabilities. These activities form part of the technological developments within the ARC TMVC Research Hub. Testing of a simultaneous detection TOF-ICP-MS model (TOFwerk, Switzerland) has demonstrated its advanced capabilities for imaging applications with LA-ICP-MS. This instrument will be installed at CODES Analytical Laboratories in 2016.

U-Pb DATING

Leader: Jay Thompson

Team Members: Leonid Danyushesvsky, Sebastien Meffre

Collaborator: Roland Maas

This project investigates the causes of limitations of Pb/U dating of minerals by LA-ICP-MS, with the aim of improving laboratory practices and instrumentation parameters to lower systematic errors and improve precision. Zinc is the primary mineral investigated, however ongoing investigations for apatite, ununinite, and monazite are currently underway.

This year, the main focus was on investigations into:
• The use of lower laser energy to decrease crater depth, element fractionation and matrix effects in the mineral zircon.
• The use of an optical profiler to improve accuracy by applying a correction to data based on precise crater depth measurements.
• Apatite matrix effects for Pb/U dating. Bulk digestion EI-ICP-MS determination is used to understand the causes of matrix effects that are seen by LA-ICP-MS.
• The causes of ICP-MS U-Pb and Pb-Pb drift. Successfully resolving the causes has allowed for more reliable analyses over longer sessions, leading to common use of 24-hour long sessions.

THEME 2

ALGORITHMS AND SOFTWARE FOR GEOCHEMICAL MODELLING AND ANALYTICAL DATA PROCESSING

LA-ICP-MS DATA REDUCTION SOFTWARE

Leader: Leonid Danyushesvsky

Team Members: Sarah Gilbert, Sebastien Meffre, Sasha Stepansov, Jay Thompson

Collaborators: Paul Agnew, Anthony Harris, Alan Kobussen, Ashley Norris

This project, partially co-funded by Newcrest Mining (until April 2014) and Rio Tinto (from December 2014) as part of their support for the R&D program of the CODES Analytical Laboratories, aims to develop comprehensive, user-friendly LA-ICP-MS data processing software, capable of:
• Quantification of data acquired using multiple calibration standards and a range of internal standard elements.
• Quantification of images depicting distribution of major and trace element concentrations in fine-grained multi-mineral aggregates of sulfides, silicates, phosphates and carbonates.
• Identification of mineral phases in, and sizes of, micro inclusions in minerals.

Activities in 2015 were directed toward developing algorithms for identification of time-resolved signals free of micro-inclusions; advanced handling of time-resolved instrumentation backgrounds and calibrations; and algorithms for un-mixing time-resolved signals recorded during ablation of fine-grained mineral aggregates. A fully functional beta-version was installed for testing in-house, and at the Rio Tinto analytical facility.

MODELLING OF CRYSTALISATION AND MELTING PROCESSES

Leader: Leonid Danyushesvsky

Collaborators: Alexey Ariskin, Pavel Peotchov

The aims of this project are to:
• Develop model-independent algorithms for tracking the behaviour of trace elements during magma generation and evolution processes.
• Conduct modelling of post-entrapment modifications in melt inclusions in minerals.
• Simulate processes of mantle and crustal melting, and melt crystallisation.
• Develop a range of general petrological tools. (These algorithms are continuously implemented in future versions of the ‘Petrolog’ software package).

In 2015, work continued on developing a new model for plagioclase-silicate

FROM TOP: Mike Hamil from Australian Scientific Instruments, aligning laser beams on the RESolution laser probe; Sarah Gilbert presenting at the AMAS Xlll Symposium; Sebastien Meffre (Ph Slamming David Beatty, from AUSAL, the LA-ICP-MS facilities.

ENABLING TECHNOLOGIES
melt equilibrium under hydrous conditions at variable pressures, and incorporating a new model of sulfur solubility in silicate melts into the Petrolog3 software. An updated version of this software will be made available on the Petrolog home page in 2016 (http://petrolog.web.ru).

**THEME 3**  
**COMPUTATIONAL KNOWLEDGE DISCOVERY FOR GEOSCIENCE**

**TARGET GENERATION AND GEOLOGY MAP REFINEMENT FROM DATA-DRIVEN COMPUTATION**

**Leader:** Matthew Cracknell  
**Team Member:** Anya Reading  
**Student:** Stephen Kuhn  
**Collaborators:** Andrew Foley, Tim Ireland, Chris Wijns

This project aims to test and refine supervised and unsupervised learning methods for the automated classification of lithology and alteration zonation from geological, geophysical and geochemical data. By exploring unique characteristics of individual ore deposit styles (e.g., orogenic gold, sedimentary copper, etc.) this project will identify mineralisation targets, especially in areas concealed by overlying geological strata.

**TECHNIQUE DEVELOPMENT IN COMPUTATIONAL KNOWLEDGE DISCOVERY FROM HIGH-D DATA**

**Leader:** Anya Reading  
**Team Member:** Matthew Cracknell

This project is aimed at computational knowledge discovery from high-dimensional (high-D) data. During 2015, computational experiments were conducted on several projects relating to knowledge discovery from multi-layered data. Work of this nature is the ‘sand pit’ from which successful applied Earth informatics workflows emerge. One experiment looked at the potential for the use of changepoint methods on similar datasets to those that have been used successfully in other machine learning applications, such as the improvement of geological maps using lithology prediction on high-D data. These computational experiments will continue in 2016.

**GEODATA ANALYTICS, VISUALISATION AND DECISIONS**

**Leader:** Anya Reading  
**Student:** Peter Morse  
**Collaborator:** Christopher Lueg

This project expands the scope of research undertaken within CODES and the Discipline of Earth Sciences into geodata analytics and innovative visualisation strategies. By utilising the existing expertise in technique development and the practical application of methods in computational geophysics and Earth informatics, the project focuses on using the visualisation as part of the data inference process, rather than being simply a way of viewing the final output.

2015 saw the release of the beta version of the ‘Tagger’ application, developed by PhD student Peter Morse, for the reconnaissance analysis of large volumes of geosciences data. This application combines high-performance graphics with the ability to work with scientific format data located locally or on a cloud-based platform. Peter gave an invited talk at the ‘IEEE International Symposium on Big Data Visual Analytics’, held in Hobart. Amongst other topics, he presented an overview of the visualisation process behind the Pausiris Mummy exhibit (commissioned for the opening of MONA in 2011).

**LOOKING FORWARD**

During 2016, research activities within the Module will focus on continuing analytical and computational developments. Analytical developments will include:

- Characterisation of the ablation process for a range of sulfide minerals, using the 248 nm excimer laser system.
- Finalising the development of the STDGL3 sulfide standard, and determination of correction coefficients for different laser systems and sulfide minerals.
- Testing of ablation cell designs, with the aim of developing a fast response, low memory cell for improved imaging capabilities and throughput.

Computational developments will include:

- The construction of informative models of the Zambian Copperbelt, through the integration of soil geochemical and airborne geophysical data.
- The trial of methods for detection of major lithology contacts under cover.

The addition of two significant items of equipment during 2016 will further enhance the technical facilities within CODES’ Analytical Laboratories. The planned installation of a new Time-of-flight (TOF) ICP-MS will enable improved LA-ICP-MS imaging capabilities, while the new optical profiler will allow for routine crater depth measurements to be performed, leading to more accurate Pb/U dating applications.

Several papers will be submitted to international peer-reviewed journals, covering research on:

- Application of ‘Tagger’ to interactive data analytics for geoscience.
- Formation of oxide species in LA-ICP-MS.
- Matrix effects of U-Pb dating ofapatites by LA-ICP-MS.

In addition to the Module activities, team members will be increasingly involved with the research being performed by the TMVC Research Hub. Assistance will focus on:

- Developing data processing algorithms for high data generating scanning sample characterisation equipment, such as the CoreScan drill core logger.
- Applying big data approaches to geoenvironmental prediction.
- Building laser ablation sample cells capable of accommodating large sections of drill core.

FROM LEFT: Classification results from the St Ives project (left: sample data, right: output/train). Classification Trees / Random Forests example from the software used to execute machine learning.
TRAINING

OBJECTIVES
- Provide an ongoing supply of world class PhD, Masters and Honours geoscience graduates.
- Deliver a range of professional development short courses and workshops tailored to meet the needs of the minerals industry in terms of re- and up-skilling its workforce.

INTRODUCTION
The Centre has developed an international reputation for delivering excellence in postgraduate education, which includes providing students with a comprehensive grounding in the Earth sciences. Students come from all parts of the world to study at CODES, with many progressing to senior roles in the minerals industry, state and federal governments, and academia.

Training activities also play a vital role in the Centre’s research program via a wide array of student theses, which are integral to research activities throughout the other three Modules. In recognition of these attributes, CODES has developed a Module within its structure dedicated solely to training. Areas covered under this Module range from the Higher Degree by Research (HDR), Master of Economic Geology and Honours programs, through to a variety of short courses and workshops, most of which are aimed at re- and up-skilling of professionals in the minerals industry.

HIGHLIGHTS
It was another good year for the Training Module, which was marked by healthy enrolments for both the HDR and Master of Economic Geology programs. There were 12 new enrolments for the HDR program, up from nine in 2014. This figure included a record high of nine Australian enrolments, which bettered the previous figure of seven, set just last year.

The Master of Economic Geology Program enjoyed another strong year, with the number of UTAS-based students active in the program equalling an all-time high, complemented by a good throughput of completions and graduations.

Anya Reading was appointed as joint leader of the Module in January, taking over from Jocelyn McPhie who retired at the end of 2014. Anya’s primary role will be as Graduate Research Co-ordinator. Anya brings a wealth of experience to the role, particularly in relation to HDR training and student liaison, ensuring a smooth handover from Jocelyn, who performed these duties with distinction for a number of years.

The postgraduate students continued to make major contributions to Centre activities during the year. For example, they produced 11 chapters in books, 22 refereed journal articles, and presented 25 papers and 30 posters at major international conferences in Australia, Canada, Chile, the Czech Republic, France and Peru.

A highlight of the CODES SEG Student Chapter’s professional development program was the 19-day field trip to Iceland and Sweden, where the students enjoyed a hands-on learning experience on the mineralisation and alteration processes related to hydrothermal systems in ancient and modern volcanic terranes.
Australian students Nathan Chapman, enrolments were comprised of (54 PhD and 2 MSc), which included enrolled in the program during 2015. There was a total of 56 students opportunities for local applicants. a greater prevalence of scholarship Australia’s minerals industry, plus the intake of nine new domestic candidates continued to gain momentum, with the enrolments for Australian students remained high, the trend of increasing nationalities. However, even though continued in 2015 with over 30 research training centre. This success students from overseas is underpinned CODES’ success in attracting HDR projects made a major contribution to CODES’ research activities. Ninety per cent of HDR programs are integrated into the Centre’s three research modules and the ARC TMVC Research Hub, and about 80% of the projects involve collaborations with the minerals industry. CODES’ success in attracting HDR students from overseas is underpinned by its international reputation as a research training centre. This success continued in 2015 with over 30 international students enrolled in the program, representing a total of 17 nationalities. However, even though the ratio of international students remained high, the trend of increasing enrolments for Australian students continued to gain momentum, with the intake of nine new domestic candidates beating the previous year’s record high of seven. This is considered to be partly due to the challenging employment conditions that continue within Australia’s minerals industry, plus the greater prevalence of scholarship opportunities for local applicants. There was a total of 56 students enrolled in the program during 2015 (54 PhD and 2 MSc), which included 12 new PhD students. These new enrolments were comprised of Australian students Nathan Chapman, strong year in 2015, with the number of UTAS-based students active in the program equaling an all-time high, complemented by a good thoroughness of completions and graduations. Nine students graduated: Billy Beas, Lynelle Blindie, Peter Duerden, Phil Gilmore, Xuan Truong Le, Neil Macalalad, Michael Musaikie, Stephanie Robertson and Edward Summerhayes. In addition, Imam Malik, Maria Faustino and Joanna Condon completed their degrees late in the year, and will be eligible to graduate in 2016. These departures have been balanced by an intake of eleven new students, with another two lapsed students also re-joining the program. This brings the total number of UTAS-based students active in the program to a record equaling 52 – and with a marked increase in enrolments from prospective students towards the end of the year, the signs are good that this success will be carried forward into 2016. CODES ran three Master of Economic Geology short courses (units) during the year, in line with its usual biennial model of scheduling. Despite challenging circumstances in the minerals industry, attendance figures were only slightly down in comparison with the same courses held in previous years. The coursework based Master of Economic Geology degree at CODES forms part of the national Minerals Geoscience Masters (MGM) program – a collaboration between UWA, JCU and UTAS. The MGM remains the course of choice for industry-based geoscientists, attracted by the opportunity of studying for an internationally recognised degree, while still being able to pursue their careers in the minerals industry. The Centre’s Master of Economic Geology Program enjoyed another first-hand experience in one of the premier mineral provinces of the world. Deposit types visited included porphyry, epithermal, IOCG, skarn and MVT deposits, and the trip included visits to some of the world’s largest mines. CODES and invited presenters with a diverse spread of expertise. The invited experts were Rick Sibson (Otago University), Shaun Barker (University of Waiako), Phil Bevin (Geological Survey of NSW), Lesley Wyborn (Geoscience Australia), and respected minerals industry consultants, Scott Halley and Nick Oliver. The final unit for the year was held over the last two weeks of October, attracting 15 participants. Geometallurgy was ably led and organised by Ron Berry, Julie Hunt, and Anita Parbhakar-Fox. Invited presenters were Dve Braidshaw (University of Queensland / University of Cape Town) and Melissa Humphries (School of Physical Sciences, UTAS). The course covered key aspects of this highly specialised field, including rock properties, sample selection, mineralogy, comminution and mineral processing, statistical analysis and modelling, environmental issues, and finances. The short course included a three-day field trip to northwest and western Tasmania, visiting the ALS Laboratory in Burnie, Grange Resources’ Savage River iron ore mine, and Bluestone Mines Tasmania’s Renison Tin mine. CODES extends its gratitude to the staff at each of these facilities for arranging visits that were both enjoyable and highly informative. Special thanks also go to both Ron (retired) and Julie (now with Université de Liège, Belgium), who voluntarily gave up their time to, once again, run a very successful short course, which they first delivered in 2012.

ORE DEPOSIT GEOCHEMISTRY, HYDROLOGY AND GEochronology

Nathan Fox and David Cooke devised a packed program for the second short course of the year. Ore Deposit Geochemistry, Hydrology and Geochronology, held in June, was attended by 22 Masters students, with class numbers swelled further by the attendance of up to 15 CODES Honours and PhD students, who attended all or part of the short course. The course is designed to introduce participants to a range of geochemical, isotopic, hydrological, and geochronological techniques used to interpret ore genesis and ore forming environments. The unit was delivered by a mixture of CODES and invited presenters with a diverse spread of expertise. The invited experts were Rick Sibson (Otago University), Shaun Barker (University of Waiako), Phil Bevin (Geological Survey of NSW), Lesley Wyborn (Geoscience Australia), and respected minerals industry consultants, Scott Halley and Nick Oliver. The final unit for the year was held over the last two weeks of October, attracting 15 participants. Geometallurgy was ably led and organised by Ron Berry, Julie Hunt, and Anita Parbhakar-Fox. Invited presenters were Dve Braidshaw (University of Queensland / University of Cape Town) and Melissa Humphries (School of Physical Sciences, UTAS). The course covered key aspects of this highly specialised field, including rock properties, sample selection, mineralogy, comminution and mineral processing, statistical analysis and modelling, environmental issues, and finances. The short course included a three-day field trip to northwest and western Tasmania, visiting the ALS Laboratory in Burnie, Grange Resources’ Savage River iron ore mine, and Bluestone Mines Tasmania’s Renison Tin mine. CODES extends its gratitude to the staff at each of these facilities for arranging visits that were both enjoyable and highly informative. Special thanks also go to both Ron (retired) and Julie (now with Université de Liège, Belgium), who voluntarily gave up their time to, once again, run a very successful short course, which they first delivered in 2012.

THE PROGRAM FOR 2016:

• 6 – 20 March: Volcanology and Mineralisation in Volcanic Terrains (KEA703 / KEA708)
• 30 May – 10 June: Exploration in Brownfield Terrains (KEA705 / KEA710)
• 17 – 28 October: ore Deposit Models and Exploration Strategies (KEA701 / KEA712)

From left: Graduates Phil Glimer (Master of Economic Geology), Jeff Druilhl (PhD), and Sarah Gilbert (PhD).
HONOURS PROGRAM
The Honours program was coordinated by Garry Davidson and David Selley, who administered 20 students in the first half of the year and 12 thereafter, taking into account students that either enrolled or completed mid-year.

Out of this cohort, Adam Abersteiner joined the group from the Australian National University, Melanie Haycroft from the University of New South Wales, Jake Molten from the University of Adelaide, and Murray Brownings and Mark Geddings, both from James Cook University. The remaining students came to the program via an undergraduate degree at the University of Tasmania.

The program saw four departures prior to thesis completion, which is an unusually high number. As it has been rare to have even one departure from this program during an academic year, this is expected to be an anomalous occurrence, restricted to 2015.

The projects covered most of the subject areas, with only classical sedimentology not represented. The distribution was economic geology (5), geophysics (4), igneous geochemistry (3), environmental geology (2), volcanology (2), ocean chemistry (2), structural geology (1), geochronology (1), and palaeontology (1). Ten of the projects were based in Tasmania, five on the mainland, and six overseas, including Myanmar (2), South Africa/Finnland, South Pacific, Japan and New Caledonia.

One highlight of the year was the completion of a study by Jake Molten into methods of identifying completion of a study by Jake Moltzen from the West Tasmanian region. This study, restricted to 2015.

Potential, with participants asked to identify any previously untested areas in which base metal deposits could be feasibly occur within 500 m of the surface.

The eight-day camp was held twice, in February and March, with a total of 48 students from eight universities participating.

Due to the current downturn in the minerals industry, and the consequent reduction of funding to MTEC, 2015 sadly saw the demise of MTEC's long-running and very successful Minerals Geoscience Honours Program Honours coursework program.

ORE DEPOSIT MODELS
Course Presenter: David Cooke, Garry Davidson, Bruce Gemmell, Robert Scott, David Selley, Jeff Steadman
In May, 12 students attended the five-day Ore Deposit Models Honours-level short course, which provides an introduction to the key features of several major classes of economically important mineral deposits. Each deposit style was discussed in terms of geological and tectonic framework, mineralisation, alteration, genetic models and exploration criteria.

The deposits covered were:
- Volcanic hosted massive sulfide.
- Epithermal, porphyry copper and skarn.
- Iron-oxide copper gold.
- Sediment-hosted orogenic gold.
- Sediment hosted uranium, copper and lead-zinc.

Each day of the short course involved a mixture of lectures and practical exercises. Lectures covered the general characteristics and setting of the aforementioned deposit types, as well as the various genetic models that have been put forward to explain their formation. In the practical exercises, students examined and interpreted samples from many of the premier mineral deposits and mineralised districts throughout the world.

PRACTICAL IGNEOUS PETROLOGY
Course Presenter: Leonid Danyshevsky
Also in May, 17 students attended the five-day Practical Igneous Petrology course presented by Leonid Danyshevsky. The five-day program is a mixture of lectures and practical exercises, aimed at postgraduate students at Honours level and above with an interest in the formation and evolution of basic and ultrabasic magmas and their relationship to magmatic ore deposits.

Topics covered included:
- Key theoretical aspects of petrology, including units of concentration, solid solution and mineral formulas, activities and equilibrium, the phase rule, mass balance, phase diagrams, and equilibrium/fractional crystallisation.
- Examination of a large layered intrusion (the Doyeren Magmatic Complex in Siberia), the effects of pressure and H_2O on melting and crystallisation, and the causes of melting and crystallisation.
- An introduction to the concept of distribution coefficients for trace elements.
- Trace elements in the main rock-forming minerals.
- Modelling of crystallisation and studies of melt inclusions.
- Reviews from MORB, subduction-related lavas and komatiites.
STUDENT PROJECTS IN AUSTRALIA

Project locations are shown in capitals. Unless marked otherwise, student projects shown here are PhDs. Projects related to the ARC TMVC Research Hub are marked with an asterisk.

1. ANDEMESKEL, EYOBI. TAS (Masters)
   Litho- and chemo-stratigraphic, structural and mineral prospectivity aspects of the Rosebery Group, an enigmatic Cambrian volcano-sedimentary succession on Tasmania’s west coast.

2. APUKHTINA, OLOGA. SA
   Stable isotopes (C, S and O) and halogens (Cl, F) in gangue and ore minerals at Olympic Dam: Evaluation of mantle and crustal contributions to mineralisation.

3. AWD-PASCUAL, RICHELLE. TAS
   The characteristics and role of coloids in the mineral formation in Gneisses Siding Zn-Pb-Pt deposit, western Tasmania.

4. BAKER, WAYNE. WA (Hons)
   Sulfide textures at Tropicana Gold Mine: Relationship to deposit genesis, gold deportment and implications for ore processing, exploration, and environment.

5. CAVILL, CHLOE. VIC (Masters)
   Geochemical classification of onebearing/metaliferous fluids of the Costerfield region, Victoria.

6. CHAPMAN, NATHAN. SA
   Pb-isotopic insights into the crustal evolution and metallogenesis of the Gawler Craton.

7. CHERRY, ALEXANDER. SA
   Petrology, provenance and composition of bedded sedimentary facies in the Olympic Dam deposit.

8. CONDON, JOANNA. WA (Masters)

9. DOUTCH, DAVID. WA
   The geology and geological controls on gold mineralisation at the Invincible deposit, St Ives Gold Mine, Kambalda, WA.

10. ESHAGHI, ESMAEIL. TAS
    3D petrophysical and geophysical modeling of west and northwest Tasmania.

11. FERGUSON, MATT. SA
    Regional metal and fluid sources for IOCG mineralisation around Olympic Dam, and geology, geochronology and mineral-chemical zonation of the Wirra Well deposit.

12. GIULIANI, BERNADETTA. VIC (Hons)
    Basaltic volcanic successions in the Ordovician Girldambore Group, New South Wales.

13. FOX, JODI. TAS
    Exhalative horizons and volcanic-associated massive sulfide mineralisation in the Ordovician Girldambore Group, New South Wales.

14. GILMORE, PHIL. NSW (Masters)
    Geochemical, geophysical, investigations of the L13 Prospect, Highclaire, Northwest Tasmania.

15. HARDWICK, BRENDAN. WA (Masters)
    Distribution of, and controls upon, pyrite trace element content of hydrothermal alteration zones at Hercules VHMS ore deposit, Tasmania and NCO IOCG ore deposit, Northwest Territories, Canada.

16. HARRADE, CASSANDRA. NSW (Hons)
    Geotechnical and geomechanical assessment of the Cadia East deposit using Corescan automated logging technology.

17. HAUKE, MARGOY. WA
    Geological evolution of the DeGrussa Cu-Au VHMS deposit, Western Australia.

18. HAYCROFT, MELANIE. NS (Hons)
    The eastern mineralisation, Broken Hill, NSW.

19. HILDREW, CHRIS. WA (Hons)
    Understanding the nature of the host rock succession to the Archaean Nimbus Ag-Zn-Pb-Au deposit, WA.

20. HOLMES, TRAVIS. TAS (Hons)
    Geology, timing and controls on alteration and mineralisation at the Big Wilson Tin Prospect, NW Tasmania.

21. HONG, WEI. TAS
    Magmatic-hydrothermal volatile evolution and mineralisation in Tasmanian Sn granites.

22. HUANG, QIUYUE. SA
    Mafic magmatism in the Gawler Craton: Distribution, composition, timing, sources and tectonic setting.

23. JACOBSON, LAURA. NSW (Masters)
    Regional metal and fluid sources for IOCG mineralisation around Olympic Dam, and geology, geochronology and mineral-chemical zonation of the Wirra Well deposit.

24. KENDALL, WILL. TAS (Hons)
    Geophysical assessment of potential magmatic skarn mineralisation at the L13 Prospect, Highclaire, Northwest Tasmania.

25. KIT, JASON. WA
    Geophysical interpretation of the Merey River metamorphic complex.

26. KAY, ANNE. TAS (Hons)
    Geophysical assessment of potential magmatic skarn mineralisation at the L13 Prospect, Highclaire, Northwest Tasmania.

27. LAMBERT, JOHN. TAS
    Structure and metamorphism of the Mersey River metamorphic complex.

28. LEWIS, NICHOLAS. WA
    Magmatic-hydrothermal volatile evolution and mineralisation in Tasmanian Sn granites.

29. LUKIN, PETER. TAS (Hons)
    Magmatic-hydrothermal volatile evolution and mineralisation in Tasmanian Sn granites.

30. MUKHERJEE, INDRANI. NT
    Distribution, nature of sediments and depth to bedrock in Bass Strait, in the region of Brunie Port.

31. MULDER, JACOB. TAS (Hons)
    From Nuna to Gondwana: An evaluation of the early tectonic history of Tasmania.

32. OSTERSEN, THOMAS. TAS (Hons)
    Multi-scale geotectonic, and combined geophysical, investigations of Tasmania and Southeast Australia.

33. PEREIRA DA FONSECA, PEDRO. TAS
    Facies analysis and correlations in complex mineralised submarine volcanic successions: Mount Read Volcanics, western Tasmania.

34. ROGERS, BRONSON. NSW (Hons)
    Environmental significance of the Broken Hill Gossan: A mineralogical and geochemical study.

35. SHARMA, SUBIRA. QLD (Hons)
    Evaluation of links between Merlin- and geophysical study.

36. SMITH, MARK. TAS (Hons)
    Geophysical classification of onebearing/metaliferous fluids of the Costerfield region, Victoria.

37. STEADMAN, JEFFREY. WA
    BFIs, black shales, and gold deposits: A re-evaluation.

38. VEJELYTE, IRMA. SA (Masters)
    Geological evolution of the Windy Well Prospect, Gawler Craton, South Australia.

39. WARN, LESLIE. TAS (Hons)
    Gravity and magnetic modelling of the Cygnet area, Tasmania.

40. WHITNEY, BEN. QLD (Hons)
    Geological framework and characteristics of the Specimen Hill high sulphidation epithermal system, southern Queensland, Australia.
OUTSIDE AUSTRALIA

Project locations are shown in capitals. Unless marked otherwise, student projects shown here are PhDs. Projects related to the ARC TMVC Research Hub are marked with an asterisk.

1. ABERSTEINER, ADAM. FINLAND, SOUTH AFRICA (HONS)
   Petrographic and melt inclusion constraints on the petrogenesis and composition of kimberlites from Finland and South Africa.

2. BAKER, FABIAN. ARMENIA (MASTERS)
   Amutlar HSE Au deposit, Armenia.

3. BASORI, MOHD BASRIL. ISWADI BIN. MALAYSIA
   Geology of volcanic hosted massive sulfide (VHMS) deposits in Central Belt, Peninsular Malaysia.

4. BEAS CACERAS, BILLY. PERU (MASTERS)
   Black shales.

5. BENAVIDES, SEBASTIAN.

6. BERKENBOSCH, HEIDI. ARGENTINA (MASTERS)
   Volcanic stratigraphy at La Zanja Mining District in the northern Peruvian Andes, Cajamarca, Peru.

7. CALDERON-TIPIANI, CESAR.

8. CAVE, BEN. CANADA, NEW ZEALAND
   A metamorphic core for tungsten in metasedimentary-hosted orogenic gold deposits.

9. CEILZ, DIOHANNE. KENYA (MASTERS)
   The geology, alteration, and mineralisation of the Sagay deposit in northern Negros, Philippines.

10. CHEN, JING. CHINA
    The geology, mineralisation, alteration and fluid evolution at Zinshen ore field, Fujian Province, China.

11. DRAIYERS, EVAN. SW PACIFIC (HONS)
    Detailed mineralogy of tonalite and arc-tholeite lavas from the Hunter Ridge: Implications for plumbing system and magma generation processes.

12. ESCOLME, ANGELA. CHILE
    Ore characterisation and geotectonic modelling at the Productora Cu-Au-Mo deposit, Chile.

13. FAUSTINO, MARIA LOURDES M. PHILIPPINES (MASTERS)
    Intrusive history and genesis of Bayuyo porphyry copper-gold deposit, Surigao Del Norte, Philippines.

14. GARAY, AMOS. PERU*
    Magnetite and epidote chemistry and textures at Las Bambas Cu-Au-Fe skarn, Peru: Assessing district and deposit-scale fertility - implications for ore genesis and exploration.

15. HARRISON, RACHEL. INDONESIA
    Tumpangantu porphyry Au-Cu-Mo and high-sulfidation epithermal Au-Ag deposit, Tujuh Bukit project, SE Java, Indonesia - geology, alteration, and mineralisation.

16. HEATHCOTE, JACOB. ZAMBA
    Gold distribution and association at the Kansoishi copper-gold deposit, Zambia: Processes responsible for gold precipitation and implications for ore zone delineation and recovery.

17. HOLT, SAM. USA
    Understanding of basaltic eruption dynamics and mechanisms: Effusive and explosive eruptions in Hawaii.

18. IKEGAMI, FUMIHKO. NEW ZEALAND
    2012 submarine silicic eruption of Hauri volcano and implications for ancient submarine successions in Australia.

19. JIMENEZ TORRES, CARLOS ANDRES. PHILIPPINES (MASTERS)
    Bantug lithocap, Negros Island, Philippines: Mineralogy, textures, and chemistry.

20. JOHNSSON, SEAN. FINLAND
    Distribution of, and controls upon, pyrite trace element content of hydrothermal alteration zones at Hercules VHMS ore deposit, Tasmania and NICO IOCG ore deposit, Northwest Territories, Canada.

21. KAMVONG, TEERA. THAILAND, LAOS
    Geology and genesis of porphyry copper deposits at the Northern Loei and Thung Son Fold Belts, Thailand and Laos.

22. KNIGHT, JOSEPH. MYANMAR
    The geodynamic and metallogenic setting of Cu-Au mineralisation in Myanmar: Implications for mineral exploration.

23. KUTKIEWICZ, ANNA. USA (MASTERS)
    Trace element chemistry of chalcopyrite in the Vlaminik Trend MVT deposits, USA.

24. LAWLS, ERIN. PNG
    Au-bearing pyritic core of Lihir, Papua New Guinea: Its physicochemical character and nature of the causative fluids.

25. LE, XUAN TRUONG. VIETNAM (MASTERS)
    Geological setting and mineralisation characteristics of the Me Xi gold deposit, Quang Tri Province, Central Vietnam.

26. MACALALAD, NEIL. INDONESIA (MASTERS)
    Geology, alteration, mineralisation and vectoring to porphyry centre at the Almacuçar prospect, Irian Jaya, Indonesia.

27. MAKOUNDI, CHARLES. MALAYSIA
    Geochemistry of carbonatice black shale, sandstone, and chert in Malaysia: Insights into gold source rock potential.

28. MCLELLAND, REBEKAH. NEW ZEALAND (MASTERS)
    Gold mineralisation at the Reefton Goldfield, New Zealand.

29. MCMONULTY, BRIAN. CANADA
    Geology and genesis of the mineral deposits of the Myra Falls VHMS District, Canada.

30. McNULTY, BRIAN. CANADA
    Geology and genesis of the mineral deposits of the Myra Falls VHMS District, Canada.

31. MUHIEREE, INDRANI. INDIA
    Pyrite trace element chemistry of black shales of the “fukiing balion” period.

32. MUSIALIKE, MICHAEL. ZAMBA (MASTERS)
    The geological setting and mineralisation characteristics of the Dumbadin deposit, Zambia.

33. NUNA-LONG, SARANYA. MYANMAR (MASTERS)
    Paragenesis, pyrite geochemistry and ore fluids at Hongyi gold mines, Myanmar.

34. OROVAN, EVAN. FIJI
    Geology, geochemistry and genesis of the Namosi porphyry Cu-Au deposits, Fiji.

35. PHILLIPS, JOSHUA. USA*
    Geologic and geochemical vectors to mineralisation at the Resolution porphyry Cu-Mo deposit, Arizona.

36. PIQUE ROMO, JOSE. CHILE
    Structural geology of the Andes of Central Chile: Evolution, controls on magmatism and the emplacement of giant ore deposits and implications for exploration.

37. POTTER, NAOMI. TANZANIA, FINLAND, RUSSIA
    An investigation into the genesis of intrusive and extrusive carbonate melts.

38. RINNE, MARC. PNG
    Geology and genesis of the contrasting Walti-Golpu porphyry-epithermal deposit, Papua New Guinea.

39. SHEPPARD, JORDAN. MYANMAR (HONS)
    Trace element variations in Devonian shale in Northern Shan State, Myanmar.

40. STEADMAN, JEFFREY. USA
    BIFs, black shales, and gold deposits: A re-evaluation.

41. STEEVES, NATHAN. USA
    Ore genesis of the Greens Creek VHMS Deposit, Alaska: Implications for mining, milling and exploration.

42. SYKORA, STEPHANIE. USA
    Geological, structural, geochemical and genetic significance of the antihydrite zone at the Lihir gold deposit, Papua New Guinea.

43. TESTA, FRANCISCO. ARGENTINA, CHILE
    Structural geology of the Andes of Central Chile: Evolution, controls on magmatism and the emplacement of giant ore deposits and implications for exploration.

44. THOMPSON, JENNIFER. INDONESIA, PHILIPPINES*
    Detailed investigation into carbonate minerals in geochemical dispersion halos around Cu, Au and Mo porphyry deposits to identify potential indicators of deposit location beyond what is possible in whole rock geochemistry.

45. TRAYNOR, JONATHAN. MYANMAR (HONS)
    Genesis of Modi-Momi Taung orogenic gold deposit in central Myanmar: Constraints from structure, wall rock alteration and mineral chemistry.

46. VERGANI, DANIELE. REUNION
    The 2007 explosive activity at Piton de la Fournaise volcano (Reunion): Constraints on the eruptive processes by the volcanological study of the erupted deposits.

47. WHITTEN, MATTHEW. NEW ZEALAND (HONS)
    Formation de Kone: Recording the final stages of Gondwana break up in New Caledonia.
LAB-BASED PROJECTS

Unless marked otherwise, student projects shown here are PhDs.

GAL, MARTIN
The development of array and single station methods for the analysis of on-land ambient seismic signals from deep ocean storms and coastal sources.

GILBERT, SARAH
Development of analytical methods and standard reference materials for analysis of trace elements and isotopic ratios in sulfides.

KUHN, STEPHEN
The application of machine learning algorithms for lithological mapping and minerals targeting in key ore deposit settings.

LOUNEJEVA, ELENA
Geochemical study of three marine sediments sequences corresponding to the Late Permian-Early Triassic stratigraphic boundary.

MOLTZEN, JAKE (HONS)
Integrated techniques for rapid drill core mineralogical characterisation.

MORSE, PETER
Combined computational and human interaction strategies in knowledge generation from spatial and spatiotemporal information.

THOMPSON, JAY
Understanding the specifics of H2O-free aerosol behaviour in the inductively-coupled plasma in geochemical LA-ICPMS applications involving U/Pb dating and accurate trace element analysis in silicate minerals and glasses.

SOCIETY OF ECONOMIC GEOLOGISTS (SEG) STUDENT CHAPTER

Jay Thompson, who is a member of CODES technical staff, and also pursuing his PhD studies, which includes a lab-based project related to LA-ICP-MS.

The CODES SEG Student Chapter is an integral part of the Centre, whose activities have a wide ranging and positive impact in so many areas of its operations. It plays a vital role in creating a welcoming environment for students who come to CODES from widely differing cultural backgrounds, and ensures that their time spent at the university is both enjoyable and professionally rewarding. It also makes a significant contribution to raising the profile of CODES, and disseminating its research outputs internationally. The past year has been exceptional in terms of all these attributes and outputs, with just some of the highlights listed below.

PROFESSIONAL DEVELOPMENT

The highlight of the year’s professional development activities was the field trip to Iceland and Sweden, conducted in partnership with Lakehead University in Canada, and sponsored by the SEG, AMIRA International, the Geological Association of Canada, the Institute on Lake Superior Geology, and the UTAS Postgraduate Society.
The participants started the excursion in Iceland, taking a roughly circular route, beginning in Reykjavik, then moving up and around the northern areas, before returning via the remote central highlands to take in the recent Holuhraun lava flow and spectacular Laxa Fissure. Other highlights included exploring the subterranean geology of a 1.4 km lava tube, having lunch in a volcanic cinder cone, seeing some astounding Plinian deposits at the Askja crater, and visits to a collapsed lava lake, a rift valley, and several lava fields and waterfalls. They even managed an evening ‘dip’ in a river freshly heated by recent volcanic activity.

Highlights of the Sweden leg of the journey included a trip to the island of Ulo, in the Stockholm archipelago, which included stops at historic iron and silver mines. Back on the mainland, they also visited the Historic Sala Silver Mine, and the Garpenberg mine, owned by New Boliden, which produces complex ores containing zinc, lead, silver, copper, and gold. Other highlights included visits to the world-class Skellefte VHMS district, the huge Aila geopark Chromium deposit, and the Kirunavara magnetite-apatite deposit.

The field trip was led by David Cooke and Jocelyn McPhie from CODES, and Peter Hollings from Lakehead University, Canada.

The students were also successful in attracting a number of expert external speakers to CODES during the year, who conducted presentations on a diverse range of geological topics. Guest speakers included John Bishop and Kate Hine, from Mire Geophysics; and Dan Wood from the University of Queensland.

SOCIAL EVENTS

Social events play a vital role in helping students settle into life on campus, particularly those from interstate and overseas. They also help to develop a sense of camaraderie within the group, and establish friendships that often endure long after graduation. Events organised by the Student Chapter in 2015 included wine tastings and a charity fundraiser for the victims of the Nepal earthquake. In addition, Student Chapter members assisted with the Christmas BBQ and participated in a host of other social events including weekly soccer games, ice hockey, indoor volleyball, badminton and squash, and a movie night. There were also a number of get-togethers to celebrate… well, just about anything really. Slightly more serious gatherings were their ever-popular fortnightly Talking Geology Informally on Fridays (TGIF) sessions in the CODES Conference Room, which adhered to a winning formula of a 20-minute talk, a 20-minute slide show of images, followed by snacks, beverages and socialising. Although the Student Chapter is mostly comprised of PhD students, it also plays an important role in welcoming other postgraduate students. For example, in 2015, the Chapter welcomed new Honours students with a traditional barbeque, and organised welcome drinks for the predominantly industry-based students who participated in the two on-campus Master of Economic Geology short courses. They also organised a number of social events allied to the SEG 2015 Conference, including a highly successful reception to welcome students from around the world, and a quintessential Aussie ‘sausage sizzle’.

AWARDS AND GRANTS

It was another successful year in terms of grants and awards, with the following students receiving recognition:

- Jacob Mulder – The Australian Government’s 2016 (awarded in 2015) Endeavour Postgraduate Scholarship for study in the USA
- Jacob plans to spend up to 10 months at his host institution, the University of New Mexico, in 2016. Jacob will be involved in exciting field work across SW USA, collaborating with world-renowned experts, and making use of world-class laboratory facilities as part of his PhD studies. He will particularly be focussing on the ancient geological links between Tasmania and the SW USA.
- Michelle Awid-Pascual, Jing Chen, Maria Lourdes M. Faustino, Wei Hong – SEG Hugh E. McKinstrey Student Research Awards.
- Laura Jackson – SEG Foundation 2015 Graduate Student Fellowship Award. Laura was also awarded best paper at the AusIMM Conference: Tailings and Mine Waste Management for the 21st Century.
- Angela Escalmí – awarded ‘Best Student Presentation’ at the SEG 2015 Conference.

COURSES FOR INDUSTRY

CODES introduced a series of specialised courses, aimed primarily at mining companies looking for an effective means of improving the skills of their workforce with minimal disruption to work schedules. The first of these courses, Geophysics for Geologists and Engineers, was introduced in 2013, which was augmented by Advances in Geologging in 2014.

Although the concept for these courses continues to receive widespread support from the industry, the current downturn in operating conditions has naturally had an impact on enrolments. As a result, it was decided to hold one course in 2015, and then place a temporary hold on the program in 2016, with a resumption anticipated when conditions improve.

LOOKING FORWARD

The current trends in postgraduate training at CODES are expected to continue in 2016.

While the HDR program should maintain a relatively high proportion of international students, it is anticipated that the recent successes in attracting Australian students will be sustained, partly due to the prevailing economic climate in the minerals industry.

The difficult operating environment for the industry has also resulted in a temporary hold being placed on the courses for industry program. However, CODES will be closely monitoring the business conditions, with a view to restarting activities in 2017.

Funding to MTEC has also suffered due to the downturn, sadly resulting in the cessation of the long-running national Mineral Geoscience Honours program. As a consequence, from 2016 onwards, the Exploration and Field Skills Mapping Camp will run once a year, and offered as part of the VIEPS coursework program. However, a proposal is also being considered to develop an expanded version of this course, to be offered as part of the Master of Economic Geology program.

The Master of Economic Geology Program is scheduled to have a full offering of three short courses, including Volcanology and Mineralisation in Volcanic Terrains, which encompasses field-based activities in New Zealand and Tasmania. Overall admissions to the Masters program are expected to remain close to the record levels achieved in recent years, however, unit enrolments are expected to fall due to a decrease in the average number of units taken per student, per year and a significant reduction in the cross-institutional intake. Although the milestone of 100 completions was achieved in the current reporting period, the official celebration for the 100th Master of Economic Geology graduate will take place at the first graduation ceremony of 2016.

Discussions are underway with Universitas Gadjah Mada, Indonesia, to run a joint Master of Economic Geology Degree. The two-year program will be a mix of classroom- and field-based studies and a research thesis. The proposal is for the program to be conducted in Indonesia and Australia, with teaching duties shared between the two universities.

The SEG Student Chapter is planning to have another full schedule of social and professional development events, the highlight of which will be a field trip to Myanmar.
OBJECTIVES

The Australian Research Council Research Hub for Transforming the Mining Value Chain (TMVC) aims to resolve some of the greatest challenges currently facing the minerals industry, by improving efficiencies along the entire mining value chain. Its principal objectives are to:

- Achieve real-time automated acquisition and interpretation of detailed mineralogical, textural and geochemical data in mine site core sheds, that can be used immediately for 3D-modelling of geometallurgical and geoenvironmental parameters and ore zone footprints.
- Move the mining industry from the data-rich, but comparatively knowledge-poor, environment that they currently work in to a data-rich, knowledge-rich environment that allows for rapid decision making during the exploration and development phases of mining operations.
- Develop tools and protocols that allow near-instantaneous identification of proximity to ore zones, together with geometallurgical and geoenvironmental characterisation of ores and waste through automated core logging and spectral analyses of drill core. This will enable 3D exploration, mining and geometallurgy models to be developed that are continually updated as the exploration or resource drilling program continues.

INTRODUCTION

The TMVC encompasses a wide array of activities from exploration, discovery, ore deposit characterisation, and environmental assessment, through to mining, ore processing and waste rock disposal. It sets out to improve efficiencies within this value chain, focussing on areas that will have a marked impact on the value of Australia’s mineral resources. By helping to develop more efficient and environmentally sustainable practices throughout the mining value chain, it is anticipated that the Hub’s research outcomes will extend the lives of mines and create employment opportunities across Australia’s regional mining centres.

The TMVC provides substantial benefits for the minerals industry through advanced mineral characterisation methods, and innovative technologies for their implementation, which can be applied much earlier in the mining value chain. This enhances decision making and maximises productivity and profitability at Australian mine sites.

The TMVC is housed within CODES at the University of Tasmania (UTAS) – the Administering Organisation. In addition to CODES, the industry partners involved in the research hub include BHP Billiton, Corescan, Newcrest Mining, and a consortium of global companies co-ordinated by AMIRA International. Other organisations affiliated with the initiative include Laurin Technic, National Information Communications Technology Australia (NICTA) and RWTH Aachen University in Germany.

HIGHLIGHTS

The TMVC commenced operations on June 30th 2015 after the signing of the collaboration agreement by the Administering Organisation and Partner Organisations. The research hub was officially launched on the 24th of September by Professor Aiden Byrne (ARC), Senator David Bushby and Professor Mike Calford (UTAS). While the recruitment of postdoctoral research fellows, professional staff and PhD students has occupied a significant portion of the first six months of operation, this has provided fruitful results with the establishment of a critical mass of personnel essential to the successful implementation of the research program.

Other highlights in TMVC’s relatively short period of operation include:

- Successful launch of the AMIRA P1153 project: Applying the explorers’ toolbox to discover porphyry and epithermal Cu, Au and Mo deposits. Field campaigns initiated at new study sites in Sweden, U.S.A. and Canada.
- Development of a tool that has the potential to revolutionise geometallurgical data acquisition, replacing the laborious manual geotechnical logging procedures that currently form the industry standard, and allowing large volumes of consistent geotechnical data to be acquired through automated core logging.
- TMVC activities extensively showcased at the SEG 2015 Conference in Hobart.
THE TMVC TEAM

DIRECTOR: David Cooke

TEAM MEMBERS:
CODES: Mike Baker, Ivan Belousov, Ron Berry, Matt Cracknell, Leonid Dansuhashvily, Nathan Fox, Bruce Gennrell, Sarah Gilbert, Ross Large, Sebastien Meffre, Paul Clin, Anita Parbhakar-Fox, Anya Reading, Leunj Zhang
AMIRA INTERNATIONAL: Bernd Lottermoser
BHP BILLITON: Kathy Ehrl
CORESCAN: Neil Goodey
HI LAB: Henry Duh
LAURIN TECHNICAL: Michael Shelley
NEWCREST MINING: Stephen Hardy
NICTA: Stephen Hardy
RWH AACHEN UNIVERSITY: Bernd Lottermoser
PHD STUDENTS: Amos Garay, Cassady Harraden, Carlos Jimenez, Laura Jackson, Josh Phillips, Francisco Testa, Jennifer Thompson
IMPERIAL COLLEGE LONDON, UK: Adam Paracy

MASTERS STUDENTS:
LAKEHEAD UNIVERSITY, CANADA
Ayat Baig, Wes Lueck, Emily Smyk

COLLABORATORS:
CONSULTANT: Noel White
GUANGZHOU INSTITUTE OF GEOCHEMISTRY, CHINA
Huayong Chen, Jinsheng Han
HEFEI UNIVERSITY OF TECHNOLOGY, CHINA
Shiwei Wang, Dayu Zhang, Taofa Zhou
LAKEHEAD UNIVERSITY, CANADA
Peter Hollings
NATURAL HISTORY MUSEUM, UNITED KINGDOM
Jamie Wilkinson

PROJECT SUMMARIES

THEME 1 DETECTING PROXIMITY TO ORE (FOOTPRINTS)

APPLYING THE EXPLORERS’ TOOLBOX TO DISCOVER PORPHYRY AND EPITHERMAL CU, AU AND MO DEPOSITS (AMIRA P1153)

Leaders: David Cooke, Bruce Gemmell

Team Members: Mike Baker, Nathan Fox, Leunj Zhang

Students: Ayat Baig, Amos Garay, Carlos Jimenez, Wes Lueck, Adam Pacey, Josh Phillips, Jose Piquer, Emily Smyk, Francisco Testa, Jennifer Thompson

Collaborators: Huayong Chen, Jinsheng Han, Peter Hollings, Shiwei Wang, Noel White, Jamie Wilkinson, Dayu Zhang, Taofa Zhou

The AMIRA P1153 project, which is being conducted in collaboration with researchers from Lakehead University, the Natural History Museum, Guangzhou Institute of Geochemistry, and Fhefe University of Technology, will develop new methods for discovering porphyry and/or epithermal deposits through improved geochemical detection of ore deposit footprints. Analysis of the geochemical signals recorded in hydrothermal alteration halos will provide explorers with both fertility (how large?) and vectoring information (how far, and in what direction?), allowing the presence, location and significance of porphyry and/or epithermal copper, gold and molybdenum deposits in an exploration tenement to be determined during the early stages of exploration. This approach has particular relevance to exploration involving drilling under post-mineralisation cover, or in areas where outcrop is limited or difficult to access.

The main outcomes will be tools for testing the fertility of mineral districts, and for vectoring to mineralised centres. These will involve the use of key alteration minerals from green rock, white rock and lithocap environments. Cost-effective field-based methods will also be developed that can be applied by explorers who do not have access to suitable laboratory facilities for LA-ICP-MS analyses.

Following the commencement of the project in mid-2015, the research team has initiated field campaigns at new study sites in Sweden, U.S.A. and Canada. Three new graduate research projects based at CODES will form key components of the overall research project, i.e. Josh Phillips (Resolution porphyry Cu-Mo deposits), Jennifer Thompson (Carbonate mineral chemistry) and Amos Garay (Late Bambas porphyry Cu-Mo-Au and Cu-skarn districts). Students who did not complete their research within AMIRA P1050, the forerunner to this new initiative, will report their final results within AMIRA P1153. José Piquer published a manuscript from his PhD study in Economic Geology in December, 2015.

THEME 2 OPTIMISING GEOMETALLURGICAL PREDICTION

• Geometallurgical developments evolving from the GeM® project
• Geotechnical and geometallurgical assessment of the Cadia East deposit using Corescan automated core logging technology

THEME 3 MINIMISING GEOENVIRONMENTAL RISKS

• Mineralogical domaining of low grade and no grade zones using automated drill core logging

THEME 3 SUMMARIES

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A program to test the line scan methods for documenting core mineralogy was designed and funding approved. Testing of LIBS and laser Raman methodologies on drill core has commenced. Excel spreadsheets were developed to use for teaching underlying principles of sampling and data mining methods in geometallurgical situations. These products were tested in short courses.

GEOMETALLURGICAL AND GEOMINERALOGICAL ASSESSMENT OF THE CADIA EAST DEPOSIT USING CORESCAN AUTOMATED CORE LOGGING TECHNOLOGY

Leaders: Sebastien Meffre, Michael Roach, Ron Berry
Team Members: Matt Cracknell, Neil Goodey
Student: Cassady Harraden
Collaborators: James Lett, Ann Winchester

The goal of this PhD project by Cassady Harraden is to determine the correlation between Corescan™ data and measured deportment data, processing parameters and geotechnical conditions. Hyperspectral data will be used to determine functional proxies that will ultimately be built into predictive algorithms and applied to the mine-wide dataset to produce geometallurgical domains. These domains can then be modelled in 3D and integrated with the Cadia Mine’s current geologic, structural and geometallurgical models. A major breakthrough was made late in the year, when the researchers developed a new tool for utilising automated core logging technology to extract geotechnical index parameters. The new tool has the potential to revolutionise geometallurgical data acquisition, replacing the laborious manual geotechnical logging procedures that currently form the industry standard, and allowing large volumes of consistent geotechnical data to be acquired through automated core logging. After a pilot study, the tool is now being up-scaled to enable it to be implemented during a major program of automated core scanning by Newcrest Mining and Corescan in 2016. Results of the pilot study will be released at the 3rd International Geometallurgy Conference in 2016.

FM FROM LEFT: High resolution hyperspectral images of drill core are collected using Corescan’s automated system. Chalcopyrite on a broken quartz vein surface.

FROM TOP: Geoenvironmental characterisation of waste rock using the net acid generation test. EXPLOR TEST.

THEME 3
MINIMISING GEOENVIRONMENTAL RISKS

MINERALOGICAL DOMAINING OF LOW GRADE AND NO GRADE ZONES USING AUTOMATED DRILL CORE LOGGING

Leader: Anita Parbhakar-Fox
Team Members: David Cooke, Nathan Fox, Neil Goodey, Anthony Harris, Bernd Lottermoser
Student: Laura Jackson

Prediction of acid rock drainage (ARD) at the earliest life of mine stages is critical for designing the most appropriate environmentally conscientious waste management strategies and storage facilities. However, geochemical tests typically used for predicting waste characteristics are texturally destructive, and therefore do not appropriately describe how ARD might evolve and the role of secondary minerals in metal cycling in the surficial environment. This research is developing a protocol by which different mineralogical techniques can be effectively integrated to allow for mineralogical and textual information pertinent to environmental characterisation to be obtained from intact-waste materials (i.e., drill core materials, tailings as received).

Method development of these techniques has involved two site visits. A preliminary site assessment and geology study was undertaken during the first visit, while the second visit specifically focussed on using Corescan to gain hyperspectral data. Two hundred and forty-seven samples, representative of two major drill holes through the deposit, have been selected for the method development stage. Following the field campaigns, further analyses is being undertaken, including hardness testing, ARDI, UV fluorescence and carbonate staining. Following completion of these studies, 30 subsequent samples will be chosen for detailed mineralogical and geochemical analyses.
INTRODUCTION

The Discipline of Earth Sciences falls under the School of Physical Sciences, within the Faculty of Science Engineering and Technology at the University of Tasmania (UTAS). Although the Discipline is a separate entity to CODES, the two areas have been inextricably linked since the latter was formed in 1989. From the outset, the two areas have enjoyed a harmonious and constructive relationship, creating a synergy that has undoubtedly benefitted both groups over the years. This co-operation has been possible because most academic staff, and many technical and administrative staff, hold joint appointments in both areas. There is no better example of this symbiotic relationship than Leonid Danyushevsky, who is Head of Discipline, while also playing a pivotal role in CODES as Leader of the Enabling Technologies Module.

In support of this close relationship, it was decided to allocate a section of this issue of the CODES Annual Report to showcase the significant number of projects that are being conducted within the Discipline and, in most cases, in collaboration with the Centre of Excellence.

In 2015, the Discipline developed a strategic plan aligned to its relationship with CODES, and the strategic objectives of the School, the Faculty, and the University as a whole. The current research strengths within the Discipline are listed below:

MARINE GEOSCIENCE

Marine geoscience is classed within two of the University’s priority areas, and the Discipline has consistently demonstrated its research strengths in this area for a prolonged and sustained period of time. Recent successful funding applications within the ARC’s National Competitive Grants Programme are testament to its capabilities in this area, as is the exceptional level of related research outputs, including a number of high profile publications and conference presentations. The current focus in this field of research is on:

- Trace metal ocean chemistry through time.
- Marine geophysics.
- Submarine and ocean island volcanism and magmatism.
- Global tectonics and sedimentary basins.
- Ocean storm seismology.

DEEP TIME EARTH

Over the past three years, the Discipline has branched out into research related to deep time, which is ideally suited to its proven strengths in the geology, geochemistry and geophysics of ancient continental provinces and marine sediments. The Discipline has gained international recognition for its research, resulting in numerous high profile publications and conference presentations. The current focus is on:

- Paleoceanography/palaeontology.
- Geochronology.
- Sedimentary and mineral chemistry.
- Ocean chemistry modelling.
- The origin of life.
- Biogeochemistry.
- Seismology.
- Volcanism and magmatism.

COMPUTATIONAL AND ANALYTICAL GEOSCIENCE

Research in this area is developing new computational and analytical approaches, and evolving data-led research that enables advances in other areas of the Earth sciences. The computational geoscience aspect of these studies is undertaken in close collaboration with the UTAS Central Science Laboratory. Current research directions include:

- New algorithms and visualisation approaches to working with Big Data.
- Development of human / computer interaction paradigms for knowledge discovery.
- Integrated 3D Earth modelling.
- Development of seismic array analysis algorithms.
- Integrated informatics and inverse theory approaches to geophysical modelling.
- Optimising decision making from spatial information.
- Development of micro-analytical approaches.

The Discipline is known for its consistent output of innovative publications, and the delivery of high profile conference presentations related to these areas of research.

MANTLE STRUCTURE, DYNAMICS AND GEOCHEMISTRY

This field of research has been prominent at UTAS since the 1970s and has earned the Discipline a high-profile international reputation. Current research is focussed on the following areas:

- Origin of kimberlites and lamproites.
- High pressure and temperature experimental petrology.
- Lithospheric structure and fluid pathways.
- Global tectonics.
- Origin of Large Igneous Provinces.
- Seismic tomography.
- Global geophysics.
- Computational geoscience.

VISION

To be internationally recognised for research and educational excellence in Earth sciences by maintaining and increasing the Discipline’s national and international reputation and rankings.

OBJECTIVES

- Generate knowledge through innovation and research excellence.
- Provide the highest quality undergraduate education and graduate training in Earth sciences.
- Contribute to the national and international standing of the School of Physical Sciences and CODES.
- Maintain and improve the Discipline’s reputation as a major source of professional geoscientists, thereby addressing the evolving needs of the nation, with a focus on the National Research Priority Areas.
HIGHLIGHTS

FELLOWSHIPS
Rebecca Carey began her prestigious Australian Research Council 3-year postdoctoral DECRA fellowship, which is focused on submarine volcanology and hydrothermal systems on the modern seafloor.

SHORT COURSES
Ross Large organised a short course entitled ‘Ore deposits, atmosphere oxidation and evolution of life: how they are related’, which was presented by an international team as part of the SEG 2015 Conference in Hobart.

PUBLICATIONS AND CONFERENCE PRESENTATIONS
A paper presenting a new model for the origin of Group II kimberlites was published in Nature Communications by Vadim Kamenetsky and co-authors.

A paper describing the first occurrence of magmatic halite in mantle-derived carbonate melts was published in Geology by Vadim Kamenetsky and co-authors.

A series of papers published by Ross Large and co-authors used LA-ICP-MS analyses of marine pyrite in black shales to reveal systematic changes in trace element concentrations in the oceans through time. These changes have great significance because they can be related to the evolution of life and cycles of marine ore deposits.

Anya Reading and Martin Gal delivered an invited talk, entitled ‘Improved detection and location of ocean microseism signals using array techniques’, at the American Geophysical Union Fall Meeting in San Francisco.

OTHER RESEARCH OUTCOMES
Michael Roach led the development of the Virtual Library of Australia’s Geology.

Anya Reading was part of a team that developed new constraints on the tectonic evolution of southeastern Australia using ambient seismic tomography techniques.

Rebecca Carey was a co-chief scientist of a research voyage to the submarine Haure volcano.

The CRC ORE team developed a new plant bioaccessibility test, which was trialled at the Wheat Mald tailings storage facility, UK.

Anita Parbhakar-Fox and Laura Jackson identified rehabilitation options for the Old Tailsings Dam at the Savage River mine in Tasmanian.

A presentation related to this research won Blest Paper at the AusIMM Tailings and Mine Waste Management conference in Sydney.

Patrick Quilty described five new multilocus species from the classic Marine Plan deposit in the West Fulford Hills, East Antarctica.

Rebecca Carey visited the Hawaiian Volcano Observatory, as well as Stromboli volcano, Italy for deployment of monitoring equipment.

Anita Parbhakar-Fox led a project characterising waste rock materials at the Savage River mine (Grange Resources) supporting the adoption of alternative waste handling approaches.

THE DISCIPLINE OF EARTH SCIENCES TEAM

DISCIPLINE HEAD:
Leonid Danyushevsky

STAFF MEMBERS:
CONTINUING APPOINTMENTS AT UTAS: Academic: Rebecca Carey, David Cooke, Garry Davidson, Bruce Gernert, Vadim Kamenetsky, Ross Large, Anya Reading, Michael Roach Professional: Isabella von Lichtan, Ian Little, Deborah Macklin

FIXED-TERM AND HONORARY APPOINTMENTS: Academic: John Aalbers, Shaton Allen, Trevor Falloon, Nathan Fox, Dan Gregory, Jacqueline Halpin, Julie Hunt, Peter McGoldrick, Jocelyn McPhie, Taryn Noble, Karin Orth, Patrick Quilty, Robert Scott, David Selley

PHD STUDENTS:
Jodi Fox, Martin Gal, Sam Hott, Olivia Haywood, Yiming He, Laura Jackson, Sean Johnson, Elena Louniejeva, Charles Makoundi, Indrani Mukherjee, Naomi Potter, Daniele Vergani

HONOURS STUDENTS:
Adam Abersteiner, Bronson Rogers, Jake Maltzen

COLLABORATORS:
ABERDEEN UNIVERSITY, UK
Nicholas Rawlinson
AUSTRALIAN NATIONAL UNIVERSITY
Richard Arculus, Stephen Cox, Penny King, Simone Pilla, Hirvije Tkalic, Greg Yaxley
BROWN UNIVERSITY, USA
Ryan Ponirh
CASCADES VOLCANO OBSERVATORY, USA
Michael Poland
CURTIN UNIVERSITY
Andrea Agangi, Fred Jourdan
FLINDERS UNIVERSITY
John Long
FROGTECH
Lynn Pryer
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
Peter Haines, Charles Hickman
GEOMAR, GERMANY
Steffen Kutterolf
GEOSCIENCE VICTORIA
Rosa Caley
GRANGE RESOURCES
Tony Ferguson, Roger Hill
HAWAIIAN VOLCANO OBSERVATORY, USA
Tim Orr, Matthew Patrick
INSTITUTE OF THE EARTH’S CRUST, RUSSIA
Alexei Ivanov
INSTITUTE OF GEOLOGY AND MINERALOGY, RUSSIA
Alexander Golovin
JAMSTEC, JAPAN
Iona McIntosh, Alex Nichols
INSTITUTE OF VOLCANOLOGY AND SEISMOLOGY, RUSSIA
Alexander Belousov
JAPANESE NATIONAL MUSEUM OF NATURE AND SCIENCE
Kenichiro Tani
MACQUARIE UNIVERSITY
Elena Belousova
MINERAL RESOURCES TASMANIA
Clive Calver, Grace Cumming, Mark Duftett, John Everard, Andrew McNeill, Andy Wakefield
MURoran Institute of Technology, Japan
Yoshihiko Goto
NATIONAL INSTITUTE OF WATER AND ATMOSPHERIC RESEARCH, NEW ZEALAND
Richard Wyżgołowski
OREGON STATE UNIVERSITY, USA
Robert Duncan
OXFORD UNIVERSITY, UK
Jane Barling
REUNION ISLAND OBSERVATORY, FRANCE
Andrea DiMuro
SEOUL NATIONAL UNIVERSITY, SOUTH KOREA
Jung-Woo Park
SMITHSONIAN INSTITUTION, USA
Richard Fiske
UNIVERSITY OF BARCELONA, SPAIN
Marc Campany, Arna Castelano
UNIVERSITY OF BRITISH COLUMBIA, CANADA
Dominique Weis
UNIVERSITY OF CALIFORNIA BERKELEY, USA
Michael Manga
UNIVERSITY OF EXETER, UK
Brend Lottmerser, Eli van Veen
UNIVERSITY OF HAWAII, USA
Bruce Houghton
UNIVERSITY OF MELBOURNE
Andrea Guitiarr, Roland Maas, Sandra Mclaren, Ashton Soltys
UNIVERSITY OF NOTRE DAME, USA
Wei Chen
UNIVERSITY OF OTAGO, NEW ZEALAND
James White
UNIVERSITY OF QUEENSLAND
Charles Verdel, Kevin Welsh
UNIVERSITY OF SYDNEY
Marla Seton
UNIVERSITY OF TASMANIA
Mike Coffin, Karsten Goemann
UNIVERSITY OF TORONTO, CANADA
James Mungall
UNIVERSITY OF UTAH, USA
Keith Koper
UNIVERSITY OF WESTERN AUSTRALIA
Annette George
WOODS HOLE OCEANOGRAPHIC INSTITUTION, USA
Daniel Forenari, Adam Soule
THE DISCIPLINE OF EARTH SCIENCES

CORE PROJECTS

- Beneath Bass Strait: Ambient seismic tomography
- Seismic array investigations of ocean storms
- Determination of magma ascent rates for subduction zone volcanoes
- Kimberlites and flood basalts: Linking primary melts with mantle and crustal sources
- Explosive volcanoes: Rates for subduction zone volcanoes
- Geology and paleontology of Antarctica and the Southern Ocean
- Characterising pyrite chemistry at the Old Tailing Dam, western Tasmania
- Savage River: Kinetic trials of waste rock materials
- Savage River: Kinetic tests of waste rock materials
- Savage River: Geochemical and mineralogical characterisation of the abandoned Scoda mine, northern Tasmania
- Savage River: Kinetic trials of Scoda mine tailings: An evaluation of water quality
- CRC ORE: Environmental indicators

PROJECT SUMMARIES

BENEATH BASS STRAIT: AMBIENT SEISMIC TOMOGRAPHY
Leader: Anya Reading
Collaborators: Ross Cayley, Mark Duffett, Simone Pilla, Lynn Pryer, Nicholas Rawlinson
This project is being conducted in collaboration with ANU, Mineral Resources Tasmania, Geoscience Victoria, and FROOTECH, and is funded by the ARC Linkage Program. Major outputs of the project were published in 2015, including evidence of the influence of a microcontinent trapped in the Pacific margin of Gondwana, which had a big impact on the subsequent formation of the Lachlan Orogen. The evidence comes from employing ambient seismic tomographic techniques, using data collected during a major field campaign (2011-2013) run jointly with ANU. Having established the structure of the crust in this complex area of the Australian continent, further seismological data analysis will reveal the lower crust and mantle structure to provide new constraints on the controversies remaining regarding the regional geology of southeast Australia.

SEISMIC ARRAY INVESTIGATIONS OF OCEAN STORMS
Leader: Anya Reading
Student: Martin Gal
Collaborators: Keith Koper, Hrvoje Tkalić
This project aims to gain a better understanding of the dynamics of ocean storms, using seismic array investigations. Significant progress was made during the year. PhD student Martin Gal implemented the ‘CLEAN’ algorithm, which is used widely in radio astronomy, to improve the detection of ocean microseisms – the cause of ambient seismic noise. The computer programs have been developed for use on 1-component and also 3-component data. They have been applied to data from Australian seismic arrays and allow a much more complete picture of the ambient seismic wavefield to be understood.

DETERMINATION OF MAGMA ASCENT RATES FOR SUBDUCTION ZONE VOLCANOES
Leader: Ivan Belousov
Collaborator: Alexander Belousov
This project aims at constraining the rate at which magma ascends from the storage region at depth in the Earth’s crust to the surface, which is a critical parameter governing the style and intensity of volcanic eruptions. Existing data suggest that the ascent rates vary over three orders of magnitude (0.1–30 metres/second), depending on eruption styles. This research is currently funded under the UTAS Research Enhancement Grants Scheme.

The technique employed is based on studies of melt embayments in phenocrysts in lavas. Melt in the embayments is re-equilibrating with the melt surrounding the crystal through diffusion processes. Volatile contents in the surrounding melt decreases during magma ascent due to degassing. Therefore, diffusion profiles of volatile components from the centre of embayments towards the outside melt can be used to determine rates of magma ascent. In 2015, the ascent rates were examined for the Karymsky and Tolbachik volcanoes (Kamchatka) in Russia. Both volcanoes are characterised by rapid magma ascent via a fissure. Melt embayments and melt inclusions in olivine phenocrysts were exposed and prepared for measurement of diffusion profiles, using a NanoSIMS technique at the Centre for Microscopy, Characterisation and Analysis (UNA). This technique is able to measure contents of volatile species (H₂O, CO₂, Cl, SO₂, F) with high spatial resolution (~1 micron). Major element compositions of melt embayments and host olivines were measured at the UTAS Central Science Laboratory, and trace element contents were measured using LA-ICP-MS techniques at CODES. The data will be used to assess rates of ascent of magmas and evolution paths of primary melts.

KIMBERLITES AND FLOOD BASALTS: LINKING PRIMARY MELTS WITH MANTLE AND CRUSTAL SOURCES
Leader: Vadim Kamenskis
Team Member: Maya Kamenskis
Students: Adam Abersteiner, Qiuyue Huang
Collaborators: Andrea Agangi, Elena Belousova, Karsten Goermann, Alexander Golovin, Andrea Giuliani, Alexei Ivanov, Roland Maas, James Mungall, Jung-Woo Park, Ashton Soltsy, Greg Yaxley
This project is aimed at understanding the relationship between kimberlites and diamonds, and between flood basalts and sulphide mineralisation, by linking mantle structure, composition, and temperature to the melting processes that generate these mantle-derived magmas.

The outcomes have been published in several high-profile publications during the year. A paper in Nature Communications addressed the origin of Group-II kimberlites (orangeites) through a study of MARID (mica- amphibole-rich, iron-rich) xenoliths from the Bultfontein kimberlite in South Africa. This demonstrated that orangeites can be formed during melting a MARID-rich lithospheric mantle.

An experimental study published in Geochimica et Cosmochimica Acta proposed that interaction between a silicate mantle rock and a natrocarbonatite melt results in carbonate-silicate liquid immiscibility, which forms globules of a CO₂-rich silicate melt. On decompression, the dispersed silicate melt phase ensures a continuous supply of CO₂ bubbles, which decrease density, increase buoyancy and promote the rapid ascent of the magmatic emulsion. A paper in Geology addressed the origin of platinum-group element...
**THE DISCIPLINE OF EARTH SCIENCES**

**CODES | ANNUAL REPORT 2015**

**TRACE ELEMENTS IN ANCIENT OCEANS**

**Leader:** Ross Large

**Team Members:** Leonid Danyushevsky, Dan Gregory, Jaqueline Halpin, Peter McCoard, Sebastien Methre, Jeff Steadman

**Students:** Sean Johnson, Elena Lonevneva, Charles Makouindi, Indrani Mukherjee

**Collaborators:** Olav Calver, Peter Haines, Charles Hickman, John Long

This project uses analytical LA-ICP-MS technology developed at CODES to track changes in the trace element history of sedimentary pyrite through the Precambrian and Phanerzoic. Currently, this project is funded by an ARC Discovery grant, and is being conducted in collaboration with members of the CODES Ore Deposits Characterisation and Context Module.

During 2015, the marine pyrite analytical database was increased from 3,000 to over 5,000 LA-ICP-MS analyses. This database has a unique potential to supply information on ocean nutrient supply through time, P/O2 variations in the atmosphere, and trends in bio-essential trace elements.

Four significant papers were published during the year:

- An overview of the chemical composition of sedimentary pyrite and chemical criteria for distinguishing sedimentary pyrite from other types of pyrite.
- A study of the gold content of marine pyrite has, for the first time, assessed the gold content of paleo-oceans through time and revealed a low gold content of the oceans in the mid-Proterozoic compared to the Archean and Phanerzoic.
- Trace elements contained in marine pyrite were used to reveal cycles of bio-essential nutrient trace element supply and define periods when oceans were nutrient-rich, which were followed by periods when they were nutrient-poor. A relationship between tectonics, nutrient supply, and O2 evolution of marine life was proposed.
- A follow-up paper showed that during the nutrient-poor periods the global ocean was severely depleted in the bio-essential element selenium, ultimately causing three of the five mass extinction events in the Phanerzoic.

**SUBAERIAL VOLCANOLOGY**

**Leader:** Rebecca Carey

**Team Members:** Sharon Allen, Jocelyn McPhee, Karin Orth

**Students:** Fumihiko Ikegami

**Collaborators:** Fabio Caranori-Tortini, Richard Fiske, Daniel Fomari, Bruce Houghton, Michael Manga, Iona McIntosh, Alex Nicholls, Adam Soule, Kenichiro Tani, James White, Richard Wysoczanski

The Discipline has developed an international reputation for its research into ancient volcanic successions and VHMS deposits. This project expands on the scope of this research by looking at the theme of modern submarine volcanic environments. Currently, this project is funded by an ARC DECPA Fellowship awarded to Rebecca Carey.

Rebecca Carey and PhD student Fumihiko Ikegami participated in a ship-based voyage to the southern Kermadec arc, which was conducted by the Institute for Water and Atmospheric Research, New Zealand. The cruise focussed on structures, volcanology and geothermal systems associated with rhyolite caldera successions of this segment of the arc.

**Collaborator Kenichiro Tani and Rebecca Carey were successful in applying for research ship time with the Japanese Marine Science and Technology Institute to visit three submarine volcanoes in the Izu-Bonin volcanic arc, south of Japan. Kenichiro and PhD student Fumihiko Ikegami will take part in this expedition in May 2016, and will explore these rhyolitic caldera volcanoes using underwater vehicles.**

Rebecca Carey was invited to co-author a chapter in the second edition of the Encyclopaedia of Volcanoes, which is the field’s leading reference publication. Rebecca was also a Chief Editor of an AGU Monograph on Hawaiian volcanism. International visitors included Visiting Scholar Thorvald Thorson from the University of Iceland, who collaborated with Rebecca Carey and Jocelyn McPhee, and presented two public lectures. In addition, two PhD students visited UTAS to work with Rebecca on projects related to submarine volcano projects. The students were from the University of Hawaii, USA, and the University of Otago, New Zealand.

**SUBMARINE VOLCANOLOGY**

**Leader:** Rebecca Carey

**Team Members:** Trevor Falcon, Jocelyn McPhee, Karin Orth

**Students:** Jodi Fox, Sam Holt, Naomi Potter, Daniele Vergani

**Collaborators:** Richard Arculus, Mike Coffin, Grace Cumming, Andrea DiMuro, Robert Duncan, John Everard, Yoshiko Gobe, Bruce Houghton, Fred Jourdain, Steffen Kutterolf, Andrew McNeil, Tim Orr, Matthew Patrick, Michael Poland, Ryan Porter, Dominique Weis, James White

**Students:** Sharon Allen, Vittorio Borselli, Ross Large, Jocelyn McPhee, Karin Orth, Daniele Vergani, Jodi Fox, Sam Holt, Naomi Potter, Michael Roach, Richard Wysoczanski

The project is generating a virtual library of Australia’s Geology, with the aim of providing free virtual access to significant outcrops across the Australian continent for secondary, tertiary and professional education, as well as public outreach.

The library delivers a variety of immersive visualisations including full 3D photorealistic models, ‘deep zoom’ imagery, full spherical panoramas, 360 degree video and virtual tours of geological sites. All visualisations can be accessed and downloaded from the AusGeol.org website.

**AUSGEOL - A VIRTUAL LIBRARY OF AUSTRALIA’S GEOLOGY**

**Leader:** Michael Roach

**Collaborators:** Stephen Cox, Annette George, Penny King, Sandra McLaren, Charles Verdel, Kevin Walsh

The AusGeol project is funded for a two-year period (February 2015 - February 2017) through an Innovation and Development Grant from the Federal Office of Learning and Teaching, with additional contributions from universities and government geoscience organisations.

The project is generating a virtual library of Australia’s Geology, with the aim of providing free virtual access to significant outcrops across the Australian continent for secondary, tertiary and professional education, as well as public outreach.

The library delivers a variety of immersive visualisations including full 3D photorealistic models, ‘deep zoom’ imagery, full spherical panoramas, 360 degree video and virtual tours of geological sites. All visualisations can be accessed and downloaded from the AusGeol.org website.

**The project is also generating lesson plans, and teaching and learning objects, for tertiary and secondary education. The AusGeol database currently includes virtual objects from approximately 2000 sites across Australia.**
A major achievement of this project has been the description of the Pliocene marine molluscan fauna from the classic marine plan deposit in the Westfold Hills, East Antarctica. This includes description of five new species of great value to the understanding of the evolution of Antarctic molluscs. A paper on the subject is currently in the final proof stage.

Work continued on the volcanic history of the region between Heard Island and Kerguelen Plateau. A paper is in the final stages of preparation.

Other projects include:
- The South Rennell Trough of northeastern Australia.
- Around Norfolk Island (based on the collection from RV Southern Surveyor cruise SS00/01).
- An Ettrin marine sediment core E27-23 southwest of Macquarie Island.

**CHARACTERISING PYRITE ROCK, SAVAGE RIVER, TASMANIA: EVALUATING TAILINGS REPROCESSING AS A MANAGEMENT OPTION**

**Leader:** Anita Parbhakar-Fox

Collaborator: Andy Wakefield

This project aims at characterisation of sulfide minerals in historic mine tailings to determine if there is any economic value in reprocessing the material using modern practices. At the Old Tailings Dam (OTD), western Tasmania, 38 million tonnes of pyritic tailings were deposited from 1967 to 1982. Materials collected from around the site were examined using LA-ICP-MS as a first-pass technique to establish the potential for metallurgical reprocessing. Elevated concentrations of cobalt, a critical metal, were identified in pyrite. Considering this finding, in-depth economic evaluations to establish the benefits of cobalt extraction should be undertaken. This may represent the best option for rehabilitating this historic site.

**ENVIRONMENTAL CHARACTERISATION OF NORTH PIT WASTE ROCK, SAVAGE RIVER, TASMANIA**

**Leader:** Anita Parbhakar-Fox

Collaborators: Tony Ferguson, Roger Hill

This research focussed on using static geochemical tests on a range of waste materials collected from North Pit of the Savage River mine to determine the geochemical response of blending various waste types at different ratios. This investigation was undertaken to assist with the design of long-term kinetic tests using these specific waste materials, i.e., to determine appropriate blend ratios. Both static testwork and kinetic trial data will provide an indication of whether, from a geochemical perspective, alternative waste handling methods are suitable at this operation.

**KINETIC TESTING OF WASTE ROCK, SAVAGE RIVER, TASMANIA**

**Leader:** Anita Parbhakar-Fox

Collaborator: Andy Wakefield

This project focussed on determining, through kinetic testing, how acid generating tailings at the abandoned Scotia Mine would behave long-term when capped with lime additives to control acid mine drainage formation. Materials from different tailings storage repositories were subjected to thirty-week column leach testing using a weekly heating cycle. Weekly assessments of water quality (pH and EC) and monthly assessments of the water chemistry (elemental content and sulfate).

**GEOCHEMICAL AND MINERALOGICAL CHARACTERISATION OF THE ABANDONED SCOTIA MINE, NORTHERN TASMANIA**

**Leader:** Anita Parbhakar-Fox

**Team Members:** Nathan Fox

**Student:** Laura Jackson

**Collaborator:** Andy Wakefield

This research project focussed on designing accurate tests that predicted waste types with greater certainty, more knowledge and at lower cost. The project was completed in 2015. The underlying aims of the project were to support:
- More effective mineral processing.
- Greater environmental performance of mining operations.
- Better storage of waste.
- Improved mine closure outcomes.

Through extensive laboratory testwork, and research on individual case study projects, a new architecture of integrative, staged acid rock drainage (ARD) testing was developed by the Environmental Indicators team. Better ARD prediction starts with improving the definition of geoenvironmental models and waste units, followed by a range of low-cost and rapid tests for the screening of samples, conducted on site and prior to the performance of established tests and advanced analyses using state-of-the-art laboratories. ARD prediction supports more accurate and cost-effective waste management during operation, and ultimately less costly mine closure outcomes. New tests and protocols developed include:
- Enhanced laboratory tests.
- Microwave Assisted Thermal Energy (MATE) pH test.
- Computed Acid Rock Drainage (CARD) risk grade assessment protocol.
- Low-cost test to predict the biocorrosive form of environmentally significant elements that could elute from mine waste materials.
- Predictive waste classification.
- Improved geochemical and mineralogical characterisation of dust.
- Characterisation of mineral dust properties.
- Geometallurgical indicators for predicting ARD.

**RESEARCH**

- Investigation of the deep structure beneath Bass Strait using receiver function methods.
- Participation in three research voyages to the Izuz-Bonin volcanic arc (2) and Heard Island.
- Preparation for a Chapman Conference titled: Submarine volcanology: New Approaches and Research Frontiers. This prestigious international conference is run under the auspices of the American Geophysical Union’s Chapman Program, and will be held in Hobart during January 20 and February 5, 2017. The program will focus on the next decade of research in submarine volcanism.

**PUBLICATIONS AND CONFERENCE PRESENTATIONS**

- Findings on the estimation of the ascent rate of magmas for two volcanoes in Karahalira will be submitted for publication.
- The latest results on the origin of the Angolan carbonatites are being prepared for publication in Nature.
- Research on a new proxy for ocean acidification in deep time will be submitted for publication and presented at a conference.

**HIGHER DEGREE BY RESEARCH COMPLETIONS**

- Graduation of PhD student Sam Holt.
OUTREACH

There was a full and varied program of outreach activities in 2015, which included a range of community favourites, augmented by a number of new initiatives.

SCIENCE EXPERIENCE

Activities began in January with the Science Experience initiative, which has become a regular feature of the early part of the outreach calendar. This national program provides the opportunity for Year 9 and 10 students to participate in a series of hands-on science activities under the guidance of researchers. This year’s visit was led by Sebastain Meffre, with support from Karin Orth and Sasha Stepanov, and included a look at a variety of petrological microscopes, a demonstration of LA-ICP-MS processes, and an interactive practical exercise in which the students placed fossils in order of the history of the Earth.

LIVE LINK TO VOYAGE ON THE HAVRE VOLCANO

In March and April, a link was placed on the CODES website enabling schoolchildren to follow Rebecca Carey on her voyage to the Havre volcano in the Kermadec Arc, New Zealand. Dr Carey was part of an international team of researchers, whose key objective was to investigate the seafloor deposits of a remarkable submarine eruption that occurred in 2012, which turned out to be the largest event of its type ever recorded. The schoolchildren were directed to the website via communications in collaboration with the Bookend Trust.

UTAS OPEN DAY

Staff and students played a major role in the University’s annual Open Day in August. Activities included volcanoology presentations, a microscopic tour of the rocks of Tasmania, a seismic demonstration at the UTAS Open Day; Students from Dover District High performing a seismic demonstration at the UTAS Open Day; and a hands-on simulation of a mass extinction using inflatable dinosaurs.

SCIENTISTS IN SCHOOLS

Izzy also continued with her involvement with the CSIRO’s Scientists in Schools program, which aims to create and support long-term partnerships between school teachers and scientists. In March, she participated in a networking forum aboard the Lady Nelson on Hobart’s River Derwent, where she was able to share ideas on future outreach activities with school teachers and other scientists in the program.

SCHOOL VISITS

The year saw the usual mix of visits by various pre-tertiary institutions, including The Hutchins School, Dover District High, Huonville High, and Rosetta Primary School. In addition, Rebecca Carey visited Corpus Christi Catholic School in Hobart to give a talk on submarine volcanoes.

PUBLIC LECTURES

Ross Large, Karin Orth and Indrani Mukherjee each gave presentations to the general public as part of the Royal Society of Tasmania Winter Lecture Series, within the themes of ‘Middle Earth – the Slingshot of Life’, ‘East meets West: the Great Barrier Reef’ and ‘Sixteen Legs: Enter the Cave’, by making spider-related props that were used during filming. In addition, when the project exhibition went on the road, she traveled to Ulverstone in Tasmania’s north, and Naracoote in South Australia, to help erect displays of two giant spiders, which she had built.

A PROJECT WITH LEGS

Curator of the Rock Library, Izzy von Lichtahn, continued to make significant contributions to the Bookend Trust’s Sixteen Legs project, which is bringing the mysterious and extraordinary world of Tasmania’s underground cave systems to the community. During the year, she helped with the production of the movie ‘Sixteen Legs: Enter the Cave’, by making spider-related props that were used during filming. In addition, when the project exhibition went on the road, she travelled to Ulverstone in Tasmania’s north, and Naracoote in South Australia, to help erect displays of two giant spiders, which she had built.

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– plus a ‘packed to the rafters’ presentation on mass extinctions by Ross Large.

LORDS OF THE PUB

One of the most successful (and fun) events of the year was when Ross Large, Indrani Mukherjee and Jeff Steadman, AKA Gandalf, Galadriel, and Aragorn, gave three highly entertaining talks as part of the national Science in the Pub program. Using the Lord of the Rings as their theatrical vehicle, the trio took the audience through Earth’s history of evolution and mass extinctions from 3.2 billion years ago, right up to the present day. The event was held at Hobart’s New Sydney Hotel, and was ‘standing room only’.

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MEDIA

In addition to coverage in specialised media, it was a particularly prolific year for general media coverage, with a number of stories making headlines, both locally and worldwide. Rebecca Carey’s trip to the Havre volcano featured prominently in the Mercury and Examiner newspapers, and via an interview on ABC Radio. Rebecca was also interviewed by Sydney’s 2UE radio station in relation to a new island that had formed in Tonga.

Further afield, Khin Zaw was interviewed by Myanmar’s MRTV television station after giving a keynote address at a major geological conference in the country. Honours student Sally Mattner took advantage of the temporary draining of Tasmania’s Lake Rowallan to study Precambrian rock formations that had not been visible since the last ice Age, which received coverage by ABC TV. Ross Large and his team announced that they had discovered a new technique to estimate the amount of gold present in ancient oceans, attracting extensive international media coverage, including a substantial article featuring Director Bruce Gemmell in the Sunday Tasmanian.

Finally, towards the end of the year, researchers Jacqueline Halpin and Jacob Mulder revealed links between Antarctica and the ancient Nuna supercontinent, which received extensive national and international media exposure, including filming for an episode of ABC TV’s Catalyst program, which is set to air in 2016.
INDUSTRY LINKS & RESEARCH COLLABORATIONS

OBJECTIVES

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

CODES is recognised as a world leader in industry-linked, collaborative ore deposit research. Strong relationships have been developed with a range of industry partners and researchers who invest in, support, and contribute to, research projects. Fostering and growing these national and international collaborations is a key strategic focus.

INDUSTRY LINKS AND SYNERGIES

CODES has strong, enduring and mutually beneficial links with a group of 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.

In 2015, the group of CODES’ industry partners comprised of five Australian and international mining companies: Anglo American, Buenaventura, Newcrest Mining, Rio Tinto, and Teck Resources.

Partner companies provide support of up to $75,000 in cash per year to the core research budget of the Centre. 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 potential directions for new research.

INDUSTRY PARTNERSHIP OPPORTUNITIES

CODES offers a range partnership opportunities that can be tailored to company requirements. Although all partnership agreements expired when CODES tenure as a funded ARC Centre of Excellence concluded at the end 2013, many companies have signed new agreements. These renewed commitments are testament to the value that companies place in a partnership with CODES, especially considering the current tough operating conditions in the minerals industry.

Major benefits of a partnership agreement include enhanced prospects of discoveries, optimisation of existing reserves, first call on geoscience graduates, and access to a world-class research team and state-of-the-art facilities. For further details of partnership opportunities, contact the Director, Bruce Gemmell:

E. bruce.gemmell@utas.edu.au
Tel. +61 3 6226 2893.

ROLE OF AMIRA INTERNATIONAL

AMIRA plays a vital role in facilitating the funding of collaborative research involving university research groups and the minerals industry. AMIRA has agreed to fund projects within the Centre, which will run over a period of three to four years. In 2015 it funded AMIRA P1153 Applying the explorers’ toolbox to discover porphyry and epithermal Cu, Au and Mo deposits, which is being conducted within the new ARC FMVC Research Hub.

RESEARCH COLLABORATIONS AND INTERNATIONAL VISITORS PROGRAM

In 2015, CODES further cemented its reputation for cultivating research collaborations with other Australian and international research organisations. Throughout the year, collaborative research was conducted with 42 international and 19 national organisations.
OBJECTIVES

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

TECHNOLOGY TRANSFER ACTIVITIES

CODES undertakes strategic and applied research into ore deposits (characterisation and context) and geology, and the development of innovative enabling technologies to support these research endeavours. These initiatives create knowledge, processes, methods and solutions for the minerals industry and ore deposit researchers – locally, nationally and internationally.

Research results and technical developments in the applied research modules are transferred to end-users via regular research meetings, research reports, monographs, books, digital presentations and software packages, where appropriate. In 2015, 84 research reports were presented to industry clients. Meetings were also held to present the following publications that were sold during 2015:

- *Basins, fluids and Zn-Pb ores*.

SHORT COURSES, WORKSHOPS, CONFERENCES AND FIELD TRIPS LED BY CODES

**2018 SHORT COURSES, WORKSHOPS, CONFERENCES AND FIELD TRIPS LED BY CODES**

**TITLE** | **PRESENTERS** | **NO.** | **LOCATION** | **DATE**
--- | --- | --- | --- | ---
Geophysics for Geologists and Engineers | Michael Roach, Hugh Tassell | 8 | CODEIS, Hobart | 2 – 7 February
MTGEC - Exploration Field Skills Mapping Camp | Evan Oravan, Robert Scott, Nathan Sleeves, Selina Wu | 24 | Queenstown, Tasmania | 8 – 10 February
Australian Microbeam Analysis Symposium (AMAS) XIII: Pre-Symposium LA-ICP-MS Workshop | Leond Danyushevsky, Dace Paul, Jon Woodhead | 14 | CODEIS, Hobart | 9 February
Australian Microbeam Analysis Symposium (AMAS) XIII | >50 presenters, including Sarah Gilbert, Sebastien Meffre, Jay Thompson | 118 | CODEIS, Hobart | 11 – 13 February
MTGEC - Exploration Field Skills Mapping Camp | Sean Johnson, Jacob Mulder, Josh Phillips, Robert Scott | 24 | Queenstown, Tasmania | 8 – 10 March
One Deposits of South Amercia | David Cooke, Bruce Gemell, Jose Piquer, David Salley | 17 | Chile and Peru | 13 – 27 March
Characteristics, Settings and Genesis of High Sulphidation and Porphyry Deposits | David Cooke | 50 | Universidad Nacional de Ingeniería, Lima, Peru | 28 March
77th International Association of Geochemistry Symposium Short Course - Isotopes in Mineral Exploration | David Cooke, Kurt Herup, Matt Laybourne, Ryan Mathur, Ed Van Hees, Rich Harly | 18 | Arizona, USA | 19 April
VEPS - One Deposit Models | David Cooke, Garry Davidson, Bruce Gemell, Robert Scott, David Salley, Jeff Steadman | 12 | CODEIS, Hobart | 11 – 15 May
VEPS - Practical Igneous Petrology | Leonid Danyushevsky | 17 | CODEIS, Hobart | 18 – 22 May
AMFRA P1060 Workshop | Mike Baker, Lejun Zhang | 10 | CODEIS, Hobart | 3 June
One Deposit Geochemistry, Hydrology and Geochronology Short Course | Mike Baker, Shaun Barker, Ron Barry, Phil Bairvn, David Cooke, Tony Crawford, Leonid Danyushevsky, Garry Davidson, Nathan Fox, Scott Halley, Sean Johnson, Ross Large, Sebastien Meffre, Nick Oliver, Robert Scott, Rob Sibson, Leslie Wyborn, Lejun Zhang | 37 | CODEIS, Hobart | 8 – 10 June
SE Asia: Tectonics and Ore Deposits | Khin Zaw | 54 | West Yangon University, Myanmar | 22 July
Tectonics and Ore Deposits of SE Asia | Khin Zaw | 28 | Universiti Teknologi Malaysia (UTM) | 30 July
SEG Student Chapter Field Trip to Iceland and Sweden | David Cooke, Peter Hollings, Jocielyn McPhie | 22 | Iceland and Sweden | 4 – 21 August
Deposits of the Gold-rich Ordovician Alkaline Porphyry and Epithermal Province, Macquarie Arc, NSW. Pre-Conference Field Trip – SEG 2015 Conference | Nathan Fox, Anthony Harris | 21 | Orange, NSW | 23 – 25 September
TECHNOLOGY TRANSFER

PERFORMANCE INDICATORS

PERFORMANCE MEASURES IN 2014 – 2018 STRATEGIC PLAN

TARGET 2015

Research Findings
Publications in international journals
50pa 65
Percentage of publications in high quality international journals
70% 85%
Reports to industry collaborator
80pa 84
Special issues and/or research monographs
1 per 2 years 2 (2016)
Invitations to give keynote conference presentations
10pa 2
Papers at national/international meetings
70pa 147

Research Training and Professional Education
Percentage of HDR students attracted from interstate
25% 20%
Percentage of HDR students attracted from overseas
65% 64%
Number of Honours students in CODES’ modules
15 5
Number of HDR students in CODES’ modules
50 41
Percentage of students in projects linked with industry
80% 75%
Professional short courses/workshops for industry
4pa 27

International, National and Regional Links and Networks
CODES’ national or international conferences/workshops
1 per 2 years 2
Registrants at CODES’ conferences/workshops
600pa 1562

End-user Links
Frequency of meetings with industry representatives
15pa 20

National Benefit
CODES’ research has input into a major mineral discovery
1 per 5 years 9 in 27 years

<table>
<thead>
<tr>
<th>TITLE</th>
<th>PRESENTERS*</th>
<th>NO.**</th>
<th>LOCATION</th>
<th>DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEG 2015 Conference</td>
<td>&gt;100 presenters/Chairs, including David Cooke, Leonid Danyshevskey, Garry Davidson, Angela Escolina, Bruce Gemmell, Dan Gregory, Wei Hong, Julie Hunt, Sean Johnson, Vadim Kamenetsky, Ross Large, Indrani Mukherjee, Robert Scott, David Selley</td>
<td>742</td>
<td>Hobart</td>
<td>27 – 30 September</td>
</tr>
<tr>
<td>Drill Core Measurements and Domaining for Geometallurgy Post-Conference Short Course – SEG 2015 Conference</td>
<td>Ron Berry, Julie Hunt, Michael Roach</td>
<td>16</td>
<td>Hobart</td>
<td>1 October</td>
</tr>
<tr>
<td>Geometallurgy Short Course</td>
<td>Ron Berry, Dee Bradshaw, Sandrin Feig, Nathan Fox, Sarah Gilbert, Melissa Humphries, Julie Hunt, Aníta Parrish-Fox, Thomas Rodemann, Jay Thompson</td>
<td>15</td>
<td>CODES, Hobart</td>
<td>19 – 30 October</td>
</tr>
<tr>
<td>AMIRA P1153 Workshop for FreepointMcMoRan</td>
<td>David Cooke</td>
<td>15</td>
<td>Manila, Philippines</td>
<td>7 November</td>
</tr>
<tr>
<td>Ore Deposit Models and Exploration</td>
<td>Zhaoxian Chang, Huayong Chen, David Cooke, Rich Golden, Dave Leach, Chuan Li, Steve Scott, Neal White, Kaili Yang</td>
<td>141</td>
<td>Wun, China</td>
<td>10 – 14 November</td>
</tr>
<tr>
<td>Volcanic Successions</td>
<td>Patrick Hayman, Rebecca Carey, Ray Cas</td>
<td>20</td>
<td>Merimbula, NSW</td>
<td>16 – 20 November</td>
</tr>
<tr>
<td>AMIRA P1153 Geochemistry Workshop Two</td>
<td>David Cooke, Tim Ireland, Josh Phillips, Adele Seymour, Mike Vinnik, Jamie Wilkinson, Lejun Zhang</td>
<td>15</td>
<td>CODES, Hobart</td>
<td>1 December</td>
</tr>
<tr>
<td>Magmatic-Hydrothermal Ore Deposits</td>
<td>Bruce Gemmell</td>
<td>50</td>
<td>Kiel, Germany</td>
<td>16 – 17 December</td>
</tr>
</tbody>
</table>

* CODES presenters in bold. ** Number of attendees. * ARC TMVC Research Hub.

A practical session of the Ore Deposit Geochemistry, Hydroligraphy and Geochronology short course.

ANNUAL REPORT 2015
FINANCES

2015 INCOME
Total CODES income was $8.5 million (see Table 1). This was derived principally from the combined income sources of the ARC TMVC Research Hub (32%), UTAS (32%) and industry (20%) (see Figure 1). The main income streams over time are compared in Figure 2, showing the recovery following the commencement of the ARC TMVC Research Hub’s funding.

SUMMARY OF THE MAIN INCOME STREAMS TO CODES IN 2015:

- ARC TMVC Research Hub: The combined income sources for the TMVC amounted to $2.7 million in 2015, comprising of funding from the ARC ($2.1 million), industry Partner Organisations ($584k), and Host Institution ($64k). The figure for the ARC includes funding covering the period from 2013 to 2015, which was dispensed to the Budget Centre in 2015.
- Industry income: Industry funding of $1.7 million comprises funding related to Industry Partner support, industry funded student projects, and other research projects. This figure does not include industry-based support for the ARC TMVC Research Hub (see above).
- Host institution support: Funding from UTAS in 2015 was up compared to the adjusted figure for 2014, mostly due to an increase in operating grant support. UTAS funding relates primarily to research salaries, PhD scholarships and income earned by the Centre from research output.

“An adjustment has been made to the 2014 UTAS income figure to reflect that $64k of funding reported was due to the ARC TMVC Research Hub. The revised UTAS figure of $2,356,155 for 2014 is now reflected in the adjusted figures and graphics contained in this current report.

2016 INCOME ESTIMATES
The total income figure is anomalous in 2015, as it includes funding for the ARC TMVC Research Hub that was backdated to 2013. While this will result in a comparative drop in funding levels from the ARC for the TMVC in 2016, industry funding for the AMIRA P1153 project will increase (funding in 2015 was for a six month period only). Other funding into CODES is expected to remain similar to 2015.

### TABLE 1 CASH INCOME FINANCIAL STATEMENT 2015

<table>
<thead>
<tr>
<th>Category</th>
<th>Amount</th>
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</thead>
<tbody>
<tr>
<td>ARC TRANSFORMING THE MINING VALUE CHAIN RESEARCH HUB</td>
<td>2,093,344</td>
</tr>
<tr>
<td>Partner Organisations</td>
<td>584,000</td>
</tr>
<tr>
<td>AMPAR P1153</td>
<td>269,800</td>
</tr>
<tr>
<td>BHP Billiton Olympic Dam</td>
<td>150,000</td>
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<td>Newcrest Mining</td>
<td>165,200</td>
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<tr>
<td>Host Institution</td>
<td>63,869</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>2,741,213</strong></td>
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<td>ARC GRANTS</td>
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<tr>
<td>Discovery Grants</td>
<td>169,901</td>
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<tr>
<td>Specific Projects</td>
<td>145,245</td>
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<tr>
<td>Student Projects</td>
<td>7,000</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>147,245</strong></td>
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<td>OTHER COMMONWEALTH GOVERNMENT</td>
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<tr>
<td>State Government</td>
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<tr>
<td>Miscellaneous</td>
<td>1,362</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>1,362</strong></td>
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<tr>
<td>INDUSTRY/PRIVATE</td>
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<td>CODES Industry Partners</td>
<td>302,500</td>
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<td>Minerals Council of Australia (MCA/MTEC)</td>
<td>67,400</td>
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<tr>
<td>Directly Funded Research Projects</td>
<td>836,625</td>
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<td>Directly Funded Student Projects</td>
<td>501,381</td>
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<td>Miscellaneous</td>
<td>4,299</td>
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<td><strong>Total</strong></td>
<td><strong>1,712,205</strong></td>
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<td>CONTRACTS/CONSULTANCIES/REVENUE RAISING</td>
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<td>Short Courses</td>
<td>121,505</td>
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<td>Book Sales</td>
<td>29,013</td>
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<td>Miscellaneous (incl. Analytical Services)</td>
<td>740,105</td>
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<td><strong>Total</strong></td>
<td><strong>890,624</strong></td>
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<td>UNIVERSITY OF TASMANIA - HOST INSTITUTION SUPPORT</td>
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<td>Operating Grant</td>
<td>1,521,727</td>
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<td>Scholarships and Tuition Fee Waivers</td>
<td>1,097,240</td>
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<td>Strategic Projects</td>
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<td>Miscellaneous</td>
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<td><strong>Total</strong></td>
<td><strong>2,733,994</strong></td>
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<td>OTHER INCOME SOURCES/INTEREST</td>
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<td>Overseas Governments</td>
<td>10,465</td>
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<td>Society of Economic Geologists - Student Scholarships</td>
<td>9,247</td>
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<td>Student Support</td>
<td>1,032</td>
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<td>Specific Projects</td>
<td>42,850</td>
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<td>Miscellaneous</td>
<td>13,366</td>
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<td><strong>Total</strong></td>
<td><strong>76,959</strong></td>
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<td>TOTAL ANNUAL INCOME</td>
<td><strong>8,473,083</strong></td>
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NOTES TO, AND FORMING PART OF, THE FINANCIAL STATEMENTS FOR 2015

The financial pages of this Annual Report were prepared by Helen Scott (ARC TMVC Research Hub Manager). Data for the financial statements was extracted from UTAS systems, particularly its Finance System. All Financial Statements shown here have been reviewed by UTAS Central Finance.

Income statement explanations
The income figures in Table 1 represent actual income recorded in the University’s finance system, transferred internally from UTAS to CODES during 2015, or centrally administered for CODES RHD students (as in the case of scholarships and tuition fee waivers).


Luther, G.W., Sun, H., and Huang, Q., 2015, A record of volcanic-hosted massive sulfide (VHMS) mineralization in the Archean Yilgarn Craton, Western Australia: tectonic, stratigraphic and geochemical associations: Precambrian Research, v. 263, p. 113-151.


brecias at the Zijinshan high sulfidation Cu-Au deposit, Fujian Province, China, SGA Biennial Meeting 2015, Nancy, France, Extended Abstracts, p. 1071-1074.


Faustino, M., Cooke, D.R., Del Bello, E., Scarlato, P., and Parnell, C., Uranium mineralization and mineral chemistry as a tool to discriminate mineralized from barren Sn-granites, western Tasmania, Australia, SEG 2015 Conference, Hobart, Australia.

Goulet, J.B., Role of education in supporting the development of capability and capacity in exploration, in process, in site, in regional and in national Energy Conference 2015, Oueanouen, Australia.


Dinan, N., and Young, M. Evidence of micro-continent entrainment in the growth of the east Gondwana margin from Bayesian ambient noise tomography, EGU General Assembly 2015, Vienna, Austria, EGU2015-19999.


PiQuar, J., and Cooke, D.R., Porphyry Cu-Mo systems emplaced under contrasting tectonic regimes: examples from central Chile and SE China, Chilean Geological Congress 2015, La Serena, Chile, Proceeding.


Smyk, E., Hollings, P., Cooke, D.R., Lee, R., and Lulu, J. Gold-rich weathering rings around pyrite and arsenopyrite near a Mo-Cu porphyry deposit in the Copper Basin, Nevada, implications for supergene enrichment and possible relationships with Carlin-style mineralisation, SEG 2015 Conference, Hobart, Australia, Poster.


Smyk, E., Hollings, P., Cooke, D.R., Lee, R., and Lulu, J. Gold-rich weathering rings around pyrite and arsenopyrite near a Mo-Cu porphyry deposit in the Copper Basin, Nevada, implications for supergene enrichment and possible relationships with Carlin-style mineralisation, SEG 2015 Conference, Hobart, Australia, Poster.


Soule, S., Carey, R.J., Jones, M., Iagam, F., Yoeger, D., and Parnari, D. Transport and deposition during the 2012 submarine explosive eruption of H-Day volcano, AGU Fall Meeting 2015, San Francisco, USA, Abstract V02a-06.


Steeves, N.J., Gammell, J.B., Large, R.R., Hanington, M.D., and Callaghan, R. Late-stage Cu and Ag replacement at the Greens Creek massive sulfide deposit, Alexander Terranes, Southeast Alaska, SEG 2015 Conference, Hobart, Australia, Poster.


Sutherland, F.L., Graham, I., Harris, A.C., Infrared imaging of geothermal activity within the Lienatz open pit, Lihir Au mine, PNG; Influence of faults and porphyry- and epithermal-style breccias on modern-day high-temperature fluid flow, SEG 2015 Conference, Hobart, Australia, Poster.


Thompson, J.M., and Danyushevsky, L. Diatomic gas addition for LA-ICP-MS: Effects of physical properties of plasma, EWCPS 2015, Munster, Germany, Poster.

Tran, H.T., Khi Zhaw, Le, T.X., and Manaka, T. Multiphase thermoelastic overprinting in southeastern Tuong Son fold-thrust belt and its role for regional gold metallogeny, AOGS Conference 2015, Singapore, CD-ROM.
DISCIPLINE OF EARTH SCIENCES (18)


Doutch, D., 2015, The geology and geological controls on gold mineralisation at the Invincible Deposit, St Ives Gold Project, Western Australia, 6 p.


Doutch, D., 2015, The geology and geological controls on gold mineralisation at the Invincible Deposit, St Ives Gold Project, Western Australia, 6 p.


Doutch, D., 2015, The geology and geological controls on gold mineralisation at the Invincible Deposit, St Ives Gold Project, Western Australia, 6 p.


### MASTER OF ECONOMIC GEOLOGY (52)

<table>
<thead>
<tr>
<th>STUDENT</th>
<th>SUPERVISORS</th>
<th>PROJECT</th>
<th>SUPPORT</th>
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<tbody>
<tr>
<td>Fabian Baker</td>
<td>Cooke</td>
<td>Aur curls HSE Au deposit, Arminia</td>
<td>Liyanian International</td>
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<tr>
<td>Billy Beas Caceres</td>
<td>McPhail, Gemmill</td>
<td>Volcanic stratigraphy at La Zanja Mining District in the northern Peruvian Andes, Cajamarca, Peru</td>
<td>Cia de Minas Buenaventura (SAA/ Minera La Zanja SRL)</td>
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<td>Lynelle Baines</td>
<td>coursework only</td>
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<td>Sebastian Behanides</td>
<td>Cooke</td>
<td>Characterisation of phyllic assemblages at Taca Taca Bajo, Argentina</td>
<td>First Quantum</td>
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<td>Christopher Booth</td>
<td>coursework only</td>
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<td>Cesar Calderon-Tipani</td>
<td>Gemmill</td>
<td>Chancas low sulfidation deposit, Peru</td>
<td>Buenaventura</td>
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<tr>
<td>Wayne Carter</td>
<td>coursework only</td>
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<td>Glen Catthor</td>
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<td>Chien Cavill</td>
<td>G.Davidson</td>
<td>Geochemical classification of orebearing/metaliferous fluids of the Coolfield region, Victoria</td>
<td>MandaI Resources</td>
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<tr>
<td>Johanna Cole</td>
<td>Cooke</td>
<td>The geology, alteration, and mineralisation of the Sagar deposit in northern Negros, Philippines</td>
<td>Freeport-McMoRan Exploration Corporation</td>
</tr>
<tr>
<td>Joanna Condron</td>
<td>Gemmill</td>
<td>Mineral characterisation of the DeGrussa deposit: Implications for mining, milling and exploration</td>
<td>Sandfire Resources</td>
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<td>Richard Cotton</td>
<td>coursework only</td>
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<td>Lucas Doherty</td>
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<td>Peter Duerden</td>
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<td>Eric Dutch</td>
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<td>Daniel Ervin</td>
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<td>Patric Farias</td>
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<tr>
<td>Maria Lourdes M. Faustino</td>
<td>Cooke</td>
<td>Intrusive history and genesis of Baguio porphyry copper-gold deposit, Surigao Del Norte, Philippines</td>
<td>DFAIT, Philex Mining, SEG</td>
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<td>Franco Ferreyra</td>
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<td>Arga Firmansyah</td>
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<td>Daniel Flores</td>
<td>coursework only</td>
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<td>Phil Gilmore</td>
<td>G.Davidson</td>
<td>Exhalative horizons and volcanic-associated massive sulfide mineralisation in the Ordovician Gibraltana Group, New Scotland</td>
<td>Geological Survey of NSW</td>
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<td>David Greer</td>
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<td>Brendan Hardwick</td>
<td>TBD</td>
<td>Sulfide textures at Tropicana Gold Mine: Relationship to deposit genesis, gold deportment and implications for ore processing, exploration, and environment</td>
<td>AngloGold Ashanti</td>
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<td>Kyle Hodges</td>
<td>coursework only</td>
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<td>Jonathan Hoya</td>
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<td>Kyle Hughes</td>
<td>coursework only</td>
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<td>Danny Husman</td>
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<td>Anna Koldeweit</td>
<td>Large</td>
<td>Trace element chemistry of chalcopyrite in the Vitoorum Trend MTX deposits, USA</td>
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<td>Thomas Langley</td>
<td>coursework only</td>
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<td>Xuan Truong Le</td>
<td>Large</td>
<td>Geological setting and mineralisation characteristics of the Mo Xi gold deposit, Guang Tri Province, Central Vietnam</td>
<td>Axion Mining, Haroi University of Mining and Geology, OR Geos Resources Limited, Deposits of SE Asia Project</td>
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<td>Chantelle Low</td>
<td>Ehrig (BHPliton)</td>
<td>An aspect of the geology of the Olympic Dam deposit</td>
<td>BHP Billiton</td>
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<td>Walter Lozano Garcia-Naranjo</td>
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### BACHELOR OF SCIENCE (HONOURS) (21)

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<th>PROJECT</th>
<th>SUPPORT</th>
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<tbody>
<tr>
<td>Adam Abarstine</td>
<td>V.Kamenetsky</td>
<td>Petrographic and mafic inclusion constraints on the petrogenesis and compositional implications for kimberlites from Finland and South Africa</td>
<td>ARC</td>
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<tr>
<td>Wayne Baker</td>
<td>McPhail</td>
<td>Lithostratigraphy and facies architecture of the footwall to the DeGrussa volcanic hosted massive sulfide deposit, Western Australia</td>
<td>Sandfire Resources</td>
</tr>
<tr>
<td>Corey Bellchambers</td>
<td>G.Davidson, Maff</td>
<td>Pyrite trace element and isotopic zonation at the Henty Au deposit, Tasmania</td>
<td>Unity Mining Resources</td>
</tr>
<tr>
<td>Murray Browning</td>
<td>Large</td>
<td>Investigating Tasmanian black shale and associated pyrite for evidence of the SPICE event</td>
<td>UTAS</td>
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<tr>
<td>Evan Drayners</td>
<td>Danyushhevsky</td>
<td>Detailed mineralogy of boninite and anorthosite lavas from the Hunter Ridge: Implications for plumbing system and magma generation processes</td>
<td>UTAS</td>
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<tr>
<td>Mark Giddings</td>
<td>V.Kamenetsky</td>
<td>Investigating non-magnetic solutions to the chromite genesis conundrum: A petrological and geochemical study of Hidaka Mountain chromite bearing peridotites and Hornblende Massif Ophiolite</td>
<td>UTAS</td>
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<tr>
<td>Melanie Haycroft</td>
<td>G.Davidson, Plimer</td>
<td>The eastern mineralisation, Broken Hill, NSW</td>
<td>OBH Resources</td>
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<td>Chris Hile</td>
<td>McPhail</td>
<td>Understanding the nature of the host rock succession to the Anchean Nimbus Ag-Zn-Pb-Au deposit, WA</td>
<td>MadPherson Resources</td>
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<td>Travis Holmes</td>
<td>Cooke, Baker, Fox</td>
<td>Geology, timing and controls on alteration and mineralisation at the Big Wilson 1th Prospect, NW Tasmania</td>
<td>Venture Minerals</td>
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<td>Sally Mather</td>
<td>Scott</td>
<td>Structure and metamorphism of the Mason River metamorphic complex</td>
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<tr>
<td>Will McAdam</td>
<td>Roach, Duffett (MRT)</td>
<td>A geophysical interpretation of the Mole Creek area, Tasmania</td>
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<td>Reuben McCormack</td>
<td>Roach</td>
<td>Geophysical assessment of potential massive sulfide mineralisation at the L13 Prospect, Highclere, Northwest Tasmania</td>
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<td>Jake Mottson</td>
<td>Parthakar-Fox, Fox</td>
<td>Integrated techniques for rapid drill core mineralogical characterisation</td>
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<td>Bronson Rogers</td>
<td>Fox, Parthakar-Fox</td>
<td>Environmental significance of the Broken Hill Gossan: A mineralogical and geochemical study</td>
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<td>Jordan Sheppard</td>
<td>Zaw, Large</td>
<td>Trace element variations in Devonian shale in Northern Shan State, Myanmar</td>
<td>ARC</td>
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<td>Mark Smith</td>
<td>Roach, Tassell (GHD)</td>
<td>Distribution, nature of sediments and depth to bedrock in Bass Strait, in the region of Bruny Port</td>
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<td>Peter Tongue</td>
<td>McGoldrick</td>
<td>Taphonomy and depositional environment of Horodyskia willardensis fossils from the Cassiliterite Creek Quartzite, Tasmania</td>
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<td>Jonathon Traynor</td>
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<td>Genesis of Modi-Momi Taung high sulfidation epithermal system, southern Queensland, Australia</td>
<td>Sandfire Resources</td>
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<td>Leslie Warn</td>
<td>Roach, G.Davidson</td>
<td>Gravity and magnetic modelling of the Coygrat area, Tasmania</td>
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<td>Ben Whitney</td>
<td>Zhang, G.Davidson</td>
<td>Geostatistical modelling and characterisation of the Tropicana Hill high sulfidation epithermal system, southern Queensland, Australia</td>
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<td>Matthew Whitten</td>
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<td>Formation de Kone: Recording the final stages of Gondwana break up in New Caledonia</td>
<td>Université de la Nouvelle-Caledonia</td>
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<td>Neil Macaladsa ¹ ²</td>
<td>Cooke</td>
<td>Geology, alteration, mineralisation and vectoring to porphyry centre in the Aisaipur prospect, Irian Jaya, Indonesia</td>
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<td>Inam Malik ³</td>
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<tr>
<td>Rebecca McLellan ⁴ ⁵</td>
<td>Scott</td>
<td>Gold mineralisation at the Reefton Goldfield, New Zealand</td>
<td>Oceana Gold</td>
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<td>Joanne Morrison ⁶</td>
<td>Berry</td>
<td>Cadia East multi-element lithogeochemistry: Evaluation of trace element deportment important to processing</td>
<td>Newcrest Mining</td>
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<tr>
<td>Michael Muzzall ⁶</td>
<td>Scott</td>
<td>The geological setting and mineralisation characteristics of the Dunedin deposit, Zambia</td>
<td>Copperbelt University</td>
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<td>Akela Nichols</td>
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<td>Saranya Naunia-Ong</td>
<td>Zaw</td>
<td>Paragenesis, pyrite geochemistry and ore fluids at Htongyi gold veins, Myanmar</td>
<td>Ore Deposits of SE Asia Project, National Prosperity Company</td>
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<td>Chris Pigott</td>
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<td>Alan Riles</td>
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<td>Stephanie Robertson ⁷</td>
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<td>Christopher Shanley</td>
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<td>Markus Staubmann</td>
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<td>Edward Summatjaras ⁸</td>
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<td>Chris Thau</td>
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<td>Neville Vandersnik</td>
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<td>Peter Watson</td>
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<tr>
<td>Orur Yilmaz ¹</td>
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**MASTER OF SCIENCE (2)**

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<tr>
<td>Eyob Andemaseket</td>
<td>Selley</td>
<td>Litho- and chemo-stratigraphic, structural and mineral prospectivity aspects of the Rosebery Group, an enigmatic Cambrian volcano-sedimentary succession on Tasmania's west coast</td>
<td>MMS</td>
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<tr>
<td>Irina Vajlyte ¹ ²</td>
<td>V.Kamenetsky, McPhie, Ehrig (BHPBilliton)</td>
<td>Geological evolution of the Wirrda Well Prospect, Gawler Craton, South Australia</td>
<td>UTAS, CIE, BHP Billiton, ARC</td>
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**DOCTOR OF PHILOSOPHY (54)**

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<tr>
<td>Olga Apurutina ¹ ²</td>
<td>V.Kamenetsky, McPhie, Maas (UMelb)</td>
<td>Stable isotopes (C, O and D) and hydrogels (H2O) in gongue and ore minerals at Olympic Dam: Evaluation of mantle and crustal contributions to mineralisation</td>
<td>BHP Billiton, Olympic Dam, UTAS, CRC ORE</td>
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<td>Ricardo Arid-Pascual</td>
<td>V.Kamenetsky, Goeman, Noble, N.Aiken (consultant)</td>
<td>The characterisation and role of coals in the mineral formation in Graves Island l1 Pb-Zn deposit, western Tasmania</td>
<td>CoE, UTAS, CRC ORE</td>
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<tr>
<td>Mohd Baerli Iswadi</td>
<td>Zaw, Large</td>
<td>Geology of volcanic-hosted massive sulphide (VMS) deposits in Central Belt, Peninsular Malaysia</td>
<td>Malaysian Govt, One Deposits of SE Asia Project</td>
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<tr>
<td>Heidi Borkanbosc</td>
<td>Gemmill, McNeill (MRT), Christie (UTAS Science)</td>
<td>Geochemistry of hydrothermal mineral chimneys from Brothers volcano, Kermadec: Arc</td>
<td>UTAS, CoE, GNS Science, UTAS, SEG, AusIMM, Australian Synchrotron</td>
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<tr>
<td>Ben Cave</td>
<td>Large, Danyushkevich</td>
<td>A metamorphic core for tungsten in metasedimentary-hosted orogenic gold deposits</td>
<td>UTAS, CIE</td>
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<tr>
<td>Nathan Chapman</td>
<td>Miftah, V.Kamenetsky</td>
<td>Pb-Isotopic insights into the crustal evolution and metamorphogenesis of the Gawler Craton</td>
<td>ARC, BHP Billiton</td>
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<tr>
<td>Jing Chen</td>
<td>Cooke, Zhang</td>
<td>The geology, mineralisation, alteration and fluid evolution of Zijinshan ore field, Fujian Province, China</td>
<td>UTAS, Chinese Govt, SEG, Zijin Mining</td>
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<tr>
<td>Alexander Cherry</td>
<td>V.Kamenetsky, McPhie, Ehrig (BHPBilliton)</td>
<td>Petrology, provenance and composition of bedded sedimentary facies in the Olympic Dam deposit</td>
<td>UTAS, ARC, BHP Billiton</td>
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<td>David Douth</td>
<td>Scott, Cas</td>
<td>The geology and geological controls on gold mineralisation at the Inivisible deposit, St Ives Gold Mine, Kambalda, WA</td>
<td>St Ives Gold</td>
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<td>Angela Escome</td>
<td>Cooke, Hunt, Berry</td>
<td>Ore characterisation and geometallurgical modelling at the Productoria Cu-Au-Mo deposit, Chile</td>
<td>UTAS, Hot OVL, CSIRO, AusIMM</td>
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<td>Esmaili Esfahani</td>
<td>Reading, Roach</td>
<td>3D petrophysical and geophysical modelling of west and northwest Tasmania</td>
<td>UTAS</td>
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<tr>
<td>Matt Ferguson</td>
<td>V.Kamenetsky, Miftah, Ehrig (BHPBilliton)</td>
<td>Regional metal and fluid sources for IOCG mineralisation around Olympic Dam, and geology, geochemistry and mineral chemical zonation of the Wirrda Well deposit</td>
<td>UTAS, CIE, ANZS, Australian Antarctic Science Program, Betty Mayne Scientific Research Fund For Earth Sciences</td>
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<tr>
<td>Jodi Fox</td>
<td>McPhie, Carey</td>
<td>Basaltic volcanic successions in Tasmania and on Heard Island</td>
<td>UTAS, CIE, BHP Billiton</td>
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<tr>
<td>Martin Gal</td>
<td>Reading, Elingson (Physics)</td>
<td>The development of array and single station methods for the analysis of on-land ambient seismic signals from deep ocean storms and coastal sources</td>
<td>UTAS</td>
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<tr>
<td>Amos Garay ¹ ²</td>
<td>Cooke</td>
<td>Magnetic and epigene chemistry and textures at Las Bambas Cu-Au-Fe skarn, Peru: Assessing district and deposit-scale fertility - implications for ore genesis and exploration</td>
<td>AMIRA P1153</td>
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<tr>
<td>Sarah Gibert ¹ ²</td>
<td>Danyushkevich, Large</td>
<td>Development of analytical methods and standard reference materials for analysis of trace elements and isotopic ratios in sulfide</td>
<td>CoE, CODES, Agoge Technologies</td>
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<tr>
<td>Cassidy Harraden ¹ ²</td>
<td>Miftah, Berry</td>
<td>Geotechnical and geometallurgical assessment of the Cadia East deposit using Corescan automated logging technology</td>
<td>UTAS, TMVC, Newcastle, Corescan</td>
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<tr>
<td>Rachel Harrison</td>
<td>Cooke</td>
<td>Tumpangpitu porphyry Au-Cu-Mo and high-sulfidation epithermal Au-Ag deposit, Tujuh Bukit project, SE Java, Indonesia - geology, alteration and mineralisation</td>
<td>UTAS, SEG</td>
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<td>Margaret Hawke</td>
<td>Gjeml, Large, O.Davison</td>
<td>Geological evolution of the DaGruassa Cu-Au VHMS deposit, Western Australia</td>
<td>UTAS, Sandfire Resources</td>
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<tr>
<td>Jacob Heathcote</td>
<td>Scott, G.Davidson</td>
<td>Gold distribution and association at the Kansanshi copper-gold deposit Zambia: Processes responsible for gold precipitation and implications for ore zone delineation and recovery</td>
<td>First Quantum Minerals</td>
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* Core yard at Productora Cu-Au-Mo deposit, northern Chile.
STUDENT | SUPERVISORS | PROJECT | SUPPORT
--- | --- | --- | ---
Sam Holt | Carey, McPhee | Understanding of basaltic eruption dynamics and mechanisms: Eruptive and explosive eruptions in Hawaii | UTAS, CODES, Hawaii Volcano Observatory, USGS, CEIR
Wei Hong | Cooke, Zhang, Fox | Magmatic-hydrothermal volatile evolution and mineralisation in Tasmanian Sn granites | UTAS, CODES, SEG, Geoscience Australia
Guoyue Huang | V.Kamenetsky, McPhee, Allan | Mafic magmatism in the Gawler Craton: Distribution, composition, timing, sources and tectonic setting | UTAS, BHP Billiton, ARC
Fumihiko Higami | Carey, McPhee | 2012 submarine slurry eruption of Huna volcano and implications for ancient submarine successions in Australia | UTAS, ARC, US National Science Foundation
Laura Jackson * | Parthakar-Fox, Cooke, Fox | Domaining of geoenvironmental properties in drill core | ARC TMVC, UTAS
Carlos Andres Jimenez Torres | Cooke, White, Baker | Baringit lithropic, Negros Island, Philippines: Mineralogy, textures, and chemistry | UTAS Foundation, AMIRA P1560
Sean Johnson | Large, Maffe, McGoldrick | The trace element content and suite of chemistry of metaliferous black shales | UTAS, CODES, Mining Institute of Scotland, ANZRC: IODP, ECORD, NERC, Taivaal Mining, GTK, SEG
Teara Kampong * | Zaw, Maffe | Geology and genesis of porphyry-skarn Cu-Au deposits at the Northern Loei and Truang Son Fold Belts, Thailand and Laos | IFRIS, ARC, Linkage, CODES, PanAust, One Deposits of SE Asia Project
Joseph Knight | Zaw, Large | The geochemical and metallogenetic setting of Cu-Au mineralisation in Myanmar: Implications for mineral exploration | CODES
Stephen Kuhn | Reading, Cracknell, Roach | The application of machine learning algorithms for lithological mapping and minerals targeting in key ore deposit settings | UTAS, CODES
Elin Lawlis | Cooke | Au-bearing pyritic ore of Lihir, Papua New Guinea: Its physicochemical character and nature of the causative fluids | Newcrest Mining, UTAS, SEG
Elona Lounisjova | Danyushevsky, Large | Geochemical study of three marine sediments sequences corresponding to the Late Permian-Early Triassic stratigraphic boundary | ARC, CODES
Charles Makoundi # | Zaw, Large | Geochemistry of carbonaceous black shales, sandstone, and chert in Malaysia: Insights into gold source rock potential | IFRIS, UTAS, Ore Deposits of SE Asia Project
Clare McFadden | G.Davidson | Distribution of, and controls upon, pyrite trace element content of hydrothermal alteration zones at Hercules VHMS ore deposit, Tasmania and NICO IOCG ore deposit, Northwest Territories, Canada | ARC
Brian McNulty | Gemmell, G.Davidson | Geology and genesis of the mineral deposits of the Myra Falls VHMS District, Canada | Nystar
Larriana Morgan ^ | G.Davidson, Butt, Selley | Controls on copper mineralising process in the central McArthur Basin, NT (Redbank Package), and its implications for the metallogeny of extensional basins | NTGS, UTAS
Peter Morse | Reading, Lueg (Computing) | Combined computational and human interaction strategies in knowledge generation from spatial and spatiotemporal information | UTAS, CODES
Indrani Mukherjee | Large, Halpin, Maffe | Pyrite trace element chemistry of black shales of the “boring billion” period | UTAS, SEG, AMIRA
Jacob Mulder | Maffe, Halpin, Berry, Scott | From Huna to Gundawana: An evaluation of the early tectonic history of Tasmania | UTAS, CODES
Evan Orrman | Cooke, Harris | Geology, geochemistry and genesis of the Namosi porphyry Cu-Au deposits, Fiji | CODES, Newcrest Mining, SEG, Namioi Joint Venture
Thomas Ostersen | Reading, Roach, Thiel (GSSA) | Multi-scale geologic, and combined geophysical, investigations of Tasmania and Southeast Australia | UTAS, CODES, MRT, U Adelaide, Geoscience Australia, GSSA

STUDENT | SUPERVISORS | PROJECT | SUPPORT
Pedro Pereira da Fonseca | McPhee, Neill (MRT), Palvai (SafCPL) | Facies analysis and correlations in complex mineralised submarine volcanic structures: Mount Read Volcanics, western Tasmania | Portuguese Govt (PCT), CODES
Joshua Phillips * | Cooke | Geologic and geochemical vectors to mineralisation at the Resolution porphyry Cu-Mo deposit, Arizona | ARC TMVC, AMIRA P1153, Rio Tinto, Resolution Copper Ltd
Jose Muilen Riker Roma ^ | Cooke, Berry, Scott | Structural geology of the Andes of Central Chile. Evolution, controls on magmatism and the emplacement of giant ore deposits and implications for exploration | Chilean Govt, Codetic, AMIRA P1060
Naomi Potter V.Kamenetsky, Goemann, M.Kamenetovsky | An investigation into the genesis of intrusive and extrusive carbonatic melts | UTAS, ARC
Marc Pinne ^ | Cooke, Jensen | Geology and genesis of the contrasting Wai-Gohpu porphyry-epithermal deposit, Papua New Guinea | Newcrest Mining, Harmony Gold, Morobe Mining Joint Venture, UTAS
Subira Sharma | G.Davidson, Cooke | Evaluation of links between Merlin-style Mo-Re mineralisation and magmatism in the Cloncurry fold belt, Queensland: Implications for exploration | UTAS, Nova Resources
Jeffrey Steadman ^ | Large, Butt, G.Davidson | BIFs, black shales, and gold deposits: A re-evaluation | Coll, CSIRO, Hylina Mining
Nathan Stevens | Gemmell, Large, Harrington (OJ1018) | Ore genesis of the Greens Creek VHMS Deposit, Alaska: Implications for mining, milling and exploration | Hylina Mining, UTAS
Stephanie Silsarya | Cooke, Selley | Geological, structural, geochemical and genetic significance of the anhydrite zone at the Lihir gold deposit, Papua New Guinea | Newcrest Mining, UTAS
Francisco Testa | Cooke, Baker | Tourmaile breccia pipes: San Francisco de los Andes, Argentina and Rio Blanco-Los Bronces, Chile | UTAS, AMIRA P1620
Jay Thompson | Danyushevsky, Maffte | Understanding the specifics of H2O-free aerosol behaviour in the inductively-coupled plasma in geochemical LA-ICPMS applications involving U/Pb dating and accurate trace element analysis in silicate minerals and glasses | UTAS AMIRA P1563
Jennifer Thompson * | Cooke, Danyushevsky, Maffte | Detailed investigation into carbonates in geochemical dispersion halos around Cu, Au and Mo porphyry deposits to identify potential indicators of deposit location beyond what is possible in whole rock geochemistry | UTAS AMIRA P1563
Danielle Vergari | Carey, McPhee | The 2007 explosive activity at Piton de la Foumire volcano (Reunion): Constraints on the eruptive processes by the volcanological study of the erupted deposits | UTAS, CODES, Reunion Volcano Observatory

* Affiliated with the ARC TMVC Research Hub # Degree completed, not yet graduated ^ Graduated § Withdrawn/terminated

Student associates at the AMAS XIII Symposium, from left: Irma Vejelyte, Richelle Awid-Pascual, Indrani Mukherjee, Subira Sharma, Jeff Steadman, Jennifer Thompson, Sara Johnston, and Cecily Herakovich.
APPENDICES

ARC INDUSTRIAL TRANSFORMATION RESEARCH HUB GRANTS 2015

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<thead>
<tr>
<th>INVESTIGATORS</th>
<th>PROJECT</th>
<th>FUNDING BODY</th>
<th>PERIOD</th>
<th>ARC FUNDING FOR 2015</th>
<th>PARTNER FUNDING FOR 2015</th>
<th>UTAS FUNDING FOR 2015</th>
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<tr>
<td>Cooke, Danyushkevich, Du, Gemmell, Large, Mithra, Reading, Harris (Newcrest), Seymour (AMIRA), Ellis (BHP Billiton), Godfrey (Koresco), Hardy (MCTA), Lottermoser (Geochron), Shelly (Launir Technic)</td>
<td>Transforming the mining value chain</td>
<td>ARC, AMIRA International, BHP Billiton Olympic Dam, Newcrest Mining, UTAS</td>
<td>2015 - 2020</td>
<td>$2,193,344</td>
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ARC DISCOVERY GRANTS 2015

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<td>Large</td>
<td>Pyrite: A deep-time capsule of ocean chemistry and atmosphere oxidation</td>
<td>2015 - 2017</td>
<td>$169,991</td>
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INDUSTRY AND OTHER EXTERNALLY FUNDED RESEARCH GRANTS 2015

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<tr>
<td>Cooke, Jarson, Salley, Harris (Newcrest)</td>
<td>Exploring the porphyry environment</td>
<td>Newcrest Mining Limited</td>
<td>July 2009 - 2016</td>
<td>$233,723</td>
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<td>Large, Danyushkevich</td>
<td>Research and development in mineral deportment and exploration</td>
<td>Newcrest Mining Limited</td>
<td>2012 - 2016</td>
<td>$235,000</td>
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<td>Large, Gregory, Steadman</td>
<td>DeGrussa vectoring project</td>
<td>Sandfire Resources</td>
<td>2015 - 2016</td>
<td>$162,917</td>
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<td>Scott, G, Davidson, Healthcot (student)</td>
<td>Gold distribution and association at the Kansanshi copper-gold deposit</td>
<td>Kansanshi Mining</td>
<td>2014 - 2017</td>
<td>$103,000</td>
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<td>Danyushkevich, TBA (student)</td>
<td>PhD project title TBD</td>
<td>Laurin Technic</td>
<td>2015 - 2016</td>
<td>$86,000 **</td>
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<td>Large, Mithra, Gregory</td>
<td>South Australia pyrite, hematite and maghette fingerprint database</td>
<td>Geological Survey of South Australia</td>
<td>2012 - 2015</td>
<td>$56,000</td>
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<td>Scott, Gas, Douth (student)</td>
<td>The geology and geological controls on gold mineralisation at the Inco nickel deposit, St Ives Gold Mine, Kambalda, WA</td>
<td>St Ives Gold</td>
<td>2015 - 2018</td>
<td>$55,000</td>
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<td>Steadman, Large</td>
<td>Pyrite and pyrrhodite as ore vectors and stratigraphic markers for epithermal gold, Carlin gold, VHMS, DOCs, sediment-hosted copper, and stratiform zinc targets</td>
<td>Sandfire Resources, Enterprise Metals, Pioneer Resources</td>
<td>2015 - 2017</td>
<td>$81,000</td>
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<td>Gemmell, G, Davidson, McNulty (student)</td>
<td>Geology and genesis of the mineral deposits of the Myra Falls VHMS District, Canada</td>
<td>Nyrstar Myra Falls</td>
<td>2015 - 2017</td>
<td>$50,000</td>
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<td>Haplin</td>
<td>Metamorphic architecture of the central-northern Gawler Craton</td>
<td>Geological Survey of South Australia</td>
<td>2015</td>
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<td>Gemmell, Large, Hannington (Monalisa), Stavros (student)</td>
<td>Ore genesis of the Stears Creek VHMS Deposit, Alaska: Implications for mining, milling and exploration</td>
<td>Hecla Mining Company</td>
<td>2013 - 2016</td>
<td>$47,000</td>
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<td>Danyushkevicy</td>
<td>LAM data reduction software development</td>
<td>Rio Tinto</td>
<td>2014 - 2016</td>
<td>$46,000</td>
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<td>Large, G, Davidson, Mithra, Belousov</td>
<td>Development and application of a Yiglam pyrite and magnetite fingerprint database</td>
<td>Geological Survey of Western Australia</td>
<td>2012 - 2015</td>
<td>$39,000</td>
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<tr>
<td>Cooke, Hurt, Berry, Escotia (student)</td>
<td>Ore characterisation and proteomic and mineralogical modelling of the Productora Cu-Au-Mo deposit, Chile</td>
<td>Hot Chili</td>
<td>2013 - 2016</td>
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INVESTIGATORS | FUNDING BODY | PERIOD | FUNDING FOR 2015 |
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<tr>
<td>Zaw, Large, Knight (student)</td>
<td>The geodynamic and metallogenic setting of Cu-Au mineralisation in Mawmluh: Implications for mineral exploration</td>
<td>Anglo American</td>
<td>2015 - 2016</td>
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<tr>
<td>Cooke, Chan (student), Fan (visitor), Zhang, Zhou (visistor)</td>
<td>Porphyry and skarn mineralisation in China</td>
<td>Hefal University of Technology</td>
<td>2015 - 2016</td>
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<tr>
<td>Large, Gregory, Steadman, Wu</td>
<td>Peak gold project</td>
<td>Drummond Gold</td>
<td>2014 - 2015</td>
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<tr>
<td>C, McPhie, Hilde (student)</td>
<td>Understanding the nature of the host rock succession to the Archean Nimbus Au-Sn-Pb-Ag deposit, WA</td>
<td>MacPhersons Resources</td>
<td>2015</td>
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<td>G, Davidson, Cooke, Sharma (student)</td>
<td>Evaluation of links between playstyle Mo-Re mineralisation and magmatism in the Cloncurry fold belt, Queensland: Implications for exploration</td>
<td>Inova Resources</td>
<td>2013 - 2016</td>
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<td>Granite geochemistry and related REE deposits in Southeast Asia</td>
<td>Japan Society for the Promotion of Science</td>
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<td>Gemmell, Large, G, Davidson, Hawke (student)</td>
<td>Geological evolution of the DeGrussa Cu-Au VHMS deposit, Western Australia</td>
<td>Sandfire Resources</td>
<td>2012 - 2016</td>
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<td>Zhang, G, Davidson, Whitney (student)</td>
<td>Geological framework and characteristics of the Specimen Hill high sulfidation epithermal system, southern Queensland, Australia</td>
<td>Signature Gold</td>
<td>2015 - 2016</td>
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<td>Cooke, Zhang, Fox, Hong (student)</td>
<td>Magmatic-hydrothermal volatile exsolution and mineralisation in Tasmanian Sn granites</td>
<td>Society of Economic Geologists</td>
<td>2015</td>
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<td>Roach, McCormack (student)</td>
<td>Geophysical assessment of potential magnetite skarn mineralisation at the Lihp Rosoport, Highlands, Northwest Tasmania</td>
<td>Lottah Mining</td>
<td>2015</td>
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<td>Roach, Tassell (GHD), Smith (student)</td>
<td>Distribution, nature of sediments and depth to bedrock in Bass Strait, in the region of Blume Port</td>
<td>GHD</td>
<td>2015</td>
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<td>Cooke, Faustino (student)</td>
<td>Intrusive History and genetics of Bayside porphyry copper-gold deposit, Surigao Del Norte, Philippines</td>
<td>Sociey of Economic Geologists</td>
<td>2015</td>
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<td>Cao (Monash), McPhie, Baker (student)</td>
<td>Urtrostratigraphy, tectics architecture, alteration and geochemistry of the footwall of the DeGrussa volcanic hosted massive sulfide deposit</td>
<td>Sandfire Resources</td>
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<td>Orth</td>
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<td>Geological Survey of Western Australia</td>
<td>2014 - 2015 **</td>
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<td>McNell, Foig, Falcon, D.H,Grean</td>
<td>Sulfur and metal evolution in parental mid ocean ridge basalt magmas</td>
<td>IODP (via Australian National University)</td>
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<td>V.Kamenetsky, McPhie, A, V.Kamenetsky, McPhie, A,</td>
<td>Stable isotopes (C, S and Cl) and halogens (Fs) in gangue and ore minerals at Olympic Dam: Evaluation of mante and crustal contributions to mineralisation</td>
<td>BHP Billiton Olympic Dam Corp</td>
<td>2012 - 2015 **</td>
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* projects with greater than $2,000 external funding per year.
** all project funding received, project still active
‡‡ full project funding received in one year

APPENDICES
Thordarson, University of Iceland; Ulrich Kesten, Sympatec.

VISITORS TO CODES, FROM LEFT: David Buxton, BHP Billiton; Nick Roberts, Lawrence Berkeley National Laboratory, USA; Thorvaldur Thordarson, University of Iceland; Ulrich Kesten, Sympatec.

APPENDICES

VISITORS 2015

INDUSTRY VISITORS

<table>
<thead>
<tr>
<th>NAME</th>
<th>COMPANY</th>
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<tbody>
<tr>
<td>Paul Agnew</td>
<td>Rio Tinto Exploration</td>
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CODES | ANNUAL REPORT 2015 |
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<td>Ulrich Keskin</td>
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INTERNATIONAL ACADEMIC AND GOVERNMENT VISITORS

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<tr>
<td>Charlotte Allen</td>
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<tr>
<td>Hansruedi Maurer</td>
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<td>Rolf Horitz</td>
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^ Visitor for longer than three months.
The Rio Blanco copper mine in northern Peru – one of the stops on the Ore Deposits of South America short course.
THIS REPORT INCLUDES SECTIONS ON
THE ARC RESEARCH HUB – TRANSFORMING
THE MINING VALUE CHAIN, AND THE
UTAS DISCIPLINE OF EARTH SCIENCES