

ORE SOLUTIONS

NEWSLETTER OF CODES

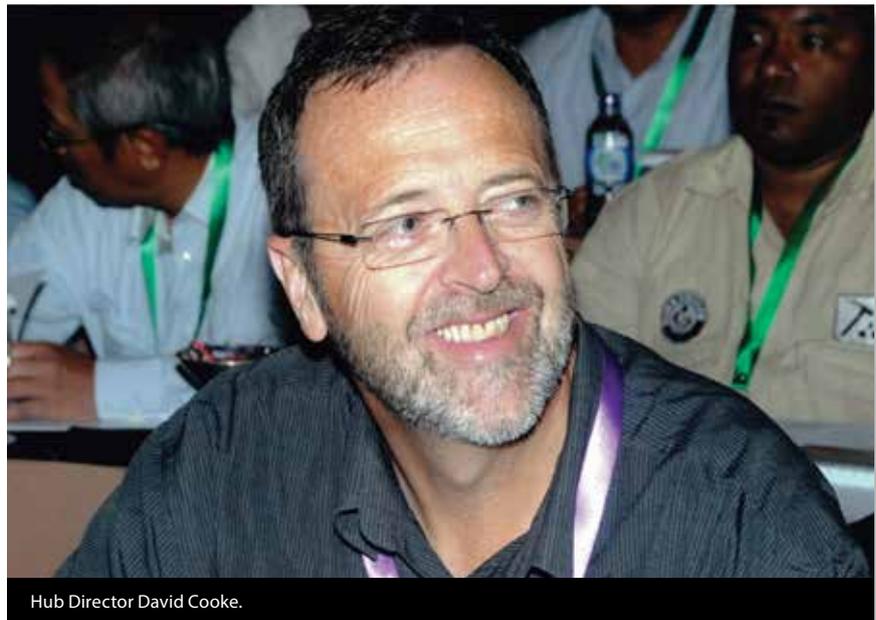
ARC CENTRE OF EXCELLENCE IN ORE DEPOSITS

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CODES to play lead role in new ARC Hub

CODES, together with its research partners, has been awarded one of the Australian Research Council's (ARC) Industrial Transformation Research Hubs in the organisation's latest funding round, announced in June. The ARC has allocated nearly \$4 million over the five-year life of the Hub, with a further \$4 million of matching funds being pledged by participants within the minerals industry. Professor David Cooke has been appointed as Hub Director, and will be supported by a team of world class researchers from within CODES, plus industry partners.



Hub Director David Cooke.

In addition to a consortium of global companies co-ordinated by AMIRA International, the Australian partner organisations are Newcrest Mining, BHP Billiton – Olympic Dam, and the service company Corescan. Other organisations affiliated with the initiative include Laurin Technic, National Information Communications Technology Australia (NICTA) and the University of Exeter in the UK.

The role of the Hub

The Hub is entitled Transforming the Mining Value Chain (TMVC) and 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 this value chain, focussing on areas that will have a marked impact on the value of Australia's mineral resources, thereby benefiting the nation's economy.

"The minerals industry will benefit greatly through advanced mineral characterisation methods, and innovative technologies for their implementation, which will be able to be applied much earlier in the mining value chain. This will enhance decision making and maximise productivity and profitability at Australian mine sites," says Professor Cooke.

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CODES
ARC CENTRE OF EXCELLENCE IN ORE DEPOSITS



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Research themes

The Hub will focus on the country's highest earning precious metal gold, the base metal copper, and the main energy metal uranium. Each of these commodities has its own scientific challenges, which the Hub will tackle through three principal research themes:

Theme 1: Detecting proximity to ore (footprints).

Theme 2: Quantifying geometallurgical characteristics.

Theme 3: Predicting geoenvironmental behaviour.

Challenges become opportunities

The Hub is set to resolve some the greatest challenges currently facing the minerals industry. The aims are to:

- Achieve real-time automated acquisition and interpretation of detailed mineralogical, textural and geochemical data in mine site coresheds 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 3-D exploration, mining and geometallurgy models to be developed that are continually updated as the exploration or resource drilling program continues.

By helping to develop more efficient and environmentally sustainable practices throughout the mining value chain, it is anticipated that the Hub will extend the lives of mines and create employment opportunities across Australia's regional mining centres.

Funding ends, but Centre of Excellence status retained

CODES has obtained approval from the Australian Research Council (ARC) to retain its Centre of Excellence (CoE) status, despite its tenure as a funded Centre coming to a conclusion at the end of 2013.

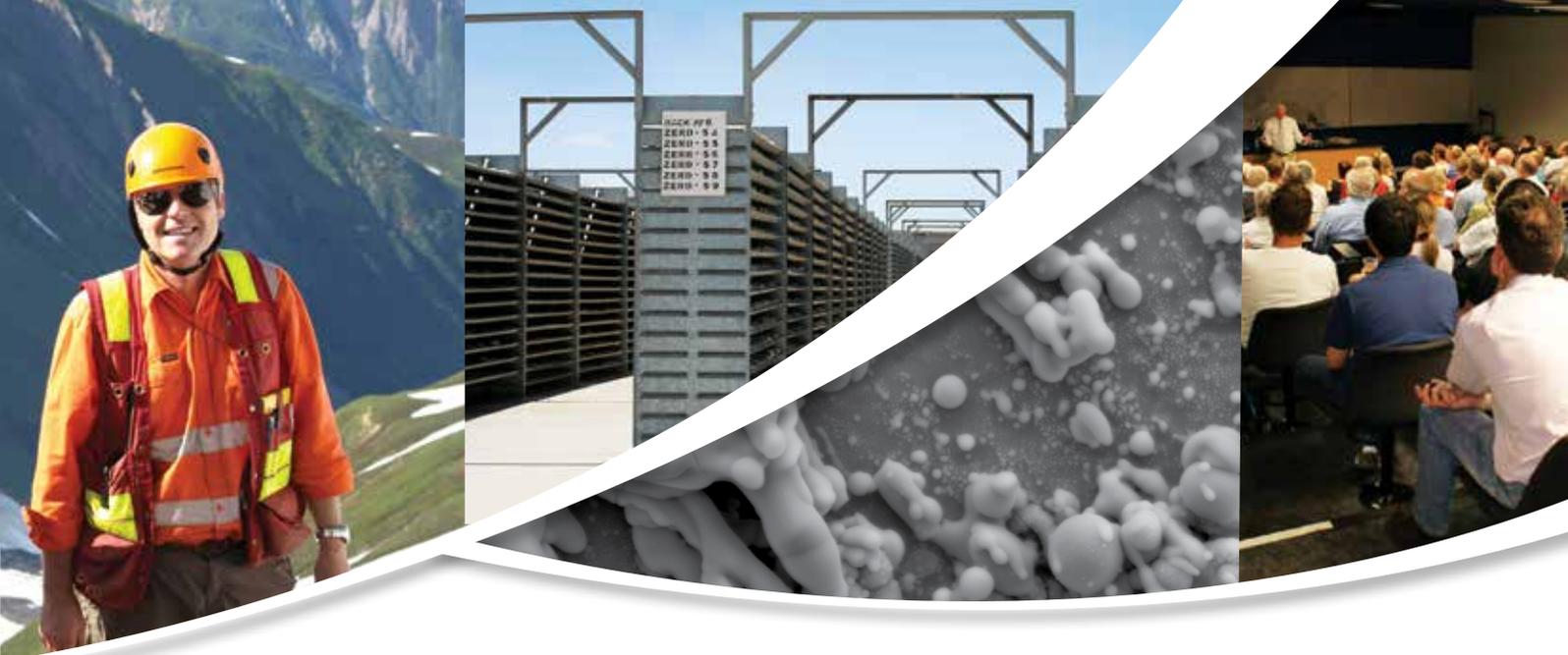
Provision is made in the ARC rules for Centres to apply to retain their CoE status, providing they meet certain criteria. One of the key requirements is that there must be no substantive changes to the Centre's research program. Although CODES has transitioned to a new four-Module research model (see article on opposite page), its primary strategy remains to build on the

research strengths that industry partners have valued during its tenure as a funded CoE.

Therefore, the case for meeting this criterion was relatively straightforward to make. Nevertheless, a detailed application had to be submitted to the ARC, which was executed via the University of Tasmania. Confirmation of the successful outcome was received in May.



Australian Government
Australian Research Council



Four module model takes over from the programs

Following the completion of its tenure as an ARC-funded Centre of Excellence, CODES has introduced a four module research model to replace the five program system that was in place previously.

Key objectives in developing this model are to ensure all the well established and valued research capabilities are maintained, while enhancing the structure to better reflect the Centre's strengths. It is believed that this model also better positions the Centre to adapt to the evolving needs of the minerals industry and other stakeholder groups.

The new integrated research modules provide a step-change in exploration techniques for metal discovery, new practices for sustainable mining, a steady supply of world class geoscience graduates, as well as creating a platform to meet the training and up-skilling needs of the minerals industry.

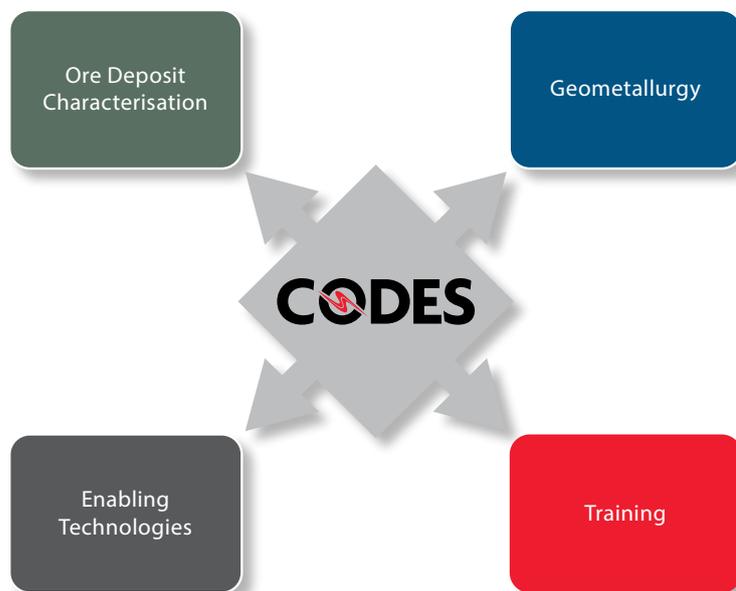
The new modules

- **Ore Deposit Characterisation**, led by Dr Garry Davidson, provides end-users with process-based models for the formation of high value metalliferous 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).

- **Geometallurgy**, led by Dr Julie Hunt, builds on the success of the AMIRA P843/A GeM^{III} projects and the involvement with CRC ORE. This module aims 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, rather than during feasibility assessment.
- **Enabling Technology**, led by Professor Leonid Danyushevsky, continues the work carried out under the old Technology Program by producing innovative analytical and computational tools, and facilitating technology transfer to the minerals exploration and geoanalytical industries.

- **Training**, jointly led by Professor Jocelyn McPhie (graduate research) and Dr Robert Scott (Master of Economic Geology Program), builds on CODES' ability to produce highly-skilled Honours, Masters and PhD graduates, and provide professional development short courses and workshops for re- and up-skilling of the minerals industry workforce.

While some of the projects under the Programs were timed to come to a natural conclusion with the expiry of the Centre of Excellence funding, a large majority of the research work is continuing under the new structure. In addition, a number of new projects will continue to be introduced as the modules evolve.



Tassie's oldest rocks linked to North America

Research led by Dr Jacqui Halpin and Dr Peter McGoldrick has established a close prehistoric connection between Tasmania and western North America.

Using CODES' leading-edge laser ablation technology to date monazite and zircon from sedimentary rocks found in the Rocky Cape Group in north-west Tasmania, the researchers showed that the rocks had been deposited in an ancient ocean between 1.45 and 1.33 billion years ago – making them the oldest rocks discovered so far in Tasmania.

On further investigation, they found a remarkable similarity with zircon age patterns from sedimentary formations



Jacqui and Peter discussing their research.



Jacqui and Peter being interviewed by the media for the evening's TV news.

from Montana, Idaho and southern British Columbia, known as the Belt-Purcell Supergroup.

"The close genetic footprint provides strong evidence that Tasmania was once geographically close to western North America when both areas formed part of the ancient Nuna supercontinent. As plate tectonics and the supercontinent cycle started to rift Nuna apart, a large sedimentary basin formed between the two rifting continental blocks that included the Rocky Cape Group and the Belt-Purcell Supergroup rocks. The continued breakup of Nuna eventually dispersed parts of this ancient sedimentary basin to opposite sides of the Earth," said Jacqui.

The theory is given further support by another recent important discovery.

"A few years ago, a prospector named Martin Laan found fossils visible to the naked eye in Rocky Cape Group rocks. These turned out to be *Horodyskia* 'String of Beads' fossils similar to those previously known from the Belt-Purcell Supergroup. As it is extremely rare to find fossils visible to the naked eye in rocks older than 635 million years, and both these geographically distant formations are more than twice this age, we believe this provides further evidence of the ancient link," said Peter.

Since the discovery was announced in late July, the story has received widespread media coverage around the world, and been published in *Precambrian Research*.

Grand day for planning

The annual Science Planning Meeting was held at the Hotel Grand Chancellor in Hobart on July 15. This popular event provides a platform for CODES' researchers to update colleagues and key stakeholders on the progress of their projects, and gain invaluable feedback on proposed new initiatives. It also enables senior management to map out the future directions of the Centre, and gather input on the challenges and opportunities that lie ahead.

This year, a large portion of the proceedings was allocated to the postdoctoral researchers and postgraduate students who provided brief synopses of their projects, which were supported by poster presentations that could be viewed by participants during the breaks. These refreshment intervals also gave the delegates the opportunity to discuss the research in more detail with the originators.



The poster displays were popular during the breaks. Jacqui Halpin won the prize for the best poster from a postdoc., and Matt Cracknell took the honours for the PhDs.



Director Bruce Gemmill mapping out CODES future.



'Power of Pyrite' proposal seeks partners

Over the past three years, researchers at CODES have demonstrated that the trace element chemistry of pyrite can be used to track ore deposits from the distal edges to the target centre of hydrothermal systems. This principle has subsequently been used to develop an exciting new project that is expected to provide significant benefits to the minerals industry.

A collaborative research project, with the Geological Survey of Western Australia (GSWA), led the team to discover that pyrite chemistry is a powerful tool for determining fertility and enabled vectoring toward orogenic gold and VHMS targets. The team is now proposing to expand upon this research, and the extensive database built during the project.

The plan is to expand the scope of pyrite chemistry research beyond orogenic gold and VHMS deposits,



Team member Ivan Belousov.

to include IOCG, sediment-hosted copper and stratiform zinc targets. This initiative will greatly enhance the ability of mining companies to target a broader range of economic mineral deposits in a cost effective manner using the chemistry of pyrite.

The team is looking for partner companies to join the project, via financial support of \$17,000 per year over a three-year period.

This investment will give participants access to the wealth of research data already available, and the opportunity to

conduct case studies on two deposits or prospects of their choice.

The project team consists of Ross Large, Jeff Steadman, Ivan Belousov and Dan Gregory. For further information, please contact:

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Matt Cracknell presenting his research at a Science Planning Meeting.

Random research achieves specific results

PhD student Matt Cracknell's data inference research project is being used to significantly enhance the understanding of parts of western Tasmania's Mount Read Volcanics, with the potential for the techniques to be used on ore bodies around the world. Matt is performing this highly promising research under the supervision of Anya Reading and in close collaboration with Andrew McNeill at Mineral Resources Tasmania. Utilising pre-existing data, his work involves objectively assessing geological maps using machine learning techniques, such as Random Forests.

Random solutions

Random Forests (RF) employs statistical learning techniques to partition data into logical groupings by constructing multiple decision trees, hence the term forest. Each tree in the 'forest' generates classifications with unique properties

due to the random selection of input variables. The RF algorithm then selects the most likely classification for a given sample via a majority voting scheme.

The advantages are manifold, including:

- Exceptional accuracy with limited training data.
- Automated, fast inference.
- Efficient use on large datasets.
- Large numbers of variables can be inputted without deletions.
- Important variables are accurately identified.
- Inherent ability to balance errors in unbalanced datasets.
- Capability to estimate missing data.

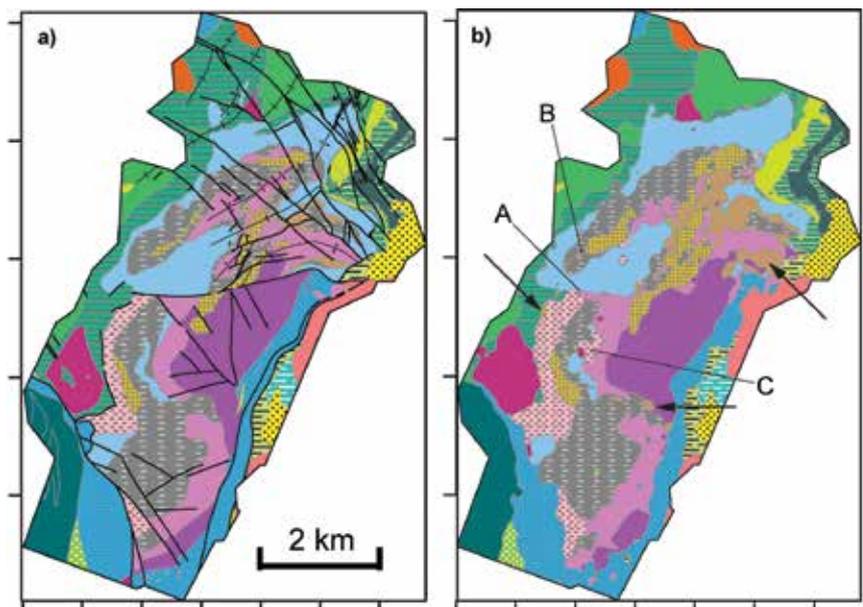


Fig. 1. Comparison between a) pre-existing geological map of the Hellyer region and b) RF classifications. Letters A-C highlight significant similarities or differences between a) and b). The arrows in b) indicate regions classified as strongly altered/VHMS mineralisation host rocks not identified in the pre-existing data.

- Greatly enhanced knowledge, while using pre-existing data.
- Forests can be stored for future applications.

The team found that the RF technique provides a robust estimate of the uncertainty associated with categorical predictions. Estimates of uncertainty were then used to identify the bulk of misclassified samples. Therefore, incorrect or ambiguous RF predictions were isolated, resulting in a significant improvement in overall prediction accuracies on the remaining samples.

Matt and the team also compared another machine learning technique, Support Vector Machines (SVM), but they found that RF proved to be superior in a number of areas. For example, uncertainties estimated for SVM predictions were not associated with incorrect classifications, as they had been for RF.

Full analysis of the comparison between the two systems is covered in more depth in Matt and Anya's paper published in *Geophysics*, Volume 78, Issue 3, 2013.

Test in the west

Although geological maps exist for the Que-Hellyer Volcanics and associated Pb-Zn VHMS ore deposits, which are situated towards the northernmost exposure of Tasmania's Mount Read Volcanics, these maps are based mostly on subjective interpretations and

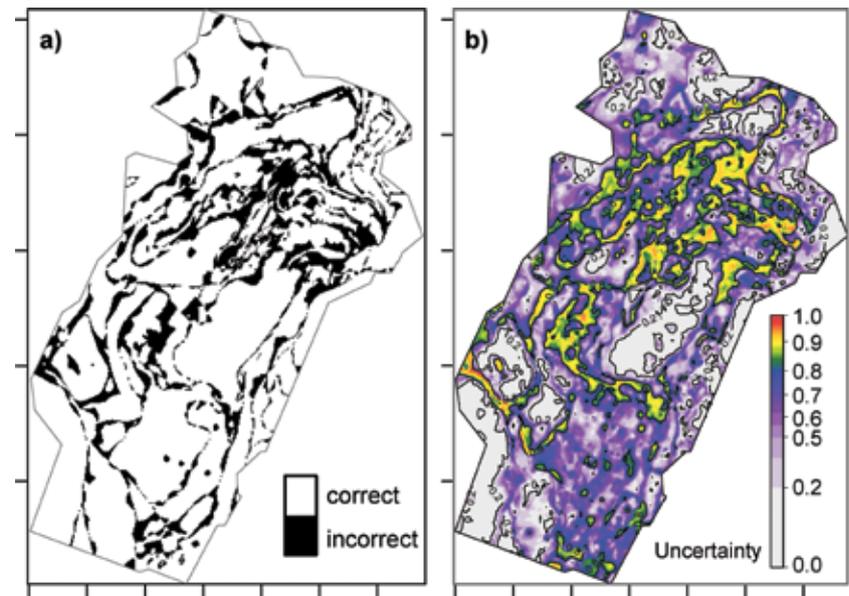


Fig. 2. a) Map of correct and incorrect RF classifications for the Hellyer region based on comparisons with pre-existing data (See Fig 1.), and b) spatial distribution of RF classification uncertainty. Note the close correspondence between incorrect classifications and high uncertainty.

limited field observations. Furthermore, geological mapping in this region is a challenging prospect due to thick soil profiles and a covering of dense temperate rainforest. Therefore, much of the knowledge of the deposits is limited to soil geochemistry and airborne geophysics. By utilising RF machine learning techniques, the researchers were able to assess these maps objectively and identify interactions between these integrated datasets and VHMS host lithologies.

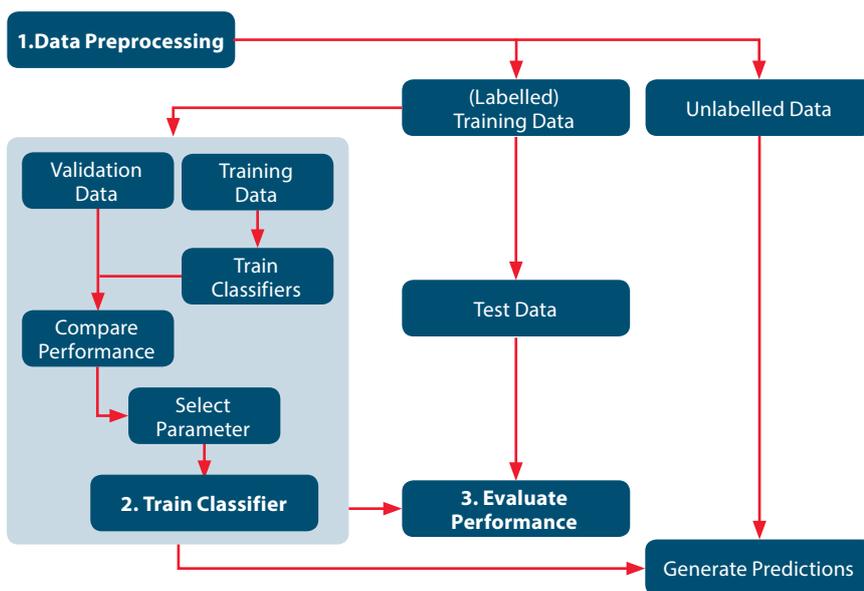
The team was also able to take this relatively limited data and, through the use of RF, identify significant extensions of units representing strongly altered rocks. These results were achieved with an exceptional accuracy of 0.784 ± 0.018 .

More detailed findings of this research are included in a paper by Matt, Anya and Andrew (MRT), which was published in Volume 61, Issue 2 of the *Australian Journal of Earth Sciences*, 2014.

Future applications

The successes on Tasmania's west coast open up the prospect of much wider applications, both on mainland Australia and internationally. The team hopes to apply the techniques to validate many more existing geological maps, and also identify previously unmapped altered units. This additional knowledge can then be used to highlight areas and contacts of geological interest that warrant further observations, and infer the source of compositional differences within lithologies.

The use of RF techniques is significantly enhancing the ability to attain a more comprehensive and accurate body of data on an ore body. This will greatly aid geologists in prioritising field work, and help them gain a much better understanding of complex geological phenomena. The potential for increased and more cost effective ore body discoveries is significant.



Machine learning supervised classification generalised workflow showing the three main steps required to preprocess input data, train classifiers, and evaluate predictions using observed (labelled) data.

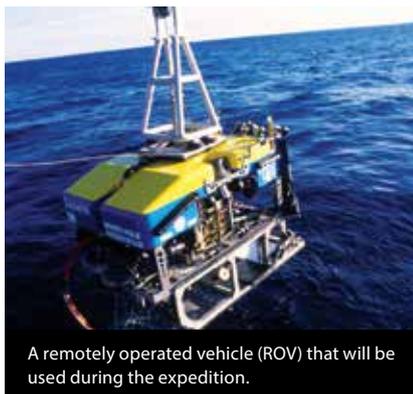
Rebecca plays key role investigating world's largest submarine eruption

Rebecca Carey has been appointed as Co-Chief Scientist for an expedition to the Havre volcano in the Kermadec Arc, early next year. The key objective of the voyage is to investigate a remarkable eruption in 2012, which turned out to be the largest event of its type ever recorded and challenges current thinking of the depth limit of explosive silicic eruptions on the seafloor.

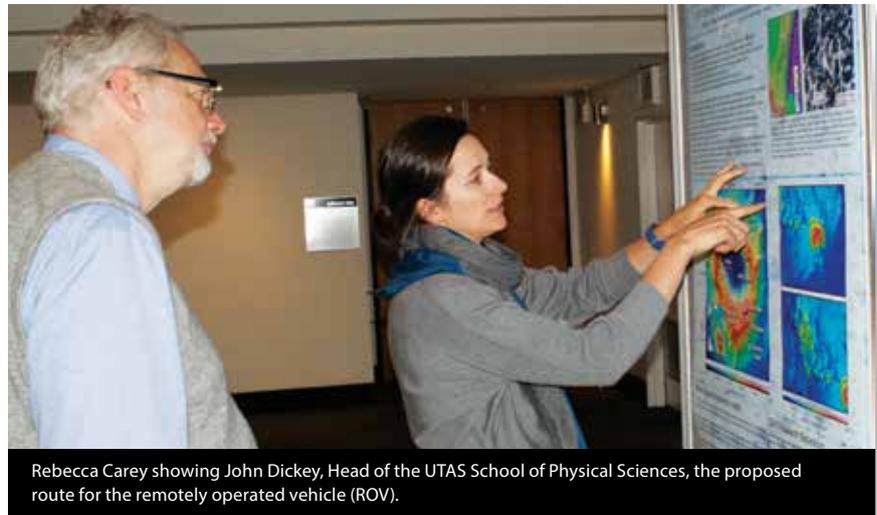
The story around the discovery of the eruption is an intriguing mix of serendipity, thorough detective work and excellent science.

A chance discovery alerts scientists

It was likely to have been twice the size of the renowned Mount St Helens eruption of 1980, and perhaps more than ten times bigger than the more recent Eyjafjallajökull eruption in Iceland. However, while those two events dominated news headlines around the world, the submarine silicic eruption at Havre volcano in the Kermadec Arc, New Zealand, passed without fanfare. In fact, for a while no one even knew it had occurred. The first clue that something extraordinary had taken place was only revealed nearly two weeks after the event, when an airline passenger spotted an unusual



A remotely operated vehicle (ROV) that will be used during the expedition.



Rebecca Carey showing John Dickey, Head of the UTAS School of Physical Sciences, the proposed route for the remotely operated vehicle (ROV).

light brown substance on the surface of the ocean. This chance observation alerted geoscientists to the possibility that the pumice had been blasted to the surface by a submarine eruption.

Tracking the source

Subsequent investigations by the Laboratoire de Geophysique (Tahiti), using data from the Polynesian Seismic Network, revealed that there had been frequent magnitude 3 to 5 earthquakes at Havre volcano between the 18th and 21st of July 2012. Contemporaneously, scientists examined NASA MODIS Terra and Aqua satellite images and discovered gigantic rafts of silicic pumice, a plume in the atmosphere emitted from a point source, and a thermal hotspot, all of which could be traced to eruptions from the Havre volcano on the 18th and 19th of July. As no pumice was observed prior to these days, it was considered probable that the eruptive activity was limited to less than a day. With the point source identified, the team was able to study existing mapping and surrounding bathymetry to ascertain that the eruption was likely to have occurred below 720m and likely at ~900m below sea level.

"We had discovered evidence of what later turned out to be the largest and deepest submarine silicic eruption ever documented. Submarine eruptions are common, but most are at much shallower depths. The tremendous weight of the overlying water acts to suppress a volcano's explosivity. Therefore, explosive eruptions at

great depth, like the one at Havre, are extremely rare. It is a very exciting discovery," says Rebecca Carey.

2015 expedition – a rare opportunity to gain knowledge

The eruption of magma in deep submarine settings is a poorly understood natural hazard, as many of the world's submarine volcanic arcs remain largely unexplored. Submarine silicic eruptions are rare events, and the precise role of hydrostatic pressure in modulating eruptive dynamics is unknown. In fact, had this explosive eruption not occurred, it would likely not have been predicted due to the prevailing idea that hydrostatic pressure at the eruption depth (which exceeds ~9 megapascals at Havre volcano) can significantly suppress explosivity.

"The depth to which explosive silicic volcanic eruptions occur is controversial, and there is little observational data to inform that debate. This eruption provides a rare opportunity to further the understanding of deep submarine volcanic eruption processes, and is enhanced by unprecedented constraints of eruption dynamics such as hydrostatic pressure at vents, timing, ejecta volume, and its dispersal," says Rebecca.

The event raises many intriguing questions, including:

- What processes promoted the development of a subaerial eruption plume from seafloor depths of up to 1,400 metres?

- How efficient is fragmentation in deep submarine settings?
- What is the partitioning of primary dispersed ejecta and that which entered the raft?

With so many unanswered questions, the expedition to Havre in 2015 is eagerly anticipated. As well as expanding the knowledge of submarine volcanism in general, it will provide an opportunity to throw more light on this remarkable eruption. To aid their search for answers, the researchers plan to deploy a remotely operated vehicle (ROV) and an autonomous underwater vehicle (AUV) in tandem to collect samples and conduct detailed mapping of eruption vents and products. By combining information and observations from the eruption plume and raft with pre-eruption and post-eruption bathymetry, an accurate measure of vent pressures and ejecta volumes can be produced, and transport styles evaluated.



The RV Roger Revelle, the ship scheduled to be used for the expedition in 2015.

Rebecca will be joined on the expedition by fellow Co-Chief Scientist, Dr Adam Soule from the Woods Hole Oceanographic Institute, plus international collaborators including Dr Richard Wysoczanski from the National Institute of Water and Atmospheric Research in New Zealand, Prof. Bruce Houghton from the University of Hawaii, Prof. James White

from the University of Otago and Prof. Michael Manga from the University of California at Berkeley. One of Dr Carey's collaborators on the research is former CODES PhD student, Dr Martin Jutzeler, who is now with the National Oceanographic Centre in the UK.

NB. This copy is based on articles that originally appeared in EOS and The Age.

Pumice from Havre eruption found on Tassie beaches

In an unexpected twist to the latest chapter in the story of the Havre volcano, pumice from the eruption has been washing up on beaches on Tasmania's north and east Coasts – almost two years after the historic event. The pumice was first spotted in March this year at Binalong Bay in the state's north-east, and has since been found at various other beaches.

"Pumice is extremely porous, with a density less than water, which enables it to travel great distances across the oceans. Havre is located approximately 1,000 kilometres north of Auckland, so the first

reported landing was, unsurprisingly, along the coastline of New Zealand's North Island. We then tracked its travels through its arrivals in Fiji, Tonga, and then Australia. The first sighting in Australia was in Queensland in the early part of 2013. It then steadily progressed down Australia's eastern seaboard and has finally found its way to Tassie, some 12 months later," says Rebecca.

The pumice can provide vital information for the researchers in their quest to piece together the sequence of events surrounding the eruption. Therefore, as soon as she heard of the arrivals in Tassie, Rebecca sent out an

appeal for information to anyone that had spotted the rocks, asking them to note the location, time of discovery, and send a photo, if possible. The response has been excellent, and the team are now busy collating all the information and incorporating it into their research.

Although the samples provided by the wandering pumice were a bonus for researchers investigating the Havre eruption, they pose a potentially major threat for the marine environment.

"It is believed that pumice rafts have been a primary means of transport for sedentary marine species since prehistoric times. So far, we have found about 80 species that have latched on to the Havre pumice and hitched a ride to our shores. Many of these species won't survive in the colder waters of Tasmania, but there is always the potential that invasive pests may be introduced. As a consequence, we are working in close collaboration with researchers at the Queensland University of Technology to identify the marine species," says Rebecca.



Rebecca Carey with samples of the pumice collected on Tasmanian beaches.



Revolutionary idea leads to evolutionary solutions

A team, led by Ross Large, has adapted ore deposit technology developed in CODES to analyse seafloor pyrite to provide breakthrough answers to some age-old evolutionary questions.

At a weekly seminar at CODES, Ross Large was listening to a presentation by Peter McGoldrick when he had a 'light bulb moment' that was to revolutionise research methods for determining if trace elements in the ocean were a driver of evolutionary change.

"I was listening to Peter explain how scientists in the US had used computer models to predict the trace element chemistry of the ancient oceans, when it

struck me that there was no reason why we couldn't use CODES' laser technology for the same purpose. This would have the major advantage of using empirical measurements on the ancient rock record, rather than modelling.

"At the time, I was heading a team that was mapping trace element variations in pyrite, using a laser attached to a mass spectrometer. Therefore, I reasoned that if we could track the chemical history of trace elements in ancient ore fluids, we should be able to analyse sedimentary pyrites that formed on the ancient sea floor to track the chemistry of oceans," says Professor Large.

Preparing for the challenge

Although his theory proved to be technically sound, he faced the daunting prospect of needing to analyse thousands of sedimentary pyrites from around the world, in rocks up to 3.5 billion years old.

Never one to be daunted by such obstacles, he set about formulating the Trace Elements in the Oceans (TEO) project, recruiting the leader of the Enabling Technologies Module, Leonid Danyushevsky, who was tasked with devising new ways of analysing sedimentary pyrite, and Jacqui Halpin, who would lead the critical sample

dating process. He also approached some of the world's top specialists in this field to join the team as collaborators.

Oxygen proxies found in the oldest oceans

Scientists have suspected for some time that the evolution of life in the oceans was strongly influenced by trace metal concentrations, as many metals are taken up by marine species and are critical for life and evolutionary change. The TEO team is putting this theory to the test and has already provided some major surprises.

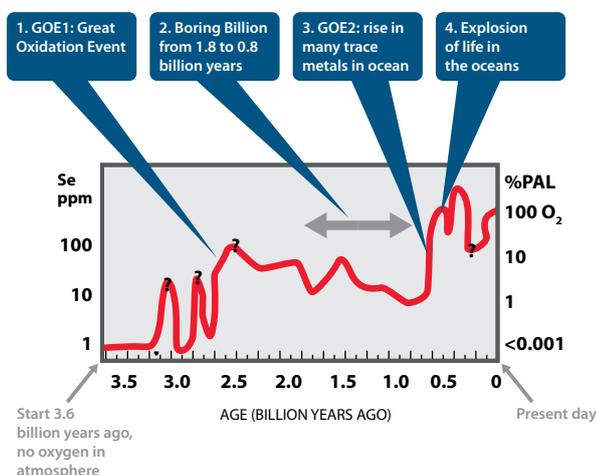
The first surprise is that the oldest oceans, from 3.5 – 2.5 billion years ago, contain far greater enrichments of certain trace elements than originally expected. For example, these oceans contained from 10 – 100 times more nickel, cobalt, arsenic, mercury and gold than in present oceans. The arsenic and mercury levels alone would have made them toxic to marine life as we know it.

However, bursts or pulses of nutrient trace elements, such as molybdenum and selenium, were detected in sedimentary pyrite as far back as 3 billion years ago. These elements are both oxygen proxies and important for marine life, supporting other scientific studies that have shown evidence of single-celled life and atmosphere oxygen pulses during the same period.

The trace elements and oxygen link

The second surprise was that the abundance of many of the trace elements in the ocean correlated with jumps in oxygen in the atmosphere.

OXYGEN CURVE OVER 3.5 BILLION YEARS



The red line is the interpreted curve for atmosphere O_2 variation through time based on the LA-ICPMS Se content of sedimentary pyrite measured in the CODES Lab.

It has been accepted that there was virtually no oxygen in the atmosphere in the Archean period (older than 2.5 billion years ago), and that oxygen increased in two steps known as the Great Oxidation Events (GOEs).

The first event was around 2.3 – 2.5 billion years ago, and the team's research shows that selenium, molybdenum, thallium, uranium and manganese increased, whereas nickel, cobalt, arsenic and mercury decreased during this event. This suggests that after the first GOE the oceans became less toxic and more accommodating for life as we know it.

The second jump in oxygen occurred around 700 – 500 million years ago, a time when a large number of trace elements increased in concentration, including those necessary for life (molybdenum, selenium, zinc, cadmium, copper, manganese, cobalt, and nickel). This correlation allowed the team to identify certain trace elements as proxies for changes in oxygen in the atmosphere.

The boring billion years

Another surprise relates to the middle years of Earth's history (1.8 to 0.8 billion years ago), known as the 'boring billion' due to the stability of the tectonic environment.

Previous scientific data had suggested that the amount of oxygen in the atmosphere during this period was about one twentieth of what it is today and it remained fairly static. However, the CODES research indicates that both oxygen levels in the atmosphere and trace element levels in the oceans gradually declined, reaching a minimum

about 800 million years ago, a period known as the Cryogenian Trough, and marking the end of the 'boring billion'.

For example, selenium, an element critical for life, declined to about one tenth of the value at the start of this period. Other trace elements to show a significant decline were molybdenum, chromium, silver and vanadium. These decreases in nutrient elements, and oxygen, in the ocean would have placed considerable stresses on the evolutionary pathways of the single-celled and nucleated celled species throughout this period to the point that evolution was slowed, and in some periods thrown into reverse.

How life survived the boring billion

The team addressed the perplexing question of how life in the oceans went from the point of extinction at the end of the Cryogenian Trough to a time, known as the Cambrian Explosion (520 million years ago), when life was rampant. Once again, trace elements in the ocean, and oxygen in the atmosphere appear to be the keys.

Results from ocean pyrite tracking research show a steady increase in nutrient trace elements in the oceans from about 700 to 520 million years ago, possibly caused by continental erosion related to tectonic activity, which subsequently released the elements into the rivers and oceans.

This increase set in place a chain of events that, once started, was difficult to stop. The team believes that the increased trace elements could have stimulated evolution back into the game, leading to a rapid increase in bacteria and plankton in the oceans. This, in turn, released oxygen into the atmosphere, and sped up oxidative erosion of the continents.

The increased ocean productivity led to increased burial of carbon on the seafloor, which drew down trace elements and sulfur into the seafloor muds within sedimentary pyrite (the key to the ocean pyrite tracking technology). The carbon and sulfur burial had the effect of increasing atmospheric oxygen even more. Subsequently, a runaway O₂ scenario with abundant nutrient trace elements was maintained to further stimulate evolution, eventually resulting in the Cambrian Explosion of life.

The team has analysed about 3,000 pyrites so far, but still needs to collect and study a further 7,000 samples from around the globe. This will generate a robust scientific picture of ocean chemistry and its effect on evolution and ore deposit formation.



Project leader Ross Large (L) with collaborator Valeriy Maslennikov from the Russian Academy of Sciences.



Cluster of framboidal pyrite from Permian mudstones.



Jeff strikes new gold at Kalgoorlie

The discovery by PhD student Jeff Steadman of gold-bearing pyrite nodules at the Golden Mile Super Pit in Kalgoorlie is expected to have major implications for gold ore genesis modelling in the Yilgarn terrane.



Jeff Steadman searching for pyrite.

During his studies, Jeff found that diagenetic pyrite nodules within an interflow shale near the top of the Archaean Paringa Basalt in Western Australia were significantly enriched in gold and other ore-forming elements, when compared to crustal averages.

The nodules also contained lead that was not as radiogenic as lead typically found in ore-stage pyrites. Furthermore, sulfur isotope work indicated that the nodules and ore-stage pyrites formed from different sulfur sources operating under different physico-chemical conditions at different times.

These findings suggested to Jeff and his fellow researchers that the nodules are syn-sedimentary to early diagenetic (i.e., older than the ore-stage pyrites), and the high amount of diverse trace elements they contain, including gold, are original.

“Many of the ‘old timers’ suspected there was a link between these interflow shales and the ore bodies, but they lacked the necessary equipment to prove their theories. Thanks to our LA-ICP-MS technology at CODES, we have been able to unravel a big part of the

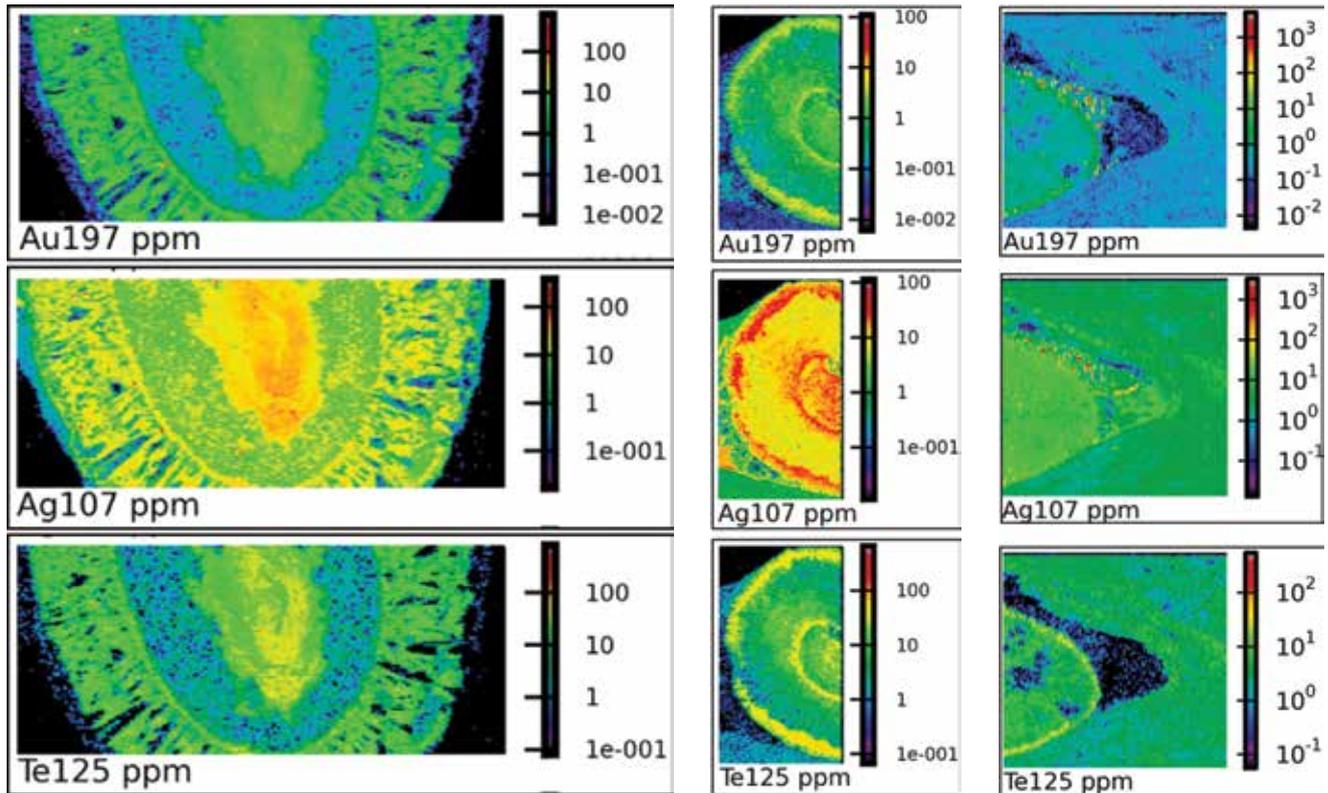
early-stage geochemical complexity of this giant gold deposit. We firmly believe that these data need to be understood by geologists in the mining industry and integrated into their typically structurally-dominated genetic models, which in turn will influence regional exploration strategies, culminating in maximised discovery potential for these giant ore deposits,” says Jeff.

The main analyses were conducted using optical and scanning electron microscopy at the UTAS Central Science Laboratory and LA-ICP-MS at CODES, with additional analyses performed on SHRIMP-SI at ANU’s Research School of Earth Sciences in Canberra.

Other researchers involved with the work are Ross Large (Jeff’s supervisor), Sebastien Meffre, Paul Olin, Leonid Danyushevsky, Dan Gregory, Ivan Belousov, and Elena Lounejeva, plus Trevor Ireland and Peter Holden from ANU, and David Nixon from KCGM.

The researchers have produced a paper on their findings, which will be published in *Economic Geology* later this year.

Pyrite nodule LA-ICP-MS images



Au, Ag, and Te images for three pyrite nodules from the Paringa interflow shale. Concentrations are shown in parts per million (ppm). These three elements are all concentrated at high levels (Au > 5 ppm, Ag > 30 ppm, Te > 30 ppm) in the pyrite-rich cores and rims of the nodules, with intermediary pyrite-poor zones containing lesser amounts of these trace elements. The right-hand nodule exhibits a pressure shadow filled with quartz and other sulfides, including pyrite. This later generation of pyrite contains small inclusions of electrum (AuAg alloy), though the pyrite itself is Au-poor.

Green Leaders – predictable if you are in the zone?

The gold-bearing pyrite nodules that Jeff Steadman discovered at the Golden Mile Super Pit are closely associated with a type of gold-tellurium ore that has divided opinion amongst geologists for decades. Green Leader ore bodies, so named because they are green and they 'lead' all other Kalgoorlie ore types in terms of the volume and quality of the gold they contain, are

highly sought after by mineral explorers. However, these treasure troves are getting harder to find with time, mainly because most of them have already been discovered and mined out. Or have they?

"There's a myriad of opinions on this issue, but the prevailing view is that Green Leader ore has a random distribution, and if you find a Green Leader you are lucky. However, I am of the school of thought that says they

occur in a distinct stratigraphic horizon, and can thus, *in theory*, be found across the entire Eastern Goldfields of Western Australia, provided the explorer is focusing on the right zone," says Jeff.

Jeff admits that his view is controversial. Nevertheless, if he is right, it would have a profound impact on the minerals industry.

We welcome your feedback

What's your view on Jeff's theory? Is he on the money, or is his hypothesis filled with more holes than a kitchen colander? We encourage views from both sides of the fence, and we will print a selection of feedback in the next issue of *Ore Solutions*. If we get a good response, we hope to make this exchange of views a regular feature in the newsletter. Please send your response to steve.calladine@utas.edu.au



No time for siesta as students visit the Iberian Pyrite Belt

This year's choice for the annual CODES SEG Student Chapter field trip was the Iberian Pyrite Belt (IPB). This renowned mineral belt is around 250 kilometres long and between 30 to 50 kilometres wide, starting in Alcacer do Sal in Portugal and ending in Sevilla in Spain. The belt was formed in the Devonian and is one of the most important and abundant VHMS districts in the world. Mining in the area dates from as far back as the eighth century BC.

Back to basics south of Lisbon

Led by Professor Jorge Relvas from the University of Lisbon, who was in charge for the Portugal leg of the tour, the group spent their first day south of Lisbon with the Avrupa Minerals team, where they mapped areas and inspected core. Avrupa is a small exploration company who are actively exploring along the Neves Corvo trend with very positive results.

"I was impressed with their 'back to basics' approach, which focuses on re-logging previous drill cores, intensive mapping, and simply concentrating on the geology rather than large, expensive geochemical and geophysical methods. This approach has enabled a small group of skilled geologists to create a new geological and structural interpretation of the area, which they are using to very good effect. I believe that it was refreshing for the students and industry participants to see how this simple, no frills approach has led to growing success for the company," says Student Chapter President, Sean Johnson.

In total, the group was comprised of seven CODES PhD students, two industry participants, and three geologists from Portugal (who joined the group for part of the trip).

Moving on to the centre of science

The second day was taken up by a visit to the Lousal Mining Village, a 19th and



Jing Chen valued seeing the varied mining processes at Aguas Tenidas.



Irma Vejelyte prepares to go underground at Neves-Corvo.



Quiyue Huang, Ben Cave, Sean Johnson and Irma Vejelyte discussing textures in volcaniclastics at Aguas Tenidas.



The group before going underground at Neves-Corvo.

20th century sulfur mine that has been converted into a science centre. Here the group was provided with a series of talks covering the rich geological and mining history of the area, including its environmental programs. As part of the visit, the group was also treated to an exclusive tour of the facility and the old open pit mine adjacent to the Village.

Armed with copious notes from the previous day, the group ventured underground at the nearby Aljustrel mine, operated by Almina. The mining area covers 4.7 km², and includes the deposits of São João, Moinho, Feitais and Estação, and is one the world's finest copper-zinc-lead-silver VHMS deposits. Of particular interest during the underground tour was an excellent

example of a cross section through a VHMS system, totalling more than 300 metres in length.

Neves-Corvo and zig-zagging the border

The morning of their penultimate day in Portugal was spent at the massive Neves-Corvo mine, which is operated by Somincor. This copper-zinc operation is the largest active mine in the region, and achieves extremely high grades.

In the afternoon, the group conducted a transect along the Guadiana River, which took them through the varied volcano-sedimentary units that epitomise the region. During the journey, their guide enlightened them on the environment in which the

geological features were formed.

The guide was Carlos (Caze) Rosa, one of Jocelyn McPhie's former PhD students at CODES. Carlos is now working with EMD in Portugal.

As the group travelled towards the Spanish border, they visited Roman mining works, and other historical sites, and learned about the extensive environment management programs that are underway in the region after millennia of mining.

In an area with such a high magnitude of outstanding VHMS deposits, the group were spoilt for choice as they took a diversion to spend time in the field investigating outcrops and the stratigraphy of the area. This included



Sean Johnson crossing the border between Portugal and Spain.



The group being guided through the La Cruces open pit.



Margy Hawke feeling the weight of a drill bit at the Lousal Science Museum.



Ben Cave and Sean Johnson at the Rio Tinto deposit.



The group discussing acid rock drainage at the source of the Rio Tinto River.

extensive zig-zagging across the border between Portugal and Spain in a search for the best outcrops.

Reinaldo takes the reins in Spain

When the group crossed the border for the last time, Reinaldo Saez from Spain's Huelva University took over as group leader. Reinaldo started proceedings by explaining the regional stratigraphy of the Tharsis mining district, which is one of the most exploited and metal-rich areas of the IPB, containing over 15 individual deposits. With everyone thoroughly briefed, the group made full use of some great weather, and long daylight hours, to fully investigate the black shale-hosted mineralisation at Tharsis.

A well-deserved rest day was spent in Seville, sampling the food, wine and cultural delights for which the city is famous. This welcome break helped recharge the batteries before they headed east to visit the Aguas Tenidas polymetallic deposit in the region of Andalusia. This relatively new deposit was discovered in the early 1980s, and is currently operated by the Trafigura Mining Group. After a site tour, the group were given the opportunity to view core from the company's latest exploration project, before visiting the drilling sites.

"I found that this stop on the itinerary was particularly valuable for students like me who got to see many things

on their 'wish list' for the first time. It was really good to experience so many stages of the process, including drilling, underground mining and even an open pit blast!" says PhD student, Jing Chen.

Tracing the origins of Rio Tinto

The highly enjoyable and educational trip was sadly nearing its end as the travellers visited the Las Cruces open pit mine, operated by First Quantum Minerals, and the famous Rio Tinto deposit, currently owned by EMED Mining. The latter deposit was the catalyst for the formation of Rio Tinto, which is now one of the world's leading mining and metals companies. The company was formed when they reopened the ancient copper mine way back in 1873.

Despite the fact that the mine is not currently in operation, while the company undertakes extensive work and studies, EMED Mining generously granted the group VIP access to the area. This allowed them to visit the large open pits, and venture through the massive stockwork and gossanous zones of the mine.

Concluding a fantastic day at the Rio Tinto mine, the group travelled along the Rio Tinto River, where Dr Miguel Niento of Huelva University introduced the group to aspects of acid rock and acid mine drainage. He also discussed new developments and applications that are being implemented to help manage environmental factors associated with high metal content in the river system.

Thank you to...

The CODES SEG Student Chapter would like to thank the following people, companies and institutions that helped make the trip such a success:

- Group leaders Jorge Relvas (University of Lisbon), and Reinaldo Saez (Huelva University).
- Supported by: Jose Miguel Niento (Huelva University), and Joao Matos and Carlos 'Caze' Rosa (Portuguese National Laboratory of Energy and Geology and EMD, respectively).
- The sponsors: SEG and AMIRA International.
- Companies that assisted during the various mine and site visits: Avrupa Minerals, EMED, First Quantum Minerals, Somincor/ Lundin Mining, Almina, and the Trafigura Mining Group.
- Industry/Government participants from OZ Minerals and Mineral Resources Tasmania, Avrupa Minerals and EMD.

Khin Zaw explaining retrograde gold skarn mineralisation at the Wabyutaung deposit in the northern Mogok Belt, Myanmar.



Researchers unlock the mineral riches of SE Asia

CODES' research in SE Asia is helping mining companies pinpoint mineral-rich ore deposits in previously unexplored areas of the sub-continent. The team has built on years of UTAS-based research to make major advances to the geological knowledge of the region, and significantly expand the scope and geographical footprint of the earlier studies.

"Our main aims are to provide mining companies with a greater understanding of the formation and evolution of the ore deposits in the region and, most importantly, where they are located," says project leader Professor Khin Zaw.

The researchers have used a range of geochemical, isotopic and geochronological techniques to build invaluable exploration models for SE Asia, which enables them to pinpoint favourable volcanic belts and identify specific ore types.

Khin Zaw believes that this research will play an important role in unlocking the

wealth of a region that has the potential to be one of the drivers of the rapid economic development within Asia.

"There is no doubt that we are in the Asian Century and, as a result, mining in SE Asia is expanding very quickly. This is mainly being fueled by increasing demand for mineral commodities from powerful neighbours such as China, Korea, Japan, and India. However, even with this level of expansion, mining companies are struggling to meet demand. Therefore, they are keen to finance further exploration. As our research enhances exploration efficiencies, and greatly improves the chances of discovering world class deposits, we are confident that it will attract more funding to enable us to continue our studies.

"Even though we have greatly expanded the geological knowledge of the region, it is an area that still contains so much untapped potential through its vast and diverse range of mineral deposits. There is so much more still to be learned and discovered," says Khin Zaw.

The CODES' researchers that have been involved with the project are Khin Zaw, Tony Crawford, Jacqui Halpin, Joe Knight, Chun-kit Lai, Ross Large, Takayuki Manaka, Sebastien Meffre, and

Abhisit Salam. The project is sponsored by ten international mining companies.

The out-of-confidentiality research results have recently been published in a special issue of *Gondwana Research* (July, 2014), entitled *Tectonics and Metallogeny of Mainland SE Asia*. The publication includes fourteen papers contributed by researchers from CODES and the Discipline of Earth Sciences.

The publication provides the reader with a comprehensive understanding of the tectonics and metallogeny of SE Asia, and offers a timely reminder of the immense minerals potential within this rapidly emerging region.



MRT collaboration enriches the knowledge of the geology of Tasmania

A collaborative project with Mineral Resources Tasmania (MRT) is combining geological and geophysical constraints to provide new insights into the deep geological structure of western Tasmania.

The team is using the latest generation 3D geological modelling to bring together decades of geological field observations and interpretations with gravity and magnetic modelling. The 3D geological models are subsequently being refined with the best possible constraints from all the available information. The anomalies that remain are proving to be of key importance, providing new insights into details of facies changes, mineralisation and alteration systems.



Three of the research team members: Mark Duffett (MRT), Anya Reading (CODES) and Daniel Bombardieri (CODES/MRT).

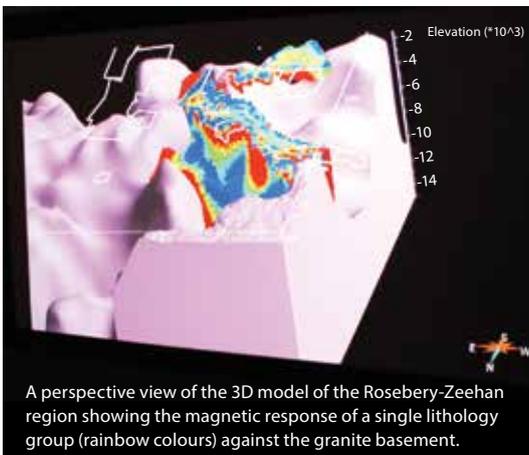
The research has already led to the development of a 3D model for the Rosebery-Zeehan region, which will assist exploration for tin and other metals in this richly mineralised province. The team is now focusing on extending the model southwards to include the important ore systems around Mount Lyell.

“The model is based on data synthesised from many cross-sections, which is enabling us to develop a significantly revised structural interpretation of the region. The next step

is to test the new geological model against existing magnetic and gravity data via 3D potential field calculations. This work will include uncertainty characterisation using GeoModeller™ software,” says Daniel Bombardieri, who is playing a leading role in the project.

In keeping with the collaborative nature of this initiative, Daniel is a joint appointment between CODES and MRT. Other key members of the team are CODES researchers Anya Reading and Michael Roach, together with Mark Duffett and Andrew McNeill from MRT.

The collaboration is being assisted by research support for graphics-intensive computing from MMG.



A perspective view of the 3D model of the Rosebery-Zeehan region showing the magnetic response of a single lithology group (rainbow colours) against the granite basement.

AMIRA P1060 final meeting

The AMIRA P1060 project came to a successful conclusion in June, via a final meeting held at CODES. The project built on earlier research projects to develop mineral chemistry fingerprinting and vectoring tools in magmatic-hydrothermal mineral deposit districts that have created a step change in minerals exploration practices for mining companies around the world. It had the support of 21 major international mining companies and was the largest geoscience project in the history of AMIRA International. Collaborators on the project were Lakehead University, Canada; Guangzhou Institute of Geochemistry, China; and Imperial College London. Planning is in progress for the implementation of AMIRA P1153, which will further build on this research.



Attendees at the final meeting of the AMIRA P1060 project.

SEG Conference comes to Hobart

The Society of Economic Geologists (SEG) has appointed CODES as its partner for its annual conference and exhibition in 2015. The event is the biggest conference in the world for economic geology, and is expected to attract at least 600 national and international delegates. This is the first time that this major international event has been held in Tasmania. See advertisement below for further details.



Call for Papers; Abstract deadline: April 1, 2015

This SEG-CODES conference will include key presentations from leaders in research and industry on the discovery of world-class ore deposits, their geology and the recovery of metals from ores, and cover the issues and controversies that affect exploration.

Key sub-themes with new examples:

- Ores in subduction-related arcs: Relations and controls
- Ores in sedimentary environments: Sources, transport, deposition, and hydrology
- Magmatic deposits: Characteristics and mechanisms
- Geometallurgy through the mining chain
- Post-collisional ores: Characteristics, relationships, and genesis
- IOCG and magnetite-apatite deposits: Similarities, differences, controls, and genesis

Short courses and workshops will look at skarn deposits, sediment-hosted gold deposits, footprints of major mineralizing systems, and uranium deposits. Field trips will visit major mining districts in Australia, Indonesia, and New Zealand.

We look forward to welcoming you to this unique part of the world and hope you can extend your visit to enjoy some of the best Tasmania has to offer—our food, wine, museums, and wilderness.

September 27–30, 2015
Hobart, Tasmania, Australia
www.seg2015.org



CODES gets a new look

– WHILE RETAINING STRONG LINKS WITH THE PAST

After eight successful years as an ARC-funded Centre of Excellence, the timing was considered right to introduce a new logo that not only reflects the evolution of CODES, but also marks the next phase in its history.

The key elements of the design brief were as follows:

- It was recognised that CODES had built considerable equity in its brand over many years, so one of the key elements of the brief was that any change must retain strong links to the previous logo.
- The logo had evolved from its original concept, with elements being added at various milestones in the Centre's history. While this logo was well liked and unique, the design had become quite intricate and not easy to reproduce in certain situations. Therefore, another objective was to revert back to a simpler design.
- The logo needed to be strong and bold, and include the CODES name for easy recognition.
- It needed to reflect CODES' standing as a truly international research centre – growing from a few Australian-based projects in 1989, to conducting projects in over 30 countries, spread across six continents.

Various designs were presented to staff, triggering much debate on what elements, if any, needed to be retained, and how the new logo should look. Unsurprisingly, there was a broad spread of views on the subject. However, the general consensus was that the red symbol at the heart of the then current logo was a vital element that should be retained. Some people call it a swish, and some call it a squiggle, but all geoscientists recognise it as a graphical representation of a folded ore body. With the unique nature of this symbol, and its strong geological connections, it became the key link to the past on which the new logo was built. Another very strong link is the retention of the primary brand colours of red and black, as well as the use of the CODES name as an integral part of the logo – only now it is bigger and bolder.



Visitors to CODES

Below is a selection of just a few of the recent visitors to CODES who have conducted seminars.



Dr Dave Hale from the Colorado School of Mines, USA, visited in July and presented a seminar titled: 3D Seismic Interpretation of Faults and Horizons.



Dr Dave Huston from Geoscience Australia presented a seminar titled: Metallogeneses in Eastern Australia: New (and old) Insights from Spatial and Temporal Variations in Radiogenic Isotopes.



Dr Michael Perfit from the Department of Geological Sciences, University of Florida, USA, delivering a presentation titled: Geochemistry of Basalts from Near-Ridge Seamounts: Insights into Mantle Sources and Melting Processes.



Paul Hilliard from Sandfire Resources delivered a talk titled: The Geology and Metal Zonation of the DeGrussa VHMS Deposit, North Western Australia.



Professor Ray Cas from Monash University visited CODES in August and delivered a seminar titled: Volcanology and Possible Origins of Intra-plate Volcanism in Southeastern Australia: the Still Active Newer Volcanics Province, Victoria, as a Case Study.



Sandeep Chandola, the Society of Exploration Geophysicists' 2014 Pacific South Honorary Lecturer, delivered a seminar titled: Marine Seismic Acquisition: Expanding the Possibilities!



Professor Terry Plank from Columbia University, USA, presented a seminar on Diffusion Clocks: At the Speed of Magma Ascent.



Yoshi Goto from the Muroran Institute of Technology, Japan, presented a seminar titled: Geology and Evolution of a Post-caldera Volcano in Toya Caldera, Hokkaido, Japan, Revealed by Aerial Laser-mapping Survey.

In honour of Mike



Highly respected geologist Professor Noel White delivering the Mike Solomon Lecture in July. The lecture is an annual event in honour of the UTAS/CODES teacher and researcher, Mike Solomon, who passed away in 2009. Noel delivered an intriguing and thought provoking talk entitled: Vapour-Transport of Metals in Porphyry and Epithermal Deposits: What Does Geology Tell Us?

Geological knowledge of Tasmania – updated, expanded and simplified

CODES, along with the Discipline of Earth Sciences, Mineral Resources Tasmania and Vedanta Resources, is a principal sponsor of a new book covering the geological knowledge of Tasmania, recently launched by the Geological Society of Australia (GSA), Tasmania Division. The other sponsors are Bluestone Mines, Geoscience Australia, Grange Resources, GSA (main organisation) and Shree Minerals.

The Geological Evolution of Tasmania is the third compilation covering this topic, but this publication is undoubtedly the most comprehensive to date. The 660-page volume includes ten chapters

that have been arranged to give the reader a reasonably chronological view of Tasmania's geological evolution, with the major tectonic, magmatic and mineralisation events placed in their order of occurrence. In addition, a simplified account of the geology and geological history of the island has been added to make the volume more accessible to the general reader.

The publication includes a DVD that contains representative major- and trace-element analyses, plus digital geological and geophysical maps of Tasmania, courtesy of Mineral Resources Tasmania.

The prices are \$99 (incl. GST) for GSA members and \$113.30 (incl. GST) for



GEOLOGICAL EVOLUTION OF TASMANIA

Edited by K. D. Corbett, P. G. Quilty and C. R. Calver

non members. Additional charges apply for postage and packing. For further information, or to purchase the book, go to utas.edu.au/codes/publications. The book can also be purchased through the GSA website: gsa.org.au/publications Reference Special Publication 24.

SEG grants, an award – and a special issue

Grants



Recipients of the SEG grants with SEG Executive Director Brian Hoal. From left: Subira Sharma, Angela Escolme, Stephanie Sykora, Brian Hoal, Indrani Mukherjee and Richelle Pascual.

Details of the grants are as follows:

Graduate Student Fellowships (USD 10,000 each):

Angela Escolme (sponsored by Barrick Gold), and Stephanie Sykora (sponsored by Anglo American).

Hugh E. McKinstry Student Research Awards:

Richelle Pascual (USD 3,000) and Jing Chen (USD 4,050). Jing was not available for the photograph.

Student Research Award:

Indrani Mukherjee (USD 1,650).

Field Trip Travel Grant:

Subira Sharma (value approximately USD 5,000).

Award

PhD student Sam Holt has been awarded the David Groves Medal (2014) for the best paper published in the *Australian Journal of Earth Sciences* by a young author.

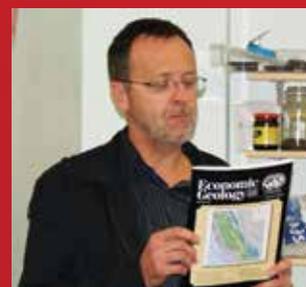


Special issue of *Economic Geology*

Professor David Cooke, together with Dr Thomas Bissig from the University of British Columbia, was guest editor of a Special Issue of *Economic Geology* devoted to 'Alkalic Porphyry Cu-Au and Epithermal Au Deposits'.

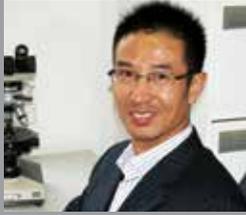
The publication features in Volume 109, Number 4 of this highly rated journal and includes contributions from 15 authors affiliated to CODES.

This research was based on a collaborative project between CODES and the Mineral Deposit Research Unit (MDRU) at the University of British Columbia.



David Cooke addresses colleagues at a function to mark the publication of the Special Issue.

Moving in



Dr Wenbo Li joined CODES for one year as a Visiting Scholar, supported by the China Scholarship Council and Peking University. Wenbo's tenure at CODES ended in September, but he has been working with David Cooke on research associated with the origin and exploration of porphyry Cu-Au and orogenic Au deposits in China.



PhD student Nathan Steeves, from Alberta, Canada, is working with Bruce Gemmell and Ross Large, studying the ores at the Ag-rich Greens Creek VMS deposit in Southeast Alaska.



Master of Economic Geology student Maria Lourdes Faustino, from the Philippines, is working with David Cooke on the Bayugo porphyry copper-gold deposit, which is in her home country.



PhD student Larriana Morgan is working with Garry Davidson on a project supported by the Northern Territory Geological Survey, investigating copper mineralisation in the McArthur Basin.



PhD student Jing Chen, from China, is working with David Cooke and Lejun Zhang on a project focused on the spatial, temporal and genetic relationships between porphyry and epithermal deposits of the Zijinshan ore field, China.



Dr Dave Selley has returned to CODES after a period working for BHP Billiton in Singapore. David has been appointed as a research fellow working with Newcrest and the co-ordinator for Honours coursework.



PhD student Esmaeil Eshaghi (or Esi for short) has joined CODES from the Geological Survey of Iran. His research project involves a petrophysical and geophysical investigation of west Tasmania, and his supervisory team comprises of Anya Reading, Michael Roach and Mark Duffett (Mineral Resources Tasmania).



PhD student Indrani Mukherjee, from Bengal, India, is working with Ross Large, Jacqui Halpin and Sebastien Meffre on a project related to the earth-ocean oxygenation and zinc-lead mineralisation in the period 1800 to 800 Ma (the 'boring billion'). Her field studies are being conducted in both India and Australia.

August PhD Graduations

A selection of PhD graduates and supervisors* taken at the August graduation ceremony. From left: Ross Large*, Vic Braniff, Bruce Gemmell*, Dan Gregory, Roisin Kyne and Matt Cracknell.



End of an era as old friends retire

Three stalwarts of CODES and Earth Sciences have decided to officially retire after many years of dedicated and loyal service. However, their services have not been entirely lost to the two areas.

Associate Professor Ron Berry

was a founding member of the small research team at the inception of CODES in 1989. In those early days, Ron was involved in the application of structural geology to ore deposits, and has worked and published extensively on the relationship between structure and mineralisation.

In later years, Ron played a pivotal role in the AMIRA GeM^{III} Geometallurgy project, applying his unique skills in mineralogy, image analysis, programming, statistics etc. to predict processing performance of ores.

Ron has also supervised and taught many of CODES postgraduate students, who have benefitted from Ron's willingness to pass on his exceptional wealth of knowledge. It is good to know that his knowledge will continue to be passed on via his new honorary research position.



Dr Peter McGoldrick

joined CODES in 1991, where he led research into Proterozoic sedimentary zinc systems for almost ten years, followed by projects relating to sedimentary copper deposits in Zambia and South Australia.

In more recent times, Peter did an excellent job as joint co-ordinator of the Honours program, and took on a large teaching role. Peter is well known for his passion for improving the quality of geology teaching at the university, and always taking the time to talk to the many students that sought out his expert knowledge.

Peter will be difficult to replace, but the good news is that he has also been retained in an honorary research capacity – as the article on page 4 testifies.



Peter Cornish

has been with UTAS since 1972, when he was appointed as a Technical Officer in what was then the Department of Geology. In this position, Peter played a crucial role in the development of high pressure experimental equipment that underpinned research activities related to igneous petrology.

After a relatively brief period in a finance role, and then as School Manager, Peter was appointed as Laboratory Manager, where he provided wide ranging support for the day-to-day activities of CODES and Earth Sciences.

Peter has been retained as a University Associate, so his services have not been entirely lost to staff and students.



Industry partners pledge their support

Six major companies have committed to be industry partners since CODES' Australian Research Council Centre of Excellence funding ceased at the end of 2013. The current partners are Anglo American, AngloGold Ashanti, Buenaventura, Newcrest Mining, Rio Tinto and Teck Resources.

"I wish to thank these partners for their continued support for CODES, especially when one considers the current tough operating conditions

in the mining sector," says Director, Professor Bruce Gemmill.

Companies have the choice to become a partner at Platinum (\$100K pa), Gold (\$75K pa) or Silver level (40K pa), depending on their planned level of involvement with the Centre.

A partnership offers a series of benefits, which escalate depending on the level. Major benefits include:

- Enhanced prospects of new discoveries.
- Optimisation of existing reserves.

- Research projects tailored to company requirements.
- Access to a continual supply of world class geoscience graduates.
- Access to a comprehensive range of industry-focused training courses, which can be tailored to partner requirements.
- Decision making input to the strategic direction of CODES, via a place on its Advisory Board (Gold and Platinum levels).

To find out more about being a CODES industry partner contact the Director, Bruce Gemmill:
Tel. +61 3 6226 2472
bruce.gemmill@utas.edu.au

Further information, including the full list of benefits, is also available at: utas.edu.au/codes



Spider-Woman spins her magic

Izzy von Lichten makes a few final adjustments to one of the two giant model spiders that she helped build for the Bookend Trust's Sixteen Legs exhibition, which was held at the Rosny Barn on Hobart's eastern shore in August. The 5.5 metre wide cave-dwelling arachnids formed an integral part of an event that focused on the mysterious and extraordinary world of Tasmania's underground cave systems.

As well as being the curator of the Rock Library, Izzy is a professional maker of scientific replicas, and is responsible for producing the many exceptional dinosaur reproductions exhibited within CODES and the Discipline of Earth Sciences.

The Bookend Trust is a UTAS-based not-for-profit education initiative that seeks to inspire students to pursue careers in science.

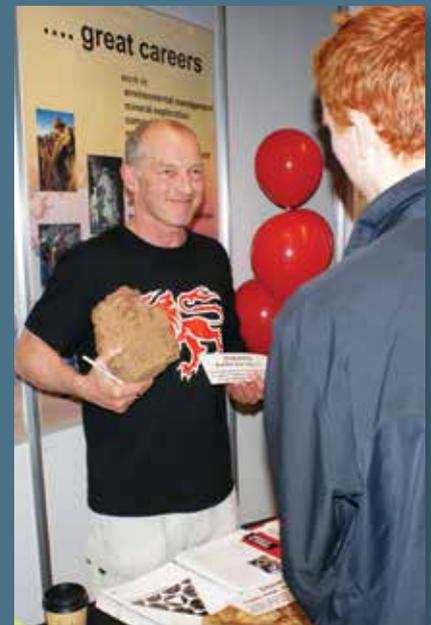


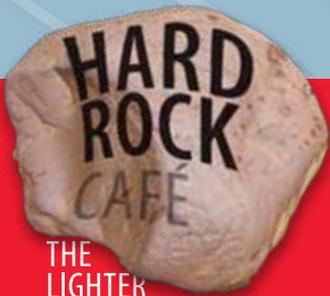
Taroona Scouts

A visit to CODES has become a popular event for everyone involved with Taroona Scouts. The Centre hosted two groups during September, which included a mix of scouts, parents and scout leaders. In the image top left, Scout Leader Simon Stephens is seen helping the youngsters during a tour of the lapidary section, where Simon worked before he retired. The image left shows Simon explaining the geological timeline, and how little of that timespan has included the existence of humans. The image above shows scouts looking at a poster board that explains basic geology in simple terms.

Open Day

CODES and the Discipline of Earth Sciences played a big part in the University of Tasmania's Open Day, which attracted over 10,000 people across the university's various Tasmanian campuses and centres. Clockwise: Indrani Mukherjee replaces the blow-up dinosaurs that have been knocked over by youngsters (and adults) throwing meteorites (soft balls) in a simulation of the mass extinction. Garry Davidson explains the benefits of a career in the earth sciences. PhD student Sean Johnson simulates a volcanic eruption with the aid of baking soda and red dye. Elena Lounejeva helps a visitor study dolerite samples from Mount Wellington. Michael Roach simulates a seismic event as the spectators protect their ears.





THE LIGHTER SIDE OF CODES

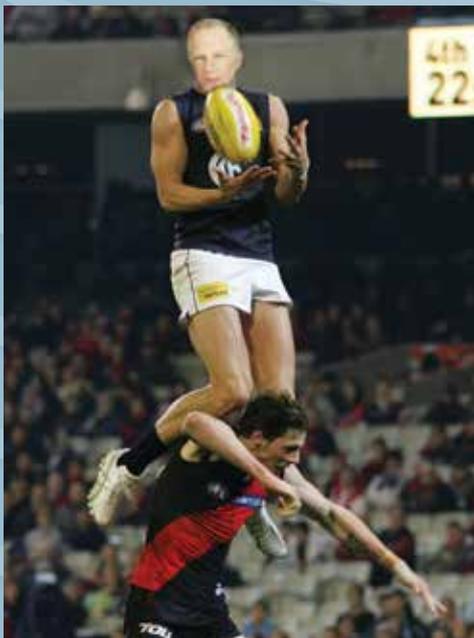
Futsal frenzy

Who said that they can't play soccer in Canada? A multinational team from CODES that included an Iranian, a Peruvian and three Canadians came a creditable third in the UTAS futsal competition, and finished as the top ranked co-ed team. From left, showing off their trophy for third place: Stephanie Sykora, Nic Jansen, Dan Gregory, Billy Beas, Margy Hawke, Esi Eshaghi, and Jacob Mulder.

Esi also received the 'players' choice' award, and Nic Jansen took the honours for 'outstanding performance'.

Up there Ca...Cornish

Peter Cornish retired recently and Izzy von Lichtan put together a hilarious spoof presentation of 'highlights' of his life. There were many notable achievements, from captaining the Starship Enterprise, to running into the surf in Baywatch. However, most people's favourite was Peter in his beloved Carlton shirt taking a screamer. Best wishes Peter. See also the (serious) feature on Peter's retirement on page 23.



Days of wine and noses

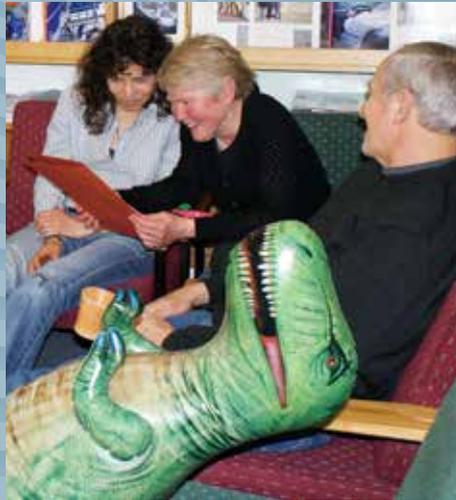
Staff and students savour the aroma and bouquet of the selection of delectable wines on offer at one of the regular wine tastings organised by the SEG Student Chapter.



Milestone for Joce

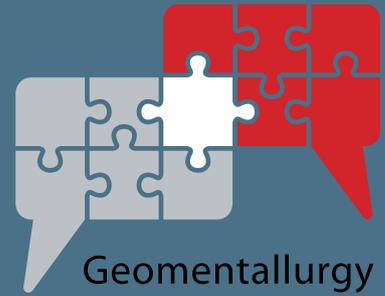
Jocelyn McPhie celebrates her 'big 60' with a cake that was specially made for the occasion. Appropriately, it included representations of a volcano, including lava (sweet snakes) and sparklers for the fire.

Joce enjoys reading the amusing entries staff have entered in her birthday card, while the dinosaur looks to have had a little too much of the bubbly.



Students on a roll

With the days getting longer, and warmer, it will soon be time for the SEG Student Chapter to arrange another of its popular Bowls Days. Photo taken at the last event, which was too long ago now – it's time to get things rolling.



The lie of the village

This issue's puzzle is an adaptation of an old conundrum that many people will have seen before – the trick is remembering the answer!

A geologist is on a field trip when they come to a fork in the road that leads to two villages. In one village the people always tell lies, and in the other village the people always tell the truth. The geologist needs to get supplies in the village where everyone tells the truth. A man from one of the villages is standing in the middle of the fork, but there is no indication of which village he is from. The geologist approaches the man and asks him one question. From the villager's answer, the geologist knows which road to follow. What did the geologist ask?

Email entries to:

steve.calladine@utas.edu.au
by Friday, 19 December, 2014.
The winner will have the choice of receiving either one of CODES' publications or a reversible vest from the new range of promotional gifts. The competition is open to readers in Australia and overseas.

SOLUTION TO PREVIOUS PUZZLE:

1. Fill 7L jug from 10L jug.
2. Fill 3L jug from 7L jug.
3. Empty 3L jug into 10L jug.
4. Fill 3L jug with 7L jug.
5. Empty 3L jug into 10L jug.
6. Put 1L remaining in 7L jug into 3L jug.
7. Fill 7L jug with 9L remaining in 10L jug.
8. Fill 3L jug with 7L jug.
9. Empty 3L jug into 10L jug, which leaves exactly 5L in each of the jugs.

THE WINNER was recent PhD graduate Dan Gregory, who chose one of CODES new reversible vests.

Geophysics course returns in February

Geophysics for Geologists and Engineers, one of the new additions to CODES expanded short course program, is making a welcome return to the training calendar early in 2015. This practical course in applied geophysics is specifically designed to provide geoscientists and engineers with a good understanding of the diverse applications of geophysical methods for exploration, mining, geotechnical and environmental projects. It is considered ideal for a range of professionals who are seeking an up-to-date overview of modern geophysical investigation methods.



The course is being run in partnership with GHD, which is one of the world's leading engineering, architectural and environmental consulting companies.

Intensive course, with flexible options

Participants can book for the full six days of the course, or opt to attend one or more of the two-day segments. While it is anticipated that most people will book for the full six days, the option of attending the shorter segments is expected to appeal to those that may be restricted for time, budget, or simply want to focus on certain topics. The course and segments for 2015 are as follows:

Days 1 & 2 –

Monday Feb. 2 to Tuesday Feb. 3:

Gravity and Magnetic Methods.

Days 3 & 4 –

Wednesday Feb. 4 to Thursday Feb. 5:



Electrical, Electromagnetic and Borehole Methods.

Days 5 & 6 –

Friday Feb. 6 to Saturday Feb. 7:

Seismic Methods.

Course overview

The intensive six-day program provides a modern overview of the application of geophysical methods to geological exploration, mining issues, geotechnical investigations and environmental assessments. It is designed to provide professional geoscientists and engineers with the necessary background understanding to utilise a wide variety of geophysical methods, together with important practical skills in technique selection, survey planning, data acquisition and interpretation.

The important theoretical background for each geophysical technique is covered with a minimum of mathematical formalism. The focus is on practical application of geophysical methods to solve geological or geotechnical problems. The course integrates formal presentations on geophysical theory, data processing and data analysis with numerous practical sessions including data acquisition exercises, interpretation projects, and geophysical equipment demonstrations.

Applied geophysical investigations can be undertaken at any scale and the basic physical principles, survey procedures and data analysis methods are not dependent on the size of the study area. The course exposes participants to a diverse collection of geophysical datasets and exercises ranging from regional-scale greenfields exploration to small-scale geotechnical and environmental projects.

Booking deadline and cost

The inaugural course was held in February 2014, and was well received by the participants. Therefore, places are expected to fill quickly for the second course. Although the deadline for bookings is 23 January, 2015, participants are urged to secure their places as soon as possible. Please note that places are limited to a total of 20 participants.

The full six-day course is available at a discounted rate of \$3,200 including GST. The three two-day segments are \$1,200 per segment including GST.

For further information you can download a brochure from the CODES website: utas.edu.au/codes or contact Michael Roach:
Tel. +61 3 6226 2474.
michael.roach@utas.edu.au



CODES

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