Annual Report 2022

CODES

UNIVERSITY of TASMANIA

CODES

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.

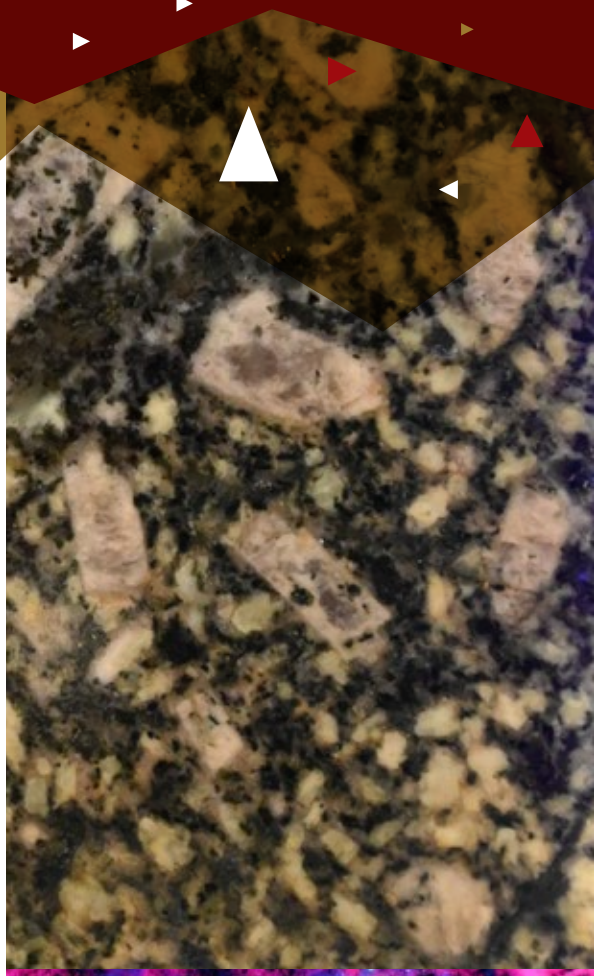
ABOVE: Team members of the new Regional Research Collaboration critical metals project take a breather during a stop at Trial Harbour on their December 2022 orientation trip to Tasmania's West Coast region.

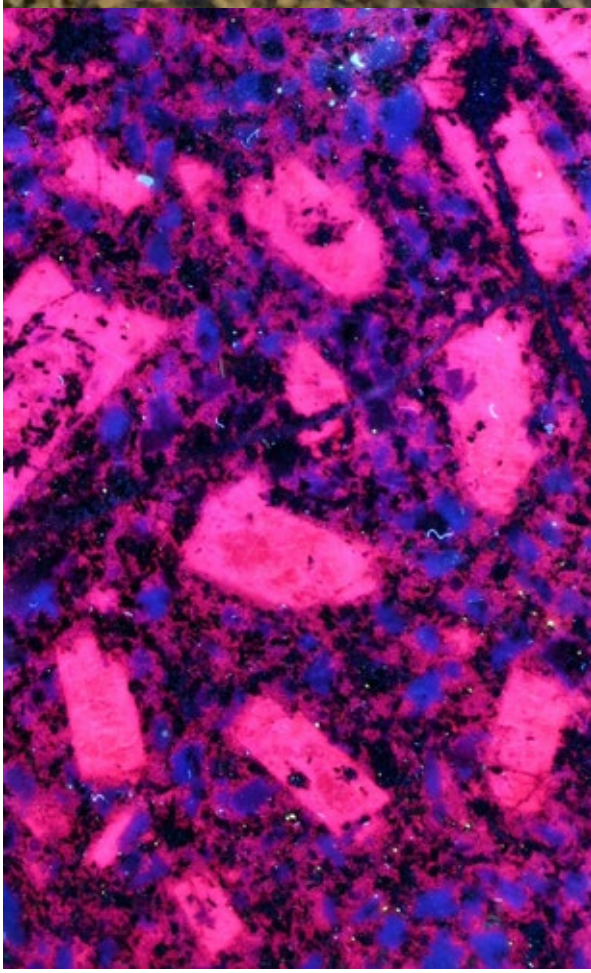
FRONT COVER: Examining drill core in the Henty Gold Mine core shed during a trip to the West Coast region of Tasmania in December 2022 are (L–R): Dr Lejun Zhang, Magdaline Kepo (Geology Manager at Henty), Thomas Methorst (Senior Geologist at Henty) and CODES PhD student Angela Costa.

BACK COVER: Participants of the 2022 CODES SEG Student Chapter field trip to New South Wales examining rocks in the Gidginbung Mine (high sulphidation gold) owned by Sandfire Resources.

OPPOSITE: Granodiorite porphyry from the Zijinshan district, China, viewed under visible light and under ultraviolet light. CODES staff member Dr Lejun Zhang entered this photo in the 2022 CODES Photo Competition.

Contents





Director's report 2022

The past year saw many great achievements by CODES staff, students and adjuncts, whether through their contributions to research across the fundamental to applied spectrum, or by providing world-class training through our Master of Economic Geology and Graduate Certificate in Economic Geology programs, regular community outreach and engagement activities, or through the continued growth of research innovation and industry engagement that is being achieved by CODES Analytical Laboratories staff. Our team have strived to achieve excellence and innovation across this full spectrum of activities, and have been busy conceiving, developing and conducting compelling new research projects, and continuing to deliver a pipeline of exceptional, highly qualified, well-trained graduates for industry, government and academia. Many of these achievements have only been possible thanks to the contributions and support of our collaborators, research partners and industry sponsors. The 2022 Annual Report highlights the successes of our team across this spectrum of CODES' activities for the past year.

While there were many highlights and achievements throughout the year, 2022 was also in many ways a time of transition for our team. We experienced our first major change early in the year, when Australia's COVID-related international travel restrictions eased. The immediate impact was that several of our students who had been working remotely on their theses overseas during the pandemic were able to return to CODES in early 2022, facilitating a return to on-campus study and reuniting with friends and colleagues here in Hobart. The easing of travel restrictions also meant that our staff and students could once again engage in international fieldwork and participate in conferences in-person. The transition was timely, as it ensured that as we commenced new national and international research projects, the barriers to fieldwork created by the pandemic were no longer an impediment. It also allowed us to return to in-person delivery of the 'Volcanology and Mineralisation in Volcanic Terrains' course in New Zealand and Tasmania in November, providing the major highlight of the Master of Economic Geology program in 2022.

> The 2022 Annual Report highlights the successes of our team across [the] spectrum of CODES' activities for the past year.

Because several of our major research projects concluded in 2021, development and initiation of new collaborative research projects was a significant focus in 2022, and our success in this regard was another major highlight of the year. With those new major research projects came the recruitment of new staff and students, leading to a significant influx of PhD students and some new staff that began late in 2022. As happens every year, there were also some staff and students who chose to move on from CODES to take up new challenges and new opportunities. This transition in personnel is providing a significant opportunity for renewal at CODES, as outlined in more detail throughout this Annual Report.

Research highlights

The Amira Footprints research project entered its sixth phase of research since initiating in 2004 with our new five-year Amira project, P1249 'Exploring, characterising, and optimising complex orebodies –

In February 2022 staff, students and collaborators for the new Amira P1249 project, 'Exploring, characterising, and optimising complex orebodies – Upscaling orebody knowledge to add value across the mining value chain', took part in the first meeting to kick off the research at CODES.

Integrated deposit knowledge to add value across the Mining Value Chain', commencing in February 2022. The Amira Footprints program has been the most sustained research program at CODES for the past two decades and has been a significant factor in building and sustaining CODES' reputation for research and training excellence in industry-related research. The new P1249 project is providing its 15 industry sponsors with new tools for recognising proximity to high-grade ore, and new tools, methods and workflows for translating and upscaling mineralogical, geochemical and hyperspectral data into quantitative mineralogy for complex orebodies of Cu, Au and other metals. In addition to a February start-up meeting, two sponsors review meetings and technology transfer workshops for the project were held in June and November, allowing the research team and sponsors to meet and discuss research progress and plans in person, with additional participants joining in online. Four new PhD students joined the P1249 research team at CODES, as did two Honours students at Universidad Austral de Chile in 2022, with fieldwork getting underway in Australia, Central Asia, Chile and Argentina. Drs Matthew Cracknell, Mike Baker and Lejun Zhang were outstanding team members of this project during the year.

A major and unexpected highlight of 2022 was our success in securing $3.5 million in research funding from the Australian Government Department of Education through its Regional Research Collaboration funding scheme. Funding was awarded for a new three-year project entitled 'Building capacity in regional Australia to enhance Australia's economy through research, training, and environmentally sustainable production of critical metals'. This project was conceived, submitted and funded in 2022, and is a partnership between CODES and the School of Education at UTAS. The project will investigate pathways to environmentally sustainable production of critical metals from Tasmania, and strategies to improve educational outcomes and regional job opportunities for communities in Tasmania's West Coast region. Nine Tasmanian-based industry partners supported the funding application, together with Minerals Resources Tasmania and the Tasmanian Mining, Manufacturing and Energy Council, and two academic partners – University of Queensland and Université de Liège (Belgium). This project was fast-tracked after funding success was announced by the Federal Minister for Regional Education in May

A major and unexpected highlight of 2022 was our success in securing $3.5 million in research funding from the Australian Government Department of Education through its Regional Research Collaboration funding scheme.

Professor David Cooke with Professor Sharon Fraser (School of Education) pictured in May 2022 at the Kara mine processing plant during the launch of the Regional Research Collaboration project entitled 'Environmentally sustainable production of critical metals'.

Professor Ross Large (right) receives the Society of Economic Geologists' 2022 R.A.F. Penrose Gold Medal from the SEG President, Chico de Azevedo, at a ceremony in Denver, Colorado, during August. The medal is the SEG's highest honour, and Ross was its 56th recipient.

2022, with the recruitment of nine PhD students and four postdoctoral research fellows occurring in the second half of 2022. The project officially commenced in late November, and an orientation field trip took place in December.

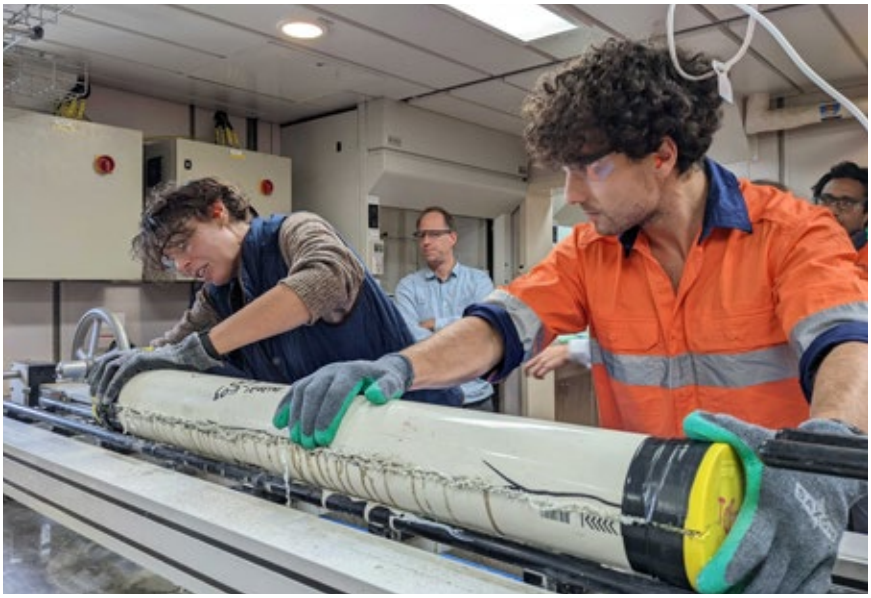
CODES staff commenced a new collaboration with Geoscience Australia (GA) in mid-2022 with postdoctoral researcher Dr Sheree Armistead and Professor Sebastien Meffre collaborating with Drs David Huston, Andrew Cross and Geoff Fraser on GA's Exploring for the Futures program. This two-year project is part of the Temporal Controls on Mineralisation Module of the GA research program and is focussed on providing new timing constraints on the metallogenic evolution of western Tasmania. Initial results have already provided exciting new insights into Tasmania's metallogenic evolution.
A second collaboration with GA continued throughout 2022 as part of the Exploring for the Futures program in the Australia's Resources Framework project, with CODES research fellow Dr Jonathon Cloutier working as an embedded researcher at GA to conduct mineral prospectivity assessments in collaboration with Dr Arianne Ford. Dr Jeff Steadman and Professor Sebastien Meffre initiated a new three-year industry-funded project entitled 'Iron oxide copper-gold deposits: geochemistry and geometallurgy', which is a partnership with several industry partners and state government surveys.

The major fundamental research highlight for our team in 2022 was the successful completion of the Marine National Facility (MNF) voyage to investigate 'Sedimentation at its extreme: how powerful are submarine caldera-forming eruptions (Kermadec arc)?'. Dr Martin Jutzeler was Chief Scientist on this month-long cruise, with Associate Professor Rebecca Carey one of several Principal Investigators for the voyage. Several CODES staff, students and adjuncts participated in the cruise, providing them all with one of their major research career highlights. The cruise surveyed several submarine volcanoes, acquiring exceptional imaging results for the depositional products from the 2012 Havre submarine eruption and significant sediment core samples for future analysis. CODES PhD student Acacia Clark was fortunate to have the opportunity to participate in a second oceanographic cruise in late 2022, as part of the International Ocean Drilling Program (IODP) Expedition 398 – 'Volcanism and tectonics in an island arc rift environment (VolTecArc): Christiana-Santorini-Kolumbo marine volcanic field, Greece'. Acacia and fellow PhD student Hannah Moore also finally had the opportunity to conduct field research for their volcanology PhD studies in New Zealand in 2022, joined by Associate Professor Rebecca Carey and Dr Michael Roach, after two years of frustrations caused by international travel bans.

Awards and accolades

Professor Ross Large received the 2022 R.A.F Penrose Gold Medal from the Society of Economic Geologists (SEG) at the SEG annual conference in Keystone, Colorado, in August 2022. This is the highest accolade offered by the Society and recognises Ross' outstanding lifetime contributions to the field of Economic Geology. Since 1924, the Penrose Gold Medal has been awarded 55 times, with six Australians receiving this honour. Four of those six recipients are former staff or students of UTAS, with Ross joining Noel White, Mike Solomon and David Groves in being honoured with this lifetime achievement award, testament to the sustained excellence in Economic Geology training and research fostered by Ross and Mike during their tenures as the leading Economic Geology lecturers at UTAS for four decades.

Dr Sheree Armistead was awarded the Chris Powell Medal at the 2022 Specialist Group in Tectonics and Structural Geology conference. This medal is awarded to an outstanding research paper arising from postgraduate research on some aspect



TOP: Honorary Professor Noel White is pictured here in a Corazon Mining video about the company's Mt Gilmore copper project with CODES researchers Dr Lejun Zhang (right) and Dr Francisco Testa (left).
ABOVE: The Marine National Facility VULKA-22 voyage to the Kermadec Arc/ Rangitāhua was the major fundamental research highlight for CODES in 2022. Here (L–R) Shannon Frey, Martin Jutzeler, Issi Port and Malai Ila'ava are undertaking core splitting on board the CSIRO Research Vessel RV Investigator.

of structural geology or tectonics. Alex Farrar was awarded the best student presentation at the same conference – well done Sheree and Alex!

Several CODES and Earth Sciences students were recognised at the UTAS Student Recognition Evening in May 2022. Hannah Moore received the PhD Award for Outstanding Performance during Postgraduate Studies in Earth Sciences. Eva Baukes won the Dr Ramsay J. Ford Memorial Prize for proficiency in Geology (1st year). Issi Port was awarded the I.B.I. Smith Prize in Geology for the greatest proficiency in Geology, and the Dr Garry Davidson Memorial Prize for the greatest achievement during the Geological Field Excursion (2nd year). Daniel Fisher received the W.D. Parkinson Prize for the greatest proficiency in Geophysics or Exploration Geophysics (3rd year). Kate Jenkins was awarded the Geological Society of Australia Carey Prize for the best Honours student in Earth Sciences at the University of Tasmania (4th year). Well done to all our high-achieving students!

Some of our staff and adjuncts were also recognised for their services to UTAS in 2022. Professor Khin Zaw was presented with the Outstanding Adjunct Award in the 2022 College of Sciences and Engineering (CoSE) Awards at a ceremony in early October. The award is presented for 'Exceptional contributions to the mission of the University through enrichment of academic work or impact on key strategic areas.' CODES/Earth Sciences Rock Curator and part-time casual teaching assistant Izzy von Lichtan received an honourable mention in the Student Focus category of these awards.

CODES Adjunct Professor Pete Hollings received the 2020 Association of Applied Geochemists (AAG) Cameron-Hall Copper Medal on behalf of Professor David Cooke and co-authors at the International Applied Geochemistry Symposium in Valparaiso, Chile, in October 2022. The AAG awards this medal to the lead author for the most outstanding scientific publication in *Geochemistry: Exploration, Environment, Analysis* (GEEA).

Masters/PhDs

CODES delivered six units as part of the Master of Economic Geology program in 2022. Four of these were online (Fundamentals of Economic Geology: April–May; Ore Deposit Models and Exploration Strategies: June–July; Geodata Analytics: August–October; Exploration in Brownfield Terrains: October–December). Online delivery has proven a boon for those students located offshore during the pandemic and is also popular for our students with family commitments or FIFO work rosters. But there is no doubt that the student cohorts who participated in our two in-person field courses (Advanced Field Skills in Economic Geology: February; and Volcanology and Mineralisation in Volcanic Terrains: November) were both relieved and greatly appreciative of a return to field-based training after two years of travel restrictions impacting on delivery of these units. We saw increased engagement with our new Graduate Certificate in Economic Geology program in 2022, which is providing both a micro credentialling opportunity and an alternative pathway for entry into the Master of Economic Geology program. Dr Robert Scott continued to do a superb job as Masters Co-ordinator.

Ten new domestic and international PhD students commenced PhD studies at CODES in 2022: Chris Allen (Australia), Isaac Brown (UK), Markus Staubmann (Australia), Victor Torres (Peru), Joanne Morrison (Australia), Billy

The highly successful Volcanology Masters short course, which ran in November 2022, was led by Associate Professor Rebecca Carey and Professor David Cooke. Participants are pictured here on the septa between explosive craters produced during the 1886 eruption of Tarawera volcano, Aotearoa/NZ.

Beas (Peru), Axel Cima (Argentina), Emrecan Yudakul (Türkiye), Angela Costa (Brazil) and Javier Gil Rodriguez (Colombia). Chris, Angela, Emrecan and Javier are working on the RRC project; Billy, Markus and Axel are working on P1249; Joanne is part of the new IOCG project; Isaac is working on the Haiveron Cu-Au deposit in Western Australia, supported by Newcrest Mining Ltd; and Victor is researching the Soledad Cu-Au tourmaline breccia pipes in Peru, supported by Chakana Copper.

Conferences and trips

A return to in-person participation at international conferences was a feature of 2022, with several CODES team members presenting their research findings at the SEG Conference in Denver, the Goldschmidt Conference in Hawaii and the MGEI Conference in Indonesia. Unfortunately, New Zealand's pandemic travel restrictions didn't lift in time to allow for in-person participation at the year's major Economic Geology conference – the SGA meeting in March – meaning that several CODES staff and students delivered online presentations and workshops as part of that event. On the domestic conference front, the Eighth Mines and Wines conference in Orange, NSW, was a boisterous event in May 2022. The conference had been postponed by one year to ensure in-person participation could occur. Eight past and present CODES staff and students gave oral presentations and two CODES students presented posters at this three-day event.

The CODES SEG Student Chapter ran a highly successful field excursion to the porphyry, epithermal, skarn, orogenic gold and VHMS deposits of NSW in late September. Twelve students and two staff members were joined by 11 industry participants on a week-long trip that reviewed outcrops, open pits and drillcore from more than 20 mineral deposits and prospects in the Macquarie Arc, providing an amazing opportunity to become familiar with the diversity of mineral resources in this highly prospective metallogenic region.

Sebastien Meffre, Sheree Armistead and Alex Farrar with geologists from IMAS and MRT organised the 2022 Specialist Group in Tectonics and Structural Geology three-day field conference – 'Structure in the Strait' on King Island, Tasmania, in November 2022. This small, specialist group meeting provided participants with great opportunities to learn about King Island's spectacular geology, including its complex history of deformation and metamorphism through day trips, and provided a forum to discuss the latest findings in research from Australia's tectonics and structural geology research community.

The annual Tasmanian Geoscience Forum was held in Tullah in late November 2022. This event brings together industry, government and academia to discuss the latest advances in Tasmanian geosciences. A highlight of the 2022 forum was Dr Julie Hunt's introductory presentation to the Regional Research Collaboration project. This was the first official presentation of the RRC team and helped to raise awareness of the research project amongst the Tasmanian mining and exploration community. Martin Jutzeler, Sheree Armistead, and CODES adjunct Dr Tony Webster also gave excellent presentations on CODES research and community outreach activities at the Forum.

Out in all weathers: CODES team members examine an outcrop of alteration minerals at the Mount Lyell site as part of the orientation field trip in December 2022 to the Tasmanian West Coast region for the new RRC project.

Staff changes

We were pleased to have several new staff join CODES in 2022, and sad to see some of our staff move on to new opportunities. After protracted COVID-related delays, Dr Jeffrey Oalmann finally arrived in Tasmania in January 2022. Jeff is now the Deputy Leader of CODES Analytical Laboratories, specialising in geochronology and bringing a wealth of research and analytical experience to CODES. Fanghua Dai also rejoined CODES as a Laboratory Analyst in early 2022. Dr Wei Hong rejoined CODES as a Research Fellow in October 2022 after completing a postdoctoral role as part of the Minex CRC. Wei will be working on Amira P1249 and the RRC project. Dr Owen Missen joined CODES in November 2022 as an Environmental Geochemistry Postdoctoral Research Fellow in the RRC project. Owen previously completed a PhD study of tellurides at Monash University and a postdoctoral fellowship focussed on cobalt at Museums Victoria, and brings great skills in geochemistry and mineralogy to our team, with a strong research focus on critical minerals. With regards to staff departures, Dr Indrani Mukherjee left CODES in May 2022 to undertake a postdoctoral fellowship at the University of Toronto. We wish Indrani all the best for the future.

We were pleased to have several new staff join CODES in 2022, and sad to see some of our staff move on to new opportunities.

Outreach

Hannah Moore received a STEM Stage Skills scholarship in 2022, kindly supported by Hydro Tasmania, which facilitated her involvement in the 2022 Festival of Bright Ideas. Hannah and four colleagues developed a thematic stage show entitled 'From little things, big things explode' which they performed to around 1,000 people in five packed-out shows, showcasing their PhD research to the public. During the Festival, Acacia Clark, Alex Farrar, Dan Fisher and Madison Mulder ran the UTAS Earth Sciences stall, promoting the joys and wonders of studying geology to future potential students.

CODES contributed to the University of Tasmania's 'STEPs' program (Skills, Training, Education, Pathways) in western Tasmania in 2022. This program aims to build confidence in participants by learning how their life experiences, interests and existing skills can be developed to take advantage of learning and work opportunities on the

West Coast. PhD students Zeb Zivkovic and Richard Hill, together with David Cooke, ran mining-focussed sessions in collaboration with staff from the Henty Au and Avebury Ni mines for local community members to broaden their awareness of minerals industry-related jobs/careers and learning opportunities that are available locally. The half-day sessions were held in Queenstown (May), Zeehan (June) and Strahan (September), and included presentations and hands-on activities, including site visits to exploration core sheds and an overview of water sampling and monitoring of the King–Queen river system.

Publications

With the ongoing challenges of online teaching, the initiation of several new research projects and various other issues, CODES had a comparatively quiet year of publications in 2022, although a series of quality papers were published by our team across the fundamental to applied spectrum. Professor Khin Zaw and Dr Charles Makoundi were Guest Editors of a two-volume special publication on 'Emerging Trends in Earth Science for Sustainable Futures in the SE Asia region', which was published by the *Journal of Asian Earth Sciences*. This volume includes several contributions co-authored by CODES staff and adjuncts. CODES Adjunct Tony Webster published an excellent book entitled 'The foundation of Australia's capital cities: geology, landscape, and urban character' in 2022. In this great example of community outreach, Tony has provided an entertaining and informative account of the effects of each Australian capital city's diverse geology and original landforms influencing city development patterns that have persisted today.

Dr Sheree Armistead after receiving the Chris Powell Medal at the 2022 SGTSG conference for her research paper on structural geology.

STATISTICS AT A GLANCE 2022

Academic research staff	49
Postgraduate students	129
Major research projects	46
Countries involved	35
Publications in refereed journals	34
Research reports to industry	274
Workshops and short courses	
Number	21
Countries	2 plus online delivery
Attendees	~650
Funding	
Industry	$1.58 million
UTAS	$1.75 million
Worldwide collaborations	
Industry	58
Institutes and universities	86

The year ahead: what does 2023 hold?

The Regional Research Collaboration project 'Environmentally sustainable production of critical metals' will ramp up significantly in 2023, with most of the student cohort and several staff scheduled to commence at CODES in the first two months of the year. This project will see ten new PhD studies initiated on Tasmania's geology and ore deposits, returning CODES to its roots with a new generation of Tasmanian-focussed research.

Martin Jutzeler will lead a new MNF cruise in early 2023 to investigate 'Tsunamgenic submarine landslides and deep-marine canyons of Australia's Tasman Sea margin – causes and consequences'. This research will help identify the risks that locally generated tsunamis from submarine landslides can pose to communities along the coast and inform strategies to mitigate those risks, as they have occurred along the east coast of Australia for about 15 million years and are expected to occur again. Jeff Steadman and Sebastien Meffre are developing a new industry- and government-funded research project investigating the Tennant Creek IOCG deposits.

The ARC Linkage project 'Exploration targeting from next-generation volcanic facies reconstruction' will conclude next year, but Rebecca Carey has plans for submitting new ARC grant proposals in 2023 to continue fundamental research into explosive volcanism and is recruiting a new PhD student in 2023 to work as part of this research program. Amira P1249 will continue to recruit new students and plans to initiate field studies in South Africa, Ghana, Spain, Canada and Chile, across a diverse array of mineral systems from porphyry copper and epithermal gold to orogenic gold, VHMS, PGE and sediment-hosted Cu environments. On a sad note, Dr Michael Roach will retire in 2023, after three decades of amazing contributions to geophysics teaching, supervision, and research at CODES.

While this report was being compiled we learnt of the tragic passing in August 2023 of one of our PhD students. Joanne Morrison, who was working within Programs 2 and 3, will be sadly missed by all her colleagues and friends here at CODES.

David Cooke
Director of CODES

Participants on the highly successful CODES SEG Student Chapter field trip to the Macquarie Arc are here pictured examining drill core at Newcrest's Cadia facilities in New South Wales.

Profile and research structure

An overview

CODES commenced operations in 1989, evolving over two and a half decades from an Australian Research Council-funded Key Centre to a Special Research Centre and then a Centre of Excellence. Now in its fourth decade of operations, CODES is known as the Centre for Ore Deposit and Earth Sciences. Based at the University of Tasmania, CODES has grown substantially over the years and is regarded widely by industry and academia as a global leader in ore deposit research and postgraduate training. With 49 highly qualified research staff and 129 postgraduate students, CODES is one of the largest university-based teams of ore deposit researchers in the world.

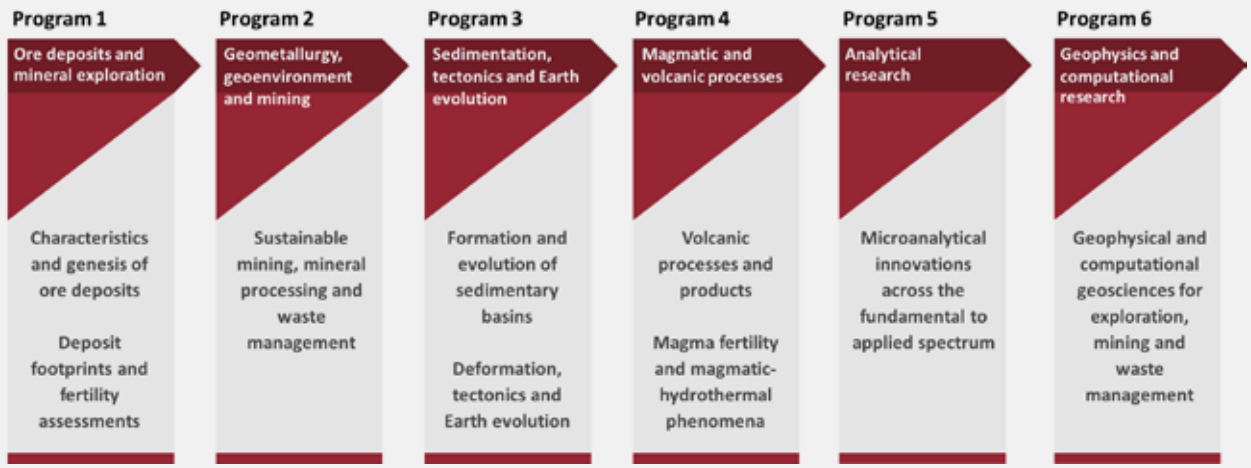
Highly productive worldwide collaborations have been developed with over 58 industry companies, plus a host of joint research initiatives with 86 institutions and universities – 20 in Australia and 66 overseas. It currently has 46 major research projects spanning 35 countries, across six continents. It is also a leading academic group to publish in *Economic Geology*. In the past year, despite the lingering restrictions brought about by COVID-19, it maintained its reputation for delivering excellence in technology transfer by producing 274 reports to industry and conducting 21 short courses, workshops, conferences and field trips. The majority of these were online, due to the changes wrought by COVID-19. However, the online format allowed participants from several continents, who would not otherwise have been able to attend, to join these courses and workshops.

Industry-focussed research

CODES' research is conducted within and across six research programs (see CODES Program Structure graphic below). Our research spans a range of fundamental and applied activities, and our industry-focussed research aims to

Codes Program Structure

The CODES program structure covers the full spectrum of research from fundamental to applied:



The Director of CODES, Professor David Cooke (second from right) explains the significance of critical metal production to Senator Bridget McKenzie (then Federal Minister for Regional Education) while Gavin Pearce (Member for Braddon, left) and Greg Coster (Tasmania Mines Pty Ltd, right) look on. This photo was taken at the launch of the RRC critical metals project in May 2022, held at the Kara mine processing plant, south of Burnie.

develop new exploration techniques for mineral discoveries, and new practices for sustainable mining, mineral processing and waste management. Our research across this spectrum of activities allows CODES to provide the minerals industry with a constant supply of world-class geoscience graduates and creates the platform for our training and upskilling of minerals industry professionals through our Master of Economic Geology and Graduate Certificate in Economic Geology programs.

Our industry-focussed research aims to develop new practices for sustainable mining, mineral processing and waste management.

Training and education

Training and education at CODES provides an ongoing supply of highly sought-after 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. 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, Geochemistry and Environmental Geology.

Graduate Certificate in Economic Geology

This new postgraduate offering, introduced in 2021, is designed for professional geoscientists keen to gain a stronger understanding of ore deposits, either for professional development, or as a foundation for further postgraduate training. The one-year degree requires completion of one compulsory unit and one other unit from our coursework Masters offerings, and can be counted as credit towards the Master of Economic Geology program.

Master of Economic Geology

Industry geologists can participate in a series of intensive, predominately two-week courses aimed at the working geologist in order to upgrade their skills; the MEconGeol is available in coursework only (8 units) and coursework (6 units) plus research

thesis options. The degree is part of the national Minerals Geoscience Masters (MGM) program. In 2022 a total of six MEconGeol units were offered: Advanced Field Skills in Economic Geology, Fundamentals of Economic Geology, Ore Deposit Models and Exploration Strategies, Geodata Analytics, Exploration in Brownfield Terrains, and Volcanology and Mineralisation in Volcanic Terrains. All of these except the Advanced Field Skills and Volcanology units were run online.

PhD and MSc

These higher degree by research (HDR) 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 who are international leaders in their respective fields.

Participants on the 2022 Advanced Field Skills in Economic Geology Masters short course pictured on Tasmania's east coast. These short courses are aimed at working geologists who want to upgrade their skills.

Research facilities

CODES Analytical Laboratories contain state-of-the-art analytical facilities for a wide range of geological analyses, encompassing the routine multielement analysis of sulphide and oxide minerals, including the full range of platinum group elements; U/Pb dating of zircon and monazite; and multielement 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 lapidary department and sample preparation facilities. In addition, portable analytical techniques are provided, including shortwave infrared (SWIR) and portable XRF.

CODES has reciprocal access 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.

CODES has established its position at the leading edge in mineral chemistry research for exploration through the development of unique analytical techniques, data processing and screening methods, and calibration standards, combined with employing staff who have extensive expertise in analytical protocols and the interpretation of results.

Timeline

- **1989** – CODES formed as an ARC Key Centre.
- **1997** – Awarded Special Research Centre status by the ARC.
- **2005** – Awarded Centre of Excellence status by the ARC.
- **2008** – Successful mid-term review guarantees ARC funding for the final two years of the original proposal, plus an extension until the end of 2013.
- **2013** – Tenure as an ARC-funded Centre of Excellence ends.
- **2014** – ARC grants approval for CODES to retain its Centre of Excellence Status – note that no further extensions of funding were permitted under the ARC's rules for this type of Centre.
- **2015** – TMVC commences operations.
- **2016** – CODES' researchers, together with a group of industry partners, awarded one of the ARC's Industrial Transformation Research Hubs: Transforming the Mining Value Chain (TMVC).
- **2017** – Collaboration as an Essential Research Partner to CRC ORE commences.
- **2019** – CODES became known as the Centre for Ore Deposit and Earth Sciences.
- **2020** – TMVC extended to June 2021
- **2021** – COVID-19 pandemic interrupted fieldwork
- **2022** – TMVC concluded; RRC project commenced

Staff and management 2022

Centre Director

Professor David Cooke has been the Centre Director since mid-2017; he is responsible for the scientific leadership and operational management of the Centre. Also providing support to these roles are the Advisory Board and the Executive Committee.

Advisory Board

The Advisory Board meets at least 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 for Energy and Mining, South Australia, who has extensive experience in the minerals industry and the public service. Paul Agnew from Rio Tinto is Deputy Chair.

In 2022 the Advisory Board resumed a face-to-face meeting format post-COVID. An industry-focussed meeting was held in June (with only industry representatives attending) and a full Advisory Board meeting was held in November.

Executive Committee

The Executive Committee consists of the Centre Director, Deputy Director (vacant), Head of the Discipline of Earth Sciences, and a representative from the areas of applied research, fundamental research, education and administration. It meets approximately six times a year, working closely with the Director to develop the Centre's goals, strategies and research directions.

Students joined staff in the CODES Rock Garden for the Chinese New Year gathering on 4 February.

Annual Review

The Annual Review is an annual one-day forum of presentations relating to the Centre's research. The membership is wider than that of the Advisory Board and includes representatives from partner companies, research collaborators and other geoscience stakeholders. The Annual Review is designed to provide stakeholders and interested parties with an opportunity to see the breadth of the research conducted at CODES and to influence future research directions.

In 2022 the Annual Review was held in late November in a face-to-face format at CODES; it gave participants a chance to network and renew friendships following a long period when such meetings were not possible due to COVID-19.

Staff movements

Appointments

Academic/research staff

Dr Wei Hong, who completed his PhD at CODES in 2017, then worked for three years at the MinEx CRC at the University of Adelaide, returned to CODES towards the end of 2022 to work as a Research Fellow in Critical Minerals Characterisation. He will be working on both the Regional Research Collaboration critical metals project and on the Amira P1249 project called 'Exploring, characterising and optimising complex orebodies'.

Dr Owen Missen joined CODES at the end of November as a Research Fellow in Environmental Geochemistry and Mineralogy, and will be working on the Regional Research Collaboration critical metals project with a focus on sites in northwestern Tasmania. He previously worked as a geosciences researcher at Museums Victoria.

Professional/ technical staff

Fanghua Dai arrived at CODES in early 2022 to work as a Laboratory Technician in the mineral separation lab within the CODES Analytical Laboratories.

Departures/role changes

Academic/research staff

Dr Indrani Mukherjee, who gained her PhD at CODES in 2018, and became a postdoctoral researcher here, left CODES in May for a six-month stint at the University of Toronto, Canada, before accepting a position as Lecturer in Earth Sciences at the University of New South Wales in Sydney.

Professional/ technical staff

Regi Broeren left her role as a part-time Technical Officer for CODES/Earth Sciences in January, to continue her PhD in Biological Sciences.

Vanessa Seabourne left her role in Earth Sciences administration; her role was taken over by a reorganisation of College Services and Jake Reynolds was appointed as the Senior Administration Officer, College Services.

TOP LEFT: L–R: University Associate Dr Charles Makoundi with PhD student Peerapong Sritangsirikul and Research Fellow in Critical Minerals Characterisation Dr Wei Hong at the CODES Annual Review in November. TOP RIGHT: Professor Noel White, a CODES honorary researcher and collaborator, with PhD student Xin Ni Seow, pictured at the CODES Annual Review on 28 November 2022.

MIDDLE LEFT: L–R: Dr Stuart Bull, Xin Ni Seow, Paloma Elvira, Dr Margie Hawke and Dr Lejun Zhang with Zeb Zivkovic and Dr Angela Escolme (both in red) listening to Professor Sebastien Meffre speaking at the CODES 2022 Christmas BBQ. MIDDLE CENTRE: Dr Karin Orth takes a break in the CODES tea room. MIDDLE RIGHT: CODES and Earth Sciences staff pictured at the LGBQTI bake-off in the CODES tea room on 6 July: (L–R) David Cooke, Matthew Cracknell, Michael Roach (eating, as always), Nicholas Direen (obscured) and Sheree Armistead.

BOTTOM RIGHT: New CODES Research Fellow in Environmental Geochemistry and Mineralogy Dr Owen Missen (left) with Acting Leader of the CODES Analytical Laboratories, Dr Paul Olin, at an Amira BBQ held in the CODES Rock Garden.

STAFF AND MANAGEMENT

NAME	SPECIALISATION	%*
Director, Professor David Cooke, BSc Hons (Latrobe), PhD (Monash)	Porphyry Cu-Au, fluid-rock geochemistry	50

ACADEMIC/RESEARCH STAFF AT UTAS

NAME	SPECIALISATION	%
Dr Sharon Allen, BSc (Massey), MSc (Auckland), PhD (Monash)	Volcanic facies analysis	Hon
Dr Sheree Armistead, BSc Hons (Monash), PhD (UAdelaide)	Plate tectonics, isotope geochemistry, structural geology	90
Dr Mike Baker, BSc Hons (Sydney), PhD (UTAS)	Igneous petrology, mineral chemistry	100
Associate Professor Ron Berry, BSc, PhD (Flinders)	Structure of mineralised provinces, CHIME dating, geometallurgy	Hon
Dr Stuart Bull, BSc Hons, PhD (Monash)	Clastic and carbonate sedimentology and volcanology	Hon
Associate Professor Rebecca Carey, BSc Hons (UTAS), PhD (U Hawaii)	Volcanology	50
Dr Jonathan Cloutier, BSc, MSc, PhD (Queen's U, Canada)	Economic geology, geochemistry, hyperspectral reflectance	100
Dr Matthew Cracknell, BSc Hons, PhD (UTAS)	Geophysics, machine learning and data mining	50
Professor Tony Crawford, BSc Hons, PhD (Melbourne)	Petrology, geochemistry and tectonics of volcanic arcs	Hon
Dr Paul Davidson, BSc Hons, PhD (UTAS)	Melt and fluid inclusions	Hon
Dr Angela Escolme, MEarthSci Hons (Manchester), PhD (UTAS)	Geometallurgy, geochemistry, mineralogy	50
Dr Trevor Falloon, BSc Hons (Canterbury), BTeaching, PhD (UTAS)	Marine geoscience, petrology	Hon
Professor J Bruce Gemmell, BSc (UBC), MA, PhD (Dartmouth)	VHMS deposits and epithermal Au-Ag	Hon
Professor David Green, BSc Hons, MSc, DSc, DLitt Hon (UTAS), PhD (Cambridge)	Experimental petrology	Hon
Dr Wei Hong, BSc (CUG), MSc (CAGS), PhD (UTAS)	Economic geology and mineral characterisation	100
Dr Julie Hunt, MSc (UBC), PhD (JCU)	Geometallurgy, economic geology	50
Dr Martin Jutzeler, MSc (U Lausanne), PhD (UTAS)	Volcanology and clastic sedimentology	77
Dr Maya Kamenetsky, PhD (UTAS)	MLA-SEM, geometallurgy, petrology	100
Professor Khin Zaw, BSc (Rangoon), MSc (Queen's), PhD (UTAS)	Fluid inclusions, SE Asian metallogenesis	Hon
Professor Ross Large, BSc Hons (UTAS), PhD (UNE)	Volcanic-hosted and sediment-hosted base metal and gold ores	Hon
Dr Charles Makoundi, MSc, PhD (UTAS)	Geochemistry (incl exploration and isotope geochemsitry), geochronology, clastic sedimentology	Hon
Dr Peter McGoldrick, BSc Hons, PhD (Melbourne)	Ore deposits and their halos	Hon
Professor Jocelyn McPhie, BA Hons (Macquarie), PhD (UNE)	Volcanic facies architecture and volcanic textures	Hon
Professor Sebastien Meffre, BSc Hons, PhD (Sydney)	Petrology and tectonics of the SW Pacific	50
Dr Clare Miller, BSc Hons, PhD (Queen's U, Canada)	Environmental geochemistry and remediation of mining-impacted environments	50
Dr Owen Missen, BSc, MSc (UMelb), PhD (Monash)	Environmental geology, minerology and biogeochemical cycling	100
Dr Michael Roach, BSc Hons (Newcastle), PhD (UTAS)	Geophysical responses of ore deposits	20
Dr Robert Scott, BSc Hons, PhD (Monash)	Structural geology, gold deposits/Masters Program Coordinator	65
Dr David Selley, BSc Hons (Adelaide), PhD (UTAS)	Structural geology, basin analysis, ore deposit modelling	Hon
Dr Jeff Steadman, BSc (Central Missouri), MSc (Iowa), PhD (UTAS)	Ore and sedimentary pyrite geochemistry; seawater composition through geologic time	77
Dr Tony Webster, BSc Hons (Latrobe), BA (UNE), BAVE, BEd Hons (UTAS), GDipMinEng (UNSW), MSc (JCU), PhD (UTAS)	Mining structural geology, complexly deformed deposits	Hon
Dr Lejun Zhang, BSc, PhD (HFUT)	Porphyry Cu-Au and HS epithermal	100

*Research percentage

ACADEMIC/RESEARCH STAFF BASED AT COLLABORATIVE INSTITUTIONS/INDUSTRY

NAME		%*
Dr Shaun Barker	MDRU, University of British Columbia	Hon
Dr John Bishop	Consultant	Hon
Dr Daniel Bombardieri	Mineral Resources Tasmania	Hon
Mr Ralph Bottrill	Mineral Resources Tasmania	Hon
Dr Ana Liza Cuison	Emmerson Resources	Hon
Dr Kathy Ehrig	BHP	Hon
Dr Scott Halley	Mineral Mapping	Hon
Dr Anthony Harris	Newcrest Mining	Hon
Professor Peter Hollings	Lakehead University	Hon
Mr Terry Hoschke	Consultant	Hon
Dr David Huston	Geoscience Australia	Hon
Mr Adi Maryono	J Resources	Hon
Dr Gerrit Olivier	Institute of Mine Seismology	Hon
Dr Evan Orovan	British Columbia Geological Survey	Hon
Dr Joshua Phillips	JP Geoscience	Hon
Professor Noel White	Independent	Hon

TECHNICAL/ADMINISTRATIVE STAFF

NAME		%*
Dr Ivan Belousov, BSc, MSc (Moscow), PhD (Vernadsky)	Laboratory Analyst in LA-ICP-MS	100
Mrs Michele Chapple-Smith, GDipAppSci (UTAS)	Lapidary Technician	80
Mr Alex Cuison, BSCE (SLU, Philippines)	Lapidary Manager	100
Ms Fanghua Dai, MSc (CUGW)	Laboratory Analyst	80
Ms Karen Huizing	Administrative Officer	100
Ms Elena Lounejeva, MSc (UNAM)	Laboratory Analyst	60
Mrs Michelle Makoundi, B Acc (U Marien Ngouabi)	Technical Officer	100
Ms Caroline Mordaunt, BA Hons (King's College London)	Editor and Administrative Officer	70
Mr Maxwell Morissette, BSc (McGill)	Laboratory Analyst in LA-ICP-MS	100
Mrs Claire Newland, BBus (Acc) (RMIT)	Administrative Support Officer	70
Dr Jeffrey Oalmann, BSc (Kansas State), MSc (Texas Tech), PhD (KU)	Laboratory Analyst in LA-ICP-MS	100
Dr Paul Olin, BA (SOU), MSc, PhD (WSU)	Acting Leader – CODES Analytical Laboratories	100
Ms Helen Scott, BSc Hons (UTAS), BEd (QUT)	Project Administration Manager	100
Ms Isabella von Lichtan, BSc Hons (UTAS)	Curator	25

*Research percentage

ADVISORY BOARD

NAME	
Chair: Paul Heithersay	Department for Energy and Mining, South Australia
Deputy Chair: Paul Agnew	Rio Tinto Exploration
Terry Bailey	College of Sciences and Engineering, UTAS
Rufus Black	Unviersity of Tasmania
Alex Brown	Mt Isa Mines (Glencore)
Rebecca Carey	Earth Sciences and CODES, UTAS
Angela Castles	College of Sciences and Engineering, UTAS
David Cooke	CODES, UTAS
Jacqui Coombes	Amira Global
Leonid Danyushevsky	CODES, UTAS
Mark Doyle	AngloGold Ashanti
Simon Ellingsen	School of Natural Sciences, UTAS
Alex Farrar	First Quantum Minerals
Anthony Harris	Newcrest Mining
Ned Howard	Evolution Mining
Jonathon Hoye	CMOC – Northparkes
Andrew Jenkins	AngloGold Ashanti
Anthony Koutoulis	Research, UTAS
Neil Macalalad	Anglo American
Andrew McNeill	Mineral Resources Tasmania
Sebastien Meffre	Earth Sciences and CODES, UTAS
Kevin Robinson	Mineral Resources Tasmania
Sam Spinks	Teck
Olga Verezub	Amira Global
Noel White	Independent
Chris Wijns	First Quantum Minerals

EXECUTIVE COMMITTEE

NAME	
Chair: David Cooke	Director, CODES
vacant position	Applied Research
Rebecca Carey	Fundamental Research
vacant position	Deputy Director, CODES
Sebastien Meffre	Head, Discipline of Earth Sciences
Helen Scott	Administration
Robert Scott	Education

Program one: Ore deposits and mineral exploration

OBJECTIVE

This program aims to use newly developed geological, geochemical, mineral chemical and geophysical features of ore-forming systems and terrains in order to devise better means of discovering mineral resources at surface and under cover.

Introduction

Program 1: Ore deposits and mineral exploration provides industry-focussed process-based models for the formation of base and precious metal ore deposits. It also seeks to develop innovative new tools for determining the most prospective regions for minerals exploration (fertility), and for targeting of buried ore deposits (vectoring). In 2022, Program 1 contained five key projects (as well as other smaller projects), which reflect the range of expertise and level of diversity in the field of hard-rock geology at CODES.

Highlights

CODES Program 1 has continued to produce quality applied research across a number of multi-year projects that have provided significant outputs to both the academic and professional community, both locally and around the world.

The multi-year project on the Loei and Troung Son fold belts in SE Asia has produced or partnered in a series of publications in 2022, including co-editing of the *Journal of Asian Earth Sciences* (JAES) special issue on Emerging Trends in Earth Science for Sustainable Futures in the SE Asia region by Adjunct Professor Khin Zaw and Dr Charles Makoundi; PhD candidate Peerapong Sritangsirikul's paper in the *Journal of Exploration Geochemistry* on geochemical characteristics and controls that distinguish fertile magmas associated with mineral deposits in these orogenic belts; and a paper co-authored by Dr Charles Makoundi on U-Pb dating, lead isotopes and trace element composition of pyrite hosted in black shale and magmatic rocks in Malaysia, published in the journal *Minerals*.

Another major Program 1 highlight for 2022 was the successful commencement of Amira Global's P1249 project 'Exploring, characterising, and optimising exploring complex orebodies – Upscaling orebody knowledge to add value across the mining value chain'.

> CODES Program 1 has continued to produce quality applied research across a number of multi-year projects.

The new Amira P1249 project, which commenced in February 2022, involved fieldwork in Central Asia.

This new five-year project seeks to build upon the significant contributions made by the succession of Amira Footprints research projects over the past 18 years whilst also forging new ground in the fields of data analytics and classification. Two PhD theses from prior Amira Footprints research projects were also submitted in 2022: Jennifer Thompson's thesis on textural, geochemical, and fluorescence variations of calcite in porphyry Cu-Au deposits and Javier Merrill's thesis on geological domaining and mineral textural clustering.

The Epithermal and Porphyry research projects also saw postgraduate research project completions or commencements, including the acceptance of Rob Davidson's PhD thesis on the San Sebastian intermediate sulfidation epithermal deposit in Mexico, and the commencements of Victor Torres' PhD project on the Soledad tourmaline breccia complex in central Peru and David Portocarrero's Master of Economic Geology project on the Antakori deposit in northern Peru.

Also in 2022, University Adjunct Professor Khin Zaw was awarded the CoSE Award for Outstanding Contribution by Adjunct, Clinical, University Associate or Professional Fellow Title Holder.

Adjunct Professor Khin Zaw after having received his CoSE award is pictured here with (left) Professor Simon Ellingsen and Professor Sebastien Meffre.

The program team

LEADER MIKE BAKER
DEPUTY LEADER LEJUN ZHANG

TEAM MEMBERS:

Ron Berry, Stuart Bull, Jonathan Cloutier, David Cooke, Matthew Cracknell, Angela Escolme, Bruce Gemmell, Ross Large, Charles Makoundi, Adi Maryono, Sebastien Meffre, Michael Roach, Robert Scott, David Selley, Jeff Steadman, Francisco Testa, Khin Zaw

PHD STUDENTS:

Billy Beas, Peter Berger, Axel Cima, Takeshy Coaquira, Stephen Cooke, Rob Davidson, Alex Farrar, Jacob Heathcote, Rhiannon Jones, Joseph Knight, Javier Merrill, Xin Ni Seow, Jaime Osorio, Emily Smyk, Markus Staubmann, Peerapong Sritangsirikul, Yi Sun, Jennifer Thompson, Victor Torres, Tristan Wells, Zebedee Zivkovic

MASTERS STUDENTS:

Lieth de Selincourt, Patrick Hamilton (Lakehead), Brendan Hardwick, Kyle Hughes, Ashleigh Job, Ben Johnson, Mitch Marcelissen (Lakehead), David Portocarrero

HONOURS STUDENTS:

Felix Dobbin (UTAS), Reinaldo Gonzalez, Francisco Torres (both U Austral de Chile)

COLLABORATORS:

ANGLO AMERICAN
David Braxton, Iain Dalrymple

ANGLOGOLD ASHANTI
Ben Hames, Andrew Jenkins, Luke Swift

AKITA UNIVERSITY, JAPAN
June J. Born, Patthana Bounliyong, Akira Imai, Yasushi Watanabe

BHP
Natalie Caciagli, Simon Gatehouse

BOLIDEN
David Drejing-Carroll, Tobias Hermansson, Sean Johnson

BRITISH GEOLOGICAL SURVEY, UK
Mike Crow

CHAKANA COPPER CORP
David Kelley

CHENGDU RESEARCH CENTRE, CHINA GEOLOGICAL SURVEY, CHINA
Linnan Guo, Meifeng Shi

CHIANG MAI UNIVERSITY, THAILAND
Phisit Limtrakun

CHULALONGKORN UNIVERSITY, THAILAND
Arkar Moe Myint, Pitsanupong Kanjanapayont, Abhisit Salam

CMOC/NORTHPARKES
Jon Hoye

CODELCO
Martin Kock, Sergio Pichott, Carolina Rodriguez

CONSULTANT
Noel White

DEPARTMENT OF MINERAL RESOURCES, THAILAND
Punya Charusiri

DGO GOLD
Eduard Eshuys

DIRECTORATE OF GEOLOGICAL SURVEY AND EXPLORATION, MYANMAR
Zaw Htet

EVOLUTION MINING
Ned Howard

FIRST QUANTUM MINERALS
David Arribasplata, James Banyard, Federico Cernuschi, Tim Ireland

FORTESCUE METALS GROUP
Cam Quinn, Dana Olafson

GEOLOGICAL SURVEY OF SOUTH AUSTRALIA
Adrian Fabris, Anthony Reid

GEOSCIENCE AUSTRALIA
Karol Czarnota, Michael Doublier, Arianne Ford, David Huston, Anthony Schofield

GLENCORE/MT ISA MINES
Ben Andrew, Alex Brown

GUANGZHOU INSTITUTE OF GEOCHEMISTRY, CHINESE ACADEMY OF SCIENCES, CHINA
Chao Wu

HANOI UNIVERSITY OF MINING AND GEOLOGY, VIETNAM
Hai Thanh Tran

HECLA MINING
Kurt Allen, Stephen Redak

INSTITUTE OF TECHNOLOGY OF CAMBODIA
Seang Sirisokha

LAKEHEAD UNIVERSITY, CANADA
Peter Hollings

MAHASARAKHAM UNIVERSITY, THAILAND
Clive Burrett

MAHIDOL UNIVERSITY, THAILAND
Pyrinya Putthapiban

MAWLAMYINE UNIVERSITY, MYANMAR
Zin Mar Oo

MDRU, CANADA
Shaun Barker

MINERAL MAPPING
Scott Halley

MINERAL RESOURCES TASMANIA
Clive Calver, Grace Cumming, John Everard, Andrew McNeill

MONASH UNIVERSITY
Laurent Aillères, Ray Cas

MYINGYAN UNIVERSITY, MYANMAR
Htet Sandar Aung

NEWCREST MINING
Rizal Fraval, Karyn Gardner, Anthony Harris, Hana Lee

NEWMONT
Jeff Bigelow, Simon Marshall

NO.2 MINING ENTERPRISE, MINISTRY OF NATURAL RESOURCES AND ENVIRONMENTAL CONSERVATION, MYANMAR
Kyaw Thu Htun

REGULUS RESOURCES
Kevin Heather

RIO TINTO
Paul Agnew, Debora Araujo, Adam Pacey, Mike Whitbread

SANDFIRE RESOURCES
Kristyn Adamczyk, Joel Kitto, Paull Parker, Peter Willems, Jerry Zieg

SOUTH32
Renato Bobis

UNIVERSIDAD AUSTRAL DE CHILE, CHILE
José Piquer

UNIVERSITI BRUNEI DARRUSALAM, BRUNEI
Chun-Kit Lai

UNIVERSITI KEBANGSAAN, MALAYSIA
Mohd Basril Iswadi Bin Basori

UNIVERSITY OF MELBOURNE
Roland Maas

UNIVERSITI SAINS MALAYSIA, PENANG, MALAYSIA
Zakaria Endut

US GEOLOGICAL SURVEY, USA
Jay Thompson

Projects

Tectonic evolution, magmatic processes, and mineral deposits of the Loei and Troung Son fold belts in SE Asia

Amira P1249: Exploring, characterising, and optimising complex orebodies – upscaling orebody knowledge to add value across the mining value chain

Epithermal research

Porphyry research

National mineral potential mapping

Project summaries

TECTONIC EVOLUTION, MAGMATIC PROCESSES AND MINERAL DEPOSITS OF THE LOEI AND TROUNG SON FOLD BELTS IN SE ASIA

Leaders: Khin Zaw, Sebastien Meffre

Team members: David Cooke, Charles Makoundi, Lejun Zhang

Student: Peerapong Sritangsirikul

Collaborators: Arkar Moe Myint, Mohd Basril Iswadi Bin Basori, Patthana Bounliyong, June J. Born, Clive Burrett, Punya Charusiri, Mike Crow, Zakaria Endut, Linnan Guo, Hai Thanh Tran, Htet Sandar Aung, Akira Imai, Kyaw Thu Htun, Chun-Kit Lai, Pitsanupong Kanjanapayont, Phisit Limtrakun, Pyrinya Putthapiban, Abhisit Salam, Sokha Seang, Meifeng Shi, Yasushi Watanabe, Zaw Htet, Zin Mar Oo

Significant achievements and advancements have been made in the study of the tectonic evolution, magmatic processes, and mineral deposits of the Loei and Truong Son fold belts in SE Asia. These fold belts host abundant mineral resources such as copper, gold, silver, base metals, tin and tungsten, found in various deposit styles including Cu-Au porphyry-skarn, epithermal Au, Sn-W veins and orogenic Au. This research project aims to investigate the tectonic history, metallogenic settings and timing of mineralisation of the various deposit types within these fold belts. The study employs zircon geochronology and trace elements, whole-rock geochemistry, and Hf isotopes to evaluate the fertility of magmas and distinguish the geochemical features of mineralised and barren intrusions. Specifically, the project will identify which intrusions are likely to be fertile based on their oxidised and hydrous magmas. In his PhD research, Peerapong Sritangsirikul investigated the geochemical characteristics and controls that distinguish fertile magmas associated with mineral deposits in these belts funded by Rio Tinto, providing insights into a complex ore genesis. The outcome of his research was presented online at the GSA Earth Sciences Student Symposium (GESSS) in November 2022 and a paper is submitted to the *Journal of Exploration Geochemistry.*

This project is interconnected with various other projects in the region. One of these is the 'Geochronology of ore deposits in Cambodia,' headed by Dr Seang (Sokha) Sirisokha from the

CODES PhD student Xin Ni Seow using an ARCoptix FT-NIR instrument to analyse rock as part of her PhD research within the Amira P1249 project.

Institute of Technology in Phnom Penh, Cambodia. This project is supported by the Japan International Cooperation Agency (JICA). Dr Seang recently completed U-Pb zircon geochronology studies on mineralised porphyry intrusions of the Phnom Sro Ngam and Halo Cu-Au Prospects in southwestern and northeastern Cambodia along the Loei Fold Belt. A paper is currently in preparation on the implications for the tectonic evolution and metallogenesis of the Loei Fold Belt.

The other projects are the 'Tectonic evolution and mineralization along the Loei Belt,' led by Professor Punya Charusiri and funded by Chulalongkorn University. Dr Charles Makoundi (CODES) and Dr Zakaria Endut (Universiti Sains Malaysia) also lead another project titled 'Pyrite geochemistry, isotopes, ore fluids and U-Pb geochronology of orogenic gold deposits in Central Malaysia'. This project is supported by the Malaysian Government and has recently published a paper on 'U-Pb dating, lead isotopes, and trace element composition of pyrite hosted in black shale and magmatic rocks, Malaysia: Implications for orogenic gold mineralization and exploration' in the journal *Minerals*.

Our collaboration extends to the Chengdu Research Centre of China Geological Survey, China, where we work together on the timing, geodynamics and mineral deposit types of the Loei and Truong Son belts. Several joint papers have been published, such as Shi *et al.'s* 'Geochronology and petrogenesis of Carboniferous and Triassic volcanic rocks in NW Laos: Implications for the tectonic evolution of the Loei Fold Belt,' in the recent *Journal of Asian Earth Sciences* (JAES) special issue on Emerging Trends in Earth Science for Sustainable Futures in the SE Asia region. This special issue was edited by Professor Khin Zaw and Dr Charles Makoundi from CODES, along with Dr Mohd Basril Iswadi Basori, a former CODES PhD student, and his group from the National University of Malaysia (UKM).

The SE Asia region holds great potential for uncovering world-class deposits of porphyry copper-gold-molybdenum as well as granite-related lithium and other battery minerals. However, the lack of comprehensive information and regional-scale studies on critical minerals and metal systems presents a challenge for the region's green energy and low-carbon development and modern technologies such as communication, computing and transport. Further collaborative research works are in progress to understand the factors that control the tectonic-magmatic history, ore formation, exploration strategy and environmentally friendly ore extraction necessary for the transition from fossil fuels to clean energy in the future.

AMIRA P1249: EXPLORING, CHARACTERISING, AND OPTIMISING COMPLEX OREBODIES – UPSCALING OREBODY KNOWLEDGE TO ADD VALUE ACROSS THE MINING VALUE CHAIN

Leader: David Cooke

Team members: Mike Baker, Ivan Belousov, Matthew Cracknell, Wei Hong, Julie Hunt, Clare Miller, Thomas Rodemann (CSL), Lejun Zhang

Students: Billy Beas, Axel Cima, Takeshy Coaquira, Stephen Cooke, Rhiannon Jones, Javier Merrill, Jaime Osorio, Xin Ni Seow, Emily Smyk, Markus Staubmann, Yi Sun, Reinaldo Gonzalez (U Austral), Patrick Hamilton (Lakehead U), Mitch Marcelissen (Lakehead U), Ivania Rojas (U Austral), Francisco Torres (U Austral), Jenson Uribe (U Austral)

Collaborators: Paul Agnew, Laurent Aillères, Ben Andrew, Debora Araujo, Jeff Bigelow, Renato Bobis, David Braxton, Alex Brown, Natalie Caciagli, Ferderico Cernuschi, Iain Dalrymple, David Drejing-Carroll, Rizal Fraval, Simon Gatehouse, Scott Halley, Ben Hames, Anthony Harris, Tobias Hermansson, Peter Hollings, Ned Howard, Jon Hoye, Tim Ireland, Andrew Jenkins, Sean Johnson, Martin Kock, Hana Lee, Simon Marshall, Dana Olafson, Adam Pacey, Paull Parker, Sergio Pichott, José Piquer, Cam Quinn, Carolina Rodriguez, Luke Swift, Mike Whitbread, Noel White, Peter Willems

Following on from the success of the Amira P1202 project, which concluded in mid-2022, Amira Global's P1249 'Exploring, characterising, and optimising exploring complex orebodies – Upscaling orebody knowledge to add value across the mining value chain' project commenced in February 2022. This new five-year project will provide its

sponsors with new tools for recognising proximity to high-grade ore, and new tools, methods and workflows for translating and upscaling mineralogical, geochemical and hyperspectral data into quantitative mineralogy for complex orebodies of copper, gold, critical and other metals. The project team will aim to optimise orebody knowledge and provide the information required for mineralogical domaining and resource definition at the mine scale. P1249 will focus on transition zones – the alteration domains that extend from the orebody into the surrounding unmineralised rocks. Although the primary focus of the project will be on porphyry, epithermal, carbonate replacement and skarn deposits, the project is also applicable to Mt Isa-style Cu, IOCG, orogenic Au and other deposit styles.

CODES PhD student Jaime Osorio and an FQM geologist sampling lithocap outcrop, Ventana prospect, Argentina.

By delivering new and more effective methods and workflows for mineralogical characterisation in the transition zone, P1249 will deliver better exploration models, facilitate informed decision making at all stages of the mining value chain, and identify value opportunities in waste streams that may help reduce waste volumes, thereby providing new orebody knowledge essential for optimising ore extraction and recovery from complex orebodies. The research team will provide new and refined geochemical and geological tools for fertility assessments to establish whether there is a significant mineral resource nearby (i.e., how large is the resource?) and to ensure that deposits are discovered more quickly and at less cost by reducing the amount of drilling required for discovery (vectoring – how far, how deep and in what direction?). These tools will be designed to ensure cost-effective exploration through implementation early in an exploration program, allowing opportunities to be recognised from near-miss drilling, and to allow the presence, location, and potential size of porphyry, epithermal, skarn, carbonate-replacement and other resources to be determined rapidly.

Amira P1249 is being conducted by a large team of researchers including 11 UTAS staff, six collaborators and 17 students (PhD, Masters and Honours) from four academic institutions (UTAS, Monash University, Lakehead University and Universidad Austral de Chile). Several sub-projects within P1249 involve postgraduate students. Takeshy Coaquira, Rhiannon Jones, Javier Merrill, Jaime Osorio, Xin Ni Seow, Emily Smyk and Yi Sun are continuing their PhD studies on the Resolution porphyry Cu-Mo deposit (USA), the Northparkes E26 porphyry Cu-Au deposit (New South Wales), geological domaining, the Rincones de Araya prospect (Argentina) and Valeriano porphyry Cu-Au deposit (Chile), alunite and APS mineral chemistry, the Christmas porphyry Cu-Mo deposit (USA) and the Lepanto district (Philippines), respectively. Patrick Hamilton (Lakehead University) is continuing his MSc study of the Pemberton Hills deposit lithocap (Canada). Mitch Marcelissen, also at Lakehead University, is continuing his MSc project on magma fertility in the Sunda-Banda Arc, Indonesia. The

CODES PhD student Jaime Osorio's project includes research into the Valeriano deposit, Chile. This photo was taken during fieldwork carried out in 2022.

Program 1 leader Dr Mike Baker, seen here at the Mount Isa Mines core shed during 2022 fieldwork.

Honours projects of Reinaldo Gonzalez (Santa Marta lithocap, Chile) and Francisco Torres (Tibetano prospect, Chile) are also nearing completion at Universidad Austral de Chile. Several new P1249 PhD sub-projects have also commenced in 2022, including Billy Beas (halogen chemistry in the Northparkes E44 deposit, New South Wales), Axel Cima (influence of mineral micro-inclusions on porphyry prospectivity), Stephen Cooke (computer-based modelling of geochemical data), and Markus Staubmann (Cowal GRE46 gold deposit, New South Wales). Also, in early 2022 Jennifer Thompson submitted her PhD thesis on textural, geochemical, and fluorescence variations of calcite in porphyry Cu-Au deposits.

The total cost of the Amira P1249 project over the five years will be AU$16.1 million including research organisation and in-kind contributions of AU$6.8 million and Amira Global development and oversight fees. The total industry and government investment required to fully fund the project is approximately AU$9.31 million over five years. As of December 2022, 15 companies sponsor P1249, including Anglo American, AngloGold Ashanti, BHP, Boliden, CMOC-Northparkes, CODELCO, Evolution Mining, First Quantum Minerals, Fortescue Metals Group, Glencore (Mt Isa Mines), Newcrest, Newmont, Rio Tinto, Sandfire Resources, and South32.

EPITHERMAL RESEARCH

Leaders: Bruce Gemmell, David Cooke

Student: Rob Davidson

Collaborators: Kurt Allen, Stephen Redak

Rob Davidson PhD thesis, which passed examination with minor corrections in 2022, was on the San Sebastian intermediate sulfidation, Ag-Au-Cu-Pb-Zn epithermal deposit, Saladillo district, Durango, Mexico. Financial and logistical support was provided by Hecla Mining. The Saladillo district contains two known Ag-Au +/- Pb-Zn epithermal deposits (San Sebastian and Don Sergio), a historic mercury mine (La Roca) and a historic antimony mine (El Caballo). Since 2001, the San Sebastian mine has produced 23.7 Moz of Ag and 0.25 Moz of Au and sits within the Mexican Silver Belt. San Sebastian is hosted within mudstones and graywackes, as opposed to more common volcanic rocks. The San Sebastian deposit consists of parallel veins (Professor, Francine and Middle) offset by post-mineral movement along the San Ricardo fault.

A coherent, deposit-scale, geologic model, based upon 3D interpretations of major structures, lithology, alteration and veins, was developed. It allows for a broad understanding of how the main geological components of the deposit interact and influence one another, which in turn reveals key observations into the genesis of the deposit.

Characteristics of the district geology, vein geology, mineralogy, hydrothermal alteration and metal zoning at San Sebastian were combined to develop exploration criteria, which can be used to generate new targets in the San Sebastian district, as well as in other intermediate sulfidation epithermal districts hosted in sedimentary rocks.

PORPHYRY RESEARCH

Leader: David Cooke

Team members: Michael Baker, Matt Cracknell, Sebastien Meffre, Lejun Zhang

Students: Lieth de Selincourt, David Portacarrero, Victor Torres

Collaborators: Kevin Heather, David Kelley, Joel Kitto

In mid-2022, Victor Torres commenced his PhD study of Cu-Au mineralisation of the Soledad tourmaline breccia complex, central Peru, supported by Chakana Copper Corp. This is an integrated geological, geochemical and geometallurgical investigation designed to provide comprehensive orebody knowledge of the Soledad breccia pipes, including their geological setting, age, alteration and mineralisation features, controls on mineralisation and mineral processing characteristics. Victor is well advanced in the first year of his PhD study and has already made significant impacts with regards to exploration and mine planning. Results of his PhD research will be presented at the ProExplo and SEG conferences in 2023.

Multi-stage intrusion, brecciation and mineralization at the Antakori Cu-Au-Ag project, northern Peru Cu-Au-Mo

Leaders: David Cooke, Lejun Zhang

Student: David Portocarrero

Collaborator: Kevin Heather

David Portocarrero initiated a Master of Economic Geology research project in 2022 that is investigating the

characteristics and origins of epithermal, porphyry and skarn mineralisation in the Antakori Cu-Au deposit, northern Peru. Antakori is a complex magmatic-hydrothermal system, with volcanic-hosted high sulfidation Cu-Au ores hosted in Tertiary volcanics, which unconformably overlie deformed sedimentary basement rocks (quartz sandstones and limestones) that host porphyry Cu-Au and skarn mineralisation. Intermediate sulfidation epithermal veins also cut the district. David is undertaking a comprehensive geological and geochronological study of the district, supported by Regulus Resources.

Cu-Au-Mo porphyry mineralisation in the Temora district, New South Wales, Australia

Leaders: David Cooke, Sebastien Meffre, Michael Baker, Matthew Cracknell

Student: Lieth de Selincourt

Collaborators: Kristyn Adamczyk, Joel Kitto

Lieth de Selincourt completed his analytical work for his Master of Economic Geology thesis into the porphyry Cu-Au prospects of the Temora district in the Junee-Narromine belt of the Ordovician Macquarie Arc, Central West NSW, supported by Sandfire Resources. Lieth presented his research results to the NSW exploration community at the Mines and Wines conference in Orange, NSW, in May 2022, providing new insights into the magmatic and hydrothermal evolution of porphyry-style mineralisation in the Temora region.

Adjunct Professor Khin Zaw (right) and Dr Charles Makoundi holding the two volumes of their Journal of Asian Earth Sciences *special issue on 'Emerging trends in earth science for sustainable futures in the SE Asia region', which was published in October 2022.*

NATIONAL MINERAL POTENTIAL MAPPING

Leader: Jonathan Cloutier

Collaborators: Karol Czarnota, Michael Doublier, Arianne Ford, David Huston, Anthony Schofield

Dr Jonathan Cloutier began a new collaborative project in 2021 with Geoscience Australia focussed on national-scale mineral potential assessments. The three-year project involves the creation of Cu and Zn-Pb sediment-hosted and IOCG mineral potential assessments of Australia using a mineral systems approach to support the discovery of new resources needed for the transition to net zero. It involves identifying, understanding and utilising relationships between the spatial and temporal distributions of mineral deposits and diverse geoscientific datasets.

The first two years of the project focussed on assessing the mineral potential of six sediment-hosted systems. The systems assessed were 1) sediment-hosted stratiform Cu; 2) Mount Isa Cu; 3) clastic-dominated siliciclastic-carbonate (McArthur-type); 4) clastic-dominated siliciclastic-mafic (Selwyn-type); 5) Mississippi Valley-type; and 6) Irish-type. The remainder of the project will focus on IOCG mineral systems. The maps and extended abstract will be available on the Geoscience Australia portal at https://portal.ga.gov.au/.

LOOKING FORWARD

The Amira Global P1249 project has only just commenced and will provide longer-term contributions to the excellent applied research into magmatic-hydrothermal systems by the research team for the next four years. Over the coming 12 to 18 months, several new postgraduate student sub-projects at both PhD and Masters levels will also be added to this project, continuing to build upon the quality research capacity at CODES and our collaborator institutions.

As in previous years, student projects continue to be the lifeblood of Program 1, as they generate high-quality research outcomes including theses, peer-reviewed publications, and models for the development of mineralised systems in a diverse range of environments. Program 1 postgraduate research projects continuing into 2023 include ten CODES PhD sub-projects within Amira P1249 (students: Billy Beas, Axel Cima, Takeshy Coaquira, Stephen Cooke, Rhiannon Jones, Jaime Osorio, Xin Ni Seow, Emily Smyk, Markus Staubmann and Yi Sun); Victor Torres' PhD project on the Soledad tourmaline breccia complex in central Peru; Peerapong Sritangsirikul's PhD project on the geochemistry of fertile magmas in SE Asia; Lieth de Selincourt's MSc project on porphyry Cu-Au prospects in the Temora district of central NSW; and David Portocarrero's MSc project on the Antakori Cu-Au deposit in northern Peru.

Program two: Geometallurgy, geoenvironment and mining

▶ OBJECTIVES

To facilitate sustainable mining, mineral processing and waste management practices in the minerals industry. Our goals are to minimise the impacts and maximise the benefits of metallic mining in diverse environments, at all stages of the production chain, to assist with remediation of legacy issues and to develop innovative solutions for production of commodities from mining waste streams.

Introduction

Program 2: Geometallurgy, geoenvironment and mining addresses some of the challenges the minerals industry faces in the accurate prediction of processing performance and variability in performance due to the limited number of samples that can be tested for metallurgical parameters. Significant technical and operational risks exist where orebodies are poorly characterised. Work within geometallurgy at CODES/UTAS seeks to efficiently integrate and use tools that help characterise geological parameters, particularly mineralogical and geochemical attributes, to undertake deposit-wide characterisation in order to maximise orebody knowledge.

Through a holistic approach, geometallurgy activities identify attributes that contribute to the realised value of a resource, and enable ore variability to be factored into the flowsheets, infrastructure design, and the production and quality forecasts over the life-of-mine. This includes variability in traditional attributes, such as grade, as well as less traditional factors, such as hardness (crushability, grindability), mineral species and abundance, mineral liberation, metallurgical recovery, concentration of deleterious elements, acid generating potential, neutralising potential and smelter enabling characteristics.

Over the past ~15 years, CODES has established itself as a national centre for geometallurgical research, spurred on and supported by an increased interest in the discipline by the minerals industry. This increase in industry involvement led to the large Amira P843 and P843A (GeM^{III}) projects collaboratively run with the JKMRC, University of Queensland, from 2005 to 2013. In these projects, an array of geometallurgical methods and protocols were developed in the areas of mineralogy, comminution, heap leaching and flotation – and were tested

Masters student Karla Morales pictured with CODES Director Professor David Cooke at the SNS Student Recognition Evening in September 2022. Karla completed her Masters thesis on 'Geological predictors for preconcentration' in February 2022.

Dan Fisher pictured at the Scotia legacy mine, northeast Tasmania, thinking about the mammoth task before him as he embarks on his Honours thesis, which examined water quality.

on case study sites culminating in the publication of a series of technical reports released to the Amira sponsors.

The outcomes of the GeM[III] project provided a solid foundation for further research, particularly in relation to understanding mineralogical and textural controls on processing performance. Further research in this field was carried out in the Amira P1202 Module 4 project and as part of CRC ORE's (Cooperative Research Centre for Optimising Resource Extraction) remit, of which CODES was an Essential Research Participant. Both of these projects were completed in 2021.

In 2022 geometallurgy-focussed research continued as part of the Amira P1249 project which commenced in January 2022 as:

- a CRC ORE continuation project based at CODES, and
- a CSIRO Futures project.

Late in 2022, with the beginning of the Regional Research Collaboration (RRC), a new geoenvironment postdoctoral fellow joined CODES, with a second Program 2 postdoc and three new PhD students expected to join in 2023.

Highlights

- Dr Owen Missen joined CODES in November and commenced work in geoenvironment and mineralogy as part of the RRC project (see the RRC project section on page 64 for more details).
- Karla Morales submitted her Masters thesis, titled 'Geological predictors for preconcentration', in February 2022. This project sits within the CRC ORE project P1-006.
- Completion of Honours thesis by Eva Knight, titled 'The geochemistry and mineralogy of estuarine sediments: Implications for Rice Grass removal in the Rubicon Estuary', supported by Cradle Coast NRM, and sitting within the geoenvironment aspect of Program 2.
- Javier Merrill submitted his PhD thesis, titled 'Quantification of mineral textures for geometallurgical predictive modelling' in November.
- Angela Rodrigues (Monash) was awarded her PhD in 2022. Her thesis title was 'Machine-supported mineralogical interpretations from hyperspectral and geochemical datasets' and Drs Matthew Cracknell and Angela Escolme were advisors.
- The capacity of the CODES Environmental Geology labs was expanded and the facilities upgraded to include a new laboratory incorporating a glovebox for work to be conducted under nitrogen, and new bench and storage space.
- Daniel Fisher substantially completed his MSIIP-supported Honours thesis titled 'Lithological, geochemical and mineralogical drivers of water quality at the legacy Scotia Mine, northeast Tasmania', and it will be submitted early in 2023.
- Annah Moyo's PhD entitled 'Controlling acid and metalliferous drainage generated by legacy mine wastes in Tasmania using industrial wastes' was submitted in September.

PhD student Markus Staubmann at the Cowal gold mine in New South Wales; Markus's PhD research will aid opportunity recognition and decision-making through all stages of the mining value chain.

Technology transfer

- Morales *et al.* published an extended abstract: 'Geological controls for pre-concentration in an intrusive-related gold deposit' as part of the SGA 2022 conference.
- A final project report was delivered to CRC ORE for the extension project, titled 'Geological predictors for pre-concentration: Library of mineralization styles and upgrade potential for screening'. The library can be viewed at the following link: https://www.ausgeol.org/assets/media/uploads/tours/codes_crcore_p1_006/index.html

Conferences

In 2022 research outcomes were presented by staff and students at several conferences and geological society meetings, including:

- CODES Masters student Karla Morales gave an oral presentation entitled 'Geological controls for pre-concentration in an intrusive-related gold deposit' at the SGA Conference in March.
- Dr Hunt gave an oral presentation at the SGA Conference, titled 'Geological characterisation to identify upgrade potential and enhance mining efficiency'.

Honours student Eva Knight carrying out fieldwork for her project entitled 'The geochemistry and mineralogy of estuarine sediments: Implications for Rice Grass removal in the Rubicon Estuary', supported by Cradle Coast NRM, and sitting within the geoenvironment aspect of Program 2.

- Dr Hunt gave an invited oral presentation at the Tasmania Geoscience Forum, titled 'Environmentally sustainable production of critical metals: a new Tasmania-focussed research project at CODES/UTAS' introducing the new RRC project.
- Abstracts highlighting the multidisciplinary research 'Multidisciplinary characterisation of groundwater flow and contaminant transport in legacy mine wastes' were accepted for oral presentations at ICARD and Goldschmidt, and were delivered by Dr Miller in early 2022.

The program team

LEADER JULIE HUNT
ACTING DEPUTY LEADER OWEN MISSEN

TEAM MEMBERS:

Ron Berry, David Cooke, Jonathan Cloutier, Matthew Cracknell, Angela Escolme (on extended maternity leave), Sebastien Meffre, Clare Miller, Paul Olin, Michael Roach

PHD STUDENTS:

Christopher Allen, Takeshy Coaquira, Angela Costa, Rhiannon Jones, Javier Merrill, Annah Moyo, Sibele Nascimento, Angela Rodrigues (Monash), Markus Staubmann, Yi Sun

MASTERS STUDENTS:

Lucy Jones, Karla Morales

HONOURS STUDENTS:

Daniel Fisher, Eva Knight

COLLABORATORS:

ALS GLOBAL
Shengli Zhao

ANGLO AMERICAN
Dave Braxton, Iain Dalrymple, Luke Keeney

ANGLOGOLD ASHANTI
Vaughan Chamberlain

BHP
Natalie Caciagli

BLUESTONE MINES TASMANIA
Kate Cheesman, Louise Cherrie, Brian Dalton, Derek Sutton, Ben Wraith

CENTRAL SCIENCE LABORATORY (UTAS)
Sandrin Feig, Karsten Goemann

CONSULTANT
Patrick Walters

COPPER MINES OF TASMANIA
Geoff Cordery

CORESCAN
Neil Goodey

CSIRO
Vladimir Jokovic, Carsten Laukamp, Paul Revell

DIAMONDBACKS PTY LTD
Greg Wilkie

EVOLUTION MINING
Ned Howard

MINERAL RESOURCES TASMANIA
Ralph Bottrill, David Green, Andrew McNeill, Jake Moltzen, Carol Steyn, Lia Unwin

NEWCREST MINING
Anthony Harris, Mary Harris

OKANE RESOURCES
Mike Okane

RIO TINTO
Paul Agnew, Debora Araujo, Adam Pacey, Michael Whitbread

'Fieldwork mornings, Rubicon estuary, northern Tasmania': Clare Miller entered this shot in the 2022 CODES Photo Competition.

Projects

Amira P1249: Exploring, characterising, and optimising complex orebodies – upscaling orebody knowledge to add value across the mining value chain

Geological controls on grade-by-size fractionation (CRC ORE P1-006)

CSIRO Futures project: A methodology for measuring and modelling gangue liberation using geological analysis and particle grade distributions

RRC project: Environmentally sustainable production of critical metals: Element 2 Pathways to production

Getting stuck into fieldwork for Eva Knight's Honours; (L-R): Iona Fleet and Nick Jamson (both from Cradle Coast NRM), Eva Knight and Dr Clare Miller.

Project summaries

AMIRA P1249: EXPLORING, CHARACTERISING, AND OPTIMISING COMPLEX OREBODIES – UPSCALING OREBODY KNOWLEDGE TO ADD VALUE ACROSS THE MINING VALUE CHAIN

(See Program 1 for full details about this project including all collaborators).

Student: Markus Staubmann

The new Amira project P1249 includes geometallurgical and geoenvironmental research within Program 2.

In 2022 Markus Staubmann joined CODES and the Amira P1249 project to pursue a PhD project entitled 'Integrated ore deposit knowledge: Optimising mineralogical characterisation through the mining value chain' which will develop workflows, methods and tools for mineralogical characterisation that allow effective upscaling from the microscopic to the deposit-scale, and will aid opportunity recognition and decision-making through all stages of the mining value chain.

GEOLOGICAL CONTROLS ON GRADE-BY-SIZE FRACTIONATION (CRC ORE P1-006)

Leader: Julie Hunt

Team members: Ron Berry, Matthew Cracknell, Michael Roach

Student: Karla Morales

Collaborators: Luke Keeney, Paul Revell, Patrick Walters, Greg Wilkie

Although the P1-006 project completed deliverables to CRC ORE in June 2021 it continued until June 2022 in order to deliver additional outcomes. Masters student Karla Morales submitted her thesis titled 'Geological predictors for preconcentration' in February 2022. In addition, an online 'Library of mineralisation styles and upgrade potential via screening' was completed and is available at: https://www.ausgeol.org/assets/media/uploads/tours/codes_crcore_p1_006/index.html. Summaries of the work were presented at the 16th SGA Conference in 2022: 'Geological characterisation to identify upgrade potential and enhance mining efficiency' and 'Geological controls for preconcentration in an intrusive related gold deposit'.

CSIRO FUTURES PROJECT: A METHODOLOGY FOR MEASURING AND MODELLING GANGUE LIBERATION USING GEOLOGICAL ANALYSIS AND PARTICLE GRADE DISTRIBUTIONS

Leader: Julie Hunt

Collaborators: Vladimir Jokovic, Paul Revell, Greg Wilkie

The CSIRO Futures project continues the work developed in CRC ORE on pre-concentration, i.e., exploitation of the natural heterogeneity of an orebody to divert gangue or low-value material out of the mining value chain at relatively coarse particle sizes prior to fine crushing and milling.

The extension project is a collaboration between Diamondbacks, CSIRO Mineral Resources and CODES, and is

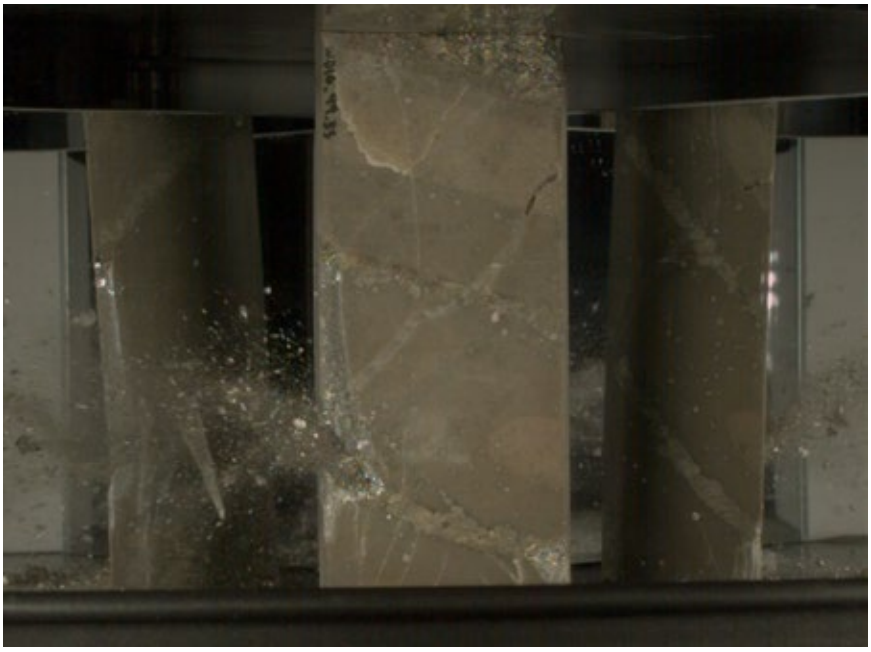
focussed on the liberation of gangue material and the inherent particle grade distributions present in these coarse particle size ranges. The objective of the project is to combine geological characterisation with different analytical techniques (chemical analysis, X-ray tomography) to characterise coarse ore feeds that cannot be analysed by traditional automated mineralogy methods due to the large size of the particles. Particle grade distributions are being examined to determine the particle size where liberation of gangue occurs. Results from this approach can be used to model gangue liberation and predict mass and value flows going to accept and reject streams.

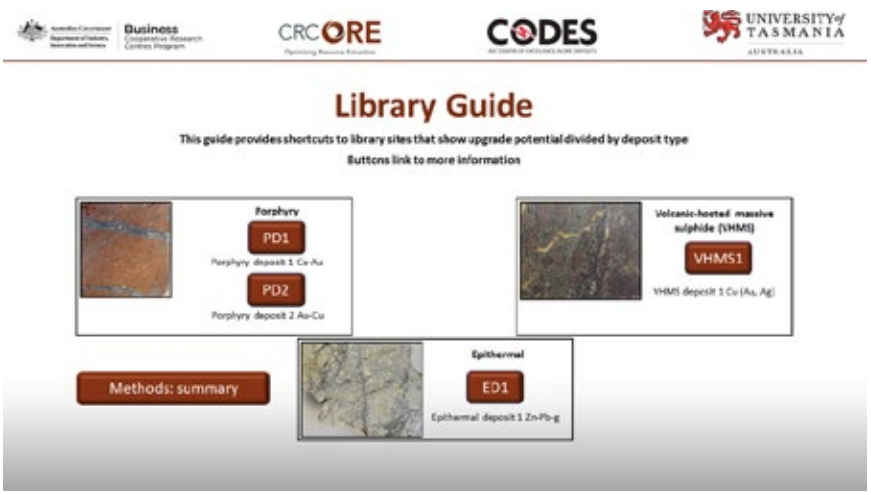
RRC PROJECT: ENVIRONMENTALLY SUSTAINALBLE PRODUCTION OF CRITICAL METALS: ELEMENT 2 PATHWAYS TO PRODUCTION

(See the RRC Project section for full details of this project including all collaborators.)

Student: Christopher Allen

Christopher Allen has returned to Tasmania from the mineral exploration industry to embark on a PhD. His research is focussed on 'Geoenvironmental and geometallurgical characterization of weathered polymetallic wastes: Implications for mine closure, western Tasmania' and is jointly supported by MRT, Bluestone Mines Tasmania Joint Venture, Copper Mines of Tasmania, and Okane Consultants.





TOP: Example image of high-speed videography of rock breakage showing differential breakage of sulphide vein material and host sedimentary rocks. Breakage video ~4350 frames per second. Mirrors are reflecting the reverse side of the sample. Karla Morales included this type of experiment in the research carried out for her MSc. ABOVE: Screenshot image from the CRC ORE/CODES online library guide for the 'Geological predictors for pre-concentration: Library of mineralization styles and upgrade potential via screening'.This library was developed as part of the continuation of the CRC ORE project.

LOOKING FORWARD

The Regional Research Collaboration (RRC) project 'Environmentally sustainable production of critical metals' began late in 2022 and will gain traction in 2023. Program 2 research at CODES is particularly focussed on the Pathways to Production aspect (Element 2) of the RRC, which seeks to enable innovative ways to produce critical metals from both ores and wastes, focusing on the Tasmanian context. It will address industry's barriers to cost-effective critical metal production (e.g., crushing and grinding, mineral separation and energy efficiency).

The team for the RRC will steadily arrive into Hobart to begin working on this critical metals project in Tasmania during the early months of 2023. The first Program 2 postdoc (Dr Owen Missen; geoenvironment) arrived in late 2022, and the second Program 2 postdoc and three new PhD students are expected to arrive in 2023. Work on this project will ramp up in 2023 with fieldwork trips to the west coast and King Island taking place early in the year.

An Honours project funded by Mineral Resources Tasmania will begin in 2023, focusing on the drivers of alkaline drainage at a rehabilitated coal mining site in northeast Tasmania.

We are also looking forward to the submission of Sibele Nascimento's PhD thesis in 2023.

Program three: Sedimentation, tectonics and Earth evolution

▶ OBJECTIVE

This program aims to understand the formation and evolution of sedimentary basins, including their metamorphic and deformation histories, within the broader context of geodynamic processes and Earth evolution through time. A new branch of the program includes assessment on the stability of the modern Australian shelf, by studying Tertiary to Pleistocene mass-wasting events on the western Tasmanian coast and the eastern Australian seaboard. Our goal is ultimately to develop new and refined genetic and exploration models for diverse sediment-hosted mineral systems across all time periods of Earth history, and to assess natural hazards linked to submarine landslides.

Introduction

Program 3: Sedimentation, tectonics and Earth evolution encompasses all aspects of sedimentary basin geologic history and the development of life on Earth, including how cycles revealed in marine geochemistry profiles and craton amalgamation may influence the location and timing of sediment-hosted mineral systems. This has a direct impact on the search for, and understanding of, a vast array of ore types, including sedimentary exhalative (SEDEX) Zn-Pb-Ag, Broken Hill-type Ag-Pb-Zn, sediment-hosted orogenic Au, and Zambian-style Cu-Co-Au.

Catastrophic events count for a substantial part of the geological record, and these occasional but extreme events may affect and modify entire basins and coastlines. Further, modern submarine landslides are substantial risks to coastal populations and underwater structures, and studying their deposits will allow us to refine tsunami models for the Australian coast.

Highlights

2022 began much like the end of 2021, in that there were few in-person conferences and opportunities for fieldwork. However, by the middle of the year, the world began to reopen after more than two years of COVID-related cancellations, postponements and online substitutions for the real things.

The major highlight for Program 3 in 2022 was the commencement in September of a new collaborative industry-funded project, 'Iron oxide copper-gold deposits: Geochemistry and geometallurgy', or IOCG[3], led by Dr Jeff Steadman. This project has study sites in the Eastern Succession of the Mt Isa Inlier, NW QLD, the Gawler Craton, SA, and the Arthur Lineament in western Tasmania. One PhD student – Joanne Morrison – has been recruited, with another to be recruited by mid-2023. Furthermore, two field campaigns have been conducted so far, with a third planned for mid-2023.

The year witnessed the departure of a team member from Program 3: Research Fellow, Dr Indrani Mukherjee, left CODES in May for a six-month stint at the University of Toronto, Canada, before accepting a position as Lecturer in Earth Sciences at the University of New South Wales in Sydney. Indrani spearheaded much of the Program 3

An unsealed country road through a freshly-harvested wheat field masks the metallic riches underground at the Hillside iron oxide copper-gold (IOCG) deposit, Yorke Peninsula, South Australia. St Vincent Gulf can be seen in the background on the left, with the Hillside homestead visible in front of that. Dr Jeff Steadman carried out fieldwork here in 2022 as part of the new IOCG³ project.

> Our goal is to develop new and refined genetic and exploration models.

research concerning the evolution of Earth's biosphere and hydrosphere through deep time, while simultaneously maintaining an active presence in economic geology-related research topics. Her contributions to Program 3 will be dearly missed.

Dr Sheree Armistead joined CODES as part of Program 3 with a new two-year project looking at the formational ages of ore deposits in western Tasmania, funded by Geoscience Australia. This project will shed light on the timing of mineralisation in some of western Tasmania's ore deposits. The team includes UTAS researchers Professor Sebastien Meffre and postdoctoral researcher Dr Sheree Armistead, Geoscience Australia's Drs David Huston, Andrew Cross and Geoff Fraser, and MRT's Ralph Bottrill. Researchers aim to constrain the ages of mineralisation from the Interview River, Savage River, Henty, Darwin South and Mount Lyell deposits.

Publications in 2022

Key research outcomes from Program 3 projects that were overdue for publication finally saw the light of day in 2022. Chief among these was a paper led by Emeritus Distinguished Professor Ross Large on a reinterpretation of the so-called Great Oxidation Event (GOE) as a prolonged series of oxygen increases and decreases that ultimately reached a peak after nearly 500 million years. This paper went through several stages of peer-review in multiple journals over the past two years. Co-authors of this manuscript included collaborators from the Carnegie Institute in Washington, D.C., as well as Dr Indrani Mukherjee and Dr Jeff Steadman.

In addition, Program 3 PhD student Colin Jones published the first paper from his PhD thesis in 2022, focusing on O and Hf isotopic data from zircons in Devonian granites from eastern Tasmania. This work identified and quantified mantle and crustal contributions to the formation of the granites.

Awards

A.B. Edwards Medal

The A.B. Edwards Medal is awarded by the Geological Society of Australia on an annual basis for the best paper on aspects of economic geology published in the *Australian Journal of Earth Sciences* (AJES). CODES PhD student Tristan Wells and his co-authors received the 2020 and 2021 medals for work on his papers 'Porphyry fertility in the Northparkes district: indicators from whole-rock geochemistry' and 'Geology and geochronology of the Two-Thirty prospect, Northparkes district, NSW'.

D.I. Groves Award

Tristan Wells also received the 2021 D.I. Groves Award medal for the paper 'Assessment of magmatic fertility using pXRF on altered rocks from the Ordovician Macquarie Arc, New South Wales'. The award is given for the best paper in AJES by a 'young' author who is lead author on the paper (young means someone less than six years out from their degree, be it BSc, MSc, or PhD).

The program team

LEADER ROBERT SCOTT
DEPUTY LEADER JEFF STEADMAN

TEAM MEMBERS:

Sheree Armistead, Ron Berry, Stuart Bull, David Cooke, Jonathan Cloutier, Matthew Cracknell, Martin Jutzeler, Ross Large, Peter McGoldrick, Sebastien Meffre, Indrani Mukherjee, Karin Orth, Michael Roach

PHD STUDENTS:

Alex Farrar, Umer Habib, Max Hohl, Colin Jones, Elena Lounejeva, Joanne Morrison, Thomas Schaap, Peerapong Sritangsirikul, Tristan Wells

MASTERS STUDENTS:

Brendan Hardwick, Kyle Hughes, Ben Johnson

HONOURS STUDENT:

Till Gallagher

COLLABORATORS:

AUSTRALIAN NATIONAL UNIVERSITY
Marc Norman

CARNEGIE INSTITUTION, USA
Robert Hazen

CENTRAL SCIENCE LABORATORY (UTAS)
Sandrin Feig, Karsten Goemann

CSIC, UNIVERSITY OF MADRID, SPAIN
Fernando Tornos

CURTIN UNIVERSITY
William Collins

GEOLOGICAL SURVEY OF NSW
John Greenfield, Robert Musgrave

GEOLOGICAL SURVEY OF QUEENSLAND (DEPARTMENT OF RESOURCES)
Elena Belousova

GEOSCIENCE AUSTRALIA
Antony Burnham, Andrew Cross, Geoff Fraser, David Huston, Scott Nichol

IMEX CONSULTING
Mark Arundell

INSTITUTE FOR MARINE AND ANTARCTIC STUDIES (UTAS)
Neville Barrett, Jacqui Halpin, Rafael Leon, Vanessa Lucieer, Joanne Whittaker

INSTITUTO ITALIANO DI PALEONTOLOGIA UMANA, ROME, ITALY
Alan Cannell

MINERAL RESOURCES TASMANIA
Ralph Bottrill, Clive Calver, Grace Cumming, John Everard, Claire Kain, Andrew McNeill, Mike Vicary

MONASH UNIVERSITY
Jacob Mulder

NATIONAL OCEANOGRAPHY CENTRE, UK
Michael Clare

RUSSIAN ACADEMY OF SCIENCE, RUSSIA
Valeriy Maslennikov

RUTGERS UNIVERSITY, NEW JERSEY, USA
Nathan Yee

TASMANIAN INSTITUTE OF AGRICULTURE (UTAS)
Ross Corkrey

UNIVERSIDADE FEDERAL DE MINAS GERAIS, BRAZIL
Fabricio Caxito

UNIVERSITY OF MELBOURNE
Roland Maas

UNIVERSITY OF NEWCASTLE, NSW
Hannah Power

UNIVERSITY OF SYDNEY
David Airey, Samantha Clarke, Tom Hubble, Michael Kinsela, Maria Seton

UNIVERSITY OF UTRECHT, NETHERLANDS
Peter Bijl, Frida Silsteveit Hoem

Numerous specimens of Musca domestica *– the common house fly – decorating the back of Dr Jeff Steadman at the Hillside IOCG deposit. Jeff learned not to open his mouth when examining drill core during his field visit!*

Projects

Trace elements in ancient oceans

Ore deposits and tectonic evolution of the Lachlan Orogen, SE Australia

Building Tasmania: The Cambrian and beyond

Temporal controls on Tasmanian and eastern Australian deposits

Iron oxide copper-gold deposits: Geochemistry and geometallurgy (IOCG[3])

Stability of the Australian continental shelf

Project summaries

TRACE ELEMENTS IN ANCIENT OCEANS

Leader: Ross Large

Team members: Indrani Mukherjee, Jeff Steadman

Collaborators: Alan Cannell, Fabricio Caxito, Ross Corkrey, Robert Hazen, Valeriy Maslennikov

This project uses the trace element content of sedimentary pyrite through time to interpret changes in the trace element content of past oceans and relationships to atmospheric oxygen. This study combines the results from two totally different methods to estimate atmosphere oxygen concentrations during the Precambrian and Phanerozoic.

In 2022 research continued with the previously developed sedimentary pyrite proxy for atmosphere oxygenation to understand evolutionary processes in the Neoproterozoic and Phanerozoic. Collaborator Alan Cannell has worked with the team to develop a revised calibration of the pyrite Se/Co atmosphere proxy which better matches our data for the Phanerozoic.

Several past attempts to model the variation in atmospheric oxygen through the Paleozoic give generally conflicting results, but all agree that pO_2 rose to a peak in the late Paleozoic between 320 and 260 Ma. The Pyrite Proxy, based on the concentrations of Se and Co in sedimentary pyrite, provides an alternative to the modelling approach. The proxy exhibits systematic variations in pO_2 (by weight) through the Silurian to Carboniferous period that are shown to closely correlate with evolutionary changes in the biosphere. In particular the proxy demonstrates how oxygen levels increased through the Silurian and early Devonian along with the development of vascular plants, the first hexapods and giant fish, followed by a sharp decline through the late Devonian coinciding with a period of high-frequency magnetic reversals, the hexapod and charcoal gaps and the Devonian mass extinction events. Professor Fabricio Caxito, from Brazil, has also collaborated on this project.

In 2022 several papers were published in connection with the project, including 'Evidence that the GOE was a prolonged event with a peak around 1900 Ma' *(Geosystems and Geoenvironment)* and 'Sedimentary pyrite proxy for atmospheric oxygen: evaluation of strengths and limitations' *(Earth-Science Reviews)*. See the Publications section of this report for further details.

ORE DEPOSITS AND TECTONIC EVOLUTION OF THE LACHLAN OROGEN, SE AUSTRALIA

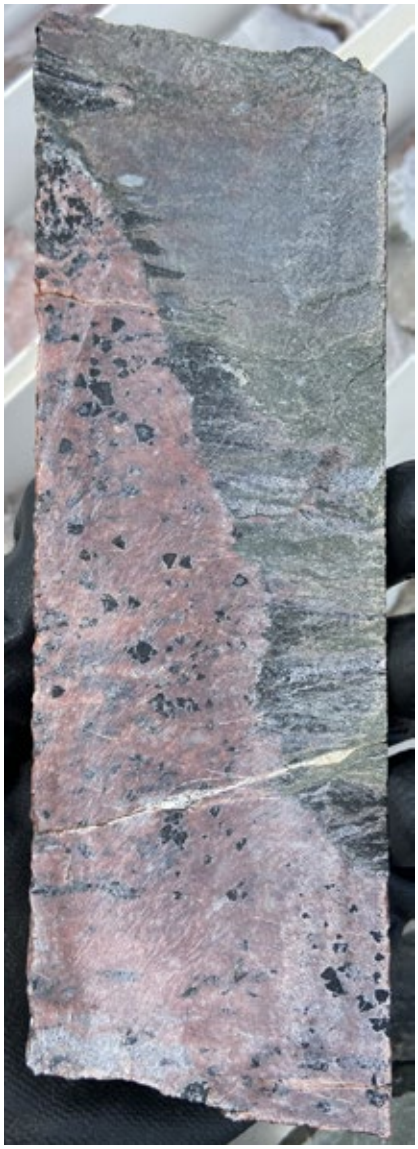
Leaders: Sebastien Meffre, David Cooke, Matthew Cracknell

Team members: Ron Berry, Michael Roach, Jeff Steadman

Students: Umer Habib, Colin Jones, Thomas Schaap, Tristan Wells

Collaborators: Mark Arundell, Elena Belousova, William Collins, John Greenfield, David Huston, Roland Maas, Robert Musgrave, Marc Norman, Joanne Whittaker

This ARC Linkage project, aimed at understanding the geology, tectonic evolution and ore deposits of the Lachlan Orogen in southeastern Australia, ran from December 2016 to 2019, but research by four PhD students and three Masters students continued to 2022. All of the students have now submitted their theses with the final two theses by Thomas Schaap and Colin Jones under examination.



A granite pegmatite body (left) that intruded and altered a previously epidote altered metashale (right) of the Wallaroo Group at the Hillside IOCG deposit. Drill core is 20 cm long. The pegmatite contains abundant tourmaline (black triangles). Tourmaline has also formed along the contact with the metashale, which also contains abundant epidote (green).

A total of four papers arising from this project were published in 2022 including two papers on detrital zircons from eastern Australia from Umer Habib, one paper on Hf and O isotopes in Tasmanian granites from Colin Jones and one co-authored paper on fossils from the Northparkes area from Tristan Wells.

BUILDING TASMANIA: THE CAMBRIAN AND BEYOND

Leaders: Sebastien Meffre, Robert Scott

Team members: Ron Berry, Karin Orth

Collaborators: Ralph Bottrill, Clive Calver, Grace Cumming, John Everard, Jacqui Halpin, Andrew McNeill, Jacob Mulder, Mike Vicary

This project, focussed on Tasmanian-based geochronology and tectonics, has been running for a number of years and has provided some major new insights into the tectonic history of the island. In 2022 Robert Scott, Ron Berry, Sebastien Meffre and Jack Mulder presented new structural and geochronology data from Tasmania and King Island at the Specialist Group for Structural Geology and Tectonics meeting on King Island. This data places important new constraints on the timing of deformation and metamorphic events throughout Tasmania.

TEMPORAL CONTROLS ON TASMANIAN AND EASTERN AUSTRALIAN DEPOSITS

Leaders: Sebastien Meffre, Sheree Armistead

Team member: Jeff Steadman

Collaborators: Ralph Bottrill, Andrew Cross, Geoff Fraser, David Huston, Jacob Mulder

This two-year project is part of the Temporal Controls on Mineralisation Module within Geoscience Australia's Exploring for the Future Program, which aims to stimulate mineral exploration investment, including critical minerals, and to open new mineral provinces.

In 2022 work was started on dating monazite, apatite and xenotime using the LA-ICP-MS U-Pb technique in the Interview River, Savage River and Alpine deposits in western Tasmanian. These deposits have few temporal constraints on mineralisation and are difficult to characterise in terms of genetic models. Sheree Armistead presented preliminary data at the Tasmanian Geoscience Forum in December which confirmed the complicated and protracted mineral growth history of these deposits.

IRON OXIDE COPPER-GOLD DEPOSITS: GEOCHEMISTRY AND GEOMETALLURGY (IOCG^3)

Leader: Jeff Steadman

Team members: Sheree Armistead, Matthew Cracknell, Karsten Goemann (CSL), Julie Hunt, Sebastien Meffre

Student: Joanne Morrison

Collaborators: Ralph Bottrill, Grace Cumming, Fernando Tornos

A follow-on project from the very successful 'Mineral geochemistry vectoring: Uncovering northwest Queensland's hidden potential' initiative, IOCG^3 was inaugurated in September 2022 at CODES during a blended sponsors' review meeting (i.e., there were virtual as well as in-person attendees). Fieldwork was undertaken at two study sites (Ernest Henry and Hillside) in November and December, respectively.

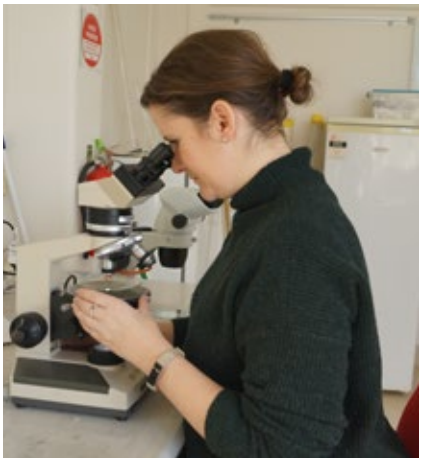
At Ernest Henry, recent drilling below the current mining level has revealed unexpected changes in Au:Cu ratios, which are generally consistent at approximately 1ppm Au to 2% Cu throughout the existing resource. However, Au:Cu ratios below the existing workings can be as high as 4ppm Au to 1% Cu, despite overall similarities in bulk mineralogy between the two areas. PhD student, Jo Morrison, a geometallurgist with over 15 years' experience, is researching the deportment of Au at Ernest Henry, with an eye towards the application of her results to other study sites within IOCG^3 and beyond.

The Hillside IOCG deposit is best known for its well-developed (and partially retrogressed) skarn mineralogy, including abundant epidote and chlorite. However, it is not known whether the trace element compositions of these minerals can be used to vector towards currently unknown targets or provide constraints on the fertility of the system. Initial petrography on Hillside samples has confirmed the widespread occurrence of pyrite, epidote and chlorite, together with martite (hematite after magnetite). However, first-pass trace element studies of epidote indicate that it is relatively poor in some of the 'hallmark' elements (e.g., As and Sb) that characterise epidote from other ore systems, such as porphyry deposits.

A new PhD project planned to commence in October 2023 will continue the trace element work commenced at Ernest Henry and Hillside as well as new study sites such as Prominent Hill IOCG, South Australia.

'Loops' of brick-red K-feldspar in a calcite vein (white background) that contains fragments of magnetite (dark grey)-pyrite (metallic yellow) altered host rock from the Ernest Henry IOCG deposit, northwest Queensland. PhD student, Jo Morrison, is using samples such as these to build a calculated mineralogy model for the Ernest Henry deposit, with an eye towards understanding mineralogical changes across the orebody.

Dr Sheree Armistead and Professor Sebastien Meffre panning for detrital zircons from the Alpine Deposit in western Tasmania in one of the labs at CODES. U-Pb dating of these zircons will help constrain the age of the host rocks.



Examining detrital zircons under the microscope as part of the 'Temporal controls on Tasmanian and eastern Australian deposits' project.

STABILITY OF THE AUSTRALIAN CONTINENTAL SHELF

Leader: Martin Jutzeler

Collaborators: David Airey, Neville Barrett, Peter Bijl, Michael Clare, Grace Cumming, Samantha Clarke, Tom Hubble, Claire Kain, Michael Kinsela, Rafael Leon, Vanessa Lucieer, Scott Nichol, Hannah Power, Maria Seton, Frida Snilstveit Hoem, Joanne Whittaker

Western Tasmania submarine slide

In 2019 Dr Martin Jutzeler and IMAS colleagues were successful in an application for a 42-day voyage that will take place in the first trimester of 2023 on board the CSIRO research vessel RV *Investigator* (IN2023_V02). In 2022, Martin prepared for the voyage with the selection of the 15 collaborators and students, expanded the objectives of the voyage, selected the sampling targets and surveys, and gathered the gear necessary for analysing the samples directly on board. In 2023 the team will investigate the deposits of a giant submarine landslide off the western Tasmania shelf. This landslide is undated and has never been formally identified before; its features suggest that it is a relatively recent event (Pleistocene?). The team will map, image and sample the landslide from its headscarp on the continental shelf to its distal deep-sea deposits, using seismic reflection, coring, dredging and deep-tow cameras.

The study will contribute to risk mitigation and tsunami hazard assessment for shelf-initiated tsunami. Mapping from continental shelf to abyssal plain will identify the offshore geology in an attempt to identify the offshore continuation of the onland geology, including the highly mineralised Mt Read Volcanics. Other objectives of this voyage include climatic, biological and ecological surveys with habitat mapping, regional fishery production, ocean productivity, marine predator activity and biodiversity patterns in collaboration with IMAS and the University of Utrecht, Netherlands. CSIRO will lead a piggy-back project to locate a 50-year-old shipwreck with a drop camera and advanced bathymetric mapping.

Qld and NSW Neogene slides

Numerous Neogene landslides are spread along the passive margin of the eastern Australian seaboard. Dr Martin Jutzeler was part of a 2019 proposal led by Associate Professor Tom Hubble (University of Sydney) to characterise the architecture of the landslides and canyons that dissect the Australian continental shelf. In May–July 2022, Tom Hubble led the CSIRO research vessel RV *Investigator* voyage (IN2022_V05) to contribute to hazard assessment for shelf-initiated tsunami. The voyage successfully retrieved piston cores and surveyed the landslide with seismic reflection.

▶ LOOKING FORWARD

Data collection is well underway for the 'Temporal controls of western Tasmania' project and is expected to ramp up in 2023. Sheree Armistead and MRT collaborator Ralph Bottrill are planning fieldwork to the northwest of Tasmania to test whether there may be mineralisation older than the widespread Cambrian–Devonian events, with the Proterozoic Rocky Cape Group identified as a potential host for Pb-Zn-Cu mineralisation. Analytical work using the SHRIMP instrumentation at Geoscience Australia is also planned for late 2023, where small minerals such as monazite can be dated.

Dr Jeff Steadman is in discussion with multiple companies active in the Norrbotten IOA-IOCG district of northern Sweden regarding IOCG^3 and how they could potentially benefit from the existing collaboration and add value to it by expanding the scope of the project to include a new world-class IOCG district. Dr Steadman and other members of the IOCG^3 research team – including Jo Morrison and a new PhD student who will start next year – will conduct field visits to multiple study sites in 2023. A sponsors' review meeting is planned for September–October 2023.

Program four: Magmatic and volcanic processes

OBJECTIVE

This program investigates magmatism, volcanism, volcano-sedimentary processes, and magmatic-hydrothermal mineral systems to unravel the interactions and connections between the mantle, crust and Earth's surface.

Introduction

Program 4: Magmatic and volcanic processes focuses on conducting fundamental research related to magma genesis and ascent, volcanic eruptions and associated volcano-sedimentary processes. This program applies that science to magmatic-volcanic-hydrothermal mineral systems in various tectonic settings, and in both subaerial and submarine environments. The understanding of magmatic and volcanic environments can have implications for natural hazards and efficient and effective vectoring towards ore deposits.

This program fosters collaboration and maintains a diverse network of partners, including national and international industry stakeholders, research institutions, and geological surveys and observatories. The contributions and expertise of these partners are highly valued in driving the program's research goals and outcomes.

Highlights

The year 2022 has been marked by remarkable progress and achievements in research, overcoming the disruptions associated with COVID-19 in previous years. With the resumption of international travel, our staff and students have been able to access field sites, our students have had opportunities for networking at conferences and workshops, and our research partners have had the opportunity for face-to-face meetings with the researchers of Program 4.

One of the highlights of the year was the successful completion of Dr Martin Jutzeler's research voyage to three caldera volcanoes in the Kermadec Arc/Rangitāhua. Further, the success of the ARC Discovery Project application to conduct science based on the results of this voyage with CIs Martin Jutzeler and Associate Professor Rebecca Carey was another highlight. This Discovery Project will begin in late 2023 and include a postdoctoral researcher and two new PhD students.

In addition, PhD student Acacia Clark was Australia's scientist on board the International Ocean Discovery Program's drilling ship, the *Joides Resolution* on a voyage departing in

CODES PhD student Hannah Moore in the Mt Tarawera fissure during a fieldwork trip in September 2022. This photo by Acacia Clark won a prize in the 2022 CODES Photo Competition.

mid-December to understand the tectonic and volcanic history of volcanic arcs and volcanoes in the Mediterranean Sea.

Awards

In October 2022 Acacia Clark received the Geological Society of Australia's Endowment Fund Award, which is awarded to one PhD student nationally per year. This prize is worth $5,000, and Acacia will use it to support her fieldwork in New Zealand in 2023. Congratulations Acacia!

Publications

A highlight for 2022 was Hannah Moore's first research publication from her PhD research – published in the *Bulletin of Volcanology* and entitled 'High-temperature oxidation of proximal basaltic pyroclasts, 1886 Tarawera, New Zealand'.

The year 2022 has been marked by remarkable progress and achievements in research.

The program team

LEADER REBECCA CAREY
DEPUTY LEADER MARTIN JUTZELER

TEAM MEMBERS:

Sharon Allen, Mike Baker, Ivan Belousov, Stuart Bull, Jonathan Cloutier, Matt Cracknell, Paul Davidson, Trevor Falloon, Jodi Fox, Bruce Gemmell, David H. Green, Maya Kamenetsky, Ross Large, Charles Makoundi, Jocelyn McPhie, Sebastien Meffre, Paul Olin, Gerrit Olivier, Karin Orth, Michael Roach, Jeff Oalmann, David Selley, Jeff Steadman

PHD STUDENTS:

Acacia Clark, Shannon Frey, Fumihiko Ikegami, Malai Ila'ava, Colin Jones, Bridie Le'Gallais, Hannah Moore, Erica Spain (IMAS), Peerapong Sritangsirikul, Chuang Wang, Zebedee Zivkovic

HONOURS STUDENT:

Till Gallagher

COLLABORATORS:

AUCKLAND MUSEUM, NZ
Tom Trnski

AUSTRALIAN NATIONAL UNIVERSITY
Richard Arculus

BHP
Kathy Ehrig

CATALYST METALS LTD
Dion Alford, Bruce Kay, Magdaline Kepo

CENTRAL SCIENCE LABORATORY (UTAS)
Christian Dietz, Sandrin Feig, Karsten Goemann, Thomas Rodemann

COLUMBIA UNIVERSITY, USA
Subramanium Ajit

CONSULTANT
Ulrich Recknagel, Adolf Rericha

DATAROCK
Yasin Dagasan, Liam Webb

DIVERSIFIED MINERALS PTY LTD
Angela Lorrigan

ETH ZURICH, SWITZERLAND
Anders McCarthy

EVOLUTION MINING
Andrew Barker, Ned Howard, Declan Radford

GEOLOGICAL SURVEY OF JAPAN, JAPAN
Osamu Ishizuka

GEOLOGICAL SURVEY OF NEW SOUTH WALES
Chris Folkes, John Greenfield, Phil Gilmore

GEOLOGICAL SURVEY OF VICTORIA
Rob Duncan

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
Christopher Phillips

GEOMAR, GERMANY
Steffen Kutterolf

GFZ GERMAN RESEARCH CENTRE FOR GEOSCIENCES, GERMANY
Rainer Thomas

GNS SCIENCE, NEW ZEALAND
Cam Asher, Ery Hughes, Paul Jarvis, Geoff Kilgour, Michael Rosenberg

HELMHOLTZ INSTITUTE FREIBERG FOR RESOURCE TECHNOLOGY, GERMANY
Alkiviadis Kontonikas-Charos

GOLD FIELDS, ST IVES GOLD MINE
Gary Sparks, Leon Grimbeek, Matthew Crawford

IFREMER, FRANCE
Martin Patriat

INSTITUT DE PHYSIQUE DU GLOBE DE PARIS, FRANCE
Lisa Retailleau

INSTITUTE OF MARINE AND ANTARCTIC STUDIES (IMAS)
Zanna Chase, Mike Coffin, Jacqui Halpin, Vanessa Lucieer, Taryn Noble, Joanne Whittaker

INSTITUTE OF MINE SEISMOLOGY
Gerrit Olivier

JAPAN AGENCY FOR MARINE SCIENCE AND TECHNOLOGY
Iona McIntosh

LABORATOIRE DE GEOLOGIE DE LYON: TERRE, PLANETES, ENVIRONNEMENT, FRANCE
Nico Coltice

LOS ALAMOS NATIONAL LABORATORY, USA
Brent Delbridge

MACQUARIE UNIVERSITY
Nathan Daczko

MDRU, CANADA
Shaun Barker

MINERAL MAPPING
Scott Halley

MINERAL RESOURCES TASMANIA
Ralph Bottrill, Grace Cumming, John Everard, Claire Kain, Andrew McNeill

MIT, USA
Maggie Zheng

MMG
Kim Denwer

MONASH UNIVERSITY
Ray Cas

MURORAN INSTITUTE OF TECHNOLOGY, JAPAN
Yoshi Goto

NATIONAL INSTITUTE OF WATER AND ATMOSPHERIC RESEARCH, NEW ZEALAND
Emily Lane, Erica Spain, Sally Watson, Suzi Woelz, Richard Wysoczanski

NATIONAL MUSEUM OF NATURE AND SCIENCE, JAPAN
Chris Conway, Kenichiro Tani

NATIONAL OCEANOGRAPHY CENTRE, UK
Michael Clare, Isobel Yeo

NORTHWEST UNIVERSITY, XI'AN, CHINA
Simon Williams

OCEANAGOLD, NEW ZEALAND
Shannon Richards, Lorrance Torckler

OREGON STATE UNIVERSITY, USA
Robert Duncan

PENNSYLVANIA STATE UNIVERSITY, USA
Tushar Mittal

QUEENSLAND UNIVERSITY OF TECHNOLOGY
Patrick Hayman

ROYAL HOLLOWAY COLLEGE LONDON, UK
F. Javier Hernández-Molina

SECOND INSTITUTE OF OCEANOGRAPHY, HANGZHOU, CHINA
Shaoru Yin

UNIVERSIDADE FEDERAL DO RIO DE JANEIRO, BRAZIL
Carolina Almeida Figueiredo

UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL, BRAZIL
Everton Bongiolo

UNIVERSITY OF AUCKLAND, NEW ZEALAND
Michael Rowe, Julie Rowland

UNIVERSITY OF CALIFORNIA, BERKELEY, USA
Michael Manga

UNIVERSITY OF CALIFORNIA, DAVIS, USA
Cathy Busby

UNIVERSITY OF HAWAII AT MANOA, USA
Bruce Houghton

UNIVERSITY OF HOUSTON, USA
William Sager

UNIVERSITY OF MELBOURNE
Stephen Gallagher

UNIVERSITY OF NEWCASTLE, NSW
Hannah Power

UNIVERSITY OF OTAGO, NEW ZEALAND
Tobi Durig, James White

UNIVERSITY OF OXFORD, UK
Jane Barling

UNIVERSITY OF STRASBOURG, FRANCE
Michael Heap

UNIVERSITY OF SYDNEY
David Airey, Samantha Clarke, Tom Hubble, Michael Kinsela, Ben Mather, Maria Seton

VANDERBILT UNIVERSITY, USA
Ralf Bennartz, Kristen Fauria, Ashok Kumar Gupta, Liam J. Kelly, John Rausch

The CSIRO Research Vessel RV Investigator *voyage team photographed prior to setting off from Hobart in March 2022 to carry out research at the Kermadec Arc/Rangitāhua, New Zealand.*

Projects

Project summaries

VOLCANOLOGY AND GEOCHEMISTRY RESEARCH RELATED TO ORE DEPOSITS

Leader: Rebecca Carey

Team members: Jonathan Cloutier, Bruce Gemmell, Martin Jutzeler, Ross Large, Jocelyn McPhie, Sebastien Meffre, Paul Olin, Gerrit Olivier, Karin Orth, Michael Roach, Robert Scott, David Selley, Jeff Steadman

Students: Malai Ila'ava, Chuang Wang, Zeb Zivkovic

Collaborators: Andrew Barker, Ray Cas, Matthew Crawford, Kim Denwer, Rob Duncan, Leon Grimbeek, Ned Howard, Andrew McNeill, Declan Radford, Gary Sparks

Detailed analysis of volcanic products and architectures are critical to unravel the mechanisms and timing of mineralisation and the characteristics of ore deposits. Our research group investigates various aspects of volcanic facies architecture in ancient seafloor environments as well as their analogues in modern settings. Our research encompasses conventional fieldwork and endeavours to find and utilise innovative approaches like geophysical techniques and machine learning to tackle questions across fundamental to applied science. In 2022, we integrated a wide range of multidisciplinary tools alongside traditional facies reconstruction for numerous sub-projects within our group.

ARC Linkage Project – Exploration targeting from next-generation volcanic facies reconstruction

This Linkage Project represents a comprehensive and multidisciplinary study aimed at enhancing our understanding of alteration processes and mineralisation within diverse volcanic lithologies. Additionally, the project seeks to reconstruct volcanic architectures by combining traditional facies analysis with a novel approach involving modern image analysis and machine learning techniques. The machine learning aspect of the project is carried out in collaboration with Datarock. It involves using photographs of volcanic facies in core samples to quantitatively assess crystal shape, abundance, and size distribution. Statistical analysis is then employed to establish correlations between different volcanic units. The ultimate goal is to develop and make available a user-friendly tool that can be employed to examine individual units and aid in accurate stratigraphic reconstructions.

To validate the effectiveness of this tool, rigorous testing is underway on facies associations found in the Mount Read Volcanics in Tasmania and the Cowal gold mine in New South Wales. The research is led by Dr Martin Jutzeler at CODES, in collaboration with Datarock, Evolution Mining and Mineral Resources Tasmania.

Malai Ila'ava's project is focussed on reconstructing the volcanic architecture of the Cowal Igneous Complex on a basin scale. Collaborating closely with Evolution Mining geologists, he spent considerable time at the Cowal site in 2022 to conduct a detailed analysis of volcanic facies. Malai plans to utilise industry software Leapfrog to integrate the fieldwork with other industry and government-sourced geological and geophysical datasets to delineate a 3D structural framework and correlate stratigraphy across fault blocks. The primary focus is the structurally complex 'Gold Corridor' which contains the E42 open pit and GRE46 underground mine, although there may be valuable insights for other epithermal and porphyry prospects present within the Cowal Igneous Complex. Looking ahead, Malai's long-term objectives encompass interpreting the volcano-magmatic and structural evolution of the Cowal Igneous Complex utilising zircon U-Pb dating and whole-rock and trace element geochemistry data generated during this project. Such interpretations could potentially shed light on metallogeny, exploration targeting, and the existing regional scale models for the Junee-Narromine Volcanic Belt.

A collaborative research team composed of Associate Professor Rebecca Carey, Dr Shaun Barker, Shannon Richards and Professor Michael Heap is actively engaged in investigating the physical properties of intermediate-felsic rocks that favour high-grade mineralisation. Specifically, the team is focusing on the selection of both non-altered and variably altered volcanic samples sourced from OceanaGold's Waihi Mine in New Zealand. To comprehensively understand the nature of these rock samples, a series of rock properties measurements and stress tests will be conducted utilising state-of-the-art facilities available at Professor Michael Heap's rock properties laboratory in Strasbourg, France. The primary objective of this project is to gain an understanding of how the process of alteration influences the strength and fracture characteristics of rocks, particularly in relation to fluid transport.

By understanding the effects of alteration on rock properties, the research team hopes to unravel the intricate relationship between alteration, rock strength, and the ability of rocks to fracture. Such insights hold great significance in the context of mineralisation processes, as they shed light on the behaviour and potential pathways for fluid flow within the geological setting.

SUBAERIAL AND SUBMARINE VOLCANOLOGY AND NATURAL HAZARDS

Leader: Rebecca Carey

Team members: Sharon Allen, Trevor Falloon, Jodi Fox, Martin Jutzeler, Jocelyn McPhie, Paul Olin, Karin Orth

Students: Acacia Clark, Shannon Frey, Fumihiko Ikegami, Hannah Moore, Chuang Wang

Collaborators: Everton Bongiolo, Ralph Bottrill, Cathy Busby, Ray Cas, Grace Cumming, Nathan Daczko, Robert Duncan, John Everard, Carolina Almeida Figueiredo, Richard Fiske, Daniel Fornari, Michael Heap, Bruce Houghton, Geoff Kilgour, Michael Manga, Gerrit Olivier, Matthew Patrick, Christopher Phillips, Michael Rosenberg, Maria Seton, Adam Soule, Kenichiro Tani, James White, Joanne Whittaker, Simon Williams, Richard Wysoczanski

Highlights of 2022:

The Australian CSIRO Research Vessel, RV *Investigator*, embarked on a remarkable expedition led by Dr Martin Jutzeler, serving as the Chief Scientist. The primary objective of the expedition was to explore and study three silicic caldera volcanoes located in the Kermadec Arc of New Zealand (Rangitāhua). The voyage proved to be immensely fruitful, with significant achievements and breakthroughs. The research conducted on the volcanic architectures of these volcanoes is poised to have a lasting impact, as ongoing investigations and analyses will continue to unfold over the course of several years.

PhD student Hannah Moore published the first paper out of her PhD, focussed on post-depositional crystallisation of eruption products. Her research findings are important, because they highlight that small <100 micron-sized crystals in volcanic clasts continue to grow after deposition, and therefore their traditional use for investigating syn-eruptive conduit processes could be problematic.

CODES PhD student Acacia Clark carries out detailed stratigraphic logging of the 1315 CE Kaharoa eruption deposits near Mt Tarawera on the North Island of New Zealand in September during a 2022 fieldwork trip to New Zealand.

PhD student Acacia Clark was Australia's scientist on board the International Ocean Discovery Program's drilling ship, the *Joides Resolution*. The purpose of the voyage (Dec 2022–Feb 2023) was to understand the tectonic and volcanic history of volcanic arcs and volcanoes in the Mediterranean. Acacia was on board for two months, and will conduct a research project together with collaborators Steffen Kutterolf (GEOMAR), Michael Manga (UC Berkeley), and Iona McIntosh (JAMSTEC) on the Late Bronze Age eruption of Santorini Volcano.

The sub-projects within 'Subaerial and submarine volcanology and natural hazards' also achieved excellent progress:

Caldera-forming submarine volcanism

Dr Martin Jutzeler and Associate Professor Rebecca Carey were successful in obtaining time on the CSIRO research vessel RV *Investigator* for a voyage to the Kermadec Arc/ Rangitāhua, north of New Zealand. Dr Jutzeler led this one-month voyage in March 2022. The team surveyed and sampled three silicic calderas using seismic reflection, piston coring and dredging. The voyage objectives were to link the behaviour of deep submarine silicic eruptions with the morphology of their deposits.

At Macauley volcano, this voyage targeted voluminous dune-like deposits, named sediment waves (eruption-fed density currents).

CODES PhD students Hannah Moore and Acacia Clark (and, if you look closely, Associate Professor Rebecca Carey and Dr Michael Roach) bush-bashing in search of volcanic deposits from eruptions of Mt Tarawera, New Zealand, during fieldwork in September.

These data will inform eruption-fed tsunami models of these large-volume eruptions and associated deposits.

At Havre volcano, the ship surveyed the trail of the pumice raft produced by the voluminous 2012 deep-water eruption using deep-towed cameras. This information will be used to understand the 2012 deposit footprint and calculate the eruption volume, which together provide constraints on transport processes of effusively erupted pumice in deep ocean settings.

At Healy caldera, cores in adjacent basins will allow the team to research provenance and age of tens of tephra layers which together allow more insight into the magmatic budget and eruption history of this part of the Kermadec Arc.

Tarawera Volcano, New Zealand

The drivers of powerful explosive basaltic volcanism are still debated after two decades of research. CODES PhD student Hannah Moore has used crystallinity of the 1886 erupted products to further elucidate those drivers for the Tarawera 1886 eruption, New Zealand. Her paper was published in 2022 in the *Bulletin of Volcanology,* and she will present this work for the first time at the IAVCEI 2023 conference, the premier conference in volcanology. See the Publications listing at the back of this report.

The last powerful silicic eruption was the 1315 CE (Kaharoa) eruption of Tarawera volcano. This particular eruption displayed a remarkable behaviour, transitioning back and forth between explosive and effusive phases likely over weeks to months. The final phase of this eruption was lava effusion which continued for at least another five years. PhD student Acacia Clark is investigating the underlying magmatic and environmental factors that influenced the transition from explosive to effusive volcanism during the 1315 CE eruption. By delving into the drivers associated with this shift in eruption style, Acacia aims to enhance our understanding of the complex dynamics and processes governing volcanic behaviour. This research has the potential to provide valuable insights into the mechanisms and triggers that facilitate such transitions, contributing to assessing volcanic hazards at silicic volcanoes globally.

Cenozoic volcanism in Tasmania

In a collaborative effort with Mineral Resources Tasmania (MRT), CODES PhD student Chuang Wang is engaged in a research project centred around passive seismic analysis in western Tasmania. The primary focus of this study is to utilise field data obtained from a dense network of seismometers located north of Hellyer mine. By leveraging this comprehensive dataset, Chuang has successfully reconstructed the depth of Tertiary basalts that overlay the mineralised Mount Read Volcanics. The findings of this passive seismic survey are further supported by a few drill holes in the region. The significance of this research lies in its ability to offer a novel approach for exploration targeting in areas where the mineralised Palaeozoic basement is obscured by significant thicknesses of younger successions, ranging from tens to hundreds of metres. By integrating passive seismic analysis into the exploration process, Chuang's work has the potential to revolutionise the identification of promising exploration targets, facilitating the discovery of mineral deposits that are concealed beneath younger geological formations.

Mantle Plume-plate interactions – Coral Sea volcanism and tectonics

Associate Professor Rebecca Carey in collaboration with Dr Karin Orth, Dr Maria Seton, Associate Professor

Jo Whittaker and Dr Simon Williams have a funded ARC Discovery Project focussed on volcanism and tectonics offshore eastern Australia. This research initiative encompasses two key aims. Firstly, it seeks to unravel the intricate relationship between plate tectonic motions, plate boundaries, and Mantle Plume activity, investigating the mutual controls and interactions between these factors. Secondly, the project aims to determine the temporal and spatial scales of volcanic output and vertical motion changes exhibited by submerged seamounts which are a part of the Tasmantid and Lord Howe Seamount Chains.

Heard Island, Kerguelen Plateau, Australian Antarctic Territory

Under the leadership of former CODES PhD student Dr Jodi Fox, a team of researchers consisting of Associate Professor Rebecca Carey and Dr Trevor Falloon is actively involved in investigating the volcanic history of Heard Island. Their primary focus revolves around understanding the characteristics and origins of the most recent volcanic rocks formed as a consequence of the Kerguelen Mantle Plume.

In 2022, the CODES group had the privilege of hosting Dr Jane Barling, a collaborator from the University of Oxford, who brought invaluable knowledge, samples and geochemical data to the project. Dr Barling is one of few geologists who has spent extensive time on Heard Island. Together, this team will publish whole-rock, mineral and isotope geochemistry data together with $^{40}Ar/^{39}Ar$ geochronology of rocks and IODP samples that will provide the first evidence for zonation of a Kerguelen Mantle Plume. This research will be published in 2023.

Balleny volcanic chain, offshore Tasmania

Beneath the Tasman Sea and Southern Ocean lies an intriguing volcanic chain believed to be linked to the Balleny Mantle Plume. This seamount chain provides a remarkable record of continental breakup events between Australia, Zealandia and Antarctica approximately 90–80 million years ago. This breakup eventually led to the opening of the Southern Ocean around 50–30 million years ago, giving rise to the powerful Antarctic Circumpolar Current (ACC).

Rebecca Carey examining the basal part of the basaltic eruption deposit from the 1886 eruption of Tarawera volcano, New Zealand.

In 2018, a dedicated team of researchers from CODES, comprising both staff and students, embarked on a voyage aboard the RV *Investigator*. Led by Associate Professor Jo Whittaker from the Institute for Marine and Antarctic Studies (IMAS), the team set out to explore this volcanic chain. Through dredging operations, mafic rocks were retrieved from 16 seamounts, setting the stage for further analysis and investigation.

Preliminary investigations involving whole-rock geochemistry and argon geochronology have provided compelling support for the Balleny Mantle Plume hypothesis. The data obtained exhibit an age-progressive trend, and HIMU mantle source geochemistry, strengthening the link between the seamount chain and the Balleny Mantle Plume. These findings are now being integrated with geochemical and geochronological data from Cenozoic volcanic centres in Tasmania, with the assistance of Dr John Everard from MRT.

Trindade Island, Brazil

Dr Martin Jutzeler provided external supervision to Carolina Figueiredo, a Brazil-based PhD student working on pyroclastic textures at Trindade Island, offshore Brazil. She is supervised by Dr Everton Bongiolo. This microtextural-focussed study used pyroclast shapes to reconstruct fragmentation histories on a variety of primary deposits. The published article in the *Journal of Volcanology and Geothermal Research* shows that the relatively low-viscosity alkaline magmas deform and fragment differently than magmas belonging to the classic calc-alkaline series.

Innovations Connections

August 2022 saw the completion of a $100,000 Innovations Connections research program that began in 2020 and formed a large component of Zeb Zivkovic's PhD work. This study was sponsored by Dreadnought Resources based in Western Australia who were interested in characterising known mineralisation and developing a range of camp to deposit scale prospectivity indicators using a combination of whole-rock and mineral chemistry tools. The study involved a range of deposit styles and commodities from the central Yilgarn and West Kimberley regions of WA and assessed potential for gold, copper, lead, zinc, lithium, nickel, bismuth, antimony and titanium resources. Work included whole-rock lithogeochemistry, greenrock, pyrite and zircon fertility analysis, and geochronology.

Coverage of recent eruptions

Hunga Tonga

Dr Martin Jutzeler was part of a UK-based NERC urgency grant to investigate the Hunga Tonga submarine caldera in the Kingdom of Tonga, in the aftermath of its climactic eruption in January 2022. The proposal led to a New Zealand-led voyage to Hunga Tonga in mid-2022.

Fukutoku-oka-no-ba

Together with a USA-led team, Dr Martin Jutzeler has been involved in the publication of an article on the rapid response of the pumice-raft forming eruption of Fukutoku-oka-no-ba in the Izu-Bonin arc, south of Japan. Formation of a pumice raft co-jointly with a stratospheric vapour plume and phreatomagmatic jets from a shallow-water vent could be identified based on multiple satellite datasets. The current technology in very-high-resolution satellite imagery allows identification of single pyroclasts during eruption. Together with lower resolution satellite images, such datasets provide exceptional data that revolutionises our understanding of eruption behaviour at poorly monitored volcanoes.

Pumice rafts

Martin has been involved in a study led by US-based colleagues and their students on machine-learning automation for near-real-time recognition of pumice rafts from satellite imagery. The study has been published this year and will provide further help for natural hazard mitigation related to pumice rafts and subaqueous eruptions in general.

Sample selection by the night shift in the laboratories of the RV Investigator. *L-R: Martin Jutzeler, Emily Conn, Malai Ila'ava and Hannah Moore.*

SEDIMENTARY VOLCANOLOGY

Leader: Martin Jutzeler

Team members: Rebecca Carey, Jocelyn McPhie, Karin Orth

Collaborators: Subramanium Ajit, Ralf Bennartz, Cathy Busby, Michael Clare, Brent Delbridge, Kristen Fauria, Stephen Gallagher, Ashok Kumar Gupta, F. Javier Hernández-Molina, Liam J. Kelly, Steffen Kutterolf, Emily Lane, Michael Manga, Tushar Mittal, John Rausch, Lise Retailleau, William Sager, Tom Trnski, Sally Watson, Suzi Woelz, Richard Wysoczanski, Isobel Yeo, Shaoru Yin, Maggie Zheng

The Sedimentary Volcanology project encompasses research on eruption, transport and deposition dynamics in modern and ancient volcanic successions. Sub-projects include:

Eruption and volcano-sedimentary processes during caldera-forming events

Starting in late 2023, an ARC Discovery proposal to study submarine volcanism and its tsunamigenic effects will begin, led by Dr Martin Jutzeler with other Chief Investigators from UTAS, Australia, USA, Germany and New Zealand. This project aims to understand explosive eruptions underwater and the dynamics of associated sediment flows that can/cannot trigger tsunami. The project will focus on Macauley submarine caldera and its 5.7 ka sediment flow deposits that were cored and surveyed during the voyage to the Kermadec Arc/Rangitāhua earlier in 2022. This project is very timely, as it targets volcanic processes very similar to those that occurred during the January 2022 eruption of Hunga Tonga. Expected outcomes include an unprecedented reconstruction of the architecture of submarine caldera volcanoes, new innovative models applicable globally for a richer understanding of volcanic tsunami and eruptions that shape the seafloor.

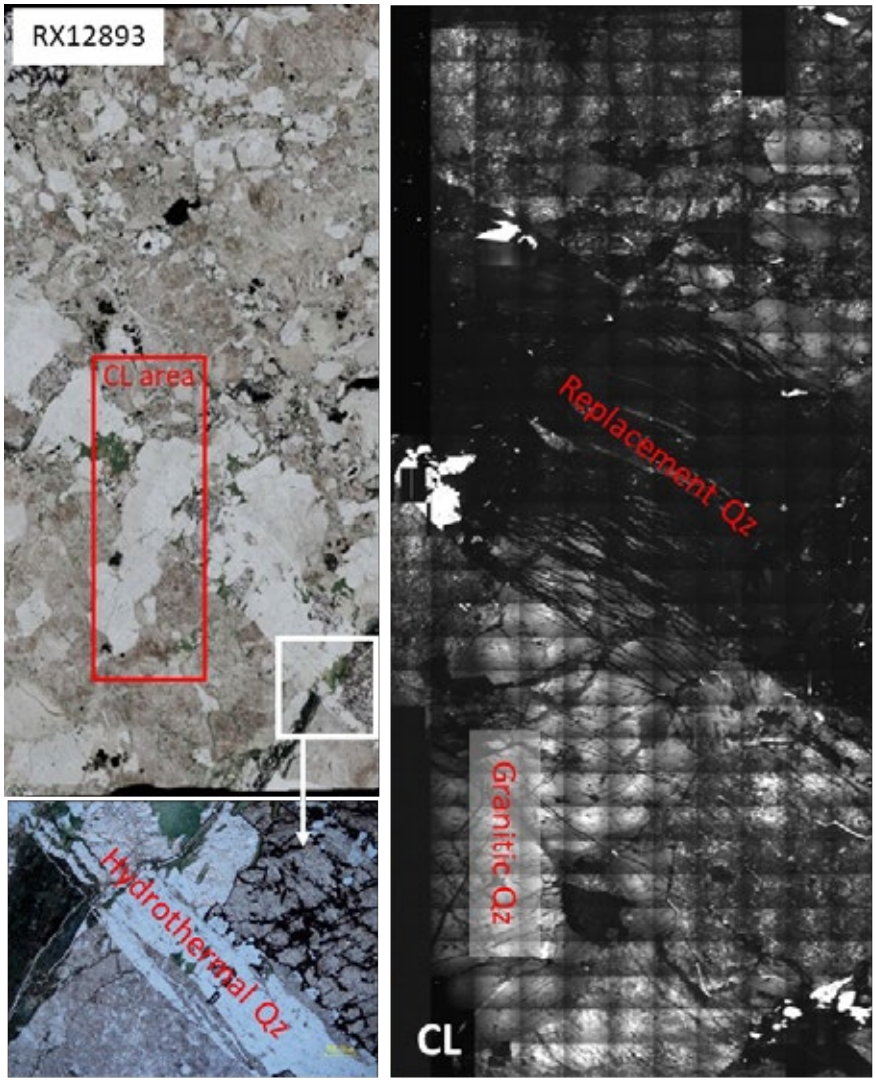
PhD student Shannon Frey is conducting research on two cores collected on sediment waves surrounding Macauley caldera. These cores recovered exceptionally interesting stratigraphy with planar and cross-bedding, and large 2-cm pumice clasts. These bedforms and components are being studied to elucidate syn-eruptive high-regime sedimentation dynamics.

Janne Scheffler, Master of Science student at GEOMAR, Germany, visited CODES for six months from late 2022 and into 2023. Janne's research is focussed on a complex 40-cm volcaniclastic unit cored at ca. 100 km from Havre and Macauley submarine calderas. Based on textural and geochemical analyses of sediment in the core, she will interpret transport processes of pyroclasts in the ocean.

Ocean currents and contourites around volcanic seamounts

Shannon Frey is currently working on the interactions between ocean currents and seamounts. Based on imagery from the IN2022_V02 voyage in the Kermadec Arc (Rangitāhua), Shannon identified that long-lasting and transient ocean currents strongly remodel seafloor sediment down to >1,000 mbsl, creating complex dune and scour fields. This study has strong implication on identification of syn- vs. post-eruption sedimentation and paleocurrent directions in the rock record.

Dr Martin Jutzeler together with sedimentologists in China and the UK are studying the formation of volcanic-hosted contourites in the NW Pacific. The team targeted contourites that onlap volcanic seamounts in the Izu Bonin arc and the Shatsky Rise. Through interpretation of seismic reflection and IODP cores stratigraphy, the team identified that the contourites, despite being thousands of km apart, recorded similar sedimentation trends related to regional deep currents in the Pacific Ocean. This project is now expanding with a focus on the Shatsky Rise itself.



Dr Maya Kamenetsky is working on the Olympic Dam project: Optical microscope and cathodoluminescence (CL, red box area) images of thin section from Olympic Dam granite show different genetic types of quartz that contain fluid/melt inclusions. The multiple generations of quartz on the scale of one thin section demonstrate the complexity of different overlapping processes affecting rocks on macro- and micro-scales.

OLYMPIC DAM FLUID/ MELT INCLUSION PROJECT

Leader: Maya Kamenetsky

Collaborators: Kathy Ehrig, Alkis Kontonikas

This project, which began in 2021, is focussed on the study of phase evolution and compositional changes of fluids recorded in melt/fluid inclusions from quartz and other minerals (carbonate, fluorite and barite) from distal to proximal granite hosting the Olympic Dam deposit.

The Olympic Dam deposit is dominated by different forms of silica, especially in a significant mass of barren quartz-hematite core. The mineralised lithologies, such as granite breccia, are enriched in quartz supplied by the Roxby Downs granite. Although quartz veining is uncommon at Olympic Dam, the sulphide mineralisation is believed to be hydrothermal in origin and derived from granite-related deuteric and external fluids.

All major genetic types of inclusions – primary, pseudo-secondary and secondary – are commonly used to characterise fluids and melts, involved in crystallisation and post-crystallisation, including compositions and temperature. In the case of the multi-element Olympic Dam deposit (C, Fe, F, U, REE, Cu, Au etc), the ore-forming potential of granite-derived (i.e., deuteric) and granite-equilibrated (distal) fluids is of particular interest.

Rock dredging by night on the RV Investigator. *Samples are selected on deck from the main load of dredged rocks.*

Our study shows the multiple generations of quartz, that contain a diverse suite of fluid/melt inclusions. It is quite often that one quartz is fully or partially replaced by another, making the recognition of fluid inclusion populations very difficult. We selected truly 'granite' and hydrothermal quartz by its petrographic and CL properties and analysed this quartz (using the LA-ICP-MS technique), targeting the areas enriched in fluid inclusions.

Our results show that most fluid inclusions in granitic quartz have unradiogenic Pb isotope compositions, and many inclusions contain Pb that comes from the crust that is older than 1.6 Ga. In terms of Pb composition these inclusions are systematically older than those in the hydrothermal quartz. Although this conclusion seems to be unimportant for the OD mineralisation at 1.6 Ga, the precursor granites should be viewed as plausible sources of economic elements and iron, fluorine and carbon at Olympic Dam.

THE TECTONIC SIGNIFICANCE OF MAFIC/ULTRAMAFIC IGNEOUS ROCKS IN WESTERN TASMANIA

Leader: Ivan Belousov

Team member: Paul Olin

Student: Bridie Le'Gallais

Collaborators: Ralph Bottrill, Grace Cumming, John Everard, Andrew McNeill

This project aims at constraining the number and geographical spread of different magmatic series that exist within western Tasmanian mafic/ultramafic complexes, the nature of parental magma compositions of these complexes, and the possible tectonic settings at which these Tasmanian mafic/ultramafic complexes have formed prior to emplacement into their current position.

In 2022, reheating experiments using the Vernadsky heating stage were conducted to homogenise the recrystallised melt inclusions and investigate temperatures of the melt at the moment of entrapment. After homogenisation, the analysis of melt inclusions was performed using EPMA and LA-ICP-MS. These analyses confirmed the very depleted nature of their primary melts. Three metabasalt samples were sent to the University of Melbourne for isotope analyses (Rb/Sr, Sm/Nd, Lu/Hf and Pb isotopes) using multi collector ICP-MS. We look forward to publishing these results in 2023/2024.

NATURE, STRUCTURE AND ORIGIN OF THE ST MARYS PORPHYRY, NORTHEASTERN TASMANIA

Leader: Karin Orth

Team members: Rebecca Carey, Sebastien Meffre

Student: Till Gallagher

Collaborators: Ralph Bottrill, Grace Cumming

Till Gallagher completed his Honours project on the St Marys Porphyry in eastern Tasmania in 2022. He aimed to re-appraise the volcanic architecture of the St Marys Porphyry, the only example of extrusive activity during the Devonian magmatism in northeastern Tasmania. Till examined one drillhole and 17 kms of coastal outcrop between Falmouth and Chain of Lagoons as well as other outcrops between Falmouth and St Marys in the west. The contact between the St Marys Porphyry and the underlying Mathinna Supergroup, marked by a basal contact breccia and basal and lower stratigraphy of the St Marys Porphyry was well preserved in the drill core. This, combined with detailed statistical analysis of the distribution and size of lithic clasts, allowed Till to unpick the seemingly monotonous St Marys Porphyry into distinct ignimbrite flow units. This was enhanced by petrology and Hylogger data. Till was the recipient of the 2021 Geological Society of Australia's Endowment Fund Award for Honours students (worth $1,000). He used the extra funds to increase the number of U-Pb zircon dates he obtained for the St Marys Porphyry and some of the surrounding sedimentary and igneous units. These dates confirm the Devonian age of the magmatism. They show that the southern Piccaninny Granite is time equivalent to the St Marys Porphyry and raises questions about the relationship between the St Marys Porphyry and the supposed feeder dyke to the northwest, the Catos Creek Dyke. The dates also show that this outflow succession formed at a different time to voluminous eruption units in Victoria which are both older (Snowy River Volcanics) and younger (Acheron, Cerberean successions). The new dates suggest a slightly older age for the Tabberabberan Orogeny in eastern Tasmania making it older than the orogenic event in Victoria. Findings from Till's Honours research will be presented as a poster at the IAVCEI conference in Rotorua in February 2023.

CODES Honours student Till Gallagher (left) with Ralph Bottrill from Mineral Resources Tasmania examining beach rocks of the St Marys Porphyry at Falmouth, northeast Tasmania. Collaborator Grace Cumming is in the background.

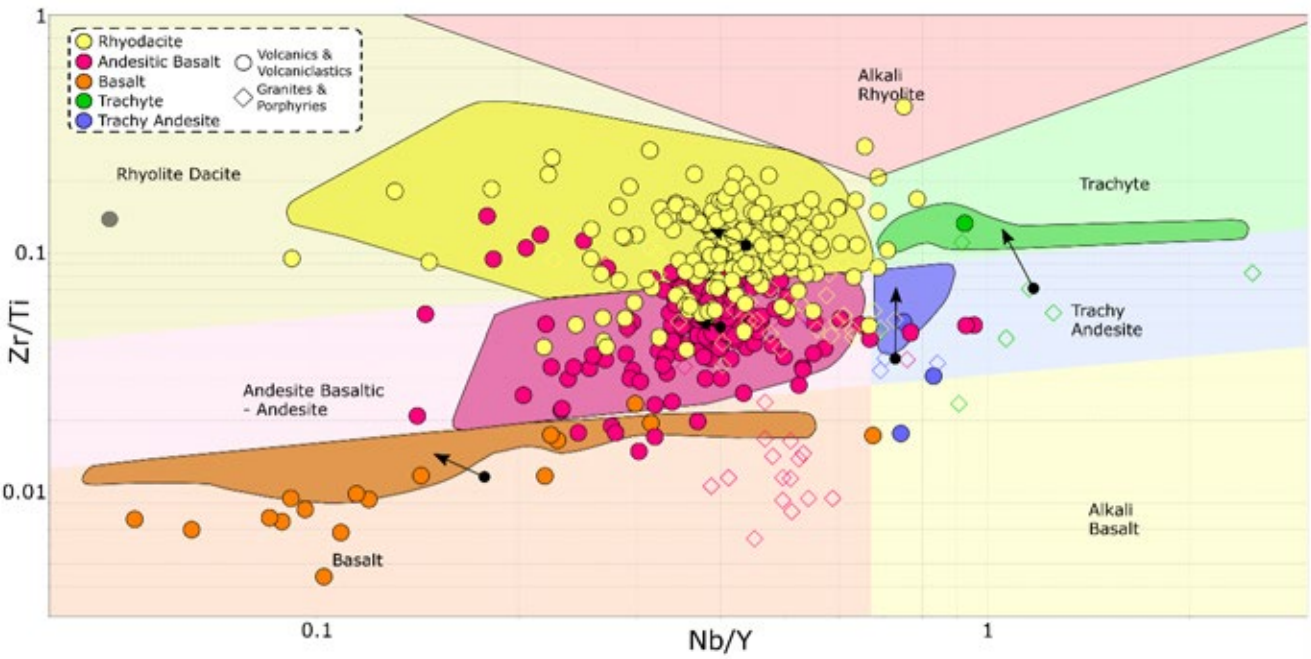
PEGMATITES AND PEGMATITE-RELATED ORES

Leader: Paul Davidson

Collaborators: Ulrich Recknagel, Adolf Rericha, Rainer Thomas

This initiative examines melt-melt immiscibility in felsic silicate melts, in the formation of pegmatites and pegmatite-related ore deposits. Pegmatites are noted for the presence of giant crystals, sometimes including rare minerals and gems, and are prime sources of several rare elements, even though their major element chemistry differs little from the standard haplogranitic melts, which are generally accepted to be their parental magmas. Therefore, it can be inferred that something in their origin favours extremely efficient partitioning, which would explain the high rare element concentrations (up to ore grade). Moreover, such processes need not be restricted to pegmatites, or even terrestrial processes.

More recently, the discovery in pegmatitic rocks of micro-diamond inclusions, some in minerals that only form at much greater depths than they were found, has important implications for the origin of pegmatite-forming



A figure taken from Zeb Zivkovic's PhD research showing volcanic rock classification after Pearce, 1996. Data coloured by Pearce classification from fusion data. Polygons represent classification extents in the fusion data. Black arrows represent the translation of the classification mean from the acid-digestion mean to the fusion mean.

melts. Such high- and ultra-high-pressure minerals and mineral inclusions implies extremely rapid transport from at least lower crustal depths. Published experimental work by various authors suggests that aluminosilicate melts formed at such depths has extraordinary abilities to dissolve fluids and metals, suggesting a new transport mechanism that may have wider implications in ore genesis.

In 2022, four papers were published as a consequence of our research, including 'Discovery of Stishovite in the Prismatine-bearing Granulite from Waldheim, Germany: A possible role of supercritical fluids of ultrahigh-pressure origin' by Rainer Thomas, Paul Davidson, Adolf Rericha and Ulrich Recknagel, which was published in *Geosciences*.

The other three papers, including one published by a Ukrainian scientific journal, are listed in the Publications section of this report.

VHMS RESEARCH – ANCIENT

Leader: Jonathan Cloutier

Team members: Mike Baker, Matt Cracknell, Charles Makoundi

Student: Zebedee Zivkovic

Collaborators: Shaun Barker, David Green, Scott Halley, Andrew McNeill

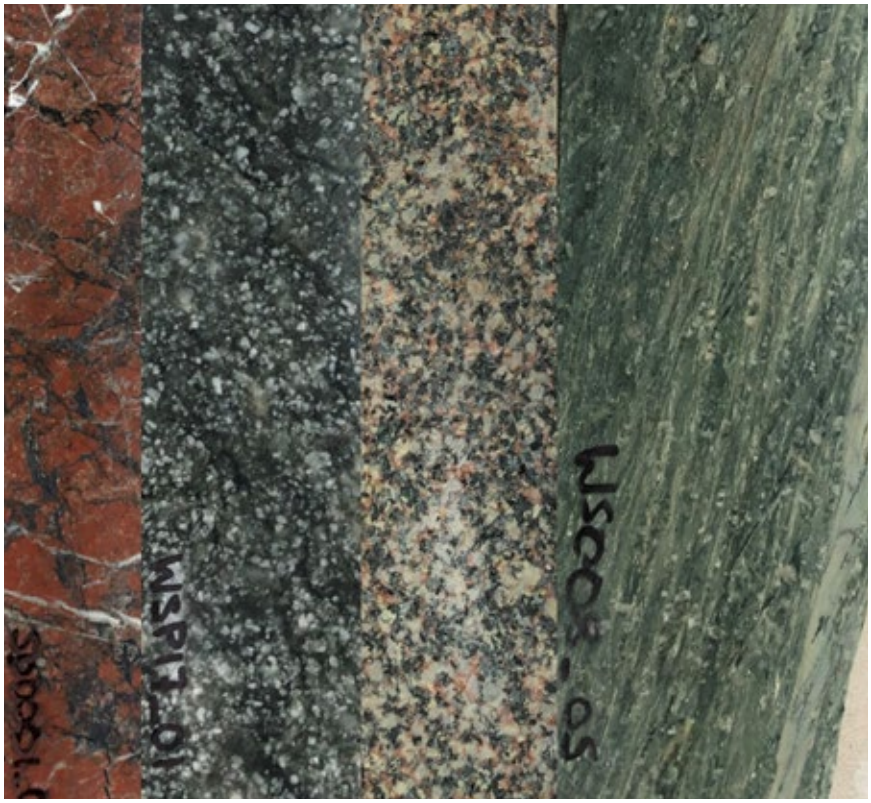
TASMANIA

Dr Mike Baker, Dr Matt Cracknell and Dr Shaun Barker (MDRU) are leading a project entitled 'Lithogeochemical fertility indicators for VHMS deposits' initiated in June 2019 as a Masters by Research, which was transferred to a PhD project in 2020, undertaken by candidate Zebedee Zivkovic. The project takes advantage of recent improvements in geochemical assay methods to produce a province-scale geochemical database classified by lithogeochemical rock-type and stratigraphy and includes two key parts. An initial study has been concluded on the effects of resistate mineralogy on multi-acid digestion datasets and the resultant lithogeochemical interpretation. The study reviewed fusion and acid digestions and found significant loss in recovery for Zr, Hf, Nb, Ta, Ti and Eu in the acid digestion; however, certain ratios including Nb(Ta)/Ti and Eu/Eu* preserved their lithogeochemical information despite significant under-reporting in individual elements. This was due to highly correlated under-reporting at a one-to-one ratio for certain elements which did not alter their respective ratios. Lithogeochemical interpretation using only acid digestion data produced more mafic and more alkaline rock compositions compared to the fusion data Additionally, fertility indicators such as Zr/Hf, Sr/Y and La/Yb would contain numerous false positives in the acid digestion data. This study has been published in *Geochemistry: Exploration, Environment, Analysis (GEEA)* and highlights the importance of using fit-for-purpose geochemical methods when undertaking lithogeochemical analysis. The second part of the study demonstrates how a mixed-acid/fusion dataset can be optimised by using Ti/Nb vs V/Sc scatterplots that are robust to resistate mineralogy and produce accurate rock compositions. A mineral prospectivity analysis is also demonstrated using this method by comparing the rock composition of the Rosebery deposit to the regional geochemical database to identify other potentially economically significant horizons.

In parallel with this work, as part of the transfer of the project to a PhD, is an Innovations Connections research collaboration (see page 46) with an industry partner with projects in the Yilgarn and Kimberley regions of Western Australia. In addition to whole-rock lithogeochemistry, work on these projects will also include mineral geochemistry of greenrock, pyrite and zircon indicator minerals from a variety of different mineralisation styles, rock types and ages.

By applying these methods to a variety of deposits, we can test the robustness of whole-rock and mineral prospectivity analysis techniques across a range of magmatic-hydrothermal mineralisation styles and geologic settings.

Dr Charles Makoundi (CODES/MRT) is continuing his work on downhole hyperspectral mineralogy and multi-element analysis to characterise the different types of alteration minerals downhole and their connections to the distribution of precious and base metals for the Mount Julia (Henty) deposit in the Mount Read Volcanic Belt. Dr Jonathan Cloutier (CODES/Geoscience Australia), University Associate Professor Khin Zaw (CODES), and Dr David Green and Dr Andrew McNeill (both MRT) are all involved in this study. Two mining companies, Catalyst Metals Limited (new owner) and Diversified Minerals Pty Ltd (prior owner), are supporting this project. The project continued its investigation of thermal-infrared mineralogy and will concentrate on quartz and plagioclase alteration.



Rocks analysed by CODES PhD student Zeb Zivkovic for his Mount Read Volcanics (MRV) study; these analyses can be used by researchers and mineral explorers to aid in the identification of rock composition and the lithostratigraphic relationships of unknown MRV rocks. They are (L–R): South Darwin, Central Volcanic Complex: hematite altered rhyolite with accessory magnetite-tourmaline and late quartz-carbonate veins. White Spur, White Spur Formation: feldspar-phyric andesitic volcaniclastic. Murchison Granite: sericite-chlorite altered, feldspar-biotite granite. West Sedgwick, Central Volcanic Complex: chlorite-sericite altered, foliated feldspar-phyric dacite.

To ascertain compositional variation and fluid evolution, a portion of the project will involve investigating the chemistry of pyrite and fluid inclusion.

▶ LOOKING FORWARD

In 2023, an ARC Discovery project to study submarine volcanism and its tsunamigenic effects will begin, led by Dr Martin Jutzeler with Associate Professor Rebecca Carey and other Chief Investigators from Australia, USA, Germany and New Zealand. We are looking forward to getting this project underway (see 'Sedimentary volcanology' above for further information).

In 2023 we are looking forward to publishing research carried out in collaboration with Dr Jane Barling, from Oxford University, which will provide the first evidence of zonation of a Kerguelen Mantle Plume.

The team is excited to welcome new postdoctoral researcher Yamila Cajal who is working with the Regional Research Collaboration (RRC); and new PhD students Vinicius da Cruz who will be working within the RRC project on the Rosebery Deposit with MMG; Billy Beas with a project called 'Mineral characterisation, halogen deportment and vectoring implications of the E44 porphyry Au-Cu system, Northparkes district, New South Wales, Australia'; and Axel Cima working on microinclusions in porphyry Cu deposits.

The team is also excited to welcome Honours student Madison Mulder in 2023. Madison will work with Rebecca, Karin and Sebastien with a focus on conducting geochemical and geochronological research on the recently discovered Louisiade Ophiolite, located south of the Solomon Islands. Madison's work will revolve around unravelling the age and tectonic setting of the Louisiade region over the past 55 million years. By utilising advanced analytical techniques and methodologies, Madison aims to gain a comprehensive understanding of the geological history and evolution of this intriguing ophiolite complex.

Looking ahead to 2023, our group has an exciting line-up of international conferences, workshops, and planned fieldwork. Overall, the group is poised for a productive and impactful year in 2023, with a strong focus on research, collaboration, and data collection to be in a position to deliver on research projects and celebrate PhD thesis submissions and graduations.

Program five: Analytical research

OBJECTIVES

- Analytical research underpins much of our most innovative research across the fundamental to applied spectrum
- New developments in analytical research generated by CODES Analytical Laboratories provide the basis for CODES' global leadership in micro-analytical techniques specifically applied to mineral exploration, U/Pb and Lu/Hf geochronology, mineral processing, ore genesis, igneous geochemistry and volcanology, and waste management.
- CODES Analytical Laboratories also provide analytical services to government, academia and industry.

Introduction

Program 5: Analytical research 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, advanced data-reduction algorithms and application of new 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, analytical data reduction, and the development of new, user-friendly software packages. In 2022, a significant proportion of research activities was focussed on developing U/Pb dating methods for rutile and garnet as well as Lu/Hf dating for garnet and other minerals.

The analytical projects using LA-ICP-MS include in-situ multielement analysis and imaging of element distribution within minerals; in-situ isotope analysis, focusing on a range of U/Pb and Lu/Hf dating applications; development of calibration standards; and technological developments aimed at improving the capabilities of the laser microprobes.

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

Highlights

Research

One publication on a method for U/Pb dating of rutile and garnet was published in 2022.

A paper on the development of reference material (STDGL3) for sulphide analysis by LA-ICP-MS was submitted for publication. Papers on epidote U/Pb dating and a method for analysing alunite are being prepared for publication.

Equipment

A LIBS attachment to one of the Resolution SE systems has been installed. One of the Agilent 7900 ICPMS instruments has been replaced with a new one.

CODES 2022 Analytical Laboratories staff pictured in the Newcrest Lab. They are (L–R): Back row: Al Cuison (Lapidary Manager); Michele Chapple-Smith (Lapidary Technician); Dr Paul Olin (Acting Leader, CODES Analytical Laboratories); Dr Ivan Belousov (Leader of Program 5). Front row: Fanghua Dai (Laboratory Analyst), Michelle Makoundi (Technical Officer), Dr Jeff Oalmann (Laboratory Analyst), Maxwell Morissette (Laboratory Analyst), Claire Rutherford (Administrative Support Officer).

Software

Three versions of LADR, a data reduction software for LA-ICP-MS analyses, were released throughout the year. The latest version significantly enhances handling of data reduction for U/Pb dating and capabilities for automatic integration interval selection.

Staff

The team welcomed Fanghua Dai as a Laboratory Analyst. She will be operating our solution ICP-MS lab, helping with running LA-ICP-MS analyses and performing analytical data reduction.

Professor Leonid Danyushevsky resigned in October 2022 from his role as the Leader of CODES Analytical Laboratories.

Conferences

No conference participation in 2022 due to COVID-19 restrictions.

Laboratory Analyst Fanghua Dai (left), who joined CODES in 2022, speaks with former CODES PhD student Dr Kit Lai from Fortescue Metals Group at the CODES Annual Review in November.

The program team

LEADER IVAN BELOUSOV

DEPUTY LEADER JEFFREY OALMANN

TEAM MEMBERS:

Matthew Cracknell, Fanghua Dai, Sebastien Meffre, Maxwell Morissette, Paul Olin (Acting Leader, CODES Analytical Laboratories)

PHD STUDENTS:

Axel Cima, Xin Ni Seow

PAST HONOURS STUDENT:

Kate Jenkins

COLLABORATORS:

AGILENT TECHNOLOGIES
Fred Fryer

CENTRAL SCIENCE LABORATORY, UTAS
Karsten Goemann

LAURIN TECHNIC
Michael Shelley

MOSCOW STATE UNIVERSITY, RUSSIA
Pavel Plechov

MDRU, CANADA
Shaun Barker

NORRIS SCIENTIFIC
Ashley Norris

UNIVERSITY OF ADELAIDE
Sarah Gilbert

UNIVERSITY OF BRISTOL, UK
Jon Blundy

UNIVERSITY OF KIEL, GERMANY
Dieter Garbe-Schönberg

UNIVERSITY OF MELBOURNE
Roland Maas

Projects

- Fundamentals of ICP-MS
- Fundamentals of laser ablation
- Calibration standards for LA-ICP-MS
- LA-ICP-MS instrumentation development
- U/Pb dating
- Lu/Hf dating
- LA-ICP-MS data reduction software
- Interpretation of LA-ICP-MS time-resolved signals

Project summaries

FUNDAMENTALS OF ICP-MS

Leader: Ivan Belousov

Team members: Maxwell Morissette, Jeffrey Oalmann, Paul Olin

Student: Xin Ni Seow

Collaborator: Fred Fryer

This project is aimed at better understanding the physical processes that occur in ICP-MS, in order to improve its performance and the range of applications for laser ablation.

The main focus in 2022 continued to be on improving our understanding of the influence of plasma conditions on quantification of analyses of different minerals. Development of methods for quantitative analyses of trace elements in minerals without using matrix-matched reference materials was continued. A paper describing the method for alunite is being prepared for publication. A study of rates of doubly charged species production for different elements has been started.

FUNDAMENTALS OF LASER ABLATION

Leader: Ivan Belousov

Team members: Maxwell Morissette, Jeffrey Oalmann, Paul Olin

Collaborators: Karsten Goemann, Ashley Norris, Michael Shelley

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

A publication describing the relationship between matrix composition, ablation rate and elemental fractionation is in preparation with submission planned for 2023.

CALIBRATION STANDARDS FOR LA-ICP-MS

Leader: Ivan Belousov

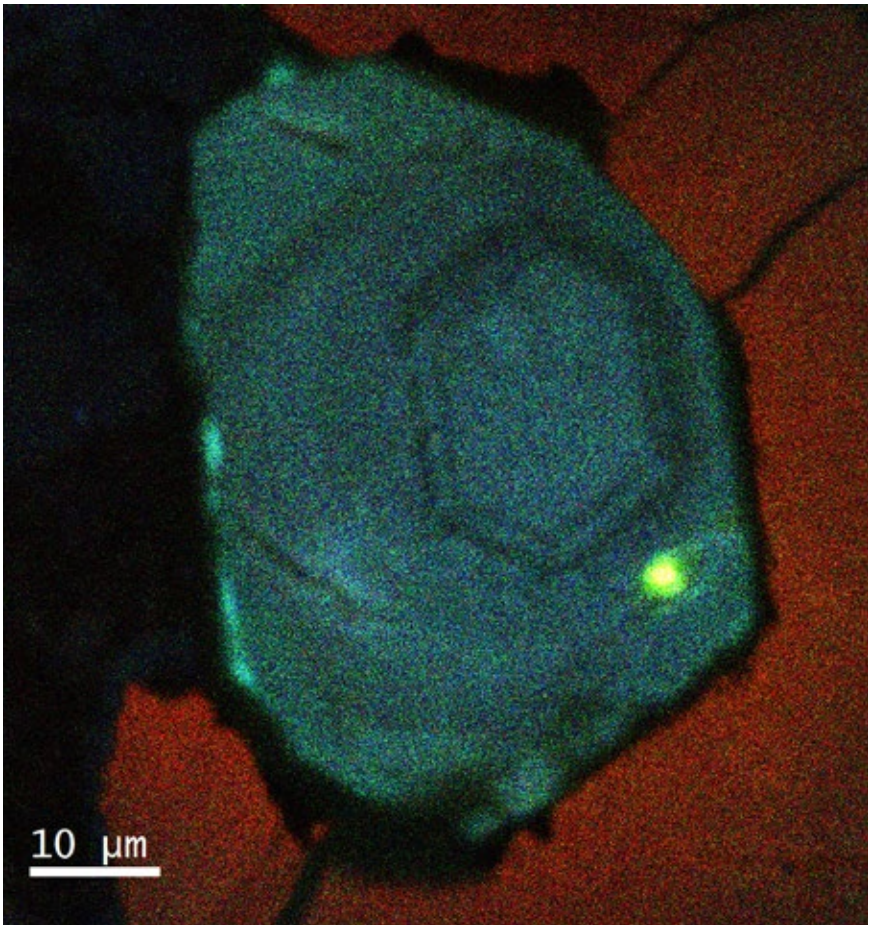
Team members: Maxwell Morissette, Jeffrey Oalmann, Paul Olin

Collaborators: Jon Blundy, Dieter Garbe-Schönberg, Karsten Goemann, Pavel Plechov

This project is aimed at the development and characterisation of new calibration reference materials for LA-ICP-MS analysis of various geological materials.

Calibration standard STDGL3 for sulphide analysis has been distributed to several more analytical laboratories worldwide. A manuscript describing this new reference material has been submitted for publication in *Geostandards & Geoanalytical Research*.

In 2022 collaboration continued with the University of Kiel, the University of Bristol and Moscow State University on reference material for plagioclase analysis by LA-ICP-MS and the use of pressed nanoparticle pellets as reference materials.



In-situ colour cathodoluminescence (CL) image of apatite grain. This technique is used for distinguishing between magmatic and hydrothermal apatite. Different zones could also be targeted by EPMA analysis for F, Cl and S contents and used for reconstruction of magma degassing history.

LA-ICP-MS INSTRUMENTATION DEVELOPMENT

Leader: Ivan Belousov

Team member: Paul Olin

Collaborators: Ashley Norris, Michael Shelley

This project tests, designs and develops new instrumentation to ensure continuing advances in geological LA-ICP-MS applications. Example developments include ablation cells, the interface between the laser and the mass-spectrometer and testing new types of laser microprobes and mass-spectrometers. In 2022 we continued to test the fast washout funnel for fast imaging using ICP-ToF.

U/PB DATING

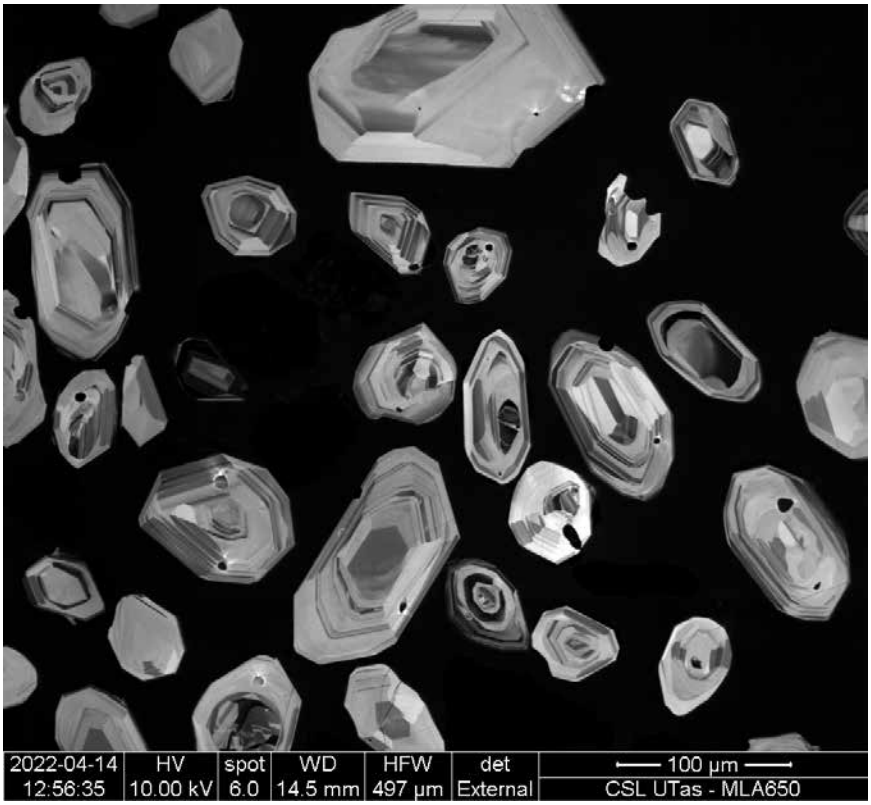
Leaders: Jeffrey Oalmann, Ivan Belousov

Team members: Maxwell Morissette, Kate Jenkins

Collaborator: Roland Maas

This project investigates the causes of limitations to U/Pb dating of minerals by LA-ICP-MS, with the aim of enhancing laboratory practices and instrumentation parameters to lower systematic errors and improve precision. Ongoing investigations for zircon, apatite, garnet, rutile, epidote and titanite are currently underway.

A paper on understanding the ablation behaviour of garnet and rutile and its impact on the accuracy and precision of U/Pb dating of these minerals has been published in *Geostandards & Geoanalytical Research*.



TOP: High-resolution SEM image of fine-grained precipitates. This technique is used for imaging of crystal shapes and carries no information about compositions. ABOVE: Cathodoluminescence image of zircon grains in a heavy mineral separate showing zonation and presence of inherited cores in some zircons. Such imaging provides information about crystallisation history of zircons and is often used for targeting of particular zones for U/Pb dating.

LU/HF DATING

Leaders: Jeffrey Oalmann, Paul Olin

Team members: Ivan Belousov, Maxwell Morissette

Collaborator: Sarah Gilbert

This project is aimed at method development for Lu/Hf dating of minerals using Agilent 8900 QQQ MS. Currently we are working on methods for garnet, apatite and monazite.

LA-ICP-MS DATA REDUCTION SOFTWARE

Leader: Jeffrey Oalmann

Team members: Ivan Belousov, Paul Olin

Collaborator: Ashley Norris

This project aims to develop comprehensive, user-friendly LA-ICP-MS data processing software, capable of:

- quantification of trace element and U/Pb dating 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 sulphides, silicates, phosphates and carbonates; and
- identification of mineral phases in, and sizes of, micro inclusions in minerals.

Activities in 2022 were directed towards improving algorithms for automatic integration interval selection and imaging elemental distributions in minerals. A software version with added capabilities for automatic integration interval selection has been tested. A new version of the software capable of processing images of elemental distributions is being developed.

INTERPRETATION OF LA-ICP-MS TIME-RESOLVED SIGNALS

Leader: Ivan Belousov

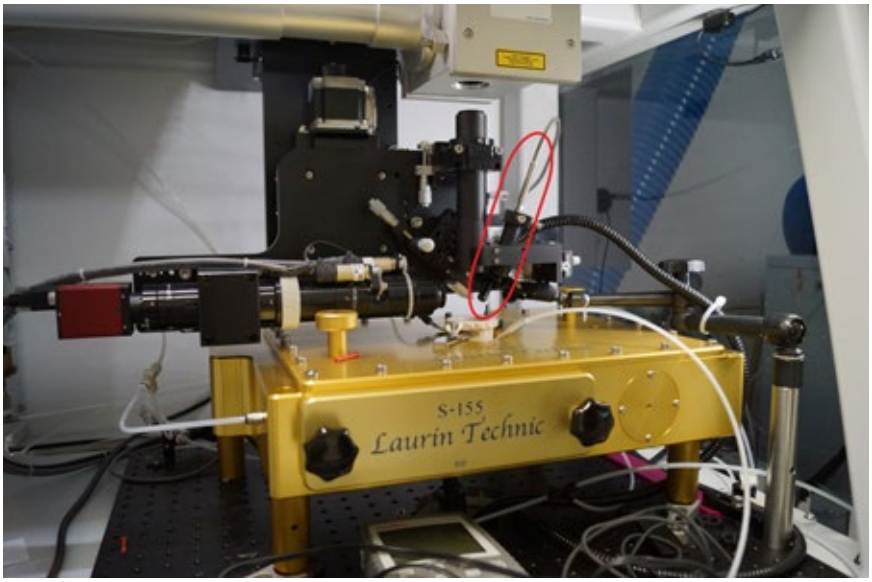
Team members: Matthew Cracknell, Sebastien Meffre

Student: Axel Cima

Collaborator: Shaun Barker

This project aims at developing algorithms for correct identification of mineral inclusion populations in LA-ICP-MS analyses. Such inclusions carry significant information about processes during formation of hydrothermal and magmatic minerals and their use could significantly improve our understanding of ore deposit formation and could be used in vectoring and fertility studies for a range of deposit styles.

During 2022 we have continued to improve algorithms for identification of micro-inclusions in time-resolved LA-ICP-MS signals from a range of minerals. A PhD project looking at the influence of micro-inclusions on vectoring and fertility assessment for porphyry Cu deposits was started in collaboration with the Amira P1249 team.



TOP: Recently installed Laser Induced Breakdown Spectroscopy (LIBS) addition to our LA-ICP-MS system. This technology captures optical emission of plasma produced during a laser shot. Highlighted in red is LIBS collection lens and optic fibre.
ABOVE: Applied Spectra LIBS spectrometer with six detectors covering a range of wavelengths from 190 to 1050 nm. This technology is sensitive to light elements and potentially could be used for measuring concentrations of halogens (F, Cl) – elements, which have high ionisation potential and are not readily measurable by LA-ICP-MS.

LOOKING FORWARD

The team will further develop its analytical research in 2023. Developments using Agilent 8900 QQQ, the LA-LIBS tandem system and ICP-ToF are expected to include:

- Use of Agilent 8900 QQQ MS for Re/Os dating of molybdenite, Rb/Sr dating of micas and S isotopic measurements for sulphides and sulphates.
- Investigating applicability of LA-LIBS systems for quantitative analysis of halogens and light elements in different minerals.
- Continued development of the application of ICP-ToF for imaging elemental distributions in minerals by LA-ICP-MS.

Program six: Geophysics and computational geosciences

▶ OBJECTIVE

This program addresses the challenges associated with technological advances in automated data acquisition and imaging methods across all aspects of the geosciences. It seeks solutions to issues associated with managing, processing, visualising and interpreting minerals industry datasets at all stages of the mining value chain from exploration to mining and mineral processing to waste management.

Introduction

Program 6: Geophysics and computational geosciences focuses on the applications of novel methods for data collection, data analysis, data integration, data-driven decision making, and visualisation. It includes a diverse range of projects researching three-dimensional geophysical interpretation, near surface and environmental geophysics, geodata analytics, data visualisation, exploration targeting and geoscience education. One of the unique aspects of Program 6 is that it contributes to all of the other CODES research programs, especially Program 2, via method development, data processing and analysis, and the interpretation and visualisation of results.

Modern minerals industry activities are undertaken in data-rich environments characterised by a wide range of quantitative and qualitative information. There have been significant recent advances in areas such as geophysical data acquisition, geophysical data processing and inversion, multi-element geochemical analyses, and a range of new optical and infrared imaging techniques. The challenge is to be able to effectively integrate these diverse data streams using new methods and workflows that can effectively transform data into information and knowledge. The ultimate aim of this data synthesis process is to facilitate more informed decision making at all stages of the mining value chain, from mineral exploration to extraction, processing and waste management.

Highlights

Thesis submissions and completions:

- Angela Rodrigues from Monash University graduated in mid-2022 for her PhD on machine-supported mineralogical interpretations from hyperspectral and geochemical datasets (linked to Amira P1202)
- Javier Merrill submitted his PhD thesis on the quantification of mineral textures for geometallurgical predictive modelling (linked to Program 2 and Amira P1202).
- Sibele Nascimento submitted her PhD thesis on the geoenvironmental characterisation of historical mine tailings (linked to Program 2 and TMVC)
- Karla Morales submitted her Masters thesis in early 2022 on geological predictors for preconcetration of Au-Cu ores (linked with Program 2 and CRC ORE)

Dr Michael Roach pictured on Mt Tarawera in 2022 whilst doing fieldwork in New Zealand with volcanology researchers Associate Professor Rebecca Carey and PhD students Hannah Moore and Acacia Clark.

- Daniel Fisher completed his Honours project, which included the use of near-surface geophysics to image fluid pathways and the internal structure of a tailings dam in northeast Tasmania (linked to Program 2 and MRT)

Publications and conference presentations:

- A description and evaluation of Javier Merrill's Mineral Co-Occurrence Probability Field (MCOPF) algorithm, published in *Minerals Engineering*
- Alex Farrar presented recent research on time series analysis of tectonic models and orogenic proxies related to process such as erosion rates and crustal thickening, at the Specialist Group for Tectonics and Structural Geology conference on King Island in November
- A summary of research outcomes from the 2020 Honours projects (including geophysical modelling) at the Endurance legacy mine site in northeast Tasmania was given by Clare Miller at the Goldschmidt conference in Hawai'i

Technology transfer opportunities through Amira P1249:

- Calculated mineralogy using pedras python package in June 2022
- Mineral texture clustering (MCOPF) python tutorial in November 2022

The program team

LEADER MATTHEW CRACKNELL
DEPUTY LEADER MICHAEL ROACH

TEAM MEMBERS:
David Cooke, Anya Reading (Physics)

PHD STUDENTS:
Stephen Cooke, Alex Farrar, Umer Habib, Richard Hill, Thomas Schaap

HONOURS STUDENT:
Daniel Fisher

COLLABORATORS:

FIRST QUANTUM MINERALS
Mike Christie, Tim Ireland

GHD
Wei Xuen Heng, Mathew Nicholls, Hugh Tassell

INSTITUTE OF MARINE AND ANTARCTIC STUDIES (IMAS)
Jacqueline Halpin, Joanne Whittaker

INSTITUTE OF MINE SEISMOLOGY
Gerrit Olivier

MINERAL RESOURCES TASMANIA
Daniel Bombardieri, Mark Duffett, Carol Steyn, Clint Siggins

UNIVERSIDAD AUSTRAL DE CHILE, CHILE
José Picquer

UNIVERSITY OF SOUTH AUSTRALIA
David Giles, Tom Raimondo

WESTERN MINING SERVICES
Jon Hronsky

Projects

Pathways to mineral discoveries through computer-based modelling of geochemical data

Integrating geology and geophysics for resources targeting

Geological visualisation and virtual education

Exploring the East Tennant region, Northern Territory

Project summaries

PATHWAYS TO MINERAL DISCOVERIES THROUGH COMPUTER-BASED MODELLING OF GEOCHEMICAL DATA

Leader: Matthew Cracknell

Team members: Michael Baker, Lejun Zhang

Student: Stephen Cooke

Stephen's project is embedded within the Amira P1249 research project and aims to further develop methods and techniques for ore deposit vectoring using geochemical data such as mineral chemistry and whole-rock analyses. His main focus is on the continued experimentation and development of the LocatOre software platform. LocateOre implements both knowledge-driven and data-driven methods for vectoring. The LocatOre knowledge-driven approach uses proximitor equations, first recognised in the Amira P765A research project, to identify the location of intrusive bodies associated with mineralisation. The data-driven approach uses a combined Monte Carlo and regression method to identify geochemical gradients in mineral chemistry data to highlight the location of intrusive bodies. While both methods are useful for vectoring, Stephen will be addressing problems around communicating model uncertainties resulting from limited numbers of samples and their potentially inadequate spatial distribution.

In late 2022, Stephen successfully completed his Confirmation of Candidature and provided updates on his research project to the Amira sponsors group. He also made good

progress with the modelling of sample spatial distributions and initiated experiments to test the efficacy of the LocatOre data-driven approach for vectoring. Stephen plans to release version 3.0 of LocatOre in mid-2023. This release will include major updates on a user's ability to interact with data and models and tools to better evaluate the robustness of outputs.

INTEGRATING GEOLOGY AND GEOPHYSICS FOR RESOURCES TARGETING

Leader: Matthew Cracknell

Team member: David Cooke

Student: Alex Farrar

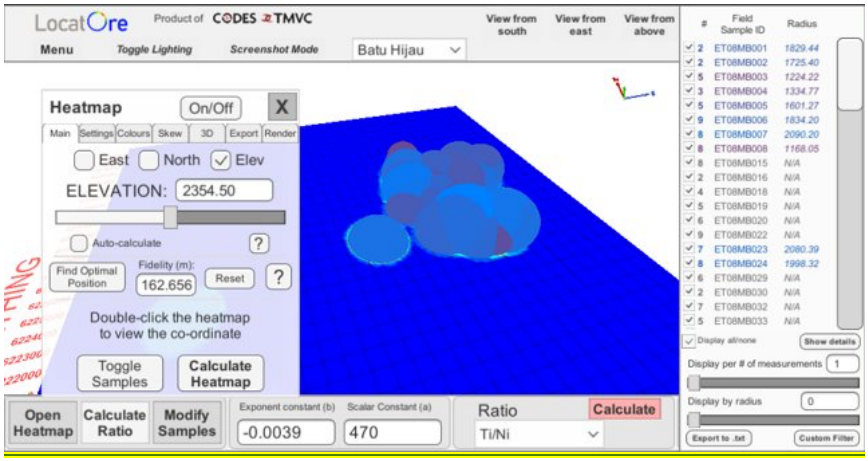
Collaborators: Mike Christie, Jon Hronsky, Tim Ireland, José Piquer

Dr Matthew Cracknell, the Leader of Program 6, is working on both the RRC critical metals and Amira P1249 projects.

CODES PhD student Alex Farrar, generously supported by First Quantum Minerals, is investigating the relationship between geodynamic and structural controls, in particular the intersections of deep-seated structural corridors, on the formation of giant porphyry copper deposits in the central Andes. The central Andes offers an excellent case study region due to its prolific metal production, well-documented geologic evolution and distinct spatial and temporal mineralisation events. Alex will use information that describes the location, timing, grade and structural setting of both economic and non-economic porphyry Cu deposits, combined with detailed structural mapping, GPlates tectonic models and spatio-temporal machine learning approaches to predict the localisation of giant porphyry camps.

In 2022, Alex completed an assessment of tectonic models of the western margin of South America against independent geochemical and chronological data as a means to assess model 'usefulness'. Alex also received the best student presentation at the Specialist Group in Tectonics and Structural Geology (SGTSG) conference on King Island for his talk on tectonic model comparisons using Granger causality analysis.

In the coming year, Alex plans to complete his spatio-temporal prospectivity model of giant porphyry copper deposits in the central Andes. This research forms the final component of his PhD thesis which he is planning to submit for examination around the middle of 2023. Good luck Alex!

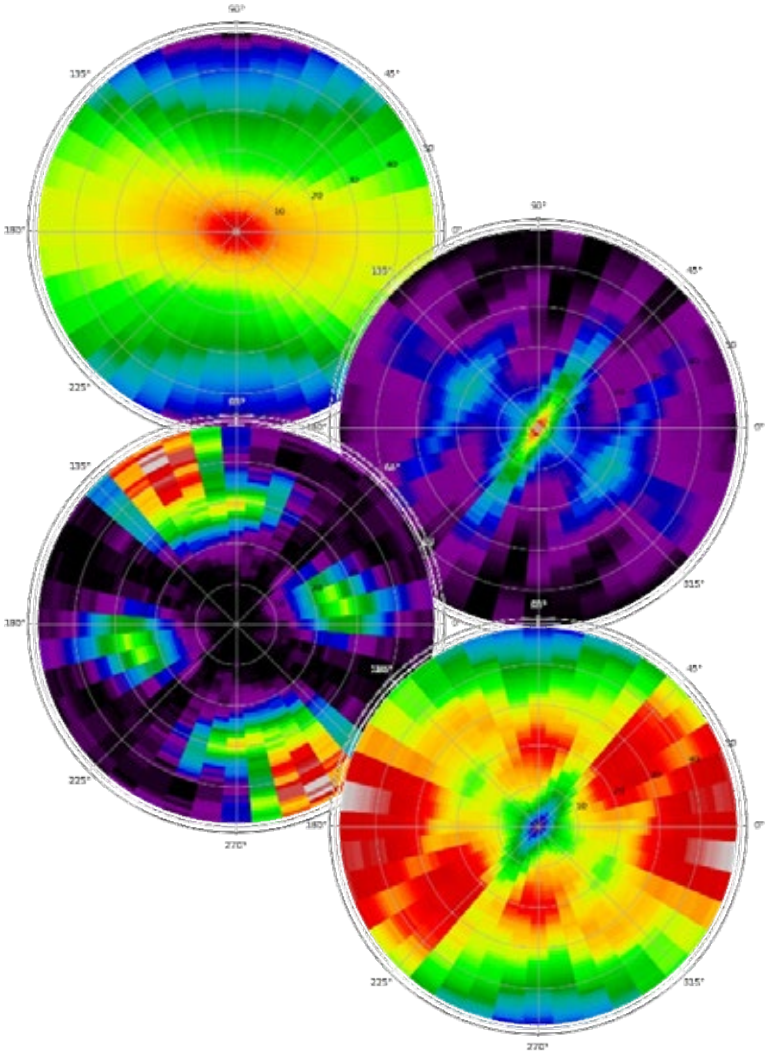


CODES PhD student Stephen Cooke is working on developments to the LocatOre software platform. This illustration shows an example of the LocatOre interface where users can generate 'heat maps' that search and highlight the model space for the most likely location of intrusions (heat and fluid sources) related to mineralisation.

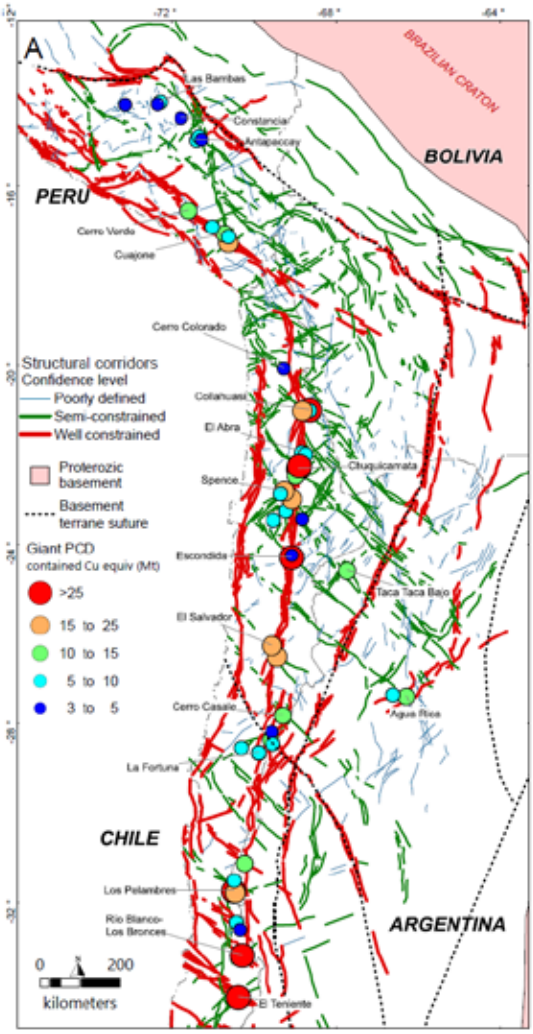
GEOLOGICAL VISUALISATION AND VIRTUAL EDUCATION

Leader: Michael Roach

In 2022 the focus of geological visualisation and virtual education was motivated by the generation of learning materials for use in undergraduate and postgraduate teaching programs and also professional education. During 2022, we continued to digitise rock samples from our teaching and research collections and these virtual objects have been made freely available through the online Sketchfab portal: https://sketchfab.com/search?q=ausgeol&sort_by=-publishedAt&type=models



Examples of the outputs of CODES PhD student Javier Merrill's Mineral Co-Occurrence Probability Field (MCOPF) algorithm, which allows users to quantify mineral texture as observed in drill core hyperspectral imagery. These outputs are then used to model the similarities between mineral textures for small sections of core, allowing the construction of drill core domains that can be used for tasks, such as 3D modelling and geometallurgical sampling. Javier submitted his thesis in November 2022.



Interpreted structural corridors across the central Andes – based on geophysical, volcanic and geological data and field observations by CODES PhD student Alex Farrar. This model will be used as a layer of information in Alex's model of giant porphyry copper deposit prospectivity in the central Andes.

EXPLORING THE EAST TENNANT REGION, NORTHERN TERRITORY

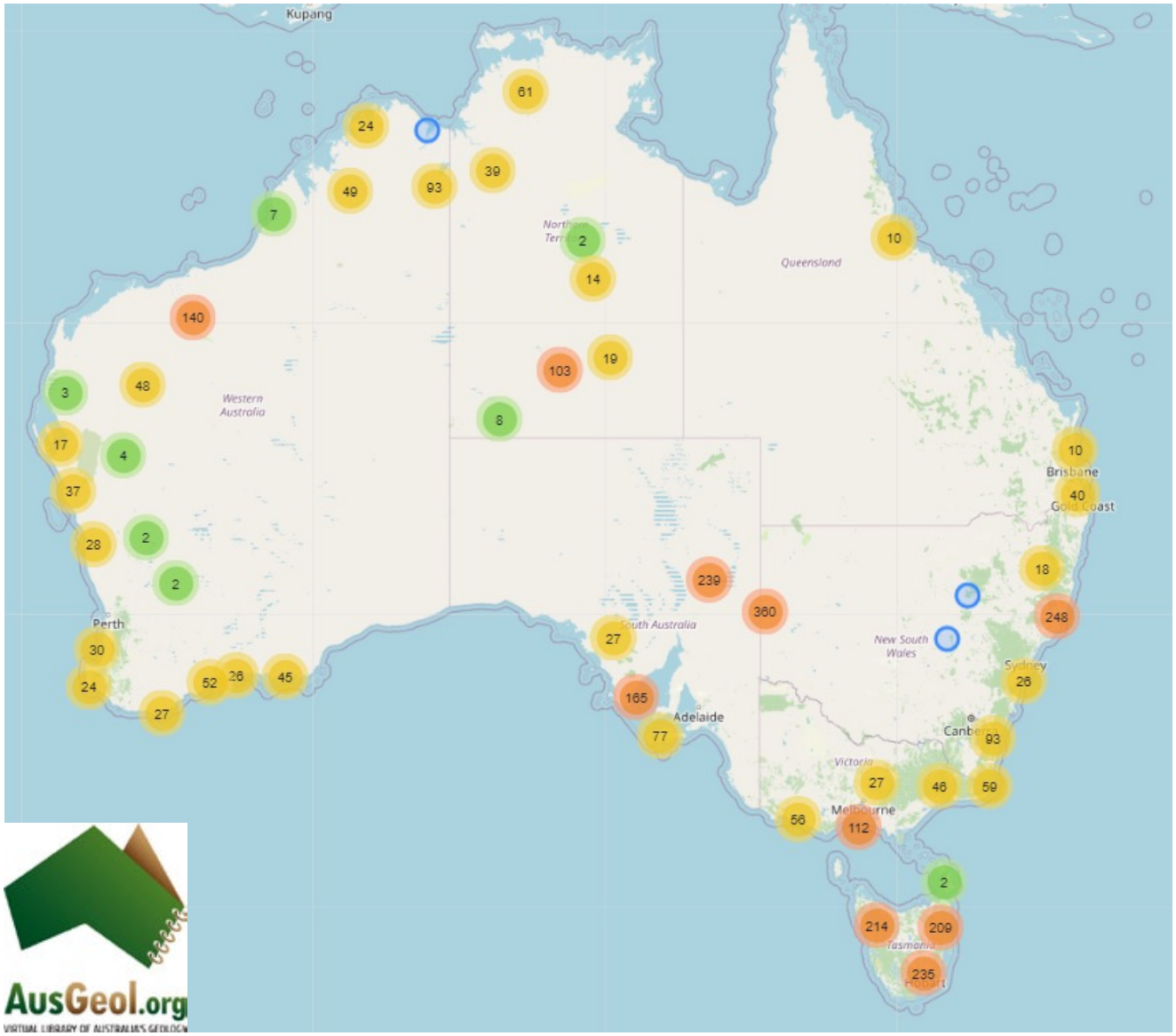
Leader: Rob Scott

Team members: Matthew Cracknell, Michael Roach

Student: Richard Hill

Collaborator: David Giles

CODES PhD student Richard Hill, supported by MinEx CRC, Strategic Energy Resources, Inca Minerals, Encounter Resources, Middle Island Resources and Datacode, is combining traditional geological and geophysical methods with data analytics and machine learning to understand the tectonic history and mineral potential of the East Tennant region of the NT. The East Tennant is an area of cover-obscured Proterozoic basement lying between the Tennant Creek mineral province in the NT and the Mount Isa mineral province in far NW Queensland. Geoscience Australia's 'Exploring for the Future' program identified crustal scale features in the area favourable for mineral systems, resulting in the follow-up collection of geophysical data and, in 2020, a ten-hole stratigraphic drilling program, run as a part of MinEx CRC's 'National Drilling Initiative'. Richard's work will focus on utilising the recently collected drilling and geophysical datasets, and a range of other datasets (including those of sponsor companies) to unravel the crustal architecture and tectonic evolution of this poorly understood region. To understand the 4D evolution of the area, 3D geological models will be made, consistent with the geophysical data and constrained by observations from drill holes. Structural/kinematic analysis will be performed, along with geochronology and thermochronology to provide a temporal framework. A geodata analysis approach will then be used to identify areas of high potential for mineral systems identified as being likely present in the area.



AusGeol visualisation sites which have been added to the Virtual Library of Australia's Geology by Dr Mike Roach; his work on this project continued throughout 2022.

▶ LOOKING FORWARD

In 2023, Program 6 will continue its involvement across many of the other CODES research projects. For example, Matt Cracknell is the Amira P1249 Module 2 leader and both he and Mike Roach will be involved in the Regional Research Collaboration (RRC) for Critical Metals project. Specifically, Mike Roach is producing his excellent virtural field tours, focussed on mine and mill operations at sites across Tasmania, e.g., Savage River and Kara Mine. Early in 2023, Program 6 will be welcoming several new postgraduate students for a number of projects, associated with Amira P1249.

Regional Research Collaboration

Project title: 'Building capacity in regional Australia to enhance Australia's economy through research, training, and environmentally sustainable production of critical metals'

OBJECTIVES

The main aims of the Regional Research Collaboration (RRC) project are to:

- Facilitate environmentally sustainable critical metals production in Tasmania.
- Grow UTAS' research capacity and capability through skills development.
- Improve student retention rates and grow the pool of job-ready graduates for the regions.
- Create sustainable long-term research partnerships.

Introduction

In May 2022 UTAS was granted $3.5 million from the Australian Government's RRC Program to fund a novel three-year collaborative partnership between researchers from CODES and the School of Education at the University of Tasmania and the Tasmanian minerals industry. The partnership enables UTAS to work with industry and government to investigate environmentally sustainable critical metals production and improve educational outcomes and regional job opportunities for communities in Tasmania's West Coast region. Nine Tasmanian industry partners supported the funding application, along with the Tasmanian Minerals, Manufacturing and Energy Council (TMEC) and Mineral Resources Tasmania (MRT). The research project will be known by its short title as 'Environmentally sustainable production of critical metals'.

Critical metals (including tungsten, cobalt, nickel, rare earth elements, indium and magnesium) are vital but scarce resources that society requires for modern technology, infrastructure and the transition to a renewable energy future. This project aims to provide new methods and approaches to critical metal processing from existing mines, and from legacy mine wastes leading to improved environmental outcomes.

The collaboration includes two partner academic institutions – the University of Queensland and the GeMMe research group at the Université de Liège (Belgium). The nine original industry partners are: Group 6 Metals (Dolphin mine on King Island), ABx Group (Deep Leads exploration project), Bluestone Mines Tasmania Joint Venture (Renison mine), Tasmania Mines (Kara mine), Mallee Resources (Avebury mine), GWR – Tasmanian Magnesium (Prospect Ridge), Copper Mines of Tasmania (Mt Lyell mine), Grange Resources (Savage River mine) and MMG (Rosebery mine). A tenth industry partner (Stellar Resources) will join the project in 2023.

The critical metals project is led by four Chief Investigators – three from CODES (Professor David Cooke, Dr Julie Hunt and Dr Lejun Zhang) and one from the

UTAS School of Education (Professor Sharon Fraser). Together they are leading a team of early- to mid-career academic and technical staff, and project-funded postdoctoral researchers in the three elements of the project.

Methodology

Students and postdoctoral researchers will spend several months on-site with the industry partners to collect samples, characterise critical metal occurrences, test new processes and workflows and help to address the objectives of the project. They will conduct laboratory research at CODES and, where appropriate, at the partner academic institutions. Funding for this project has enabled CODES to take on four new postdocs and nine PhDs, who will work alongside the nine industry partner companies, and an existing CODES PhD student (Chris Allen) has joined the project. An eleventh PhD student will work in the School of Education, researching ways in which place-based curricula can inspire young people's interest in learning STEM in school and beyond in the western Tasmanian mining communities.

The deposits that our researchers are examining in Tasmania for their critical metals potential include Devonian granite-related mineral systems at Renison Bell, Mt Bischoff and Severn; nickel at Avebury; tungsten at Dolphin and Kara; magnesium at Prospect Ridge, REE at Deep Leads, and by-product critical metals potential at the Cambrian polymetallic VHMS deposit at Rosebery; and the copper gold deposit at Mt Lyell. Extractable levels of critical metals such as antimony, bismuth, cobalt, gallium, germanium and indium may be found in these tailings and waste – and in new orebodies as well.

Research is focussing first on unearthing western Tasmania's considerable critical metals potential that lies in its existing mines, mine tailings and waste rocks. Understanding the deportment and reserves of critical metals in existing tailings and waste rock is key to unearthing new finds and helping Australia to become more self-sufficient in these resources, which will be vital for the future as the world transitions to a sustainable green energy future.

The announcement of $3.5 million in Australian Government funding for CODES and the UTAS School of Education took place on 1 May at the Kara mine (owned by Tasmania Mines Pty Ltd), south of Burnie. The funding for the 'Environmentally sustainable production of critical metals' project will enable UTAS to grow the state's important critical metals sector as well as educate and engage regional communities in the resource extraction process. Present were (L–R): Marcus Mollison (Tasmania Mines Pty Ltd), Senator Bridget McKenzie (then-Federal Minister for Regional Education), Gavin Pearce (Member for Braddon), Professor Sharon Fraser (UTAS School of Education), Professor David Cooke (Director of CODES) and Greg Coster (Tasmania Mines Pty Ltd).

Potential new industry partners are currently reaching out to expand our portfolio of critical metal resource in Tasmania including prospects of lithium and other battery metals. CODES is using analytical techniques such as automated mineral liberation analysis, X-ray fluorescence (XRF) and laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) to characterise the deportment of critical metals in fresh and weathered tailings at several sites.

Highlights

Ten new PhD students have been recruited from across the globe (nine within CODES, one within the School of Education), and together with one additional student who was already in the UTAS PhD program, will be carrying out research at the project's industry partner mine sites in Tasmania and on King Island, and with local mining communities. In addition, four new postdoctoral research fellows – Dr Yamilla Cajal, Dr Mohammad Fathi (both of whom will join us in 2023), and Dr Wei Hong and Dr Owen Missen – have been recruited to work on this three-year project alongside the three project leaders from CODES.

> **"Australia is seeking to grow its capacity in critical metal resource extraction and production to help meet these needs domestically"**
>
> **Professor David Cooke, Director of CODES**

CODES' research with the RRC project began in earnest in December with introductory field trips to Tasmania's west coast for new staff and PhD students to mine sites and exploration projects. The remaining PhD students plan to arrive early in 2023 when they will carry out individual field campaigns.

One of the great opportunities being provided by the RRC is the wealth of new geological data being provided through our new PhD studies. This is a major renewal of CODES' research into the geology and mineral resources of Tasmania, and we are excited to see the commencement of these PhD studies that will reveal the critical metals potential of many of Tasmania's most significant mineral resources.

The program team

LEADERS DAVID COOKE, JULIE HUNT, LEJUN ZHANG, SHARON FRASER (SCHOOL OF EDUCATION)




PROJECT MANAGER:

Helen Scott

TEAM MEMBERS:

CODES: Mike Baker, Ivan Belousov, Yamila Cajal, Rebecca Carey, Matthew Cracknell, Mohammad Fathi, Wei Hong, Sebastien Meffre, Clare Miller, Owen Missen, Sheree Armistead, Rob Scott, Jeff Steadman

CENTRAL SCIENCE LABORATORY:
Thomas Rodemann

SCHOOL OF EDUCATION:
Kim Beasy, Connie Cirkony

PHD STUDENTS:

CODES: Chris Allen, Alfredtina Appiah, Angela Costa, Vinicius Da Cruz, Jose Barillas Diaz, Musa Emmanuel Dogara, Nelao Natukondje Naimbale, Javier Gil Rodriguez, Arka Sahu, Emrecan Yurdakul

SCHOOL OF EDUCATION:
Jane Hall-Dadson

COLLABORATORS:

ABx GROUP LTD
Mark Cooksey

BLUESTONE MINES TASMANIA JOINT VENTURE PTY LTD
Mark Aheimer, Colin Carter, Brian Dalton, Esther Little

COPPER MINES OF TASMANIA PTY LTD
Geoff Cordery

GRANGE RESOURCES
Roger Hill, Ben Maynard, Nicholas van der Hout

GROUP 6 METALS LTD
Tim Callaghan, Keith McKnight, Rowena Murcott

GWR GROUP LTD (TASMANIAN MAGNESIUM PTY LTD)
Mick Wilson

MALLEE RESOURCES LTD
Tony Chisnall, Josh Denholm

MINERAL RESOURCES TASMANIA
Mark Duffett, David Green, Andrew McNeill, Clint Siggins, Carol Steyn

MMG AUSTRALIA LTD
Corey Jago, Don Macansh, Kevin Robinson

STELLAR RESOURCES LTD
Gary Fietz, Adam Frankcombe, Rebecca Lockley

TASMANIA MINES PTY LTD
Greg Doherty, Marcus Mollison

TASMANIAN MINERALS, MANUFACTURING AND ENERGY COUNTIL (TMEC)
Ray Mostogl, Vanessa Skipworth

UNIVERSITÉ DE LIÈGE, BELGIUM
Eric Pirard

UNIVERSITY OF QUEENSLAND
Rick Valenta

The project comprises three elements:

ELEMENT 1:

Unlocking critical metal resources – developing characterisation and deportment toolboxes and workflows for effective resource evaluation and improvements to waste management.

ELEMENT 2:

Pathways to production – address barriers to cost-effective critical metal production including issues with crushing and grinding, separation of critical metals from gangue, and efficient energy use.

ELEMENT 3:

Education and engagement – devise innovative solutions to community-based barriers that affect engagement in STEM and limit the growth of the STEM-capable workforce needed for critical metals production in regional areas.

Project summaries

ELEMENT 1: UNLOCKING CRITICAL METAL RESOURCES – DEVELOPING CHARACTERISATION AND DEPORTMENT TOOLBOXES AND WORKFLOWS FOR EFFECTIVE RESOURCE EVALUATION AND IMPROVEMENTS TO WASTE MANAGEMENT

CODES students and staff working on the RRC critical metals project survey the Mt Lyell Cu-Au mine site in western Tasmania during a December 2022 familiarisation tour of the West Coast.

CHARACTERISATION OF W MINERALISATION AT GRASSY, KING ISLAND, TASMANIA – IMPLICATIONS FOR ORE GENESIS, EXPLORATION, AND PATHWAYS TO PRODUCTION

Leader: David Cooke

Team members: Julie Hunt, Lejun Zhang, Yamila Cajal

PhD student: Angela Costa

Collaborators: Keith McKnight, Tim Callaghan, Rowena Murcott (Group 6 Metals Ltd)

This PhD study will characterise the geology, alteration and mineralisation of the Dolphin W deposit, Grassy, western Tasmania, through drill core logging, paragenetic and laboratory investigations. Ore and gangue mineralogy will be determined using petrographic, SWIR and geochemical analyses (SEM; MLA). Critical metal deportment in ores and gangue phases will be constrained through LA-ICP-MS to help optimise mineral processing options. Deportment of other metals of value (e.g., Mo) will also be assessed to evaluate geological controls on their distributions and to determine whether there is potential for by-product metal production from ores or wastes. LA-ICP-MS trace element analyses (e.g., garnet, pyroxene, carbonates, epidote, chlorite) will be tested to evaluate their potential for aiding mineral exploration in the district. A refined genetic and exploration model for W mineralisation on King Island will be proposed.

CHARACTERISATION OF COMPLEX OREBODIES IN THE SOUTHERN PART OF THE ROSEBERY–HERCULES DISTRICT, WESTERN TASMANIA

Leader: David Cooke

Team members: Lejun Zhang, Rebecca Carey, Wei Hong, Yamila Cajal

PhD student: Vinicius Da Cruz

Collaborators: Don Macansh, Corey Jago, Kevin Robinson (MMG Australia Ltd)

This PhD project will characterise the complex orebodies and volcanic-sedimentary succession at the southern end of the Rosebery mine with a focus on evaluating the potential for critical metals exploration in the district. Individual goals are: (1) Understand the stratigraphy and alteration of the Cambrian primary mineralisation and Devonian overprint mineralisation; (2) Characterise the Devonian mineralisation regarding its ore and gangue minerals; (3) Test and develop geological and geochemical constraints and vectors for the orebodies at southern Rosebery mine; (4) Assess the potential for critical metals in these complex orebodies. These aims will be achieved by (1) Compilation of data from previous research; (2) Graphical core logging with a focus on lithofacies and alteration paragenesis; (3) Petrographic investigations of representative facies and ore assemblages; (4) Geochemical analysis (e.g., mineral elemental mapping using LA-ICP-MS); (5) Combination of results from the previous methods with geochemical assay data and geological model from the mine database.

At the local to regional scale, the expected outcomes are a refined knowledge of the geology and mineralisation of the Rosebery district, especially regarding the Devonian metasomatic event and its potential for the development of high-grade orebodies and/or critical metals mineralisation. On a more holistic basis, this research will contribute to the understanding of complex VHMS systems affected by deformation and post-mineralisation hydrothermal events.

CHARACTERISATION OF THE HEEMSKIRK TIN PROJECT, ZEEHAN, WESTERN TASMANIA

Leader: David Cooke

Team members: Wei Hong, Robert Scott

PhD student: Nelao Natukondje Naimbale

Collaborators: Gary Fietz, Adam Frankcombe, Rebecca Lockley (Stellar Resources Ltd)

The Heemskirk tin project contains Australia's largest undeveloped tin resource and is located at Zeehan, western Tasmania. The project is 100% owned by Stellar Resources Ltd and comprises four deposits: Severn,

Recently arrived CODES PhD students take notes at the Avebury core shed during the December 2022 West Coast familiarisation trip for RRC critical metals project team members.

Queen Hill, Montana and Oonah. Mineralised veins are hosted in deformed quartzites, shales and siltstones of the Proterozoic Oonah Formation and clastic and volcaniclastic rocks of the Cambrian Crimson Creek Formation. Mineralisation occurs primarily as fine-grained cassiterite, mainly associated with pyrite and pyrrhotite veins, veinlets, stockworks, disseminations and breccia lodes. Mineralisation appears to be structurally controlled by NW-trending faults that transcend the deposit areas and deformed the meta-volcanic and meta-sedimentary rocks. The focus of this PhD project is to characterise the stratigraphy and structure of the Heemskirk project to aid near-mine exploration, to improve orebody knowledge through detailed geological and mineralogical characterisation and evaluate the potential for discovery and/or recovery of critical metals from the mineralised structures. To resolve these research questions, detailed core logging will be carried out to better understand the stratigraphy and its influence on structurally controlled Sn mineralisation. Alteration assemblages will be mapped during field core logging and by using hyperspectral techniques. LA-ICP-MS analyses will be used to determine critical metal deportment in sulphide minerals and cassiterite to better understand and optimise mineral processing options. LA-ICP-MS trace element analyses of accessory sulphides and gangue minerals will be tested to evaluate their potential for aiding mineral exploration.

CHARACTERISATION OF THE AVEBURY NICKEL DEPOSITS, ZEEHAN, WESTERN TASMANIA

Leader: David Cooke

Team members: Lejun Zhang, Yamila Cajal

PhD student: Jose Barillas Diaz

Collaborators: Tony Chisnall, Josh Denholm (Mallee Resources Ltd)

This PhD research project will characterise the geology, alteration, mineralisation, paragenesis, geochemistry and geochronology of the Avebury Ni deposit, western Tasmania, through drill core logging, surface-underground mapping, and advanced analytical laboratory techniques. Ore and gangue mineralogy will be determined using petrographic, SWIR and geochemical analyses (SEM; MLA; electron microprobe). Nickel deportment in sulphide and silicate minerals will be constrained through detailed LA-ICP-MS analyses to help optimise mineral processing options. Cobalt deportment will also be assessed to evaluate geological controls on its distribution and to determine whether there is potential for by-product Co production. The alteration will be identified in clay minerals using NIR (SWIR) and Raman spectroscopy mineral mapping. In conjunction with structural mapping, arsenic deportment will be assessed to determine the geological and paragenetic controls on arsenic distribution and to evaluate whether domains of elevated arsenic can be effectively identified, predicted and managed during mining and mineral processing. LA-ICP-MS trace element geochemistry analyses ± U-Pb dating of gangue minerals (e.g., garnet, calcite, magnetite, titanite) will be tested to evaluate their potential for aiding mineral exploration. A genetic model for the Avebury Nickel deposit will be proposed and implications for Ni-Co-PGE mineralisation prospectivity in western Tasmania will be outlined.

CHARACTERISATION OF RENISON BELL TIN DEPOSIT, WESTERN TASMANIA

Leader: David Cooke

Team members: Wei Hong, Owen Missen

PhD student: Javier Gill Rodriguez

Collaborators: Colin Carter, Mark Aheimer, Esther Little (Bluestone Mines Tasmania Joint Venture Pty Ltd.)

To address global supply issues, growth in critical metal resources and advances in their extraction technologies are required. Tasmania's skarn and carbonate replacement deposits have the potential to contribute significantly to growth in critical metals inventory. Renison Bell in western Tasmania is Australia's largest Sn producer, with potential for by-product Cu production. However, the potential for recovery of other critical metals such as In, Co or Ni from ores, gangue and/or waste, or discovery of other granite-related critical metal resources such as W, Nb or Ta in the district is yet to be explored. This characterisation-based PhD research project aims to aid near-mine exploration and improve orebody knowledge at Renison, in order to assist discovery of additional Sn resources, and to evaluate the potential for discovery and/or recovery of critical metals. This will be achieved by improving and updating orebody knowledge of Renison through detailed geological, mineralogical, and geochemical characterisation, applying innovative geochemical and hyperspectral exploration techniques for vectoring and fertility assessments, and assessing critical metal deportment through detailed geochemical and textural analyses.

OREBODY KNOWLEDGE OF THE WESTERN THARSIS CU-AU DEPOSIT, TASMANIA

Leader: Lejun Zhang

Team members: Mike Baker, Rob Scott

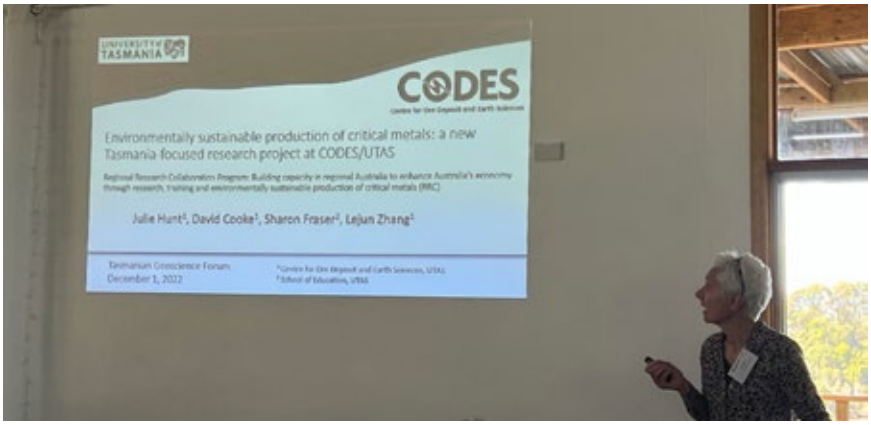
PhD student: Emrecan Yurdakul

Collaborator: Geoff Cordery (Copper Mines of Tasmania Pty Ltd)

The Western Tharsis Cu-Au deposit (12.4 Mt indicated and inferred resource, avg. 1.3% Cu-0.3 g/t Au) is one of the major unmined deposits in the Mount Lyell district, and is hosted by the Central Volcanic Complex of the Mount Read Volcanics. The orebody is steeply dipping and overturned, and is approximately 300 m long, 150 m thick and has over 1,000 m vertical continuation starting from 20 m below surface. Pyrite-bornite assemblages replaced pyrite-chalcopyrite and are accompanied by quartz, white mica and/or pyrophyllite. The main research objectives of this PhD study are to characterise the paragenesis, timing, style of mineralisation and associated alteration at Western Tharsis, and to provide a detailed geologic, exploration and geometallurgical model of the deposit. This will help to optimise mine planning, develop deposit specific exploration tools, and to understand relationships between Western Tharsis and regional tectonic and magmatic processes in the Mount Read Volcanics. The key research questions are as follows: (1) What are the mineralogical, textural and geochemical characteristics of the various alteration and mineralisation assemblages at Western Tharsis? (2) What is the timing of hydrothermal alteration related to ore deposition? (3) What are the geological and geochemical vectors to mineralisation? (4) What are the metallurgical characteristics of the major ore zones? (5) What are the main local and regional geological controlling factors in the formation of Western Tharsis and how do these compare with other deposits within the Mount Lyell district, and more broadly throughout the Central Volcanic Complex of the Mount Read Volcanics? Cobalt is enriched in pyrite at Western Tharsis, and so a component of this research will evaluate whether this critical metal can be recovered effectively from the Western Tharsis orebody.

David Cooke, Lejun Zhang, Yamila Cajal and Wei Hong using a portable UV-light torch to confirm scheelite veins within magnetite-epidote skarn at Kara mine, northwest Tasmania. This photo was taken by Owen Missen and entered in the 2022 CODES Photo Competition.

ELEMENT 2: PATHWAYS TO PRODUCTION – ADDRESS BARRIERS TO COST-EFFECTIVE CRITICAL METAL PRODUCTION INCLUDING ISSUES WITH CRUSHING AND GRINDING, SEPARATION OF CRITICAL METALS FROM GANGUE, AND EFFICIENT ENERGY USE



Dr Julie Hunt, leader of the RRC critical metals project's 'Element 2: Pathways to production', speaking about upcoming research within the project at the Tasmanian Geoscience Forum held at Tullah in December 2022.

PATHWAYS TO PRODUCTION – MAGNESITE DEPOSITS AT PROSPECT RIDGE, NORTHWEST TASMANIA

Leader: Julie Hunt

Team members: Owen Missen, Mohammad Fathi, Lejun Zhang

PhD student: Alfredtina Appiah

Collaborator: Mick Wilson (GWR Group Ltd (Tasmanian Magnesium Pty Ltd))

The Prospect Ridge exploration tenement encompasses the Arthur River and Lyons River magnesite deposits in the Arthur Lineament of NW Tasmania, a high strain zone that is 5–10 km wide and 110 km long, comprised of Cambrian metamorphosed rocks. The magnesite deposits within the Arthur Lineament are yet to be mined and have not been fully defined. This PhD thesis will evaluate pathways to production for magnesite concentrates from Prospect Ridge, including the Arthur River and Lyons River Mg deposits in the northern part of the Arthur Lineament. The local geology, alteration and mineralisation will be characterised through drill core logging, paragenetic and laboratory investigations. Ore and gangue mineralogy will be determined using petrographic, short-wave infrared (SWIR) and geochemical analyses. Magnesium deportment will be constrained through detailed LA-ICP-MS to help optimise mineral processing options. Simple field- and/or laboratory-based tools will be tested and applied to assist with domaining high-grade magnesite and discriminating it from visually similar dolomite, calcite and ankerite. Deportment of other metals of value (e.g., Cu, Au, Fe) in the adjacent rocks will also be assessed to evaluate geological controls on their distributions and to determine whether there is potential for by-product metal production in the tenement. Opportunities for blending wastes from Prospect Ridge with other mine wastes in western Tasmania will be evaluated to establish whether there are opportunities to improve environmental management of acid drainage at other mine or legacy sites.

RECOVERY OF CRITICAL METALS FROM LEGACY MINE WASTE FACILITIES – SAVAGE RIVER FE DEPOSIT, NORTHWEST TASMANIA

Leader: Owen Missen

Team members: Julie Hunt, Mohammad Fathi

PhD student: Pratichee Mondal

Collaborators: Ben Maynard, Roger Hill, Nicholas van der Hout (Grange Resources)

This PhD research project will focus on geoenvironmental and geometallurgical characterisation of waste rocks to aid opportunity recognition and decision making on the pathway to closure. It aims to assist in optimise recovery of critical metals from legacy mine waste at Savage River while in turn also reducing the environmental impacts of legacy wastes by improving mine waste characterisation to inform mineral processing and waste management. This PhD project is scheduled to commence in late 2023.

PATHWAYS TO PRODUCTION – KARA W-FE MINE, NW TASMANIA

Leader: Julie Hunt

Team members: Mohammad Fathi, Owen Missen

PhD student: Musa Emmanuel Dogara

Collaborators: Greg Doherty, Marcus Mollison (Tasmania Mines Pty Ltd)

To address global supply issues, growth in critical metal resources and advances in their extraction technologies are required. Kara in northwestern Tasmania has substantial critical metal resources such as scheelite (W) with the potential to contribute significantly to growth in critical metals inventory. Extraction of critical metals from ores and waste materials can be challenging and pose potential barriers to cost-effective recovery that need to be addressed. These include potential issues with crushing and grinding, separation of critical metals from gangue, and efficient energy use. Consequently, it has become imperative to rationalise technological schemes of sustainable mineral processing with due consideration to reducing environmental impact, energy and cost. The aim of this research is to develop sustainable pathways to tungsten production for the Fe-W skarn-type deposits at Kara mine. The objectives include: (1) Rock characterisation of representative samples to identify lithology, alteration and mineralisation using drill core

logging, petrophysics, rebound hardness, geochemistry and X-ray diffraction; (2) Detailed petrographic and geochemical characterisation of ore and gangue minerals focussed on critical metal deportment, liberation and association; (3) Evaluation of processing methods currently used on-site for W-bearing ore, using bench-scale tests to assist optimisation of critical metal recovery for different domains/ore types; (4) Assessment of the feasibility of using other techniques, not currently used on site, to help improve extraction, concentration and saleability of products; and (5) creation of characterisation and testing workflows based on the outcomes of the research to optimise critical metals recovery and sustainable/optimal use of the orebody.

The Savage River iron ore processing plant operated by Grange Resources: here CODES PhD students and staff are being shown the magnetite mineral processing circuit.

OPTIMISING REMEDIATION OF LEGACY MINES – MINERALOGICAL CONTROLS ON LONG-TERM WASTE ROCK WEATHERING AND MINE DRAINAGE

Leader: Sebastien Meffre

Team members: Matthew Cracknell, Clare Miller, Owen Missen

PhD student: Chris Allen

Collaborators: Mark Duffett, Clint Siggins, Carol Steyn (all MRT); Brian Dalton (Bluestone Mines)

Characterisation of mine wastes through lab- and field-based tests is now standard practice in the initial stages of mine closure. However, there is insufficient knowledge about how exposure and weathering may influence mine wastes in the medium-term (i.e., ~10 years). Previous studies have indicated the importance of secondary mineral formation on leachate chemistry. However, most studies typically consider only the weathering of recently extracted rocks or deeply weathered waste rocks rather than investigating both fresh and weathered materials to understand how weathering and exposure affects mineralogy, surface area and texture, grain size, and metal(loid) deportment. The Happy Valley Waste Rock dump at Mount Bischoff has been exposed to the effects of weathering over a 10–12-year period. This provides an excellent opportunity to study the progression of weathering and changes in mineralogy, surface area and texture, grain size and metal deportment on rocks exposed to weathering for a known amount of time without requiring long-term column or barrel tests in addition to having the ability to study relatively fresh materials of the same lithology. This PhD study commenced in early 2022 and is integrating geophysical studies of the waste rock pile with geochemical studies of waste products and benchtop testing to evaluate the evolution of mine wastes at Happy Valley, and to evaluate options for future waste management.

> **"The Regional Research Collaboration is a significant project from both its research aims and the number of researchers and HDR students focussed on Tasmanian critical elements research"**
>
> **Dr Owen Missen, CODES Research Fellow in Environmental Geochemistry and Mineralogy.**

ELEMENT 3: EDUCATION AND ENGAGEMENT – DEVISE INNOVATIVE SOLUTIONS TO COMMUNITY-BASED BARRIERS THAT AFFECT ENGAGEMENT IN STEM AND LIMIT THE GROWTH OF THE STEM-CAPABLE WORKFORCE NEEDED FOR CRITICAL METALS PRODUCTION IN REGIONAL AREAS

ADDRESSING REGIONAL BARRIERS TO ENGAGEMENT IN STEM – EDUCATION AND OUTREACH STRATEGIES RELATING TO CRITICAL METALS PRODUCTION

Leader: Sharon Fraser (School of Education)

Team members: Kim Beasy, Connie Cirkony, David Cooke

PhD student: Jane Hall-Dadson

As Australian society responds to climate and social challenges we need to continue to develop new technologies and a skilled workforce with more STEM graduates and increasing numbers of STEM-qualified workers. Complicating our technology development is a need for significantly more critical minerals for the energy, transport, telecommunication and medical sectors. Global demand for

View of the southern open pit at the Savage River iron ore mine in western Tasmania; the RRC project will be researching the optimisation of critical metals recovery from legacy mine waste at Savage River.

these metals and minerals is increasing while their supply is potentially unstable. Australia is well situated to supply a number of these minerals, with the potential for significant economic benefits, but mining sectors are also suffering from workforce supply issues. Local industry bodies are keen to partner with CODES and there is a growing body of evidence suggesting that place-based learning and industry partnerships are a potential pathway to improved STEM teaching and increased persistence in STEM that could contribute to a solution to the STEM worker supply issues.

This PhD study aims to strengthen partnerships between industry, schools and communities to support STEM education and engage regional students, in order to build STEM capital and enhance students' STEM identities, hence prolonging their STEM education. Specifically, this project aims to: 1) Use a STEM capital and identity lens during evaluation and analysis of the STEM capital held by students in regional mining communities; 2) Add to the knowledge of place-based STEM and the formation of effective partnerships between school and industry groups, ultimately producing a model for effective STEM education partnerships; and 3) Describe how place-based STEM programs affect STEM capital and STEM identities for students in regional mining communities.

To achieve these aims, the following objectives will be completed:
1) Engage with schools and industry to determine who and how to work together to develop place-based STEM Learning Sequences; 2) Survey students to determine the extent of their STEM capital and STEM identity; 3) Work closely with RMC teachers to co-plan STEM learning sequences that utilise industry resources with input from community, industry and/or CODES personnel; 4) Evaluate the impact of the resultant programs on the teachers, students and families who were involved.

Participants on the western Tasmania RRC orientation trip in December 2022 explore an old mine tunnel in the Mount Lyell mining district.

One of the RRC project leaders, Dr Lejun Zhang (left), and PhD Student Emrecan Yurdakul return from examining the mineralogy of one of many altered, pyrite-rich outcrops at Mount Lyell during the December 2022 West Coast orientation trip.

Training and education




LEADERS REBECCA CAREY, MATTHEW CRACKNELL, ROBERT SCOTT AND MARTIN JUTZELER

▶ OBJECTIVES

- Produce world-class PhD, Masters and Honours geoscience graduates.
- Deliver a range of professional development short courses and workshops tailored to the needs of the minerals industry.

Introduction

CODES has an international reputation for excellence in postgraduate education, which includes providing students with a comprehensive grounding in the Earth Sciences. Students come from all over the world to study at CODES, with many graduates progressing to senior roles in the minerals industry, state and federal governments, and academia.

Training and education activities also play a vital role in CODES' research across our six research programs. Training and education at CODES includes the Higher Degree by Research (both PhD and Masters of Research), Master of Economic Geology and Honours programs. CODES also runs a variety of one-off short courses and workshops (online and/or face-to-face). These short courses and workshops provide our students with diverse new skills critical to their research, in addition to those which are aimed at re- and up-skilling minerals industry professionals (see the 'Technology transfer' section in this report for details about these short courses and workshops).

Highlights

In 2022 there were four PhD and two Masters graduations at CODES. Umer Habib graduated in May 2022 and is working for Zenith minerals as a lithium explorer. Jennifer Thompson graduated in May and is working at WSP in Denver. Tristan Wells graduated in June, and is working as a Senior Project Geologist at Fortescue Metals Group. Peter Berger graduated in September 2022 and has gone on to be a postdoctoral researcher at the Helmholtz Centre Potsdam at the German Research Centre for Geosciences. Peter is now working in the field of reactive transport modelling of mining-related activities and carbon sequestration. Nathaly Guerrero Ramirez and Karla Morales also graduated in January and July

Participants on the Volcanology Masters course that ran in November 2022 are pictured on Mt Tarawera in New Zealand after a day out in the field.

respectively with Master of Science degrees. Nathaly is working in South America, while Karla is working as a geologist at MMG in Rosebery.

It's important to recognise the success of these students in the context of most of their candidature being conducted during the COVID-19 pandemic where there were significant challenges across personal life and PhD candidature. Massive congratulations to these students, we miss their smiling faces around the building.

Postgraduate programs

CODES runs a range of postgraduate programs that provide many of the next generation of world-class geoscientists. We have programs at the following levels: PhD, Masters by Research, Master of Economic Geology, Graduate Certificate in Economic Geology and Honours.

PHD AND MASTERS BY RESEARCH PROGRAM

Much of the exciting research conducted at CODES is produced by our PhD and Masters students, who make a major contribution across the breadth of CODES' research activities and outputs. Postgraduate projects at CODES range across the spectrum of our research programs and include sponsorship/collaborations with industry in Tasmania, Australia and globally, and with the Tasmanian State Government, geological surveys and other academic institutes throughout the world. Currently 73% of our HDR students have projects with partners in the minerals industry.

Our PhD and Masters students are high-calibre individuals attracted to CODES by our global reputation for excellence as a research training centre. PhD and Masters students are supported by UTAS-derived scholarships and tuition fee waivers, in addition to industry funding of scholarships and research costs.

In 2022, six graduating students were enrolled in research at PhD or Masters level. New PhD students starting in 2022 included Christopher Allen (Australia), Billy Beas (Peru), Isaac Brown (Australia), Axel Cima (Argentina), Angela Costa (Brazil), Joanne Morrison (Australia), Javier Gil Rodriguez (Colombia), Markus Staubmann (Australia), Victor Torres (Peru) and Emrecan Yurdakul (Turkey). Many of these students came to CODES to carry out research within the Regional Research Collaboration Critical Minerals project. We wish them all the best for their PhD studies.

Our PhD and Masters students are high-calibre individuals attracted to CODES by our global reputation for excellence as a research training centre.

MASTER OF ECONOMIC GEOLOGY PROGRAM

The coursework-based Master of Economic Geology degree at CODES forms part of the national Minerals Geoscience Masters (MGM) program – a collaboration between UWA, UTAS and Curtin University. 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 full-time careers in the minerals industry.
Dr Robert Scott is the program coordinator for all Master of Economic Geology short courses at CODES.

2022 was another year of change and growth for the Master of Economic Geology (MEconGeol) and associated Graduate Certificate in Economic Geology (GCertEconGeol) programs. New course structures, to commence in 2023, were approved by the university in mid-2022. For the MEconGeol, the new course structure includes, for the first time, compulsory units. All new students must now complete Fundamentals of Economic Geology, Ore Deposit Models and Exploration Strategies, and at least one of the three field-based units. There are few restrictions on student choice for the remaining five units, which may include up to three units completed by cross-institutional study at UWA and Curtin. The new course structure also allows students to complete either a one- or two-unit research project as part of their degree. Twelve students commenced the MEconGeol and three commenced the GCertEconGeol in 2022, for a total number of 81 students active in the program for the year.

CODES delivered six MEconGeol units in 2022, beginning and ending the year with the field-based units; namely Advanced Field Skills in Economic Geology in February (14 participants) and Volcanology and Mineralisation in Volcanic Terrains in November (24 participants). The remaining four units were all delivered online and included: Fundamentals of Economic Geology (April–May, 16 participants), Ore Deposit Models and Exploration Strategies (May–July, 40 participants), Geodata Analytics (September–October, 40 participants) and Exploration in Brownfield Terrains (October–December, 43 participants). Ten students either graduated or completed the MEconGeol degree in 2022. Ian Borg, Mertkan Bozoglu, Glen Cathers, Kyle Hodges, Pascal Kabilo, Emma Beattie, Alister Orton and Kyle Hughes all graduated, while Brendan Hardwick and Carl Jackman completed their degrees and will graduate in 2023.

Summaries of the six UTAS-based Masters short courses held during 2022 follow:

Participants on the Advanced Skills in Economic Geology Masters short course, that took place on 13–26 February 2022, are pictured at Bluestone Bay.

ADVANCED FIELD SKILLS IN ECONOMIC GEOLOGY

13–26 FEBRUARY 2022

The first week of this course was delivered concurrently with the CODES/Victorian Institute of Earth and Planetary Sciences (VIEPS) Honours/Masters Exploration Field Skills short course. This part of the course, based out of Queenstown, provided the 13 participants with the opportunity to develop or enhance existing skills in geological mapping, core logging and structural analysis, within a mineral exploration context. Thanks are due to Hydro Tasmania for facilitating access to the mapping area, and Mineral Resources Tasmania for laying out over 1,300 m of drill core from the area for participants to log and interpret.

At the end of the week, there followed a two-and-a-half-day Anaconda mapping and core logging exercise on the Mt Lyell mine lease in Queenstown. CODES is extremely grateful to Geoff Cordery from CMT for facilitating this activity. Participants then travelled to George Town (northeast Tasmania) for three days of structural mapping exercises in multiply deformed, Lower Palaeozoic turbidites exposed in wave-cut rock platforms at Bellingham and Beechford. On the final day, participants travelled to the Freycinet Peninsula on the east coast, to examine features formed in granitic rocks at the magmatic–hydrothermal transition exposed at Bluestone Bay. Here the students completed another Anaconda method mapping exercise.

FUNDAMENTALS OF ECONOMIC GEOLOGY

4–9 APRIL 2022 AND 2–6 MAY 2022

The second delivery of Fundamentals of Economic Geology was in two, week-long, online intensive blocks in April and May. Participant numbers were down on the previous year, largely because of the short time between the successive offerings. Fundamentals has moved from Semester 2 to its new home in Semester 1, where (from 2023 onwards) it will be offered annually as a core unit in both the MEconGeol and GCertEconGeol. The unit is presented by a mix of CODES staff and guest presenters and introduces participants to the fundamental skills and theory needed by all economic geologists. The unit includes a major virtual field mapping exercise based on the Dolphin scheelite deposit, King Island, Tasmania. CODES is grateful to Tim Callaghan and King Island Scheelite for their support in the development of this activity.

ORE DEPOSIT MODELS AND EXPLORATION STRATEGIES

30 MAY–4 JUNE 2022 AND 4–8 JULY 2022

Ore Deposit Models and Exploration Strategies was delivered mid-year, in two, week-long, online intensive blocks. There were 40 participants including 13 MEconGeol/GCertEconGeol students. The unit was presented by six CODES staff and over 20 specialist invited speakers. Particular highlights of the 2022 delivery were extended sessions on Broken Hill Type deposits (led by Tony Webster), the Central African Copper Belt (led by David Selley and Stuart Bull), IOCG deposits (led by Kathy Ehrig and Nick Oliver) and Sn-W skarn deposits (led by Lejun Zhang, Wenbo Cheng and Matthieu Harlaux). This long-running and popular unit is offered biennially (even-numbered years), and from its next delivery in 2024 onwards, it will be a compulsory unit in the MEconGeol degree.

GEODATA ANALYTICS

8 AUGUST–18 SEPTEMBER 2022 AND 19–24 SEPTEMBER 2022 AND 26 SEPTEMBER–16 OCTOBER 2022

In 2022, the Geodata Analytics course was run entirely online over three months in the second half of the year. Approximately 40 students took part in this Master of Economic Geology unit, which introduces students to a range of fundamental data analytics topics, such as data wrangling, machine learning and image processing, with a focus on their application to geological problems. This online unit is suitable for a wide variety of participants, including exploration and mine geologists, geometallurgists and data scientists. Geodata Analytics is composed of three sections. The first section is self-paced, and involves a series of pre-recorded lectures, prescribed readings and associated exercises. Participants carry out a literature review that involves uploading videos to YouTube – a great way to get students engaging with one another and fostering a sense of shared learning. The second section involves a week of live lectures and practicals, with guest presenters from across the world delivering topics such as geochemical data analysis, hyperspectral image classification and what the future of geodata analytics might look like. In the third section course participants are split into teams and tackle a geodata analytics problem; the results of these sessions are shared in a series of group presentations. The outstanding quality of teaching and student engagement offered by this unit was highlighted with Matt Cracknell (Unit Coordinator) receiving a Teaching Commendation due to high student satisfaction rates. The excellent student experience would not be possible without the support and assistance from the Master of Economic Geology team.

EXPLORATION IN BROWNFIELD TERRAINS

24–29 OCTOBER 2022 AND 28 NOVEMBER–2 DECEMBER 2022

Forty-three participants (including 12 MEconGeol/GCertEconGeol students) attended Exploration in Brownfield Terrains, delivered online in two, week-long, online intensive blocks. The unit was presented by Michael Roach and Robert Scott, along with 19 specialist invited speakers. This unit is designed to update participants on the latest exploration techniques and approaches to working with historical datasets. It covers both new and widely used technologies in geophysics, geochemistry and 3D visualisation. As part of the unit, participants work with real data from world-class mineralised districts, including a major project using a large, multi-faceted brownfields dataset from the Pine Creek area in the Northern Territory. CODES is particularly grateful to Wes Edgar and Meg Ellis from Agnico Eagle for both compiling and sharing this data for use in the short course.

VOLCANOLOGY AND MINERALISATION IN VOLCANIC TERRAINS

11–24 NOVEMBER 2022

The 2022 delivery of this unit was a resounding success, with all available spots filled by enthusiastic participants. This was the first time the course had been held in New Zealand since 2018,

An orientation trip to Tasmania's West Coast in December 2022 included five new CODES PhD students who had just commenced their research projects within the major new RRC critical metals project. They, along with colleagues from CODES, are pictured at the Mount Lyell mine.

Participants in the 2022 Exploration Field Skills Mapping Camp, pictured at Hall Rivulet Canal, western Tasmania.

owing to travel restrictions imposed by the COVID pandemic. It was truly an international affair, with participants hailing from countries as far away as Sweden, showcasing the global interest in this CODES unit in volcanic studies.

Over the course of nine action-packed days in New Zealand, we embarked on an exploration of the stunning modern volcanic environment encompassing Auckland, the Coromandel Peninsula, and the Taupo Volcanic Zone. Each day was filled with up to five site visits, allowing us to examine a diverse range of volcanic features and landscapes.

One of the standout highlights of the trip was our visit to Tauhara quarry, on the northern margin of Lake Taupo. Here, participants were treated to the sight of a cross-section through the Tauhara andesite dome – a dome that is notable for the presence of both olivine and quartz – an unusual combination! Even more exciting was the exposure that cut across both intrusive and extrusive parts of the dome, providing a rare view of the volcanic and intrusive facies and their geometries. We extend our gratitude to Mike Rosenberg from GNS Science for facilitating this visit, describing his findings, and enriching our experience.

Another perennial highlight of the course was our visit to OceanaGold's Waihi gold mine. Shannon Richards, OceanaGold's Senior Exploration Geologist, delivered a presentation on the historical context of the mine, as well as the latest drilling efforts and exciting discoveries made in a site distal to the main open pit. OceanaGold generously provided us with access to type sections of core samples from past and recent drilling, showcasing spectacular volcanic breccias with mineralisation formed through explosive diatreme formation. Additionally, we marvelled at the remarkable epithermal veins exhibiting intense silica and acid alteration. We extend our great appreciation to Shannon and the geologists at OceanaGold for their warm hospitality and for making this visit a memorable experience.

The Master of Economic Geology short course program for 2023:

- 12–25 February: Advanced Field Skills in Economic Geology
- 12–24 March: Ores in Magmatic Arcs (Indonesia)
- 17–22 April AND 8–12 May: Fundamentals of Economic Geology
- 29 May–3 June AND 3–7 July: Ore Deposit Geochemistry, Hydrology and Geochronology
- 7 August–16 September AND 18–22 September AND 25 September–15 October: Geodata Analytics
- 16–27 October: Geometallurgy
- October–November: Ores in Magmatic Arcs (South America)

In addition to the six Masters courses, CODES also ran the following course, facilitated by Associate Professor Rebecca Carey:

VOLCANIC PROCESSES, DEPOSITS, GEOLOGY AND RESOURCES SHORT COURSE

4– 10 DECEMBER, 2022, MERIMBULA, NSW

During the first week of December 2022, approximately 35 participants from Australia and one from Peru joined the Volcanic Processes short course organised by Pat Hayman from QUT and Rebecca Carey from UTAS. This course is designed for geologists and geology enthusiasts interested in understanding modern volcanic processes and the origins and settings of ancient volcanic successions.

The course spanned three days of lectures interspersed with practical exercises and field trips. The practical exercises are designed to apply material learned in lectures and uses a comprehensive display of rock specimens and thin sections from modern and ancient volcanic successions and volcanic-hosted mineralised rocks.

In addition to the lectures and practical sessions, the course included two full field days along the spectacular Sapphire Coast in southeast New South Wales. Participants had the opportunity to observe Devonian submarine and terrestrial volcanic successions with the stunning backdrop of dolphins swimming nearby. The field days served as a perfect complement to the classroom material.

HONOURS PROGRAM

The program consists of thesis-based research balanced with a literature review and four weeks of short course units that take place in Tasmania or at universities in Victoria. The Honours program has two intakes a year (February and July) and consists of around 38 weeks of study, with graduations in December and August. Our Honours program allows full- or part-time enrolment and has been proven as an efficient path for our graduate students to move into some of the best industry jobs. The Honours

Professor David Cooke lectures to VIEPS course participants on the Environmental Geology Field Techniques course that ran in August 2022.

program was coordinated by Dr Indrani Mukherjee for the first few months of 2022, and was then transferred back to Dr Martin Jutzeler after a pause of two years in this role.

The 2022 academic year saw three Honours students complete their studies, while a fourth student will complete his Honours in early 2023. Eva Knight had a project involving environmental geochemistry, in collaboration with colleagues in the Discipline of Geography and Environment, in which she quantified the release of contaminants following Rice Grass eradication in estuaries in northern Tasmania. Felix Dobbin completed his Honours thesis on the geology, alteration and mineralisation at Kingswood Porphyry Cu-Au Prospect, NSW, in collaboration with Magmatic Resources. He obtained First-Class Honours. And Till Gallagher completed his Honours thesis on the St Marys Porphyry in eastern Tasmania during 2022. Dan Fisher is completing his Honours on the characterisation of dam wall material and water quality in tailings at the Scotia Mine in NE Tasmania. His ongoing research is undertaken in collaboration with MRT.

Honours coursework program – VIEPS

In 2022, CODES offered two short courses as part of the Victorian Institute of Earth and Planetary Sciences (VIEPS) Honours coursework program. This program is attended by CODES and Victorian Honours students.

EXPLORATION FIELD SKILLS MAPPING CAMP
Course leader: Dr Rob Scott

Eight Honours students followed this course in 2022, in addition to three MSc and one PhD students and one industry participant. This course provides participants with the opportunity to develop or enhance existing skills in geological mapping, core logging and structural analysis, within a mineral exploration context. Students map and interpret a ~5 km^2 area in the highly mineralised Cambrian Mount Read Volcanics. Prior to travelling to Tasmania's west coast participants spent a day examining drill cores from the mapping area at Mineral Resources Tasmania's core storage facility in Hobart. HyLogger data for the drill cores provides important insights into the nature and extent of hydrothermal alteration affecting the rock sequence exposed in the study area. Insights from drill core coupled with an analysis of data collected during the fieldwork, provide the basis for the students' assessment of the future exploration potential of the study area.

ENVIRONMENTAL GEOLOGY FIELD TECHNIQUES
Course leader: Dr Clare Miller

This course, which ran in August in conjunction with the KEA348 Environmental Geology trip to Tasmania's west coast, provided the 15 participants with the opportunity to develop skills in geoenvironmental sampling and in-field analyses, geophysical surveying with an environmental focus, and laboratory analysis. It ran for a week, starting with two days of lectures and practicals at CODES, followed by field site studies conducted in western Tasmania.

Honours skills workshops

As in previous years Honours students attended a number of workshops covering software programs and communication skills.

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 are marked with an asterisk.

1. **Allen, Christopher.** TAS

Optimising remediation of legacy mines – mineralogical controls on long-term waste rock weathering and mine drainage.

2. **Beas, Billy.** NSW

Exploration significance of halogens in hydrothermal ore deposits.

3. **Bozoglu, Mertkan.** NSW (Masters)

Phyllic alteration at Northparkes.

4. **Brown, Isaac.** WA

Geology, geochemistry and genesis of the Havieron gold copper deposit, Paterson Province, Western Australia.

5. **de Selincourt, Lieth.** NSW (Masters)

Application of mineral chemistry to aid exploration for Cu-Au-Mo porphyry mineralisation in the Temora district, New South Wales, Australia.

6. **Dobbin, Felix.** NSW (Honours)

Geology and genesis of the Kingswood porphyry Cu-Au prospect, NSW.

7. **Fisher, Daniel.** TAS (Honours)

Lithological, geochemical and mineralogical drivers of water quality at the legacy Scotia Mine, northeast Tasmania.

8. **Gallagher, Till.** TAS (Honours)

The emplacement processes of the St Marys Porphyry in Eastern Tasmania.

9. **Gil Rodriguez, Javier.** TAS

Characterisation of skarn-type deposits: Renison Bell Sn deposit.

10. **Habib, Umer.** VIC, NSW

Tectonic evolution of the Paleozoic rocks in southeast Australia using geophysical, geochronological, geochemical and Hf isotope systematics.

11. **Hardwick, Brendan.** WA (Masters)

Mineralised textures at the Tropicana gold mine: Implications for the genetic model and deportment of gold.

12. **Hill, Richard.** NT

Exploring the East Tennant region: Unravelling the crustal architecture, tectonic evolution and mineral systems potential of an undercover Proterozoic terrane through the integrated use of geophysics, drill hole data and machine learning/geodata analysis techniques.

13. **Hohl, Max.** QLD

Defining the mineral chemistry footprints of IOCG deposits in northwest Queensland.

14. **Hughes, Kyle.** NSW (Masters)

Paragenesis of the Dobroyde Deposit, central NSW.

15. **Ila'ava, Malai.** NSW

Volcanic architecture of the Cowal Igneous Complex.

16. **Johnson, Benjamin.** QLD (Masters)

Pyrite textures and trace element chemistry of the Century Deposit – implication for exploration.

17. **Jones, Colin.** TAS

Petrogenesis of northeast Tasmanian granites.

18. **Jones, Lucy.** QLD (Masters)

An investigation into the mineral associations and relationship between chalcopyrite and sphalerite at Cannington Mine, North Queensland.

19. **Jones, Rhiannon.** NSW

The significance of phyllic alteration at the E26 porphyry Cu-Au deposit, Northparkes district, NSW, Australia.

20. **Knight, Eva.** TAS (Honours)

The geochemistry and minerology of estuarine sediments: Implications for Rice Grass removal in the Rubicon Estuary.

21. **Le'Gallais, Bridie.** TAS

The tectonic significance of mafic/ultra mafic igneous rocks in western Tasmania.

22. **Morrison, Joanne.** QLD, SA

Geometallurgy of Australian IOCGs.

23. **Nascimento, Sibele Cristina do.** TAS*

Geoenvironmental characterisation of historic mine tailings: Evaluating opportunities for reprocessing.

24. **Santos Costa, Angela Isaura.** TAS

Characterisation of tungsten mineralisation at Grassy, King Island, Tasmania – implications for ore genesis, exploration, and pathways to production.

25. **Schaap, Thomas.** TAS, NSW, VIC

Tectonic evolution of the Palaeozoic Lachlan Orogen.

26. **Staubmann, Markus.** TAS

Integrated ore deposit knowledge: optimising mineralogical characterisation through the mining value chain.

27. **Wang, Chuang.** TAS

Application of seismic techniques to reconstruct volcanic architecture.

28. **Wells, Tristan.** NSW

Indicators of, and vectors to, fertile magmas in the Northparkes district and broader Macquarie Arc.

29. **Yurdakul, Emrecan.** TAS

Orebody knowledge of the Western Tharsis Cu-Au deposit, Tasmania: implications for ore processing and mineral exploration.

30. **Zivkovic, Zebedee.** TAS, WA

Lithogeochemical and mineral analysis of magmatic-hydrothermal mineralisation systems: Implications on mineralisation and exploration.

OUTSIDE AUSTRALIA

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

1. **Cima, Axel.** Indonesia

Microinclusions in porphyry Cu deposits.

2. **Clark, Acacia.** New Zealand, Greece

Dynamics of subaerial silicic explosive volcanism: The 1315 CE Kaharoa eruption and the Late Bronze Age eruption of Santorini.

3. **Coaquira, Takeshy.** USA

Resolving multiple generations of white mica and clay alteration at the Resolution porphyry Cu-Mo deposit, Arizona.

4. **Davidson, Rob.** Mexico

Geology and genesis of the San Sebastian vein system, Durango, Mexico.

5. **Farrar, Alex.** Peru, Chile, Argentina

Investigating the relationship between regional-scale structure and tectonics for the formation and localisation of giant porphyry copper deposits in the central Andes.

6. **Frey, Shannon.** New Zealand

Behaviour of submarine caldera-forming silicic eruptions in the Kermadec arc, New Zealand.

7. **Guerrero Ramirez, Nathaly.** Colombia (Masters)

Geological controls on grade by size fractionation in gold systems.

8. **Heathcote, Jacob.** Zambia

Gold distribution and association at the Kansanshi copper-gold deposit Zambia: Processes responsible for gold precipitation and implications for ore zone delineation and recovery.

9. **Job, Ashleigh.** Chile (Masters)

Geology, structural control and exploration implications of Au mineralized Fenix gold project, Maricunga Belt, Chile.

10. **Knight, Joseph.** Myanmar

The geodynamic and metallogenic setting of base- and precious-metal mineralisation in Myanmar: Implications for Cu and Au exploration.

11. **Merrill, Javier.** Chile

Quantification of mineral texture for geometallurgical predictive modelling.

12. **Moore, Hannah.** New Zealand

Shallow conduit and vent processes in the 1886 basaltic Plinian eruption at Tarawera, New Zealand.

13. **Osorio, Jaime.** Chile

Anatomy of the porphyry-epithermal transition in the Valeriano Cu-Au deposit, Chile.

14. **Seow, Xin Ni.** South Korea, USA

Geochemistry, mechanism of formation and exploration implications of alunite supergroup minerals.

15. **Smyk, Emily.** USA

Geology, geochemistry, geochronology and exploration footprints of the Christmas porphyry Cu-Mo deposit, Arizona.

16. **Sritangsirikul, Peerapong.** Mainland SE Asia

Tectonic evolution and related mineral deposits of mainland SE Asia: Insights from geochemistry and geochronology of zircons.

17. **Sun, Yi.** Philippines

Mineralogical, textural, geochemical characterisation and geometallurgical models of Lepanto Quartz – Pyrite – Gold vein and breccia system, Philippines.

18. **Thompson, Jennifer.** Indonesia, Philippines

Carbonate mineral chemistry in epithermal and porphyry hydrothermal systems.

19. **Torres Pacheco, Victor.** Peru

Geology, genesis, and geometallurgy of Cu-Au-Ag mineralized tourmaline breccia pipes at Soledad, central Peru.

Low light at Beechford, northeast Tasmania; this photo was taken by student Max Kiernan during the 2022 KEA310 field trip.

Lab-based projects

Projects related to the ARC TMVC are marked with an asterisk.

Berger, Peter.

Understanding and predicting hypogene and supergene footprints of Carlin-type gold deposits using a hydrochemical modelling approach.

Cooke, Stephen.

Pathways to mineral discoveries through computer-based modelling of geochemical data.

Lounejeva, Elena.

Geochemical signature of syngenetic and diagenetic pyrite from marine sediments as a paleo-environmental tool.

Morales, Karla. (Masters)

Geological predictors for pre-concentration.

Moyo, Annah.*

Controlling acid and metalliferous drainage at legacy sites in Tasmania using industrial wastes.

Sahu, Arka.

Multi-scale hyperspectral and mineral chemistry data mining.

The CODES SEG Student Chapter ran a field trip to the Macquarie Arc in NSW, which also included a side trip to Canberra to look at the 'Capital Hill unconformity', which is a cover sequence to many of the deposits seen later in the field trip.

Society of Economic Geologists (SEG) Student Chapter

The CODES SEG Student Chapter at the University of Tasmania is a branch of the Society of Economic Geologists. We are dedicated to fostering an inclusive and collaborative social fabric within the geosciences research community with a focus on engagement between students and industry. We pride ourselves on making significant contributions to the social and professional lives of students from a diverse range of backgrounds and cultures.

The 2022 calendar year saw a return to (relative) normalcy with a full social calendar and our first out-of-state field trip since 2016. This year also saw the Chapter recruit our first undergraduate members. This was a big focus in 2022 with numerous PhD students submitting and no new students due to commence until late 2022, resulting in dwindling membership, engagement with the undergraduate cohort was essential. This was done through SEG/GeoSoc mixed social events and open invitations to undergraduate students to attend field trips. Following the 2022 AGM, we now have undergraduates represented in our Executive Committee and expect to see undergraduate numbers grow over the following years.

The Chapter held its AGM in October 2022 and elected a new partial committee. Newly elected committee members were undergraduate students Bryce de Hahn (Secretary) and Yvette Chan (Treasurer). Fortunately, an influx of keen new PhD students is just around the corner, and we plan to hold a second AGM in early 2023 to elect further committee members. The outgoing committee members Acacia Clark (Vice President), Alex Farrar (Treasurer) and Max Hohl (Secretary) are thanked for their tremendous efforts in making 2022 another successful year for the Chapter.

Field trip

The highlight of the year for the Student Chapter was the annual student field trip which was held in Central NSW from 26 September to 3 October. A total of 12 students (including three undergraduates), 11 industry participants (from seven different companies) and two UTAS staff met in Orange where we began our tour of the Macquarie Arc, its geology and various mines, prospects and deposit styles. The tour was led by Professor Dave Cooke who expertly navigated us through the various porphyries, skarns, epithermal and orogenic deposits that make the Macquarie Arc one of the premiere mining districts on the planet. Over six days, we were introduced to 24 different deposits/prospects (plus or minus a couple), met with nine different companies and visited three active mine sites and two inactive mines. The trip was a big success with positive reviews from both our students and the industry geologists whose participation helped fund the trip. Interest from industry in attending the trip was enormous resulting in a fully booked tour with a significant waiting list. Additionally, various companies spoke with students about opportunities for vacation work and their graduate programs. This bodes very well for future field trips and helps maintain strong bonds with industry for which CODES is well known.

The Student Chapter is enormously grateful to Professor Dave Cooke who generously donated his time to be our field guide and help facilitate access to the various sites. The participating student members are also thanked for their time writing and compiling the detailed field guide, which received welcome positive reviews from the industry geologists who found it a useful companion for the tour.
A copy of this guide can be found at: https://bit.ly/48fWjgX

Special thanks to Zeb Zivkovic, Alex Farrar and Malai Ila'ava without whom the trip would never have happened. They all donated a significant amount of their time in planning and organising the trip as well as using their various contacts to help fill out the itinerary.

A final thanks is given to Karen Huizing for a huge effort in helping secure accommodation (not easy in small mining towns!) and Helen Scott who helped manage the finances (also not easy with so many different companies).

Social events

Social events through the year included a number of BBQs (GSA, Evolution Mining and GeoSoc Mixer), a fossicking trip to the Frome River with the undergraduates and our annual Fun Bus tour (this is becoming somewhat of a tradition for the Student Chapter).

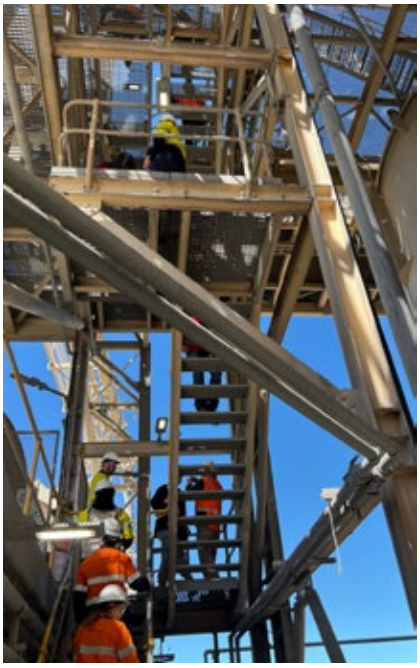
Lectures and meetings

In March, the student SEG Chapter hosted representatives from Evolution Mining who presented to students on the opportunities available in mining and exploration. This was followed by the BBQ mentioned already. In April, the Chapter helped coordinate and host a hyperspectral workshop run by Jessica Stromberg and Carsten Laukamp from CSIRO which introduced students to hyperspectral data and how to manipulate and interpret it using TSG software.

Finances and fundraising

The main fundraising activity this year was through income from fee-paying participants who attended the field trip. This not only paid for the field trip (including all student costs) but also resulted in a net profit which will put the Chapter in good standing for 2023.

Additional fundraising included numerous BBQs and sales through our equipment store. The store sells a variety of geological equipment such as hammers, hand lenses, various field notebooks and scribes. This service not only helps raise funds for the Chapter but is important in introducing the Chapter to new students and driving new memberships.



CODES SEG Student Chapter 2022 field trip participants at the Tomingley gold mine owned by Alkane Resources.

Future plans

The SEG student chapter now boasts more members than in the past several years. This influx of new and eager students is keen to continue building the momentum developed over the past year. The positive financial standing of the Chapter raises the possibility of further interstate or even international field trips in the coming years. The 2023 calendar year will also see continued focus on engagement with the undergraduate students, as well as another trip on the Fun Bus!

▶ LOOKING FORWARD

In 2023 we look forward to the growth of our PhD cohort with a further nine international and domestic students joining our program. The addition of such a diverse cohort of students will continue the positive and dynamic student community at CODES.

Fieldwork opportunities in 2023 are almost back to pre-pandemic levels. The upcoming year is shaping up to be a busy one, particularly for the newly arrived PhD students who will embark on their fieldwork projects starting in early 2023.

One of our major research endeavours in 2023 will be the Regional Research Collaboration which is heavily based at field sites in Tasmania. Many of our new PhD students will spend significant time on Tasmania's West Coast, conducting field investigations and collaborating with industry geologists on site.

In addition to the fieldwork in Tasmania, our PhD students will be travelling to various locations in Australia, conducting field surveys and working in core sheds. A few of our students will also be embarking in fieldwork overseas in locations such as New Zealand and South America.

At CODES our postdoctoral researchers play a vital role in supervision and mentorship of PhD, Masters and Honours students. Their expertise and guidance will not only contribute to the students' research progress, but also allow them to engage in fieldwork in new and exciting environments.

Outreach and media

With most COVID-19 restrictions removed, 2022 was once again full steam ahead for the many outreach activities undertaken by CODES and Earth Sciences staff and students.

UTAS Open Days

In 2022 UTAS had its first face-to-face Open Days without masks since the beginning of the pandemic, and there was a large turnout. Undergraduate students Madison Mulder and Kay Wilson managed the Earth Sciences stand in Hobart, engaging future students with a range of activities. The most popular was the petrographic microscope with several slides presented from rock types found across Hobart. Adults and kids alike were fascinated that you could study rock samples under a microscope and how different they looked from the hand specimens presented on the table. As always, Rosie the Utah Raptor was a hit; even though she wasn't walking around, her presence on the Earth Sciences stand fascinated passers-by, who asked lots of questions. The little ones at the stall especially loved the gemstone identification and taking home their gemstone prize. Thank you to all the Earth Sciences staff and students that helped make this Open Day a success, particularly Sebastien Meffre who ran around locating samples and equipment for us. Hopefully, next year rocks just as much as the 2022 Hobart Open Day!

CODES PhD student Shannon Frey was one of the volunteers who helped to run the UTAS Open Day stalls in 2022. Here she is pictured in Burnie with Rosie the dinosaur helping out.

Other Open Days were held in Burnie (18 September) with Shannon Frey and Dan Fisher lending a hand; and in Launceston (25 September), again with Shannon and Dan running the show.

The Festival of Bright Ideas

The 2022 Festival of Bright Ideas (FoBI), held on 20 August in the PW1 venue on the Hobart waterfront, was another successful science outreach event which this year included a stage show. The show, called 'From Little Things, Big Things Explode', played to five capacity audiences – and starred our very own CODES PhD student Hannah Moore, who gave an overview of how and why volcanoes happen. Hannah received a STEM Stage Skills scholarship, funded by Hydro Tasmania, to help her develop her performance role.

The CODES/Earth Sciences stall was run by PhD students Alex Farrar and Acacia Clark with assistance from ES students Madison Mulder and Dan Fisher. They were kept busy throughout the day with a steady stream of interested patrons, both young and old.

It Takes a Spark!

Professor Sebastien Meffre attended this STEM conference at St Brendan-Shaw College in Devonport on 2 September where he ran a session called 'Cycling rocks: actively learning about the rock cycle'. PhD student Chris Allen and Honours student Dan Fisher also ran a demonstration on the

TOP: Earth Sciences student Madison Mulder means business: here she's running the Earth Sciences stall at Agfest, which in 2022 took place in August. ABOVE LEFT: The Festival of Bright Ideas (FoBI) took place in August 2022, and was enthusiastically supported by (L–R) CODES PhD student Acacia Clark, Earth Sciences student Madison Mulder and CODES PhD student Alex Farrar. ABOVE RIGHT: In August 2022 CODES PhD student Hannah Moore took part in the FoBI stage performance called 'From Little Things, Big Things Explode', which performed to five capacity audiences (around 1,000 people).

source and impact of acid mine drainage. The conference, attended by several hundred people, was designed to inspire STEM learning in primary and high school students.

Agfest

On 24–27 August AgFest was held just outside Launceston at Quercus Park. Earth Sciences students Daniel Fisher and Madison Mulder amused visitors with volcano races, gemstone identification, samples of volcanic rocks and a large geological map of Tasmania. Despite the chilly weather, there was decent foot traffic over all four days with over 12,000 visitors making their way through the University Pavilion and 80% of surveyed patrons spending more than 10 minutes looking at the exhibits. There was a wide representation of the community engaging with the Earth Sciences stand with everyone from little ones to teenagers, to amateur fossickers, to elderly farmers wanting to know the geology of the land they farmed – a true indicator of the reach that geology has.

The little ones thoroughly enjoyed the volcano race display where they learnt about the viscosity of lavas. We asked them to draw a little town at the bottom of a sheet of paper which was placed on a slope. Then multiple items with different viscosities were dyed red, such as honey, hand sanitiser, and Elmer's glue, and raced down the slope. Many squealed in delight as their town was 'destroyed' and could correctly pick out which viscosity matched the volcanic samples we had on the table. The gemstone identification was also a hit with people of all ages. Adults and teenagers were fascinated by the large geological map of Tasmania and loved learning about the difference between the east and west coasts.

Associate Professor Rebecca Carey gave a Royal Society of Tasmania lecture entitled 'Bang, fizzle, pop: case studies of the interactions between volcanoes and magma with the ocean' in November 2022.

Overall, AgFest was a resounding success; many thanks go to other stall holders and organisers for all their help. Hopefully, next year the University Pavilion and Earth Sciences stall is bigger and better than ever!

Geohug

The regular online forum geology discussions run by Geohug have gained in popularity and in 2022 CODES Honorary staff member Dr Tony Webster gave a presentation, which was well-received: 'Geology, pre-European landscapes, and their influences on capital city centres'. Tony talked about the role geology and landscape played in the foundational years of three state capitals; Perth, Adelaide and Melbourne, and how they influenced the earliest land-use choices made as the British adapted to their new Australian environments. See: https://www.youtube.com/watch?v=HpXR5YHqg1Y

Many past CODES students also gave Geohug talks during the year.

The Royal Society of Tasmania

The RST has an active invited speakers' program, and in 2022 several members of CODES staff gave presentations:

- In March Dr Indrani Mukherjee talked about 'Understanding Early Earth Environments: a powerful approach providing key clues to evolution of life on Earth and beyond!'
- In May Dr Tony Webster gave a talk entitled: 'Geology, landscape and European settlement: small things mean a lot.' This talk was also repeated by Tony for the Hobart Probus club and the Kingston U3A (University of the Third Age).
- Dr Peter McGoldrick gave a popular talk with a very long name in August: '"Tasmania's oldest fossil". What a palaeontologist from New Jersey, a nineteenth-century Irish rebel, some of the bloodiest battles of the American Civil War and 1.4-billion-year-old fossils from the Tarkine have in common'.
- October saw Associate Professor Rebecca Carey give a presentation on 'Bang, fizzle, pop: case studies of the interactions between volcanoes and magma with the ocean'. See: https://rst.org.au/view-recording-of-lecture-by-dr-rebecca-carey-oct2022/

UTAS STEPs Program

In 2022 UTAS implemented a new community outreach program in western Tasmania. The 'STEPs' program (STEPs stands for 'Skills. Training. Education. Pathways.') is coordinated by Christine Gray from UTAS and aims to build confidence in participants who can discover how their life experiences, interests and existing skills can be developed to take advantage of learning and work opportunities on the West Coast.

During the year CODES staff and students were involved in three outreach sessions on the West Coast:

- May (Queenstown)
- 28 June (Zeehan)
- 1 September (Strahan).

These sessions provided participants with opportunities to experience a range of mining-related activities as well as an overview of reclamation activities. CODES director, Professor David Cooke, took part along with PhD students Richard Hill and Zeb Zivkovic. The activities included examining drill core, collecting water samples, and digging out samples of items affected by acid mine drainage from the King River delta at Strahan.

Christine said of CODES' involvement: 'We are extremely grateful for the support Dave Cooke and the team at CODES has given the West Coast STEPs program. Visiting sites such as core sheds and the King River Delta provided us with the opportunity to see first-hand the learning and work opportunities involved in the mining industry. It was hard for us all not to be excited by the genuine enthusiasm shown by Dave and PhD students as they shared their knowledge and stories.'

School visits and trips

Again, numerous school visits were facilitated by CODES and Earth Sciences staff and students during the year including:

- 4 May: Acacia Clark and Hannah Moore ran a 'Careers in STEM' day for Grade 11 and 12 students at Hobart College. Around 20 students attended.
- 19 May: Sebastien Meffre gave a presentation to two high school teachers from Southern Christian School.
- 18 November: Honours students Dan Fisher and Eva Knight spoke to students at Taroona High School.

Launceston Gem and Mineral Show

On 19–20 November, Honours student Dan Fisher attended the Launceston Gem and Mineral Show at the Elphin Sports Centre in Launceston and had a couple of busy days spruiking the experience of studying Earth Sciences at UTAS.

UTAS Science Experience Hobart

Twenty-three Year 9/10 students from eight schools attended CODES/Earth Sciences (including some students who travelled down from northwest Tasmania) on 6 December to discover some of the exciting aspects of Earth sciences. The enthusiastic students participated in three different CODES outreach workshops: geological time scale and geochronology (Sebastien Meffre), rocks under the microscope (Owen Missen), and seismic wave demonstrations (Dan Fisher). Their trip to CODES/ES was one part of three days of activities across the UTAS School of Natural Sciences.

Geoscience Australia

On 15 June Dr Michael Roach gave an online Geoscience Australia public talk on the topic of 'Geological visualisation for education, research and outreach'. See: https://www.youtube.com/watch?v=Xan6w76nVLA&list=PL0jP_ahe-BFmG86erK7sDH2ldl21aKiC2&index=7

Media

- Dr Indrani Mukerjee was appointed a superstar of STEM towards the end of 2022: https://scienceandtechnologyaustralia.org.au/what-we-do/superstars-of-stem/meet-the-superstars-of-stem/ and https://ommcomnews.com/world-news/3-indian-origin-women-among-australias-superstars-of-stem
- Associate Professor Rebecca Carey did a number of interviews in 2022 including this one on 13 December with James O'Loghlin on ABC Radio *Afternoons* about volcanic eruptions in Hawaii. The item was called 'Are there more volcanoes than usual this year?': https://www.abc.net.au/sydney/programs/afternoons/volcanoes/101767184
- Annah Moyo completed her PhD on the use of alkaline wastes and shells for treating AMD generated by mine waste during the year, and her results were covered by *The Advocate*: https://www.theadvocate.com.au/story/7864427/could-seashells-be-the-solution-to-tackling-old-mines-pollution/

TOP: Earth Sciences took part in the 2022 Launceston Gem and Mineral Show, which was held in November at the Elphin Sports Centre. Honours student Dan Fisher officiated. ABOVE: Dr Michael Roach gave an online Geoscience Australia presentation entitled 'Geological visualisation for education, research and outreach' during June.

Participants in the Strahan session of the UTAS STEPs Program on the beach. CODES played an important part in this outreach program in 2022.

- Stockhead, which specialises in online news for the lesser-known ASX-listed companies, featured several companies working with CODES geologists. Among them were:
  - July 2022: CODES' role in developing porphyry vectoring and fertility tools: https://stockhead.com.au/resources/corazon-mining-following-up-on-hints-of-porphyry-copper-at-mt-gilmore/
  - August 2022: Professor Noel White's research: https://stockhead.com.au/resources/something-big-lurks-at-corazons-mt-gilmore-copper-project/
- Our researchers pop up on YouTube quite regularly: Watch Professor White enthusing about the work done by CODES researchers and the possible future directions of the Mt Gilmore copper project. Great to see Lejun Zhang and Francisco Testa out in the field discussing this potential orebody and taking in the words of this highly experienced economic geologist. See: https://www.youtube.com/watch?v=7EWj4LLferY
- *Australian University Science:* The new Regional Research Collaboration project into critical metals in Tasmania encompasses collaboration with several mining companies including G6 Metals. This was covered in brief in the *Australian University Science* magazine: https://issuu.com/refractionmedia/docs/acds08-issuu?mc_cid=7aa97ec552&mc_eid=59b5b87b44
- TWICS: PhD student Hannah Moore was an expert guest on 'That's What I Call Science (TWICS)' radio show and podcast. She talked about volcanology and her recent fieldwork on a volcano in New Zealand. The interview was broadcast on Edge radio in November 2022 and is available on popular podcast apps, as well as on the TWICS website: https://thatsscience.org/2022/11/20/episode-176-volcanology-rocks/. Hannah is now also an editor and co-host for TWICS.
- **UTAS media:** CODES and Earth Sciences researchers, students and staff continued to be showcased in several UTAS intranet articles during 2022 including coverage of CODES visitor Professor Eric Roberts; Professor Ross Large and Dr Indrani Mukherjee's Superstar of STEM appointment.

Industry links

Team effort: *The 2022 CODES Annual Review was held on 28 November; it was the first time that a face-to-face Annual Review had been held since 2019. Here industry participants are pictured with CODES staff and PhD students in the CODES Rock Garden.*

▶ 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 2022, the group of CODES' Industry Partners comprised of seven Australian and international mining companies: Anglo American, AngloGold Ashanti, First Quantum Minerals, Mount Isa Mines (Glencore), Newcrest Mining, Rio Tinto and Teck.

Partner companies have been providing support of up to $60,000 in cash per year to the core research budget of the Centre. Gold and Platinum Partners are also offered a seat on the CODES Advisory Board, which meets at least annually to discuss the strategic direction of the Centre.

Representatives of these companies are invited to the CODES Annual Review, along with other government and university researchers. The Annual Review showcases the breadth of research undertaken at the Centre through a day of oral and poster presentations for our stakeholders, and offers the opportunity to influence future research directions. In 2022 CODES was able to hold a face-to-face Annual Review meeting for the first time since 2019.

CODES offers partnership opportunities aligned to the evolving needs of mining companies.

Industry partnership opportunities

CODES offers partnership opportunities aligned to the evolving needs of mining companies. The minerals industry is cyclical by nature, and operating conditions can vary greatly from one year to the next, often through unforeseen circumstances. For this reason, our partnership opportunities are offered on an annual basis, giving partners the flexibility to adjust their involvement in line with their current operating conditions and research requirements. Funding levels are tailored to suit all levels of operation, from junior explorers through to the large multinationals. Companies may sign up at the Silver ($20K), Gold ($40K) or Platinum ($60K) level, depending on their planned level of involvement with the Centre. Benefits of a partnership agreement vary depending on the level of investment, but 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.

Further details can be found at: https://www.utas.edu.au/codes/about-us/industry-partnership-program

Rio Tinto trio: *Paul Agnew, Mike Whitbread and Ingrid Flemons from Rio Tinto at the Amira P1249 Project Sponsors' Meeting in November, which was held at CODES.*

Working with industry: *Rizal Fraval, Senior Geologist at Newcrest, talks with Professor David Cooke at the Amira P1249 Project Sponsors' Meeting in November pictured during a tea break in the CODES Conference Room.*

Role of Amira Global

Amira Global plays a vital role in facilitating the funding of collaborative research involving university research groups and the minerals industry. Amira funds projects within the Centre, which run over a period of one to five years. In 2022 it funded the new five-year project – Amira P1249 'Exploring, characterising, and optimising complex orebodies – upscaling orebody knowledge to add value across the mining value chain'.

Research collaborations

In 2022, CODES continued its reputation for cultivating research collaborations with other Australian and international research organisations. Throughout the year, collaborative research was conducted with 66 international and 20 national organisations.

CODES Industry Partners 2022

PLATINUM

AngloAmerican

GOLD

FIRST QUANTUM MINERALS LTD.

MOUNT ISA MINES A GLENCORE COMPANY

NEWCREST MINING LIMITED

RioTinto

Teck

SILVER

ANGLOGOLDASHANTI

Technology transfer

OBJECTIVES

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

Participants of the April 2022 Introduction to HyLogger Data and Advanced Hyperspectral Data Processing two-day course which ran at CODES and was organised by Dr Lejun Zhang (pictured at far left).

Technology transfer activities

CODES undertakes strategic and applied research into ore deposits (characterisation and context) and geometallurgy, 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 programs are transferred to end-users via regular research meetings, research reports, monographs, books, digital presentations and software packages, where appropriate. In 2022, 274 research reports were presented to industry clients. Meetings were also held to present and discuss progress and adoption of research results.

Projects that delivered significant technology transfer objectives during 2022 included the CRC ORE project (led by Dr Julie Hunt), which delivered an online library of mineralisation styles (www.ausgeol.org/assets/media/uploads/tours/codes_crcore_p1_006/index.html), and early results from the new Amira P1249 project (led by Professor David Cooke).

Participants in the Amira P1249 Sponsors' Review Meeting in June 2022 listening to one of the presentations given over the two days of the gathering at CODES in Hobart.

Publications targeted at end-users

CODES also delivers knowledge and applications to end-users and the wider scientific community through a selection of special publications that represent the culmination of major research efforts by the Centre's staff. The following publications were sold during 2022:

- *Altered volcanic rocks: A guide to description and interpretation* (2005). Authors: C. Gifkins, W. Herrmann and R. Large (31 copies).
- *Geophysical signatures of copper-gold porphyry and epithermal gold deposits, and implications for exploration* (2011). Author: T. Hoschke (11 copies).
- *Giant ore deposits: Characteristics, genesis and exploration. CODES Special Publication 4* (2002). Editors: D. Cooke and J. Pongratz (1 copy).
- *Earth, Universe, Cosmos* (1996). Author: S. Warren Carey (1 copy)
- *The expanding Earth: A symposium* (1981). Editor: S Warren Carey (3 copies).
- *New developments in Broken Hill type deposits.* CODES Special Publication 1 (1996). Editors: J. Pongratz and G. Davidson (2 copies).
- *The geology of the Broken Hill Pb-Zn-Ag deposit, NSW, Australia* (2006). Author: A. Webster (1 copy).
- *Volcanic textures: A guide to the interpretation of textures in volcanic rocks* (1993). Authors: J. McPhie, M. Doyle and R. Allen (30 copies).
- *24ct Au workshop. CODES Special Publication 5* (2004). Editors: D. Cooke, C. Deyell and J. Pongratz (1 copy).

CODES-led short courses, workshops, conferences and field trips for end-users

With the gradual lifting of COVID-19 restrictions in 2022 CODES was again able to include face-to-face short courses, workshops and conferences in its timetables, and they continued to play a key role in the Centre's technology transfer activities. During 2022 a total of 21 such events were held either in-person or online.

Total attendance by industry geologists, academic researchers and postgraduate students was approximately 650 with 36 presenters from CODES involved in delivering the courses or leading the conferences or field trips.

CODES and Earth Sciences staff and students also played major roles in other events such as the Specialist Group in Tectonics and Structural Geology 2022 Conference on King Island in November and the 'Volcanic Processes, Deposits, Geology and Resources' short course in Merimbula in December.

2022 SHORT COURSES, WORKSHOPS, CONFERENCES AND FIELD TRIPS LED BY CODES

TITLE	PRESENTERS	NO.	LOCATION	DATE
Amira P1249 Start-up Meeting	**Mike Baker, Ivan Belousov, David Cooke, Matthew Cracknell, Leonid Danyushevsky,** Scott Halley, Peter Hollings, Olga Verezub, **Lejun Zhang**	44	CODES	10–11 February
Advanced Field Skills in Economic Geology (MEconGeol short course)	**Mike Baker, Robert Scott, Lejun Zhang**	7	Western, eastern and northeastern Tasmania	13–26 February
Exploration Field Skills Mapping Camp (VIEPS)	**Robert Scott, Zeb Zivkovic**	7	Hobart/western Tasmania	13–20 February
16th SGA Biennial Meeting 2022: Fundamentals of spectral reflectance for mineral exploration and mining	**Jonathan Cloutier,** Carsten Laukamp, Ekaterina Savinova, Jessica Stromberg, **Lejun Zhang**	27	Online	26–27 March
16th SGA Biennial Meeting 2022: Machine learning for geologists	**Matthew Cracknell,** Shawn Hood, Mclean Trott	~25	Online	1 April
16th SGA Biennial Meeting 2022: Porphyry and high sulfidation epithermal deposits	**David Cooke, Lejun Zhang**	23	Online	1–2 April
Fundamentals of Economic Geology (MEconGeol short course)	**Mike Baker,** Tim Callaghan, **David Cooke,** Karsten Goemann, Scott Halley, Cassady Harraden, Larry Meinert, **Michael Roach, Robert Scott, Francisco Testa, Noel White, Lejun Zhang**	16	Online	4–9 April AND 2–6 May
Introduction to HyLogger Data and Advanced Hyperspectral Data Processing	David Green, Carsten Laukamp, Jessica Stromberg, **Lejun Zhang**	55	CODES	28–29 April
Ore Deposit Models and Exploration Strategies (MEconGeol short course)	Jared Broome, **Stuart Bull,** Huayong Chen, Yanbo Cheng, **Jonathan Cloutier,** John Collier, **David Cooke, Leonid Danyushevsky,** Irene del Real Conteras, Kathy Ehrig, Steve Garwin, **Bruce Gemmell,** Scott Halley, Matthieu Harlaux, Kate Hine, Danny Huisman, Lucy Jones, Simon Jones, Cam McCuaig, Shelley Mills, Nick Oliver, **Michael Roach,** Rob Rutherford, **Robert Scott, David Selley, Jeff Steadman, Francisco Testa, Tony Webster, Noel White, Lejun Zhang**	40	Online	30 May–4 June AND 4–8 July
Amira P1249 Sponsors Review Meeting 1	Laurent Aillères, **Mike Baker, Ivan Belousov, David Cooke, Stephen Cooke, Matthew Cracknell, Leonid Danyushevsky,** Mitch Marcelissen, **Javier Merrill,** Angela Rodrigues, **Markus Staubmann,** Olga Verezub, **Lejun Zhang**	55	CODES	22–23 June
Amira P1249 Calculated Mineralogy and Pedras (python package) Workshop	Laurent Aillères, **Matthew Cracknell,** Lachlan Grose, Scott Halley, Angela Rodrigues	25	CODES	22–23 June
Geodata Analytics (MEconGeol short course)	Rocky Barker, **Shaun Barker,** Natalie Caciagli, **Matthew Cracknell,** Michael Gazley June Hill, Shawn Hood, Kyen Knight, **Javier Merrill,** Angela Rodrigues	40	Online	8 August–18 September AND 19–24 September AND 26 September–16 October
Environmental Geology Field Techniques (VIEPS)	**David Cooke, Clare Miller**	~10	CODES	29 August
CODES SEG Student Chapter Field Trip to the Macquarie Arc	**David Cooke,** James Egan, **Alex Farrar, Malai Ila'ava, Zeb Zivkovic**	25	ACT, NSW	26 September–2 October
Micropaleontology Workshop	Martin Crundwell (CODES visitor)	16	CODES	October
Exploration in Brownfield Terrains (MEconGeol short course)	John Ashton, Tim Baker, Paul Dale, Oliver Davies, Wes Edgar, Kim Frankcombe, Scott Halley, Kate Hine, **Terry Hoschke,** Ned Howard, David Isles, Corey Jago, **Andrew McNeill,** David Rhys, **Michael Roach,** Francois Robert, Shaun Schmeider, **Robert Scott, Tony Webster, Jo Whelan,** Lesley Wyborn	43	Online	24–29 October AND 28 November–2 December
Volcanology and Mineralisation in Volcanic Terrains (MEconGeol short course)	**Isaac Brown, Rebecca Carey, Acacia Clark, David Cooke, Martin Jutzeler, Andrew McNeill, Michael Roach, Zeb Zivkovic**	24	New Zealand and Tasmania	11–24 November
Amira P1249 Mineral Texture Clustering Using MCOPF Method Workshop	**Stephen Cooke, Matthew Cracknell**	20	CODES	30 November
Specialist Group in Tectonics and Structural Geology (SGTSG) 2022 Conference	**Sheree Armistead,** Ross Cayley, Grace Cumming, Nick Direen, John Everard, **Alex Farrar, Jacqueline Halpin, Sebastien Meffre,** Tobias Staal	50	King Island	22–24 November
Amira P1249 Sponsors Review Meeting 2	**Mike Baker, Billy Beas, Ivan Belousov,** Jeff Bigelow, Alex Brown, **David Cooke, Matthew Cracknell,** Scott Halley, Peter Hollings, **Wei Hong, Jaime Osorio,** José Piquer, **Xin Ni Seow, Markus Staubmann, Jeff Steadman,** Olga Verezub, **Lejun Zhang**	56	CODES	29–30 November
Volcanic Processes, Deposits, Geology and Resources short course	**Rebecca Carey, Jonathan Cloutier,** Pat Hayman	36	Merimbula, NSW	4–10 December

Performance indicators

PERFORMANCE MEASURES

	TARGET	2022
Research Findings (CODES and Earth Sciences)		
Publications in international journals	50pa	34
Percentage of publications in high-quality international journals	70%	64%
Reports to industry collaborators	80pa	274
Special issues and/or research monographs	1 per 2 years	1
Invitations to give keynote conference presentations	10pa	4
Papers at national/international meetings	70pa	32
Research Training and Professional Education		
Percentage of HDR students attracted from interstate	25%	13%
Percentage of HDR students attracted from overseas	65%	60%
Number of Honours students in CODES' programs	15	4
Number of HDR students in CODES' programs	50	45
Percentage of students in projects linking with industry	80%	73%
Professional short courses/workshops for industry	4pa	21
International, National and Regional Links and Networks		
CODES' national or international conferences/workshops	1 per 2 years	1
Registrants at CODES' conferences/workshops	600pa	~650
End-user Links		
Frequency of meetings with industry representatives	15pa	30+
National Benefit		
CODES' research has input into a major mineral discovery	1 per 5 years	10 in 33 years

NOTE: The COVID-19 pandemic again reduced the number of conferences that CODES researchers and HDR students were able to attend in person in 2022. Similarly, international HDR student commencements in the first half of the year were impacted due to Australian border restrictions.

The North Pit of the Savage River Mine photographed during the December 2022 orientation trip to Tasmania's West Coast region for the new Regional Research Collaboration project staff and students.

Finances

2022 income

Total CODES income was $6.2 million (see Table 1). This was derived principally from Contracts/Consultancies/Revenue Raising (34%), UTAS (28%), and Industry (25%) (see Figure 1). The main income streams over time are compared in Figure 2, showing a decrease in overall income to CODES in 2022 when compared to 2021. This decrease occurred in the ARC funding stream (the ARC TMVC Research Hub which concluded in 2021), and support from UTAS. All other categories showed increases, partially mitigating the reductions in ARC and UTAS funding during the year.

Summary of the main income streams to CODES in 2022:

- **Contracts/Consultancies/Revenue Raising:** Combined funding of $2.1 million comprises funding related to Short Courses ($220k), Analytical Services ($1.9 million) and Book Sales ($8k).
- **Host institution support:** Funding from UTAS in 2022 was $1.8 million, down from $1.9 million in 2021, mostly attributable to a reduction in PhD scholarship funding (living and tuition fee) from central sources, due to several PhD completions during the year. UTAS funding relates primarily to research salaries, PhD scholarships and income earned by the Centre from research output.
- **Industry income:** Industry funding of $1.6 million comprises funding related to Industry Partner support and industry funded student and other research projects.

2023 income estimates

There is expected to be an increase in external research funding to CODES in 2023 when compared to 2022, due to the commencement of a new Commonwealth-funded collaboration research initiative and the continuation of several research projects. UTAS and Other funding to CODES is expected to increase into 2023, with the expectation of sustained use of CODES analytical services, and an influx of new PhD candidates supported by UTAS scholarships.

TABLE 1: CASH INCOME FINANCIAL STATEMENT 2022

ARC Grants	
Discovery Grants	45,207
Linkage Grants	60,894
	106,101
Other Commonwealth Government	
Specific Projects	504,672
Student Projects	8,000
	512,672
State Government	
Specific Projects	10,000
Student Projects	122,931
	132,931
Industry/private	
Amira Global Projects	596,052
CODES Industry Partners	190,000
Cooperative Research Centre Projects	20,000
Directly Funded Research Projects	560,344
Directly Funded Student Projects	199,422
Miscellaneous	12,090
	1,577,908
Contracts/consultancies/revenue raising	
Short Courses	219,599
Book Sales	7,869
Miscellaneous (incl. Analytical Services)	1,866,736
	2,094,203
University of Tasmania – host institution support	
Operating Grant	943,017
Scholarships and Tuition Fee Waivers	808,007
	1,751,025
Other income sources/interest	
Student Support	17,890
Specific Projects	5,000
Miscellaneous	12,749
	35,638
Total annual income	**6,210,478**

FIGURE 1:

Total Cash Income 2022

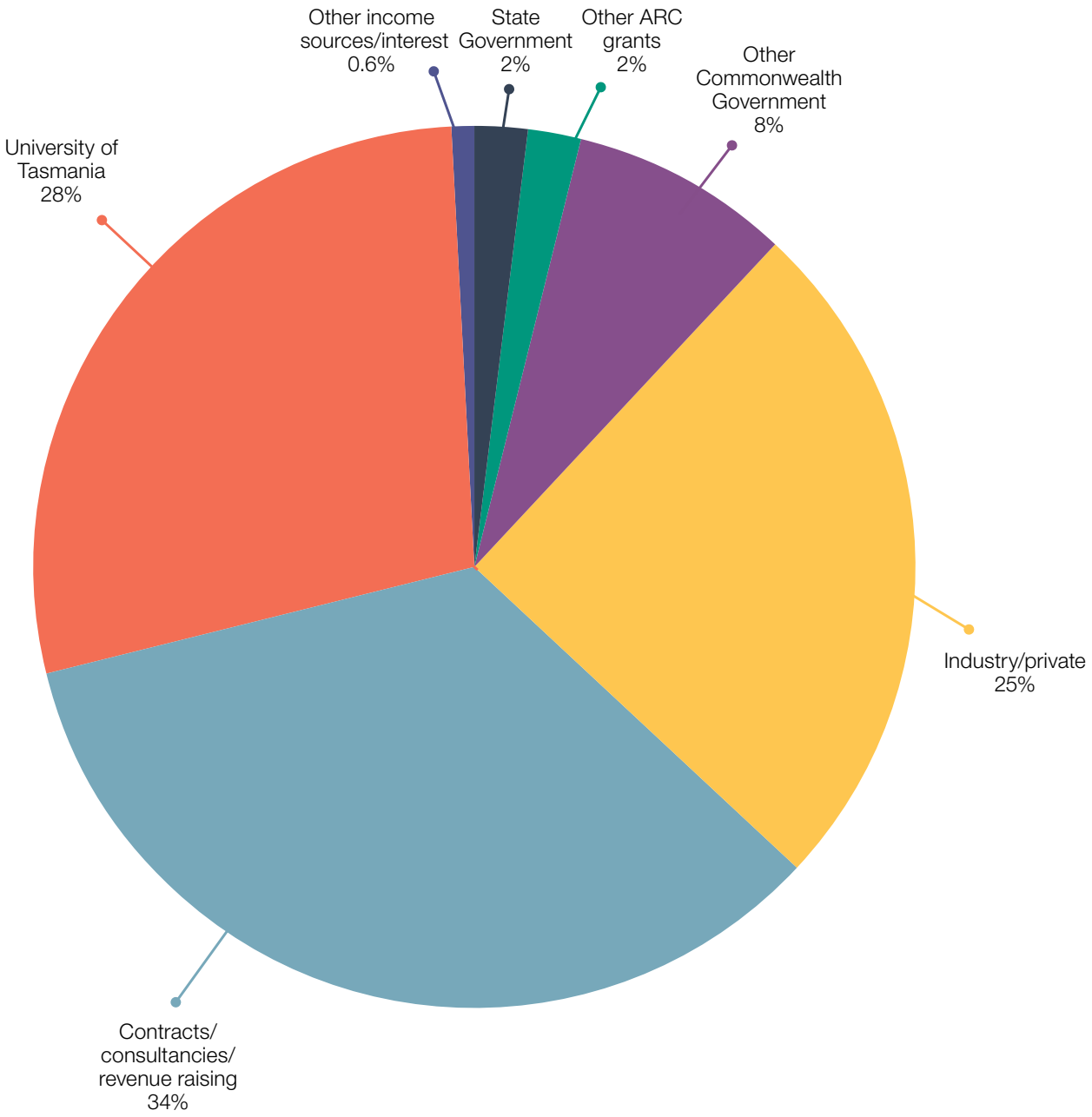
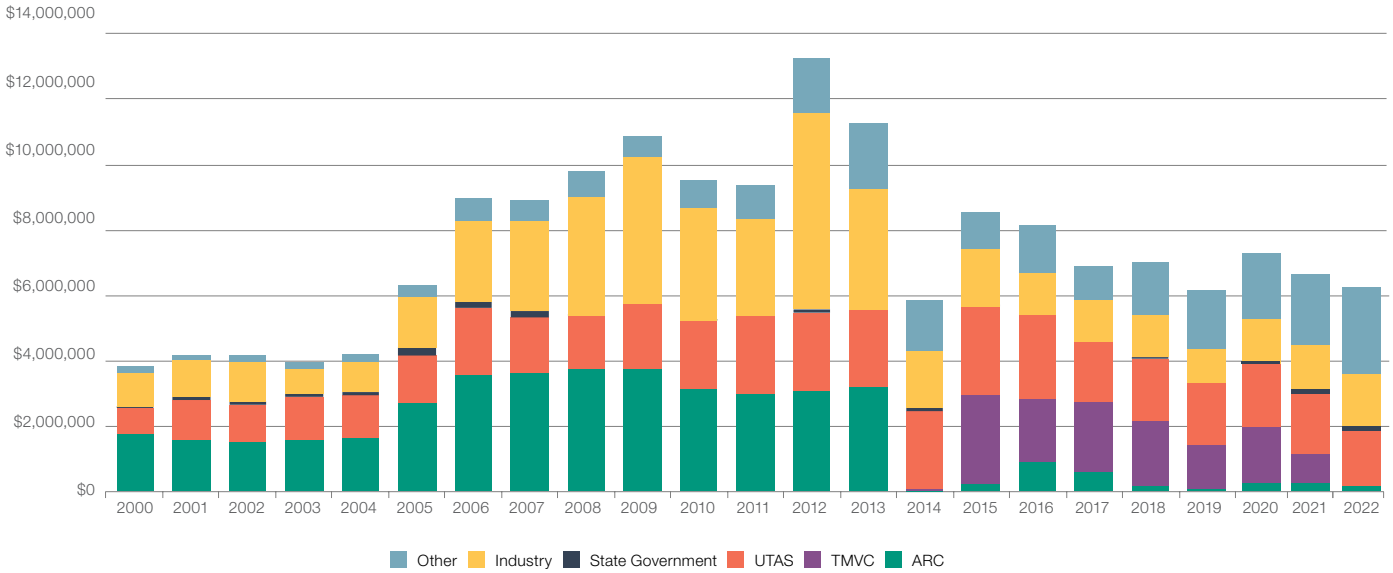


FIGURE 2:

Comparison of CODES main income streams 2000–2022



Notes to, and forming part of, the financial statements for 2022

The financial pages of this Annual Report were prepared by Helen Scott (Project Administration Manager). Data for the financial statements was extracted from UTAS systems, particularly its Finance System.

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 2022, or centrally administered for CODES RHD students (as in the case of scholarships and tuition fee waivers).

Publications 2022

Refereed journal articles (34)

Abersteiner, A., **Kamenetsky, V.,** Goemann, K., Golovin, A., and **Kamenetsky, M.,** 2022, Olivine in kimberlites: magma evolution from deep mantle to eruption: Journal of Petrology, v. 63(7), p. 1-32.

Aung Zaw Mying, Wagner, T., and **Khin Zaw,** 2022, Telluride-bearing Au-Ag mineralization in the Singu-Tabeikkyin gold district, Mogok metamorphic belt, Myanmar: New constraints on an intermediate-sulfidation epizonal orogenic ore system: Journal of Asian Earth Sciences, v. 227, Article 105120

Endut, Z., Ng, T.F., Aziz, J.H.A., **Makoundi, C.**, Dauad, H., and Ariffin, K.S., 2022, Texture and morphology of veins and their relationship to gold mineralization in the Penjom deposit, Malaysia: Resource Geology, v. 72(1), Article e12288.

Falloon, T.J., Hoernle, K., Schaefer, B.F., Bindeman, I.N., Hart, S.R., Garbe-Schonberg, D., and Duncan, R.A., 2022, Petrogenesis of lava from Christmas Island, Northeast Indian Ocean: implications for the nature of recycled components in non-plume intraplate settings: Geosciences, v. 12(3), Article 118.

Figueiredo, C.A., Bongiolo, E.M., **Jutzeler, M.,** Gomes, O.F.M., and Neumann, R., 2022, Alkalic pyroclast morphology informs on fragmentation mechanisms, Trindade Island, Brazil: Journal of Volcanology and Geothermal Research, v. 428, Article 107575.

Habib, U., Meffre, S., Berry, R., and **Kultaksayos, S.**, 2022, Detrital zircon ages, provenance and tectonic evolution in the early Paleozoic of Tasmania and Waratah Bay, Victoria: Australian Journal of Earth Sciences, v. 69(5), p. 650-665.

Hao, J., Liu, W., Goff, J.L., **Steadman, J.A., Large, R.R.,** Falkowski, P.G., and Yee, N., 2022, Anoxic photochemical weathering of pyrite on Archean continents: Science Advances, v. 8(26), Article eabn2226.

Hu, F., Wu, F-Y., Wang, J-G., Ducea, M.N., Chapman, J.B., **Khin Zaw,** Lin, W., Sein, K., and **Meffre, S.,** 2022, Newly discovered Early Carboniferous and Late Permian magmatic rocks in eastern Myanmar: implications for the tectonic evolution of the eastern Paleo-Tethys: Journal of Asian Earth Sciences, v. 227, Article 105093.

Hughes, S., **Meffre, S.**, Gregory, D., and Chase, Z., 2022, Quantifying and characterising metal concentrations in Derwent Estuary sediments using portable X-ray fluorescence spectrometry: Australian Journal of Earth Sciences, v. 69(5), p. 742-765.

Khin Zaw, Makoundi, C., Basori, M.B.I., Lai, G.T., and Rahman, Z.A., 2022, Emerging trends in earth science for sustainable futures in the SE Asia region: Journal of Asian Earth Sciences, v. 237, Article 105358.

Jones, C.L., Orovan, E.A., Meffre, S., Thompson, J., Belousova, E.A., **Cracknell, M.J.**, Everard, J., Bottrill, R., Bodorkos, S., and **Cooke, D.R.,** 2022, Zircon O and Lu-Hf isotope evidence of mantle and supracrustal origins of Tasmanian Devonian granites: Gondwana Research, v. 110, p. 1-12.

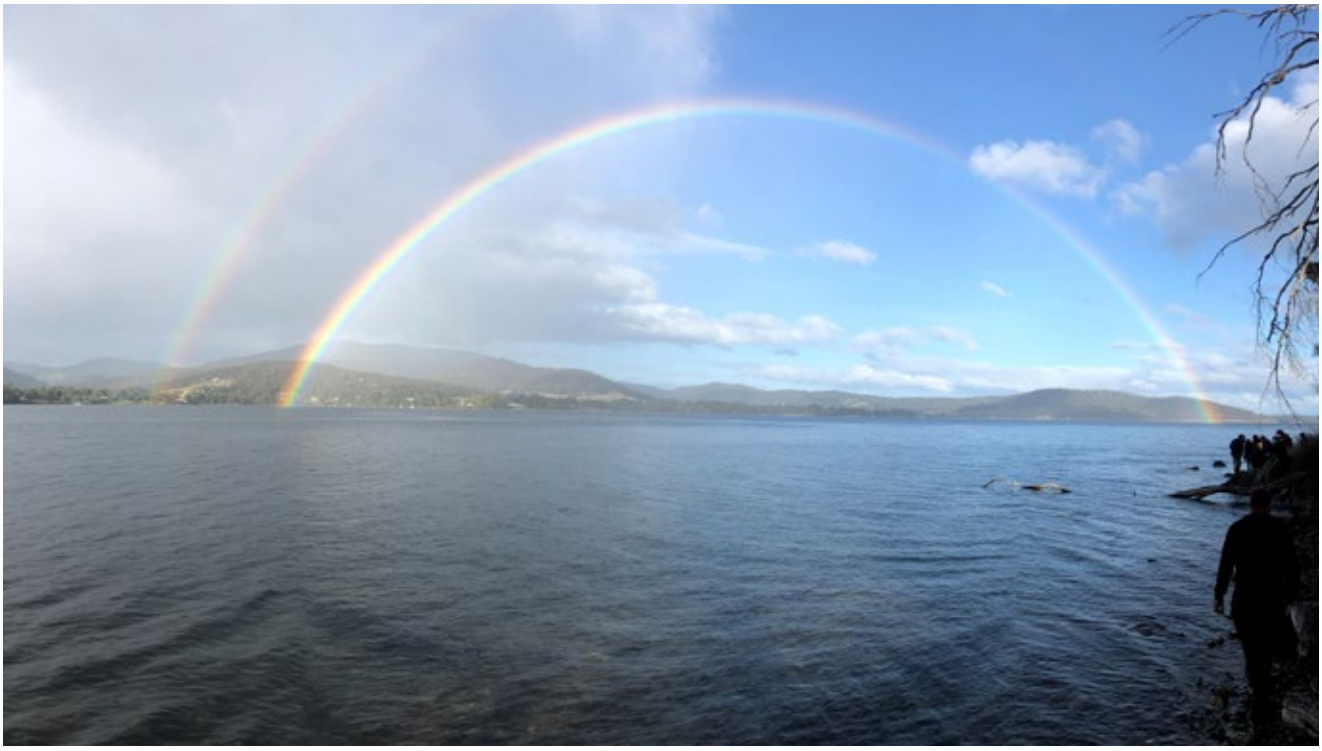
Large, R.R., Hazen, R.M., Morrison, S.M., Gregory, D.D., **Steadman, J.A.,** and **Mukherjee, I.,** 2022, Evidence that the GOE was a prolonged event with a peak around 1900 Ma: Geosystems and Geoenvironment, v. 1(2), Article 100036.

Large, R., Mukherjee, I., Danyushevsky, L., Gregory, D., **Steadman, J.,** and Corkrey, R., 2022, Sedimentary pyrite proxy for atmospheric oxygen: evaluation of strengths and limitations: Earth-Science Reviews, v. 227, Article 103941.

Li, W., Qiao, X., Zhang, F., and **Zhang, L.,** 2022, Tourmaline as a potential mineral for exploring porphyry deposits: a case study of the Bilihe gold deposit in Inner Mongolia, China: Mineralium Deposita, v. 57, p. 61-82.

McCarthy, A., **Falloon, T.J., Danyushevsky, L.V.,** Sauermilch, I., Patriat, M., Jean, M.M., Maas, R., Woodhead, J.D., and Yogodzinski, G.M., 2022, Implications of high-Mg# adakitic magmatism at Hunter Ridge for arc magmatism of the Fiji - Vanuatu region: Earth and Planetary Science Letters, v. 590, Article 117592.

McCarthy, A., Magri, L., Sauermilch, I., Fox, J., Seton, M., Mohn, G., Tugend, J., Feig, S., **Falloon, T.,** and Whittaker, J.M., 2022, The Louisiade ophiolite: a missing link in the western Pacific: Terra Nova, v. 34(2), p. 146-154.



'Double rainbow': this photo was taken by PhD student Zeb Zivkovic on an Australian Institute of Geologists field trip to Cygnet in April 2022, and was an entry in the 2022 CODES Photo Competition.

McNulty, B.A., Jowitt, S.M., and **Belousov, I.,** 2022, The importance of geology in assessing by- and coproduct metal supply potential; a case study of antimony, bismuth, selenium, and tellurium within the copper production stream: Economic Geology, v. 117(6), p. 1367-1385.

Merrill-Cifuentes, J., Cracknell, M.J., and **Escolme, A.,** 2022, Unsupervised textural classification of rocks in large imagery datasets: Minerals Engineering, v. 180, Article 107496.

Miller, C.B., Cleaver, A., Huntsman, P., Asemaninejad, A., Rutledge, K., Bouwhuis, R., and Rickwood, C.J., 2022, Predicting water quality in Canada: mind the (data) gap: Canadian Water Resources Journal, v. 47(4), p. 169-175.

Miller, C.B., Parsons, M.B., Jamieson, H.E., Ardakani, O.H., Patterson, R.T., and Galloway, J.M., 2022, Mediation of arsenic mobility by organic matter in mining-impacted sediment from sub-Arctic lakes: implications for environmental monitoring in a warming climate: Environmental Earth Sciences, v. 81(4), Article 137.

Mitchell, S.J., Hudak, M.R., Bindeman, I.N., **Carey, R.J.,** McIntosh, I.M., Houghton, B.F., and Rubin, K.H., 2022, Isotopic signatures of magmatic fluids and seawater within silicic submarine volcanic deposits: Geochimica et Cosmochimica Acta, v. 326, p. 214-233.

Moore, H.C., Carey, R.J., Houghton, B.F., **Jutzeler, M.,** and White, J.D.L., 2022, High temperature oxidation of proximal basaltic pyroclasts, 1886 Tarawera, New Zealand: Bulletin of Volcanology, v. 84, Article 46.

Penrose, B., MacIntosh, A.E., **Parbhakar-Fox, A.,** Smith, L.B.E., **Sawyer, T.**, D'Agnese, E., and Carver, S., 2022, Heavy metal wombats? Metal exposure pathways to bare-nosed wombats (*Vombatus ursinus*) living on remediated tin mine tailings: Science of the Total Environment, v. 835, Article 155526.

Shah, S.H.A., **Habib, U.,** Mohamed, A., Aziz, M., Rehman, Q.U., and Saleem, A., 2022, Laboratory and in situ stabilization of compacted clay through granite waste powder: Sustainability, v. 14(21), Article 14459.

Shah, S.H.A., Tanoli, J.I., **Habib, U.,** Rehman, Q.U., Ali, E., and Mohamed, A., 2022, Assessing potential of Dor River as small hydro project for lessening energy crisis and enhancing Tarbela Reservoir life in Khyber Pakhtunkhwa, Pakistan: Water, v. 14(17), Article 2683.

Steadman, J.A., Goemann, K., Thompson, J.M., MacRae, C.M., **Belousov, I.,** and **Hohl, M.,** 2022, Hyperspectral cathodoluminescence, trace element, and U-Pb geochronological characterization of apatite from the Ernest Henry iron oxide copper-gold (IOCG) deposit, Cloncurry district, Queensland: Frontiers in Earth Science, v. 10, Article 926114.

Thomas, R., **Davidson, P.,** and Rericha, A., 2022, Prismatine granulite from Waldheim/Saxony: Zircon-Reidite: Journal of Earth & Environmental Science, JEES-103.

Thomas, R., **Davidson, P.,** Rericha, A., and Recknagel, U., 2022, Discovery of Stishovite in the prismatine-bearing granulite from Waldheim, Germany: A possible role of supercritical fluids of ultrahigh-pressure origin: Geosciences, v. 12(5), Article 196.

Thomas, R., **Davidson, P.,** Rericha, A., and Recknagel, U., 2022, Water-rich coesite in prismatine-granulite from Waldheim/Saxony: Veröffentlichungen Museum für Naturkunde Chemnitz, v. 45, p. 67-80.

Thomas, R., **Davidson, P.,** Rericha, A., and Voznyak, D.K., 2022, Water-rich melt inclusion as "frozen" samples of the supercritical state in granites and pegmatites reveal extreme element enrichment resulting under non-equilibrium conditions: Mineralogical Journal (Ukraine), v. 44(1), p. 3-15.

Vergani, D., McPhie, J., Carey, R., and Di Muro, A., 2022, Intracaldera explosions and lava emissions during the 2007 caldera collapse of Piton de la Fournaise, La Réunion Island: Bulletin of Volcanology, v. 84, Article 19.

Wang, Y., Chen, H., **Falloon, T.J.,** and Han, J., 2022, The Paleozoic-Mesozoic magmatic evolution of the Eastern Tianshan, NW China: Constraints from geochronology and geochemistry of the Sanchakou intrusive complex: Gondwana Research, v. 103, p. 1-22.

Yin, S., Hernandez-Molina, F.J., **Jutzeler, M.,** and Li, J., 2022, Progressive intensification of Pacific Deep Water circulation since the early Pliocene: Geophysical Research Letters, v. 49(9), Article e2022GL098051.

Zheng, M., Mittal, T., Fauria, K.E., Subramaniam, A., and **Jutzeler, M.,** 2022, Pumice raft detection using machine-learning on multispectral satellite imagery: Frontiers in Earth Science, v. 10, Article 838532.

Invited keynotes addresses (4)

Cooke, D.R.,2022, Geological evolution of the Lihir gold deposit, Papua New Guinea: SGA 2022 – Virtual, Rotorua, New Zealand.

Cooke, D.R., 2022, Mineral systems in convergent margin settings – opportunities for discovery in the Tasmanides: Mines and Wines 2022, Orange, Australia.

Cooke, D.R., 2022, Understanding ore-forming processes to lead to a discovery: MGEI Annual Convention, Banyuwangi, Indonesia.

Khin Zaw, 2022, Recent advances in studies of tectonic and metallogeny of Loei and Trouson Fold Belts in SE Asia: GEOINDO 2022 – Online.

Conference abstracts (32)

Armistead, S., Meffre, S., Bottrill, R., Cross, A., Huston, D., Mulder, J., Steadman, J., and Halpin, J., 2022, New timing constraints on the metallogenic evolution of western Tasmania: Tasmanian Geoscience Forum, Tullah, Australia, PowerPoint presentation, 20 slides.

Armistead, S.E., Meffre, S., Bottrill, R., Cross, A., Huston, D., Mulder, J., Steadman, J., and Halpin, J., 2022, New timing constraints on the metallogenic and tectonic evolution of western Tasmania: GSA SGTSG Biennial Meeting, King Island, Australia, Abstract, p. 4.

Armistead, S.E., Boone, S.C., Chen, B., Dalton, H., Dux, F., Gleadow, A., Gréau, Y., Hodgekiss, S-A., Ananuer, H., Kohlmann, F., Kohn, B., McInnes, B., Nixon, A., Noble, W., Phillips, D., Prent, A.M., Rawling, T., Theile, M., Wang, X., Ware, B., and Zhou, R., 2022, AusGeochem – a novel geochemistry data platform for enabling big-data geochemical studies into Earth's composition and evolution: GSA SGTSG Biennial Meeting, King Island, Australia, Abstract, p. 5.

Baker, M.J., Thompson, J., and Zhang, L., 2022, Discrimination of magmatic-hydrothermal events using quartz texture and mineral chemistry: SGA 2022 – Virtual, Rotorua, New Zealand, Proceedings v. 2, p. 4.

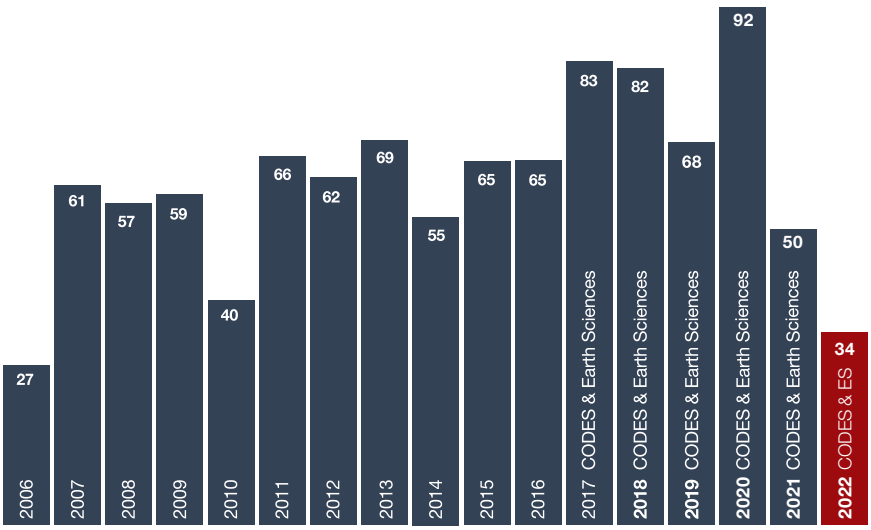
Berry, R., Bottrill, R., Cumming, G.V., Everard, J.L., and Goemann, K., 2022, Multiple events along the shear zones of King Island, Tasmania: GSA SGTSG Biennial Meeting, King Island, Australia, Abstract, p. 8.

Cloutier, J., Steadman, J.A., Hohl, M., Cooke, D.R., and Barker, S.L.L., 2022, Geology and mineral chemistry of alteration minerals at the Mt Eliott, Corbould and SWAN deposits, NW Queensland, Australia: SGA 2022 – Virtual, Rotorua, New Zealand, Proceedings v. 2, p. 39.

Cracknell, M.J., Baker, M., Cooke, S., Cooke, D.R., Danyushevsky, L., Belousov, I., and Olin, P., 2022, LocatOre: a tool for modeling proximitor equations using multi-element mineral chemistry data: SGA 2022 – Virtual, Rotorua, New Zealand, Proceedings v. 2, p. 41.

Direen, N.G., 2022, Overturning paradigms: Detailed field observations from the Himalayan Main Frontal Thrust and frontal foldbelt, Nepal: GSA SGTSG Biennial Meeting, King Island, Australia, Abstract, p. 17.

do Nascimento, S.C., Parbhakar-Fox, A.K., and Cracknell, M.J., 2022, Geoenvironmental characterisation of the King River Delta: A combined geophysical, geochemical and mineralogical approach: Goldschmidt 2022, Hawaii, USA, Poster.



REFEREED JOURNAL ARTICLES

'Multiply deformed sandy turbidites of the Early Ordovician Stony Head Sandstone (Mathinna Supergroup), Stony Head, Tasmania, taken during the KEA310 field trip to northeast Tasmania, 2022': this photo was taken by Rob Scott and was an entry in the 2022 CODES Photo Competition.

Escolme, A., 2022, Trace element deportment – knowledge is power: SGA 2022 – Virtual, Rotorua, New Zealand, Proceedings v. 2, p. 53.

Farrar, A., Cooke, D.R., Cracknell, M., Hronsky, J., and Piquer, J., 2022, Lithospheric architecture of the central Andes and the localization of giant porphyry copper deposits during key geodynamic epochs: SGA 2022 – Virtual, Rotorua, New Zealand, Proceedings v. 2, p. 55.

Farrar, A., Cracknell, M., Schaap, T, and Cooke, D.R., 2022, Comparing plate motion models and crustal thickening in the central Andes using time-series analysis and data analytics: GSA SGTSG Biennial Meeting, King Island, Australia, Abstract, p. 19.

Harris, A.C., Fitzpatrick, N., MacCorquodale, F., Wilson, A.J., Cooke, D.R., and Tosdal, R.M., 2022, Alkalic Au-Cu deposits of the Cadia Valley (New South Wales) and Red Chris (British Columbia): unconventional ancient porphyry deposits associated with post-subduction magmatism: SGA 2022 – Virtual, Rotorua, New Zealand, Proceedings v. 2, p. 71.

Hohl, M., Steadman, J.A., Cloutier, J., Cooke, D.R., and Barker, S.L.L., 2022, Trace element systematics of magnetite from the Starra IOCG system, NW Queensland, Australia: SGA 2022 – Virtual, Rotorua, New Zealand, Proceedings v. 2, p. 73.

Hunt, J., Cooke, D., Fraser, S., and Zhang, L., 2022, Environmentally sustainable production of critical metals: A new Tasmania-focused research project at CODES/UTAS, Tasmanian Geoscience Forum, Tullah, Australia, PowerPoint presentation, 17 slides.

Hunt, J., Guerrero, N., Morales, K.A., Cracknell, M.J., and Roach, M.J., 2022, Geological characterization to identify upgrade potential and enhance mining efficiency: SGA 2022 – Virtual, Rotorua, New Zealand, Proceedings v. 2, p. 80.

Ilaava, M., Greene, M., Reid, B., Milojkovic, T., Clifford, M., Browne, C., Biggam, J., Leslie, C., Barker, A., Howard, N., and Jutzeler, M., 2022, Cowal gold mine: new insights and research update: Mines and Wines 2022, Orange, Australia, p. 225-227.

Ilaava, M., Jutzeler, M., Carey, R., and Cas, R., 2022, Volcanic Facies Architecture of the Cowal Igneous Complex, NSW: Mines and Wines 2022, Orange, Australia, p. 1-17.

Jones, R., Cooke, D.R., Escolme, E., Zhang, L., and Hoye, J., 2022, The significance of phyllic alteration at the E26 porphyry Cu-Au deposit, Northparkes, NSW, Australia: SGA 2022 – Virtual, Rotorua, New Zealand, Proceedings v. 2, p. 88.

Jones, S.L., Cumming, G.V., Waltenberg, K., Everard, J.L., Vicary, M.J., Duncan, R., Bodorkos, S., Champion, D.C., Huston, D.L., Meffre, S.J., Bottrill, R.S., Waugh, S., and Fraser, G.L., 2022, ISOTOPIC ATLAS OF AUSTRALIA: An Update: GSA SGTSG Biennial Meeting, King Island, Australia, Abstract, p. 33.

Jutzeler, M., Dagasan, Y., and Carey, R., 2022, Machine-learning image analysis on phenocrysts to reconstruct lithostratigraphy in mineralised terrains: An example with dacites in the Mt Read Volcanics: Tasmanian Geoscience Forum, Tullah, Australia, PowerPoint presentation, 25 slides.

'Mt Tarawera, NZ, distant view: August–October volcanology fieldwork for my PhD': this photo was taken by CODES PhD student Hannah Moore and was an entry in the 2022 CODES Photo Competition.

Meffre, S., Habib, U., and Berry, R., 2022, Constraining the Cambrian to Early Ordovician tectonic history of the Lachlan Orogen: GSA SGTSG Biennial Meeting, King Island, Australia, Abstract, p. 34.

Merrill-Cifuentes, J., Cracknell, M.J., and Escolme, A., 2022, Comminution hardness forecasting from hyperspectral drill core image derived textural clusters: Process Mineralogy, Sitges, Spain, 1p.

Merrill-Cifuentes, J., Cracknell, M.J., and Escolme, A., 2022, Quantitative image textural analysis for copper flotation recovery: SGA 2022 – Virtual, Rotorua, New Zealand, Proceedings v. 2, p. 118.

Miller, C.B., Cracknell, M.J., Wilson, O., Heng, W., Fisher, E., Roach, M., Cooke, D., Virtue, R., and Steyn, C., 2022, Multidisciplinary characterisation of groundwater flow and contaminant transport in legacy mine wastes, Endurance Mine, northeast Tasmania: Goldschmidt 2022, Hawaii, USA, Oral Presentation.

Morales, K.A., Hunt, J., Cracknell, M.J., and Roach, M., 2022, Geological controls for pre-concentration in an intrusive related gold deposit: SGA 2022 – Virtual, Rotorua, New Zealand, Oral Presentation and Extended Abstract, Proceedings v. 1, p. 259-262.

Roach, M.J., Zhang, L., Cooke, D.R., Testa, F., and Callaghan, T., 2022, 3D geological model of the Dolphin tungsten skarn deposit, King Island, Australia: SGA 2022 – Virtual, Rotorua, New Zealand, Proceedings v. 2, p. 154.

Scott, R.J., Roach, M.J., Corbett, Z., Port, I., Reeve, A., Fisher, D.B., Keo, K., and Waldron, J., 2022, Bye-bye Benambran? Reappraising the evidence for early Silurian deformation in Tasmania/lutruwita: GSA SGTSG Biennial Meeting, King Island, Australia, Abstract, p. 43.

Seow, X.N., and Zhang, L., 2022, Aluminum phosphate-sulfate (APS) minerals: a new potential exploration tool in porphyry – high-sulfidation epithermal deposits: SGA 2022 – Virtual, Rotorua, New Zealand, Proceedings v. 2, p. 166.

Steadman, J.A., 2022, Tracking the Ernest Henry signature: insights from epidote and chlorite chemistry: SGA 2022 – Virtual, Rotorua, New Zealand, Proceedings v. 2, p. 173.

Steadman, J.A., and Hohl, M., 2022, Controls on Fe-Ti oxide formation in the Cloncurry district, Mt. Isa Inlier, NW Queensland: insights from Ernest Henry and Starra 222: SGA 2022 – Virtual, Rotorua, New Zealand, Proceedings v. 2, p. 173.

Zhang, L., Testa, F., Cooke, D.R., Moltzen, J., Goemann, K., Feig, S., and Callaghan, T., 2022, Using visible-near, shortwave and thermal infrared spectral data, and mineral chemistry to aid tungsten skarn exploration: a case study from the Dolphin deposit, King Island, Australia: SGA 2022 – Virtual, Rotorua, New Zealand, Proceedings v. 2, p. 194.

Research reports to industry/government agencies (274)

AMIRA P1249 research team, 2022, Cowal (GRE46), NSW, Australia: AMIRA P1249 SRM #1, 21 & 22 June 2022, p.111-139.

AMIRA P1249 research team, 2022, Introduction: AMIRA P1249 SRM #2, 29 & 30 November 2022, p. 1-23.

AMIRA P1249 research team, 2022, P1249 Forward program – June 2022: AMIRA P1249 SRM #1, 21 & 22 June 2022, p.280-284.

Andrew, B.S., Brown, A., Rea, P., Shaw, T., Barker, S.L.L., Baker, M., and Cooke, D.R., 2022, Lithogeochemical evidence of cryptic metasomatic alteration associated with Cu mineralisation, Mount Isa, Northwest Queensland: AMIRA P1249 Review Meeting, 10 February 2022, p. 63-107.

Baker, M., and Piquer, J., 2022, El Teniente, Chile progress report: tourmaline reanalysis and Honours sub-projects: AMIRA P1249 SRM #1, 21 & 22 June 2022, p. 46-78.

Baker, M., and the AMIRA P1249 research team, 2022, Introduction: AMIRA P1249 SRM #1, 21 & 22 June 2022, p. 1-21.

Baker, M., Cooke, D.R., Barker, S., Cracknell, M., Hollings, P., Smyk, E., Jedemann, A., Arcos, C., Piquer, J., Enkhbold, B., Orovan, E., Belousov, I., Danyushevsky, L., Marcelissen, M., Cooke, S., Wilkinson, J., Phillips, J., Garay, A., Ahmed, A., Thompson, J., Gorner, E., Vrzovski, J., Fay, L., Ireland, T., Olin, P., Thompson, J., and Wilkinson, C., 2022, AMIRA footprints projects: exploration in green and white rocks: AMIRA P1249 Review Meeting, 10 February 2022, p. 17-62.

Baker, M., Danyushevsky, L., Garay, A., Belousov, I., Marcelissen, M., Hollings, P., and Morissette, M., 2022, Magmatic mineral chemistry in the AMIRA footprints projects: AMIRA P1249 Review Meeting, 10 February 2022, p. 294-340.

Baker, M., Piquer, J., Hollings, P., Rojas, I., and Uribe, J., 2022, El Teniente, Chile - Progress report: white mica analysis and Honours sub-projects: AMIRA P1249 SRM #2, 29 & 30 November 2022, p. 218-248.

Beas, B., Zhang, L., Cooke, D.R., Staubmann, M., Jones, R., and Hoye, J., 2022, Exploration tools for assessing fertility and vectoring to high-grade ore: E44 Northparkes District: AMIRA P1249 SRM #2, 29 & 30 November 2022, p. 24-50.

Belousov, I., 2022, P1334. Chlorite and epidote chemistry for 7 samples: Report to BHP Peru, 4 p.

Belousov, I., 2022, P1343. Chlorite and epidote chemistry for 5 samples: Report to Inflection Resources, 3 p.

Belousov, I., 2022, P1416. Chlorite and epidote chemistry for 19 samples: Report to Copperman Chile, 5 p.

Belousov, I., 2022, P1424. Chlorite and epidote chemistry for 3 samples: Report to BHP Peru, 3 p.

Belousov, I., 2022, P1428. Chlorite and epidote chemistry for 4 samples: Report to Inflection Resources, 3 p.

Belousov, I., and Danyushevsky, L., 2022, P1174. Chlorite and epidote chemistry for 2 samples: Report to Almaden Minerals, 3 p.

Belousov, I., and Danyushevsky, L., 2022, P1197. Chlorite and epidote chemistry for 11 samples: Report to First Quantum Minerals, 4 p.

Belousov, I., and Danyushevsky, L., 2022, P1210. Chlorite and epidote chemistry for 3 samples for Report to BHP Peru, 3 p.

Belousov, I., and Danyushevsky, L., 2022, P1227. Chlorite and epidote chemistry for 14 samples: Report to Copperman Chile, 5 p.

Belousov, I., and Danyushevsky, L., 2022, P1245: U-Pb zircon geochronology report: Report to Codelco, 10 p.

Belousov, I., and Danyushevsky, L., 2022, P1247. Chlorite and epidote chemistry for 6 samples: Report to Inflection Resources, 3 p.

Belousov, I., and Danyushevsky, L., 2022, P1254. Chlorite and epidote chemistry for 5 samples: Report to BHP Peru, 3 p.

Belousov, I., and Danyushevsky, L., 2022, P1345. Chlorite and epidote chemistry for 27 samples: Report to First Quantum Minerals, Argentina, 6 p.

Belousov, I., and Danyushevsky, L., 2022, P1345. Garnet and titanite chemistry: Report to First Quantum Minerals, Argentina, 3 p.

Belousov, I., and Danyushevsky, L., 2022, P1345. Magnetite chemistry for 16 samples: Report to First Quantum Minerals, Argentina, 4 p.

Belousov, I., and Morissette, M., 2022, P1402: U-Pb zircon geochronology report: Report to Anglo American Chile, 7 p.

Belousov, I., and Morissette, M., 2022, P1403: U-Pb zircon geochronology report: Report to ALS Perth, 7 p.

Belousov, I., and Morissette, M., 2022, P1404a: U-Pb zircon geochronology report: Report to ALS Perth, 7 p.

Belousov, I., Cooke, D., and Danyushevsky, L., 2022, P1174 Fertility and vectoring report, Report to Almaden Minerals, 11 p.

Belousov, I., Cooke, D., and Danyushevsky, L., 2022, P1227 Copperman fertility and vectoring report: Report to Copperman Chile, 11 p.

'"Are you wet yet?": KEA348/VIEPS environmental geology students enjoying a snack while the rain holds off, Bank D, King River, Aug/Sept 2022': this photo was taken by Matthew Cracknell and was an entry in the 2022 CODES Photo Competition.

Belousov, I., Cooke, D.R., Danyushevsky, L., and Baker, M., 2022, Nolasco/Santa Clara Rio Tinto Blind Test: AMIRA P1249 SRM #1, 21 & 22 June 2022, p.270-279.

Belousov, I., Cooke, D.R., Danyushevsky, L., Halley, S., Piquer, J., and Baker, M., 2022, Nolasco/Santa Clara Rio Tinto Blind Test: AMIRA P1249 SRM #2, 29 & 30 November 2022, p. 249-287.

Belousov, I., Danyushevsky, L., and Morissette, M., 2022, P1161: U-Pb zircon geochronology report: Report to ALS, 7 p.

Belousov, I., Danyushevsky, L., and Morissette, M., 2022, P1180. Chlorite and epidote chemistry for 8 samples: Report to BHP Peru, 3 p.

Belousov, I., Danyushevsky, L., and Morissette, M., 2022, P1197 U-Pb zircon geochronology report: Report to First Quantum Minerals Chile, 9 p.

Belousov, I., Danyushevsky, L., and Morissette, M., 2022, P1200: U-Pb zircon geochronology report: Report to Codelco, 7 p.

Belousov, I., Danyushevsky, L., and Morissette, M., 2022, P1201 U-Pb rutile geochronology report: Report to Kirkland Lake Gold, 6p.

Belousov, I., Danyushevsky, L., and Morissette, M., 2022, P1201: U-Pb zircon geochronology report: Report to Kirkland Lake Gold, 6 p.

Belousov, I., Danyushevsky, L., and Morissette, M., 2022, P1204: U-Pb zircon geochronology report: Report to Codelco, 9 p.

Belousov, I., Danyushevsky, L., and Morissette, M., 2022, P1215: U-Pb zircon geochronology report: Report to Codelco, 9 p.

Belousov, I., Danyushevsky, L., and Morissette, M., 2022, P1217 U-Pb zircon geochronology report: Report to ALS Perth, 6 p.

Belousov, I., Danyushevsky, L., and Morissette, M., 2022, P1222: U-Pb zircon geochronology report: Report to Codelco, 11 p.

Belousov, I., Danyushevsky, L., and Morissette, M., 2022, P1235: U-Pb zircon geochronology report: Report to ALS Perth, 8 p.

Belousov, I., Danyushevsky, L., and Morissette, M., 2022, P1242 U-Pb zircon geochronology report: Report to ALS Brisbane, 7 p.

Belousov, I., Danyushevsky, L., and Morissette, M., 2022, P1249: U-Pb zircon geochronology report: Report to Teck Chile, 10 p.

Belousov, I., Danyushevsky, L., and Morissette, M., 2022, P1261: U-Pb zircon geochronology report: Report to Teck Chile, 7 p.

Belousov, I., Danyushevsky, L., and Morissette, M., 2022, P1265: U-Pb zircon geochronology report: Report to Anglo American Peru, Hobart, Australia, 10 p.

Belousov, I., Danyushevsky, L., and Morissette, M., 2022, P1268 U-Pb zircon geochronology report: Report to BHP Peru, 7 p.

Belousov, I., Danyushevsky, L., and Morissette, M., 2022, P1278: U-Pb zircon geochronology report: Report to Anglo American Ecuador, 9 p.

Belousov, I., Danyushevsky, L., and Morissette, M., 2022, P1279: U-Pb zircon geochronology report: Report to Anglo American Namibia, 18 p.

Belousov, I., Danyushevsky, L., and Morissette, M., 2022, P1291 Apatite and Titanite: U-Pb zircon geochronology report: Report to Anglo American Zambia, 7 p.

Belousov, I., Danyushevsky, L., and Morissette, M., 2022, P1300: U-Pb apatite and titanite geochronology report: Report to First Quantum Minerals, 6 p.

Belousov, I., Danyushevsky, L., and Morissette, M., 2022, P1305. Chlorite and epidote chemistry for 26 samples: Report to BHP Peru, 6 p.

Belousov, I., Danyushevsky, L., and Oalmann, J., 2022, P1176: U-Pb zircon geochronology report: Report to ALS Perth, 8 p.

Belousov, I., Danyushevsky, L., and Oalmann, J., 2022, P1177: U-Pb zircon geochronology report: Report to ALS Perth, 1 p.

Belousov, I., Danyushevsky, L., and Oalmann, J., 2022, P1178 U-Pb zircon geochronology report: Report to Teck Chile, 13 p.

Belousov, I., Danyushevsky, L., and Oalmann, J., 2022, P1221 U-Pb zircon geochronology report: Report to ALS Perth, 1 p.

Belousov, I., Danyushevsky, L., Oalmann, J., and Morissette, M., 2022, P1170: U-Pb zircon geochronology report: Report to Teck Chile, 8 p.

Belousov, I., Danyushevsky, L., Oalmann, J., and Morissette, M., 2022, P1185 U-Pb zircon geochronology report: Report to Teck Peru, 11 p.

Belousov, I., Danyushevsky, L., Oalmann, J., and Morissette, M., 2022, P1185: U-Pb apatite geochronology report: Report to Teck Peru, 5 p.

Belousov, I., Danyushevsky, L., Oalmann, J., and Morissette, M., 2022, P1281: U-Pb apatite geochronology report: Report to Fortescue Metals Group (FMG), 7 p.

Belousov, I., Oalmann, J., and Danyushevsky, L., 2022, P1181 U-Pb zircon geochronology report: Report to BHP Peru, 10 p.

Belousov, I., Oalmann, J., and Danyushevsky, L., 2022, P1191: U-Pb zircon geochronology report: Report to Codelco, 10 p.

Belousov, I., Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1175: U-Pb zircon geochronology report: Report to Codelco, 8 p.

Bigelow, J., 2022, Newmont AMIRA P1249 Study Site Proposal: AMIRA P1249 SRM #2, 29 & 30 November 2022, p. 339-350.

Brown, A., 2022, Textural Clustering of Colour Images – An Adventure in Technology: AMIRA P1249 SRM #2, 29 & 30 November 2022, p. 133-145.

Cooke, D.R., and P1249 research team, 2022, P1249 Forward program – November 2022: AMIRA P1249 SRM #2, 29 & 30 November 2022, p. 406-411.

Cooke, D.R., and the AMIRA P1249 research team, 2022, Exploring, characterising, and optimising complex orebodies – Integrated deposit knowledge to add value across the mining value chain: AMIRA P1249 Start-up Meeting, 11 February 2022, p. 1-14.

'Mt Tarawera, NZ: August–October volcanology fieldwork for my PhD': taken by Hannah Moore. This photo won first prize in the 'Scenic' section of the 2022 CODES Photo Competition.

Cooke, D.R., and the AMIRA P765, 765A, 1060, 1153 and 1202 research teams, 2022, AMIRA footprints projects overview: AMIRA P1249 Review Meeting, 10 February, p. 1-16.

Cooke, D.R., Cracknell, M., Baker, M., Zhang, L., Hollings, P., White, N., Belousov, I., Gemmell, J.B., Thompson, J., Wilkinson, J., and Chang, Z., 2022, The Explorer's Toolbox for exploring in green and white rocks: AMIRA P1249 Review Meeting, 10 February 2022, p. 170-202.

Cooke, D.R., Zhang, L., Chang, Z., Danyushevsky, L., White, N., Hollings, P., Hedenquist, J., Baker, M., and Deyell, C., 2022, Baguio lithocap, Philippines: AMIRA P1249 SRM #1, 21 & 22 June 2022, p.232-269.

Cooke, S., Cracknell., M.J., and Danyushevsky, L., 2022, Pathways to mineral discoveries through computer-based modelling of geochemical data: AMIRA P1249 SRM #1, 21 & 22 June 2022, p.170-184.

Cracknell, M., and the AMIRA P1249 research team, 2022, Module 2: Characterisation and domaining: Upscaling from micro- to macroscopic to enhance orebody knowledge: AMIRA P1249 Start-up Meeting, 11 February 2022, p. 63-84.

Cracknell, M., Cooke, S., Cooke, D.R., Baker, M., Smyk, E., Danyushevsky, L., and Belousov, I., 2022, LocateOre Version 2.0 and Heat and Fluid Source Vectoring: AMIRA P1249 Review Meeting, 10 February 2022, p. 144-169.

Cracknell., M.J., Baker, M., Testa, F., Leslie, C., Zhang, L., Belousov, I. and Danyushevsky, L., 2022, Cowal green rock multivariate analysis (a revisit): AMIRA P1249 SRM #1, 21 & 22 June 2022, p. 94-110.

Cracknell., M.J., Baker, M., Zhang, L., and Cooke, D.R., 2022, Aligning P1249 study sites with research objectives: AMIRA P1249 SRM #1, 21 & 22 June 2022, p. 79-93.

Danyushevsky, L., and Morissette, M., 2022, P1123 U-Pb zircon geochronology report: Report to Chilean Geological Survey, 26 p.

Danyushevsky, L., and Morissette, M., 2022, P1129 U-Pb zircon geochronology report: Report to Chilean Geological Survey, 9 p.

Danyushevsky, L., and Morissette, M., 2022, P1136 U-Pb zircon geochronology report: Report to Chilean Geological Survey, 6 p.

Danyushevsky, L., and Morissette, M., 2022, P1142: U-Pb zircon geochronology report: Report to Solgold, 6 p.

Danyushevsky, L., and Morissette, M., 2022, P1143 U-Pb zircon geochronology report: Report to Chilean Geological Survey, 17 p.

Danyushevsky, L., and Morissette, M., 2022, P1149: U-Pb zircon geochronology report: Report to Chilean Geological Survey, 6 p.

'Lake Rosebery – I was lucky to visit Tullah for the first time on the one sunny day of the year!': taken by Owen Missen and entered in the 2022 CODES Photo Competition.

Danyushevsky, L., and Morissette, M., 2022, P1151: U-Pb zircon geochronology report: Report to Godolphin Resources, 5 p.

Danyushevsky, L., and Morissette, M., 2022, P1313/P1327/P1332/P1339: U-Pb zircon geochronology report: Report to Merdeka Copper Gold, 23 p.

Danyushevsky, L., and Morissette, M., 2022, P1379 Report on quartz trace element contents: Report to Fortescue MG, 20 p.

Danyushevsky, L., and the AMIRA P1249 research team, 2022, Mineral chemistry data reduction overview: AMIRA P1249 SRM #1, 21 & 22 June 2022, p.212-231.

Danyushevsky, L., Belousov, I., Baker, M., Zhang, L., Testa, F., Smyk, E., Cooke, D.R., and Morissette, M., 2022, P1202 Module 3: Learnings from prospectivity assessment blind tests: AMIRA P1249 Review Meeting, 10 February 2022, p. 341-360.

Danyushevsky, L., Belousov, I., Oalmann, J., and Morissette, M., 2022, P1233: U-Pb zircon geochronology report: Report to Inflection Resources, 10 p.

Danyushevsky, L., Morissette, M., and Oalmann, J., 2022, P1309: U-Pb zircon geochronology report: Report to Teck Chile, 5 p.

Danyushevsky, L., Morissette, M., Oalmann, J., and Belousov, I., 2022, P1246: U-Pb zircon geochronology report: Report to Codelco, 11 p.

Danyushevsky, L., Morissette, M., Oalmann, J., and Belousov, I., 2022, P1254: U-Pb zircon geochronology report: Report to BHP Peru, 9 p.

Danyushevsky, L., Morissette, M., Oalmann, J., and Belousov, I., 2022, P1266: U-Pb zircon geochronology report: Report to Teck Chile, 10 p.

Danyushevsky, L., Morissette, M., Oalmann, J., and Belousov, I., 2022, P1297: U-Pb zircon geochronology report: Report to Codelco, 13 p.

Danyushevsky, L., Oalmann, J., and Morissette, M., 2022, P1302: U-Pb zircon geochronology report: Report to Anglo American Ecuador, 8 p.

Halley, S., 2022. Cowal calculated mineralogy model: AMIRA P1249 Start-up Meeting, 11 February 2022, p. 85-112.

Halley, S., Baker, M., Osorio, J., and Cima, A., 2022, Ventana Progress report – November 2022: AMIRA P1249 SRM #2, 29 & 30 November 2022, p. 288-317.

Halley, S., Staubmann, M., and Jones, R., 2022, Endeavour 44 - Lithogeochemistry and Mineralogy: AMIRA P1249 SRM #2, 29 & 30 November 2022, p. 51-79.

Hollings, P., Cooke, D.R., and Zhang, L., 2022, P1249 research at Lakehead University – Red Lake, Ontario and Vancouver Island, BC: AMIRA P1249 SRM #2, 29 & 30 November 2022, p. 318-338.

Hollings, P., Gorner, E., Vrzovski, J., Fay, L., Cooke, D.R., Orovan, E., Zhang, L., Baker, M., Belousov, I., and Olin, P., 2022, Mineral chemistry of the Hemlo Au district: AMIRA P1249 Review Meeting, 10 February 2022, p. 108-143.

Hong, W., Zhang, L., Cooke, D.R., Fox, N., and Chang, Z., 2022, Martabe lithocap, Indonesia: AMIRA P1249 SRM #2, 29 & 30 November 2022, p. 351-378.

Ilaava, M., Jutzeler, M., Carey, R., and Cas, R., 2022, Volcanic architecture of the Cowal Igneous Complex Junee-Narromine Volcanic Belt, Macquarie Arc, NSW: University of Tasmania, p. 52.

Ilaava, M., Jutzeler, M., Carey, R.J., and Cas, R., 2022, Volcanic facies architecture of the Cowal Igneous Complex, NSW (before later intrusions and deformation): ARC Linkage Meeting, p. 64.

Lounejeva, E., 2022, P1195. Identification and quantification of mineral phases by X-ray diffraction (XRD) in five samples: Report to BMTJV, 2 p.

Lounejeva, E., 2022, P1196. Identification and quantification of mineral phases by X-ray diffraction (XRD) in eight samples: Report to BMTJV, 3 p.

Lounejeva, E., 2022, P1219. Identification and quantification of mineral phases by X-ray diffraction (XRD) in five samples: Report to BMTJV, 2 p.

Lounejeva, E., 2022, P1239. Identification and quantification of mineral phases by X-ray diffraction (XRD) in five samples: Report to BMTJV, 2 p.

Lounejeva, E., 2022, P1256. Identification and quantification of mineral phases by X-ray diffraction (XRD) in five samples: Report to BMTJV, 2 p.

Lounejeva, E., 2022, P1271. Identification and quantification of mineral phases by X-ray diffraction (XRD) in five samples: Report to BMTJV, 2 p.

Lounejeva, E., 2022, P1275 - FPA - Wet sieving results: Report to FPA, 8 p.

Lounejeva, E., 2022, P1303. Identification and quantification of mineral phases by X-ray diffraction (XRD) in nine samples: Report to BMTJV, 2 p.

Lounejeva, E., 2022, P1317. Identification and quantification of mineral phases by X-ray diffraction (XRD) in five samples: Report to BMTJV, 2 p.

Lounejeva, E., 2022, P1347. Identification and quantification of mineral phases by X-ray diffraction (XRD) in five samples: Report to BMTJV, 2 p.

Lounejeva, E., 2022, P1370. Identification and quantification of mineral phases by X-ray diffraction (XRD) in five August 2022 samples: Report to BMTJV, 2 p.

Lounejeva, E., 2022, P1400. Identification and quantification of mineral phases by X-ray diffraction (XRD) in five September 2022 samples: Report to BMTJV, 2 p.

Lounejeva, E., 2022, P1422. Identification and quantification of mineral phases by X-ray diffraction (XRD) in five October 2022 samples: Report to BMTJV, 2 p.

Makoundi, C., 2022, P1267 - Petrography and microthermometry report: Report to First Quantum, 10 p.

Marcelissen, M., Hollings, P., Belousov, I., and Danyushevsky, L., 2022, Magmatic mineral chemistry of the Sunda arc, Indonesia: AMIRA P1249 SRM #1, 21 & 22 June 2022, p.140-169.

Merrill, J., Cracknell., M.J., and Escolme, A., 2022, Flotation recovery and AMICS image processing: AMIRA P1249 SRM #1, 21 & 22 June 2022, p.185-211.

Morissette, M., 2022, P1363. Chlorite and epidote chemistry for 4 samples: Report to BHP Peru, 4 p.

Morissette, M., 2022, P1365. Chlorite and epidote chemistry for 2 samples: Report to BHP Peru, 4 p.

Morissette, M., 2022, P1389. Chlorite and epidote chemistry for 12 samples: Report to BHP Peru, 4 p.

Morissette, M., 2022, P1407. Chlorite and epidote chemistry for 3 samples: Report to BHP Peru, 3 p.

Morissette, M., Belousov, I., and Danyushevsky, L., 2022, P1172: Chlorite and epidote chemistry for 10 samples: Report to BHP Ecuador, 4 p.

Moyo, A., Parbhakar-Fox, A., Meffre, S., Miller, C.B., and Cooke D.R., 2022, Controlling acid and metalliferous drainage at legacy mine sites in Tasmania using industrial waste: Report to MRT, February 2022, 163p.

Oalmann, J., and Danyushevsky, L., 2022, P1352. Trace element compositions of 80 minerals: Report to ALS Perth, 3 p.

Oalmann, J., and Morissette, M., 2022, P1387 U-Pb zircon geochronology report: Report to First Quantum Chile, 10 p.

Oalmann, J., and Morissette, M., 2022, P1396: U-Pb zircon geochronology report: Report to Inflection Resources, 7 p.

Oalmann, J., Belousov, I., Morissette, M., and Danyushevsky, L., 2022, P1269: U-Pb zircon geochronology report: Report Part 1 to Teck Chile, 16 p.

Oalmann, J., Belousov, I., Morissette, M., and Danyushevsky, L., 2022, P1269: U-Pb zircon geochronology report: Report Part 2 to Teck Chile, 12 p.

Oalmann, J., Belousov, I., Morissette, M., and Danyushevsky, L., 2022, P1269: U-Pb zircon geochronology report: Report Part 3 to Teck Chile, 10 p.

Oalmann, J., Belousov, I., Morissette, M., and Danyushevsky, L., 2022, P1269: U-Pb zircon geochronology report: Report Part 4 to Teck Chile, 12 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1069 Part 10: U-Pb zircon geochronology report: Report to BHP Peru, 8 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1069 Part 11: U-Pb zircon geochronology report: Report to BHP Peru, 7 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1069 Part 12: U-Pb zircon geochronology report: Report to BHP Peru, 8 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1069 Part 13: U-Pb zircon geochronology report: Report to BHP Peru, 8 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1069 Part 6: U-Pb zircon geochronology report: Report to BHP Peru, 8 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1069 Part 7: U-Pb zircon geochronology report: Report to BHP Peru, 8 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1069 Part 8: U-Pb zircon geochronology report: Report to BHP Peru, 9 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1069 Part 9: U-Pb zircon geochronology report: Report to BHP Peru, 8 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1139 Part 1: U-Pb zircon geochronology report: Report to BHP Chile, 9 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1139 Part 2: U-Pb zircon geochronology report: Report to BHP Chile, 10 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1150: U-Pb zircon geochronology report: Report to Codelco, 9 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1152 U-Pb zircon geochronology report: Report to Anglo-American Chile, 13 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1153: U-Pb zircon geochronology report: Report to Teck Ireland, 10 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1155: U-Pb zircon geochronology report: Report to Newmont, 9 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1157 U-Pb zircon geochronology report: Report to Anglo-American Chile, 9 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1158: U-Pb zircon geochronology report: Report to Codelco, 10 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1160 U-Pb zircon geochronology report: Report to Anglo Gold Ashanti Chile, 6 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1162 U-Pb zircon geochronology report: Report to Anglo-American Chile, 7 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1166: U-Pb zircon geochronology report: Report to Teck Chile, 12 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1171 Part 1: U-Pb zircon geochronology report: Report to BHP Peru, 8 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1171 Part 2: U-Pb zircon geochronology report: Report to BHP Peru, 8 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1171 Part 3: U-Pb zircon geochronology report: Report to BHP Peru, 8 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1171 Part 4: U-Pb zircon geochronology report: Report to BHP Peru, 9 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1173: U-Pb zircon geochronology report: Report to BHP Chile, 7 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1179: U-Pb zircon geochronology report: Report to Codelco, 8 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1184: U-Pb zircon geochronology report: Report to Teck Vancouver, 6 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1186 U-Pb zircon geochronology report: Report to Anglo American Ecuador, 7 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1187: U-Pb zircon geochronology report: Report to ALS, 8 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1194 U-Pb zircon geochronology report: Report to Anglo-American Chile, 6 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1205: U-Pb zircon geochronology report: Report to Anglo American Chile, 9 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1206: U-Pb zircon geochronology report: Report to BHP Chile, 6 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1208: U-Pb zircon geochronology report: Report to ALS, 6 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1211: U-Pb zircon geochronology report: Report to Codelco, 7 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1223 U-Pb zircon geochronology report: Report to Stavely Minerals, 8 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1226: U-Pb zircon geochronology report: Report to Codelco, 11 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1229 U-Pb zircon geochronology report: Report to ALS Perth, 6 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1230: U-Pb zircon geochronology report: Report to Anglo American Chile, 6 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1231: U-Pb zircon geochronology report: Report to Anglo American Chile, 7 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1241 U-Pb zircon geochronology report: Report to ALS Perth, 7 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1244 U-Pb zircon geochronology report: Report to BHP Peru, 6 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1244: U-Pb zircon geochronology report: Report to Anglo American, Chile, 6 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1272 U-Pb zircon geochronology report: Report to BHP Chile, 7 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1281: U-Pb zircon geochronology report: Report to Fortescue Mining Group, 9 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1282: U-Pb zircon geochronology report: Report to BHP Peru, 6 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1287: U-Pb zircon geochronology report: Report to ALS Perth, 6 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1288: U-Pb zircon geochronology report: Report to ALS Perth, 8 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1289: U-Pb zircon geochronology report: Report to Amawta Geoconsultores, 11 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1290: U-Pb zircon geochronology report: Report to First Quantum Minerals, 6 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1295 - U-Pb zircon geochronology report: Report to ALS Perth, 6 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1296: U-Pb zircon geochronology report: Report to ALS Perth, 7 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1298: U-Pb zircon geochronology report: Report to Amawta Geoconsultores, 8 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1300: Igneous: U-Pb zircon geochronology report – Additional analyses on rounded grains: Report to First Quantum Minerals, 6 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1306: U-Pb zircon geochronology report: Report to BHP Peru, 10 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1316 U-Pb zircon geochronology report: Report to Newmont Australia, 7 p.

'Folded Precambrian metamorphic rocks at Cape Wickham on King Island': this photo was taken by Sebastien Meffre and was entered in the 2022 CODES Photo Competition.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1322: U-Pb zircon geochronology report: Report to Teck USA, 6 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1323: U-Pb zircon geochronology report: Report to BHP Peru, 7 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1325: U-Pb zircon geochronology report: Report to ALS Perth, 7 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1326: U-Pb zircon geochronology report: Report to ALS Perth, 6 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1335: U-Pb zircon geochronology report: Report to BHP Peru, 12 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1337: U-Pb zircon geochronology report: Report to BHP Peru, 7 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1338: U-Pb zircon geochronology report: Report to ALS Perth, 8 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1342: U-Pb zircon geochronology report: Report to Inflection Resources, 6 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1346: U-Pb zircon geochronology report: Report to BHP Chile, 8 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1348: U-Pb zircon geochronology report: Report to Anglo American Chile, 10 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1349: U-Pb zircon geochronology report: Report to Anglo American Chile, 9 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1351: U-Pb zircon geochronology report: Report to ALS Perth, 8 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1360: U-Pb zircon geochronology report: Report to Anglo American Chile, 13 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1363 U-Pb zircon geochronology report: Report to BHP Peru, 7 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1365: U-Pb zircon geochronology report: Report to BHP Peru, 11 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1366: U-Pb zircon geochronology report: Report to First Quantum Chile, 6 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1374: U-Pb zircon geochronology report: Report to Amawta Geoconsultores, 7 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1378 Part 1: U-Pb zircon geochronology report: Report to ALS Perth, 9 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1378 Part 2: U-Pb zircon geochronology report: Report to ALS Perth, 12 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1383: U-Pb zircon geochronology report: Report to ALS Perth, 5 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1385: U-Pb zircon geochronology report: Report to ALS Perth, 8 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1386: U-Pb zircon geochronology report: Report to ALS Perth, 8 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1390: U-Pb zircon geochronology report: Report to BHP Peru, 7 p.

Oalmann, J., Danyushevsky, L., and Morissette, M., 2022, P1395: U-Pb zircon geochronology report: Report to Teck Chile, 6 p.

Oalmann, J., Danyushevsky, L., Belousov, I., and Morissette, M., 2022, P1216: U-Pb zircon geochronology report: Report to ALS Perth, 9 p.

Oalmann, J., Danyushevsky, L., Morissette, M., and Belousov, I., 2022, P1260: U-Pb zircon geochronology report: Report to BHP Chile, 10 p.

Oalmann, J., Danyushevsky, L., Morissette, M., and Belousov, I., 2022, P1270: U-Pb zircon geochronology report: Report to Teck Chile, 10 p.

Oalmann, J., Morissette, M., and Danyushevsky, L., 2022, P1146: U-Pb zircon geochronology report: Report to BHP Chile, 13 p.

Oalmann, J., Morissette, M., and Danyushevsky, L., 2022, P1193: U-Pb zircon geochronology report: Report to BHP Chile, 13 p.

Oalmann, J., Morissette, M., and Danyushevsky, L., 2022, P1291 Part 1: U-Pb zircon geochronology report: Report to Anglo American Zambia, 7p.

Oalmann, J., Morissette, M., and Danyushevsky, L., 2022, P1291 Part 2: U-Pb zircon geochronology report: Report to Anglo American Zambia, 8 p.

Oalmann, J., Morissette, M., and Danyushevsky, L., 2022, P1291 Part 3: U-Pb zircon geochronology report: Report to Anglo American Zambia, 8 p.

Oalmann, J., Morissette, M., and Danyushevsky, L., 2022, P1291 Part 4: U-Pb zircon geochronology report: Report to Anglo American Zambia, 7 p.

Oalmann, J., Morissette, M., and Danyushevsky, L., 2022, P1291 Part 5: U-Pb zircon geochronology report: Report to Anglo American Zambia, 8 p.

Oalmann, J., Morissette, M., and Danyushevsky, L., 2022, P1300: Igneous U-Pb zircon geochronology report: Report to First Quantum, 6 p.

Oalmann, J., Morissette, M., and Danyushevsky, L., 2022, P1300: U-Pb zircon geochronology report: Report to First Quantum, 7 p.

Oalmann, J., Morissette, M., and Danyushevsky, L., 2022, P1304: U-Pb zircon geochronology report: Report to Anglo American Ecuador, 7 p.

Oalmann, J., Morissette, M., and Danyushevsky, L., 2022, P1307: U-Pb zircon geochronology report: Report to Newmont, 12 p.

Oalmann, J., Morissette, M., and Danyushevsky, L., 2022, P1312a: U-Pb zircon geochronology report: Report to ALS Perth, 6 p.

Oalmann, J., Morissette, M., and Danyushevsky, L., 2022, P1312b: U-Pb zircon geochronology report: Report to ALS Perth, 6 p.

Oalmann, J., Morissette, M., and Danyushevsky, L., 2022, P1312c: U-Pb zircon geochronology report: Report to ALS Perth, 1 p.

Oalmann, J., Morissette, M., and Danyushevsky, L., 2022, P1321: U-Pb zircon geochronology report: Report to Amawta Geoconsultures, 9 p.

Oalmann, J., Morissette, M., and Danyushevsky, L., 2022, P1344: U-Pb zircon geochronology report: Report to ALS Brisbane, 6 p.

Oalmann, J., Morissette, M., and Olin, P., 2022, P1371a. U-Pb zircon geochronology report: Report to Codelco, 7 p.

Oalmann, J., Morissette, M., and Olin, P., 2022, P1391: U-Pb zircon geochronology report: Report to BHP Peru, 15 p.

Oalmann, J., Morissette, M., and Olin, P., 2022, P1409: U-Pb zircon geochronology report: Report to Teck, 14 p.

Oalmann, J., Morissette, M., Belousov, I., and Danyushevsky, L., 2022, P1262: U-Pb zircon geochronology report: Report to Teck Chile, 12 p.

Oalmann, J., Olin, P., and Morissette, M., 2022, P1371b. Trace element compositions of minerals from white halos: Report to Codelco, 2 p.

Olin, P., and Danyushevsky, L., 2022, P1198. Whole-rock analysis for gallium and germanium in three homogenized core segment samples: Report to Mount Burgess Mining, 4 p.

Olin, P., and Danyushevsky, L., 2022, P1199. Gold contents in pyrite and arsenopyrite in one sample: Report to ALS, 9 p.

Olin, P., and Danyushevsky, L., 2022, P1203. Composition of zinnwaldite in one sample: Report to ALS, 3 p.

Olin, P., and Danyushevsky, L., 2022, P1220. Gold contents in pyrite and arsenopyrite in two samples: Report to ALS, 8 p.

Olin, P., and Danyushevsky, L., 2022, P1224. Gold contents in pyrite and arsenopyrite in one sample: Report to ALS, 6 p.

Olin, P., and Danyushevsky, L., 2022, P1225. Copper contents in mica minerals in one sample: Report to ALS, 8 p.

Olin, P., and Danyushevsky, L., 2022, P1234. Gold and trace element contents in pyrite in 15 samples: Report to ALS, 8 p.

Olin, P., and Danyushevsky, L., 2022, P1236. Trace elements in selected sulphide and sulphate minerals in ten samples: Report to University of Queensland, 1 p.

Olin, P., and Danyushevsky, L., 2022, P1238. Assessment of mercury (Hg) and selenium (Se) 'contamination' in epoxy: Report to ALS, 17 p.

Olin, P., and Danyushevsky, L., 2022, P1240. Cobalt contents in pyrrhotite and chalcopyrite in two samples: Report to University of Queensland, 8 p.

Olin, P., and Danyushevsky, L., 2022, P1243. Trace elements in olivine and pyroxene in eight samples: Report to University of Queensland, 1 p.

Olin, P., and Danyushevsky, L., 2022, P1250. Tin contents in rutile in one sample: Report to ALS, 7 p.

Olin, P., and Danyushevsky, L., 2022, P1253. Gold contents in pyrrhotite, pyrite, and arsenopyrite in one sample: Report to ALS, Hobart, Australia, 9 p.

Olin, P., and Danyushevsky, L., 2022, P1259. Further assessment of mercury (Mg) and selenium (Se) 'contamination' in epoxy: Report to ALS, 3 p.

Olin, P., and Danyushevsky, L., 2022, P1273. Gold contents in pyrite and arsenopyrite in three samples: Report to ALS, 10 p.

Olin, P., and Danyushevsky, L., 2022, P1276. PGE contents in various minerals in two samples: Report to ALS, 5 p.

Olin, P., and Danyushevsky, L., 2022, P1292. Gold contents in pyrite in one sample: Report to ALS, 6 p.

Olin, P., and Danyushevsky, L., 2022, P1293. Gold contents in pyrite and arsenopyrite in one sample: Report to ALS, 6 p.

Olin, P., and Danyushevsky, L., 2022, P1294. Gold contents in pyrite and arsenopyrite in three sample: Report to ALS, 10 p.

Olin, P., and Danyushevsky, L., 2022, P1314. Thorium, uranium, and rare earth element contents in various minerals from one sample: Report to ALS, 9 p.

Olin, P., and Danyushevsky, L., 2022, P1315. Lithium and iron contents in spodumene in one sample: Report to ALS, 4 p.

Olin, P., and Danyushevsky, L., 2022, P1318. Gold contents in arsenopyrite in four samples: Report to ALS, 8 p.

Olin, P., and Danyushevsky, L., 2022, P1320A. PGE contents in sulfides in three samples: Report to ALS, 9 p.

Olin, P., and Danyushevsky, L., 2022, P1320B. Nickel contents in silicates and sulfides in three samples: Report to ALS, 7 p.

Olin, P., and Danyushevsky, L., 2022, P1329. Lithium contents in various minerals in three samples: Report to ALS, 7 p.

Olin, P., and Danyushevsky, L., 2022, P1330. Gold contents in pyrrhotite, pyrite, and arsenopyrite in four samples: Report to ALS, 11 p.

Olin, P., and Danyushevsky, L., 2022, P1353. Lithium and iron contents in spodumene in one sample: Report to ALS, 4 p.

Olin, P., and Danyushevsky, L., 2022, P1372. Gold contents in pyrite and arsenopyrite in five samples: Report to ALS, 13 p.

Olin, P., and Danyushevsky, L., 2022, P1381. Gold contents in pyrite and arsenopyrite in one sample: Report to ALS, 6 p.

Olin, P., and Danyushevsky, L., 2022, P1394. Sodium contents in hematite in one sample: Report to ALS, 7 p.

Olin, P., and Danyushevsky, L., 2022, P1417. Lithium contents in various minerals in one sample: Report to ALS, 5 p.

Osorio, J., Zhang, L., and Cooke, D.R., 2022, Valeriano Cu-Au deposit, Chile – A vertical profile of a weakly to moderate overprinted porphyry – high sulfidation system: AMIRA P1249 SRM #2, 29 & 30 November 2022, p. 182-217.

Seow, X., Rodemann, T., and Zhang, L., 2022, Near infrared (NIR or SWIR) spectra: Can we glean more information?: AMIRA P1249 SRM #2, 29 & 30 November 2022, p. 379-405.

Staubmann, M., Halley, S., Cooke, D.R., Miller, C., and Cracknell, M., 2022, Calculated Mineralogy and Hyperspectral Data – Cowal (GRE46), NSW, Australia: AMIRA P1249 SRM #2, 29 & 30 November 2022, p. 80-99.

Steadman, J., 2022, Pyrite at Mount Isa: AMIRA P1249 SRM #2, 29 & 30 November 2022, p. 100-132.

Testa, F., Cooke, D.R., Baker, M., and Zhang, L., 2022, Epidote and chlorite chemistry from the Cowal district: AMIRA P1249 Start-up Meeting, 11 February 2022, p. 36-62.

Zhang, L., and the AMIRA P1249 research team, 2022, P1249 Module 1 vectoring and fertility program – An introduction: AMIRA P1249 Start-up Meeting, 11 February 2022, p. 15-35.

Zhang, L., and the AMIRA P765, 765A, 1060, 1153 and 1202 research teams, 2022, Exploring lithocaps – historical perspective: AMIRA P1249 Review Meeting, 10 February 2022, p. 203-266.

Zhang, L., and the AMIRA P765, 765A, 1060, 1153 and 1202 research teams, 2022, Exploring lithocaps – the journey continues: The challenges and opportunities of complex systems: AMIRA P1249 Review Meeting, 10 February 2022, p. 267-293.

Zhang, L., Belousov, I., and Jones, R., 2022, Kurpetai-3 field sampling campaign - an active exploration site: AMIRA P1249 SRM #2, 29 & 30 November 2022, p. 146-181.

Zhang, L., Seow, X.N., Rodemann, T., Testa, F., and Belousov, I., 2022, Predicting tourmaline elemental composition from NIR spectral data – A proof of concept study: AMIRA P1249 SRM #1, 21 & 22 June 2022, p. 22-45.

Appendices

CODES postgraduate students 2022

Bachelor of Science (Honours) (4)

Student	Supervisors	Research Program	Project	Support
Felix Dobbin ^	Cooke, Zhang	1	Geology and genesis of the Kingswood porphyry Cu-Au prospect, NSW	Magmatic Resources
Daniel Fisher	Miller, Cracknell	2	Lithological, geochemical and mineralogical drivers of water quality at the legacy Scotia Mine, northeast Tasmania	MRT
Till Gallagher ^	Orth, Carey, Cumming (MRT), Bottrill (MRT)	3, 4	The emplacement processes of the St Marys Porphyry in Eastern Tasmania	MRT, UTAS Foundation, GSA
Eva Knight ^	Miller, Meffre, Prahalad (Geography)	2	The geochemistry and minerology of estuarine sediments: Implications for Rice Grass removal in the Rubicon Estuary	Cradle Coast Authority, Natural Resource Management

Graduate Certificate in Economic Geology (4)

Student	Supervisors	Research Program	Project	Support
Caitlin Brown			coursework only	
Samuel Connell			coursework only	
Benjamin Coughlin			coursework only	
John Robinson			coursework only	

Master of Economic Geology (76)

Student	Supervisors	Research Program	Project	Support
Michael Adams			coursework only	
Greg Amalric			coursework only	
Jessica Askew			coursework only	
Stuart Badock			coursework only	
Grace Barber			coursework only	
Emma Beattie ^			coursework only	
Joel Blake			coursework only	
Ian Borg ^			coursework only	
Mertkan Bozoglu ^	Cooke, Zhang, Escolme	1	Phyllic alteration at Northparkes	Turkish Government, ARC TMVC, AMIRA P1202
James Bresnahan			coursework only	
Callan Brown			coursework only	
Matt Brown			coursework only	
Nicole Casilla			coursework only	
Kaitlin Catalano			coursework only	
Glen Cathers ^			coursework only	
Duncan Chessell			coursework only	
Brianna Clark			coursework only	
Sarah Cochrane			coursework only	
Jamin Cristall			coursework only	
Craig Crossland			coursework only	
Oliver Davies			coursework only	
Lieth de Selincourt	Cooke, Baker, Cracknell, Meffre	1	Application of mineral chemistry to aid exploration for Cu-Au-Mo porphyry mineralisation in the Temora district, New South Wales, Australia	Sandfire Resources
Luziane de Souza Castell			coursework only	
Laura Dowling			coursework only	
Mark Eastlake			coursework only	
David Eddy			coursework only	
Paul Edmonds			coursework only	
Brynache Ellingworth			coursework only	
Lauren Elliott			coursework only	
Benjamin Ferguson			coursework only	
Michael Fisher			coursework only	
Joshua Greene			coursework only	
Emma Haley			coursework only	
Claire Hardgrove			coursework only	
Brendan Hardwick	Meffre, Doyle (AngloGold Ashanti)	1, 3	Mineralised textures at the Tropicana gold mine: Implications for the genetic model and deportment of gold	AngloGold Ashanti
Michael Harris			coursework only	
Jane Harvey			coursework only	
Jonathan Higgins			coursework only	
Kyle Hodges ^			coursework only	
Kyle Hughes ^	Meffre	1, 3	Paragenesis of the Dobroyde Deposit, central NSW	ARC Linkage
Carl Jackman			coursework only	
Fungai (Grace) Jaravani			coursework only	

Student	Supervisors	Research Program	Project	Support
Ashleigh Job	Cooke	1	Geology, structural control and exploration implications of Au mineralized Fenix gold project, Maricunga Belt, Chile	Rio2 Limited
Benjamin Johnson	Mukherjee, Large, Steadman	1, 3	Pyrite textures and trace element chemistry of the Century Deposit – implication for exploration	PY005 project
Lucy Jones	Escolme	2	An investigation into the mineral associations and relationship between chalcopyrite and sphalerite at Cannington Mine, North Queensland	South32
Pascal Kabilo ^			coursework only	
Greer Lane			coursework only	
Karen MacQueen			coursework only	
David Mallon			coursework only	
Francisco Maturana			coursework only	
Todd McGilvray			coursework only	
Jonathan McLoughlin			coursework only	
Karl McNamara			coursework only	
Dominic Murphy			coursework only	
Alister Orton ^			coursework only	
Christian Oviawe			coursework only	
Anil Ozturk			coursework only	
Robbie Parr			coursework only	
Jose Pascual			coursework only	
Bailey Payten			coursework only	
Catherine Pearse			coursework only	
Thomas Pearson			coursework only	
Luke Pickering			coursework only	
Chris Piggott			coursework only	
David Gerardo Portocarrero Ccaccya			coursework only	
Cameron Quinn			coursework only	
Steven Rennick			coursework only	
Alex Richards			coursework only	
Torrin Rowe			coursework only	
Henry Schaumburg			coursework only	
Joel Sidoruk			coursework only	
Angelo Socio			coursework only	
Antoinette Stryk			coursework only	
James Taylor			coursework only	
Madeline Wallace			coursework only	
Megan Weatherman			coursework only	

Master of Science (2)

Student	Supervisors	Research Program	Project	Support
Nathaly Guerrero Ramirez ^	Cracknell, Hunt, Escolme	2	Geological controls on grade by size fractionation in gold systems	CRC ORE, UTAS
Karla Morales ^	Hunt, Cracknell, Roach	2	Geological predictors for pre-concentration	CRC ORE, UTAS

Doctor of Philosophy (43)

Student	Supervisors	Research Program	Project	Support
Christopher Allen	Miller, Cracknell, Jamieson (Queens U)	2	Optimising remediation of legacy mines – mineralogical controls on long-term waste rock weathering and mine drainage	UTAS, MRT, Bluestone Mines
Billy Beas	Cooke, Zhang	1	Exploration significance of halogens in hydrothermal ore deposits	UTAS, Amira P1249
Peter Berger ^	Barker, Cooke	1	Understanding and predicting hypogene and supergene footprints of Carlin-type gold deposits using a hydrochemical modelling approach	UTAS
Isaac Brown	Zhang, Cooke, Rodemann (CSL)	1	Geology, geochemistry and genesis of the Havieron gold copper deposit, Paterson Province, Western Australia	Newcrest, UTAS
Axel Cima	Belousov, Cooke, Cracknell	6	Microinclusions in porphyry Cu deposits	UTAS, Amira P1249
Acacia Clark	Carey, Jutzeler, Fox (IMAS)	4	Dynamics of subaerial silicic explosive volcanism: The 1315 CE Kaharoa eruption and the Late Bronze Age eruption of Santorini	UTAS, GNS, ANZIC, GSA Endowment Fund
Takeshy Coaquira	Cooke, Zhang, Escolme	1, 2	Resolving multiple generations of white mica and clay alteration at the Resolution porphyry Cu-Mo deposit, Arizona	ARC TMVC, AMIRA P1202, UTAS
Stephen Cooke	Cracknell, Baker, Zhang	6	Pathways to mineral discoveries through computer-based modelling of geochemical data	UTAS, Amira P1249
Rob Davidson #	Gemmell, Cooke	1	Geology and genesis of the San Sebastian vein system, Durango, Mexico	Hecla Mining, UTAS
Alex Farrar	Cracknell, Cooke	1, 3, 6	Investigating the relationship between regional-scale structure and tectonics for the formation and localisation of giant porphyry copper deposits in the central Andes	First Quantum Minerals
Shannon Frey	Jutzeler, Carey	4	Behaviour of submarine caldera-forming silicic eruptions in the Kermadec arc, New Zealand	UTAS
Javier Gil Rodriguez	Cooke, Zhang	1	Characterisation of skarn-type deposits: Renison Bell Sn deposit	RRC, UTAS, Bluestone Mines
Umer Habib ^	Meffre, Roach, Musgrave (GSNSW)	3, 6	Tectonic evolution of the Paleozoic rocks in southeast Australia using geophysical, geochronological, geochemical and Hf isotope systematics	ARC Linkage, Geological Survey of NSW
Jacob Heathcote	Scott, Barker	1, 3	Gold distribution and association at the Kansanshi copper-gold deposit Zambia: Processes responsible for gold precipitation and implications for ore zone delineation and recovery	First Quantum Minerals
Richard Hill	Scott, Cracknell, Roach	6	Exploring the East Tennant region: Unravelling the crustal architecture, tectonic evolution and mineral systems potential of an undercover Proterozoic terrane through the integrated use of geophysics, drill hole data and machine learning/geodata analysis techniques	MinEx CRC, UTAS, Strategic Energy Resources, Inca Minerals, Middle Island Resources, Encounter Resources
Max Hohl	Steadman, Cloutier, Barker	3	Defining the mineral chemistry footprints of IOCG deposits in northwest Queensland	UTAS, GSQ
Fumihiko Ikegami §	Carey, McPhie	4	2012 submarine silicic eruption of Havre volcano and implications for ancient submarine successions in Australia	UTAS, ARC, US National Science Foundation
Malai Ila'ava	Jutzeler, Cas, Carey	4	Volcanic architecture of the Cowal Igneous Complex	ARC Linkage, UTAS, Evolution Mining
Colin Jones	Meffre, Cooke, Orovan	3, 4	Petrogenesis of northeast Tasmanian granites	MRT, ARC TMVC, UTAS
Rhiannon Jones	Cooke, Zhang, Escolme	1, 2	The significance of phyllic alteration at the E26 porphyry Cu-Au deposit, Northparkes district, NSW, Australia	AMIRA P1202, ARC TMVC, UTAS

Student	Supervisors	Research Program	Project	Support
Joseph Knight #	Orovan, Zhang, Cooke	1	The geodynamic and metallogenic setting of base- and precious-metal mineralisation in Myanmar: Implications for Cu and Au exploration	Anglo American
Bridie Le'Gallais	Belousov, Carey, Olin	4	The tectonic significance of mafic/ultra mafic igneous rocks in western Tasmania	UTAS, MRT
Elena Lounejeva	Steadman, Large	3	Geochemical signature of syngenetic and diagenetic pyrite from marine sediments as a paleo-environmental tool	ARC Discovery, CODES
Javier Merrill #	Cracknell, Escolme	2	Quantification of mineral texture for geometallurgical predictive modelling	AMIRA P1202, Minerals Council of Australia, BECAS Chile, ARC TMVC
Hannah Moore	Carey, Jutzeler	4	Shallow conduit and vent processes in the 1886 basaltic Plinian eruption at Tarawera, New Zealand	UTAS, UHawaii, UOtago, GNS Science
Joanne Morrison	Steadman, Meffre, Hunt	2, 3	Geometallurgy of Australian IOCGs	UTAS
Annah Moyo #	Cooke, Meffre, Miller, Parbhakar-Fox (UQ)	2	Controlling acid and metalliferous drainage at legacy sites in Tasmania using industrial wastes	UTAS, MRT, ARC TMVC
Sibele Cristina do Nascimento	Cracknell, Cooke, Meffre, Parbhakar-Fox (UQ)	2	Geoenvironmental characterisation of historic mine tailings: Evaluating opportunities for reprocessing	ARC TMVC, UTAS
Jaime Osorio	Zhang, Cooke	1	Anatomy of the porphyry-epithermal transition in the Valeriano Cu-Au deposit, Chile	ARC TMVC, UTAS, AMIRA P1202, SEG, ATEX Resources
Arka Sahu	Zhang, Cracknell, Rodemann (CSL)	6	Multi-scale hyperspectral and mineral chemistry data mining	Amira P1249, UTAS
Angela Isaura Santos Costa	Hunt, Cooke, Zhang	1	Characterisation of tungsten mineralisation at Grassy, King Island, Tasmania – implications for ore genesis, exploration, and pathways to production	RRC, UTAS, Group 6 Metals
Thomas Schaap #	Meffre, Whittaker (IMAS), Cracknell, Roach	3, 6	Tectonic evolution of the Palaeozoic Lachlan Orogen	ARC Linkage, UTAS
Xin Ni Seow	Zhang, Orovan, Cooke	1, 5	Geochemistry, mechanism of formation and exploration implications of alunite supergroup minerals	ARC TMVC, UTAS, AMIRA P1202, SEG
Emily Smyk	Cooke, Baker, Cracknell	1	Geology, geochemistry, geochronology and exploration footprints of the Christmas porphyry Cu-Mo deposit, Arizona	AMIRA P1202, ARC TMVC, UTAS
Peerapong Sritangsirikul	Meffre, Khin Zaw, Charusiri (CU)	1, 3, 4	Tectonic evolution and related mineral deposits of mainland SE Asia: Insights from geochemistry and geochronology of zircons	Royal Thai Government Scholarship
Markus Staubmann	Miller, Cracknell, Cooke, Hunt	2, 6	Integrated ore deposit knowledge: optimising mineralogical characterisation through the mining value chain	Evolution Mining, UTAS, Amira P1249
Yi Sun	Zhang, Escolme, Cooke	1, 2	Mineralogical, textural, geochemical characterisation and geometallurgical models of Lepanto Quartz – Pyrite – Gold vein and breccia system, Philippines	ARC TMVC, AMIRA P1202, UTAS, SEG, Lepanto Consolidated
Jennifer Thompson ^	Cooke, Danyushevsky	1, 5	Carbonate mineral chemistry in epithermal and porphyry hydrothermal systems	UTAS, AMIRA P1153, ARC TMVC, SEG
Victor Torres Pacheco	Cooke, Zhang, Hunt	1	Geology, genesis, and geometallurgy of Cu-Au-Ag mineralized tourmaline breccia pipes at Soledad, central Peru	Chakana Copper, UTAS
Chuang Wang	Jutzeler, Olivier, Roach, Carey	4	Application of seismic techniques to reconstruct volcanic architecture	MRT, UTAS, IMS

Student	Supervisors	Research Program	Project	Support
Tristan Wells ^	Meffre, Cooke, Steadman	1, 3	Indicators of, and vectors to, fertile magmas in the Northparkes district and broader Macquarie Arc	ARC Linkage, UTAS, CODES, NorthParkes
Emrecan Yurdakul	Zhang, Baker, Scott	1	Orebody knowledge of the Western Tharsis Cu-Au deposit, Tasmania: implications for ore processing and mineral exploration	UTAS, MRT, CMT, New Century Resources
Zebedee Zivkovic	Baker, Cracknell, Barker	1, 4	Lithogeochemical and mineral analysis of magmatic-hydrothermal mineralisation systems: Implications on mineralisation and exploration	MRT, Mineral Mapping, Dreadnought Resources

Degree completed, not yet graduated ^ Graduated § Withdrawn

Major externally funded research projects^

ARC Discovery Grants 2022

Investigators	Project	Funding Body	Period	ARC Funding for 2022
King (ANU), V Kamenetsky	Impact of hot gas on volcanic rocks and ore-forming processes	ARC	2020–2023	$34,609
Seton (USyd), Carey, Williams (IMAS), Coltice (ENS Lyon), Duncan (Oregon)	How Earth's deep interior communicates with the surface	ARC	2020–2023	$10,598

ARC Linkage Grants 2022

Investigators	Project	Funding Body	Period	ARC Funding for 2022	Partner Funding for 2022
Carey, Cas, Cooke, Meffre, Bull (GSNSW), Rowland (U Auckland), Heap (IPGS)	Exploration targeting from next-generation volcanic facies reconstruction	ARC, Evolution Mining, Mineral Resources Tasmania	2020–2022	$87,391	$40,000

Industry and other externally funded research grants 2022

Investigators	Project	Funding Body	Period	Funding for 2022
Cooke, Baker, Cracknell, Escolme, Zhang, Aillères (Monash), Halley (Mineral Mapping), Hollings (Lakehead), Piquer (UAustral)	Amira P1249: Exploring, characterising and optimising complex orebodies – upscaling orebody knowledge to add value across the mining value chain	Amira Global representing: Anglo American, BHP, Boliden Mineral, Codelco, Evolution Mining, Fortescue Metals Group, Mount Isa Mines, Newcrest Mining, Newmont Goldcorp, Rio Tinto Exploration, South32, First Quantum Minerals, CMOC Mining, Sandfire Resources, AngloGold Ashanti	2022–2027	$596,092
M Kamenetsky	Olympic Dam fluid/melt inclusion project	BHP	2021–2023	$308,392
Steadman	Iron oxide copper-gold deposits: Geochemistry and geometallurgy	Evolution Mining, Geological Survey of Queensland, Geological Survey of South Australia, Georgina Resources, Mineral Resources Tasmania, Mount Isa Mines, OZ Minerals, Red Metal, Rex Minerals, Spanish National Research Council	2022–2025	$290,000
Cooke, Cloutier	Exploring for the future: uncovering Australia's exploration potential	Geoscience Australia	2021–2024	$192,296
Meffre, Armistead	Exploring for the future: Temporal controls	Geoscience Australia	2022–2024	$140,000
Miller, Cracknell, Jamieson (Queens U), Allen (student)	Optimising remediation of legacy mines – mineralogical controls on long-term waste rock weathering and mine drainage	Mineral Resources Tasmania	2022–2025	$80,575
		Bluestone Mines	2022–2025	$5,000

Investigators	Project	Funding Body	Period	Funding for 2022
Zhang, Cooke, Rodemann, Brown (student)	Geology, geochemistry and genesis of the Havieron gold-copper deposit, Paterson Provence, Western Australia	Newcrest Mining	2021–2025	$80,500
Cracknell, Cooke, Farrar (student)	The geodynamic and tectonic influence on giant porphyry copper deposit architectural controls	First Quantum Minerals	2020–2023	$66,175
Barker, Zivkovic (student)	Investigating mineralisation in the Tarraji-Yampi (West Kimberley) and Illaara (Yilgarn) project areas	Dept of Industry, Innovation and Science	2020–2022	$13,281
		Dreadnought Resources	2020–2022	$12,500
Zhang	Enhanced geochemical targeting at the Mount Gilmore Cu-Co-Au trend	Dept of Industry, Innovation and Science	2022–2023	$0
		Corazon Mining	2022–2023	$25,000
Zhang	Mineral chemistry vectors at Mount Gilmore Cu-Co-Au Trend, NSW	Dept of Industry, Innovation and Science	2020–2022	$9,807
		Corazon Mining	2020–2022	$12,492
Cooke, Zhang, Hunt, Torres (student)	Geology, genesis and geometallurgy of Cu-Au-Ag mineralised tourmaline breccia pipes at Soledad, central Peru	Chakana Copper	2022–2028	$21,190
Scott, Cracknell, Roach, Hill (student)	Exploring the East Tennant region: Unravelling the crustal architecture, tectonic evolution and mineral systems potential of an undercover Proterozoic terrane through the integrated use of geophysics, drill hole data and machine learning/geodata analysis techniques	MinEx CRC	2021–2024	$20,000
Cracknell, Miller, Fisher (student)	Lithological, geochemical and mineralogical drivers of water quality at the legacy Scotia Mine, northeast Tasmania	Mineral Resources Tasmania	2022	$17,550
Cooke, Portocarrero (student)	Multi-stage intrusion, brecciation and mineralization at the Antakori Cu-Au-Ag project, northern Peru	Regulus Resources	2022–2024	$17,500
Miller, Cracknell, Cooke, Hunt, Staubmann (student)	Integrated ore deposit knowledge: optimising mineralogical characterisation through the mining value chain	Evolution Mining	2022–2025	$14,427
Miller, Meffre, Prahalad (Geography), Knight (student)	The geochemistry and minerology of estuarine sediments: Implications for Rice Grass removal in the Rubicon Estuary	Cradle Coast Authority	2022	$13,155
Cracknell, Roach, Miller, Weidinger (student)	Time-lapse geophysical investigation of the Royal George tailings repository, northeast Tasmania	Mineral Resources Tasmania	2022 –2023	$12,520
Steadman	Geochemical characterisation of the Federation deposit, Cobar basin, NSW; Geochemical characterisation of the Dargues deposit, Braidwood, NSW	Aurelia Metals	2022–2023	$10,881
Cooke, Zhang, Dobbin (student)	Geology and genesis of the Kingswood porphyry Cu-Au prospect, NSW	Magmatic Resources	2022	$10,000
Miller, Barmuta (Biological Sciences), Cracknell, Cheesman (student)	Invertebrate biomonitoring: A geoscience tool for AMD remediation, north-west Tasmania	Mineral Resources Tasmania	2021–2022	$9,280

Investigators	Project	Funding Body	Period	Funding for 2022
Meffre, Steadman, Goemann (CSL)	Mineral chemistry research for Battery Minerals	Battery Minerals	2022	$9,079
Hunt	Methodology development for gangue liberation assessment	CSIRO	2022–2023	$7,588
Belousov, Olin, Le'Gallais (student)	The tectonic significance of mafic/ultramafic igneous rocks in western Tasmania	Mineral Resources Tasmania	2019–2023	$2,800
Meffre	Mineral chemistry research for Emmerson Resources	Emmerson Resources	2021–2022	$2,000
Orth, Carey, Cumming (MRT), Bottrill (MRT), Gallagher (student)	Nature, structure and origin of the St Marys Porphyrite, northeastern Tasmania	Mineral Resources Tasmania	2020–2022	$206
Cooke, Meffre, Parbhakar-Fox, Moyo (student)	Controlling acid and metalliferous drainage at legacy sites in Tasmania using industrial waste materials	Mineral Resources Tasmania	2017–2022	**
Zhang	Alteration minerals chemistry at Yaojialing Zn-Au-W skarn deposit, China: implications for ore genesis and exploration	Hefei University of Technology	2019–2022	**
Carey, Falloon, Coffin (IMAS), Barling (Oxford), Duncan (Oregon), Fox (IMAS)	The re-awakening of a mantle plume – the nature and petrogenesis of Neogene volcanism on the Central Kerguelen Plateau	Australian Antarctic Division	2020–2022	**
Carey, Whittaker (IMAS), Duncan (Oregon), Seton (USyd)	Seamounts in the Tasman Sea and Southwest Pacific: Deep seated Balleny plume vs. Pacific Superswell	Australian Antarctic Division	2020–2022	**
Cooke, Zhang, Escolme, Coaquira (student)	Resolving multiple generations of white mica and clay alteration at the Resolution porphyry Cu-Mo deposit, Arizona	Society of Economic Geologists	2021–2022	**
Zhang, Cooke, Escolme, Piquer (UACh), Osorio (student)	Porphyry to epithermal transition in the Valeriano Cu-Mo-Au deposit, Chile	Society of Economic Geologists	2021–2022	**
Zhang, Orovan, Cooke, Danyushevsky, Seow (student)	Geochemistry, mechanism of formation and exploration implications of alunite supergroup minerals	Society of Economic Geologists	2021–2022	**
Cooke, Baker, Cracknell, Meffre, de Selincourt (student)	Application of mineral chemistry to aid exploration for Cu-Au-Mo porphyry mineralisation in the Temora district, New South Wales	Sandfire Resources	2021–2023	**

^ projects with greater than $2,000 external funding per year

** all project funding received, project still active

Visitors 2022

INDUSTRY VISITORS TO CODES IN 2022

NAME	COMPANY
Paul Agnew	Rio Tinto
Ben Andrew	Glencore Mt Isa Mines
Deborah Araujo	Rio Tinto
Jeffrey Bigelow	Newmont
Renato Bobis	South32
Alex Brown	Glencore Mt Isa Mines
Jing Chen	Consultant
David Finn	Newcrest
Ingrid Flemons	Rio Tinto
Simon Gatehouse	BHP
Melissa Gregory	Rio Tinto
Scott Halley	Mineral Mapping
Ned Howard	Evolution Mining
Jon Hoye	CMOC
Andrew Jenkins	AngloGold Ashanti
Kit Lai	Fortescue Metals Group
David Le Madec	Sandfire Resources
Neil Macalalad	Anglo American
Simon Marshall	Newmont
Paull Parker	Sandfire Resources
Adam Pacey	Rio Tinto
Josh Phillips	Freeport McMoRan
Sergio Pichott	Codelco
Cam Quinn	Fortescue Metals Group
Carolina Rodriguez	Codelco
Matthew Valetich	Anglo American
Michael Whitbread	Rio Tinto

INDUSTRY VISITORS TO CODES IN 2022 WHO DIALLED IN FOR MEETINGS

NAME	COMPANY
Rebecca Allan	Newcrest
James Banyard	First Quantum Minerals
Andrew Barker	Evolution Mining
John M. Barr	Anglo American
James Biggam	Evolution Mining
David Braxton	Anglo American
Stephen Busuttil	BHP
Natalie Caciagli	BHP
Federico Cernuschi	First Quantum Minerals
Tony Chisnall	Avebury Nickel Mine
Takeshy Coaquira	BHP
Joaquin Copaja	BHP
Ian J. Dalrymple	Anglo American
Joshua Denholm	Avebury Nickel Mine
Camilo Dorado	South32
Mark Doyle	AngloGold Ashanti
David Drejing	Boliden
Patricia Durance	BHP
Riz Fraval	Newcrest
Esterio Gallardo Harry	Codelco
Miguel Gaona	Newcrest
Heather Griffin	Newmont
Ben Hames	AngloGold Ashanti
Anthony Harris	Newcrest
Tobias Hermansson	Boliden
Danny Huisman	South 32
Tim Ireland	First Quantum Minerals
Sean Johnson	Boliden
Alan Kobussen	Rio Tinto
Martin Kock	Codelco
Hana Lee	Newcrest
Ryan Manser	Agilent
Keith Martin	AngloGold Ashanti
Brigette Martini	Anglo American
Alex Mason-Apps	AngloGold Ashanti
Ian O'Grady	Sandfire Resources
Dana Olafson	Fortescue Metals Group
Marianne Richter	Rio Tinto
Carolina Rodriguez	Codelco
Ivan Semenov	Rio Tinto
Jess Silcock	Newcrest
Sergio Spichiger	Codelco
Alex Strudwick	Evolution Mining
Luke Swift	AngloGold Ashanti
Peter Willems	Sandfire Resources
David Wilson	Sandfire Resources
Flavia Xavier	South32
Jennifer Yu	Anglo American

NATIONAL ACADEMIC AND GOVERNMENT VISITORS TO CODES IN 2022

NAME	INSTITUTION
Laurent Aillères	Monash University
Ralph Bottrill	Mineral Resources Tasmania
Rebekah Bradshaw	University of Sydney
Mark Duffett	Mineral Resources Tasmania
John Foden	University of Adelaide
Sharon Fraser	School of Education, UTAS
David Green	Mineral Resources Tasmania
Lachlan Grose	Monash University
Lila Landowski	Australian Society for Medical Research
Carsten Laukamp	CSIRO
Andrew McNeill	Mineral Resources Tasmania
Owen Missen	Monash University
Thomas Rodemann	CSL, UTAS
Angela Rodrigues	Monash University
Grace Scullett-Dean	University of Western Australia
Jessica Stromberg	CSIRO
Olga Verezub	Amira Global

INTERNATIONAL ACADEMIC AND GOVERNMENT VISITORS TO CODES IN 2022

NAME	INSTITUTION
Jane Barling	University of Oxford, UK
Martin Crundwell	GNS Science, NZ
Steffen Kutterolf	GEOMAR, Germany
Hevelyn Monteiro	Consultant
Janne Scheffler	GEOMAR, Germany

Dr Jacqueline Halpin photographed on King Island during the SGTSG conference in November 2022.

CODES
Centre for Ore Deposit and Earth Sciences
University of Tasmania
Private Bag 79, Hobart, Tasmania 7001, Australia
Tel +61 (0) 3 6226 2472
ISSN: 1440-6411

Compilation: Caroline Mordaunt and Helen Scott
Editing: Caroline Mordaunt
Design: Before Creative, Hobart

CODES UNIVERSITY of TASMANIA CODES

www.utas.edu.au/codes