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EGRU Members

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Evolution Mining
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Geological Survey Qld
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CSA Global
Gnomic Exploration Services
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Lantana Exploration
Sandfire Resources
Signature Gold
Teck

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Cover photo: Outcropping migmatite, Cloncurry area, Mt Isa Inlier, North West Queensland Minerals Province
Cloncurry field photos used in the newsletter are courtesy of Eric Zurek-Haidamous.
The beginning of 2018 marks both the end of an era and the dawning of a new age for EGRU. Late last year Zhaoshan Chang accepted a professorial position at the Colorado School of Mines and, in February 2018, stepped down as EGRU Director. Zhaoshan has been the driving force of EGRU for the last 7 years and has done an outstanding job in revitalising EGRU, most notably through leading and postgraduate teaching in economic geology, renewing and fostering industry engagement, and executing the highly successful FUTORES conferences and Cloncurry/Mount Isa mineral systems workshops. We thank Zhaoshan for his tireless efforts in leading EGRU; be we sorely missed and we wish him all the best in his new position in Colorado.

The close of 2017 also saw completion of the 3.5-year North East Queensland mineral prospectivity project funded by Queensland Government’s Future Resources Program. Formal wrap-up of the project involved submission of final reports to the Geological Survey of Queensland and public presentation of the key finding in a two-day forum of seminars and discussion in December 2017. The forum (presented with GSQ, TerraSearch and Klondike Exploration Services) proved another success, with 85 delegates in attendance over the two days. Outcomes of the project are still emerging with several full papers of key results now published (Sahlstrom et al., 2018; Cheng et al., 2018) or under review in high impact journals. Not all is about closure; rather, EGRU has a bright future ahead. EGRU is widely recognised as one of the success stories at ICU, and the university has committed to supporting EGRU into the future, including reinvesting in an academic post(s) in economic geology to fill Zhaoshan’s position. From 2018 onwards we (Carl Spandler and Paul Dirks) have taken on directorial roles for EGRU. With an upsurging minerals industry and federal and state governments shifting focus towards applied research fields, we see enormous opportunities for EGRU to grow and diversify its platform of providing industry relevant research and training. As a first step, we have reinstated the position of EGRU manager, and are very pleased to announce that Kaylene Camuti will be taking this role on a part time basis. Many of you know Kaylene, and know she will be an invaluable asset to the EGRU team. Kaylene has been working with EGRU as a communications officer, and will now take on further roles in developing and managing EGRU activities (shortcourses, workshops, conferences, etc.), and promotion and marketing of research projects and EGRU’s analytical and training services. Already a number of workshops are in the pipeline for this year and next year, so stay tuned for announcements coming soon. We are working to further develop connections with China University of Geosciences, with Paul visiting Wuhan in May to present seminars and discuss opportunities for EGRU workshops and student exchange. In March we ran the “Mineral Systems of the Mount Isa Inlier” workshop in Cloncurry. This is the third industry-focused workshop of this kind in three years, and despite the heavy rainfall forcing cancellation of the much-anticipated field trip, the workshop went off without a hitch. The two-day event was attended by 70 delegates, and featured oral presentations by representatives from 5 universities, GSQ, CSIRO and 9 companies working in the region. As is now customary, the afternoons were rounded off at the Glencore/MIM barracks with drinks, BBQ/Pizza and core viewing from deposits/prospects of the region. A special thanks to Judy for the impeccable organisation, Glencore/MIM for supporting the social events and opening the barracks for our use, and Altona Mining (now acquired by Copper Mountain) for providing drinks. The general feeling from the workshop is that there is a renewed optimism for exploration and resource discovery in the North West Mineral Province. As a consolation for the cancelled fieldtrip, we will be running a more comprehensive multi-day field trip in the Cloncurry District (with the support of Chinova Resources) in late July this year. An updated schedule will be announced soon, so again stay tuned.

2018 also sees the initiation of several new research projects for EGRU. In March we signed off on a new 3-year project funded by GSQ to examine the magma fertility and prospectivity of the Mary Kathleen Domain; a relatively under-researched, but highly prospective belt of the Mount Isa Inlier. The project will be led by Paul Dirks, Carl Spandler and Ioan Sansilv, and will employ Yanbo Cheng as a postdoctoral researcher and new PhD students Joshua Struep and Luong Truong Le. Truong’s project will focus on the Tick Hill deposit, which has long stood out as an enigmatic mineralisation style in the region.
Introducing the new Directors of EGRU...

Professor Paul Dirks

Paul Dirks is Professor of Geology at JCU. He obtained an MSc degree (Geology) from Utrecht University (1987) and a PhD (Geology) from the University of Melbourne (1990), and was trained in structural geology, sedimentology and economic geology. Paul is an honorary professor in Geology and in Evolutionary Studies at the University of the Witwatersrand, South Africa. He is also an elected Fellow of the Geological Society of South Africa, an elected Fellow of the Queensland Academy of Arts and Sciences, and a member of the Society of Economic Geologists. Paul has lived and worked across five continents, with has published in over 125 peer-reviewed papers, 155 conference papers and 75 professional reports on aspects of mineral exploration and mining. He has published extensively on various facets of economic geology and mining, especially on lode-gold mineralisation in Archaean granite-greenstone terrains, but also on structural controls on nickel mineralisation, Cu-Au porphyries and kimberlite emplacement, and the links between mining and development.

Paul’s previous roles include Dean of College of Science, Technology & Engineering, JCU (2014-16); Head of School of Earth and Environmental Sciences, JCU (2009-14); Head of School of Geosciences at the University of the Witwatersrand, South Africa (2002-09); founding director of the Mineral Resources Centre, University of Zimbabwe (1998-2002); founding board member, Institute of Human Evolution, University of the Witwatersrand, South Africa; council member, Australia-Pacific region. He occasionally dabbles in experimental petrology and has investigated melting conditions and phase relationships of crustal and mantle rocks, hydrothermal fluid compositions and element diffusions rates in minerals. He has also developed new analytical techniques for in situ geochemical analysis and dating of minerals.

Paul’s research interests in economic geology extend back over 20 years. During his honours research, he discovered primary platinum-group element mineralisation in a layered mafic intrusion in southern New Zealand and he subsequently worked on the origin of chrome mineralisation in the famous Stillwater layered mafic intrusion of Montana. Since arriving at JCU, Paul and his students have been researching a range of ore forming processes involving Mo-Re (Merlin), Cu-Au (skarn, IOCG), Pb-Zn, Sn-W (SE China and Herberton) and critical metals such as REE, Zr, Nb, Ta, and Li. In 2012, he was awarded a prestigious ARC Future Fellowship to investigate the origin and evolution of REE ore deposits, and has since been working in collaboration with mining companies on all of Australia’s major hard-rock REE deposits. He has also won a number of other competitive research grants from government and industry sources, and is a current ARC College of Expert panel member. He has been involved in the organisation of numerous workshops and conferences on various aspects of geology, and has delivered keynote addresses at many international conferences.

Carl Spandler has been an academic staff member in Geology at JCU since 2008, and served as Head of Geology Discipline from 2011 to 2014. He was promoted to Associate Professor in 2015. He received his honours and PhD degree at ANU, Canberra, over a decade spanning the turn of the century (which sounds like long, long ago…), and has since held postdoctoral positions at ANU and at the University of Bern, Switzerland. Before undertaking honours, Carl worked as a geologist for a junior exploration company out of Kalgoorlie.

Carl’s research integrates petrology, mineralogy and geochemistry, and covers a broad range of topics from mantle and crust formation and evolution, to crystal-scale element partitioning and diffusion in minerals. He is an expert on subduction zones processes and associated high-pressure metamorphism, arc magmatism, and tectonic evolution, particularly in relation to the southwest Pacific region. He occasionally dabbles in experimental petrology and has investigated melting conditions and phase relationships of crustal and mantle rocks, and has built up extensive experience in Financial, HR, IR and project management, and has deep knowledge of education management.

Paul is a structural geologist with an interest in field geology, geodynamics and the tectonic history of cratonic terrains and adjacent mobile belts, investigating their tectonic evolution and associated mineralization patterns. Paul’s research is field-based with a focus on detailed geological mapping, and field-based geological analyses. Through the study of Neotectonics and landscape development in the Cradle of Humankind, South Africa, and using his skills as an explorer, Paul has been directly involved in the discovery of two new members to our ancestral family tree: Australopithecus sediba and Homo naledi, which has attracted extensive international attention. Paul leads the geological team that is involved in dating these new fossil finds and providing the geological and taphonomic context.

In 1998, Paul founded the Mineral Resource Centre at the University of Zimbabwe, to coordinate consulting services to the mining industry. Paul co-founded the AfricaArray programme in 2003 at the University of the Witwatersrand, to reverse the geoscience brain-drain from Africa focusing specifically on earthquake seismology. By 2018, AfricaArray had established over 30 geophysical observatories across 14 African countries, providing data for research and training, with projects conducted in collaboration with the mining industry. In 2011, he established an AusAid funded short course programme in GIS and Mining, to African professionals, to be trained at JCU. In 2010, Paul helped establish the Masters of Development Practise at JCU, and he has become involved in research projects linking mining to development and rainforest conservation.

As Dean of Science, Technology and Engineering at JCU, Paul established the first Internet of Things (IoT) undergraduate engineering programme in Australia (launched in Cairns in 2015) and motivated for a new undergraduate engineering programme in Australia (launched in Cairns in 2015) and motivated for a new

Paul has worked extensively as a professional consultant to the mining industry, and is a past director of SRK-Zimbabwe, past associate of SRK-South Africa, and has served as an expert member on mining and public projects. His consulting work has focused on structural geological mapping, geotechnical work for pit stability in open pits, and gold and base metal exploration, in part through the development of mineral databases. He has been involved extensively in project generation and the management of multi-disciplinary research and consulting projects, and has been a member of a number of due diligence studies of mining projects in Africa and the Philippines.

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# Research Staff

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<tr>
<th>Research Staff</th>
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<tbody>
<tr>
<td>Prof. Paul Dirks</td>
<td>Structural geology, geodynamics and the tectonic history of cratonic terrains and adjacent mobile belts, and associated mineralization patterns.</td>
</tr>
<tr>
<td>A/Prof. Carl Spandler</td>
<td>Using petrology and geochemistry, including microanalysis of minerals for trace elements and isotopes, to understand the evolution of the Earth’s crust and mantle, and the formation of metalliferous ore deposits.</td>
</tr>
<tr>
<td>A/Prof. Eric Roberts</td>
<td>Clastic sedimentology, sedimentary provenance, core logging, stratigraphy, U-Pb zircon geochronology, petroleum geology palaeontology, regional correlation.</td>
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<tr>
<td>Dr James Daniell</td>
<td>Oceanography, geomorphology, sedimentology, geophysics, remote sensing and GIS.</td>
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<tr>
<td>Dr Jan Marten Huizenga</td>
<td>Fluid-rock interaction processes in the lower crust and in hydrothermal mineralised systems, and thermodynamic modelling of carbon-oxygen-hydrogen systems.</td>
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<tr>
<td>Dr Christa Placzek</td>
<td>The interaction between climate, hydrology, and earth surface geochemistry, and quantifying rates and processes of weathering and erosion, using isotopic techniques, fieldwork, and numerical and climate models.</td>
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<tr>
<td>Dr Ioan Sanislav</td>
<td>Structural geology and tectonics with a focus on field geology, structural controls on mineralized systems and the tectonic evolution of Proterozoic and Archean terranes.</td>
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<tr>
<td>Dr Yanbo Cheng</td>
<td>Economic geology, with a focus on tin and tungsten mineralisation, petrogenesis of granitic rocks, fertility of ore-related igneous rocks and genesis of “Critical Metal” ores.</td>
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<tr>
<td>Dr Espen Knutsen</td>
<td>Vertebrate palaeontology; diversity, evolution and ecology of Mesozoic vertebrates.</td>
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<tr>
<td>Dr Huiqing (Jeff) Huang</td>
<td>Geochemistry and igneous petrology, supervision of geochemical/mineralogical processing laboratories and providing specialised technical support for staff and postgraduate students.</td>
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<td>Prof. Zhaoshan Chang</td>
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<td>Emeritus Prof. Bob Henderson</td>
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<td>Prof. Timothy Bell</td>
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<td>Prof. Tom Blenkinsop</td>
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<td>Prof. Jeffrey Hendenquist</td>
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<td>A/Prof. Tony Kemp</td>
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<td>Prof. Nick Oliver</td>
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<td>Prof. Noel White</td>
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<td>Ms Kaylene Camuti</td>
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<td>Mr Jim Morrison</td>
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<td>Mr John Nethery</td>
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Research Projects

**Research Projects**

- NE Qld Magma Fertility: Cu-Au, Sn-W
- NW Qld Magma Fertility
- Rare Earths Project
- Geita Gold Project
- Adamantine Energy & Heritage Oil Project
- Conglomerate Hosted Gold
- Tick Hill Gold Deposit
- Jurassic Arc? Reconstructing the Lost World of Eastern Australia
- Porphyry Cu-Au Systems
- Formation of Graphite Deposits in Sri Lanka
- Identifying Hydrothermal Fluids in the Cloncurry District
- Thermodynamic Modelling of Fluids in Hydrothermal Systems
- The Role of Fluids in the Lower Crust
- Seismic Stratigraphy and Petroleum Systems of the Mentelle Basin, Southwest Western Australia
- Establishing a Tectonic Framework for the Cretaceous Break-up of Eastern Gondwana
- Stratigraphy and Sedimentary Basin Analysis of Queensland’s Jurassic to Cretaceous Basins
- Jurassic-Cretaceous Tectonics, Paleogeography and Landscape Evolution, Central Africa
- Dating hominin fossils in the East African Rift, Malawi
- Seismic Stratigraphy of the Great Barrier Reef
- Earthquake Hazard Mapping and Modelling to Support Queensland Rail’s Infrastructure
- Rates of Erosion and Weathering in the Tropics
- Groundwater – Ocean Interconnection
- Sedimentary and Magmatic History of the Rukwa Rift Basin
- Geochronology of Mineralisation Processes
- Geology of the Tommy Creek Block, Mount Isa Inlier

**Locations**

- NE Queensland
- NW Queensland Minerals Province
- WA, NSW, NT, NE Queensland
- Tanzania
- Africa
- WA
- Mt Isa, NSW Queensland Minerals Province
- Eastern Australia
- Philippines, South America
- Sri Lanka
- NW Queensland Minerals Province
- Various
- WA
- SW Pacific
- Queensland
- Africa
- Africa
- Queensland
- Queensland
- Tanzania
- Various
- NW Queensland

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**PhD Project @ JCU**

**Embedded PhD Researcher**

**Dugald River Mine**

The Economic Geology Research Centre (EGRU) at James Cook University (JCU), Townsville and Dugald River Mine, MMG, are offering a PhD project in structural geology/engineering geology/geotechnical engineering, focused on developing a model for the geotechnical behavior of the ore zone and immediate wall rock at Dugald River Mine, north of Cloncurry, Australia.

Dugald River is a world-class Zn-Pb-Ag deposit (64.8Mt @ 12.0% Zn, 2.2% Pb, 31g/t Ag) in the Mt Isa district which commenced mining in 2013. The ore zone is structurally complex with a strongly sheared and faulted hanging wall, which affects mining and ore recovery.

During the project you will develop a structural model for the orebody based on face mapping and drill core logging using advanced digital mapping techniques (ADAM Tech) in combination with 3-D modelling (Leapfrog and Vulcan). The work is aimed at gaining an improved understanding of fault distribution patterns and rock mass behaviour along the ore zone, to improve the efficiency of ore recovery.

You will be based on the JCU campus in Townsville, but you are expected to work at the mine for 1 week each month, to collect data and interact with the geological and geotechnical teams at the mine.

EGRU is currently building a team of students and researchers working on mining and exploration related questions in the central part of the Mt Isa block, and you will be part of this team. This is a unique opportunity to advance your research career and learn new skills in one of the world’s major mineral provinces. The PhD project will benefit from state of the art analytical facilities hosted at JCU.

The successful applicant will have good 3-D skills with experience in structural geology, engineering geology and/or geotechnical engineering. Prior knowledge of Leapfrog, Vulcan and ADAM Tech software would be an advantage but is not a necessity. We are looking for candidates with an interest in solving practical geotechnical problems in a mining environment. A first class Honours or a Masters by research are essential to be eligible for PhD studies at JCU, and to be competitive for a scholarship.

More information about the Geoscience department and EGRU can be found at the following link:


If you are interested please send an expression of interest and your CV to:

- Prof Paul Dirks on paul.dirks@jcu.edu.au
- Dr Ioan Sanislav on ioan.sanislav@jcu.edu.au
Metal fertility and volcanic-plutonic connections in the Herberton Sn-W-Mo Mineral Field, north-east Queensland

Yanbo Cheng, Carl Spandler, Zhaoshan Chang, Gavin Clarke (EGRU - Geoscience JCU)


Introduction

Identifying distinctions between metallogenetically “fertile” and “non-fertile” magmas is of enormous benefit to mineral exploration. In recent years, substantial progress has been made in recognizing and understanding the genesis of intrusive rocks that are directly associated with porphyry Cu ± Au mineralization (Richards, 2009; Sillitoe, 2010; Loucks, 2014), which has allowed the development of magma fertility indicators (Loucks, 2014). Although Sn ± W mineralization is also primarily associated with magmatic rocks, in recent years there have been only limited studies focussing on these systems in relation to magma fertility, and these studies have looked at the granitic rocks rather than the associated volcanics, despite the fact that volcanic rocks are widespread in Sn ± W mineral fields. If the genetic links between the plutonic and volcanic rocks can be demonstrated, then the volcanic rocks may be used as indicators of mineralisation at depth.

Although models linking plutonic and volcanic rock suites of intermediate to felsic, calc-alkaline affinity are well established (Bachmann et al., 2007), the links between volcanic and plutonic rocks produced in the highly fractionated and reduced magmatic systems typically associated with Sn ± W mineralisation remain poorly understood. To investigate the relationship between granitoids and volcanic rocks associated with Sn–W–Mo mineralized magma systems, we examined one of the world’s best-known Sn–W–Mo districts: the Herberton Mineral Field (HMF) of North Queensland, Australia. This study examined extrusive and intrusive rock units of the HMF granitoids and near contemporaneous volcanic sequences, and the common presence of granitic enclaves in the volcanic rock units of the HMF (Champion and Bultitude, 2013), with many units also sharing similar I-type geochemical affinities. The close spatial association of shallow-level plutonic rocks and volcanic successions, and the common presence of granitic enclaves in the volcanic rock units of the HMF (Champion and Bultitude, 2013), with many units also sharing similar I-type geochemical affinities. The close spatial association of shallow-level plutonic rocks and volcanic successions, and the common presence of granitic enclaves in the volcanic rock units of the HMF (Champion and Bultitude, 2013), with many units also sharing similar I-type geochemical affinities.

Analytical Results

U-Pb dating

Most of the O’Brien Creek granitoids and the Old Featherbed rhyolites fall within the 335 to 315 Ma age range. In contrast, the granite samples from the Claret Creek Supersuite and the volcanic rocks from the Young Featherbed units gave ages around 50 Ma younger, between 285 and 270 Ma. Granitoid samples from the Ootann Supersuite, and an undifferentiated volcanic sample from between Bamford Hill and Wolfram Camp, returned ages between 310 and 300 Ma. These dates, which are consistent with the results by Murgulov et al. (2013), are interpreted to be the crystallization ages of both the plutonic and volcanic rocks in each of these three groups.

Whole rock geochemistry

Whole rock geochemical analyses of samples of the HMF granitoids and near contemporaneous volcanic units indicate they have:

- relatively high SiO2 contents (61 to 79 wt.%),
- a peraluminous affinity, and
- affiliation with high-K calc-alkaline and shoshonitic series magmatic rocks.
Comparison of the early (335–315 Ma) O’Briens Creek Supersuite, and the later (310–270 Ma) Ootann, Almaden and Claret Creek Supersuites, show the O’Briens Creek samples are distinctly more felsic than the younger supersuites, and tend to have higher contents of incompatible elements such as Sn, F, and Y. The O’Briens Creek granites also have low Sr, large negative Eu anomalies, and high Rb/Ba and Rb/Sr, which are indicators of extreme degrees of fractionation (Imseng et al., 2012). In contrast, in the compositions of the Ootann, Almaden, and Claret Creek Supersuite granitoids extend to lower SiO2 contents (<60 wt.% in some cases), tend have higher FeO, CaO and TiO2 contents, and are less enriched in incompatible elements.

Whole rock geochemistry of the volcanic rocks from HMF indicate distinct differences in the compositions of rocks of different ages. Samples from the Old Featherbed Volcanic Unit (335–315 Ma) extend toward more intermediate compositions with overall higher Al2O3, FeOT, TiO2, MgO, CaO and Sr, whereas the 310 to 270 Ma volcanic rocks (Young Featherbeds and undifferentiated volcanic unit) are exclusively rhyolitic. We interpret that the highly fractionated nature is consistent with their high SiO2 and alkali element contents, high Rb/Ba and Rb/Sr, and relatively low levels of ferromagnesian phases. Contemporaneous volcanic rocks of the Old Featherbed Unit have not undergone such extensive fractionation, as evident from their lower SiO2 content, higher FeOt, TiO2, MgO, CaO, Sr, and lower Rb/Sr. Nevertheless, we consider these two magma suites to be genetically related due to their close spatial and temporal relationships, their 1 type affinities, the presence of granitic enclaves in the Old Featherbed rhyolites, and similar εHf(t) (t) isotope values of ~−15 to −15.

The relatively undifferentiated εHf(t) values, along with the presence of inherited zircons of Precambrian age in the O’Briens Creek Supersuite and Old Featherbed Volcanics, are consistent with magmah derived from a source dominated by continental materials.

The 310–270 Ma I-type granitoids from the Bamford Hill area also display geochemical trends consistent with fractional crystallization from intermediate compositions through to evolved granites, as was noted by Blevin and Chappell (1992) and Blevin et al. (1996). However, the abundance of hornblende and magnetite in these rocks indicates that they formed from more oxidized and more hydrous magmas compared to the earlier O’Briens Creek Supersuite.

Granitoids and volcanic rocks from both the 310–300 Ma and 285–270 Ma age ranges have similar Hf isotope signatures and similar minor and accessory mineral assemblages, again supporting a direct genetic relationship between contemporaneous intrusive and extrusive rocks. In this case, however, the contemporaneous extrusive rocks only include the more felsic of the compositional spectrum. The Hf isotope data show a shift to more radiogenic values with time, which cannot be attributed to sequential melting of the same continental source, as such sources become less radiogenic with time. Rather, the Hf isotope trend indicates a change in magma source components with time.

Understanding the link between volcanic and plutonic systems is crucial to understanding the evolution of the continental crust through time. Current popular models linking volcanic and plutonic systems (e.g. Bachmann et al., 2007; Bachmann and Bergantz, 2008) are largely based on observations of continental arc terranes where intermediate to felsic plutonic rocks (mainly tonalite to granodiorite) can be compared to contemporaneous volcanic units. The applicability of these models to highly fractionated felsic intrusive systems, such as those of the HMF, has not previously been examined in detail.

The well-established volcanic–plutonic connection model of Bachmann et al. (2007) adequately explains the compositional characteristics and relationship between the volcanic and plutonic rocks formed in the HMF from 310 to 270 Ma. This model, highly evolved rhyolite liquids are extracted from crystal-rich mush stored in upper crustal chambers. These residual mush piles then solidify to form plutonic rocks that are less evolved than the cogenetic rhyolites; this trend is observed in the younger magmatic rocks of the Herberton region.

In contrast to the younger granitoids, the relationship between the O’Briens Creek Supersuite intrusives and the coeval Old Featherbed volcanic rocks (the 335 to 315 Ma magmatic episode) does not conform to the model of Bachmann et al. (2007). Instead, the opposite geochemical relationships are observed, with this older magmatic suite characterized by granitoids that extend to much more fractionated compositions than the cogenetic volcanic rocks. In order to reconcile these features we propose the following new petrogenetic model to link these volcanic and plutonic rocks.

We envisage large silicic magma reservoirs at depth undergoing crystallization, with periodic tapping of the chambers to produce the Old Featherbed volcanic rocks. The crystal rich nature of these volcanic rocks indicates inefficient separation of crystal from liquid in the magmatic chambers which, in turn, may have facilitated removal of any exsolving H2O-rich gas phase (Parmigiani et al., 2016). Episodic termination of the volcanic connection during magmatic evolution, possibly due to a regional compressional regime (see below), led to containment of the most fractionated felsic melts within high-level magma chambers, where fractionation continued with no feedback to the components via volatilization at the surface (Figure 2). This process led to the formation of highly fractionated intrusive rocks of the O’Briens Creek Supersuite and, overall, can explain the observed compositional differences between the intrusive and volcanic rocks over the time period from 335 to 315 Ma.

Based on the timing relationships, and on previous work demonstrating genetic links between granitoid formation and mineralization in the HMF (Champion and Chappell, 1992; Blevin and Chappell, 1992), we further confirm that both the Sn and W–Mo mineralization styles are hydrothermal products directly related to granitic magmatism and fractionation. Therefore, understanding the genetic conditions for magmatism is crucial to understanding the geologic setting and temporal development of these mineralization styles.

Based on our data and the work of Morgulov et al. (2013), we suggest that magmatism in the Herberton region was not continuous during the mid-Carboniferous to mid-Permian period of ~310 Ma. Rather, magmatism occurred within three time periods of active magmatism which were separated by two periods of magmatic quiescence that occurred between 315 and 310 Ma (Late Carboniferous) and between 300 and 285 Ma. We propose that the mid-Carboniferous magmatism in the HMF (335–315 Ma) formed under a compressional tectonic regime with magmas largely derived from melting of the thickened continental crust. Under these conditions, the derivative magmas will tend to be H2O poor (Harrison et al., 1998), and are more amenable to stalling within the crust where they may undergo extensive crystal fractionation. During the Late Carboniferous, changing plate dynamics led to eastwards rollback of the subducting plate, causing thinning of the overriding lithosphere and decompression melting of the mantle, which in turn increased the juvenile mafic input into the crust beneath the Herberton region. This scenario is broadly consistent with previous tectono-magmatic models for the region (Champion and Bultitude, 2013; Morgulov et al., 2013), and is consistent with the geochemical and isotopic signatures of the magmatic rocks in the Herberton region.

We suggest that hydrothermal alteration and mineralization indicates two main ore forming episodes in the HMF:

1) a Sn dominant mineralization event between 330 and 315 Ma
2) a W–Mo mineralization event between 310 and 300 Ma.
also corresponds to the transition from Sn dominant to W–Mo dominant mineralization. The compressional regime of the mid Carboniferous favoured the production of magmatia anatexis of reduced continental crust, and the subsequent formation of Sn-mineralized granitic intrusions after extensive fractionation. The Late Carboniferous W–Mo-associated granites formed during the transition from compression to extension and thus contain a greater proportion of relatively oxidized and juvenile components. Subsequent magmatic activity at Herberton is not associated with significant mineralization, which may indicate that periods of transition between tectonic regimes may provide fertile magmatic conditions for granite-hosted mineralization. If this is the case, the recognition of tectonic switches in the geological record could aid exploration for new Sn–W–Mo ore deposits.

**Fertility indicators of intrusive and volcanic rocks for Sn–W–Mo mineralization**

Our results support previous work by Blevin et al. (1996) and Lehmann (1990) who proposed that magma redox conditions and the degree of fractionation are essential controlling parameters for concentrating Sn to ore grade in magmatic environments. Granitic magmas do not need to undergo such extensive fractionation for W–Mo fertility (Blevin et al., 1996; Thompson et al., 1999), which is consistent with the less fractionated nature of the 310–300 Ma W–Mo granites relative to the Sn granites of the HMF. The presence of magnetite in the W–Mo granites indicates they are also more oxidized than the Sn-associated granites. The enrichment of fluxing elements, such as B, F, and Li, is considered to be a crucial factor in the formation of Sn and W–Mo deposits, as these elements serve to extend crystallization intervals to lower temperatures, allowing more extensive fractionalization (and metal enrichment) with cooling (London, 1992; Pichavant and Manning, 1984). Fluorine and low \( fO_2 \) also tend to favour Sn solubility in the melt relative to W (Bhalla et al., 2005; Che et al., 2013; Linnen et al., 1996); this fits with the elevated Sn and F concentrations of the Sn-associated granites at Herberton in comparison to the W-Mo associated granites. Elevated Sn and F concentrations may, therefore, be used as direct indicators of Sn fertility in granitic rocks.

The distinctive high Sn, F and incompatible element signature of the Sn-bearing granites at Herberton is not, however, shared by the contemporaneous volcanic rocks, so the use of the Sn-F-incompatible element signature appears to be ill-suited for applying volcanic rock geochemistry to magma fertility assessment. Nevertheless, we consider the absence of contemporaneous highly-fractionated F-rich rhyolites to be an important criterion for forming granite-hosted Sn mineralization, as volatiles and associated ore metals were not removed from the plutonic environment via eruption of highly fractionated magmas. Therefore, magmatic provinces that contain Sn-rich fractionated rhyolites may be less prospective for granite-hosted Sn mineralization, whereas the less evolved rhyolites with reduced redox state and low contents of fluxing components may be more prospective for Sn–W–Mo exploration. The temporal evolution in magmatism and mineralization at Herberton is linked to evolving tectonic regimes, and we propose that the evaluation of tectonic evolution and volcanic–plutonic connections in other Sn–W–Mo mineral fields may also guide efforts for ore deposit exploration and discovery.

**References**


Vein-type hydrothermal graphite deposits in Sri Lanka

Jan Marten Huizenga (EGRU - Geoscience JCU)

Introduction

Since the 19th century Sri Lanka has been one of the major graphite producers in the world, especially for high quality, highly crystalline graphite, containing around 95-98 wt% of pure carbon. The hydrothermal graphite deposits occur in a wide north-south extending belt in the western part of the Precambrian high-grade metamorphic terrains of the island (e.g., Kehelpannala, 1995).

The Neoproterozoic to Palaeoproterozoic basement of Sri Lanka is subdivided into three lithotectonic complexes (Figure 1; Kehelpannala, 1997): the Wanni Complex (WC), the Highland Complex (HC), and the Vijayan Complex (VC) (Cooray, 1994). The vein graphite occurrences are located in the western part of the country (Kehelpannala, 1995) in both the WC and HC (Figure 1). Most of the graphite deposits are within a distance of around 15-30 km of the WC-HC tectonic boundary. The formation post-dates the granulite facies metamorphism of both the WC and HC Complex (Kehelpannala, 1995).

Geological setting of the Highland and Wanni Complex in Sri Lanka

The HC and WC comprise a wide variety of high-grade metamorphic rocks including metapelite, quartzite, granitoid gneisses, charnockites, metamorphosed mafic igneous rocks, calcisilicates, and marble. Peak metamorphic P-T conditions in the WC are 5-7 kbar and 700-830 °C (Schenk et al., 1991; Raase and Schenk, 1994). The HC shows an increase in metamorphic P-T conditions from 4.5-6 kbar and 700-750°C in the southwest to 8-9 kbar and 800-900°C in the southeast (Dharmapriya et al., 2014; Dharmapriya et al., 2017). A significant feature of the HC is the localised occurrence of UHT granulites (e.g., Dharmapriya, 2017) in the central part (Figure 1). Peak P-T conditions of the UHT granulites are 9-12.5 kbar and 900-1150°C, respectively (e.g., Osanai et al., 2006). Retrograde metamorphism of both the WC and HC are characterised by near-isothermal decompression, followed by cooling (e.g., Dharmapriya, 2017).

Kehelpannala (2004; Figure 2) proposed that the WC, HC, and VC were three distinctly different crustal domains that amalgamated during the Late Neoproterozoic Gondwana assembly by two separate collision events following two separate subduction events (Figure 1; Kehelpannala, 1997) showing the three main lithotectonic units, their Nd model ages, and the locations of active graphite mines and major graphite deposits.

The graphite veins contain a wide variety of graphite mineralisation: physico-chemical conditions

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Graphite vein characteristics

Almost all graphite veins are oriented in an east-west direction and steeply dipping to the south. The thickness of most graphite veins varies from a few mm to tens of cm (Figure 3) with the thickest being less than 1 m. Their horizontal length ranges from a few metres to some tens of metres, the longest being over 75 m (Kehelpannala, 1999). Most of the host rocks are free of disseminated graphite. The graphite veins crosscut the axial planes of large-scale synforms and antiforms (Kehelpannala, 1999) and, therefore, post-date the major folding event, which occurred after peak metamorphism but still at granulite-facies metamorphic conditions (Kehelpannala, 1999).

The graphite veins contain a wide variety of rock and mineral assemblages including quartz, Na-K-feldspar, chloritoid, biotite, muscovite, apatite, pyrite, pyrrhotite, chalcopryte, sphalerite, marcasite, calcite, siderite, dolomite, iron ores and traces of Mn-carbonate (Kehelpannala, 1995). Graphite crystals are up to a few cm in size and show fibrous, coarse-flaky, and rosette crystal shapes. Typically, graphite occurs as fibrous aggregates at the vein edge, becoming elongated crystals intergrown with quartz approximately perpendicular to the vein wall. Massive graphite characterizes the centre of the vein (Katz, 1987). Pyrite is often associated with graphite, either as thin films within the graphite or as fracture coatings within the quartz associated with vein graphite (Katz, 1987). Textural descriptions of the graphite veins by Katz (1987) provide evidence for crack-seal events. Close to the graphite veins intense wall-rock alteration mineral assemblages include biotite, high-density CO2 fluid inclusions imply graphite precipitation. Remnants of these fluids in the form of fluid inclusions were found in quartz in the graphite veins (Figure 5). The density of the CO2 fluid inclusions indicate that graphite formation started at a pressure of approximately 7 kbar, corresponding to a temperature of around 700°C.

Graphite mineralisation: physico-chemical conditions

P-T conditions and fluids

The high-density CO2 fluid inclusions imply graphite formation at pressures around 7 kbar at approximately 700°C by extending the WC P-T path (Figure 6). The wall-rock alteration assembly includes biotite and chlorite and indicates a relatively low temperature of below around 500 °C at a pressure of approximately 1-2 kbar according to the WC P-T path (Figure 6). Therefore, graphite formation appears to have started at granulite facies P-T conditions and proceeded during most of the decompression and cooling stages.
The presence of CO$_2$ fluid inclusions and the carbon isotope signature (Figure 4) suggests mantle CO$_2$ as the primary source. Considering the fact that the graphite veins formed after the peak of metamorphism, it is unlikely that CO$_2$ was directly derived from the mantle. It is proposed that initially mantle CO$_2$ was introduced into the lower crust and trapped in UHT granulites during WC-HC collision (Figure 2), most likely because of slab breakoff and subsequent upwelling of the mantle asthenosphere (Davies and Blanckenburg, 1995). Decompression associated with fast uplift (Hiroi et al., 2014; Dharmapriya et al., 2017) mobilized CO$_2$ (either trapped in fluid inclusions or occurring in isolated pockets) due to the increasing difference between the fast decreasing lithostatic pressure and the fluid pressure. Flow of CO$_2$ fluids would have been enhanced by high-salinity brine fluids causing grainsize-scale dissolution-precipitation processes (Putnis and Austrheim, 2010; Newton and Tsunogae, 2014).

**Graphite precipitation**

Graphite precipitation in Sri Lanka is caused by the following processes:

- **Fluid reduction**: driven by the redox difference between the relatively oxidized CO$_2$ fluid and the relatively reduced host rock, according to the net reaction CO$_2$ + C + O$_2$. Reduction of CO$_2$ does not require any change in pressure and/or temperature, i.e., it was probably the main process for graphite precipitation at granulite facies conditions (ca. 700 °C, 7 kbar) at the start and during the near-isothermal decompression stage of the retrograde P-T path.

- **Fluid cooling**: the retrograde P-T path for the WC shows that cooling became significant at temperatures < 650°C after the initial stage of near-isothermal decompression. During cooling, graphite precipitates according to the net reaction CO$_2$ + 2H$_2$ $\rightarrow$ C + 2H$_2$O. Fluid cooling and fluid reduction: led to a relative increase of the H$_2$O content in the fluid phase and initiated retrograde hydration reactions. The removal of H$_2$O due to hydration would shift the above cooling reaction to the right side causing more graphite to precipitate.

**Conclusions**

The graphite veins in Sri Lanka are unique because of the large scale of their occurrence and their high crystallinity. Similar graphite veins are found in the high-grade metamorphic terranes of southern India (Luque et al., 2014) but at a much smaller scale. A number of factors have contributed to the formation of the Sri Lankan vein graphite. Each factor is critical in the process, i.e., it is the combination of these factors that allows the formation of these unique deposits. They include: (1) Temporary storage of large amounts of mantle CO$_2$ in UHT granulites during the continent amalgamation. (2) Fast exhumation in order to release CO$_2$ from UHT granulites. (3) Presence of high-salinity brine fluids to facilitate CO$_2$ mobility. (4) Pre-existing structures (e.g., faults, shear zones) that act as fluid fowcussing zones. (5) Graphite precipitation that is caused by (a) CO$_2$ reduction, (b) fluid cooling, and (c) retrograde hydration reactions. The reason for the high crystallinity of vein graphite in Sri Lanka remains an unresolved issue. Luque et al. (2009) demonstrated for the Borrowdale graphite deposit that high crystalline graphite precipitated from a moderate-temperature (ca. 500°C) fluid, i.e., the temperature is not the only factor that controls hydrothermal graphite crystallinity (Luque et al., 2014).
The Geita Greenstone Belt (Figure 1) in NW Tanzania is host to a large number of gold deposits, most of which are mined by Geita Gold Mine (GGM), owned by AngloGold Ashanti. The Geita Gold Mine produces around half a million ounces of gold annually and recently commenced underground mining for most of the operations. Since 2011, EGRU has been involved with the GGM exploration team on developing a thorough understanding of the gold mineralization from deposit to regional scale. As part of this effort, detailed studies on the geological setting, structure, alteration and genesis of individual deposits were performed as well as regional studies on the structural and tectonic controls on the gold mineralization. These studies were led by Ioan Sanislaw and Paul Dirks from EGRU in collaboration with Tom Blenkinsop from Cardiff University.

**Geita Shear Zone – a crustal scale shear zone**

Arc shear gold deposits are, in general, located on or in the vicinity of large scale shear zones. Geita Greenstone Belt is no exception and all the large deposits are located within 5 km distance of the Geita Shear Zone (GSZ; Figure 1). The GSZ is a broad (approximately 800m wide) ductile, high-strain, deformation zone that can be traced for at least 50 km along the southern margin of the GGB; to the west and east of the GGB it can be traced for at least another 50 km. It is near vertical, trends approximately east-west and separates the mafic volcanics of the Kiziba Formation, to the north, from the TTG gneisses that crop out south of the shear zone. The shear zone is hosted almost entirely by the TTG gneisses and is characterised by a well-developed mylonitic foliation near the greenstone margin that transitions into a gneissic foliation and eventually becomes a weakly developed foliation further south. It contains approximately equal amounts of dextral, sinistral, and asymmetric shear sense indicators suggesting that the shear zone accommodated mainly flattening strain, while the mineral stretching lineation defined by quartz and feldspar ribbons and stretched biotite selvages plunges shallowly westwards. A series of
Research

Gold in the Geita Greenstone Belt

Using detrital zircons to unravel the tectonic setting of ancient terranes

The distribution and rock record of sedimentary basins are a direct reflection of their tectonic setting. Of particular importance for deducing the tectonic setting of sedimentary basins is the detrital zircon record. Zircon is highly resistant to weathering and transport and can be recycled through multiple sedimentary cycles. The detrital zircon age distribution can be used to track sources and, when combined with in-situ Hf isotopic measurements, can provide important insights into the tectonic evolution of a region. The top of the sedimentary sequence in the GGB (Figure 1) contains a series of quartzitic conglomerates belonging to the so called Kavirondian Supergroup. The quartzitic conglomerates unconformably overlie the earlier Nyanzian metasediments. They have no consistent internal stratification, the clasts are generally well rounded and in places a transition to coarse sandstone can be observed. The conglomerates are poorly sorted and contain clasts of quartz-pebble conglomerate suggesting some internal reworking and possibly re-sedimentation. The conglomerates contain a rich zircon population composed mostly of fragmented and

Figure 2. Series of cartoons illustrating three possible scenarios involving the presence at depth of >3 Ga basement rocks to explain the old zircon ages found in the TTG and granite samples from both sides of the Geita Shear Zone. In all three scenarios, the melt becomes contaminated with old zircons during ascent. It is worth noting that, so far, old zircon grains have been found only within the vicinity of the Geita Shear Zone. (a) Old basement underlying both the TTG and the greenstone. If that is the case old zircon grains could be found further south. (b) Old basement underlying only the TTG and GSZ dips north at lower depths. If this is the case, GSZ could be a major tectonic boundary separating two distinct terrains. It would also suggest that the shear zones initiated before 2700 Ma. Old zircon grains could be found further south. (c) A fragment of rifted old basement underlies part of the greenstone belt. If that is the case old zircon grains would occur only in certain domains.

Figure 3. Diagrams showing the distribution of zircon ages for central Tanzania (a) and for northern Tanzania (b).
subrounded grains which display concentric growth zoning typical of igneous zircons.

The detrital zircon population (Figure 4) in the quartzitic conglomerates from the northern Tanzania Craton yield ages between 2640 Ma and 2790 Ma which includes most of the igneous history from this part of the craton. The igneous evolution is characterised by mafic volcanism with an oceanic plateau-like geochemical signature at around 2800 Ma, followed by diorite and tonalite–trondhjemite–granodiorite dominated magmatism between 2790 and 2700 Ma, which transitioned into more evolved high-K magmatism between 2700 and 2620 Ma. The εHf values of the detrital zircons range from +2.4 to -1.4 and change with time from radiogenic Hf pre-2700 Ma (98% positive εHf) to unradiogenic Hf post-2700 Ma (41% positive εHf). The petrological progression from mafic to felsic crust is reflected in the detrital age distribution and Hf isotopes, and is consistent with juvenile mafic crust slowly maturing into more evolved felsic crust through a series of successive partial melting events in an oceanic-plateau-like environment. This tectonic model takes into account the overall sedimentary, igneous and geochemical record and provides an explanation for the bell-shaped distribution of the detrital zircon population, which is consistent with internal reworking and progressive maturation of an oceanic plateau by successive partial melting events partly controlled by the changing nature of a subducting slab.

References

The Australian Synchrotron is a world-class national facility that uses highly advanced accelerator technology to produce a powerful source of light, x-rays and infrared radiation. The facility, located in Melbourne, consists of seven beamlines: infrared spectroscopy beamline, soft x-ray spectroscopy beamline, x-ray absorption spectroscopy beamline, small angle and wide angle x-ray scattering beamline, x-ray fluorescence microscopy beamline and imaging and medical beamline. The beamlines are designed to support high level scientific research in a wide range of applications including: biomedicine, defense, environmental technology, food technology, forensics, manufacturing, minerals, natural resources, and pharmaceuticals. Beamline time is awarded on a competitive basis and the selected projects benefit from the skills and knowledge of highly trained beamline scientists. The Australian Synchrotron also hosts a high quality accommodation facility where guests can stay during the duration of the experiments.

As part of our ongoing research to understand the source, transport and deposition of metals in structurally-controlled ore deposits we decided to study the distribution of metals in shales. It is well known that shales are naturally enriched in a variety of transition metals, especially Mo, Zn, Ni, Cu, Cr, V, Co, Pb, U and Ag. In addition to this wide-spread metal enrichment, shales are also host to some of the world’s largest economic concentrations of copper, lead, zinc and gold, occurring in metamorphosed shales. In general, the high concentration of the metallic elements in shales is related to a variety of metal sulfides, and it has been suggested that sulfide minerals are an integral part of sediment diagenesis. Metal-rich shales typically require conditions that are conducive to the accumulation of large quantities of organic matter and slow accumulation rates. In this study we were interested in the role played by the organic matter in the accumulation of metals in shales. We used shales that contain 0.5 to 1% organic carbon and have no sulfides preserved. However, the shales contain hematite grains.
that originally could have been sulfide minerals.

**The distribution of the organic carbon**

To find out how organic matter controls the distribution/concentration of the metals within shales we first determined the distribution of organic matter in our samples. To do this we used a Raman microscope hosted at the Advanced Analytical Centre at James Cook University. The Raman microscope can be used to identify specific mineral species based on their Raman spectra. This can be done by point analyses or by mapping targeted areas. For example carbon has two specific absorption peaks at 1340 cm⁻¹ and at 1580 cm⁻¹. The Raman map in Figure 2 shows that the organic carbon in this sample is not only disseminated within the sample but it is also concentrated in double ring-like structures. Between the two ring-like structures the composition is dominated by hematite (not shown in Figure 2) while the interior and the exterior is dominated by quartz and white micas.

**The 3D shape of the ring-like structures**

To find out the 3D shape of the ring-like organic carbon structure we used the medical and imaging beam line at the Australian Synchrotron. This beamline allows to perform 3D x-ray computed tomography on the same rock slabs from which thin sections were cut. A powerful X-ray beam penetrates the samples as a series of ~10 µm thick slices, each slice resulting in a projection of the sliced sample. Up to 3900 images were collected from a thin section block. This images are stack together and a 3D block of the thin section slab is produced and can be visualised with a specialised software. The X-rays interact with the minerals forming the rock slab based on the atomic weight of the constituent elements. Thus, different minerals can be separated and imaged based on their relative density. The images in Figure 4 show the carbonaceous double-ring like structures after minerals such as oxides, sulfides and quartz were filtered out. The 3d shape of the carbonaceous structures is sub-spherical resembling a nodule. However, the internal geometry as shown by the section cut through the middle of the structure suggests that the nature of these carbonaceous structures may be more complicated than a simple nodule origin. The complex and organized internal structure could be indicative of a microorganism.

**Metal distribution and concentration in shales**

The distribution of metals in the shale samples was mapped using the X-ray fluorescence beamline at the Australian synchrotron. We used the Maia detector, which can resolve multiple elements (heavier than Si with Z=14) at the same time, at a <1 µm resolution and dwell times of 0.5-50 msec. The advantage of using the synchrotron for mapping chemical elements over the typical electron microprobe techniques rest in the synchrotron ability to map simultaneously a much larger number of elements over a much shorter time period. For example we mapped an entire thin section at a 1 µm step in less than three hours and produced maps for 30 elements. The data was integrated using GeoPIXE.

Synchrotron mapping (Figure 5) revealed that there is a very good correlation between the location of the ring-like carbonaceous structures and metals such as Fe, Cu, Zn and Mn. The Fe and Mn is directly related to the hematite grains that fill the space between the carbonaceous rings. The close relationship between the hematite and the carbonaceous rings suggests a genetic relationship that requires further investigation. The results also show that Cu and Zn are concentrated in the hematite that occurs with the carbonaceous rings with Cu ≥ 700 ppm and Zn ≥1200 ppm. These results suggest a close link between the metal enrichment in shales and the carbonaceous matter. The complex 3D shape and the organized structure of the carbonaceous rings opens the possibility that these carbonaceous structures are not nodules but possible remains of some form of microorganisms. If that is the case our results indicate that microorganism may play an important role in concentrating metals in shales.

Reference: [www.synchrotron.org.au](http://www.synchrotron.org.au)

**Figure 2.** Photomicrograph (A) and example of a Raman map (B) filtered for the carbon 1580 cm⁻¹ showing the distribution of organic carbon. (The scale bar in (A) is 100 microns.)

**Figure 3.** Photographs of the medical and imaging beamline from the Australian Synchrotron. The left image shows the sample stage and the right image shows the X-ray beam slot.

**Figure 4.** Results of the 3D X-ray computed tomography showing the sub-spherical (A) shape of the microstructures and their complex internal structure (B). (The diameter of the microstructures is approximately 500 microns.)
Magnatic history, fertility and metallogenesis of the Mary Kathleen Domain of the Mt Isa Inlier

Paul Dirks, Carl Spandler, Ioan Sanislav (EGRU - Geoscience JCU)

The North-West Queensland Mineral Province (the Mt Isa Inlier) is a major mining region in Australia, and has contributed significantly to its economic output in terms of jobs, income and regional development over the last 100 years. The province contains major ore deposits such as mines around Mt Isa, with significant new mineral deposits such as the Ernest Henry iron oxide-copper-gold deposit being discovered up to the early 1990s. However, few significant discoveries have been made since that time.

Although magmatism has been viewed as a key driver for copper-gold mineralisation in the Mt Isa Eastern Supercession, there remains little comprehensive understanding of how mineralisation and episodes of magmatism are inter-related. This is largely due to the diversity in age, composition and evolution of magmatic rocks, diversity of mineral deposits, and the complexity of geological activities in the region. As a major contribution to an improved understanding of these relationships this research project will focus on the tectono-metallogenic evolution of a diverse range of igneous rocks, including the Wonga-Burttall and Williams-Naruku suites, and various mafic and alkaline magmatic rocks of an uncertain affiliation.

The ~1740 Ma Wonga-Burttall Suite of felsic to mafic intrusions occupies a large area of the Mary Kathleen Domain (MKD), and includes some intrusive units in the Cloncurry district, but the distribution of this magmatic suite remains unclear due to a lack of geochronology/geochemistry work. This suite is related to significant U-bearing skarn (Mary Kathleen and Elaine-Dorothy; Oliver et al., 1995) and also Cu (±Au) mineralisation (e.g. Duchess, which is hosted in granite, Trekalano, Revenue, Overlander, and Little Eva deposits). Further east, the extensive Williams and Naruku batholiths, particularly the younger phases (~1540 Ma), are commonly invoked as sources of fluids to regional alteration and hydrothermal Cu-Au mineralization in the Eastern Supercession (Perkins and Wyborn, 1998; Pollard, 2001; Mark et al., 2004). The western extent of the Williams – Naruku magmatic event remains untested, and there are indications that this magmatic episode was responsible for at least some of the mineralisation in the MKD (Spandler et al. 2016).

The project will link existing and new geochronology and isotopic geochemistry to explore the links between magmatism and mineralisation in selected regions of the MKD. This will be used as a basis to trial the development of fertility indicators in magmatic rocks to guide future exploration efforts. This approach will take advantage of recent advances in analytical capability and rapid data acquisition to greatly enhance the existing geochronological, geochronological, and isotopic information on various magmatic suites in the region. This work will largely be done at JCU using dedicated sample preparation and laser ablation ICP-MS and electron microprobe laboratories.

A crucial aspect of this work will be to directly link the new data to well constrained field relationships. Detailed fieldwork (mapping, sample collection) will focus on targeted areas where the transition between magmatism, magma-related hydrothermal alteration and ore formation can be tracked. The project aims to highlight the exploration potential in the MKD by providing key mineralisation insights that can assist mining companies to plan their exploration strategy for better targeting and enhance the potential for new discoveries. To achieve this, the project has three main objectives:

1. Establish the extent, character and timing of the dominant magmatic epochs in the Mary Kathleen Domain of the Mt Isa Inlier.
2. Develop an understanding of the tectono-magmatic history of the Mary Kathleen Domain and its links to metallogenesis.
3. Explore the applicability of magma fertility concepts as a tool for exploration for a variety of deposit types.

The rapid development of Cu isotope measurements in the last decade has demonstrated that Cu isotopes are a powerful tool in the field of economic geology. Now, a procedure for high-precision measurements of Cu isotopes using MC-ICP-MS has been developed in the Advanced Analytical Centre (AAC) at JCU. Chemical processing and ion-exchange chromatographic separation are carried out in the ultra-clean lab in the AAC, and Cu isotope ratio measurements are performed on a Thermo Finnigan Neptune multicollector ICP-MS.

Repeatability of measurements for 65Cu/63Cu ratios is assessed using the “standard-sample bracketing” method where the 65Cu/63Cu ratio in a sample is bracketed by measurements of the Cu standard. The results of repeated measurements using this technique shows a repeatability of better than 0.06 δ units at 2 standard deviation (SD) level. A δ65Cu value of the NIST 976 obtained from our analyses is 0.05‰ relative to ERM AE633, which is consistent with value of -0.01% within instrumental error that was reported by Molder et al. (2012).

High-precision measurement of Cu isotopes at JCU

Yue Wang, Zhaoshan Chang, Christa Placzek, Yi Hu

Figure 5. Synchrotron X-ray fluorescence maps showing the distribution of Fe, Cu, Zn, and Mn. There is good correlation between the distribution of these elements and the location of the carbonaceous ring-like structures. (Each image is 800 microns across.)
The project has begun in promising fashion. Dr Yanbo Cheng and Joshua Spence have joined the team as postdoctoral researcher and PhD candidate, respectively, and the first samples for geochronology have been collected from Quambay and Little Eva regions.

It is envisaged that the initial Quambay/Little Eva region studies will be supplemented by similar studies of comparable mineral systems elsewhere within the MKD further south. In particular, potential links will be investigated between the skarn events associated with the Mary Kathleen and Elaine Dorothy deposits and magmatism associated with either the Wonga-Burstall Suite or other igneous events. Collaboration and cooperation between GSQ and JCU researchers will strengthen outcomes from the project.

We thank Vladimir Lisitsin (GSQ), Paul Donchak (GSQ) and Rick Valenta (UQ) for assistance in formulation and establishment of the project, and George Ross (Altona Mining) for his guidance for fieldwork and sampling from the Little Eva area.

The project aims to:

1. Investigate and document the geological and geochemical features of the deposit, including understanding the structural evolution, magmatic history, alteration style and mineralization.
2. Classify the deposit.
3. Identify the factors controlling the location of the deposits such as structural architecture, controls of host rocks and intrusions.
4. Discover mineralogical, textural and geochemical zoning patterns that could be used as vectors to ore.

Because the deposit was mined over such a short period of time, there was little independent research done on Tick Hill, and the information available in the public domain and literature is minimal. This PhD project hopes to overcome this paucity of information, and aims to:

1. Investigate and document the geological and geochemical features of the deposit, including understanding the structural evolution, magmatic history, alteration style and mineralization.
2. Classify the deposit.
3. Identify the factors controlling the location of the deposits such as structural architecture, controls of host rocks and intrusions.
4. Discover mineralogical, textural and geochemical zoning patterns that could be used as vectors to ore.

The project started in late-2017, and so far we have discovered that it is very hard to obtain samples from the Tick hill ore zone. The “Galah” rock in the centre of the ore zone, which hosts abundant visible gold, was a bit of a collector’s item, but little of the material remains for study. MIM has generously donated material from their private collection, but we could do with more material.

If anyone reading this has material from the Tick Hill deposit, or knows people who have, we would greatly appreciate your help in securing samples to further our understanding of this important deposit.

A new PhD project investigating the origin of the Tick Hill gold deposit, south of Mt Isa, began in November 2017. Tick Hill represents a high-grade gold mineralization style that appears to be unique in the Mt Isa Block. As part of the new initiative by the Geological Survey of Queensland (GSQ) to promote mineral exploration in the North West Minerals Province, the GSQ contracted EGRU to conduct a PhD study on the deposit. This study is being undertaken by Mr Truong Le, under the supervision of Prof. Paul Dirks, Dr. Ioan Sanislav and Dr. Jan-Marten Huizenga.

The Tick Hill gold deposit is located 110 km south-east of Mount Isa. The deposit has characteristics similar to shear zone-hosted lode gold deposits (‘orogenic’ gold), which indicates a mineralization style in the region that has not yet been a major target for explorers. The deposit was mined in open pit and from underground workings between 1991 and 1995 by Carpentaria Gold and produced approximately 500,000 ounces of gold at an average grade of 23g/t Au.

A new Honours project will investigate the origin of an unusual style of gold mineralization that occurs in the Pilbara region of Western Australia. Mr Michael Nugent will work on a set of samples from mafic conglomerates at the base of the Fortescue Group. The samples, which contain “watermelon” seed gold nuggets, were generously provided by Novo Resources Corp. Michael, who works as a metallurgical engineer in WA, will investigate the textural context and composition of the gold as part of his honours project supervised by Prof. Paul Dirks and Dr. Ioan Sanislav.

The gold occurs as flat, coarse-grained nuggets in a coarse-clastic conglomerate at the base of the 2630–

References

Tick Hill gold deposit, Mt Isa Inlier
Truong Le, Paul Dirks, Ioan Sanislav, Jan Marten Huizenga (EGRU - Geoscience JCU)
Jurassic Arc?
A new ARC-funded project to reconstruct the lost world of Eastern Australia

Carl Spandler1, Eric Roberts1, Bob Henderson1, Tony Kemp2
1 EGRU-Geoscience JCU; 2 School of Earth Sciences, UWA

Introduction

Extensive documentation of Australian geology provides a framework to understand most of the Phanerozoic tectonic history of the continent. An overall convergent plate margin regime along eastern Australia from the Cambrian to the mid-Triassic is recorded by a succession of orogenic systems collectively labelled the Tasman Orogenic Zone (e.g. Cawood et al., 2011; Withnall and Henderson, 2012). From the mid-Cretaceous to present, an extensional tectonic regime developed, leading to fragmentation of the eastern continental margin and migration of the plate boundary far offshore into the Pacific (Crawford et al., 2009). Although the nature and duration of these two tectonic regimes are now very well established, they are disconnected in time. The tectonic regime that shaped eastern Australia in the intervening period - spanning ca. 80 Myr through the Jurassic Period - remains highly enigmatic. This time period saw deposition of over one million cubic kilometres of sediment, dominated by voluminous sand sheets, within the vast epicontinental sedimentary system of the Great Artesian Basin (GAB) and northern equivalents in the Papuan Basin (Figure 1; Veevers 2006; McDougall 2008). Today, the GAB is Australia’s most important reservoir for groundwater, coal and coal seam gas, and holds significant heavy mineral sand resources. Nevertheless, the source and drainage system responsible for depositing this huge sediment load, and the mechanism responsible for creating the enduring, subsidence-driven accommodation space across most of the eastern portion of the continent remains largely unknown.

JCU Geoscience has been awarded funding for a 3-year research project through the Australian Research Council Discovery Program to close the gap in our understanding of the evolution of the eastern Australian continent by modelling the tectonic and magmatic conditions during the Jurassic. The project will use an innovative multi-disciplinary methodology that combines classical analysis of sedimentary successions with geochronological, geochemical and isotopic data derived from their detrital zircon records. Jurassic-age magmatic or metamorphic rocks may once have been represented in the continental crust of the east Australian margin, but now are virtually unknown in mainland eastern Australia. They were likely removed by erosion or have subsided and translocated eastward beneath the ocean by subsequent (post-mid Cretaceous) crustal extension and seafloor spreading (Struckmeyer and Symonds, 1997). Because of this deficiency in the basement rock record, evidence-based knowledge of the Jurassic tectonic setting of eastern Australia is also lacking. Jurassic sedimentary systems will be employed to address this deficiency. Rock systems of Jurassic and Early Cretaceous age are widely developed in eastern Australia in the basinal structures that collectively comprise the GAB (Figure 1). Sampling is widely accessible through a combination of surface outcrop and extensive subsurface core obtained by drilling. Our project will examine the detrital zircon record through the Jurassic - the time interval that spans much of the gap between the Middle Triassic active margin and the mid-Cretaceous rifting and passive margin development. Our work on mid-Cretaceous (Tucker et al., 2013, 2016) and Jurassic strata has yielded strong evidence for multiple Jurassic-age zircon populations derived from igneous suites of that age (Figure 1).

The Approach and Benefits

The new project will involve a multidisciplinary approach to document complex interactions between plate tectonic and basin development and sedimentation patterns, which will result in the most comprehensive study to date on the Jurassic system of eastern Australia. We will combine sedimentary basin studies, tectonic analysis and geodynamic modelling, and an innovative and robust geochemical and isotopic approach to sedimentary provenance evaluation. The approach will combine U-Pb and Lu-Hf isotopic analyses of detrital zircon from sandstone units encompassing the spatial and stratigraphic distribution of the Jurassic system in eastern Australia to establish the timing and source of volcanism, the chronology of basinal subsidence and the uplift of sediment source areas during the Jurassic. Data obtained here will result in a new understanding of the paleogeography and tectonic setting of the continent during this enigmatic time period in Australia’s geological history.

Field sites will cover sedimentary basins across north-eastern Australia (Laura, Surat, Carpentaria, Eromanga, Clarence-Morton Basins) and Papua New Guinea, an analytical work will utilise the state-of-the-art analytical facilities at JCU and UWA. There is provision for training for a number of research students, which includes the prospect of learning new in-situ analytical techniques. This project will provide a more rigorous understanding of a large scale, epicontinental sediment system, and associated sedimentary basin type, for which a dynamic setting is very poorly understood worldwide. Our findings, therefore, will be applicable to other regions of the globe where sedimentary systems comparable to the GAB are developed (e.g., Runkel et al. 2009). In addition, our geochronological dataset will refine the timescale applied to the Jurassic as developed in the GAB. This is currently a relative timescale based on a local palynological zonation for which calibration to absolute time is entirely lacking (Burger and Shafik 1996). Age refinement through the application of maximum depositional age characterisation from detrital zircons will allow the development of a more robust subsidence history, and, together with identification of sediment transport vectors, will impact on other fields of study such as biostratigraphy and vertebrate palaeontology. Advancement of knowledge of basin evolution and architecture is of particular significance to industry, as it will directly translate to improvements in exploration for, and extraction of, coal, hydrocarbon and heavy mineral sand resources. This research will also have a positive impact on the age dating and correlation of vertebrate faunas, which will help inform ongoing evolutionary investigations related to the origins of major vertebrate groups prior to and following Gondwanan fragmentation. Although Australian Mesozoic vertebrates are the foundation of a significant tourist industry in Queensland, they are among the mostly poorly dated and least well constrained taxa in many palaeobiogeographic analyses. Providing better context for Australia’s iconic dinosaur species will be of interest to the broader scientific and public communities, and will be of benefit to dinosaur-related tourism in the region.

References

This year's EGRU workshop on IOCG and other mineral systems of the Mt Isa Inlier was held in Cloncurry. The workshop included academic and industry talks that addressed issues related to mineralisation and the regional geology. The forum covered practical and theoretical problems while suggesting solutions using the latest innovative technology to help discover the next major deposit in the district.

During the week preceding this workshop north western Queensland received a welcome once-in-10-year rain event that disrupted the drought. The rain resulted in widespread flooding that cut access to many of the mine sites in the Cloncurry area. This flooding unfortunately forced EGRU to cancel the field trip through the Selwyn mineral field to the Osborne Mine, that had been scheduled to follow the workshop, and was to be generously hosted by Chinova. Nevertheless, the technical presentations and drill core components of the workshop went ahead and participants were greeted with an unusually green Cloncurry.

The first day's program consisted mainly of academic presentations, talking about the latest research and ideas in the region. EGRU co-directors Assoc. Prof. Carl Spandler and Prof. Paul Dirks opened the workshop and welcomed delegates. They were followed by a presentation by Paul Donchak from the GSQ. Paul summarized the Proterozoic tectonic evolution of the Mount Isa region and the associated mineralised systems. This summary of the current regional understanding gave an appropriate backdrop to the workshop and was a great prelude for the talks that followed.

Steve Micklethwaite from Monash University presented an insightful talk about drones and their current and prospective use as a field and research tool. Steve highlighted the versatility and cost efficient aspect of drones, with their ability to conduct exploration and monitor areas that are not safe for employees in mine sites. He stated that this could be achieved by a variety of attachments that can acquire many different data sets such as gravity and hyperspectral imagery at a high resolution. Steve also mentioned the prospect of neural network software to autonomously process data.

Rick Valenta from the Sustainable Minerals Institute at the University of Queensland presented a talk on deposit discovery in the North West Mineral Province, and highlighted the lack of success in finding a major deposit during the last 15-20 years. Rick discussed a program to compile deposit data sets from across industry, government and academic sectors, into an atlas to assist explorers. Vladimir Lisitsin from the GSQ also referred to the lack of major deposit discoveries and outlined the plan the GSQ and Geoscience Australia have in regards to acquiring data sets. Vladimir opened the table for industry feedback on prioritizing tasks and collaboration in acquiring data.

Gordon Lister from the Australian National University spoke about the Elzeverian landscape of Mount Isa showing his preliminary results from Argo dating. These results shed new light on the possible mineralisation ages in the region that drew some enthusiastic discussion from the audience. John Walsh from CSIRO discussed the value of mapping chemical gradients as vectors to mineralisation, and demonstrated the use of a range of chemical parameters.

Joan Sanislav from EGRU presented a talk on the use of Short Wave Infrared (SWIR) spectroscopy to explore for structurally controlled deposits. He used a case study from a structurally controlled gold deposit in Tanzania to show that SWIR can be used to fingerprint gold related alteration from as far as 200 meters from the ore zone. The entire procedure is cost effective and can be automated so that the results are received and interpreted in real time.

Richard Lilly from the University of Adelaide proposed a zoned carbonate replacement model for mineralisation at Mount Isa, and presented evidence from ore textures and paragenetic relationships in the sediment hosted system. Peter Rea, from Mount Isa Mines Exploration, finished off the day’s talks with an economic focus. Peter spoke about exploration efforts in Mount Isa that have defined more copper resources. He identified paucity in drill core profiles, drilled the gaps, and discovered significant copper grades in the upper halo areas that will potentially extend the life of Black Rock Pit.

Core viewing was next on the agenda and the workshop moved to the MIM Barracks in Cloncurry where core was on display. Due to the floods transportation of some core had been hindered, but beautiful core from MIM’s exploration efforts and the Ernest Henry Mine were on display, along with drill core from other deposits. Core was made available by MIM/Clencore, MMG, Capricorn Copper, Altona Mining and Malaco Leichhardt. The core viewing sparked conversation between the participants, and was followed by a classic game of backyard cricket, a BBQ and beers, which helped promote further discussion about the day’s talks.

Presentations resumed the next day with an economic focus, with company geologists talking about recent exploration and current understanding of existing deposits. George Ross from Altona Mining opened the day, speaking about Altona’s Cloncurry Copper project in the Roseby field. George spoke about the Little Eva and Turkey Creek deposits’ resource potential, and mentioned geobotanical vegetation anomalies being used as an exploration tool. Malaco Leichhardt’s representative, Bruce Godsmark, presented a talk on the Crusader Copper Mine - including current resources, exploration, and the unusual colloform chalcopyrite.

David A-Izzeddin from Capricorn Copper gave an overview of the company’s assets and different deposit styles, with a focus on the Esperanza South deposit. Mark Whittle from Hamner Metals talked about the different mineralisation styles along the Prince of Wales - Scapper Trend, and Carolyn Deacon (MMG) gave an update on logging and fault modelling at the Dugald River Pb-Zn-Ag mine. Damian Jungmann presented evidence for the new structural and timing model for the Osborne Cu-Au deposit, and Jennifer Gunter (Virga Pty Ltd) outlined new modelling of Chinova’s Kulhor Cu-Au deposit. Ava Stephens, a recent JCU honours graduate, presented the findings from her project on the Artemis deposit and gave a concise description of this unusual deposit. The talks finished with a thank you to Judy Botting for her critical role in organizing the workshop, and organizing (and then cancelling) the arrangements for the field trip.

The Cloncurry district has a complex mineralisation history that presents challenges in exploration. Solid geological models and a better understanding of the diverse IOCG classification criteria will help in meeting these challenges. The workshop highlighted the value of cooperating and communicating across the various sectors in the search for new deposits - a message reinforced by many of the workshop speakers and delegates.

Thank you to all the companies who contributed to the workshop, who provided drill core, and who were involved in the planning of the field trip. Thank you to MIM/Glencore for the very generous provision of dinner, kitchen facilities, and the use of the Barracks for drill core viewing, and to Altona Mining for providing beverages.
Professional Development Courses: Ore Textures, Breccias, Drill Core Logging

Two professional development short courses were offered to industry geologists in late January this year. The courses are also part of the honours coursework program at JCU in 2018 and industry participants worked alongside current JCU honours students.

Ore Textures and Breccias Recognition Techniques

Course Leader: Dr Gavin Clarke

This three-day course introduced participants to the fundamentals of textural observation and interpretation in mineralized hydrothermal systems. The techniques used are simple, highly effective and require no specialised equipment for their implementation. The techniques are also extremely practical in that they generate numerous questions concerning the mineralisation being studied and commonly provide vectors toward mineralisation for drill testing. Critical evaluation factors considered during the course include:

- Infill: Recognition Criteria
- Alteration: Recognition & Evaluation
- Channelways: Recognition Criteria
- Overprinting and Paragenesis: Recognition & Sequencing Criteria
- Breccia: Recognition Criteria
- Breccia: Rudimentary Classification system
- Tectonic Breccia Systems
- Intrusive Breccia Systems
- Paragenetic Core Logging

Core Logging Techniques

Course Leader: Professor Paul Dirks

This two-day course introduced the basic skills and methodology required to review and log geological core. Emphasis was placed on the recognition, description and acquisition of oriented data (bedding planes, faults, fractures, shear zones), and how this data relates back to field observations. The course aimed to familiarise participants with the key requirements of core logging, and how to interpret and integrate drill logs with geological models.

Congratulations to...

Everyone in JCU Geoscience

In late 2017 JCU Geoscience was awarded the 2017 JCU Award for Excellence in Research. The JCU Awards for Excellence are designed to recognise staff who demonstrate outstanding achievement in activities that are aligned to the University’s Strategic Intent and the University Plan.

Dr Christa Placzek

on her promotion to Senior Lecturer

Mistrel Fetzer Boegheim

who was awarded a 2018 QCoal Foundation Scholarship

Ross Chandler

and Eric Zurek-Haidamous

who were awarded 2018 EGRU Scholarships

Ross Chandler

who was awarded a 2017 Davis-AIG Honours Bursary

Natalie McIver

who was awarded the 2017 AusIMM Ian Morley Prize
Nick Franey
Course Leader: Business and Financial Management for the Minerals Industry

Nick Franey is an exploration geologist with more than 35 years of experience, across a broad range of projects, from grassroots to feasibility study level, and including near-mine operations. He has explored for most types of gold and base metal deposits in a variety of geological terranes, in more than 20 countries.

Nick graduated from Leicester University in the UK. He began his career with the Gold Division of Anglo American (before the creation of AngloGold, now AngloGold Ashanti) as a field geologist in the Barberton and Pietersburg greenstone belts of South Africa. After a spell assigned to the Geophysical Services Department of Anglo, where he worked in the world-class Remote Sensing Section as an image processor and GIS specialist, he rejoined Anglo’s mainstream exploration team as it launched a broad initiative across Africa, when the apartheid regime in South Africa fell.

Nick’s first appointment as an Exploration Manager was to Kenya (Au & Cu), where he set up a new office for Anglo and lived with his family for two years, before transferring to a similar position in Zambia (with responsibility for the DRC), where he had his first taste of African Copperbelt geology. Nick was appointed VP Exploration (Africa) in 2000, where he led teams exploring in more than a dozen countries. He transferred to Perth, Australia, in 2003, as VP Exploration (Asia-Pacific), where he oversaw exploration and new business initiatives in Australia, the Philippines, Indonesia, India and China. Subsequent executive appointments at Anvil Mining (Copperbelt, DRC and Au, Philippines), OceanaGold (Au, New Zealand and Cu-Au, Philippines), Discovery Metals (Copperbelt, Botswana), Azumah Resources (Au, Ghana) and Renaissance Minerals (Au, Cambodia) have provided management exposure to both mid-tier and junior companies in the industry. Nick recently joined Auris Minerals as GM Geology and is now exploring for Cu and Au in the Blythe Basin of Western Australia.

In 1988 Nick obtained an MSc (with Distinction) in Mineral Exploration, at Rhodes University in South Africa, and he subsequently taught Remote Sensing and GIS as a module of the same MSc course for three years. More recently, in 2016, he teamed up with Andy White to teach the Business and Financial Management module of the MSc course in Ore Deposit Geology, offered by EGRU at JCU. And in February this year he taught the same module as part of the 2018 MSc course.

Nick is busy writing a book on Mineral Exploration Management, which he is currently editing. Watch this space...

He runs marathons for fun!

In addition to the 10 day Management course, Nick also offers several 5- and 1-day EGRU courses in Exploration Management:

**Mineral Exploration Management**

**Basic 5-day module (>5 years experience) includes:**
- Management: principles, strategy, success criteria
- Exploration Management: the exploration process, methods, drilling, contracts
- Data Management: geochemical/drilling/spatial/geophysical databases, QA/QC, management policy, logistics, tenements
- HSEC: health & safety, environment, community relations
- Personal Skills: productivity, decision making, communication

**Advanced 5-day module (>10 years experience) includes:**
- Management: key areas of business, HR basics, performance management, communication
- Business Development: exploration strategy, new opportunities, due diligence, negotiation, corporate deals
- Economic Evaluation: mineral economics, funding exploration, economic evaluation, financial models, project valuations
- Financial Analysis: accounting basics, balance sheets, cash flow, financial ratios, budgeting
- Personal Skills: productivity, decision making

**One-day modules**

- Key Skills for Exploration Management
- Day-to-day Mineral Exploration management
- Data Management for Mineral Exploration
- HR Management for Mineral Exploration
- HSEC in Mineral Exploration
- Introduction to Economic Evaluation of Mineral Exploration Projects
- Basic Accounting and the Financial Analysis of Mining and Exploration Companies

A five-day module “Mineral Exploration Management for Engineers” is also available.

Espen Knutsen

Dr Espen Knutsen is the Senior Curator of Palaeontology at the Museum of Tropical Queensland (Queensland Museum Network) and holds a joint appointment with JCU in Townsville. He is a vertebrate palaeontologist who, over the last 12 years, has conducted fieldwork and excavations in Australia, the Arctic, Europe and USA. Espen has described five new species of Jurassic marine reptiles, and was part of an international multidisciplinary research team studying a newly discovered Jurassic marine ecosystem from the Arctic Archipelago of Svalbard. The process and results of this project were featured in two international TV documentaries - “Predator X” (History Channel/BBC) and “Death of a Sea Monster” (National Geographic).

Having a special interest in the diversity, evolution and ecology of Mesozoic vertebrates, Espen’s current projects involve fieldwork throughout Australia, aiming to fill significant gaps in our knowledge and understanding of these prehistoric faunas in the southern hemisphere. In addition to his research, Espen is also developing a palaeontology subject that will be available at JCU in the second semester of 2019.

Joshua Spence

Joshua graduated from James Cook University with a Bachelor of Geology (Honours) in 2017. His honours thesis, supervised by Assoc Prof Zhaoshan Chang, examined the ‘General characteristics of the polymetallic Ag-Pb-Zn intermediate sulphidation epithermal Nightflower deposit’, located 35 km north of Chillagoe, within the Featherbed Volcanic Group (FVG). The aims of the project included: 1) documentation of geology, alteration and mineralisation; 2) investigation of the paragenesis and spatial zonations; 3) classification of the deposit and; 4) proposal of an ore genesis model linking Nightflower’s geological and fluid characteristics with the local tectonomagmatic evolution of the FVG.

Joshua’s PhD project ‘Magma Fertility of the Mary Kathleen Fold Belt (MKFB), Mt Isa Inlier’ aims to, but is not limited to, highlighting the exploration potential in the MKFB by providing key mineralisation indicators that can be used by exploration companies. To achieve this the project currently has four main objectives: 1) Elucidate the link between magmatism and mineralisation in the MKFB; 2) Improve understanding of the tectonomagmatic and metallogenic evolution of the region; 3) Provide companies with new magma fertility indicators, and 4) Build a geological model based on magma fertility indicators that can be used to advance exploration within the region. The project is supervised by Dr Ioan Sanislaw, Prof. Paul Dirk and Assoc Prof. Carl Spandler and funded by the GSQ.

Truong Le

Truong is the first Vietnamese student to join EGRU. Truong worked as an exploration geologist in Vietnam for eight years, and completed a Masters in Economic Geology at the University of Tasmania in 2014. His Masters’ project focused on the geology and mineral characteristics of a gold deposit in Vietnam.

In late 2017 Truong began his PhD project on the Tick Hill gold deposit, under the supervision of Paul Dirkx, Ioan Sanislaw, Jan Marten Huizenga and Zhaoshan Chang. The PhD study is part of the JCU research project on the Geology and Metallogeny of the Mary Kathleen Domain, which is funded by the Geological Survey of Queensland. The Tick Hill study aims to define the ore controlling factors and provide an understanding of the ore genesis.
Postgraduate Student Research Projects

Helge Behnsen (PhD)
Magma fertility related to Au-Cu mineralization in north Queensland, Australia - evaluating the potential for linked porphyry Cu±Au (±Mo) deposits at depth.
Supervisors: A/Prof. Carl Spandler, Prof. Paul Dirks

Tegan Beveridge (PhD)
Geochemical characterisation of bentonites combined with high-precision geochronology for correlation and provenance in the Cretaceous Strata of North America.
Supervisors: A/Prof. Eric Roberts, A/Prof. Carl Spandler

Alex Brown (PhD)
Base Metal Genesis, Stratigraphy and Structural Evolution of the Central Tommy Creek Domain, Mt Isa Inlier
Supervisors: A/Prof. Carl Spandler, Prof. Tom Blenkinsop, Prof. Paul Dirks

Michael Calder (PhD)
Zonation, paragenesis and fluid evolution from the root to top of the Far Southeast Lepanto porphyry epithermal system, Mankayan district, Philippines.
Supervisors: Prof. Zhaoshan Chang, A/Prof. Carl Spandler, Dr Jeffrey Hendenquist, Dr Antonio Arribas

Robert Coleman (PhD)
Evolution of the Tommy Creek Domain and associated rare earth mineralisation.
Supervisors: A/Prof. Carl Spandler, Prof. Paul Dirks

Kelly Heilbron (PhD)
Establishing a tectonic framework for the Cretaceous break-up of eastern Gondwana.
Supervisors: Dr James Daniell, Dr Rob Holm, A/Prof. Carl Spandler, A/Prof. Eric Roberts

Leigh Lawrence (PhD)
Geochemical investigation of Oligocene-aged alkaline volcanic events in the Rukwa Rift Basin, southwestern Tanzania.
Supervisors: A/Prof. Carl Spandler, A/Prof. Eric Roberts

Xuan Truong Le (PhD)
The Tick Hill gold deposit, Mt Isa Inlier
Supervisors: Prof. Paul Dirks, Dr Ioan Sanislav, Dr Jan Martin Huizenga,

Asish Mishra (PhD)
Rates of Erosion and Weathering in the Tropics.
Supervisor: Dr Christa Placzek, Prof. Michael Bird

Stephanie Mrozek (PhD)
Uplift History, Intrusive Sequence, and Skarn Mineralisation at the Giant Antamina Deposit, Peru.
Supervisors: Prof. Zhaoshan Chang, A/Prof. Carl Spandler, Prof. Lawrence Meinert

Teimoor Nazari Dehkordi (PhD)
The origin and evolution of heavy rare earth element mineralisation in the Browns Range area, Northern Australia.
Supervisors: A/Prof. Carl Spandler, Prof. Nick Oliver, Prof. Paul Dirks

Prince Owusu Agymang (PhD)
Mesozoic detrital zircon provenance of Central Africa: implications for Jurassic-Cretaceous tectonics, paleogeography and landscape evolution.
Supervisors: A/Prof. Eric Roberts, A/Prof. Carl Spandler, Dr Rob Holm

Alexander Parker (PhD)
Fluids in the lower crust: storage and mobilization.
Supervisors: Dr Jan Martin Huizenga, Dr Ioan Sanislav

Jaime Poblete Alvarado (PhD)
Geological characteristics and origin of the Watershed W Deposit, North Queensland, Australia.
Supervisors: Prof. Zhaoshan Chang, Prof. Paul Dirks, Dr Jan Martin Huizenga

Caleb Puszkiewicz (PhD)
Analyses of JCU Groundwater-Ocean Interconnection, Extent and Potential Impacts
Supervisors: Dr Christa Placzek, Dr han She Lim, Dr Bithin Datta

Jessie Robbins (PhD)
Understanding the genesis and patterns of cave fill across the Cradle of Humankind, South Africa.
Supervisors: Prof. Paul Dirks, A/Prof. Eric Roberts

David Rubenach (MSc)
Earthquake hazard mapping and modelling to support Qld Rail’s infrastructure.
Supervisors: Dr James Daniell

Fredrik Sahlsström (PhD)
Mt Carlton high-sulphidation epithermal deposit, Queensland Australia: Geological characteristics, genesis and implications for exploration.
Supervisors: Prof. Zhaoshan Chang, Prof. Paul Dirks

Paul Sleczak (PhD)
Evolution and origin of the Gifford Creek Carbonatite Complex: understanding rare earth element mobility in the continental crust.
Supervisor: A/Prof. Carl Spandler

Christopher Todd (PhD)
Sedimentary history of the Porcupine Gorge National Park and application of U-Pb detrital zircon geochronology for correlation of Cretaceous and Jurassic strata in northern Queensland.
Supervisor: A/Prof. Eric Roberts, A/Prof. Carl Spandler

Joshua Spence (PhD)
Magma Fertility of the Mary Kathleen Fold Belt (MKFB), Mt Isa Inlier
Supervisors: Dr Ioan Sanislav, Prof. Paul Dirks, A/Prof. Carl Spandler

Michal Wenderlich (PhD)
Seismic Stratigraphy of the Great Barrier Reef.
Supervisor: Dr James Daniell

Jelle Wiersma (PhD)
Cave sedimentation processes, geochronology, and the distribution of hominins at Rising Star Cave, Cradle of Humankind, South Africa.
Supervisors: A/Prof. Eric Roberts, Prof. Paul Dirks

Matthew Van Ryt (PhD)
Geochemical characterisation of gold mineralisation in Geita Hill, Geita Greenstone Belt, Tanzania.
Supervisors: Dr Ioan Sanislav, Dr Jan Martin Huizenga, Prof. Paul Dirks

Christopher Yule (PhD)
Seismic Stratigraphy and Petroleum Systems of the Mentelle Basin, south west Western Australia.
Supervisor: Dr James Daniell
EGRU Annual Report

EGRU Membership 2017
Level 1
Evolution Mining
Mount Isa Mines, a Glencore Company
South 32, Cannington
Level 2
Geological Survey of Queensland
Newmont Asia Pacific
Terra Search Pty Ltd
Level 3
Carpentaria Gold Pty Ltd
Chinova Resources
Map to Mine Pty Ltd
Minerals Resources Authority PNG
Minotaur Exploration Pty Ltd
Level 4
CSA Global
Gnomic Exploration Services
Laneway Resources Ltd
Lantana Exploration Pty Ltd
Sandfire Resources
Signature Gold Ltd
Teck, Australia Pty Ltd
Level 5
20 Individual members

Staffing Update
Promotions
Christa Placzek - Senior Lecturer
Awards
JCUC Excellence in Research Award to the Academic Group of Geoscience
Annivals/Returning
Espen Knutsen
Paul Dirks
Departures
Yanbo Cheng
Isaac Corral
Arienne Ford
Rob Holm

Conferences/Meetings attended by staff and students
FUTORES II, Townsville Qld
Zhaoshan Chang, Carl Spandler, Paul Dirks, Jan Huizenga, Kaylene Camuti, Arianne Ford, Rob Henderson, Rob Holm, Hauqing Huang, Isaac Corral, Yanbo Cheng, Ioan Sanislav, Gavin Clarke, Helge Behrens, Fredrick Sahlsström, Paul Steak, Alex Parker, Christopher Todd, Mathew Van Ryt, Jaime Poblete, Kairan Liu, Peter Illig, Robert Coleman, Stephaniean Mrosek, Teimoor Nazari Dehdashti, Mark Sedgman, Peter Illig
SEG Conference, Beijing China
Zhaoshan Chang, Yanbo Cheng, Jaime Poblete, Laura Liu, Peter Illig, Judy Bottig
Minerals and Wines, Orange NSW
Zhaoshan Chang, Peter Illig

Industry & Academic Liaison
SEG Publications Board Meeting, Toronto, Canada
Zhaoshan Chang,
Chinese Academy of Science
Zhaoshan Chang

Visiting Speakers
Patrick O'Connor, Nancy Stevens:
Ohio University
John Mennies: CMI Capital Ltd
Jesse Clark: BHP Billiton
SEG Student Chapter
Laurie Hutton:
Geological Survey QLD/GSA Qld
Angela Bush:
Senior Hydrologist, AEG Pty Ltd
Glen Walker:
CSIRO
Zhibu Dai:
State Key Laboratory of Ore Deposits Geochromy, China

EGRU Short Courses/Workshops/Seminars:
held at JCU
Ore Textures and Breccias: Recognition Techniques
Gavin Clarke,
Core Logging Techniques
Paul Dirks
Advanced Techniques in Mining & Exploration Geology
Zhao Shan Chang, Carl Spandler, Dale Sims (Consultant), Ioan Sanislav, Arianne Ford
Metallogeny and Exploration in NE Qld
Two-day seminar - GSQ NE Qld research collaboration
Zhao Shan Chang et al.
Courses associated with the FUTORES II conference in Townsville:
Leapfrog Geo Fundamentals
Structural Geology in Epithermal Systems
Porphyry Epithermal Cu-Au Deposits
Skarn Deposits

Research Grants
Continuing Grants
Grantee: Zhoshaan Chang, Paul Dirks, Carl Spandler, John Carranza, Jan Huizenga, Bob Henderson
Source: Qld Dept of Natural Resources and Mines, Future Resources Program
Title: Characterising and assessing prospectivity of intrusion-related hydrothermal mineral systems in north-east Queensland
Commmencing Year: 2014
Completing Year: 2017
Amount: $1,779,736.00
Grantee: Paul Dirks, Eric Roberts, Carl Spandler, Tom Blinkenjos
Source: Australian Research Council - Discovery Projects Grant
Title: Life and death of Australopithicus sediba: how a potential ancestor ended up dead in a cave in world heritage site in South Africa
Commmencing Year: 2014
Completing Year: 2017
Amount: $256,000.00
Grantee: Zhao Shan Chang, Paul Dirks, Christa Placzek
Source: Evolution Mining Contract Research
Title: Geological Characteristics and Genesis of Mt Carlton High-Sulfidation Epithermal Deposit, and the Implications for Exploration
Commmencing Year: 2014
Completing Year: 2017
Amount: $150,000.00
Grantee: Ioan Sanislav, Jan Huizenga, Thomas Blinkenjos, postgraduate Alex Brown
Source: Mount Isa Mines
Title: Geology of the Tommy Creek Block, Mount Isa Inlier
Commmencing Year: 2016
Completing Year: 2016
Amount: $30,000.00
Grantee: Robert Holm
Source: JCU Rising Star
Title: Investigating the the source of Enigmatic Piscense-Quaternary Magnetism in PNG
Commmencing Year: 2016
Completing Year: N/A
Amount: $15,000.00

New Grants
Grantee: Post graduate study Ashish Mudra -Supervisor Christa Placzek, Source: AINSE
Title: Quantification of Erosion and rates of landscape transformation in Nth Qld using 10Be
Commmencing Year: 2017
Completing Year: 2017
Amount: $22,500.00
Grantee: Espen Knutsen
Source: Australian Geographic Society
Title: Excavating Western Australia’s first Jurassic tetrapod skeleton
Commmencing Year: 2017
Completing Year: 2017
Amount: $3,000.00
Grantee: Paul Dirks, Honours research
Title: Geological Characteristics and Genesis of Mt Carlton High-Sulfidation Au-Cu-Ag Mine
Commmencing Year: 2017
Completing Year: 2018
Amount: $40,500.00
Grantee: Paul Dirks, post graduate research
Title: Geological Characteristics and Genesis of Mt Carlton High-Sulfidation Epithermal Deposit, and the Implications for Exploration
Commmencing Year: 2014
Completing Year: 2017
Amount: $256,000.00
Grantee: Zhao Shan Chang, Paul Dirks, Christa Placzek
Source: Evolution Mining Contract Research
Title: Geological Characteristics and Genesis of Mt Carlton High-Sulfidation Epithermal Deposit, and the Implications for Exploration
Commmencing Year: 2014
Completing Year: 2017
Amount: $150,000.00
Grantee: Ioan Sanislav, Jan Huizenga, Thomas Blinkenjos, postgraduate Alex Brown
Source: Mount Isa Mines
Title: Geology of the Tommy Creek Block, Mount Isa Inlier
Commmencing Year: 2016
Completing Year: 2016
Amount: $30,000.00
Grantee: Robert Holm
Source: JCU Rising Star
Title: Investigating the the source of Enigmatic Piscense-Quaternary Magnetism in PNG
Commmencing Year: 2016
Completing Year: N/A
Amount: $15,000.00

Equipment Purchases
Wlifrey Table
Scanning Electron Microscope Laser Ablation & ICPMS

Postgraduate and Honours Courses
MGM Postgraduate Courses
EA5028 Advanced Techniques in Mining & Exploration Geology
Zhao Shan Chang, Carl Spandler, Dale Sims (Consultant)
Source: AINSE
Title: Investigating the the source of Enigmatic Piscense-Quaternary Magnetism in PNG
Commmencing Year: 2017
Completing Year: 2017
Amount: $22,500.00
Grantee: Espen Knutsen
Source: Australian Geographic Society
Title: Excavating Western Australia’s first Jurassic tetrapod skeleton
Commmencing Year: 2017
Completing Year: 2017
Amount: $3,000.00
Grantee: Paul Dirks, Honours research
Source: Mount Isa Mines
Title: Geological Characteristics and Genesis of Mt Carlton High-Sulfidation Au-Cu-Ag Mine
Commmencing Year: 2017
Completing Year: 2018
Amount: $40,500.00
Grantee: Paul Dirks, post graduate research
Source: DNR
Title: Geological characteristics, genesis and ore controlling factors of the Tick Hill Au deposit, Diarra District NW Qld
Commmencing Year: 2017
Completing Year: 2018
Amount: $28,540.00
Grantee: Paul Dirks, post graduate research
Source: Spitfire Materials Ltd
Title: Gold mineralisation styles in the Alice River Gold Field Far Nth Qld
Commmencing Year: 2017
Completing Year: 2018
Amount: $90,000.00
Grantee: Paul Dirks, Honours research
Source: Mount Isa Mines
Title: Geological Characteristics and Genesis of Mt Carlton High-Sulfidation Epithermal Deposit, and the Implications for Exploration
Commmencing Year: 2014
Completing Year: 2017
Amount: $256,000.00
Grantee: Zhao Shan Chang, Paul Dirks, Christa Placzek
Source: Evolution Mining Contract Research
Title: Geological Characteristics and Genesis of Mt Carlton High-Sulfidation Epithermal Deposit, and the Implications for Exploration
Commmencing Year: 2014
Completing Year: 2017
Amount: $150,000.00
Grantee: Ioan Sanislav, Jan Huizenga, Thomas Blinkenjos, postgraduate Alex Brown
Source: Mount Isa Mines
Title: Geology of the Tommy Creek Block, Mount Isa Inlier
Commmencing Year: 2016
Completing Year: 2016
Amount: $30,000.00
Grantee: Robert Holm
Source: JCU Rising Star
Title: Investigating the the source of Enigmatic Piscense-Quaternary Magnetism in PNG
Commmencing Year: 2016
Completing Year: N/A
Amount: $15,000.00

Postgraduate and Honours Courses
EGRU Honours Scholarships
Joshua Spence, Ava Stevens
TropEco Excellence Award - Highly Commended
Caleb Pyskiewicz

Student Awards
Honours Candidates
EGRU Honours Scholarships
Joshua Spence, Ava Stevens
TropEco Excellence Award - Highly Commended
Caleb Pyskiewicz

New PhD Students
Alexander Brown
Leigh Lawrence
Tegan Beveridge
Christopher Yule
Michal Wenderlich

Honours Completions
Laura Turner
Ezekiel Oro
Caleb Pyskiewicz
Harrison Gardiner
Mark Sedgman
Kate Cunningham
Remi Johnson
Ava Stephens
Joel Tuffin
Theresa Orr
Joshua Spence
Eleisha Pitt
Professional Development Training, Honours & Masters Courses

<table>
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<tr>
<th>Professional Development Training - Industry Enrolments</th>
<th>2017</th>
<th>2016</th>
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<tr>
<td>Business &amp; Financial Management</td>
<td>N/A</td>
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<tr>
<td>Advanced Field Training</td>
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<tr>
<td>Advanced Techniques in Mining &amp; Exploration Geology</td>
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<tr>
<td>Integrated Spatial Analysis &amp; Remote Sensing of Exploration Targets</td>
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<tr>
<td>Ore Textures Recognition Techniques/Core Logging</td>
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<tr>
<td>IOCG and Other Mineral Systems</td>
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<tr>
<td>Understanding of &amp; Exploration for Epithetmal &amp; Porphyry Deposits</td>
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<td>Porphyry Epithetmal Cu-Au Deposits</td>
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<td>Lepafrog Fundamentals</td>
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<td>Skarns</td>
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<tr>
<td>Structural Geology in Epicthetmal Systems</td>
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Honours & Master Minerals Geoscience Courses - Student Enrolments

<table>
<thead>
<tr>
<th>Honours &amp; Master Minerals Geoscience Courses - Student Enrolments</th>
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<th>2016</th>
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<tr>
<td>EAS024 Business &amp; Financial Management</td>
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<td>EAS027 Advanced Field Training</td>
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<td>EAS028 Advanced Techniques in Mining &amp; Exploration Geology</td>
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<td>EAS029 Integrated Spatial Analysis &amp; Remote Sensing of Exploration Targets</td>
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<td>Analytical and Optical Mineralogy</td>
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<td>Geology of Australia</td>
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<td>Exploration Geophysics</td>
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<td>IOCG and Other Mineral Systems</td>
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<td>Understanding of &amp; Exploration for Epithetmal &amp; Porphyry Deposits</td>
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Undergraduate Courses

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<tr>
<th>Student Enrolments - TVL - Cairns</th>
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<th>2016</th>
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<tbody>
<tr>
<td>EA1110 Evolution of the Earth</td>
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<td>157</td>
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<tr>
<td>EV7005 Environmental Processes and Global Change</td>
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<td>EA2006 Hydrology</td>
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<td>EA2007 Applied Soil Science</td>
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<td>EA2010 Introductory Geology</td>
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<td>EA2110 Introduction to Sedimentology</td>
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<td>EA2220 Minerals &amp; Magmas</td>
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<td>EA2300 Introductory Structural and Metamorphic Geology</td>
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<td>EA2404 From Icethous to Greenhouse</td>
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<td>EVC502 Introduction to Geographic Information Systems</td>
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<tr>
<td>EA2510 Earth Resources, Exploration &amp; Environment</td>
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<td>EA2900 Intro. Field Geology</td>
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<td>EA3005 Mine Site Rehabilitation</td>
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<td>EA3007 Field Studies in Tropical Water &amp; Soil Science</td>
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<td>EA3008 Advanced Hydrology</td>
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<td>EA3100 Igneous Petrology and Processes</td>
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<td>EA3200 Advanced Structural and Metamorphic Geology</td>
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<td>EA3400 Ore Genesis</td>
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<td>EVC502 Advanced Geographic Information Systems</td>
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<td>EVC506 Remote Sensing</td>
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<td>EA3510 Geological Mapping</td>
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<td>EA3511 Field Techniques in Geology</td>
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<td>EA3640 Advanced Environmental &amp; Marine Geoscience Technologies &amp; Applications</td>
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<td>EA3650 Sedimentary Environments &amp; Energy Resources</td>
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<td>EA3800 Earth &amp; Environmental Geochemistry</td>
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<td>EA3016 Hydrology</td>
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<td>EA3017 Soil Properties and Processes (as of 2016)</td>
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<td>EA3046 Earth &amp; Environmental Geochemistry</td>
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<td>EA3048 Minerals &amp; Magmas</td>
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<td>EA3049 Introductory Structural &amp; Metamorphic Geology</td>
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<td>EA3200 Earth Resources, Exploration &amp; Environment</td>
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<td>EA3330 Field Techniques</td>
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<td>EA3340 Disturbed Site Repair</td>
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<td>EA404 From Icethous to Greenhouse</td>
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<td>EVC502 Advanced Geographic Information Systems</td>
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<td>EVC505 Introduction to Geographic Information Systems</td>
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<td>EA6440 Adv. Marine Geoscience Technologies &amp; Applications</td>
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<td>EA6550 Sedimentary Environments &amp; Energy Resources</td>
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EGRU Financial Summary
January - December 2017

Opening Balance January 2017
$281,004.00

INCOME
$ GST Exclusive
Membership 83,327.27
Publications 462.12
Short Course/Workshop 31,618.09
Consultancy 0.00
Contracts 0.00
Management Fees 18,600.00
Conference-seed funding 25,000.00
Other Professional Services 1232.43
Equipment Rental 0.00
Conference Account 47,569.00
Miscellaneous 0.00
Sponsorship Student 0.00
TOTAL INCOME $207,808.91

EXPENSES
Salaries 73,967.42
Member Benefits 4218.18
Publications 608.36
Short Course 18,405.20
Consultancy 81.82
Marketing / Communication 13,279.64
Administration 3814.17
Other Professional Services 1773.53
Equipment Rental 5287.44
Conference -863.36
Miscellaneous 0.00
Sponsorship - Expenses Other Entities 0.00
EGRU Honours Scholarship 10,000.00
Sponsorship 500.00
Sponsorship Student 500.00
TOTAL EXPENSES 123,799.43

Closing Balance December 2017
$365,013.48
2017 Publications


EGRU Professional Development Courses in 2018 include:

**A Better Understanding of Exploration Geochemistry**

**Course Leader**

**Dr Carl Brauhart, CSA Global**

This one-day course is designed for exploration geologists who wish to increase their skills in geochemistry. Familiarity with ioGAS software is not required; course delegates will gain a working knowledge of the software and learn how to use many of its functions.

**Dates:**
- Wednesday 27th June
- Thursday 28th June (subject to demand)

**Venue:** JCU Douglas Campus, Townsville Qld

**Registration Fees:**
- EGRU Members: $550 (incl GST)
- Non Members: $770 (incl GST)

Course numbers are limited. EGRU reserves the right to cancel the course if minimum registration numbers are not reached.

Delegates will need to bring a laptop with Windows 7 or higher.

After completing the course delegates will have a solid grounding in ten important skills in Exploration Geochemistry, and will be able to:
- Import and validate data
- Use X-Y plots to explore data
- Identify element associations using Principal Component Analysis
- Recognise that element associations are scale dependent
- Understand the advantages of probability plots over histograms
- Break false correlations in their data
- Construct a log additive index that highlights an anomalous metal association
- Use alteration geochemistry to better understand the mineralogy of hydrothermal alteration systems
- Discriminate rock types using immobile element ratios
- Apply immobile-incompatible element ratios to define separate magma series

**Registration Fees:**
- For either 2 or 3 days:
  - Industry: $660.00 (incl GST)
  - Students: $250.00 (incl GST)

**Dates:**
- 10th & 11th July
- 12th July

**Venue:** JCU Douglas Campus, Townsville Qld

**Fluid Inclusions in Economic Geology: Fundamentals & Practical Aspects**

**Course Leader**

**Dr Jan Huizenga, EGRU - JCU Geoscience**

This three-day short course will comprise two modules and is suitable for post-graduate students and interested minerals industry people who require an introduction to fluid inclusion analysis.

Course delegates do not need any previous experience working with fluid inclusions.

**Venue:** JCU Douglas Campus, Townsville Qld

**Registration Fees (for either 2 or 3 days):**
- Students: $250.00 (incl GST)
- Industry: $660.00 (incl GST)

Module 1 - 10th & 11th July

This module will focus on the fundamentals of fluid inclusion studies in economic geology. The course will concentrate on sample selection and sample preparation, fluid inclusion petrography, phase diagrams of single and multi-component fluid systems (H₂O, CO₂, H₂O-NaCl, H₂O-NaCl-CaCl₂, H₂O-CO₂, H₂O-CO₂-NaCl), microthermometry, data collection, data presentation and data evaluation.

Module 2 - 12th July

This module is extension work to the first two days and will concentrate on the practical aspects of fluid inclusions studies including the use and calibration of heating-freezing stage (Linkam) and laser-Raman microspectrometry.

For information on EGRU analytical services contact A/Prof. Carl Spandler: carl.spandler@jcu.edu.au
EGRU Professional Development Courses

- Ore Textures Recognition Techniques
- Core Logging Techniques
- Analytical Mineralogy
- Optical Mineralogy
- Fluid Inclusions
- Geology of Australia
- Exploration Geophysics
- Mineral Systems of the Mt Isa Inlier
- Mineral Exploration Management (10-day, 5-day & 1-day modules)
- A Better Understanding of Exploration Geochemistry
- Advanced Field Training

For further information contact:
Judy Botting, egru@egru.edu.au

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Delegates attending EGRU conferences, short courses and workshops may earn Professional Development points from their professional bodies.