

Centre for **EXPLORATION
TARGETING**



2014 Annual Report



Curtin University



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Outcrop of pillowed basalts, Kanowna region, Western Australia

VISION

Our vision is to be recognised as the global leader in research excellence, innovation, education and training in exploration targeting.

MISSION

Our mission is to increase both the rate and quality of mineral discoveries without relying on substantial increase in exploration expenditure.

OBJECTIVES

- **Establish a new paradigm for economic geology and exploration targeting.**
- **Sustain a research business of team oriented individuals effectively engaging with the minerals industry, and with thought leaders globally.**
- **Train the next generation of geoscientists how to combine fundamental and applied research within the minerals industry and academia.**
- **Produce outputs recognised and respected at high academic and industry levels.**

Applied Structural Geology in Mining and Exploration field trip participants studying outcrops in the world class gold and nickel mining districts of Kalgoorlie and Kambalda, Western Australia



CHAIRMAN'S REPORT



The downturn in the mineral exploration industry, which began at the end of 2012, continued to worsen throughout 2014. This has led to increasing stress in CET's industry support base, which has translated into a much more difficult operating environment for the CET. It became clear during the year that the CET needed to put in place measures to ensure its sustainability through these challenging times. Accordingly, the management team, led by Professor McCuaig, have subsequently proactively implemented some required changes to the organisation. Some of these have been quite difficult and I would like to acknowledge here the contribution of those members of the CET team who will be leaving us.

Experience tells us that our industry is highly cyclic and that we all need to deal with this reality. Experience also tells us that the best work in mineral exploration often occurs during the downturns because there is a much stronger focus on creativity, innovation and getting more from less. Therefore, the market remains for innovative solutions to improve business outcomes for our customers. The groups that survive the downturn, be they junior mining companies or research groups like the CET, will be the ones best positioned to reap the rewards when the next boom cycle inevitably returns.

On a much more positive note, 2014 saw a significant maturing of the CET research portfolio, with many major projects delivering their research outcomes in the form of peer-reviewed papers. As highlighted in more detail by our Director in his report, 2014 was the most productive year on record for the

CET, in terms of research output. This is a very satisfying result but it is important to emphasise that research output is not just about volume but rather critically the impact it has on the science and industry. In this context, I am happy to report that CET research is having a high impact, most notably in driving the emergence of the Mineral Systems approach to the science of Economic Geology.

The UNCOVER initiative continued to gain momentum within the Australian mineral exploration research community. The core concept underpinning UNCOVER is that meeting the challenges of finding the next generation of world-class mines in Australia requires seamless integration of the efforts of the research, government and industry sectors. CET continues to play a central role in moving this important strategic initiative forward and aspires to be [a or the?] leader in the delivery of the innovative new research outcomes that UNCOVER calls for.

I would like to take this opportunity to thank all our corporate members, those external volunteers who contribute their time and effort to the CET and our host organisations – the University of WA and Curtin University. In particular, I would like to acknowledge the dedicated and hard-working staff of the Centre. Challenging times like the present require us to all work together if we are to be successful and it is very encouraging to see the high-level of commitment, collaboration and team work exhibited by the CET staff. This bodes well for the future.

A handwritten signature in black ink, appearing to read 'JH', located above the printed name of the Chairman.

Dr Jon Hronsky
CHAIRMAN OF THE BOARD

DIRECTOR'S REPORT

Delivering value throughout the business cycle

For CET, 2014 was the most productive year on record. For the first time, we exceeded 100 peer-reviewed publications in a single year, and had a record team level of 54 staff and 36 PhD students undertaking projects on 6 continents. All of this research was on the back of significant growth in research capacity from 2009-2013. The impact of our research is also at record levels, as detailed in our section on Research Highlights. Several projects have the critical mass and end-user footprint to create this impact, such as the West-African Exploration Initiative (WAXI, now in its third phase and over \$10M funding with over 35 sponsors and 22 research and capacity building partners over a 10 year life), the ARC Centre of Excellence for Core to Crust Fluid Systems (CCFS, at \$24M the largest fundamental geoscience initiative currently co-funded by the ARC, in partnership with UWA, Macquarie and Curtin universities), CET's involvement with the Western Australian state government's Exploration Incentive Scheme (now over \$4M in funding) and the Distal Footprints of Giant ore systems (>\$17M total funding, >10 industry sponsors, partnered with GSWA, Curtin University, UWA and CSIRO). With such a strong base of large collaborative projects, a high level of research output is expected to continue through 2015 and into 2016.

More importantly, the CET research outcomes have been measurably transformational, from influencing minerals policy at top levels, to commercial and proprietary research products and tools that have led to improved workflows and discoveries, to benchmark publications that have

influenced minerals geoscientists in both academia and industry, to helping direct the national conversation on minerals geoscience through large collaborative projects and initiatives like UNCOVER ([website link](#)).

Following three successive years of >30% growth (2010-2012), and in a year that saw our industry members continue to face dire market conditions, CET's income dropped for the first time since 2009 from record highs of \$7.9M in both 2012 and 2013, to \$6M in 2014. While our end-user funding still comprises 67% of this income, reflecting our strong end-user focus, the industry proportion of this revenue has dropped to 17%, with research contracts with government and aid agencies providing the other 50%.

Positioning for the future

CET remains focussed on first-principle drivers of mineral supply and demand, namely the diminishing quality of the resource supply chain and the continued rapid development of emerging nations at >5% per annum, which will place significant pressure on the industry's ability to supply material and energy resources to society. Most would agree that these drivers will inevitably herald a return to a positive market for the minerals industry. Nevertheless, the current market downturn that our minerals industry is enduring may be prolonged. Therefore, in 2015 CET has restructured to be on a firmer footing for a continued downturn, while maintaining core expertise and capacity to provide innovation required by the industry throughout the business cycle.



A handwritten signature in black ink, reading 'Cam McCuaig'.

Professor T. Campbell McCuaig
DIRECTOR

RESEARCH HIGHLIGHTS

Global Reach

CET maintained an impressive research portfolio through 2014, with X active projects on 6 continents. Key geographic areas of focus continue to be Western Australia and Africa (particularly West Africa), with growing numbers of projects in South America.

Research Structure

CET's research structure (FIGURE) includes core capabilities in which we aspire to world leadership, and numerous commodity-based mineral systems that we apply these capabilities towards in collaboration with industry and government partners. The Integrated Exploration Targeting and Training and Knowledge Transfer Themes embrace all of these systems and capabilities and interface with end user organisations.

CET also has a number of flagship initiatives that span across several of these capabilities and mineral systems, including:

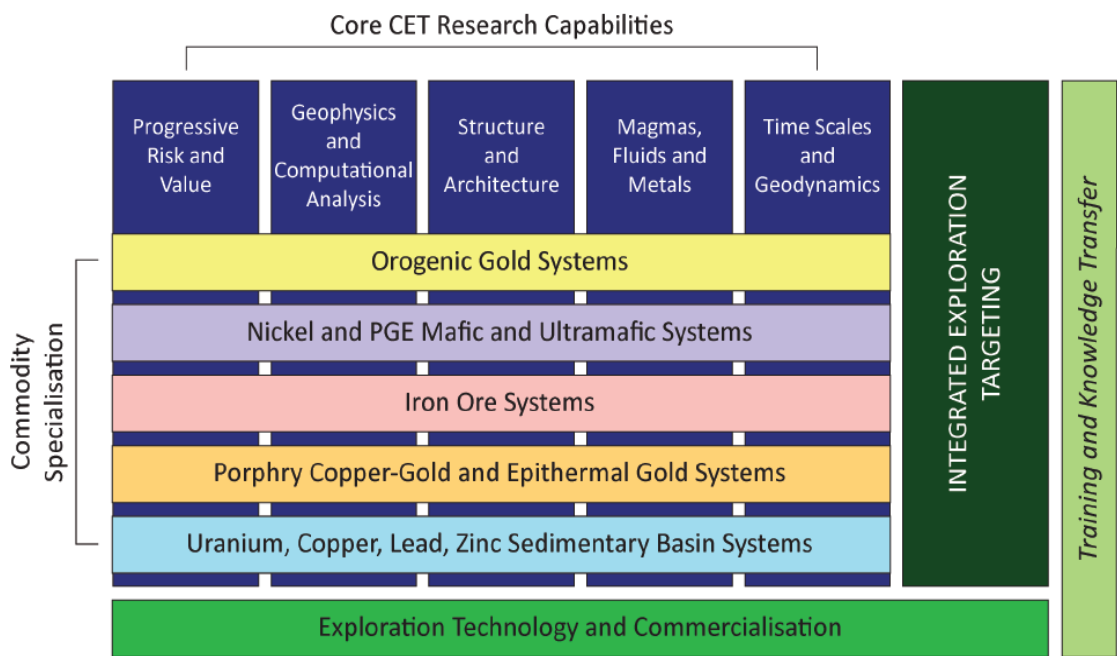
The ARC Centre of Excellence for Core to Crust Fluid Systems (CCFS) is a 7 year, \$24M program of research with key nodes in Macquarie University, UWA and Curtin University, and represents the largest fundamental geoscience initiative currently funded by the ARC. The CCFS underwent a very successful mid-term review in 2014, and will continue until 2017 (see Research Highlight, page 7).

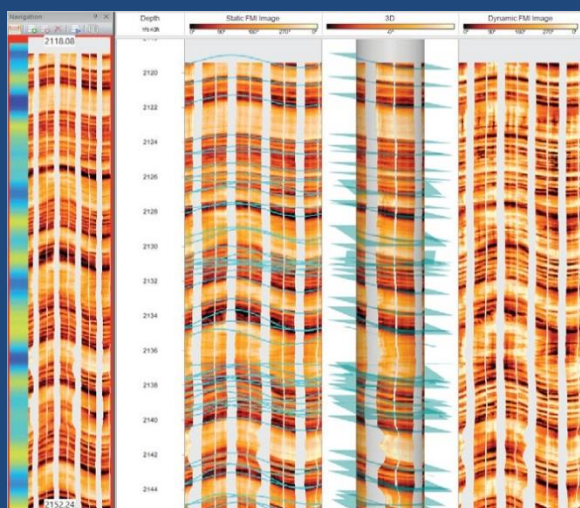
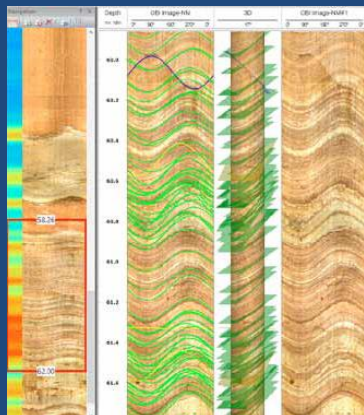
The AMIRA West African Exploration Initiative (WAXI) started its third phase in 2014. This program is now being lauded as a model for precompetitive geoscience knowledge and data generation and capacity building in developing nations (see Research Highlight, page 9).

A number of linked projects in Western Australia include the CET's involvement in the state government's Exploration Incentive Scheme (EIS2), the SIEF/MRIWA/industry sponsored Distal Footprints of Giant Ore Systems project (>\$X over 4 years, collaborative with UWA, GSWA, CSIRO and Curtin University), the Western Australian Premier's Fellowship (Professor Mark Jessell) developing next generation 3D geology-geophysics integration, inversion and modelling. These projects combined currently comprise a large percentage of CET's research activity, and projected research output (see Research Highlight, page 11).

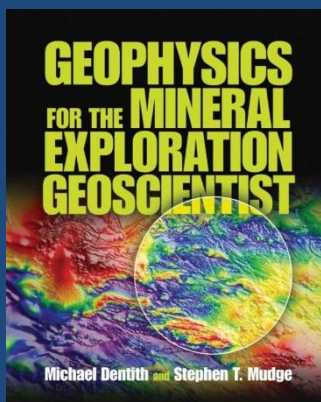
Record Output

Commensurate with the rapid growth of CET from 2009-2013, 2014 has been a year of record research outputs as many of these projects are now completed. In 2014, we produced over 100 peer-reviewed publications, a substantial achievement given the high number of project-based reports that are also produced each year. CET is quite proud of the fact that we continue our record of publishing annually in the highest ranked academic journals, such as Nature Geosciences, Nature Communications and the Proceedings of the National Academy of Sciences. Furthermore, we continue to impact upon and influence industry outcomes and government policy through our research output and commercialisation of technology. These accomplishments effectively highlight that we are achieving our goal of linking the highest quality fundamental research to application in the mineral industry.





Wellcad's Image & Structure Interpretation Workspace is featuring CET's downhole televiewer image analysis methods. A fast, objective and reproducible analysis can be achieved by harnessing the power of automated image analysis and interactive analysis methods.



Geophysics for the Mineral Exploration Geoscientist (Dentith and Mudge, 2014)

Outcomes of CET's research are too numerous to cover here, but highlights from 2014 include:

Increased influence in global mineral policy through projects with the World Bank Group, International Mining for Development Centre, including benchmark World Bank Group publication on mining tax administration (reproduced in multiple languages) and briefing notes on transfer pricing provided to the G20 summit in Brisbane (Guj et al., 2014a; 2014b; see accompanying Research Highlight, page XXX).

Continued success in commercialising data analytics tools for industry, with the release of CET's televiewer analysis methods (developed with the support of Rio Tinto) into Image & Structure Interpretation (ISI) Workspace for WellCAD software produced by Advanced Logic Technology (ALT) in 2015. This adds to the CET Grid Analysis and Porphyry Detection extensions that CET has already commercialised through Geosoft's market-leading Oasis Montage software.

A much needed textbook Geophysics for the Mineral Exploration Geoscientist (Dentith and Mudge, 2014)

First publication of maps of in-situ multi-isotopic zircon analyses as proxies for the evolution of whole-lithospheric architecture through time, and how this controls mass and energy transfer and mineralisation (Mole et al., 2014a; 2014b).

Reframing of the understanding of mineral systems into a multiscale framework for application in exploration targeting and guiding further exploration geoscience research (McCuaig and Hronsky, 2014). This framework is now being adopted by several major mineral exploration companies and influencing the AMIRA UNCOVER roadmap.

Future

With a number of large, long-term initiatives underway, such as CCFS, the EIS and WAXI programs, CET is will maintain a strong portfolio of projects into 2016 and beyond. CET continues to help lead the national conversation in mineral exploration geoscience through its strong involvement in the UNCOVER initiative (weblink) and its vision for mineral exploration geoscience in the nation. The UNCOVER Industry Roadmap, currently being led by AMIRA International, and a long-term mineral production and revenue forecasting project, both due to be released in mid-2015, are expected to strongly influence the directions of industry-government collaborative investment in mineral exploration geoscience for the next several years.

RESEARCH HIGHLIGHTS – CORE TO CRUST FLUID SYSTEMS

Pushing the frontiers of science:

The CET hub of the Australian Research Council Centre of Excellence for Core to Crust Fluid Systems

The CET is a foundation member and a key hub of the Australian Research Council (ARC) Centre of Excellence for Core to Crust Fluid Systems (CCFS), together with Macquarie University, Curtin University and the Geological Survey of Western Australia. The CCFS is the largest fundamental geoscience initiative currently funded by the ARC.

The CCFS started in 2011 with an ambitious research program to understand Earth's internal dynamics, evolution and fluid cycles from core to crust through time. To address its goals, CCFS integrates information across geology, tectonics, experimental and analytical geochemistry, petrophysics, geophysics, and petrophysical and dynamic modelling. These disciplines have traditionally represented “*research silos*”, but have been integrated in CCFS as a series of multi-scale and multi-disciplinary flagship programs, which provide a significant increase in our national research capability. The CET plays a key role in the success of CCFS by (1) leading a series of research programs that address some of the most fundamental questions in the geosciences, and (2) acting as a boundary spanner ensuring that these fundamental science initiatives are clearly linked to application in the minerals industry.

Over the past four years, CCFS has been a remarkable success, acting as a gravity well to attract national and international research institutions and their most prominent leaders to collaborate in world-class research. These collaborations have stretched the boundaries of geoscience and created a fertile environment for development of the next generation of minerals geoscience leaders.

Key outcomes in 2014 included:

- (1) establishment of a new framework for understanding mineral systems as the product of self-organising critical systems that impacts strongly on mineral exploration strategies (e.g. McCuaig and Hronsky, 2014; presentation at <http://www.cet.edu.au/news-and-media/news/news-details/2015/05/08/mineral-systems-key-to-exploration-targeting>);
- (2) multi-isotopic mapping to image earth's architecture through time and how this architecture controls the movement of magmas, fluids and the location of mineral deposits (e.g. Mole et al., 2014 PNAS);
- (3) development of a new experimental approach to investigate how volatiles strongly affect the partition coefficient of metals into different mineral phases at lithospheric and asthenospheric conditions (Adam et al., 2014);
- (4) a detailed in-situ sulphur isotopic study of eclogite-hosted sulphides, as part of a global effort to unravel the global sulphur cycle in space and time, constrained that the most likely source of sulfur-rich fluids in the deep earth is mineral devolatilisation in subducting slabs (Evans et al., 2014);



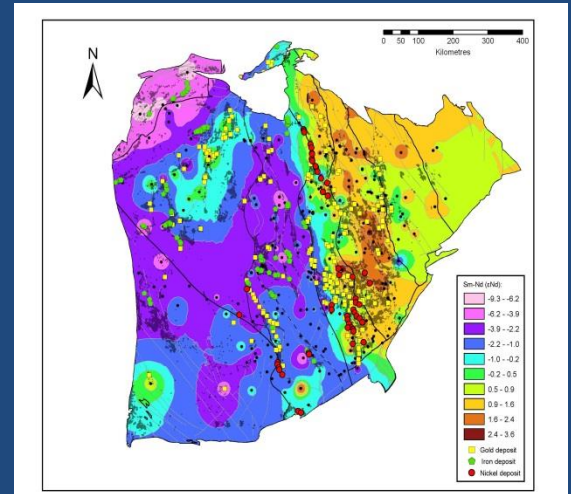
Tibet at an elevation of 4500 meters. From left to right, they are Liming Zhou (researcher at CAGS), Rui Wang (Postdoc at CSIRO), Qiuyun Li (PhD at CAGS), Youngjun Lu (CET, CCFS), Zhiming Yang (Associate Professor at CAGS) and Maoyu Sun (MSc student at CAGS).

(5) establishing that chemical and isotopic compositions of volatile-rich minerals in kimberlites can be used to constrain processes affecting kimberlite magmas prior to, during, and subsequent to eruption, providing constraints on the volatile cycle between the deep mantle and the exosphere through the lithosphere in space and time (Giuliani et al., 2014a); and (6) discovery that U–Pb dating of key accessory titanate minerals provides a new, accurate tool for dating metasomatic events in the lithospheric mantle, constraining volatile and metal transfer among different terrestrial reservoirs in space and time (Giuliani et al., 2014b).

After a very successful mid-term review in 2014, CCFS has now officially entered its second term (2014-2017) with an impressive portfolio of new flagship projects and initiatives, showcased on www.ccfs.mq.edu.au. With a focus on mineral system science and its alignment with the UNCOVER vision (www.science.org.au/publications/searching-deep-earth-vision-exploration-geoscience-australia), the CCFS aims to be the fundamental science research engine behind the future innovations that will unlock the mineral wealth of the nation.

The current CET-driven flagship initiatives focus on (1) the multi-scale four-dimensional genesis, transfer and focus of fluids and metals, and (2) planetary drivers of atmospheric, environmental and biological evolution through time. The Earth's crust represents a dynamic, evolving chemical interface between two convective fluid systems: the endosphere (linked core and mantle), and the exosphere (linked hydrosphere and atmosphere). Both life and ore deposits hosted by the lithosphere are intimately linked through the energy available from sharp chemical and thermal gradients that exist across this interface. Hence, CET-CCFS researchers investigate how the evolution of both life and ore deposits were linked to the changing whole-Earth System. Given the broadly comparable petrological evolution of the early Earth and Mars, new working hypotheses are also being developed on how life and mineral systems may have formed and evolved on the red planet.

To push the boundaries of science even farther, in 2014 a series of “high risk high reward” pilot projects were funded. Also in this realm, CET is at the forefront of scientific quest, looking at (1) developing the new generation of isotopic mapping techniques in komatiite-bearing Archean terrains, (2) understanding element behaviour during hydrous partial melting of the lower crust, and the role of mantle-derived potassium-rich magma in the formation of magmas that host porphyry Cu deposits, (3) probing the deep nitrogen cycle, and (4) exploring the use of isotopic labelling for the visualization of fluid/rock interaction in experimental and natural samples.



Isotopic map of the Yilgarn craton of Western Australia at 2.7 to 2.6 Ga, showing distribution of nickel deposits, gold deposits, and iron oxide deposits. A strong N-NW-trending gradient in the center of the image is interpreted as representing the margin of the continent 2.7 Billion years ago, and controls the distribution of high quality gold and nickel deposits. Iron-oxide deposits are restricted to the margins of stable older crust domains. Such isotopic maps enable imaging of Earth's architecture through time.



Full moon setting over the Ivrea Zone (Italy), where it is possible to study the crucial interface between the lithospheric mantle, where sulfur and the most chalcophile and highly siderophile metals reside and are sourced, and the continental crust, where complex magmatic plumbing and conduits are developed, forming ideal environments where mineralisation can form and be preserved (photo Nicolas Thebaud).

RESEARCH HIGHLIGHTS – WEST AFRICAN EXPLORATION INITIATIVE

The AMIRA International P934 West African Exploration Initiative (WAXI) this year entered its third stage, having commenced in 2006. The overall aims of WAXI are (1) to directly support the minerals industry working in West Africa through the generation of precompetitive geoscience knowledge and databases, (2) to assist in geoscience capacity building in local institutions and Geological Survey Organisations through an integrated program of research and training, and (3) enhancing the opportunities for exploration success by delivering the geoscience knowledge and capacity to encourage investment in the region by in the highly-prospective West African Craton. WAXI's aims are closely aligned with the objectives of the African Mining Vision.

Results of WAXI are reported to sponsors regularly as quarterly reports, and as annual face-to-face workshops.

Highlights of the research program include:

1. First integrated synthesis of geological stratigraphy and structural and metamorphic evolution across the West African Craton.
2. Redefinition of the tectonic assembly of the West African Craton based on stratigraphy, structure, metamorphism and new high precision geochronology, isotopic and geochemical data.
3. Review of over 30 mineral deposits/camps placing them in the new tectonic framework
4. Furthermore, a GIS continues to be updated on an annual basis and delivered to sponsor organisations. To date, this GIS contains 350 Gb of data, 210 layers, 90 of them unique to the WAXI project.

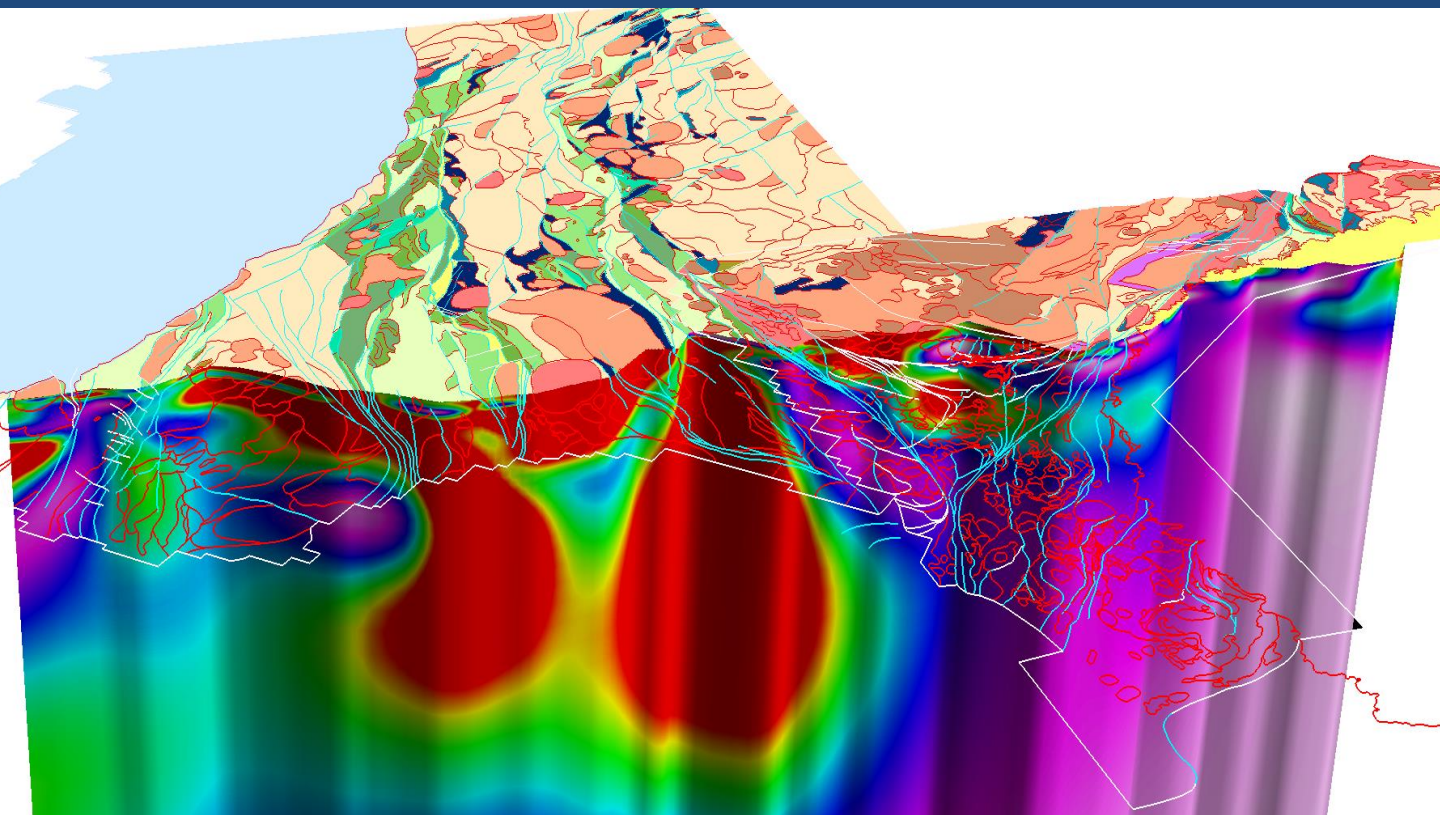
Highlights of the capacity building outcomes to date include the training of 35 MSc, PhD and Postdocs, 50% of them African as well as over 200 people trained in technical exploration skills and research management via 15 short courses provided across West Africa. The research outcomes of WAXI 2, which will be the principal focus of the two conferences discussed above, will also be the basis for 4 special volumes that will appear in 2015 (Precambrian Research, Economic Geology, Ore Geology Reviews and Journal of African Earth Sciences).

The second stage of the WAXI project was concluded in March 2013 in Accra, Ghana. In order to disseminate the outcomes from WAXI 2, CET and our WAXI research partners will be holding open workshops in both Perth and Dakar that provides a first look for non-sponsors of this major initiative under the banner of "An International conference on The Metallogenesis, Tectonics & Surface Evolution of the West African Craton", to be held in Perth, May 25th 2015 and in Dakar, Senegal, 17-18th of September 2015 (<http://www.cet.edu.au/news-and-media/events>).

In spite of the industry downturn we have already succeeded in attracting 11 sponsors for Stage 3 of the project, and are discussing with several companies that we hope to attract in the near future, and new "WAXI" graduate students have already started their projects at CET.

The P934B sponsors and researcher team at IRD, Toulouse (September 2014) (photo taken by Helen McFarlane, Monash University).





The geology of NW Ghana and SW Burkina Faso together with an early inversion of the magnetotelluric data.

The industry partners for WAXI 3 are:

- IAMGold
- Gryphon Minerals
- First Quantum Minerals
- Rio Tinto
- Resolute Mining
- Newgenco
- Newmont
- Acacia Mining (ex African Barrick Gold)
- Newcrest
- Toro Gold
- Sarama Resources
- Qatar Mining
- Mali: Direction Nationale de la Géologie et des Mines
- Guinea: Direction Nationale de la Géologie
- Burkina Faso: Bureau des Mines et de la Géologie du Burkina
- Mauritania: L'Office Mauritanien de recherches Géologiques

The in kind sponsors are:

- Sénégal: Direction des Mines et de la Géologie
- Niger: Centre de Recherche Géologique et Minière
- Liberia: Ministry of Lands, Mines and Energy
- Sierra Leone: Geological Survey Department
- Ghana: Geological Survey Department of Ghana
- Togo: Direction Générale des Mines et de la Géologie

The success of the WAXI model has led to it becoming a preferred “developmental geoscience” template for the generation and delivery of precompetitive geoscience data and knowledge in developing nations to help them unlock their mineral wealth. For example, Companies and governments are now requesting the establishment of a Central and Eastern Exploration Initiative (EAXI), also managed by AMIRA International, which is currently at the expression of interest stage.

RESEARCH HIGHLIGHTS – SIEF, MRIWA & EIS2

Helping unlock Western Australia’s Mineral Wealth: The Distal Footprints and EIS2 projects in Western Australia

The Centre for Exploration Targeting (CET) at the University of Western Australia is currently involved in exciting large-scale collaborative research programs in Western Australia. These projects represent some of the largest geoscience research initiatives in Australia at present.

The CET is one of the research hubs for the Science and Industry Endowment Fund (SIEF) and the Minerals Research Institute of Western Australia (MRIWA) research programs that together define the Distal Footprints of Giant Ore Systems Project. These are collaboration between The University of Western Australia, Curtin University, CSIRO, the Geological Survey of Western Australia (GSWA) and industry sponsors. The Distal Footprints project aims to provide the precompetitive data, interpretation and knowledge products across a range of scales to help unlock the potential mineral wealth in the relatively poorly-explored Capricorn Orogen, between the mineral-rich Pilbara and Yilgarn regions of Western Australia. Project outcomes will be used to develop

exploration strategy and appropriate tools that will significantly improve the ability to prospect under cover via integrating regional- and lithospheric-scale datasets with prospect-scale focused studies. This will determine and develop scale-dependent criteria for the recognition of the distal footprints of ore systems.

The Distal Footprints project has in excess of \$ 17 million dollars in funding from the respective agencies and partner institutions, and is managed by CSIRO’s Mineral Resources Flagship. The project has 6 major themes: *A mineral System Approach to the Capricorn Orogen, Characterisation of Cover in the Capricorn Orogen, Mineral hosts as Distal Footprints, Hydrogeochemistry for Deep Geological Sensing, Geochemical Mapping for Lithospheric Evolution & Predictive Targeting, and a 3D Digital Model using virtual environments for data integration and visualization.* The CET is involved in all of these themes, and is specifically leading the acquisition of new magnetotelluric and passive seismic data that will define the large scale architecture of the orogen, and an integrated mineral systems analysis of the orogen and innovative mapping of metal sources through sulphide geochemistry and

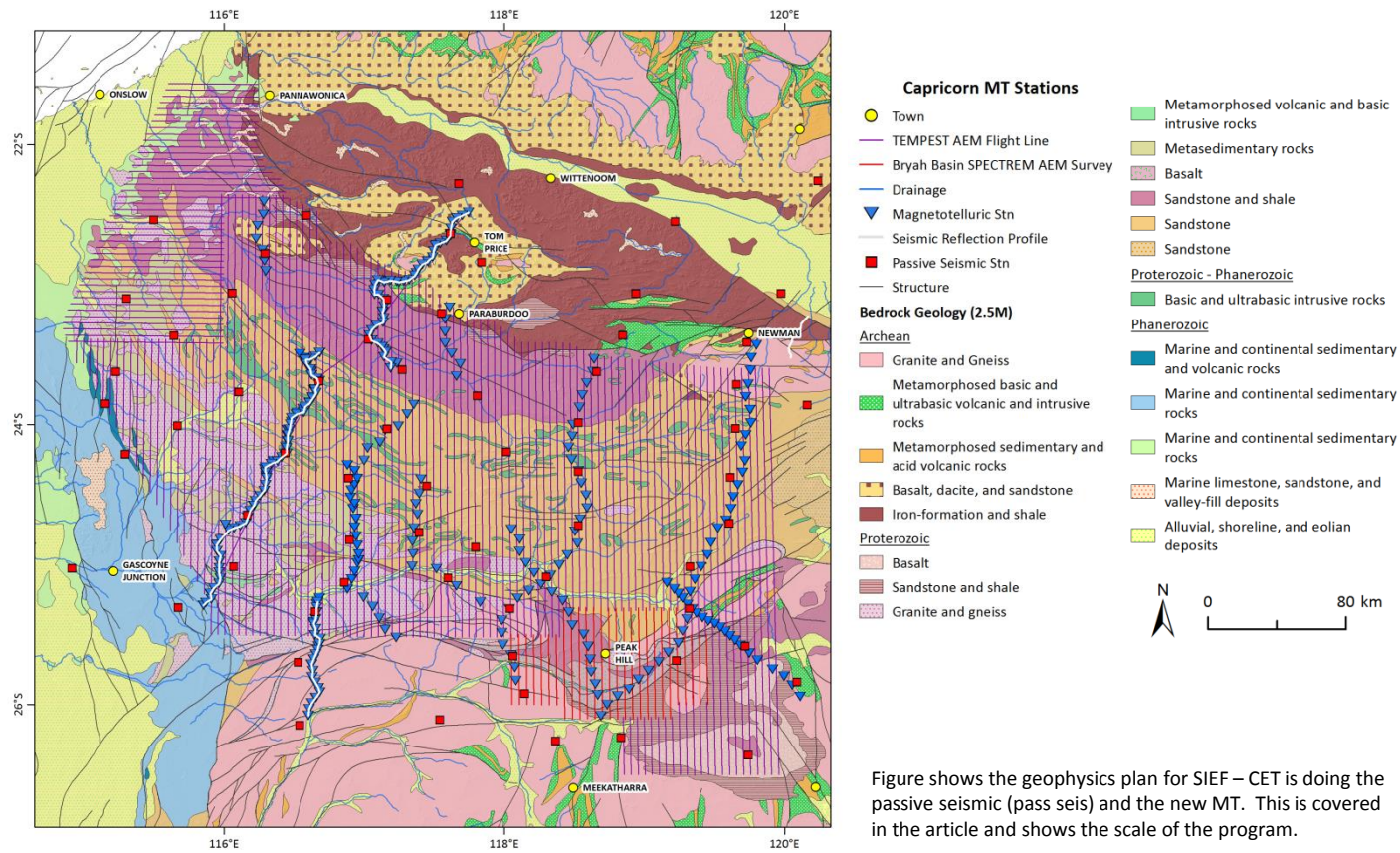


Figure shows the geophysics plan for SIEF – CET is doing the passive seismic (pass seis) and the new MT. This is covered in the article and shows the scale of the program.

multiple sulphur isotope data sets. On the combined SIEF/MRIWA project CET has 6 staff, 4 postdocs, 5 PhD's and 4 Masters projects, with an additional 2 PhD projects planned to work on the new passive seismic data. The range and resolution of geoscience datasets being collected are making the Capricorn the best characterised region on the Australian continent.

The CET is also part of the Western Australian government's Exploration Incentive Scheme Phase 2 (EIS2) research program funded through the Geological Survey of Western Australia. This program seeks to provide exploration-relevant geoscience datasets and derivative products to industry to promote WA as an exploration destination. In this program the CET is actively working on (1) new approaches to geology-geophysics joint inversion and interpretation (with Premier's Fellow Professor Mark Jessell), (2) new magnetotelluric data acquisition and 3D inversion to understand deep crustal architecture (led by Professor Mike Dentith), (3) mineral systems analysis linked to prospectivity analysis (led by Dr. Sandi Occhipinti), and (4) an integrated exploration platform (led by Associate Professor Eunjung Holden). Several MT surveys have already been delivered as part of the deep geophysical program which are heavily influencing the interpretation of the architecture of several regions in Western Australia. Numerous products have already been delivered through GSWA providing data, interpretations and mineral potential analysis to the minerals industry, and current work is focussing on the Halls Creek Orogen of the Kimberley region and the Capricorn Orogen.

The EIS2 program is also developing a State-specific software platform to allow optimum utilisation of geoscientific data in their interpretation— the Integrated Exploration Platform (IEP). This product will aim to markedly improve the ability of industry users to analyse government and proprietary datasets through new visualisation and interpretation support tools to identify potential targets within WA. In order to provide an exclusive benefit to mineral explorers operating in Western Australia, the IEP will operate free of charge only on datasets with geo-coordinates within Western Australia. A prototype will be delivered to GSWA in 2015. The CET has 8 staff, 3 postdocs, and 2 PhD's working on EIS2 programs.



RESEARCH HIGHLIGHTS - CET and the World Bank: A fruitful partnership

CET and the World Bank: A fruitful partnership in assisting developing countries.

Achievements to date: Reviews of mining taxation frameworks and related international training.

In response to concerns from African countries that their tax revenues from the mining sector did not adequately reflect recent increases in commodity prices and companies' profits, in 2011 the World Bank Group (WBG) approached Prof. Pietro Guj of CET to direct a program of research and field reviews of the mining taxation policy and administrative procedures of a number of mineral-rich Sub-Saharan African countries. The first phase focussed on West Africa (Burkina Faso, Ghana and Mali), and in 2013 the International Mining for Development Centre (IM4DC) contributed to finance extension of this program to cover Namibia and Tanzania. The team comprised both CET's personnel (Pietro Guj, UWA; Associate Professor Bryan Maybee, Curtin Graduate School of Business) and consultants specialised in the area of mining governance (Dr. Jim Limerick) and mineral royalties (Mr. Murray Meaton).

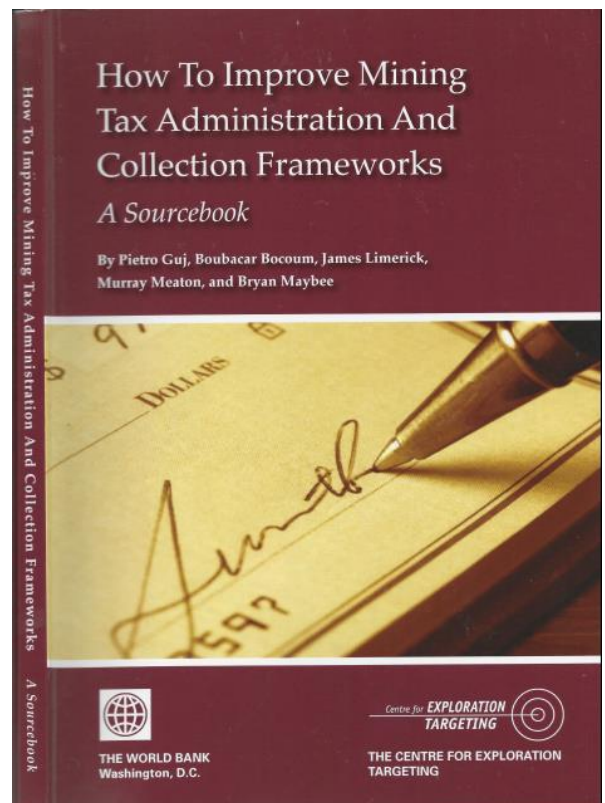
The project provided strategies and recommendations for policy and process improvement tailored to individual countries, as well as a benchmark WBG-CET publication entitled *How to improve mining tax administration and collection frameworks: A source book*. This publication and associated training materials is now used as the basis for a series of international workshops attended by senior tax practitioners from the Ministries of Finance and Mines and related tax administration authorities of a large number of resource-rich African countries. To date workshops have been conducted in Ghana, South Africa, Tanzania and Ethiopia attracting over 200 delegates.

What next? The challenge of transfer pricing.

One of the most pressing current tax issues being created by the rapidly globalising trade is ensuring that the transfer prices used in cross-border transactions between associated entities of multinational enterprises (MNEs) are at arm's length, that is to say the same that would have been agreed between independent parties for the same goods and services in an uncontrolled contestable market. Transfer mispricing can take the form of underpayment for mineral products and overcharging for goods and services provided to a mining subsidiary in a developing country by related entities that are part of the same MNE group, generally resident in low-tax jurisdictions.

Although transfer pricing has been previously recognised by the G20 as an important economy-wide concern for developing countries, the WB/CET workshops emphasised the high vulnerability of tax revenues to transfer mispricing in the mining sector as being of particular concern. Recently the UN's Economic Commission for Africa (UNECA) estimated illicit financial outflows from Africa due to trade mispricing at USD \$50B a year. UNECA echoed the opinion of the African Development Bank which attributes much of the outflow to extractive industries.

The widely recognised complexity of administering transfer pricing legislation in developing countries is compounded by the specialised nature of the mining sector, the lack of relevant comparable databases and the lack of industry-specific knowledge and experience within tax administrations. These factors limit the current capacity to adequately monitor and address transfer pricing risks. The base erosion and profit shifting (BEPS) Action Plan currently being implemented by the OECD (2013) does not specifically address the characteristics of transfer pricing issues arising in the mining sector, nor many



World Bank/CET, Mining Taxation Handbook (Guj et al., 2014)

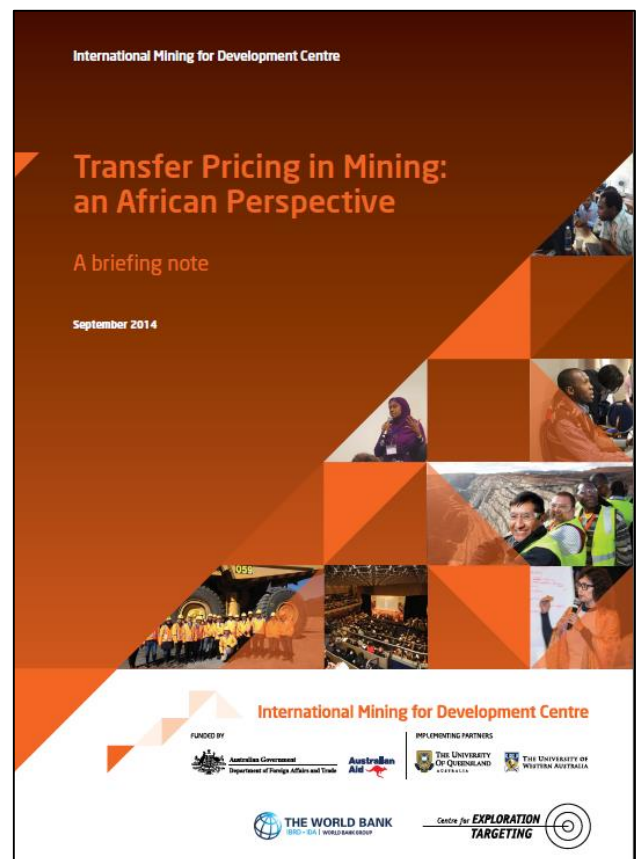
in assisting developing countries

concerns particular to developing countries. The importance and urgency of addressing these issues was highlighted in a CET-authored briefing note, entitled 'Transfer pricing in mining: an African perspective', prepared for the G20 meeting held in Brisbane in November 2014.

Scope of the WBG-IM4DC-CET transfer pricing study: a Guidance Book.

The current study complements initiatives by the WBG and others in delivering technical assistance and filling expertise gaps in the development and implementation of transfer pricing legislation, focusing specifically on risks in the mining sector and in particular on Africa. Co-ordinated by Prof. Pietro Guj of the CET, the study has harnessed an international team of experts from the WBG, the University of the Witwatersrand, and tax authorities of key mineral economies, including Ms. Stephanie Martin (a past Deputy Commissioner of the Australian Taxation Office), as well as mining taxation practitioners from both industry and accounting firms. The objective is for the WBG, IM4DC and the CET to jointly publish a Guidance Book on the subject. This benchmark publication will be a practical reference for tax officials in mineral-rich developing countries to assist them to map and quantify potential transfer pricing risks throughout the mining value chain, providing a framework to prioritise auditing efforts by concentrating scarce resources and training toward financially significant and high-risk transactions.

The Guidance Book will be structured into three parts. Part A, "The Mining Industry and Transfer Pricing", will map the main activities along the mining value chain to determine where transfer mispricing is more likely to occur. It will discuss the complexity of auditing high-value service transactions involving hard-to-value intangible assets (e.g. IP, patents and the like). It will also discuss how MNEs re-structure their business to minimise their tax liabilities at the consolidated level by providing these services (from marketing, finance and technical hubs) generally located in low-tax jurisdictions and by taking maximum advantage of double taxation agreements. Part B, "The Mining Industry in Africa and Transfer Pricing" will discuss the economic importance and future potential of the mining industry in Africa, identifying current operations and advanced mining projects for key mineral commodities and activities involving large cash flows and potential risk to revenue, supported by relevant case studies. Part C, "Institutional and Administrative Capacity" will discuss how most African tax authorities have some form of transfer pricing legislation in place, but lack adequate administrative capacity and expertise to enforce it and to comply with the OECD's transfer pricing Guidelines.



G20 Briefing notes (Guj et al., 2014)

The Guidance Book, besides being a technical transfer pricing reference, will identify specific strategies to improve the capacity of African fiscal authorities to undertake effective transfer pricing administration and auditing. Recommended actions will seek to enhance communication and negotiation skills to create a better degree of co-operation between industry and tax authorities, thus promoting voluntary compliance with sound transfer pricing principles and reducing costly and unproductive litigation. The study also explores strategies for regional knowledge-sharing and expertise-pooling through the establishment of multinational transfer pricing units. It is hoped that the study will contribute to the general endeavour towards a fairer amount of tax being paid in each of the countries where value has actually been added and profits have been generated.

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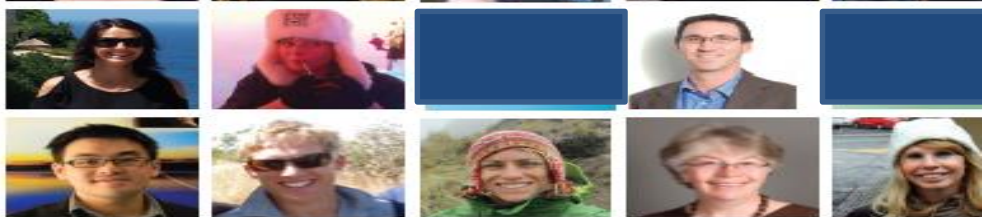
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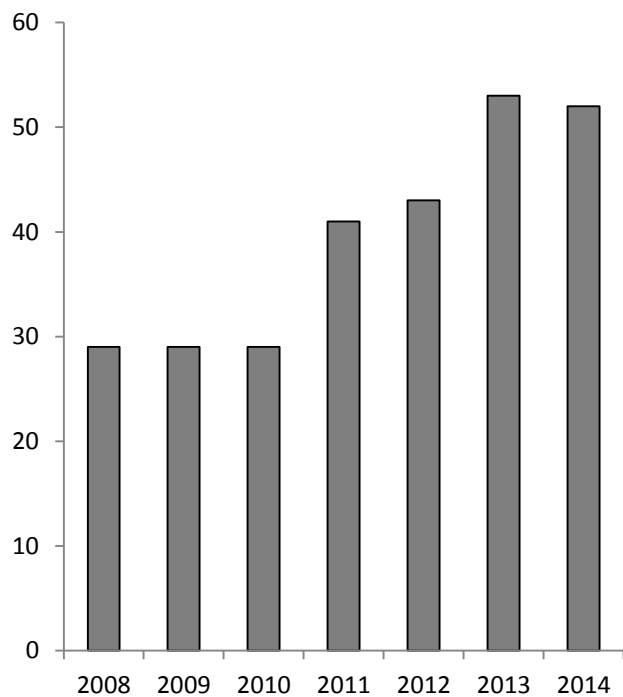
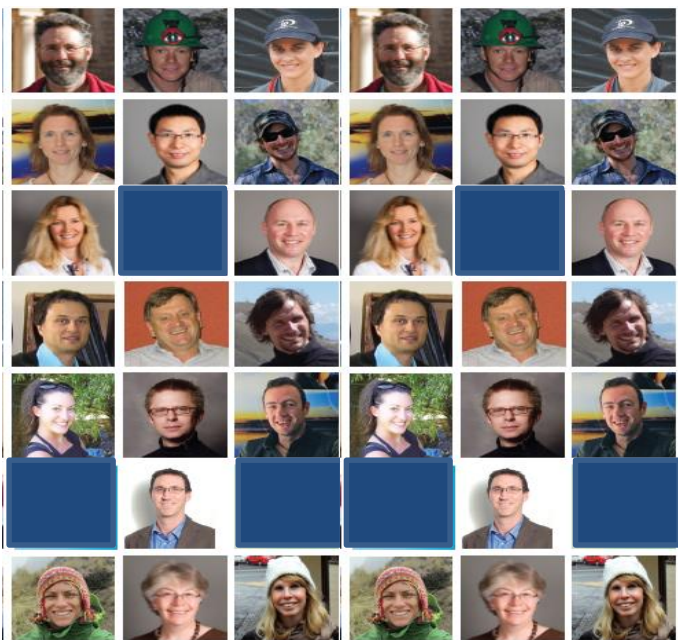


Figure showing staff growth over last 6 years.

Applied Structural Geology in Mining and Exploration field trip participants studying outcrops in the world class gold and nickel mining districts of Kalgoorlie and Kambalda, Western Australia



CET GOVERNANCE AND MANAGEMENT

CET Governance Structure

Central to CET is the engagement of the CET Board and its committees: the Finance, Risk and Commercialisation Committee (FRCC) and the External Advisory Group (EAG). These groups collectively have been tasked with ensuring proper governance of CET and ensuring that the science strategy and business directions are beneficial and relevant to the entire range of stakeholders. Members of these committees are from industry, key stakeholders and other collaborative partners.

In addition to the external committees, CET has an Executive Management Committee and a Senior Research Leaders Group, both comprised of CET staff.

Board

The 14 members of the Board provide a high-level perspective to guide the operations of CET. The members are representatives of UWA and Curtin as well as independent industry participants. The Board has overall responsibility for Centre policy with the Director accountable to the Board for executive management of CET.

The Board is responsible for CET’s mission, objectives and strategic direction. It also approves annual budgets and monitors the overall technical and financial performance of the Centre.

Finance, Risk and Commercialisation Committee

The Board’s financial monitoring responsibilities are addressed through the Finance, Risk and Commercialisation Committee. This Committee considers and recommends to the Board approval of the annual budget and monitors CET’s risk management practices, staffing strategy and opportunities for commercialisation of CET research outputs.

External Advisory Group

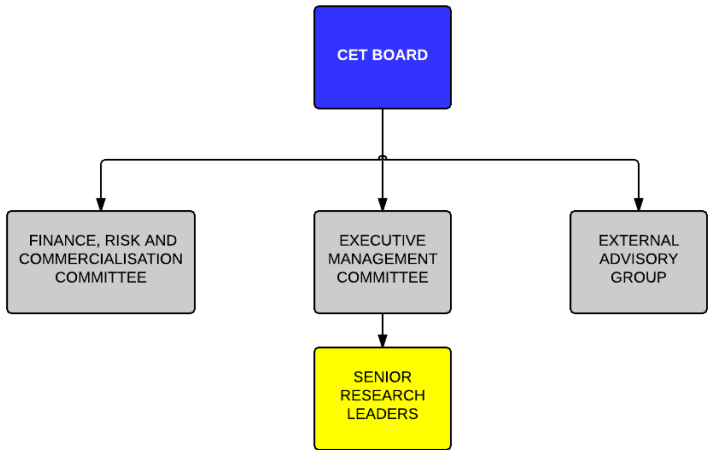
The External Advisory Group provides technical advice to the CET Board and management team. This ensures that the needs of the mineral exploration industry are being appropriately met by CET research strategies. The EAG represents current industry views through its membership of senior industry representatives and major government departments such as GSWA and CSIRO, selected to ensure coverage of all technical sub-disciplines relevant to mineral exploration.

Executive Management Committee

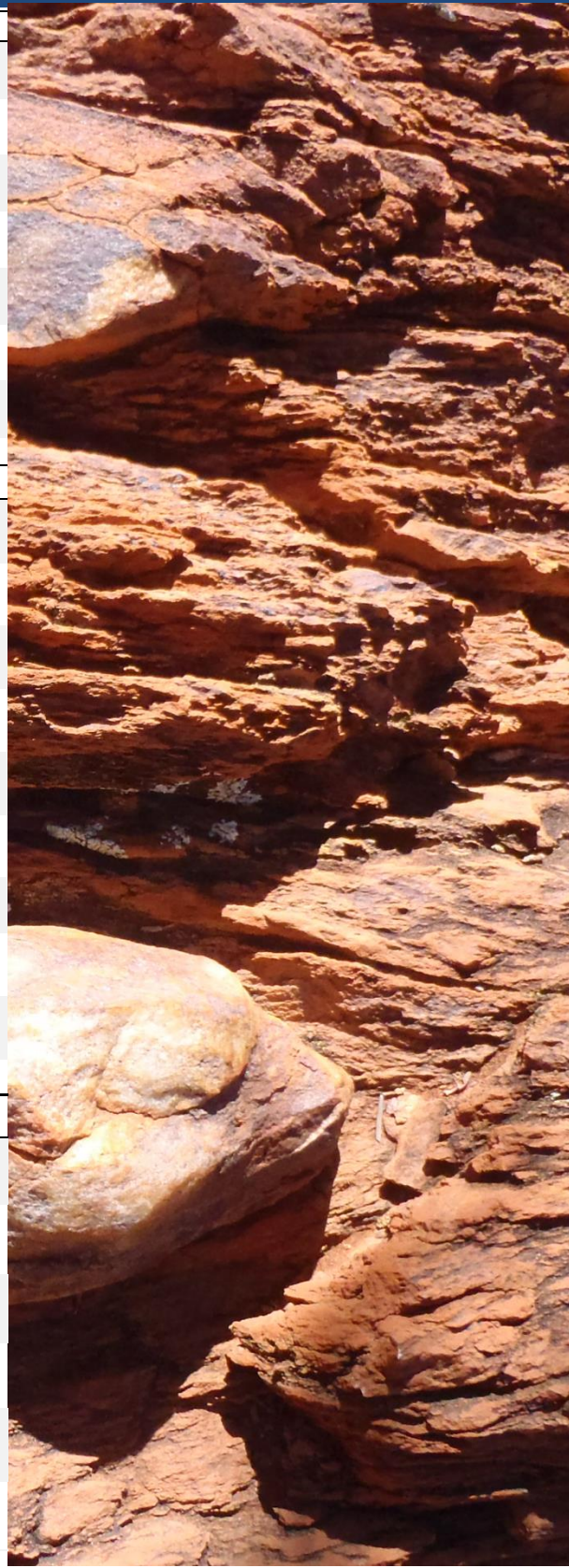
The Executive Management Committee (EMC) is made up of six staff members representing CET, School of Earth and Environment and Curtin. This role of this Committee is to develop and review major strategic business, tactical and staffing requirements of CET as well as monitor morale and needs of CET internal stakeholders.

Senior Research Leader Group

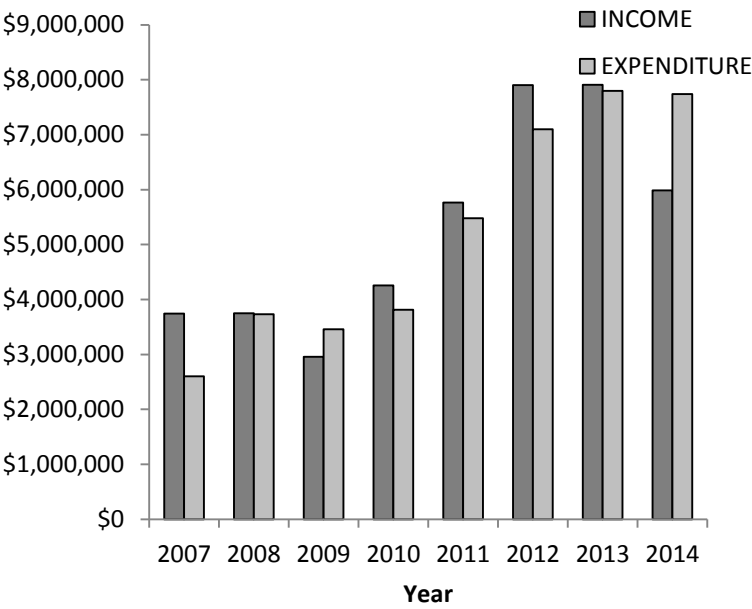
The Senior Research Leader Group provides input on the strategic science direction for CET. [Needs more]



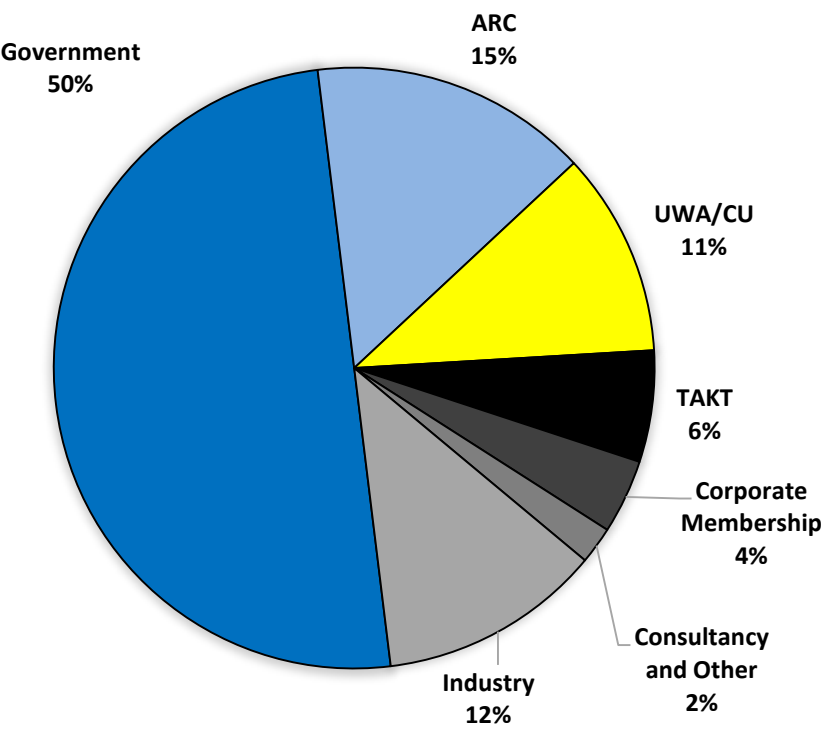
BOARD	
Jon Hronsky (Chair) Western Mining Services	Kevin Hart Endeavour Corporate
Cam McCuaig CET	Lynda Daley Sipa Resources
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Peter Buck (Chair) Independence Group and Antipa Resources	
Cam McCuaig CET	
Kevin Hart Endeavour Corporate	
John Miller CET	
Jon Hronsky Western Mining Services	
Gillian Evans CET	



FINANCIAL PERFORMANCE



In 2014, CET recorded revenues of \$6.0 million compared to expenditures of \$7.7 million. The reason for the higher expenditures was due to the fact that research expenditures typically lag behind receiving revenues. Expenditures are now being incurred on research revenues received in previous years. In addition, CET’s initial strategy in 2013/2014 was to retain staff to preserve key expertise so research capacity would not be compromised when the market recovered. CET is reviewing its financial model in light of the prolonged downturn to ensure that it is sustainable in both mining upturns as well as in downturns.



CET derives its revenue from a number of different sources: government contracts, industry contracts, matching funds from UWA, training and knowledge transfer and corporate and individual memberships. In 2014, CET experienced a decrease in revenue of 25% from 2013, mainly as a result of a decrease in industry projects. In addition, as a result of CET’s success in winning large government collaborative projects such as SIEF/EIS2, the proportion of revenue derived from industry sources has decreased from 41% in 2013 to 25% in 2014.

WHERE CET ARE WORKING



Au, Zn, Cu, U
g
u
i, Pb, Zn
u, PGE

Au, Cu-Au, (Ag)

- | REF | Project |
|-----|---|
| 28 | Multiscale Dynamics of Hydrothermal Mineral Systems |
| 29 | Structural Geology Analysis in Tennant Creek; Phases 1, 2, 3 |
| 30 | 4D Structure and Alteration study of the Telfer Mineral System & Patterson Orogen |
| 31 | Wiluna Gold District Geological Review |
| 32 | 4D Evolution of the Coolgardie and Ora Banda Gold Districts |
| 33 | Structural Review of the New Holland Deposit |
| 34 | Mineral System Analysis of the Red October Deposit |
| 35 | Mineral System Analysis of the Deep South Mineral System |
| 36 | Mineral System Analysis of the Frogs Leg Deposit |
| 37 | Mineral System Analysis Calingiri Cu-Mo-Ag-Au Mineralisation |
| 38 | The Origin, Alteration and Mineralisation of Dacites in the Jundee Goldfield |
| 39 | Mineral Prospectivity Analysis |
| 39 | Mineral Prospectivity Analysis |
- Ni-Cu-PGE**
- | REF | Project |
|-----|---|
| 40 | Radiogenic Isotope Mapping of Komatiites |
| 41 | Sulphur Isotope Map of the Capricorn Orogen |

Fe

- | REF | Project |
|-----|---|
| 42 | Machine Assisted Validation and Interpretation of Drill Hole Data |
| 43 | Assessment of Iron Mineral Systems in the Pilbara craton |
| 44 | Assessment of Iron Mineral Systems in the Yilgarn Craton |
| 45 | Mineral System Analysis Hamersley Iron |
| 46 | Mineral System Analysis of the Koodari Fe deposit |

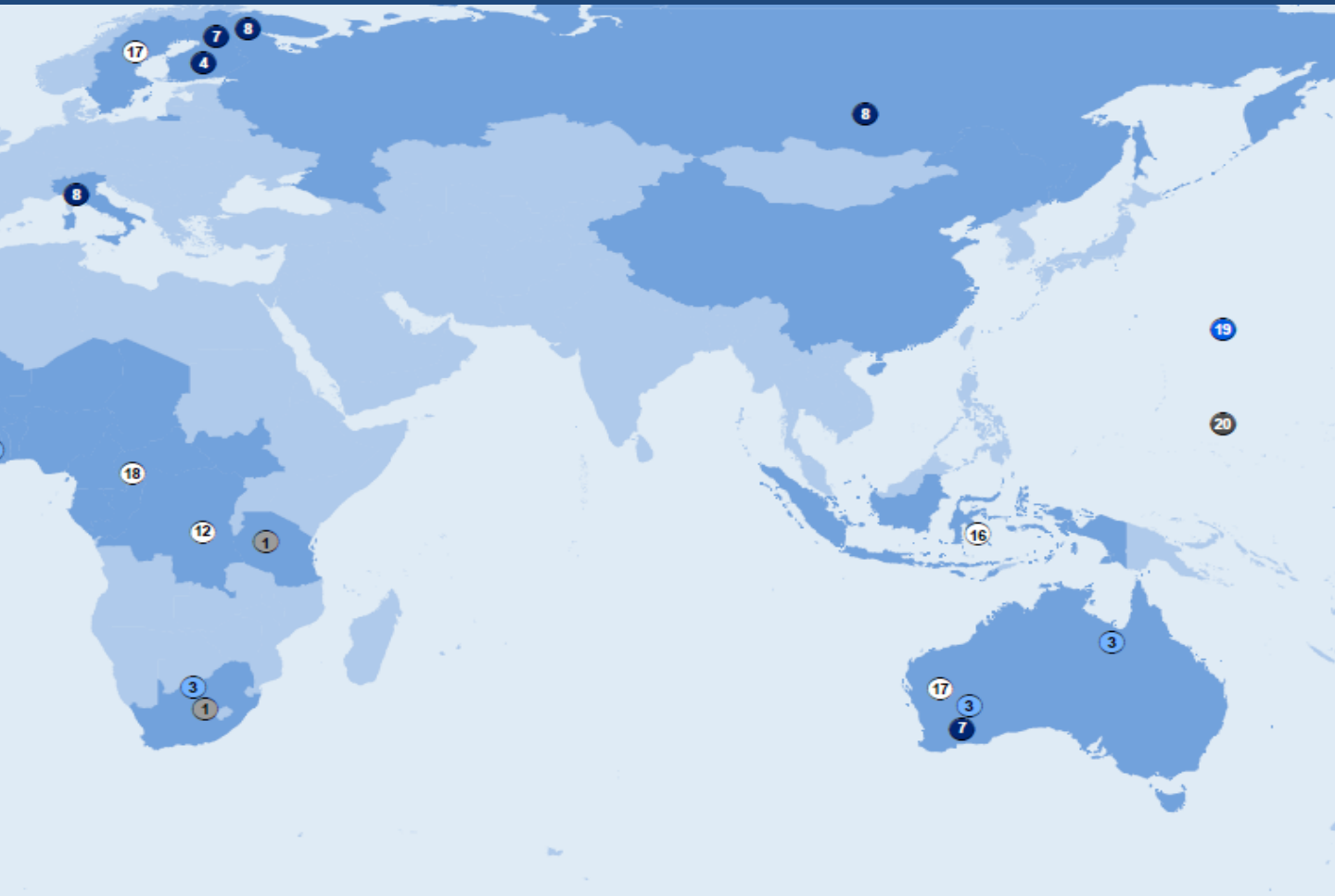
Multi-commodity

- | REF | Project |
|-----|---|
| 48 | Reducing 3D Geological Uncertainty via Improved Data Interpretation (EIS2, ARC linkage) |
| 49 | Distal Footprints of Giant Ore Systems: UNCOVER (4, 5, 6). Prospectivity Analysis of the Capricorn Orogen |
| 50 | Distal Footprints of Giant Ore Systems: UNCOVER (1, 2, 3). Prospectivity analysis of the Capricorn Orogen |
| 51 | Provision of Exploration Targeting Products, to Encourage Exploration in Western Australia |
| 52 | Second Generation Regional Targeting Products: Data Generation and Integration |
| 53 | Multiple Sulphur Isotope Mapping of Precambrian Terranes |
| 54 | 3D Modelling of West Australian Crust |
| 55 | Development of 3D Modelling Algorithms and Workflows to Visualise WA in 3D |
| 56 | Organic Geochemistry of Mineral Systems Clusters |
| 57 | Structural Analysis of the Ashburton Basin |
| 58 | Study of Multiscale Dynamics of Ore Body Formation via Numerical Simulation and Field Studies |

WHERE CET ARE WORKING



Ref	Project	Description	Location	Commodity
1	Mineral Policy of Gold Jurisdictions	Mineral Policy of Gold Jurisdictions	Africa and South America	Au
2	Architecture Controls on Andean Gold Mineralisation, Chile	Architecture Controls on Andean Gold Mineralisation, Chile	Chile	Au
3	Spatial Periodicity of Ore Deposits	The study of the Spatial Periodicity of Ore Deposits	Australia, Canada, Africa	Au, Cu, Pb, Zn, Dia
4	Developing data integration methods for inverted geophysical and downhole data	(PhD project) Machine Learning Methods Applied to Three-dimensional Lithology Classification from Inverted Mine-Scale Geophysical Surveys and Downhole Data (Student Project - Tom Horrocks)	Finland	Ni
5	Structural and hydrothermal alteration control of Au mineralization and GIS-based target generation for gold ore bodies in Argentina and Brazil	Structural and hydrothermal alteration control of Au mineralization and GIS-based target generation for orogenic gold minerali	Argentina	Au, Ag
6	Prospectivity study of Latin America	Prospectivity study of Latin America	Mexico, Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama	Au, Ag
7	Hydrothermal footprints of nickel-sulphide systems (Part 2)	Footprint analysis of Nickel Sulphide mineral systems	Western Australia, Finland	Ni, Cu, PGE
7	Hydrothermal footprints of nickel-sulphide systems (Part 1)	Footprint analysis of Nickel Sulphide mineral systems	Western Australia, Finland	Ni, Cu, PGE
8	From Core to Ore	Physical processes of magma emplacement	Italy, Greenland, Russia, USA, Western Australia	Ni, Cu, PGE



Ref	Project	Description	Location	Commodity
8	Research program into core to crust metal transport mechanisms	Metal transport mechanisms - which metals?	Italy, Greenland, Russia, USA, Western Australia, Argentina, West Africa	Cu, Ni, Pb, Zn
9	A framework study of the tectonics, metallogensis and landform evolution of the West African Craton (WAXI 3)	Tectonics and Metallogensis of the West Africa Craton	Togo, Ghana, Ivory Coast, Liberia, Guinea, Senegal, Mauritania, Mali, Burkina Faso, Niger, Sierra Leone	All
10	4D Modelling of the Siguiri Gold District	Geometric and Genetic Controls of Siguiri Gold District	Guinea	Au
11	Geometric and Genetic Controls of Sadiola Gold District	Geometric and Genetic Controls of Sadiola District	Mali	Au
12	World Bank and IM4DC Minerals Pricing study	Assessment of Transfer Pricing in Global Market	Sub Saharan Africa	All
13	Mineral System Analysis Casposo deposit analyses	Mineral System Analysis	Argentina	Au, Ag
14	Mineral System Analysis Patatz	Geochemical Study Using laser ICP-MS, sulphur isotopes, Lu-Hf isotopes	Peru	Au
15	Mineral System Analysis Kouroni project	Mineral System Analysis	Guiana	Au
16	Indonesia Micklethwaite	Exploration Initiative to help steer sustainable development	Indonesia	All
17	The search for Hadean Crust on Earth	Utilisation so Isotope geochemistry to understand ancient crustal evolution	Australia, Sweden, USA	All
18	IM4DC Open Data - A Central-African Geodata Information system	Generation of a web based database of Central-African Geodata	Central Africa	All
19	Porphyry fertility project	Detection techniques for porphyry systems	Global compilation	Au, Cu
20	Evolution of the Early Earth	Evolution of the Early Earth	Italy, Greenland, Russia, Western Australia, Mars	Cu, Ni, Pb, Zn

STUDENT RESEARCH PROJECTS

Student completed 2014

Ana-Sophie Hensler

Chemical evolution and hydrothermal processes during the genesis of itabirite-hosted, high-grade iron ore in the Quadrilatero Ferrifero, Brazil. (completed 2014)

Current Students

Abulrhaman Alghamdi

Deep Crustal and lithospheric Structure of the Warakurna Large Igneous Province and Implications for the Associated Magmatic Ni-Cu-PGE Mineral System, Australia

Aileen Robert

The role of Carbonaceous material in orogenic Au mineralisation. Pine Creek, NT Australia.

Ben Li

Tectonic evolution and gold mineralisation of the granites-tanami orogen, north Australian craton.

Cameron Adams

Understanding of the Petrophysical Properties of Altered Rocks: Implications for Geophysical Exploration, Eastern Goldfields, Western Australia. (commenced Feb 2015)

Carissa Isaac - Geochemistry of the north Eastern Goldfields, Western Australia: Examining the processes that produce nickel sulfide camps.

Christian Schindler

Petrogenesis of intrusive rocks in the Telfer region, Paterson Orogen, Western Australia: implications for gold mineralisation, Paterson Orogen, Western Australia.

Christopher Gonzalez

Numerical modeling of CO₂ devolatilization and its influence on partial melting and metasomatism in the mantle lithosphere.

David Stevenson

4D modelling of the Palaeoproterozoic Granites – Tanami Orogen and its Mineral SystemsThe Granites, Tanami Orogen, Central Australia.

Denis Fougrouse

4D modelling of the geometry and genesis of the giant Obuasi gold deposit, Ghana.

Erwann Lebrun

4D evolution of the Siguiri gold district: implications for gold targeting in Birimian sedimentary terranes, Siguiri, Guinea, West Africa.

Evren Pakyuz-Charrier

Geological 3D models need error bars: from the single best guess model to multiple plausible models.

Fariba Kohan Pour

Multi-commodity prospectivity analysis based on Mineral System Approach in East Kimberley, north of Western Australia. (commenced Jan 2015)

Francois Voute - Nature and genesis of Au mineralization in the Maranon Valley Au belt, Eastern Andean Cordillera, Peru

Heta Lampinen

Mineral Systems hyperspectral footprints in Edmund Basin of Capricorn Orogen, Edmund Basin, Capricorn Orogen, Western Australia.

James Davis - A stratigraphic and structural reconstruction of the Birimian Terrane in West Africa and implications for mineral systems.

James Warren

4D Evolution of the Coolgardie, Depot and Ora Banda domains, Yilgarn Craton, Western Australia

Jelena Markov

Understanding the influence of noise on aeromagnetic data interpretation tools: Application to structural interpretation of the Siguiri Basin, Guinea, West Africa

John Sykes

Finding the copper mine of the future: Exploration targeting for copper mines, not copper resources.

Jonathan Bell

Risk Adjusted Evaluation of Mineral Assets using Transaction Based Statistical Models

IMAGE: (left to right) Linda Iaccheri, Denis Fougrouse, Dave Stevenson



STUDENT RESEARCH PROJECTS

Katarina Bjorkman
Using multi-isotopes in zircons with structural investigations to unlock the 4D crust-mantle evolution and relationships to mineralisation of the Marmion Terrane, Western Superior Craton, Canada.

Linda Iaccheri
The study area is in the Granites-Tanami Orogen, that straddle between Western Australia and Northern Territory, Australia.

Luis Parra Avila
4D Evolution of the Paleoproterozoic Baoule-Mossi domain of the West African Craton, West Africa.

Margaux Le Vaillant
Hydrothermal remobilisation of base metals and platinum group elements around komatiite-hosted nickel-sulphide deposits: Applications to exploration methods (completed Feb 2015)

Matthew Hill
Structural, magmatic and hydrothermal evolution of the gold-copper-bismuth systems in the Tennant Creek Mineral Field, Northern Territory, Australia.

Michael Tedeschi
Integrated lithostratigraphic-structural-hydrothermal alteration-fluid model for gold mineralization at the Karouni project, central Guyana.

Mikael Grenholm
The tectonic evolution of the West African Craton, West Africa. (commenced Feb 2015)

Quentin Masurel
Project title: 4D evolution the Sadiola-Yatela gold camp, Mali, West Africa.

Raphael Baumgartner
Ore deposits of the future: magmatic Ni-Cu-PGE sulphide mineralisation on Mars.

Raphael Doutre
Spatial Periodicity, Self-Organisation and Controls on Large Ore Deposits: (WA & VIC) Australia, Africa and Canada.

Stefano Caruso
Mapping sulfur sources in selected Precambrian terranes of Western Australia to enhance predictive targeting for gold and base metal mineralizations: Precambrian terranes, Western Australia. (commenced 2015)

Tom Horrocks
Machine Learning Methods Applied to Three-dimensional Lithology Classification from Inverted Mine-Scale Geophysical Surveys and Downhole Data, Kevitsa mine, Lapland, Finland.



IMAGE: June 2014 in Mali, on top of a hill within the Sadiola gold camp. Daouda Traoré (Geo), Quentin Masurel, John Miller, Samuel Tessougue (Manager), Fousseyni Samaké (Geo)

Vasuki Yathunanthan
Semi-automatic mapping of geology using photogrammetric data.

Vikraman Selvaraja
Trace element and sulfur isotopic composition of mineralisation in the Capricorn, Orogen, Western Australia.

Volodymyr Lysytsyn
Mineral prospectivity analysis and quantitative resource assessments for regional exploration targeting: development of effective integration models and practical applications

Yathunanthan Sivarajah
Monitoring of human-data interactions towards understanding the interpretation process of geoscientific data.

Total Students	2013	2014
PhD students enrolled	30	36
PhD students completed	2	1

CORPORATE MEMBERSHIP

CET would like to thank its Corporate Members for their ongoing support in 2014

Major Producers



Junior Explorers



Mineral Finance



Emerging Producers



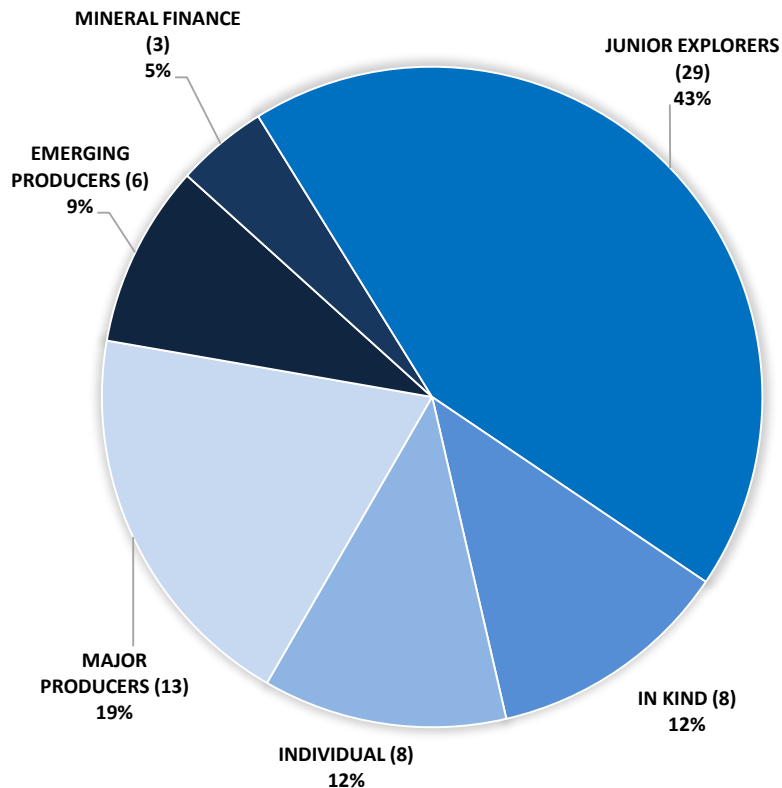
In Kind Members



CET aims to maximise industry engagement through an active membership program. Corporate membership categories are Junior Explorer, Emerging Producer, Major Producer and Mineral Finance companies. In 2014, the Individual membership category was introduced to offer a means of engagement to explorers and senior industry professionals who are not affiliated with a corporate member.

Membership fees are set at modest levels to maximise engagement from industry. Membership numbers have increased during the life of the CET with 59 corporate members and eight individual members in 2014.

Membership confers a number of benefits - notably access to the CET member website that contains publications and presentations that can be accessed by member companies via a password logon. In addition, members also receive discounted registrations to CET events and short courses and are invited to attend the annual CET Members' Day with presentations on cutting-edge topical research.



Corporate Members Day 2014



CET PUBLICATIONS

Abzalov, M.Z. and Bower, J. 2014: Geology of bauxite deposits and their resource estimation practices, *Applied Earth Science* (Trans. Inst. Min. Metall. B), v.123, No 2. p.118 – 134

Abzalov, M.Z., Drobov, S.R., Gorbatenko, O., Vershkov, A.F., Bertoli, O., Renard, D. and Beucher, H. 2014: Resource estimation of in-situ leach uranium projects, *Applied Earth Science* (Trans. Inst. Min. Metall. B), v.123, No 2. p.71 – 85

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Aitken, A., Dentith, M., Johnson, S. and Tyler, I., 2014. 3D Architecture, Structural Evolution and Mineral Prospectivity of the Gasgoyne Province. Report 123, Geological Survey of Western Australia.

Angerer, T., Duuring, P., Hagemann, S., Thorne, W., and McCuaig, T.C., 2014, A mineral system approach to iron ore in Archaean and Palaeoproterozoic BIF of Western Australia: Ore deposits in an Evolving Earth, Geological Society, London, Special Publication v. 393, p. 81-115.

Asadi, H.H., Kianpouryan, S., Lu, Y.-J., and McCuaig, T.C., 2014, Exploratory data analysis and C-A fractal model applied in mapping multi-element soil anomalies for drilling: A case study from the Sari Gunay epithermal gold deposit, NW Iran: *Journal of Geochemical Exploration*, v. 145, p. 233-241.

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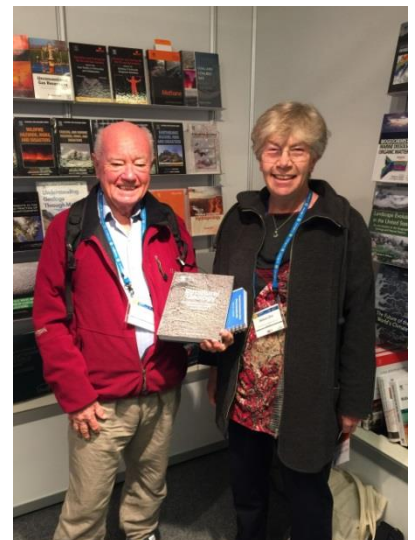
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AMEC	Association of Mineral Exploration Companies	FRCC	Finance, Risk and Commercialisation Committee
AMIRA	Australian Mineral Industry Research Association	GA	Geoscience Australia
ARC	Australian Research Council	GFC	Global Financial Crisis
ARRC	Australian Resources Research Centre	GSWA	Geological Survey Western Australia
BIF	Banded iron formation	IM4DC	International Mining for Development Centre
BEPS	Base Erosion and Profit Shifting	MRIWA	Minerals Research Institute of Western Australia
CCFS	Core to Crust Fluid Systems	MNE	Multinational Enterprises
CET	Centre for Exploration Targeting	MSc	Master of Science
CoE	Centre of Excellence	Ni-Cu-PGE	Nickel Copper Platinum
CSIRO	Commonwealth Scientific and Industrial Research Organisation	OEDC	
CU	Curtin University	PhD	Doctor of Philosophy
EAG	External Advisory Board	SIEF	Science and Industry Endowment Fund
EIS	Exploration Incentive Scheme	UNECA	United Nations Economic Commission for Africa
EMC	Executive Management Committee	UWA	University of Western Australia
ExSim	Exploration Simulator	WAXI	West African Exploration Initiative
FRCC	Finance, Risk and Commercialisation Committee	WBG	World Bank Group



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