

Annual Report 2011



The **Institute for Mineral and Energy Resources (IMER)** is an interdisciplinary research institute of the University of Adelaide, addressing scientific, technological, environmental and social challenges in the provision of mineral and energy commodities globally. This leading University, located in the city of Adelaide, South Australia, is committed to producing graduates and researchers recognised worldwide for their creativity, knowledge and skills.

IMER VISION

IMER's vision is to enable the efficient and sustainable use and development of the world's mineral and energy resources for the benefit of society, industry and the environment.

IMER MISSION

IMER's mission is to be globally recognised as a centre of excellence for fundamental and applied research, innovation and technology transfer in mineral and energy resources.

IMER OBJECTIVES

- Advance the science and technology required to enhance the prospectivity, discovery and extraction of mineral and energy resources, including petroleum and geothermal resources;
- Advance the science and technology needed to lower the cost and enhance cleaner energy generation, storage, transmission and use of energy;
- Increase the energy efficiency and reduce the impact of industrial processes, especially those related to mining and mineral processing;
- Maximise the social and economic benefits of mineral and energy resource developments across regions, states, national and international communities;
- Advance the prevention, assessment and remediation of environmental impacts of mineral and energy resource developments.

Who we are

Established in December 2008, IMER aims to become a leading research and educational facility for the mining and energy sectors in the Asia-Pacific region.

The University of Adelaide is unique within Australia for its strong research and teaching groups in geology and geophysics, petroleum engineering, mining engineering and energy technology. These groups form the Institute's core.

Key IMER Fields of Research

Earth Sciences: geology; geochemistry; geosequestration; geophysics; and physical geography.

Energy Technology: combustion and fuels; renewable power and energy systems; bioenergy generation, conversion and storage; control of sound and vibration; physical chemistry aspects of energy storage and transformation.

Resource Engineering: petroleum and mining engineering.

Additionally, cross-disciplinary research is conducted in geothermal energy, decision analysis, industry and labour economic studies and environmental impacts specifically related to energy and mineral resource developments.

World-leading research is conducted across numerous University of Adelaide schools and faculties encompassing the Workplace Innovation and Social Research Centre (WiSeR) formerly called the Australian Institute for Social Research; the Australian School of Petroleum; the Business School; School of Chemical Engineering; School of Chemistry and Physics;

School of Civil, Environmental and Mining Engineering; School of Earth and Environmental Sciences; School of Economics; School of Electrical and Electronic Engineering; School of Mathematical Sciences and School of Mechanical Engineering.

The Institute is the principal point of contact for the strategic interests of the University of Adelaide in mineral and energy resources research, both internally to the University of Adelaide and with its industry and government partners. A major global advantage of IMER is the capacity to cross link diverse disciplines to research solutions for global resource and energy challenges.



▶ CET COMBUSTION LAB

The Store House
Thebarton Campus

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Chairman's Report



Mr Robert Kennedy

I am pleased to report the progress of the Institute for Mineral and Energy Resources in its third year of operation. South Australia's resource expansion is anticipated to be the single most significant driver of economic development in the State for at least the next two generations.

IMER is ready to play its part by continuing to build on state, national and international collaborations to provide the ground-breaking research capability required in the minerals and energy resources sector for a substantial impact on that sector.

Under IMER's auspices, academic staff involved in research projects are given the opportunity to train the next generation of professionals and researchers to supply the future workforce for the sector.

The rapid expansion of the mining industry brings about significant challenges. IMER's success with government, research grants and commercial partnerships are evidence that the capabilities within the IMER team can answer these challenges.

In 2011, IMER researchers were part of a combined \$A7 million funding success through Australian Research Council (ARC) Linkage proposals and Discovery projects.

The year also brought success to IMER from commercial partnerships with global companies.

A major project focussing on the Reservoir Architecture and Heterogeneity in Marginal Marine Systems entered its second phase in partnership with 12 global oil and gas companies. The WAVE Consortium attracted leading international companies as sponsors for Phase II which began April 2011.

Another project, termed the GeoFrac Consortium Project, arose through IMER's strategic support, along with the Australian School of Petroleum. This project and a complementary ARC Linkage proposal led by Geology and Geophysics, aims to increase the recovery of natural gas from unconventional reservoirs by enhanced targeting of promising areas of reservoirs. It aims to reduce the cost of drilling for gas production and reduce the environmental and societal impact of developing unconventional reservoirs by minimising the number of wells that need to be drilled.

Through the year, IMER researchers achieved more than 330 articles in refereed books, book chapters, journal and conference articles published in 2011.

IMER's 150 staff offered research and technology expertise in close to a dozen areas including mineral exploration under cover; deep open pit mining and processing; energy efficiency in fuel combustion; syngas and synthetic liquid fuels; biofuels; wind energy and the regulatory framework and separation of radionuclides.

Other areas of IMER sponsored expertise utilised in 2011 include geothermal energy; energy storage and management; targeting and extraction of natural gas from ultra tight shale and the social and economic impacts of mineral and energy resource developments.

IMER has consolidated wide-ranging research fields under one banner to continue to showcase the success of the researchers and to benefit the mineral and energy industries in the state of South Australia, nationally and internationally.

IMER remains committed to a sound plan of growth for its research priority areas with its attention focussed on establishing industry-based partnerships, collaborative links nationally and internationally and accelerating technology transfer to its industry partners for the resultant economic benefit to all parties. This objective relies on committed researchers obtaining the satisfaction of a fulfilling career and providing the postgraduate cohort with opportunities to realize their capabilities.

My thanks go to the IMER board and particularly to the IMER Executive Director Professor Stephen Grano, his staff and IMER members for the progress made by the institute in the last year.

A handwritten signature in black ink, appearing to read 'Robert Kennedy'. The signature is stylized with a large loop at the end.

Mr Robert Kennedy
Chairman

18 July, 2012

Executive Director's Report



Professor Stephen Grano

The Institute for Mineral and Energy Resources (IMER) has an important role to play in undertaking research to benefit society, industry and government through the sustainable and efficient use of global resources.

South Australia has globally-significant mineral and energy resources consisting of major copper, iron ore, uranium and natural gas deposits. South Australia generated almost \$A4 billion in mineral export revenue over the 2010-2011 financial year – a figure nearly four times higher than a decade ago. Mineral exports are now the largest export earner for the State with a target to increase the value of minerals production and processing to \$A10 billion by 2020.

South Australia is also a leader in renewable energy generation with more than half of Australia's installed wind generation capacity, currently providing over 20% of the State's electricity production with a target to rise to 33% by 2020. South Australia has world-class geothermal, solar and wave energy resources that can potentially be harnessed.

IMER and the University of Adelaide are well placed to provide not only cutting-edge research, but also the necessary research leaders and highly-skilled graduates and post-doctorate graduates to tackle energy and resource challenges.

The University of Adelaide produces the largest number of honours level geosciences graduates in Australia. It has the largest Mechanical Engineering School in Australia. It is also a participant in the Deep Exploration Technologies Cooperative Research Centre (DET CRC), the world's largest independent research initiative in mineral exploration.

As the principal point of contact for the strategic research interests of the University of Adelaide in mineral and energy resources, IMER maximises the core strengths of existing University Centres across geology, geophysics, mining engineering, petroleum engineering as well as renewable energy and energy efficiency research.

Building on IMER's establishment in 2009, the Institute has developed strong relationships with business and government in 2011.

Numerous Australian Research Council (ARC) Linkage and Discovery Grants were successful by IMER researchers. Many projects gained multiple commercial sponsors representing some of the world's most known and respected energy and resource companies.

Through the year, workshops, public seminars and conference addresses showcased leading-edge research: in areas of solar thermal processing (Mining the Sun), uranium geology, wind energy, geothermal energy, iron oxide copper gold deposits, unconventional gas, and many other topics.

I would like to thank the IMER Advisory Board members for their valuable input through 2011 and extend acknowledgement to the hard work by all IMER members through the year.

A handwritten signature in black ink, appearing to read 'S. Grano', with a long horizontal flourish extending to the right.

Professor Stephen Grano
Executive Director

18 July, 2012

Strategies and Priorities

IMER's mission is to be globally recognised as a centre of excellence for fundamental and applied research, innovation and technology transfer in mineral and energy resources.

IMER aims to develop national and international leadership in specific research priority areas and to increase the number and portion of articles in highly-ranked journals.

By further increasing the success rate, number and scale of national competitive grants or funding, IMER intends to build research capability in the minerals and resources sector.

IMER plans to foster productive relationships with industry, government and public organisations which may offer avenues for commercialising research outcomes.

New strategic partnerships will be forged including international engagements, joint ventures and partnerships which may also bring together multi-disciplinary teams from across the University of Adelaide to address our research priority areas.

IMER uses four key performance indicators to monitor success:

- To **advance and accelerate** high-quality research performance in mineral and energy resources, targeting inter-disciplinary research challenges of global significance;
- To **foster state, national and international collaborations** and partnerships with the aim of making the University of Adelaide the recognised Asia-Pacific centre of excellence in the integrated provision of research, education and consulting services for the mineral and energy resources industries;

- To **attract, retain and develop** excellent research staff and students;
- And to **promote and support** pathways to commercialisation of applied research expertise.

Key Concepts

IMER's mission emphasises four key concepts:

- **Global recognition** reflects the strategic intent of the University of Adelaide to be considered a great research University by world standards, and necessarily places global benchmarks on the performance of IMER;
- The need to focus on both **fundamental and applied research** recognises the critical importance of fundamental research to enhance understanding, underpinning applied research. Applied research provides a focus for targeting research at problems of global significance;
- **Innovation** recognises the key importance of step-change research and the break-throughs required to make a deep and lasting impact on industry and societal problems globally;
- **Technology transfer** in all its forms, such as commercialisation and the transfer of information and know-how, is a key aspect of the University of Adelaide's interaction with industry and society.

RESEARCH PRIORITIES

IMER's research priority areas for support are:

- Non-conventional natural gas extraction and utilisation;
- Understanding, discovering, and exploiting iron, copper and gold deposits;
- Uranium and rare earth elements, exploration and extraction;
- Low-energy and low-impact exploration, mining, extraction and value adding to resources;
- Pathways to cost effectively reduce greenhouse gas emissions in energy transformation;
- Geothermal energy;
- Step-change reduction in energy consumption in mineral recovery;
- Sustainable communities and life after mining.

Answering Global Resource and Energy Challenges

IMER seeks to achieve excellent quality research performance by establishing and developing long-term partnerships with its key stakeholders in industry and government underpinning their research needs particularly in these vital, globally-significant challenges.

In 2010 IMER along with industry leaders and other key stakeholders sought to identify global trends that may affect the research directions of IMER. The global trends identified remain relevant in 2011 and into 2012. In many cases, the trends have become even more marked as the resources sector faces the challenges of meeting increasing demand, but with significantly increasing capital and operating costs.

1 Natural gas from unconventional sources, and in particular shale gas, will expand markedly as a cleaner burning, transitional fuel for the 21st century; the production of gas (as LNG) from coal and (oil) shale reserves will increase in importance;

2 Real energy prices will increase through both global competition and the introduction of the carbon tax; a key factor will be marked increases in the cost of transportable fossil fuels such as LPG and diesel, for which Australia is a net importer at present; opportunities to convert gas to liquid fuels will increase in importance;

3 The need to reduce greenhouse gas emissions from existing industries that drive Australia's mineral exports will increase markedly with the introduction of the carbon tax. This will be followed by an emissions trading scheme and carbon cap with significant increases in the price of energy;

4 Advances in technologies to explore to greater depths and under cover will be required; also new techniques and approaches to explore for ore bodies at shallower depths for which the signature at the surface is obscured or requires new approaches for discovery will be required;

5 Continuing emphasis on low-energy and low-impact exploration, mining and extraction methods. This will be particularly critical to operations which are not connected to the

electrical grid, and are dependent on imported LPG or diesel for electrical energy production for use in the operation and local community;

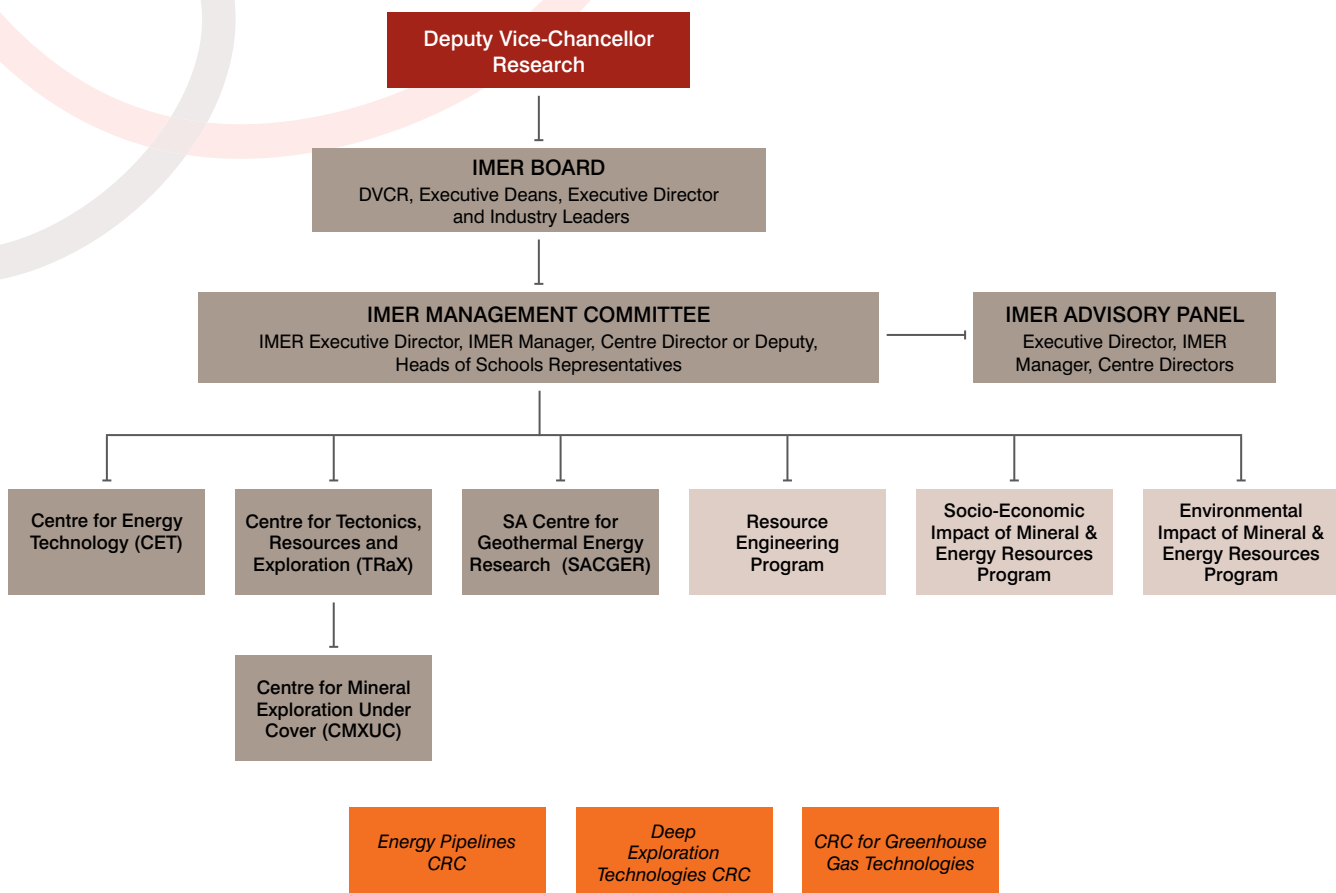
6 Nuclear energy will feature prominently into the future as a legitimate response to the need to both reduce greenhouse gas emissions and secure energy supplies by some countries;

7 Underpinning all these developments, the need to develop technology and market place strategies to allow the introduction of alternative, low greenhouse gas emission energy technologies;

8 Local, regional, state and national communities will need to benefit from the resources expansion while environmental harm has to be minimised;

9 The scale and complexity of mineral and energy resource developments will increase markedly, increasing the risk and scale of capital cost overruns and potential environmental damage, as well as the need for highly skilled people.

Organisational Structure



Key Leaders

IMER Executive

Executive Director

Professor Stephen Grano

Professor Stephen Grano was appointed Executive Director of IMER in March 2010. He is an internationally-recognised metallurgical engineer with nearly three decades' research experience and a background of delivering successful projects linked to industry.

Manager

Dr Jordan Parham

Dr Jordan Parham combines extensive experience in both research and industrial environments. In his current role, he manages the Institute's strategic research initiatives, business development, outreach activities and internal operations. He holds a PhD from the University of Adelaide in the control and optimisation of mixing and combustion for mineral processing.

Centre Directors

Director CET

Professor Graham (Gus) Nathan

Appointed as founding Director of CET in 2009, Professor Nathan specialises in thermal energy engineering in systems supplied by solar, geothermal and the combustion of fossil and bio-fuels. In particular, he specialises in novel approaches to integrate these different energy sources and the research needed to optimise them.

Director SACGER

Professor Martin Hand

Professor Hand was the inaugural Director of TRaX and was appointed SACGER Director in 2010. His current research focus is the emerging geothermal energy industry in Australia. His research expertise is in the thermal evolution of the continental crust, including a PhD on the structural and metamorphic evolution of Proterozoic terrains in Antarctica and central Australia.

Director TRaX

Associate Professor Nigel Cook

Associate Professor Nigel Cook was appointed TRaX Director in 2010. Over two decades, his work has been directed to the geology and mineralogy of sulphide ore deposits. He aims to show how mineralogical study can and should be applied to solve a range of questions in ore geology.

Director CMXUC

Professor David Giles

Professor Giles was appointed CMXUC Director and the South Australia Chair of Mineral Exploration in 2005 following a South Australian government grant. His major research interests include developing and applying geoscience concepts for mineral exploration in regions covered by recent sediments or deep weathering profiles, the evolution of geologic processes and the architecture of the Proterozoic lithosphere and its associated mineral systems.

Program Leaders

Resource Engineering Program

Associate Professor Emmanuel Chanda

Socio-Economic Impacts of Mineral and Energy Resources Development

Associate Professor John Spoehr

Environmental Impact of Mineral and Energy Resources Program

Associate Professor Sue Carthew

Associate Professor José Facelli
(from 31 December 2011)

Cooperative Research Centres

Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC)

Chief Scientist Professor John Kaldi

Deep Exploration Technologies Cooperative Research Centre (DET CRC)

Research Leaders Professor David Giles,
Associate Professor Chaoshui Xu

Energy Pipelines Cooperative Research Centre (EPCRC)

Program Leader

Associate Professor Peter Ashman

Board and Committees



Board (Left to Right): Professor Mike Brooks, Professor Peter Dowd, Professor Stephen Grano, Mr Bob Kennedy, Dr Stephen Forbes, Professor Robert Hill, Ms Susan Jeanes, Mr John England and Dr Jordan Parham (Dr Paul Heithersay not pictured).

Advisory Board

The Advisory Board brings together industry and government leaders and internal university members with extensive knowledge or experience of the mineral and energy resource sectors.

Chair | Mr Robert Kennedy
Chairman, Beach Energy Limited

Professor Mike Brooks
Deputy Vice-Chancellor and Vice-President (Research)
The University of Adelaide

Professor Peter Dowd
Executive Dean, Faculty of Engineering, Computer and Mathematical Sciences
The University of Adelaide

Mr John England
BHP Billiton, Vice President
Technology

Dr Stephen Forbes
Director, Adelaide Botanic Gardens

Professor Stephen Grano
Executive Director, Institute for Mineral and Energy Resources
The University of Adelaide

Dr Paul Heithersay
Deputy Chief Executive, Department of Manufacturing, Innovation, Trade, Resources and Energy (DMITRE)

Professor Robert Hill
Executive Dean, Faculty of Sciences
The University of Adelaide

Ms Susan Jeanes
Chief Executive Officer, Australian Geothermal Energy Association Inc.

Dr Kevin Wills
Managing Director, Flinders Mines Ltd

**Dr Kevin Wills, Managing Director, Flinders Mines Ltd, was a member of the IMER Advisory Board from August 2009 until August 2011.*

Management Committee

The Management Committee comprises relevant members from the University of Adelaide's Centres, Programs, Schools and research leaders. The group generates research ideas, reviews funding and engagement opportunities and discusses project management issues. Committee members develop IMER's research capability and oversee strategy.

Management Committee Members

Professor Stephen Grano

Executive Director, Institute for Mineral and Energy Resources

Professor Bruce Ainsworth

Deputy Head of School, Australian School of Petroleum

Associate Professor Peter Ashman

Deputy Head of School, School of Chemical Engineering

Associate Professor Barry Burgan

Head of School, Business School

Associate Professor Sue Carthew

Program Leader, Environmental Impacts of Mineral and Energy Resources Development

Associate Professor Emmanuel Chanda

Program Leader, Resource Engineering Program

Associate Professor Nigel Cook

Director, Centre for Tectonics, Resources and Exploration

Professor Christopher Findlay

Head of School, School of Economics

Associate Professor José Facelli

School of Earth and Environmental Science (incoming member 2012)

Mr Simon Firth

Commercial Development Manager, Adelaide Research and Innovation Pty Ltd

Professor Martin Hand

Director, South Australian Centre for Geothermal Energy Research

Professor Graham (Gus) Nathan

Director, Centre for Energy Technology

Dr Jordan Parham

Manager, Institute for Mineral and Energy Resources

Associate Professor John Spoehr

Executive Director, Australian Workplace Innovation and Social Research Centre (WISeR)

Management Committee Alternates

Professor Steve Begg

Head of School, Australian School of Petroleum

Associate Professor Bassam Dally

Deputy Director, Centre for Energy Technology

Dr Simon Holford

Deputy Director, Centre for Tectonics, Resources and Exploration

Dr David Lewis

Senior Lecturer, School of Chemical Engineering

Dr Chris Medlin

Senior Lecturer, Business School

Dr Yung Ngothai

Deputy Director, South Australian Centre for Geothermal Energy Research

Dr Mark Tingay

Senior Lecturer, Australian School of Petroleum

Dr Ernesto Valenzuela

Executive Director, Centre for International Economic Studies

Dr Chaoshui Xu

Senior Lecturer, School of Civil, Environmental and Mining Engineering

Advisory Panel

The Advisory Panel is comprised of the IMER Director, IMER Manager and IMER's affiliate Centre Directors and one independent member of the Management Committee.

Major Sponsors

IMER member researchers attracted sponsorship funding from leading international companies, South Australian and Australian government departments linked to competitive and prestigious research grants.

CRC for Greenhouse Gas Technologies

Core Industry and Government Sponsors:

Anglo American
Australian National Low Emissions Coal Research and Development (ANLEC R+D)
BG Group
BHP Billiton
BP Australia
Brown Coal Innovation Australia
Chevron Australia
INPEX
NSW Trade and Investment, NSW Government
Korean Institute of Geoscience and Mineral Resources (KIGAM)
Ministry of Science and Innovation New Zealand
QER Pty Ltd
Queensland Government
Rio Tinto Ltd
SASOL
Schlumberger Ltd
Shell
Solid Energy New Zealand Ltd
Stanwell Corporation Ltd
Total
Department of Primary Industries, State Government Victoria
Department of Mines and Petroleum, Government of Western Australia
Xstrata Coal Australia

Deep Exploration Technologies CRC

Core Industry, Government and Research Participants:

Anglo American
Barrick (Australia Pacific)
BHP Billiton
Boart Longyear
CSIRO
Curtin University
Department for Manufacturing, Innovation, Trade, Resources and Energy (DMITRE)
Geoscience Australia
Gold Fields Australia
Imdex
Newcrest
Vale Exploration
University of Western Australia

Energy Pipelines CRC

Core Industry Sponsor:

Australian Pipeline Industry Association (APIA)

Reservoir Architecture and Heterogeneity in Marginal Marine Systems – WAVE Consortium

Core Industry Sponsors:

Apache Corporation
Badr Petroleum Co
BG
BHP Billiton Petroleum
BP

Chevron
ConocoPhillips
Nexen Petroleum Pty Ltd
OMV Group
Shell
Statoil
Todd Energy
Woodside Energy Ltd

Major Research Sponsors

Adelaide Airport Ltd
Adelaide Brighton Ltd
Asia Pacific Partnership on Clean Development and Climate
Australian Centre for International Agricultural Research, Australian Government
Australian Federal Police, Commonwealth of Australia
Australian Genome Research Facility
Australian Research Council
Australian Learning and Teaching Council, Australian Government
Barrick Gold Australia Ltd
Beach Energy Ltd
BHP Billiton
Biomatters Ltd, NZ
CANSYD Australia
Committee for Economic Development of Australia
Commonwealth Scientific and Industrial Research Organisation
Department for Manufacturing, Innovation, Trade, Resources and Energy, Government of South Australia
Department of Environment and Natural Resources, Government of South Australia



Department of Innovation, Industry,
Science and Research, Australian
Government

Department of Premier and Cabinet,
Government of South Australia

Department of Trade and
Economic Development, Government
of South Australia

Endeavour Discoveries

ESSO Australia Pty Ltd

ExxonMobil

FCT Combustion Pty Ltd

Geodynamics Pty Ltd

Geological Survey of Western
Australia, Department of Mines and
Petroleum, Government of Western
Australia

GPA Engineering

I Want Solar Pty Ltd

IHS

Iluka Resources Ltd

Mayne Pharma Group

Midland Valley Exploration Ltd

Minerals Council of Australia

Minotaur Exploration

Newmont Australia Ltd

Oceanlinx Ltd

Onesteel Manufacturing Pty Ltd

Origin Energy Ltd

Paradigm Ltd

Petratherm Pty Ltd

Petrobras

Petrosys Pty Ltd

Process Group

Premier's Science and Research Fund,
Government of South Australia

RenewablesSA, Government
of South Australia

Rex Minerals Ltd

Roxar

SafeWork SA, Government
of South Australia

Santos Ltd

Schlumberger Ltd

Shell (Petroleum Mining) Company Ltd

South Australian Museum,
Government of South Australia

South Australian Water,
Government of South Australia

SQC Pty Ltd

Total

Woodside Energy Ltd

Research Funding

Funding which can be attributed to IMER members has been calculated from the total funding obtained by IMER member researchers for projects and research infrastructure grants relevant to IMER.

As IMER is highly cross-disciplinary and encompasses a very diverse cross-section of research fields, only projects and infrastructure that relate to core IMER research areas of expertise and priorities have been included in this financial data.

Research funding is shown according to the Australian Higher Education Research Data Collection categories:

Category 1 Nationally competitive research grants

Category 2 Other public sector funding

Category 3 Industry, donations and international grants

Category 4 Cooperative Research Centres

2011 Research Income

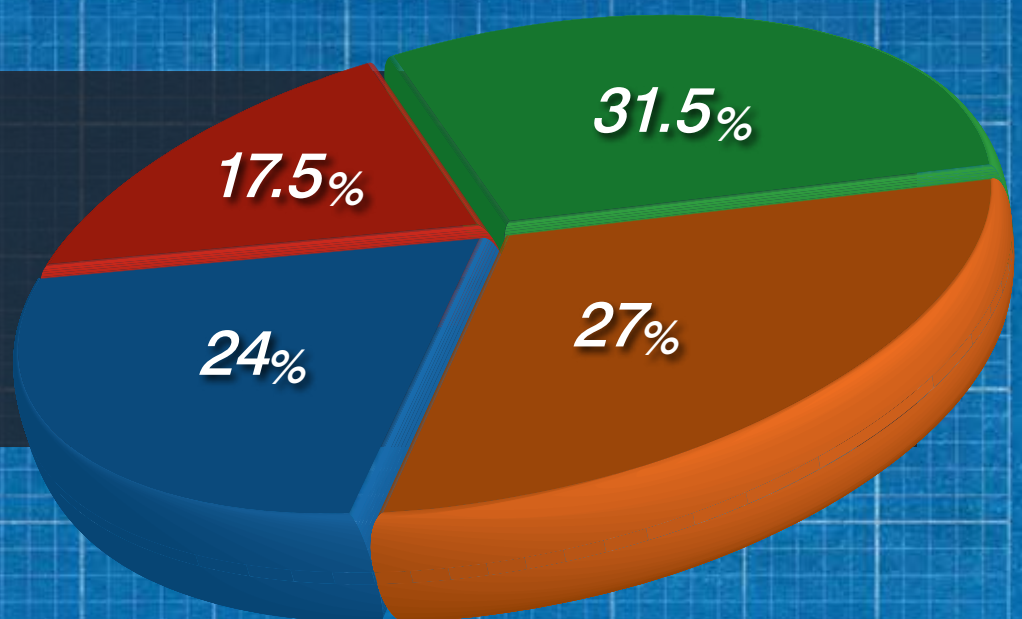
Total Income \$A12,013,445

CATEGORY 1 \$A3,775,994

CATEGORY 2 \$A3,252,176

CATEGORY 3 \$A2,881,272

CATEGORY 4 \$A2,104,003



Key Collaborations

IMER researchers collaborate with leading companies and universities across the globe. These collaborations bring together experts with diverse skills and capabilities, generating a holistic approach to solving current and future challenges facing the world.

Australia

The Australian National University
Australian Society for Exploration Geophysicists
Charles Darwin University
Commonwealth Scientific and Industrial Research Organisation (CSIRO)
Curtin University
Department for Manufacturing, Innovation, Trade, Resources and Energy, Government of South Australia
Flinders University
Geological Survey of Queensland
Geological Survey of Western Australia
Geoscience Australia
GeoScience Victoria, Department of Primary Industries, State Government of Victoria
Global Carbon Capture and Storage Institute
Geotrack International
Heathgate Resources
Ian Wark Research Institute
Monash University
Northern Territory Geological Survey
Queensland University of Technology
Panax Geothermal Ltd
Petratherm Ltd
Queensland Geothermal Energy Centre of Excellence
RMIT University
University of Melbourne
University of New South Wales
University of Queensland
University of South Australia
University of Western Australia
University of Wollongong
Urrbrae Agricultural High School
Western Australian Geothermal Centre of Excellence

International

Al Nahrain University
Aries Energy
British Geological Survey
China University of Mining and Technology
Delft University of Technology
Durham University
ERK Eckrohkessel GmbH
ETH Zurich
ExxonMobil
GFZ German Research Centre for Geosciences
GNS Science
Imperial College London
Lawrence Berkeley National Laboratory
Lulea University of Technology
Lund University
Martin Luther University Halle-Wittenberg
Nanjing University of Aeronautics and Astronautics
PE&I Cell, CSIR-IMMT
Purdue University

Royal Tyrrell Museum
RWTH Aachen University
Sandia National University
Schlumberger Limited
Simon Fraser University
South Australian Museum, Government of South Australia
Tianjin University
University of Aberdeen
University of Auckland
University of Beijing
University of Birmingham
University of California, Irvine
University of California, Los Angeles
University of Cambridge
University of Dar es Salaam
University of Edinburgh
University of Nebraska at Lincoln
University of Science and Technology Beijing
University of Southern California
University of Strathclyde
University of Texas - Austin
University of Toronto



Key Awards



Dr Simon Holford
Walter Howchin Medal

The Deputy Director of TRaX, Dr Simon Holford, was recognised with the prestigious Walter Howchin Medal in 2011.

The Medal was presented by the Geological Society of Australia, South Australian Division.

It recognises a researcher (35 years and younger) in the early stage of his or her career who is distinguished by significant published work within South Australia or from a South Australian base.

The Medal commemorates the pioneering contribution of Walter Howchin (1845-1937) who worked for more than 50 years in South Australia documenting the State's geology in more than 80 papers. He also taught at the University of Adelaide.

Dr Holford, whose home school is the Australian School of Petroleum, was recognised for his contributions to understanding tectonic processes in passive continental margins and in sedimentary basins in the British Isles and the southern margin of Australia.



Dr Philip van Eyk
ASI Fellowship

IMER researcher Dr Philip van Eyk was awarded a Fellowship by the Australian Solar Institute (ASI) in December 2011. The three-year fellowship supports his salary in the area of solar gasification. This Category 1 funding scheme is highly competitive.

Dr van Eyk is based at the School of Chemical Engineering, the University of Adelaide and is a key member of the Centre for Energy Technology.

The Australian Solar Institute (ASI) is a \$A150 million commitment by the Australian Government to keep Australia at the forefront of solar innovation.

Dr van Eyk's area of expertise is conducting research into combustion and gasification of low-rank coals and biomass to produce electricity, syngas or liquefied fuels. He will apply this expertise within the Fellowship to investigate using solar energy in combination with gasification of low-rank coals or biomass to produce liquefied transport fuels. This technology has the potential to significantly reduce the CO₂ emissions and significantly increase the production rate of liquefied transport fuels produced from these low-grade carbonaceous feedstocks.



Professor Keith King
RACI Chemistry Division
Medal 2011

Professor Keith King was honoured with the 2011 Royal Australian Chemical Institute (RACI) Physical Chemistry Division Medal announced in September, 2011.

The Medal recognises outstanding contributions by an individual to the field of physical chemistry in Australia.

Professor King said: "I am very honoured to receive a prestigious award and high-level recognition by a cognate discipline."

A Centre for Energy Technology (CET) member based in the School of Chemical Engineering, Professor King's expertise is in energy and combustion.

He also received an award of Fellow of the Royal Society of Chemistry, the largest organisation in Europe for advancing the chemical sciences. This was announced in May, 2011. Fellow of the Royal Society of Chemistry (FRSC) is the most senior category of membership; it recognises those members who have made an outstanding contribution to the advancement or application of chemical science.



Left: His Excellency Rear Admiral Kevin Scarce AC CSC RANR, Governor of South Australia presenting Dr Mark Tingay with the 2011 Tall Poppy Award

TRaX member wins Tall Poppy Award

TRaX member Dr Mark Tingay was named a South Australian Tall Poppy winner in August, 2011.

Dr Tingay, whose home school is the Australian School of Petroleum, won the award within the area of Geoscience and Petroleum Engineering.

The Australian Institute of Policy and Science created the Tall Poppy campaign to celebrate achievement in sciences with a view to communicating the passion and purpose of Australia's finest scientists to a wider audience.

Dr Tingay's research examines stresses in the Earth's crust caused by movements of its tectonic plates. In particular, he investigates how rocks buckle and break under natural processes such as the generation of earthquakes and mountain formation and through man-made influences such as tunnels and mines.

Dr Tingay also studies how oil wells are drilled to avoid and control disasters that cause oil spills.

Professor Graham (Gus) Nathan

ARC Discovery Outstanding Researcher Award (2012-14)

This Australian Research Council grant, which supports his present position, is a senior career award. This prestigious award, won in 2011, is worth \$A900,000 for the next three years. Professor Nathan is the Director of the Centre for Energy Technology (CET). Professor Nathan was one of only 26 people in Australia to receive the award. There were two other recipients from the University of Adelaide. DORAs provide opportunities for mid- to late-career research-only and teaching and research academics. Selection is based on the needs of the project in addition to the excellence of the researcher.

Dr Cristian Birzer

Finalist – 2011 Advantage SA South Australian of the Year Awards - Young South Australian of the Year

Dr Cristian Birzer was a finalist in Advantage SA's 2011 South Australian of the Year Awards, Young South Australian of the Year Category, in recognition of his academic and extra-curricular activities. The category, sponsored by BHP Billiton, aimed to recognise and acknowledge young South Australians who have demonstrated outstanding leadership, inspiring and supporting young people, as well as facilitating outstanding youth projects or activities.

Associate Professor Benjamin Cazzolato

Australian Acoustical Society President's Prize

This was awarded to the best technical paper presented at the Australian Acoustical Society Conference by a member of the Society in 2011. The paper related to "Modelling the Vibrational Behaviour of Composite Archery Arrows" from Proceedings of Acoustics 2011, Gold Coast (November 2-4, 2011). Associate Professor Cazzolato was one author along with Ms Marianne Rieckmann and Dr John Codrington.



CET

CENTRE FOR ENERGY TECHNOLOGY

Vision

The vision of the Centre for Energy Technology (CET) is to deliver innovative technologies for a clean energy future through strategic partnerships.

Mission

CET aims to accelerate the transition of national and international energy technologies from a high to low CO₂ emission intensities through world-leading research and development in partnership with leading industry, government agencies and other research organisations.

The mission encompasses cost-effective clean-energy technologies from sustainable use of fossil and alternative

fuels; to the use of solar, biomass, wind, ocean and geothermal energy sources, transport and storage systems. A particular focus is the novel integration of technologies and practices to increase cost effectiveness.

Objectives

- To increase high quality research outputs in energy technology at the University of Adelaide;
- To accelerate the development and deployment of clean energy technology;
- To provide increased support for CET researchers in line with the mission and objectives.

Director's Report Professor Gus Nathan

The Centre for Energy Technology (CET) has continued to grow during 2011 in the quality, scale and impact of its research. With input from the Advisory Board, the Centre has continued to refine its research priorities and to invest strategically to generate new opportunities to develop cost effective clean energy technologies. CET has identified particular opportunities in hybrids, since they can typically halve the cost of renewable energy and also in the direct application of renewable heat for production of liquid fuels and application in the minerals and resources sector.

CET had a number of major funding successes in 2011 including the largest Australian Research Council (ARC) Discovery grant in Australia to Professor Nathan, Dr Alwahabi, Professor Abraham and Professor Steinfeld for a project titled 'Heat transfer in novel solar thermal reactors to process minerals and solar fuels' and a Discovery Outstanding Research Award to Professor Nathan.

Professor Colin Hanson and Associate Professor Con Doolan received funding for Discovery projects in the area of wind energy. Professor Nathan was also awarded an ARC Linkage Grant with industry partner Heliotherm Pty Ltd to investigate the novel solar hybrid receiver combustor developed by the CET team. In total the Centre was awarded \$A3.5 million in new grant funding during the year.

Home Schools

School of Chemical Engineering

School of Chemistry and Physics

School of Electrical and Electronic Engineering

School of Mathematical Sciences

School of Mechanical Engineering

CET's partnership with the Adelaide Airport (AAL) commenced in earnest in 2011 with projects targeting AAL's energy footprint as well as supporting innovations that will have a broader impact. Projects led by Dr Tim Lau, Associate Professor Eric Hu and Dr Lei Chen are investigating and implementing ways to reduce energy consumption in the Terminal building T1, which is the major component of AAL's direct energy footprint.

The CET-AAL Platinum Partnership has supported the investment of some \$A250,000 in strategic initiatives including:

- A collaboration with Korean Maritime University to investigate turbine wake generation and propagation for improving wind farm operation;
- The establishment of a unique laser diagnostic facility to provide detailed measurements in flames and soot for combustion and solar hybrid research;
- Supporting ongoing research to optimise pulverised fuel combustion systems such as the Gyrotherm low NOx burner, developed in partnership with FCT-Combustion which has been employed widely in the cement and lime industry around the world;
- A novel catalytic technology for generating hydrogen from solar energy via photoelectrochemical processes;
- Efficient solar cells based on aligned carbon nanotubes.

The benefits of CET's strategic investments are well illustrated by our establishment, in partnership, with IMER and the School of Chemical Engineering, of a 12-month fellowship during 2011 enabling Dr Philip van Eyk to develop some novel concepts in the solar gasification of coal and biomass. This investment also provided bridging funding that enabled Philip to attract a Postdoctoral Fellowship from the Australian Solar Institute to continue this research to 2014.



During the year CET members have published more than 80 papers in leading international journals and more than 40 peer review conference papers. Of the journal papers, 12 were on the application of laser diagnostics to turbulent combustion, six on MILD combustion, also known as flameless oxidation and one reports the first detailed investigation of the interaction between concentrated solar radiation and a flame.

CET has continued its extensive engagement with industry and the public. During 2011 the Centre hosted the Asia Pacific Conference on Sustainable Energy Technologies which brought together over 100 researchers to Adelaide from around the world. Other events included our Mining the Sun forum at the Royal Institution of Australia to discuss the potential of solar energy to contribute to mining and mineral processing operations. It featured world-wide expert Professor Aldo Steinfeld from ETH, Zurich. The CET's leading and multi-disciplinary expertise in wind energy was also showcased at a public event 'The Impact of Wind Energy' an internal strategic workshop.

In 2011, CET recognised some of the key contributions made by its researchers. Dr Peter Kalt was awarded the 'best contribution to research quality' with Mr Wei Wu Jun awarded the 'best postgraduate contribution' and Dr Cris Birzer awarded a commendation. Dr Shaun Chan and Dr Tim Lau were awarded 'best team player award'.

Highlights

Wind Tunnel Launched

Associate Professor Richard Kelso, Professor Gus Nathan, Associate Professor Bassam Dally, Dr Peter Lanspeary, Dr Maziar Arjomandi, Dr Con Doolan.

South Australia's largest industry and research wind tunnel, the Adelaide Wind Tunnel, was officially opened on August 9, 2011 by Tim O'Loughlin, the (former) Commissioner for Renewable Energy from Renewables SA (Department for Manufacturing, Innovation, Trade, Resources and Energy). The launch was attended by around 90 delegates from industry, government and defence.

The tunnel was established with funding from the Premier's Science and Research Fund and Sir Ross and Sir Keith Fund. Its design and construction was overseen jointly by the CET and the School of Mechanical Engineering.

The facility is located at the University of Adelaide's Thebarton campus, close to Adelaide's central business district. It offers three working sections with aero-acoustic research capability plus automotive models to one-quarter scale.

The tunnel is capable of testing speeds up to 180km/h in its aerospace section and 120km/h in the wind-engineering test section and is equipped with state-of-the-art instrumentation.

The tunnel provides specialist capability for CET in commercial buildings for elements such as reducing air conditioning loads; for solar energy in areas such as convective heat losses and dust deposition; and in wind turbine research on areas such as noise control, turbine siting and micro-turbines.

Wind Energy Collaboration with Korea

Dr Maziar Arjomandi.

During the year, CET signed a Memorandum of Understanding to collaborate on research with the Korean Maritime University (KMU). The collaboration has a particular focus on renewable energy research, particularly from wave and wind sources. This followed a visit from the Korean Maritime University's Professor Young-Ho Lee, Professor Sung Cheol Koh and Professor You-Taek Kim and a reciprocal visit by Dr Maziar Arjomandi to Korea.

The collaboration between CET and KMU has commenced with a project focussed on the high-fidelity numerical modelling of wind turbine wake generation and propagation. The project is investigating the interaction between the wakes of adjacent turbine which significantly influence the energy output, lifetime and noise from a wind farm.

Professor Young-Ho Lee from KMU is visiting CET to undertake this research in collaboration with Dr Maziar Arjomandi. It is supported by CET's Platinum Partnership with Adelaide Airport and has already resulted in two conference papers and one journal paper 'Large eddy simulation of turbulent wake characteristics behind a wind turbine in a wind tunnel model'.

New Combustion Research Technique Pioneered

Professor Gus Nathan, Associate Professor Bassam Dally, Dr Zeyad Alwahabi, Associate Professor Peter Ashman, Dr Paul Medwell, Dr Peter Kalt.

The combustion research group within CET has made a number of significant steps in addressing the global challenges to mitigate soot emissions from combustion systems whilst also maintaining good heat transfer. CET has jointly initiated the launch of an ongoing International Sooting Flame (ISF) Workshop, which draws together the combined expertise of the international community to address the major challenges of achieving predictive capability in practical flames with soot. This is ahead of the first full meeting scheduled July 2012.

The team has also made a number of advances in the investigation of these flames. CET has further advanced the innovative laser diagnostic technique, known as Two-Line Atomic Fluorescence, to allow

two-dimensional measurements of temperature made in turbulent flames with soot. Four papers were published on this technique alone. The technique was also used to obtain CET's first detailed measurements of both soot volume fraction and temperature in well characterised turbulent sooting flames that will be presented at the ISF Workshop.

Progress in Solar and Geothermal Hybrid Research

Professor Gus Nathan, Associate Professor Bassam Dally, Dr Zeyad Alwahabi, Associate Professor Peter Ashman, Dr Paul Medwell, Dr Maziar Arjomandi, Associate Professor Eric Hu.

CET's program in high temperature solar thermal processes has been growing rapidly with four postgraduate student projects and one post doctoral researcher investigating a range of novel hybrids between solar thermal energy and combustion technologies.

Dr Philip van Eyk was awarded a prestigious Post Doctoral Fellowship by the Australian Solar Institute (ASI) to support the design of entrained flow and fluidised bed solar reactors by investigating the influence of high radiation flux on key gasification properties such as reactivity.

Mr Mehdi Jafarian presented an innovative concept on the integration of a hybrid system between concentrated solar thermal energy and chemical looping combustion at the Australian Combustion Symposium while Mr Ashok Kaniyal initiated a novel investigation on a hybrid concept between solar thermal energy and conventional coal to liquids technologies with a view to making a step change in emissions intensity while maintaining continuous production. Mr Jiyun Qin published an assessment of the use of geothermal energy to preheat the feedwater to fossil fuel steam cycles.

CET was awarded an ARC Linkage Grant with industry partner Heliotherm Pty Ltd to further develop its novel Hybrid Receiver Combustor. This new hybrid technology directly combines concentrated solar energy with a gas flame to achieve lower capital cost than conventional solar/fossil fuel hybrid systems, lower levelised cost of electricity and higher combustion efficiency. The technology can be applied in situations that include base load supply as well as peaking plants.

CET RESEARCH AREAS

- **Combustion and fluid mechanics:** innovative burner technologies; turbulent flows; two-phase flows; heat transfer; clean coal technologies.
- **Renewable energy integration:** solar-combustion hybrids for solar fuels; minerals processing or electricity generation; techno-economic conditioning systems; electrical power quality conditioning; low-cost converter systems.
- **Alternative fuels:** the production and utilisation of alternative fuels from biomass and micro-algae.
- **Wind energy:** micro wind turbines; aero-acoustics; novel generators; wind farm optimisation.
- **Physical chemistry:** new photovoltaic materials; nanocatalysis; gas-storage and separation; nanostructured materials for energy conversion and storage.

▶ ADELAIDE WIND TUNNEL

Building 21 (The Palace)
Thebarton Campus

Commercialisation of Biofuels Technology

Associate Professor David Lewis, Associate Professor Peter Ashman.

Associate Professor David Lewis and Associate Professor Peter Ashman were part of an international team that in 2011 completed their project 'A fully integrated process for biodiesel production from microalgae in saline water.' This was funded by the Australian Government under the Asia-Pacific Partnership on Clean Development and Climate. This four-year project, led by Murdoch University, has demonstrated that large-scale cultivation and downstream processing of a certain strain of microalgae is possible for the purposes of biofuel production. As part of this project, the team successfully operated a pilot plant in Karratha, Western Australia, and also continuously maintained smaller-scale outdoor cultures during the life of the project. The IP developed from this project is now being commercialised by Muradel Pty Ltd, a joint venture company established by Murdoch University, the University of Adelaide and the project's major industry partner, SQC Pty Ltd, a local South Australian company.

Solar Hydrogen: Photocatalytic Generation of H₂ from water

Associate Professor Greg Metha, Dr Tak Kee, Dr David Huang, Jason Alvino, Trystan Bennett.

A CET-Adelaide Airport Limited project relates to an objective to develop the technique of metal-cluster doping of titania (TiO₂) surfaces for the production of hydrogen using solar irradiation via photo-electrochemical processes. The three-year project involves the construction of a reaction cell, detection chamber, gas flow control equipment and optical pathway assembly with initial demonstrations of the capacity for hydrogen production using titania under UV light conditions. The second year of the work includes the demonstration of hydrogen production under simulated solar conditions using various forms of doped and un-doped titania plus exploration of improved efficiencies by exploring additional metal doping via laser ablation techniques. Finally, there will be an investigation of temperate effects on the system relative to hydrogen production and an exploration of other semiconductor based supports for hydrogen production and other fuel sources such as methane.

The project started in March 2011 and much of the year was focussed on the design and construction of the photo-catalysis apparatus. Other achievements in the early stage of this project include analysis of the soft x-ray photoelectron spectroscopy data (SXR) which led to an understanding of the oxidation state of the clusters. Analysis of the Absorption Spectroscopy data (X-ray) is providing information about the geometric structure of the clusters when they become bound to silica and titania surfaces. Analysis of the far-IR spectra has identified features in the very low frequency region that distinguishes between the different sized clusters.

For many years it has been proposed hydrogen would be an ideal energy carrier as a renewable, environmentally friendly and highly-efficient energy source. It has the highest energy density of the known fuels, and produces water as a sole by-product of combustion. The efficient and direct production of hydrogen from solar radiation provides a renewable energy source that is the pinnacle of clean energy. This research project aims to increase the efficiency of photo-electrochemical hydrogen production which contributes to the global effort of converting solar energy into portable chemical energy.

CET Advisory Board

Chair (ceased as chair at end of 2011) Hon John Olsen, AO
Former Premier of South Australia

Associate Professor Peter Ashman
Deputy Head, School of Chemical Engineering

Mr Mark Bonnar
Investment Director, Southern Cross Venture Partners (Investment Manager, Cleantech Ventures during 2011)

Mr Mike Congreve
Team Leader, Reservoir Development, Santos

Associate Professor Bassam Dally
Head of School, School of Mechanical Engineering

Mr Stephen de Belle
Managing Director, Granite Power

Ms Ros de Garis
During 2011 Group Sustainability Manager, Adelaide Brighton Ltd

Professor Stephen Grano
Executive Director, Institute for Mineral and Energy Resources

Dr Ross Haywood
Practice Director, Hatch Global

Mr David Holland
Director, Right Angle Business Services

Mr Terry Kallis
Managing Director, Petratherm Ltd

Professor Graham (Gus) Nathan
Director, Centre for Energy Technology

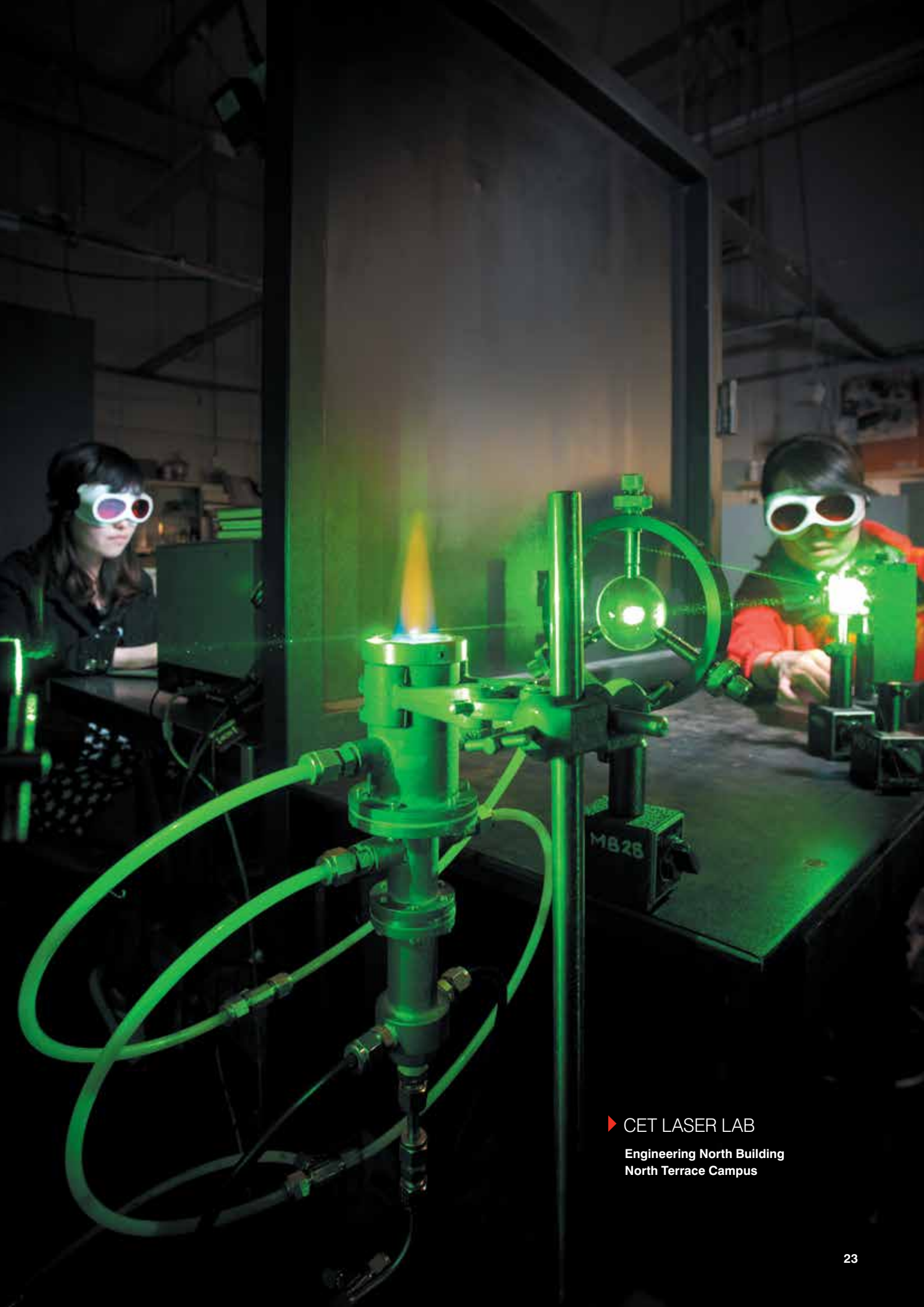
Mr Craig Oakeshott
Principal Consultant, Power and Energy Sinclair Knight Merz Pty Ltd

Dr Jordan Parham
Manager, Institute for Mineral and Energy Resources

Mr Andrew Stock
Executive General Manager – Major Development Projects, Origin Energy

Hon Trish White (Chair from 2012)
Executive Strategic Advisor, Worley Parsons

Mr Mark Young
Managing Director, Adelaide Airport Limited



▶ CET LASER LAB

Engineering North Building
North Terrace Campus

IMPACT OF HIGH INTENSITY RADIATION ON A FLAME

RESEARCH HIGHLIGHT

IMER researchers* are investigating the role of high intensity radiation on flames, with a view to reducing the cost of solar thermal energy in the future.

Combustion presently provides around 80% of the traded energy in industrialised economies and is expected to be a major energy source for the foreseeable future.

Simultaneously, the need to mitigate the emissions of CO₂ is driving the development of technologies that use alternate energy sources – including solar energy.

Despite its many advantages and potential to be a dominant source of sustainable energy in the long term, the use of concentrated solar radiation (CSR) in thermal power generation remains significantly more expensive than many alternate energy sources.

One way to reduce costs involves combining solar thermal energy with established technologies using fossil fuels. These hybrid systems can potentially halve the cost of solar thermal power by reducing infrastructure and generating potential thermodynamic synergies.

Traditional approaches to hybrid power generation technologies collect the thermal energy from the solar and combustion sources in separate devices and then combine them. However, a further infrastructure reduction is possible by collecting these energy sources in the same device.

These potential processes result in the direct interaction of concentrated solar radiation on a flame or fuel. Solar concentrators can achieve radiant fluxes of 4 MW/m². This exceeds the natural radiation from most flames, which is already known to be sufficient to couple with combustion processes. (See Figure page 25)

The paper proposed three mechanisms by which radiation can interact with a flame, namely via soot absorption, direct molecular excitation, or indirect molecular excitation.

The first mechanism is broadband, that is, soot particles absorb at all wavelengths of the solar spectrum, while the latter two are narrow band, so can only absorb a small fraction of the solar spectrum.

The combination of ethylene fuel and a CO₂ laser was chosen carefully because they allow all three mechanisms to be assessed. The CO₂ laser matches both rotational and vibrational transitions of ethylene, allowing the direct excitation of fuel molecules to be achieved. Premixing of the fuel with ethylene consumes the ethylene before the interaction region with the laser, allowing the other two mechanisms to be studied. Finally, the base of the flame provides a zone before significant soot is formed, while strongly sooting regions persist downstream. Hence careful choice of conditions allows the significance of all three mechanisms to be assessed more or less independently.

That is, the use of CO₂ lasers allows a very great simplification over the extremely complex processes that would arise from the irradiation by a broad and non-uniform concentrated solar source.

This combination of laser and fuel enabled a direct assessment of the role of the effects of high energy irradiation, albeit at a different wavelength to solar energy.

The distribution of soot volume fraction (SVF) in the laminar ethylene flame was analysed as premixed, partially premixed and non-premixed. In each case, distribution was shown both without and with the presence of a CO₂ laser beam of consistent shape (4.5 mm) diameter with a fluence of 4.3 MW/m².

The figure pictured presents the images for the non-premixed cases. It can be seen the effect of the laser irradiation on the magnitude of the SVF is most significant when the interaction height is near to the base of the flame. At this height, soot volume fraction is low, and therefore the increase in SVF is attributed largely to the mechanism of direct molecular excitation of the fuel.

The work also found that, for a diffusion flame, the high energy radiation translated the soot layer into the higher temperature, oxidising region of the reaction zone, which will increase the radiation heat transfer from the flame.

The researchers found that radiation of intensities found in solar receivers result in a significant influence of each of these mechanisms in a laminar flame.

Key findings include the influence of combined irradiation of fuel, soot and its precursors at an energy flux of 4.3 MW/m² and within a beam of 4.5mm diameter can lead to an increase in the peak soot volume fraction by up to 250%.

The mechanism found to exert the greatest influence on the maximum soot volume fraction is that of direct molecular excitation of the C_2H_4 fuel. In addition, for non-premixed flames, the irradiation translates the soot sheet further into the higher-temperature part of the flame - toward the oxidising-side of the reaction zone.

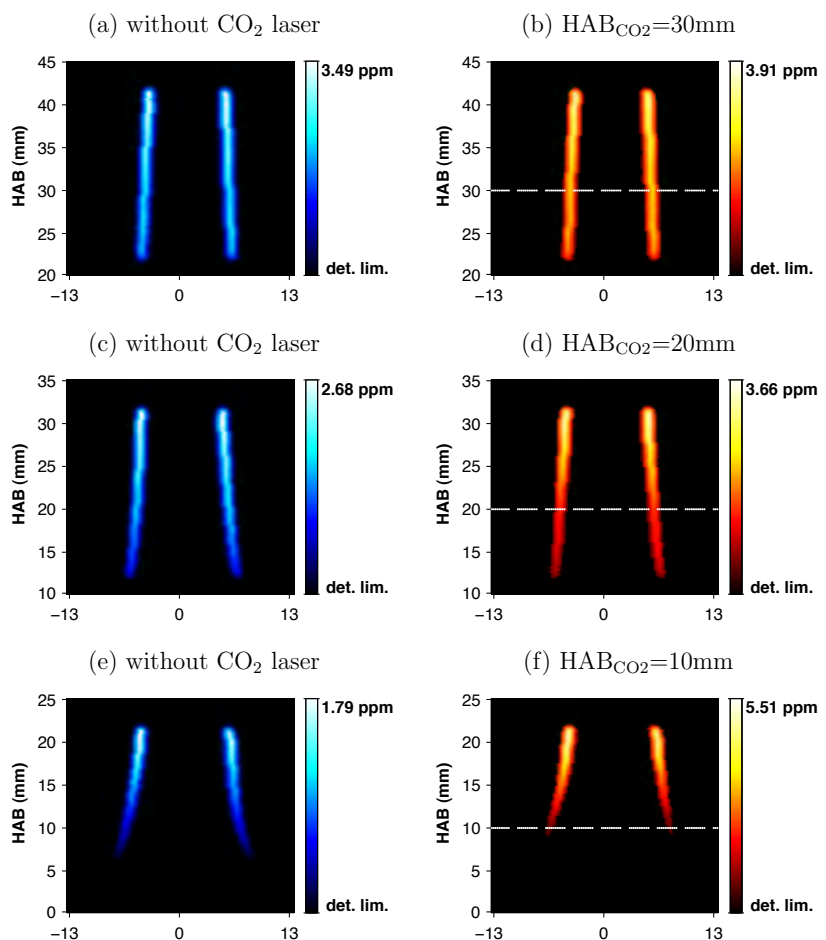
Another finding is that partial premixing of the irradiation leads to a broadening of the soot region on the fuel-rich side of the reaction zone.

The work demonstrates for the first time that highly concentrated irradiation has a significant influence on the soot distribution in a flame. More work is required to better understand the other influences.

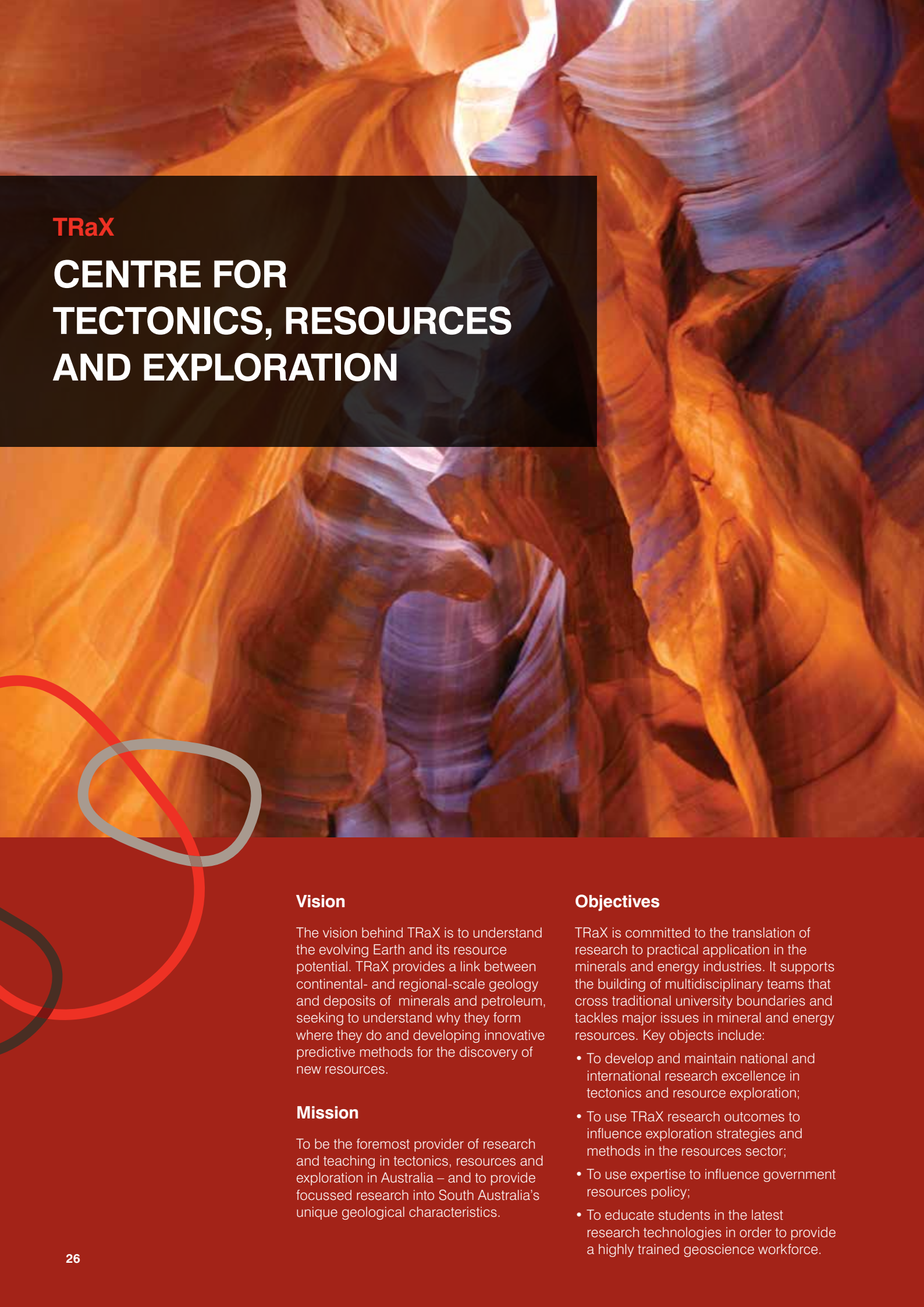
REFERENCE

*Medwell P, Nathan G, Chan Q, Alwahabi Z, Dally B, 2011, 'The Influence on the soot distribution within a laminar flame of radiation at fluxes of relevance to concentrated solar radiation', *Combustion and Flame*, Elsevier Inc. 158, 1814-1821

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Above: Averaged LII soot volume fraction images for non-premixed ethylene flames (a, c, e) without and (b, d, f) with 4.3 MW/m^2 irradiation at various heights above burner. In each image pair, the bottom of the image is aligned 10mm below HAB_{CO₂} (horizontal dashed line).



TRaX

CENTRE FOR TECTONICS, RESOURCES AND EXPLORATION

Vision

The vision behind TRaX is to understand the evolving Earth and its resource potential. TRaX provides a link between continental- and regional-scale geology and deposits of minerals and petroleum, seeking to understand why they form where they do and developing innovative predictive methods for the discovery of new resources.

Mission

To be the foremost provider of research and teaching in tectonics, resources and exploration in Australia – and to provide focussed research into South Australia's unique geological characteristics.

Objectives

TRaX is committed to the translation of research to practical application in the minerals and energy industries. It supports the building of multidisciplinary teams that cross traditional university boundaries and tackles major issues in mineral and energy resources. Key objects include:

- To develop and maintain national and international research excellence in tectonics and resource exploration;
- To use TRaX research outcomes to influence exploration strategies and methods in the resources sector;
- To use expertise to influence government resources policy;
- To educate students in the latest research technologies in order to provide a highly trained geoscience workforce.

Director's Report

Associate Professor Nigel Cook

The Centre for Tectonics, Resources and Exploration (TRaX) is targeted at stimulating research in the rapidly developing minerals sector in South Australia and within a global context.

TRaX's success in achieving acclaim for the quality of its research is acknowledged by the Australian Federal Government's Excellence in Research for Australia (ERA) results which assess the quality of research being conducted in Australian universities. The disciplines of Earth Sciences and Geology both received a score of five, an ERA definition which places the discipline as well above world standard.

TRaX staff deliver expertise in mineral, energy and resources with innovative, cross-disciplinary research within the areas of Lithospheric Evolution, Geofluids and Landscape Evolution. The team is committed to world-class research into practical applications for the minerals and energy sectors. The team is also renowned for excellence in teaching and training.

Researchers are involved with collaborations with national and international universities, federal and state agencies such as the Department of Manufacturing, Innovation, Trade, Resources and Energy (DMITRE). Industry partners

range from multinationals to junior companies, including Barrack Gold Australia Ltd, BHP Billiton, Newmont Australia Ltd, OneSteel and Woodside Energy Ltd, exploring for South Australia's ever-growing list of resources. TRaX researchers have published more than 55 contributions to scientific peer-reviewed journals in 2011, have membership of editorial boards and involvement in major national research initiatives. TRaX is a major contributor to the Deep Exploration Technologies Co-operative Research Centre.

TRaX sought new opportunities in the growing mineral sectors by hosting a series of strategic workshops in 2011 targeting the key research questions aligned to IMER's strategic priorities of uranium and rare earth element resources, South Australia's giant iron-oxide-copper-gold deposits and unconventional gas exploration.

In 2011, Dr Rosalind King was named TRaX Researcher of the Year in recognition of her successful Australian Research Council (ARC) grant application, detailed under Research Highlights. Dr King also gained important recognition in publications and offered innovative teaching. TRaX student researcher of the year was David Tassone for the



publication of five papers from his PhD project and his leadership of the American Association of Petroleum Geologists student chapter.

The Geology and Geophysics group saw the completion of 10 PhDs in 2011, the highest number of PhD completions in a year for the last decade and a testament to the drive of students and supervisors.

Home Schools

Adelaide Microscopy
Australian School of Petroleum
School of Computer Science
School of Earth and Environmental Sciences
South Australian Museum

TRaX Research Areas

Lithosphere Evolution: the growth, destruction and modification of both the Crust and the Upper Mantle with direct applications to minerals and petroleum exploration.

Geofluids: sedimentology, geochemistry, mineralogy, structural geology, ore genesis, deformation processes, diagenesis, and the migration and accumulation of hydrocarbons.

Regolith and Landscape Evolution: the nature and evolution of the cover sequences, plant, animal and micro-organism biogeochemical expression of buried substrates, regional landscape evolution models, regolith-landform mapping.

Tectonics and Metallogeny: nature of basement rocks in South Australia and Australia, their tectonic evolution and their mineral prospectivity including stress and structure of the Earth.

Geophysical Exploration: techniques to map the physical properties and infer the composition of cover and basement rocks, seismic profiling, crustal heat flow mapping, geochemical sampling groundwater detection and numerical modelling.

Minerals, Microbes and Solutions: study of metal complexes under hydrothermal conditions, high pressure-high temperature flow conditions, and biosensors.

Highlights

New Development in Geochemistry: Redox-controlled Iron Isotope

Professor John Foden, Professor Galen Halverson, Paolo Sossi.

The use of stable isotopes of iron is a new development in geochemistry. The key control of their fractionation is oxidation state. More reduced magmatic systems should fractionate to have relatively heavy iron isotopic composition (high Fe57 / Fe54 ratio) whereas more oxidised systems should be lighter.

Where granites produce ore fluids, the iron-bearing ore minerals and gangue should reflect the granite's values.

This project looks at a number of 'end-member' magmatically-related ore systems such as porphyry coppers, (most oxidised), IOCG and S-type granite Sn-W skarns (most reduced) to examine if there are systematic controls reflecting differing oxidation states. The loss of an ore fluid may leave the altered granite with anomalously heavy iron, and thus a potential exploration vector.

Australian Research Council Grant Funds Research in Detachments in Evaporites and Shales

Dr Ros King, Associate Professor Alan Collins, Dr Mark Tingay, Dr Chris Morley, Dr Guillaume Backé.

TRaX members were part of a team to successfully win an Australian Research Council (ARC) grant in 2011 relating to Detachments in Evaporites and Shales: Their Controls on Fold-Thrust Belt Style and Wedge Geometry. The \$A260,000 grant will fund work in coming years from 2012 to 2014.

Detachments are remarkable features which can promote and accommodate large amounts of deformation in an overlying fold-thrust belt. Considerable variations in structural style and vergence direction in fold-thrust belts are controlled by the nature of the underlying detachment; particularly changes in detachment thickness, dip (magnitude and direction), and strength (lithology and pore-fluid pressure).

This project uses structural mapping of outcrop analogues, microstructural analysis of field samples and forward modelling to investigate fundamental questions about the role of detachments in the deformational processes which occur in the overlying fold-thrust belt. PhD students will work on the project in coming years.

The team has embarked on work in the project, completing three fieldwork campaigns to the Osen-Roa shale detachment in Norway; the Indo-Sinian shale detachment in Thailand; and the Bitter Springs evaporite detachment in the Amadeus Basin in Australia. Field campaigns to Norway and Thailand included significant sampling for microstructural analysis.

Collaborative Research Underway with India in 2011

Associate Professor Alan Collins, Professor Martin Hand, Dr Guillaume Backé, Dr Graham Baines, Dr Caroline Forbes, Professor Martin Kennedy.

The year 2011 was the third year of the Australia-India Strategic Research Fund project lead by TRaX researchers and entitled 'The Thermal Evolution of Peninsula India: Past Behaviours and Future Potential'. The project is funded by the Australian and Indian governments and has been successful in developing collaborations between TRaX, Curtin University of Technology in Perth and the three partner institutions in India – the National Geophysical Research Institute, Hyderabad; the Indian Institute of Technology, Kharagpur; and the Indian Statistical Institute, Kolkata. The project focuses on the tectonic evolution of Peninsula India and tracking heat-producing elements through the rock cycle.

Fifteen TRaX Honours students have undertaken projects with fieldwork in India, to examine the geological evolution of both the Eastern Ghats and the Southern Granulite Terrane and examine the development and evolution of the extensive Cuddapah Basin that covers much of Andhra Pradesh. Honours projects in 2011 focussed on the southern Eastern Ghats and its relationship with the Cuddapah Basin.

The projects were:

- 'The tectonic evolution of the Ongole Domain, India: A metamorphic and geochronological approach' by Bonnie Henderson;
- 'A Geochronological and Structural Analysis of the Nallamalai Fold Belt, S.E. India' by Emma Alexander;
- 'A Geochronological and Structural Analysis of the Nallamalai Fold Belt, S.E. India' by Georgina Falster;
- 'Geochronological and Sedimentological Constraints of the Srisaillam Formation, S.E. India' by Ryan Gore.

TRaX hosted Indian researcher Dr Sukanta Roy who worked with Alan Collins, Guillaume Backé, Graham Baines and Andrew Barker to produce a manuscript on the heat production distribution of rocks found within the 'ultra-high temperature' Eastern Ghats orogen. This work not only demonstrated the unusually high thorium content of the orogen, but also confirmed the surprising observation that despite consisting of lower crustal rocks, rocks within the orogen are very high heat producers.

Other collaborations continue through 2012 culminating in an international conference planned for November.

Research Offers Application in Ore Genesis Studies and Geometallurgy

Dr Cristiana Ciobanu, Associate Professor Nigel Cook, Associate Professor Satoshi Utsunomiya, Professor Allan Pring.

Focussed ion beam-scanning electron microscopy (FIB-SEM) is a relatively new analytical tool that has been little applied to problems of ore genesis. This technique enables high resolution (cross-section) imaging and can be used to prepare thinned foils for study by transmission electron microscopy (TEM).

The researchers have been able to observe ore-forming processes at the atomic scale while they are happening. This project offered the first attempt to apply this instrumentation to ore minerals. Four case studies were analysed in this project.

Adelaide Microscopy is a world-class facility at the University of Adelaide which offers the possibility of nano-sampling in-situ.

The research offers application in ore genesis studies and geometallurgy. It also bridges scales of observation of scanning and transmission electron microscopes. The technique has been applied in studies using synchrotron radiation.

IMPLICATIONS FOR MINERAL PROCESSING RELATED TO MINERALOGY OF INDIUM IN SULPHIDE DEPOSITS

RESEARCH HIGHLIGHT

Focussed ion beam-scanning electron microscopy (FIB-SEM) is a relatively new analytical tool that has been little applied to problems of ore genesis.

This technique enables high resolution (cross-section) imaging and can be used to prepare thinned foils for study by transmission electron microscopy (TEM) at site-specific locations. Such approach is critical when trying to interpret ore-forming processes down to the smallest possible scale where atom exchange takes place.

The project was a first attempt to integrate the application of FIB-SEM and TEM techniques on ore minerals aiming at understanding the nature of minor and trace element substitutions down to the nanoscale.

Adelaide Microscopy is a world-class facility at the University of Adelaide which offers the possibility of nanosampling in-situ. The research offers application in ore genesis studies and geometallurgy. It also bridges scales of observation between that of scanning and transmission electron microscopes. The FIB-SEM technique has also been applied to obtain slices of minerals necessary for studies using synchrotron radiation.

Indium (In) has attracted considerable attention from increased demand for its use in numerous high-technology applications. This has spurred research into the geochemical distribution of the element, its mineralogy in indium-bearing ore deposits and the behaviour of In-bearing minerals during mineral processing.

IMER researchers* summarised current knowledge of the mineralogy and mineral chemistry of indium with a focus on the main economic In-bearing sphalerite in a published work in 2011.

Indium forms a small number of independent indium-bearing minerals of which roquesite (CuInS_2) is the most abundant. While trace amounts of roquesite are found from some indium bearing zinc ores, the mineral is never of serious economic importance by itself. It is only relatively abundant when the zinc content of the ore is very low and copper abundance is high.

The vast majority of indium is currently produced as a by-product of the zinc mining industry. In mines that exploit Zn-(Pb) ores, there is considerable economic interest in the by-product indium if concentrations of sphalerite are sufficiently high – even if the bulk of the current indium production is from the refining of zinc concentrates in which the indium content is rather low.

Past research by TRaX Director Associate Professor Nigel Cook using laser ablation inductively-coupled plasma mass spectroscopy (LAICP-MS) on indium concentrations in sphalerite from various worldwide deposits, demonstrated lattice-bound indium at concentrations across several orders of magnitude (<1ppm to > 5wt.%). In all cases, indium is incorporated into the sphalerite structure via the simple coupled substitution of 2Zn^{2+} by Cu^+ and In^{3+} .

This finding is supported by other researchers' experimental work in the system ZnS-CuInS_2 and in observance of In^{3+} as the stable species in hydrothermal solutions. In examining the ranges of indium concentration in sphalerite from several southern China zinc deposits, here too the indium is lattice-bound within sphalerite.

The other mineral that can carry significant indium in base metal ores is chalcopyrite however concentrations of indium are lower than in co-existing sphalerite. It is well known that trace and minor elements can significantly

influence the dissolution behaviour of a mineral. The influence which significant concentrations of indium will have on sphalerite behaviour is much less well constrained but some studies available suggest that indium presence will influence sphalerite behaviour by changing the semiconductor type of sphalerite from p-type to n-type.

Other studies dealing with the leach behaviour of an In-bearing zinc concentrate were carried out on ores from the Neves Corvo mine. Almost all the zinc and indium could be successfully leached without the addition of external oxidants, only 20% of copper was leached.

Other researchers have highlighted the main methods used in indium processing with emphasis on electrolytic recovery of zinc as cathodes and subsequent containment of the indium fraction in residues.

The leaching behaviour of indium bearing sphalerite is of direct interest to the geological community and to metallurgists. It may supply additional information on the incorporation of indium in the structure and mechanisms by which this is achieved – and thus controls on its distribution in ore deposits.

REFERENCE

Edited and summarised excerpt from *Cook, N. J, Ciobanu, C. L, Williams T, 2011, 'The mineralogy and mineral chemistry of indium in sulphide deposits and implications for mineral processing,' Hydrometallurgy, 108 p226-228 © Elsevier BV. All rights reserved.



► X-RAY LAB

Darling Building
North Terrace Campus



CMXUC

CENTRE FOR MINERAL EXPLORATION UNDER COVER



Director's Report Professor David Giles

The Centre for Mineral Exploration Under Cover (CMXUC) is a South Australian State Government-funded research centre. Its specific objective links the mineral exploration research activities of the University of Adelaide, Primary Industries and Resources South Australia (PIRSA) now named Department of Manufacturing, Innovation, Trade, Resources and Energy (DMITRE) and the mineral exploration community in order to establish an international hub for mineral exploration research and training in South Australia. The CMXUC operates as a discrete, externally-funded entity embedded within the Centre for Tectonics, Resources and Exploration (TRaX) with all CMXUC researchers also belonging to TRaX.

Funding of \$A1.2 million over four years (2005-2008 inclusive) was provided by PIRSA, through the Plan for Accelerated Exploration (PACE), to establish and seed fund the CMXUC.

This funding was continued over a three-year period (2009-2011 inclusive) within the context of PACE 2. The PACE funding allowed for the creation of the inaugural State of South Australia Chair of Mineral Exploration (and Director of CMXUC) held by Professor David Giles since January 2006.

A significant milestone for the CMXUC was realised in November 2010 with the launch of the Deep Exploration Targeting Cooperative Research Centre (DET CRC), an eight-year \$A110 million research initiative headquartered in Adelaide. The research efforts of the CMXUC in 2011 were largely incorporated within DET CRC as a major component of Research Program 3: Deep Targeting. This has enabled significant growth in terms of funding, employment of research personnel and post-graduate students and has facilitated extensive growth of the CMXUC's research network.



In addition to its research mandate CMXUC has a continuing commitment to educating South Australia's next generation of job-ready minerals industry professionals. Through its contribution to minerals industry relevant undergraduate courses and management of the Minerals Tertiary Education Council Minerals Geoscience Honours program, CMXUC has played a key role in the growth of undergraduate Geology and Geophysics at the University of Adelaide.

INSIGHTS INTO THE FORMATION OF THE NORTHEASTERN GAWLER CRATON, SOUTH AUSTRALIA

RESEARCH HIGHLIGHT

A group of scientists including IMER members* have been involved in research to gain an understanding of the tectonic history and architecture of the northeastern Gawler Craton in South Australia.

The Gawler Craton extends over a significant area of present-day South Australia from some hundreds of kilometres north of Coober Pedy and to the south through the Eyre Peninsula and parts of the Yorke Peninsula. The field area of this study, the Mount Woods Inlier is located in the northeast of the Gawler Craton between Coober Pedy and Lake Eyre.

The Mount Woods Inlier comprises Proterozoic (~1.75-1.64 billion years old) basement rocks. Knowledge of these rocks is limited as they are mostly overlain by younger sediments and are therefore poorly exposed. However, there are small exposures of metapelitic rocks suitable for study within the northern parts of the Inlier.

Samples taken from these exposures were used to determine the thermal evolution and tectonic architecture of the Mount Woods Inlier at a time of extensive mineralisation (e.g. the Prominent Hill and Olympic Dam deposits). Thermobarometric modelling was integrated with previous and newly acquired U-Pb geochronological data to assess the relative timing of burial and heating (prograde metamorphism) of the rock packages, and constrain the time when the highest temperatures of metamorphism were attained (peak metamorphism). The thermal driver for metamorphism was then considered.

The sample used for pressure-temperature (P-T) analysis in this study was a garnet-cordierite-spinel-bearing pelite taken from an exposure in the Moonlight Hills area of the Mount Woods Inlier (see images). The most

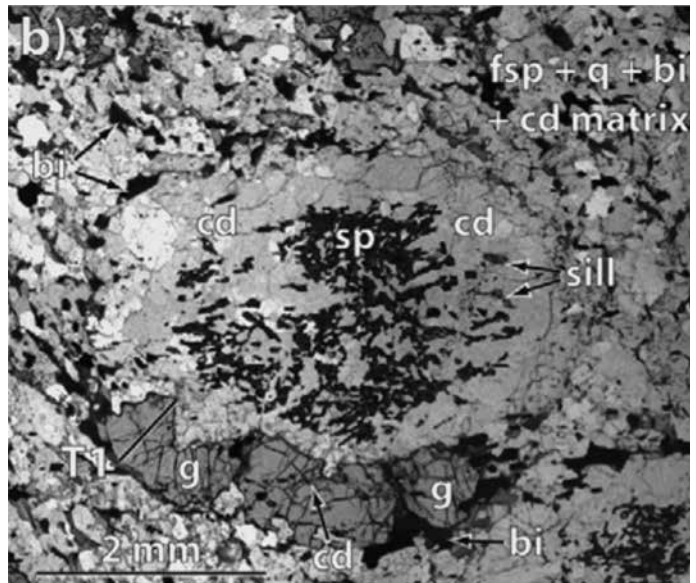
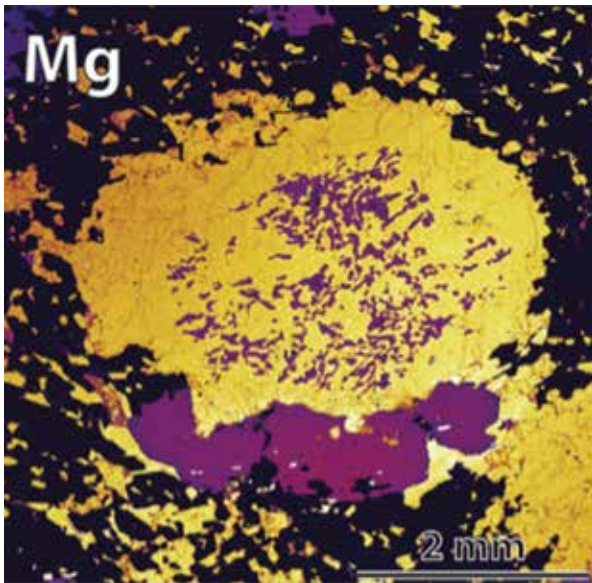
striking feature of this sample was the preservation of fine intergrowths (symplectites) of cordierite and spinel that are consistently surrounded by a cordierite moat. This moat separates the symplectites from the matrix (or the remainder) of the rock. Together, the symplectites and moats comprise around 5% of the whole rock, are up to 5mm length, and have an ovoid shape. Garnet occurs as rims around some of the cordierite moats, or as large grains that are not associated with the symplectite/moat mineral assemblage. The process of development of the symplectites and the moats, and their association with garnet are the key petrological feature that needed to be accounted for in the Moonlight Hills pelites. The researchers interpret the cordierite-spinel symplectites and the cordierite moats to have developed prior to the growth of the garnet. The garnet grains were determined to have grown at the highest temperatures that the rocks attained, implying that the moats and symplectites are features that developed during heating (prograde metamorphism) of the rocks.

The research concluded that early stages of prograde metamorphism occurred at pressures and temperatures of ~2-3 kbar (~7-11km depth) and ~550-610°C. Peak metamorphism attained conditions of ~4.7 kbar (~16-17km depth) and 750°C. The geothermal gradient during the early stages of metamorphism is therefore calculated to be 50-90°C km⁻¹, and during peak metamorphism was 45-50°C km⁻¹. As the geothermal gradient for normal crust is ~20-25°C km⁻¹, metamorphism within the Mount

Woods Inlier is therefore associated with significantly elevated geothermal gradients. The highly elevated geothermal gradients associated with prograde metamorphism suggest the Moonlight Hills metasediments initially underwent significant heating with limited burial. The elevated, but slightly lower geothermal gradients associated with peak metamorphism implies the rocks then underwent further heating associated with increased burial.

This study suggests that geothermal gradients within the Mount Woods Inlier were initially elevated due to intrusion of voluminous mafic and felsic magmas at mid- to upper-crustal levels, some of which have since been removed during exhumation of the terrane and associated erosion. The hot rocks were subsequently buried and further heated to attain conditions of peak high-temperature/low-pressure metamorphism. U-Pb geochronology of zircon and monazite grains from the Moonlight Hills pelite demonstrated that the timing of prograde- to peak-metamorphism within the Mount Woods Inlier can be constrained to ~1.61-1.59 billion years ago.

Characterising the timing and conditions of prograde-to-peak metamorphic paths at various crustal levels contributes to understanding the thermal and deformational evolution and the mechanism of strain distribution within a terrane. The results of this study have demonstrated that metamorphism and deformation in the Mount Woods Inlier was contemporaneous with



deformation and high-temperature/ low-pressure metamorphism throughout eastern Proterozoic Australia, including at Broken Hill and Mount Isa. This has implications on our understanding of the influence of large-scale (Australia-wide) crustal vs mantle thermal processes on metamorphism and deformation, and subsequently on our understanding of the genesis of giant ore deposits.

Left: Qualitative Mg chemical map of a cordierite-spinel symplectite, cordierite moat and partially rimming garnet grain from the Moonlight Hills pelite sample. Warm colours indicate higher Mg concentration. Cordierite: yellow; Spinel: small purple grains in centre of map and surrounded by yellow cordierite; Garnet: large pink to purple grain in bottom half of map. Solid cordierite can be seen surrounding the cordierite-spinel symplectite in the centre of the map. The matrix of the rock (black and small yellow grains) comprises feldspar, quartz, biotite and cordierite.

Right: Photomicrograph of cordierite-spinel symplectite, cordierite moat and partially rimming garnet shown in the adjacent Mg chemical map.

REFERENCE

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SACGER

SOUTH AUSTRALIAN CENTRE FOR GEOTHERMAL ENERGY RESEARCH



Vision

The vision of the South Australian Centre for Geothermal Energy Research (SACGER) is for a future in which the world's mineral and energy resources are managed efficiently and sustainably for the benefit of society, industry and the environment.

Mission

The mission of SACGER is to establish a world-class centre for practical, high-priority geothermal energy research with a focus on enhanced (engineered) geothermal systems and in geothermal power systems that will result in widespread benefits at a state, national and international level.

Objectives

SACGER aims to conduct research into enhanced geothermal systems and related power systems that provide an economically and environmentally viable delivery of geothermal energy.

The Centre is committed to enabling South Australia to remain at the forefront of research and development in geothermal energy which will result in widespread benefits for industry, the community and the environment.

Director's Report Professor Martin Hand

The South Australian Centre for Geothermal Energy Research (SACGER) was established in 2009 through funding from the South Australian Government's Renewable Energy Fund. SACGER brings together cross-disciplinary research excellence and expertise.

To date the only deep geothermal wells in Australia have all been drilled in South Australia: Geodynamics' Habanero and Jolokia wells; Petratherm's Paralana-2; Panax's Salamander-1 and Origin Energy's Celsius-1. The Geodynamics and Petratherm projects represent two of the world's most significant Engineered Geothermal Systems (EGS) projects. Both projects entail the enhancement of naturally fractured rocks via hydraulic fracture stimulation. In contrast the wells drilled by Panax and Origin Energy target sedimentary-hosted geothermal systems.

While 2011 has seen an industry facing challenging times with a softening of investment leading to a reduced rate of project development in the sector, SACGER has continued to grow, developing new projects, taking on five new research staff as well as students, and forging collaborations with geothermal research centres in Western Australia and Queensland, Geoscience Australia, CSIRO and the University of Auckland.

In 2011 the Centre received \$A2 million of funding from the Department for Manufacturing, Innovation, Trade, Resources and Energy (DMITRE), State Government of South Australia. This grant, along with awards from the Australian Research Council (ARC) and the South Australian Premier's Research and Science Fund (PSRF) increased SACGER's total funding to nearly \$A3 million. This promoted significant growth in analytical capacity, allowing the purchase of a second electron microprobe, a second Laser ICP-MS, to add to a recently acquired X-Ray diffractometer and improved hardware in the Centre's hydrothermal laboratory. This hydrothermal capability simulates the conditions within a geothermal reservoir and allows researchers to investigate fluid-rock interactions at temperatures of 250°C and pressures similar to those of rocks buried at depths of 3000m. Researchers within the Centre also form part of a consortium that will oversee the establishment of an ARC-funded high-pressure rock deformation and fluid-flow testing system at Monash University.

New projects initiated by SACGER in 2011 include a collaboration with Panax Geothermal Ltd to investigate the nature of the reservoir surrounding the 4,000 m deep Salamander-1 well in the Otway Basin. The aim is to develop



strategies to improve the fluid flow performance of the geothermal well in order to develop sustainable reservoir production models.

Another project commenced in 2011 is SATHerm. This research program seeks to improve the understanding of the thermal state of the South Australian crust by, in the first instance, expanding the State's thermal properties database. It includes performing thermal conductivity and diffusivity measurements with the Centre's recently acquired optical scanner device.

Research continued at Petratherm's Paralana project in the Northern Flinders Ranges where SACGER's team of geophysicists were able to electrically image the injection of fluid into the geothermal reservoir during fracture stimulation at a depth of 3,800m. This is the first time that fluid injection has been imaged in real time, and this achievement opens up a new area of monitoring fluid reservoir stimulation.



Home Schools

Australian School of Petroleum

School of Chemical Engineering

School of Civil, Environmental and Mining Engineering

School of Computer Science

School of Earth and Environmental Sciences

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Dr Adrian Williams
Former Chairman of Geodynamics Ltd

Dr Doone Wyborn
Chief Scientist and Founding
Director of Geodynamics Ltd

Highlights

International Leader in Magnetotelluric (MT) Techniques

*Professor Graham Heinson, Dr Stephen Thiel,
Mr Jared Peacock, Professor Craig Mudge.*

The University of Adelaide is internationally recognised for its expertise in the use and development of magnetotelluric (MT) techniques. It is an international leader in the development of electromagnetically based tools for the geothermal industry and aims to develop this capability further through additional industry and government funding.

The University of Adelaide's magnetotelluric equipment was deployed at Paralana in collaboration with Petratherm Ltd, as well as in the North Perth Basin in conjunction with Green Rock Energy. At the Paralana site in the Northern Flinders Ranges, researchers successfully measured changes in the electrical resistivity of the reservoir during fracture stimulation at 3,800m depth, showed for the first time that MT can be used to directly image the changing distribution of fluid in real time. This opens up a range of applications for monitoring fluid distribution during fracture stimulation in the geothermal industry but also in other areas of energy extraction, such as for example unconventional gas. In 2012 similar experiments of fracture stimulation MT monitoring are scheduled in the Cooper Basin at the Geodynamics Ltd site near Innamincka.

The work in the Cooper Basin will also involve the development of MT as a tool for temperature and permeability

prediction ahead of the drill bit as an aid to delineate new geothermal resources.

The collaborative research team involves staff from Petratherm Ltd and Green Rock Energy as well as researchers from the Institute of Earth Sciences and Engineering (IESE) at the University of Auckland.

Research Partnership to Improve Reservoir Quality and Productivity

Professor Pavel Bedrikovetsky, Dr Zhenjiang You, Dr Themis Carageorgos, Dr Alex Badalyan, Professor Allan Pring, Dr Rosalind King, Dr Simon Holford, Mr Adam Bailey, Professor Martin Hand.

SACGER has entered into a research partnership with Panax Geothermal Ltd to understand the reservoir behaviour around the Salamander-1 well near Penola in the Otway Basin. Salamander-1 was drilled to a depth of 4012 m, finding good temperatures, but fluid flows lower than predicted. The research is aimed at understanding the factors controlling the change in flow rate over time, and identifying remediation strategies that can be employed to improve the performance of the well. The research is also aimed at understanding where future geothermal wells should be drilled.

The team is investigating a number of aspects that include: (1) Possibility of fines migration toward the well leading to a reduction in permeability in the near well environment over time; (2) Diagenetic modification of the reservoir resulting in lower than predicted rock matrix permeability; and (3) Reservoir compartmentalisation due to stratigraphic and/or structural features.

So far the work has shown that sedimentary-hosted geothermal reservoirs could be susceptible to fines migration due to the thermal control on electrostatic interactions between particles. Understanding this thermo-electrostatic sensitivity will allow the team to design methods insuring optimal flow rates that minimise formation damage thereby creating an economic and sustainable geothermal flow. The magnitude of this flow will form the basis of reservoir production models and geothermal energy extraction models that will link with work conducted in the Centre on optimisation of geothermal plant efficiency.

SACGER has applied for funding from the Australian Centre for Renewable Energy (ERP ACRE, Measure) to broaden the scope of the research in order to systematically understand the variables that influence reservoir quality in sedimentary-hosted geothermal systems in Australia. If successful this funding will be primarily applied to research in the Otway and Cooper Basins.

Collaborators include staff from Panax Geothermal Ltd, Geodynamics Ltd, the Department of Manufacturing, Innovation, Trade Resources and Energy (DMITRE) and researchers from CSIRO.

Stochastic Rock Fracture Modelling, Fluid and Heat Transfer in Geothermal Reservoirs

*Professor Peter Dowd, Dr Chaoshui Xu,
Dr Rosemarie Mohais, Mr Younes Fadakar
Alghalandis, Sattar Seifollahi. Industry
partner: Geodynamics Ltd.*

Success in hot dry rock geothermal applications depends critically on establishing an enhanced geothermal

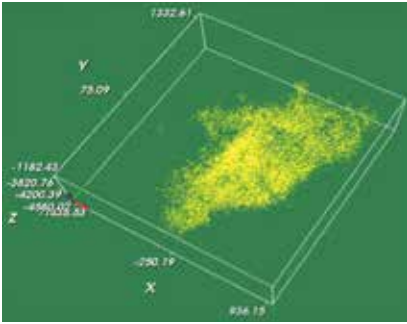


Figure 1: Seismic point cloud of Habanero fracture stimulation.

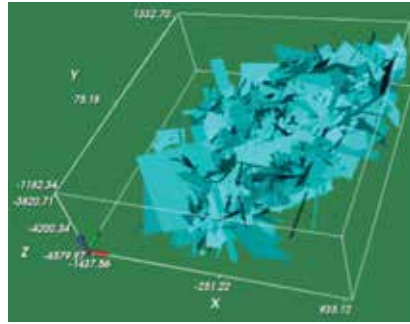


Figure 2: Fracture model for the Habanero reservoir.

system, or reservoir, by creating a network of fractures through which fluid is induced to flow. Such an effective system that will deliver technically and economically viable energy production depends crucially on realistic models of fluid flow and heat transfer within the generated fracture networks. This research aims to provide these models. The objectives of this project are to conduct research and development in algorithms, methods and tools that can be used to construct realistic reservoir fracture model for hot dry rock enhanced geothermal systems and to investigate fundamental principles of fluid flow and heat transfer in rock fractures. The project aims to provide efficient and reliable system modelling tools for industry scale geothermal applications.

Started in November 2010, this project is supported by an Australian Research Council (ARC) Discovery grant and South Australian Centre for Geothermal Energy Research (SACGER). The project aims to develop rock fracture modelling techniques that can simulate realistically the fractured reservoir for hot dry rock enhanced geothermal systems, to investigate the fundamentals of fluid flow and heat transfer within the fracture system and to develop an efficient tool for modelling industry scale geothermal applications.

Key research areas in stochastic fracture modelling include data integration, multivariate spatiotemporal modelling, conditional simulation and connectivity assessment. For fluid flow and heat transfer, the research covers initially fundamentals of mass and energy transfer in a single fracture with various boundary conditions, which will lead to the construction of the mass and energy transfer model for the entire geothermal reservoir.

Geodynamics' Habanero geothermal reservoir in the Cooper Basin of South Australia has been used in this research as a case study to cross-

validate the methods and algorithms developed. A simulated fracture model for the Habanero reservoir is given in the following figure, where the figure on the left shows absolute hypocenter locations of the seismic events generated during the fracture stimulation process and the figure on the right is a simulated fracture model conditioned on these seismic events.

Reservoir Fracture and flow modelling

Professor Peter Dowd, Associate Professor Chaoshui Xu, Dr Rosemarie Mohais.

Australia's three flagship geothermal projects are all located in South Australia (Geodynamics Cooper Basin project; Petrathern Paralana project and Panax Penola project). The Geodynamics and Petrathern projects represent two of the world's most significant Engineered Geothermal Systems (EGS) projects. Both projects require the enhancement of naturally-fractured rocks with hydraulic fracture stimulation. SACGER has significant expertise in statistical modelling of fracture systems, and is seeking to couple these spatial models to flow formulations to provide a comprehensive model for heat mining extraction in fractured geothermal reservoirs.

In order to create realistic models for fluid and heat movement in a fractured reservoir, it is necessary to develop appropriate models that describe fractures. Natural fractures are typically surrounded by a damage zone that has an effective permeability intermediate between the fracture the distant matrix. The researchers have determined an equivalent permeability of permeable-walled fracture and addressed the problem of coupled fluid flow and heat transfer within a single fracture comprised of permeable walls, determining the velocity and heat transfer profiles using slip conditions at the walls of the fracture.

Fracture Mapping

Dr Dennis Cooke, Dr Hani Abul Khair.

Knowledge of the geometry of natural fracture systems and present day horizontal stresses control the direction of hydraulic fracture propagation; this is crucial in our understanding of geothermal reservoirs. As a test study natural fractures within select stratigraphic intervals in the Cooper Basin using curvature attributes were calculated from dip-steered seismic cube. Evidence from image logs, cores, and seismic interpreted fault network correlated well in supporting the modelling results.

High density of fractures is found in the vicinity of the fault planes and tight anticlines. Similarly, a higher fracture density is correlated with higher gamma-ray values. For instance the correlation between shale content and high fracture density is confirmed by image log analysis and supported by direct observation along cores. A higher fracture density in shale than in sandstone is not intuitive, but is not a rare phenomenon in Australian basins. Likely contributors are diagenetic effects, pore pressure, stiffness, tensile vs compressive strength, in differences of the shale and of the sandstone.

Fractures interpreted from image logs provide a consistent northwest-southeast trend. This trend corresponds with the fracture set interpreted from the curvature attribute calculated at given time slices.

Most-positive curvature attribute is a powerful tool for determining the azimuth of the natural fracture network in a sedimentary basin, and at a smaller scale a geothermal reservoir. An excellent relationship can be found between the shale volume and the fracture density, both horizontally as well as vertically, using curvature attributes. Shale-versus-density relationship can be interpreted to be caused by diagenetic effects, pore pressure, stiffness, tensile vs compressive strength of the shale compared to that of the sandstone.

SACGER Research Areas

Electrical imaging of crustal fluids: the development of new methods to image the distribution of subsurface fluids to derive information about permeability, fracture orientation and stress and to image fluid movement during fracture stimulation and development of geothermal reservoirs.

Regional geothermal assessments: with work on the improvement of the thermal characterisation of the South Australian crust and beyond via a program of heat flow and thermal conductivity data acquisition to identify new areas of geothermal prospectivity. This includes the potential for direct use geothermal inputs into industrial processes such as mineral processing.

Fracture mapping using seismic tools and well logs: use of 3D seismic to image fracture systems in Australia's geothermally prospective sedimentary

basins, along with production data from existing oil and gas wells, to investigate relationships between fracture density, orientation and permeability.

Reservoir fracture and flow modelling: development of reservoir fracture models for enhanced geothermal systems and linking those to fluid flow models to create an improved understanding of fluid pathways and heat transfer in fractured rock systems.

Fluid rock interactions: focus on the geochemistry of geothermal fluids using our flow-through and batch hydrothermal reactors to evaluate the dissolution of rock minerals and resultant precipitation and scaling within the reservoir and above-ground infrastructure.

Crustal stress: work characterising and modelling contemporary crustal stresses in a number of regions around the world including areas of known geothermal potential such as the Cooper Basin; this leads to a better

understanding of the stress and fluid-pressure state in non-conventional geothermal systems.

Reservoir quality and productivity: development of models that allow understanding of reservoir quality, particularly in sedimentary-hosted systems. This work includes thermodynamic modelling of fines migration to provide a framework for optimal well design and flow testing. In understanding the thermal and chemical controls on diagenetic processes and their implications for permeability researchers are able to predict where maximum matrix permeabilities may occur.

Thermodynamic modelling of geothermal power plants: examination of how the efficiency of geothermal power plants is influenced by the complex set of engineered and natural variables that apply to geothermal systems, with the goal of understanding optimal performance criteria over time.

► CIVIL ENGINEERING MINING LAB

Engineering North Building
North Terrace Campus



FLUID FLOW AND HEAT TRANSFER INVESTIGATION INCREASES KNOWLEDGE OF HOT ROCK ENERGY EXTRACTION

RESEARCH HIGHLIGHT

Hot dry rock (HDR) geothermal energy extraction aims to obtain energy from high heat-producing granites located a few kilometres below the Earth's surface.

As these rocks are usually almost impermeable to flow in their natural state, an artificial reservoir, or enhanced geothermal system (EGS), is created through hydrofracturing which involves pumping highly-pressurised water into the rock.

Hydrofracturing opens existing fractures and generates new fractures to create a connected fracture network through which fluid can flow. Once the reservoir has been established, cold water can be introduced through injection wells flowing through the fracture network. This can be extracted at much higher temperatures at recovery wells.

Three main heat transfer processes within the reservoir are: 1) heat conduction through the intact rock toward fractures; 2) convection within the heated fluid; and 3) advection, that is the transport of heat by the bulk flow of the fluid. See Figure 1.

The modelling of fluid flow in fractured reservoir can be done with analytical techniques, numerical calculations

and experimental studies. For EGS, the reservoir cannot be directly observed on a meaningful scale and it is not possible to determine precisely what occurs between the injection and recovery wells. The most practical analytical approach is to conduct the modelling with a reduced complexity in the reservoir geometry.

IMER researchers* have worked on the mathematical analysis of fluid flow and heat transfer using a simplified fracture model to represent the connection between the injection and recovery wells of an EGS.

Dr Rosemarie Mohais (South Australian Centre for Geothermal Energy Research, SACGER), Associate Professor Chaoshui Xu (Resource Engineering Research Program) and Professor Peter Dowd (Resource Engineering Research Program) consider the walls of the fracture to have properties of a permeable medium. They studied the effect of the slip boundary conditions at the fracture walls on velocity and temperature

profiles for low Reynolds number fluid (<7) based on a similarity solution and perturbation expansion of coupled momentum and energy equations.

The researchers focused on the main attributes that would enable the problem to closely resemble a single fracture with permeable walls connecting an injection and a recovery well.

They found that the flow velocity profiles, the heat transfer profiles and the volumetric flow rate are all altered with changes in channel width, wall permeability and slip coefficient, which is a dimensionless constant related to the inherent properties of the channel.

REFERENCE

*Mohais R., Xu C., Dowd P., 2011, 'Fluid Flow and Heat Transfer Within a Single Horizontal Fracture in an Enhanced Geothermal System', Journal of Heat Transfer, November 2011, Volume 133. (Summarised version, © American Society of Mechanical Engineers).

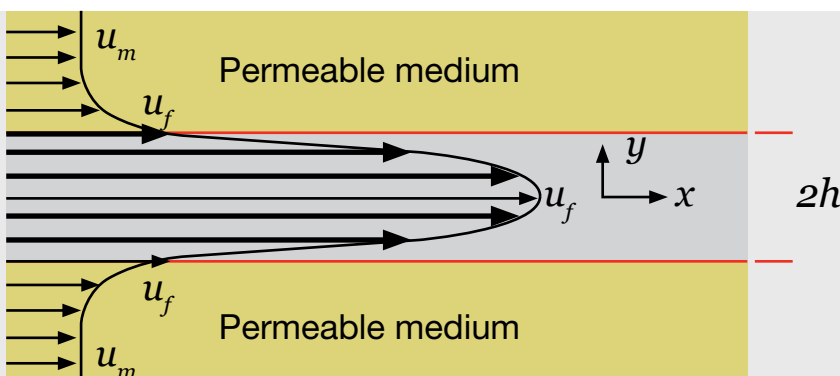


FIGURE 1

Velocity profile for coupled parallel flows within a channel and bounding porous medium according to the slip flow hypothesis of Beavers and Joseph (after Beavers and Joseph (1967) and Neale and Nadar (1974)).



**RESOURCE
ENGINEERING
PROGRAM**

Program Leader's Report

Associate Professor Emmanuel Chanda

The Resource Engineering Program comprises Mining/Geotechnical Engineering and Petroleum Engineering Research clusters.

The Mining and Geotechnical Engineering Research Group brings together capabilities in geostatistics, operations research, rock mechanics, and geotechnical engineering. The Group brings these capabilities together with a focus on improving the efficiency and safety of mining operations, both below and above ground.

Research in Petroleum Engineering is focused on four areas (1) recovery of unconventional resources (tight gas, shale gas, coal seam gas) (2) mathematical modeling, laboratory

and field studies on productivity enhancement and formation damage, (3) reservoir characterisation and simulation and (4) decision-making under uncertainty.

The Mining research group is a key part of the Deep Exploration Technologies Cooperative Research Centre (DET CRC), which aims to develop more successful, cheaper, safer and environment-friendly ways to target, drill and analyse deep mineral deposits. The DET CRC is an eight year program funded by \$A28 million cash from the Australian Government's CRC Program, \$A21 million cash (and \$A12 million in-kind) from industry participants, and \$A50 million in-kind from its research providers.



Research Highlights

Home Schools

Australian School of Petroleum
School of Civil, Environmental and
Mining Engineering

Deep Exploration Technologies

Associate Professor Chaoshui Xu, Associate Professor Emmanuel Chanda, Dr Murat Karakus, Dr Noune Melkourian, Associate Professor Hamid Sheikh, Dr Abbas Taheri, Mr Saeed Hashemi, Mr Jiayi Xu, Mr Xianqun He.

The mining group within the Resource Engineering Program contributes to two DET CRC research projects: Fundamentals of Rock Tool Interaction; and Borehole Stability. The Group has received funding totaling \$A419,000

over the three years for the two projects plus a total of six allocated PhD places.

There are three research tasks currently being carried out by the group in each of the two projects. Task one in the first project is to investigate the application of acoustic signal monitoring and analysis for the performance optimisation of drilling operations. The other two tasks in this project are to investigate the mechanical interactions between the rock and the drill bit using numerical modelling. One of them uses the finite

element method to model the failure mechanism of diamond impregnated drilling bits; and the other uses the discrete element method to model the corresponding rock cutting mechanics. Tasks one and two in the second project deals with the borehole stability issues in drilling with one in the framework of unconsolidated ground and the other one for solid rock. Task three in this project is to develop a comprehensive rock mass characterisation system for drilling operations, using the Brukunga mine as a case study. Brukunga mine is the training and drilling test site for the DET CRC.

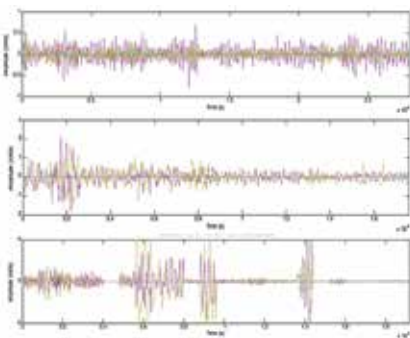


Acoustic Signal Monitoring and Analysis for Drilling Optimisation

*Dr Murat Karakus, Associate Professor
Chaoshui Xu*

Direct measurement and visualisation of the impregnated diamond drilling process is extremely difficult in deep exploration drilling. The driller currently estimates when to alter drilling parameters and to change the diamond drill bit based on experience. However drilling performance is impacted by bit wear, rock type and various fluid environment and control parameters such as drilling force and torque. The fundamental issue relates to whether drilling performance can be improved in real-time through appropriate monitoring of the drilling operation.

The research approach is to exploit acoustic emission (AE) to detect changes in the cutting response and identify the cause of AE signals, for example the bit itself, rock and mud. Generally the AE signals generated during drilling with new bits are low level representing continuous AE. In addition, the penetration pressure is minimal and friction between rock and bit is low with a new bit. However, in the case of a worn bit, a larger portion of energy is converted into heat and sound and thus the AE signal is higher and rougher than new bit signals.



Above: AE signals detected from different states of the bit.

If successful, the approach will lead to improved drilling performance, faster drilling and avoidance of catastrophic bit failure.

Real Time Monitoring of Acoustic Emissions for Prediction of Mine Rock Failures

Dr Murat Karakus

The stability of some rock excavations such as pillars, shafts, galleries and slopes are critical to ensuring a safe working environment and long-term mining operations. The mining operation is a dynamic process, after initial excavation, and the health of the structures have to be monitored constantly to ensure their long-term stability. This project aims to develop an early-warning system for potential catastrophic rock failures based on micro-seismic activities within and around the structure.

The researchers' approach is to use an array of acoustic emission (AE) sensors and signal processing stations and apply advanced noise discrimination to filter out mechanical noises, thereby isolating the 'sounds' of the rock mass and in particular, 'listening' for the sound of fracture events. The research relates to developing new criteria for identifying potential rock failures based on acoustic emission rates and developing an understanding of failure due to shearing and due to compression and tension.

The benefit of the research will be that unexpected rock falls and collapses in underground mines or slope instability can be identified early and warning of collapse provided. For deeper and steeper mines, the research aims at improving safety systems and improving profitability by being able to safely steepen rock walls.

Ground Rubblisation: Improving Mining Haul Roads and Increasing Tyre Life and Fuel Efficiency

Associate Professor Mark Jaksa, Associate Professor Chaoshui Xu

Inattention to ground compaction can lead to significant problems. Without appropriate compaction control, built structures settle excessively and often expensive foundations are required to compensate for poor site preparation. Mine haulage roads that are ineffectively compacted increase the need for vehicle maintenance and limit vehicle operation as slower speeds are required. Mine roads made up rocks of more than a certain size can result in excessive wear or puncturing of tyres. A single tyre can cost up to \$A100,000 to replace.

One approach to avoid this problem is to develop improved techniques for rolling dynamic compaction, rubblising and in situ testing and validation of the compacted space.

Rolling dynamic compaction, in the form of the four-sided impact roller, enables the ground to be compacted more efficiently than conventional compaction equipment such as vibrating drum and sheepfoot rollers. Appropriately applied, rolling dynamic compaction can also be used to rubblise rock materials, creating a smaller particle size and denser ground surface which is particularly appropriate to mine haulage roads.

An impact roller is a potentially efficient compaction method because of its speed and the energy impacted to the ground. Working together with Broom's, researchers are investigating an impact roller with outstanding properties for superior compaction including its speed and the energy impacted to the ground.

A New Cost-Effective Active Structural Health Monitoring (SHM) Technology

Dr Nouné Melkounian, Mr Stan Woithe, Mr Ian Cates, Professor Michael Griffith, Mr Gary Bowman and Mr David Hale.

A new active SHM technology has been developed within the Resource Engineering Program which is specifically designed to perform under extreme conditions for mining applications as well as in massive civil structures and infrastructures. It carries out active SHM faster and at significantly lower costs than other currently available methods. This enables wide application of the new technology and conducting active SHM on demand. The technology is currently being patented, through the University of Adelaide's commercialisation arm, Adelaide Research and Innovation Pty Ltd (ARI). Australian and international companies and government agencies have expressed interest in using the technology.

Sponsorship Enables Research on Formation Damage

Professor Pavel Bedrikovetsky, Dr Zhenjiang You, Dr Alexander Badalyan, Dr Themis Carageorgos, Dr Abbas Zeinijahromi, Associate Professor Andrei Korousov, Aadytia Khanna, Alireza Keshavbarz.

Resource Engineering Program's Professor Pavel Bedrikovetski has undertaken research on a project titled Formation Damage and Improved Oil Recovery (2009 – 2011) sponsored by Santos Ltd. The main focus of the project is on finding cheap and effective methods of enhanced oil and gas recovery, particularly low salinity water injection provoking mobilisation of fines.

Other findings include insight into a new technology for well stimulation in coal beds by graded proppant injection and a new method to identify non-productive intervals in gas fields from pressure and temperature profiles in the well. Another research highlight includes the discovery of a new method to improve recovery during pressure depletion by injection of small water volume with a composition that allows it to lift reservoir fines.

Another highlight of this research includes the creation of a new method to predict oilfield scaling from simple and robust laboratory measurements and a new method to improve oil

recovery during waterflood by injection of water with a composition that allows it to lift reservoir fines.

Centre for Improved Business Performance - Making Good Decisions

Professor Steve Begg, Dr Matthew Welsh, Mr Bernardus Wahyuputro, Ms Belinda Bruza.

The Centre for Improved Business Performance (CIBP) is a research group within the Australian School of Petroleum which has an applied research focus on Making Good Decisions with a strong emphasis on the role of uncertainty in decision-making. It has been at the forefront of a new research area in the petroleum industry: integrating management-science and psychological research on decision making under uncertainty.

The CIBP has pursued two main, integrated, areas of research on better decision making under uncertainty: Theme one: Elicitation of Expert Judgements and Probability Assessments; and Theme two: Improved Decision Modelling and Valuation Under Uncertainty.

In 2011, under Theme one, Dr Welsh with colleagues Associate Professor Nick Burns and Associate Professor Paul Delfabbro (from the School of Psychology) and Professor Begg pursued research related to individual differences in decision making. Having looked at "group" behaviour, the work is now moving towards individual difference, with two main goals: The ability to identify people prone to particular biases and thus help with appropriate job assignment/hiring and possible remediation/training; and to find, develop and design useful reward/penalty/incentive systems to try to mitigate the magnitude/prevalence of biases – tuned to individuals.

Following on from work on base rate neglect, individual differences in number preferences (the tendency of people to prefer to give round numbers when estimating) were identified as a potential source of previously unknown error in estimation. Work on this phenomenon continues but initial research on a lay sample has confirmed that people use rounded numbers as an implicit indicator of low confidence and that this is, therefore, an additional source of information

regarding a person's level of uncertainty that needs to be taken into account when working with a person's estimates. More generally, we have developed a preliminary individual differences battery, testing a variety of cognitive and personality measures, in order to determine the extent to which these predict susceptibility to a range of specific biases and, thus, on appropriate personnel selection strategies and de-biasing methods.

The year 2011 also saw the start of industry field testing of a new and improved method of eliciting uncertainty assessments from technical experts (the MOLE, More-or-Less-Elicitation). To date, techniques for uncertainty elicitation require experts to answer questions many of them feel are "unnatural". The innovation in the MOLE comes from psychological insights as to the sorts of judgments the brain is good at performing, and developing an elicitation method based on these.

Under Theme two, Professor Begg, with colleagues Professor Reidar Bratvold (University of Stavanger) and Dr Bart Willigers (British Gas) published a paper on their research on valuing swing options in gas contracts using on Least Squares Monte Carlo Simulation. Although the particular application (swing options in gas contracts) is rather specific, the solution technique (valuation using Least Squares Monte Carlo Simulation) looks very promising as a reasonably robust and easy-to-implement methodology, applicable to a wide range of valuation problems that have embedded decision options, that can be exercised in response to evolving views of uncertainty. To date, techniques for valuing these sorts of decision options have had limited applicability due to restrictive assumptions or restriction to very simple problems with few decisions or uncertainties.

UNDERSTANDING OF INJECTIVITY DECLINE REDUCES COSTS ON OFFSHORE OIL PROJECTS

RESEARCH HIGHLIGHT

Injectivity formation damage with waterflooding using sea or produce water has been widely reported in leading oil areas such as the North Sea, the Gulf of Mexico and the Campos Basin in Brazil.

Damage is caused by the capture of solid or liquid particles by reservoir rock which consequently leads to permeability decline. This can also be caused by the formation of a low, permeable external filter cake.

Injectivity damage can be prevented or mitigated by injected water treatment which is an extremely expensive operation under offshore conditions. Water treatment costs remain high - even with the relocation of treatment facilities onto the sea floor.

Cost reduction for injected water treatment is of increasing importance worldwide due to increasing oil production by waterflooding, particularly from offshore deep-water oil fields.

Resource Engineering Program's Professor Pavel Bedrikovetsky and the Australian School of Petroleum's Thi Nguyen, Andrew Hage, John Ciccarelli and Mohammad ab Wahab worked on a paper to investigate the effects of injected water quality on waterflooding using horizontal wells. Other participants were from Schlumberger, Australia and Petrobras, Brazil.

The researchers found moderate injectivity decline was not too damaging for a waterflood project with long horizontal injectors where the initial injectivity was high. In this case, the injection of raw or poorly treated water might significantly reduce the cost of water treatment which is both cumbersome and expensive.

The effects of near-well formation damage on waterflood performance has long been recognised. Skin factor in injection wells grows with time due to reservoir clogging and cake formation. See Figure 1.

The researchers published a paper investigating the effects of injectivity skin in a system of horizontal wells induced from the injection of poorly-treated water in order to create incremental oil recovery.

The waterflood black-oil reservoir simulator (ECLIPSE100) was coupled with the analytical model for injectivity decline. The simulation results showed the noticeable effect of injectivity decline provided by the injection of poor quality water on the water cut history and the reservoir sweep by waterflooding.

A wide range of conclusions was drawn from the project research. It was found that injection of poor quality water created in-homogeneously distributed skin factor as the skin varied along the well according to the injection rate variable.

It was found that the induced skin yielded a partial homogenisation of the injectivity profile.

The researchers found poor quality water injection resulted in significant reduction of injected and produced water compared with clean water flooding with some increase in sweep efficiency while causing a total production rate reduction. This

negative was compensated by the positive effect of water cut reduction for lateral flood of a two-permeability-zone reservoir where the induced skin did not affect the oil production history.

Incremental recovery factor proved higher for lower viscosity oils yet the ratio between the incremental recovery factor and the recovery factor after 1 PVI increased with increasing oil viscosity.

The researchers gratefully acknowledge Petrobras as a generous sponsor of the injectivity damage project over many years.

REFERENCE

Bedrikovetsky P. G.^{a*}, Nguyen T. K. P., a Hage A.,^a, Ciccarelli J. R.,^a and ab Wahab M. a, Chang G.^b, de Souza A. L. S.,^c and Furtado C. A.,^c, 2011, 'Taking Advantage of Injectivity Decline for Improved Recovery During Waterflood with Horizontal Wells', *Journal of Petroleum Science and Engineering*, 78, 288-303. Summary from this publication, © Elsevier BV. All Rights reserved.

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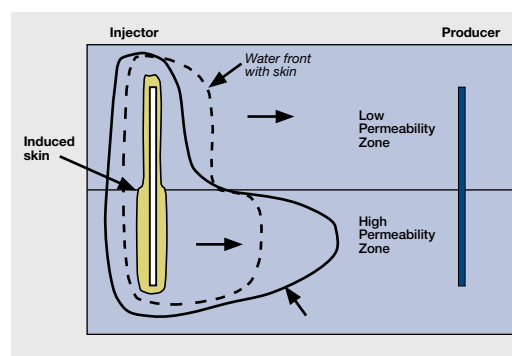



FIGURE 1

Schematic for improved sweep of low permeability zone due to skin, induced by injectivity of low quality water, in a two-permeability-zone reservoir.





ENVIRONMENTAL IMPACTS OF MINERAL AND ENERGY RESOURCES PROGRAM



Program Leader's Report

Associate Professor José Facelli

Mineral exploration and mining are increasing at an unprecedented rate across parts of Australia, and in particular in South Australia. More and more, these activities are occurring in relatively pristine areas – mostly in semi-arid or arid environments that are susceptible to disturbance. So the impacts on the natural system have the potential to be both large and long-term.

The Environment Impacts of Mineral and Energy Resources Development Program aims to ensure that an area's environmental biodiversity is known and how mining activity may affect the environment. Researchers need to understand the important ecosystem processes and how they might be disrupted and then use this knowledge to inform mineral exploration approaches. Through this, environmental impacts

can be avoided or minimised and ultimately the ecosystem can be fully restored afterwards.

Research in the program is aimed towards these goals, but achieving them is not without challenges. Natural systems are complex and heterogeneous and often little is known about the intact system before exploration and mining.

The research program currently involves two main areas:

- Endangered species conservation to understand where species of concern occur, what habitat they require and why and how mining activities might affect them. There are legislative requirements to minimise any detrimental effects on such species.



- Effective restoration post disturbance to assess methods of restoration and their effectiveness and investigate patterns of restoration – particularly in environments where changes can be slow.

Highlights

Root Distribution and Salinity and Soil Water Dynamics in a Chenopod Shrubland: Implications for Restoration Ecology

Associate Professor José M. Facelli, Professor David Chittleborough, Associate Professor Jenny Watling, Dr Emma Steggles, Dr Leanne Pound, Dr Laurence Clarke and Ms. Keli Payne.

Underground ecosystem processes (i.e. water distribution and use by plants) are central to arid land ecology, but they are complex and poorly understood. In post-mining reconstructed soil profiles these processes have to be re-established to make the system self sustained.

This project investigates the distribution of roots and the use of water by key species in open woodlands with shrub under-storey in natural and restored sites in South Australia. It also investigates the effects of salinity redistribution after restoration, and the consequences for revegetation outcomes. The information will help to understand long term dynamics of these extended ecosystems and provide insight in their possible responses to climate change. The project involves multidisciplinary collaboration between plant ecologists, plant ecophysiologicals, geopedologists and molecular biologists.

Iluka Resources has recently started mineral extraction in Ambrosia Mine, 230 km NW from Ceduna, SA. A trench 30 m deep, 1 km wide and 10 km long will be opened to extract mineral sands. The separation of the minerals (zirconium and titanium) uses hypersaline water from a paleochannel. The tailings are then returned to fill the bottom of the trench as hypersaline sludge. At a later stage the tailings are covered with layers of untreated subsoil and top soil before revegetation starts. The long-term success of the revegetation hinges upon the soil-salt-water-root interactions established in the restored area.

There are important questions regarding the water dynamics and root distribution in the soil that will determine the success of the restoration efforts. For example, species that need deep root systems to survive may be highly affected by the hypersaline conditions deeper in

the reconstructed profile, but species able to persist with shallow roots may be unaffected. However, salts may be brought to the surface or subsurface by hydraulic redistribution or deposition of plant litter with high salt content. The researchers have started the characterisation of root distribution of key species, measurements of water movement along roots and within the soil profile, and the experimental assessment of the response of various species to saline and hypersaline conditions. One of the most exciting developments so far is the use of molecular markers to determine the presence of root of various species at different depth, in collaboration with the Australian Centre for Ancient DNA. The techniques allow researchers to identify genetic markers to match above and below components of species in the area and to identify the presence of species from root material collected at various depths.

This project is supported by Iluka Resources Ltd. with an ARC Linkage Grant for continuation until 2015.

Conservation and Management of the Sandhill Dunnart

Associate Professor Sue Carthew and Ms Amanda McLean.

The recent expansion of mining activity in arid Australia has resulted in impacts to areas that have previously been pristine natural environments. This can have important effects on a range of native species that may potentially come under threat. This project focuses on the endangered dasyurid marsupial, the Sandhill Dunnart (*Sminthopsis psammophila*). A detailed management plan has not been implemented as little is currently known about this species.

The project is conducted in the Middleback Ranges of Eyre Peninsula in South Australia, where the species occurs in mallee dune habitat with an understorey of hummock grass (*Triodia irritans*). The project is jointly funded by both industry and environmental groups including OneSteel, Nature Foundation SA, Holsworth Wildlife Research Endowment, Sir Mark Mitchell Foundation, Field Naturalists Society of SA, and Australia and Pacific Science Foundation. The project has established a long-term study to investigate broad habitat



Home School

School of Earth and Environmental Sciences

preferences of the sandhill dunnart in areas with different fire history. Together with complementary information from other sites (e.g. Great Victorian Desert and Western Australia) this will produce management plans to guide industry activities that have minimal impact on this endangered species.

Mine Related Disturbances in Semi-Arid Ecosystems: Effects and Restoration Strategies

Dr Phillip Ainsley (Botanic Gardens of Adelaide), Dr Leanne Pound, Lindy Scott, Dr Emma Stegles

This project investigates the effects of disturbances produced by mining related activities such as mineral exploration. The plant component of the study focuses on the differences in the plant community structure and dynamics between linear clearances used for mineral prospecting and adjacent undisturbed sites. Another aspect of the project includes the study of the requirements of native species for germination and establishment in areas used for mineral sand mining.



SOCIO-ECONOMIC IMPACTS OF MINERAL AND ENERGY RESOURCES PROGRAM

Program Leader's Report

Associate Professor John Spoehr

The mineral and energy resources policy landscape has been a busy one over the last year with the rolling out of the Clean Energy Package, the Carbon Pollution Reduction Scheme and the Minerals Resource Rent Tax. All of these initiatives have significant social, economic and environmental implications which we need to better understand.

The fast pace of mineral and energy sector development presents significant challenges as well as opportunities. Recognising this, researchers from the Faculty of Humanities and Social Sciences and the Faculty of the Professions are establishing new collaborations to better understand the social and economic dimensions of growth and change in these major industrial sectors.

The researchers are fast-tracking the development of innovative industry and employment modelling and impact assessment capabilities to be able to better respond to the research needs of government, industry and community stakeholders.

Key areas of focus include:

- Understanding the socio-economic impacts of major energy and resource projects.
- Developing better ways of measuring the demand for skills in the mineral and energy resource sectors and understanding the drivers that underpin successful attraction and retention in the sectors.



Home Schools

Australian Workplace Innovation and Social Research Centre

Business School

School of Economics

School of History and Politics

Highlights

Extractive Industries: Ensuring a cultural license to operate

Dr Carlo Tognato

Since 2000, the World Bank estimates the contribution of the emerging economies to the global supply of minerals has increased at an accelerating pace. As extractive operations expand around the world, episodes of community resistance against them have also multiplied, with some resulting in a backlash beyond single operations. Dr Tognato, visiting Research Fellow at the Indo-Pacific Governance Research Centre, suggests the pursuit of a social license does not address cultural risk while that of a cultural licence to operate does. A sustained interaction between local companies and neighbouring communities may change local negative stereotypes

about these industries. The pursuit of 'cultural' license to operate for extractive corporations entails a close engagement with creative ventures. To engender positive representations of the extractive industries in the public imagination, an ample choice of cultural instruments is available including dramas, musicals, soap operas, documentaries, stand-up comedies, songs and caricatures.

Understanding the Two Speed Economy

Professor Kanishka Jayasuriya, Associate Professor Andrew Rosser, Associate Professor John Spoehr, Michael O'Neil.

A two-day workshop in December 2011 on 'Politics and the Two-Speed Economy – Transformation, Participation and Equality' convened by the Indo-Pacific Governance Research Centre brought together local and national researchers and policymakers to discuss

the challenges associated with the two-speed economy. Opened by Senator Penny Wong the workshop examined the political, economic and social dimensions of the two-speed economy.

OZ Minerals Research Partnership

Associate Professor John Spoehr, Dr Ann-Louise Hordacre and Dr Kate Barnett.

The Australian Workplace Innovation and Social Research Centre (WISeR) was commissioned by OZ Minerals to assist with the identification of the socio-economic dimensions and impacts of its Prominent Hill operations South Australia. Extensive interviews with key stakeholders in Coober Pedy and Adelaide were undertaken to inform an analysis of the benefits, costs and challenges associated with mining. This work is informing planned decommissioning as well as new projects.



FOCUS ON

Australian School of Petroleum

We focus here on the Australian School of Petroleum to highlight a key School which strongly contributes to research in IMER.

Vision

The vision of the Australian School of Petroleum is to be the destination of choice for students, staff and external stakeholders; to be a recognised school for the integration of petroleum engineering, petroleum geosciences and petroleum business; to have strong relationships with the petroleum industry locally, nationally and internationally; to engage the community on broader issues related to the development of petroleum accumulations; and to build world-class research groups.

Mission

- To provide high quality education for undergraduate and postgraduate students and industry professionals;
- To perform applied research with the overall aim of improving outcomes for the petroleum industry;
- To foster co-operation between the petroleum industry, academia and government for mutual benefit and of society at large.

Objectives

- To prepare undergraduate and postgraduate students for industry;
- To provide support to the petroleum industry through joint research;
- To develop co-operative ventures with Australian and international petroleum companies and government organisations.

Head of School's Overview

Professor Steve Begg

The Australian School of Petroleum (ASP) is Australia's pre-eminent centre for education, training and research in petroleum geoscience, engineering and management. It resulted from the merger of the School of Petroleum Engineering and Management (SPEM) and the National Centre for Petroleum Geology and Geophysics (NCPGG).

The School was created by the University of Adelaide in 2003 and offers two disciplines: geoscience; and petroleum engineering and management. ASP contributes research expertise to TRaX, SACGER and the Resource Engineering Program.

The gift from Santos of \$A25 million over a 10-year period from 2001 to set up the SPEM represented the largest single corporate contribution to the University of Adelaide at that time. It enabled building – from the ground up – a completely new School with a purpose-designed building; with staff recruited from academia and industry around the world to present training programs new in concept and content for Adelaide. It also allowed a focus on the practical needs of the international oil and gas industry for comprehensively trained engineers and managers.

ASP is the largest petroleum-focussed university program in the southern hemisphere and one of only a few institutions in the world offering fully-integrated teaching and research programs covering petroleum geoscience, engineering and management.

It is one of a small number of universities globally operating within a Master research and training agreement with ExxonMobil.

The Australian School of Petroleum has a number of research groups:

- The Reservoir Analogues Research Group (RARG) is led by Professor Bruce Ainsworth. It is the largest sedimentology/stratigraphy research group in the southern hemisphere. The group runs two major research projects funded

by consortiums of leading global oil and gas companies: Lake Eyre Basin Research Group (LEBARG) focussed on dryland reservoirs; and the WAVE Consortium focussed on the prediction of reservoir geometries and heterogeneities in marginal marine systems. RARG also provides expertise to the Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC);

- The Stress, Structure and Seismic Group (S3) within the ASP consists of petroleum geoscientists and engineers with expertise on petroleum geomechanics, tectonics, neotectonics and seismic interpretation;
- Professor Steve Begg oversees the Centre for Improved Business Performance (CIBP), which is a research 'club' that supports research into "Decision-Making Under Uncertainty";
- The ASP also has staff investigating the petrology and diagenesis of reservoirs associated with petroleum and CO₂ sequestration;
- Seals Research at the ASP consists of a group of petroleum geoscientists characterising fine grained sediments in terms of mercury injection capillary pressure (MICP) seal capacity, scanning electron microscopy (SEM) and X-ray mineralogy;
- Other areas of research are Improved Oil Recovery, Formation Damage and Reservoir Simulation. This encompasses elements such as fines-assisted waterflooding and also involves water production management during oil and gas field depletion. The technologies are based on a new theory of fines migration in porous media. Other areas of research include flow visualisation of miscible CO₂ flooding under gravity domination, a project which has dual applications for EOR and CO₂ sequestration. The findings can be applied at larger scales through dimensional analysis. A new methodology has also been



developed and tested by a combination of parameterisation, Bayesian regularisation and different evolutionary optimisation with the automatic history matching in reservoir simulation using a genetic algorithm.

- Within the area of unconventional reservoirs, a new technology for well simulation in coal seam gas (CSG) formations and geothermal reservoirs has been proposed and modelled. Fines migration has been investigated for geothermal wells and used for exploration of formation damage. Recently-developed methods of gas well rate determinations from temperature profiles in the gas column have been successfully applied. A project on production data analysis in shale gas and tight gas reservoirs looks at reliable reserve estimations and reservoir characterisation in unconventional reservoirs achieved through type curve matching techniques.
- Other projects within unconventional reservoirs include experiments and modelling of thermal recovery of CSG, a new recovery technique developed for the elimination of dewatering operations and for improving gas recovery by combination of sedimentary hot aquifers and CSG reservoirs. Other work involves the petrophysical evaluation of shale gas reservoirs where shale samples in the Cooper Basin have been studied to characterise their free porosity, permeability and adsorption behaviour through quantitative evaluation of minerals by scanning electron microscopy and other imaging methods.

- The 'GeoFrac Consortium Project' aims to increase recovery of natural gas from unconventional reservoirs by enhanced targeting of promising areas in reservoirs. It aims to reduce the cost of drilling for gas production and reduce the environmental and societal impact of developing unconventional reservoirs by minimising the number of wells that need to be drilled. This project is outlined in detail in another part of this 2011 Annual Report. The project will be undertaken from May 2012 with an expected completion date of April 2015.
- CO2CRC staff in the ASP are predominantly involved in storage projects comprising both fundamental and applied areas of research. The prime focus of the research is the selection of storage sites, their adequate characterisation with respect to storage capacity and containment; and an understanding of the physical and chemical processes which take place during and after injection.

The Australian School of Petroleum has many key collaborators spanning the globe including Anglo American, BAPETCO, BHP Billiton, BP, Chevron, ConocoPhillips, ExxonMobil, OMV,



Petronas, Rio Tinto Limited, SASOIL, Shell, Statoil and Woodside Energy to name a few.

Staff and students are active in professional societies including the Society of Petroleum Engineers (SPE), the American Association of Petroleum Geologists (AAPG), and the Petroleum Exploration Society of Australia (PEGA).

The School offers short courses specifically for delivery to industry professionals, usually delivered as in-house courses for the staff of a client company. Engineering short courses

offered include: Decision Making and Risk Analysis; Fiscal Regimes; Value of Information and Flexibility; Psychological Aspects of Expert Judgements and Uncertainty Assessment; and Portfolio Management. Geoscience courses include: Petroleum Geomechanics, Introduction to Reflection Seismology; Evaluation of Reservoirs, Seals and Pay; Sedimentology and Sequence Stratigraphy and Basic Principles of Petroleum Exploration for Non-technical Staff. Some courses run for up to five days, others are one day only.

ASP Advisory Board

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Peter Vincent

Chief Geoscientist (Exploration and Subsurface) Santos Ltd

Dale Womacks

Frac/Acid Principal Technical Professional, Halliburton

Zaidah M Zain

Student Advisor Australia and New Zealand, Petronas

Highlights

The WAVE Consortium

The WAVE Consortium is a major project focussed on the Reservoir Architecture and Heterogeneity in Marginal Marine Systems. In 2011, it entered its second phase in partnership with 12 companies including Chevron, Shell, BP, Statoil, OMV, Woodside, Nexen, Apache, BG Group, BHP Billiton, Todd Energy and BAPETCO. Phases I and II of the project have brought in funding of over \$A3 million.

Wave-influenced shallow marine systems are generally regarded to form good quality, highly continuous reservoirs. However tidal and fluvial processes acting in these depositional environments can introduce significant levels of heterogeneity which can lead to uncertainties in predicting the distribution and lateral continuity of reservoir facies.

The WAVE Consortium aims to better characterise mixed-influence (wave, tidal and fluvial) processes coastal depositional environments and to analyse the potential impact of heterogeneities (shale and cemented zones) on reservoir connectivity and compartmentalisation and how it can be best predicted and mitigated in the subsurface.

The project is led by Professor of Petroleum Geology Bruce Ainsworth.

Phase I (April 2008 to August 2010) delivered results from three different field areas and defined a new process-based classification system for marginal marine systems integrated into the WAVE Knowledgebase. Predictive aspects of this WAVE Knowledgebase can be used in exploration, development and production settings.

Phase II (from April 2011 to March 2014) aims to focus on further development of the WAVE Knowledgebase via improved ichnological data integration, further geometrical data population and focussed fieldwork in Australia's Gulf of Carpentaria, Egypt's Fayoum and Canada's Drumheller. Detailed static 3D reservoir models will be developed from each of these field areas.

Key Phase II deliverables include the completion of the WAVE Knowledgebase population for low accommodation settings; initiation of population of the Knowledgebase for high accommodation settings and fine-tuning of the predictive capabilities to meet the needs of individual sponsors.

ARC Success

Dr Mark Tingay gained an Australian Research Council (ARC) Discovery Project announced late 2011. The project brings \$A380,000 funding over three years (2012 to 2014).

Dr Tingay is the chief investigator for the project "Contemporary stress and tectonics of Australia". He will work with Adjunct Professor Oliver Heidbach of GeoForschungsZentrum Potsdam, Germany.

The project will conduct a detailed examination of the state and controls on present-day tectonic stress in Australia. Tectonic stresses are a primary control on deformation in the Earth and this project has direct applications for earthquake hazard assessment, mine stability, production of petroleum and geothermal energy and carbon dioxide sequestration.

To date, efforts to model the stress pattern, and thus estimate the forces controlling stresses in Australia, have been unable to replicate the stress orientations in some areas and often do not match with observed stress magnitudes.

This project will collect stress data in previously unexamined areas of Australia such as coal seam gas regions, minerals and geothermal provinces, as well as updating the stress information in petroleum regions.

The project will provide the first widespread and comprehensive dataset of present-day tectonic stress orientations and magnitudes in Australia.

Dr Tingay was announced as a 2011 Young Tall Poppy Science Award in August, 2011. The Australian Institute of Policy and Science created the Tall Poppy campaign to celebrate achievement in the sciences and communicating the passion and purpose of Australia's finest scientists to a wider audience.

Distinguished Lecture Tour

ASP Head of School, Professor Steve Begg completed a Society of Petroleum Engineers (SPE) Distinguished Lecture tour with visits to Asian cities including Singapore, Baku, Tokyo, Daqing and Ho Chi Minh.

Leadership at Top Industry Research Conference

Professor Begg also gained a prestigious invitation to lead four sessions at the SPE' invitation-only event in Dubai in December 2011. Dr Matthew Welsh, a post doctorate Cognitive Scientist employed through Professor Begg's CIBP research program also led a session.

The events, known as Forums, bring together global experts in the field from industry to discuss current research, future trends and emerging areas. This forum was titled "Uncertainty Management and Risk Mitigation Over Asset Lifecycles".

Professor Begg was the opening Keynote Speaker and a Discussion Leader at three other sessions. His topics ranged from the psychological aspects of assessing uncertainty to methods of modelling its impacts on value and ultimately managing those impacts to create value by risk mitigation and opportunity capture.

The Society of Petroleum Engineers is the largest individual-member organisation serving managers, engineers, scientists and other professionals worldwide in the upstream segment of the oil and gas industry.

▶ #1 TEST WELL

Santos Petroleum Engineering Building
North Terrace Campus



Depth 7
Bottom
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GEOFRAC CONSORTIUM PROJECT DEVELOPS

INDUSTRY PARTNERSHIP PROJECT

In 2011, IMER researchers at the University of Adelaide, recognised their capabilities could address industry's need to improve understanding of different geomechanical and geochemical contributions to variations in wellbore productivity from unconventional reservoirs.

Identified as the GeoFrac Consortium Project, a series of meetings were held in May and June 2011 to develop the concept, which became a joint IMER-Australian School of Petroleum initiative.

The project will be undertaken from May 2012 with an expected completion date of April 2015.

The project is formally called 'Variations in Wellbore Productivity from Unconventional Reservoirs – The GeoFrac Consortium Project'.

Development of existing 'resource plays' such as shale gas, coal seam gas and basin-centre or tight gas is often done with pattern drilling based on the assumption the reservoir is homogeneous with spatially uniform reservoir quality. This pattern drilling or 'manufacturing mode' approach does lower the cost per development well.

Performance analysis using those development wells' production data shows very significant variations in well flow rates that is likely to be caused by spatial changes in reservoir quality. Many of these resource plays are marginally economic and would be more profitable if companies could predict and drill the more profitable well locations and avoid poor well locations.

The project aims also to increase recovery from natural gas from unconventional reservoirs by enhanced targeting of promising areas in reservoirs. It aims to reduce the cost of drilling for gas production and reduce the environmental and societal impact of developing unconventional reservoirs by minimising the number of wells that need to be drilled.

Project leader Dr Dennis Cooke said the GeoFrac project results can also be used for making geothermal reservoirs economically attractive.

IMER researchers involved in the project offer cross-disciplinary areas of expertise.

Dr Cooke is the Program Manager, Unconventional Resources at the University of Adelaide's School of Petroleum. He has more than 25 years' experience in the oil and gas industry doing research, exploration and development. Research interests include seismic imaging, seismic inversion and geomechanical modelling.

Other contributors to the Geofrac project include TRaX's Dr Mark Tingay, Resource Engineering Program's Associate Professor Chaoshui Xu, Associate Professor Hamid Sheikh and Dr Murat Karakus.

Professor Martin Kennedy is a key contributor to the Geofrac project and is also the Chief Investigator of a complementary Australian Research Council Linkage grant, submitted in 2011. This proposal, titled "From organo-mineral nanocomposite to Australian basins; an integrated approach to unconventional gas exploration and development" will be a major research effort to identify the geological processes critical to carbon burial, diagenesis, and hydrocarbon generation in shale. It proposes to use new microbeam technologies to allow the nano-scale organomineral interactions characteristic of shale to be studied for the first time, hence increasing the fundamental understanding of carbon sequestration which can then be used to direct enhanced exploration tools for specific use in Australian Basins. Professor Kennedy is a staff member of the Centre for Tectonics, Resources and Exploration.

Potential Geofrac sponsors are invited to contact Dr Dennis Cooke for details on dennis.cooke@adelaide.edu.au



FOCUS ON

Centre for Advanced Nanomaterials

Vision

The Centre undertakes ground-breaking trans-disciplinary research at the forefront of materials science.

Mission

The Centre provides an environment to foster, connect and harness research activities centred on the synthesis, processing and study of nanomaterials which have the ability to create disruptive technologies essential to Australian industries.

Objectives

- To develop the fundamental research in nanomaterials that will lead to disruptive technologies that will benefit Australian industries;
- To develop the Centre into a nationally leading research centre and an ARC Centre of Excellence.
- Increase the profile of the University of Adelaide by publishing results in leading international journals;
- Attract high quality international PhD students and independently funded research fellows to the University of Adelaide

Research Leaders

Dr Christian Doonan, Dr Christopher Sumbly

The Centre for Advanced Nanomaterials (CAN), a stand alone Centre of the University of Adelaide, was established in 2011.

Key research themes include: chemical and electrical energy storage; energy waste management; heterogenous catalysis; and nanoporous materials for gas separations.

The Centre has been established for an initial period of three years with Dr Christian Doonan as inaugural Director. CAN, a separate Centre of the University of Adelaide, has a strong scientific affiliation with IMER. The leadership grouping comprises Dr Chris Sumbly, Professor Mark Biggs, Professor Jim Hill and Professor Shizhang Qiao.

Researchers with expertise in materials chemistry, chemical engineering and mathematical modelling, design and apply materials to solve real-world challenges.

By 2050 the world's population is expected to reach eight billion. This will require between 30 to 60 terawatts (TW) per year of energy. Current energy generation based predominantly on fossil fuels produces 13 TW per year. Over the last 40 years, this has contributed to a 14% rise in atmospheric CO₂.

Further, the demand for resources such as minerals, water, food and chemical feedstocks is increasing.

A major challenge will be to deliver energy from new technologies in a clean and sustainable manner and to develop renewable, non-fossil fuel alternatives for chemical feedstocks. Furthermore, to achieve a cleaner energy future, materials that form the basic technologies for CO₂ capture will be required. In the transport sector, high density energy storage is necessary while the chemical industry is searching for more efficient and economical processes to produce commodity and fine chemicals.

Nanomaterials have unique structural and functional properties and are poised to revolutionise the field of materials science.

Porous nanomaterials are being developed within the University of Adelaide to act as highly-efficient adsorbants for the processes involved

in the separation and storage of CO₂. It is anticipated such materials will dramatically lower the energy costs associated with capturing CO₂. Ultimately, materials that catalyse the reduction of CO₂ into value-added products, such as fuels or chemical feedstocks, will also be desired.

Analogous materials are being investigated as electrodes for batteries which will improve their overall energy density and reduce production costs as catalyst supports and membranes for fuel cells.

CAN is hosted within the School of Chemistry and Physics with access to state-of-the-art research laboratories including solid-state materials synthesis and characterisation laboratory, the Bragg Crystallography Facility for solid-state structure determination and characterisation, a femtosecond laser facility, and supercomputing facilities.

Major research areas of focus include:

Chemical and Electrical Energy Storage

Two areas where porous nanostructured materials make a significant impact in energy science and technology are fuel cells (chemical storage) and batteries (electrical storage) technologies. CAN uses a novel approach employing predictive modelling and computational simulations to provide a design blueprint for the 3D porous architectures that compose fuel cell membranes, catalysis and battery electrodes. These components are then synthesised using 'bottom up' building block techniques established by Centre members.

Energy Waste Management

The need to reduce greenhouse gas emissions is an international issue. Relying on inefficient separation technologies, current pilot projects look to find approaches to store carbon dioxide in geological features. CAN's activities include the use of new crystalline nanomaterials to efficiently separate carbon dioxide with low-energy penalties

from flue gases. CAN will also use crystalline nanomaterials to recycle carbon dioxide in reusable commodity chemical feedstocks or fuels.

Heterogenous Catalysis

The overarching aim of this research is to develop a general method for synthesising catalysts based on open nanostructured materials such as metal-organic frameworks and covalent organic frameworks. These materials will incorporate the advantages of both heterogeneous catalysts offering stability and ease of product separation, and homogeneous catalytic systems with well-defined structures. Heterogeneous catalysts are ubiquitous in industry, however a significant drawback is that their structures are not precisely understood, thus exactly how catalysis is performed remains unclear. Subsequently, improvements in performance are typically made by trial-and-error methods. CAN facilitates the development of these novel hybrid catalysts by using a multifarious modelling-simulation-synthesis approach.

Gas Separations

The ability to separate gas mixtures is fundamental to numerous industries. In the energy generation sector, natural gas wells with significant levels of carbon dioxide require 'sweetening'; adsorbents capable of separating carbon dioxide from methane are highly desirable. Carbon dioxide and nitrogen separations are essential for energy waste management. Within the chemical industry, gas separations are required such as ethane and ethylene. A fundamental understanding of the requirements for efficient separation are a focus of CAN through combined theoretical, modelling and experimental investigations. This knowledge can be implemented to generate disruptive approaches for gas separation relying on crystalline porous materials.

RESEARCHERS DEMONSTRATE REVERSIBLE GUEST-INDUCED BREATHING BEHAVIOUR FOR A SILVER PCP

RESEARCH HIGHLIGHT

The University of Adelaide researchers* Dr Chris Sumbly and Mr Witold Bloch have demonstrated for the first time, a reversible guest-induced breathing behaviour for a silver(I) porous coordination polymer (PCP). This work was undertaken through the Centre for Advanced Nanomaterials.

PCPs exhibiting a degree of flexibility or dynamic behaviour have been extensively studied over the last decade. Their dynamic properties make them useful for applications which are not easily accessible by rigid frameworks such as efficient gas separations or sensing.

Examples of dynamic behaviour include drastic solid-state expansion, contraction or swelling as well as reversible and non-reversible crystal-to-crystal transformations. Such transformations occur in these solid-state materials with retention of structural regularity.

Dynamic materials, like those under investigation at the University of Adelaide, have been studied in the context of gas storage and separation where crystal-to-crystal transformations can be used to reversibly enhance or diminish a PCPs' capacity for gas uptake. The ability to alter the size of pore apertures or channels is also relevant to catalysis in PCPs.

New materials are sought to extend the types of dynamic behaviour that could be used for these applications.

The researchers found two different types of dynamic behaviour in a 3-D PCP (PCP-1) formed from an organic molecule and a silver(I) salt. They found the as-synthesised PCP (PCP-1a) has a flexible structure with a sodalite topology. This can facilitate either guest-induced expansion and contraction in the solid-state or a transformation into a 2-D framework upon complete desolvation. See figures 1 and 2.

To the researchers' knowledge, this work represents an unprecedented dynamic behaviour in the context of a 3-D silver(I) PCP, in particular the first example of a silver(I) PCP that displays solid-state breathing.

The researchers observed that crystal-to-crystal solvent exchange occurred in a facile manner while the material retained structural regularity.

The findings from this work provide the proof-of-principle for the design of more robust dynamic porous coordination polymers that are applicable to the separation of particular solvents and gases. In particular that material reported might be capable of application to separating low molecular weight hydrocarbons, principally those capable of coordinating silver(I) from a mixture of compounds.

Dr Sumbly acknowledges an ARC Future Fellowship for supporting this research.

REFERENCE

Summarised and edited excerpt. *Sumbly C. J., Bloch W. M., 2012 (accepted in 2011) "Guest-induced crystal-to-crystal expansion and contraction of a 3D porous coordination polymer" *ChemComm*, 48, p2534-2536, 2012 - Reproduced by permission of the Royal Society of Chemistry.

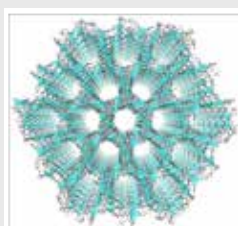


Figure 1

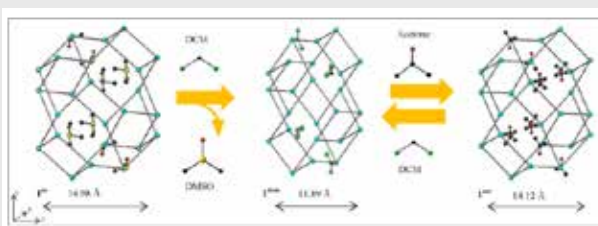


Figure 2

FIGURES

Figure 1: The 3-D PCP (PCP-1) formed from an organic molecule and a silver(I) salt.

Figure 2: Solid-state breathing showing the contraction of the channel walls by about 20%.





Cooperative Research Centres at the University of Adelaide

The University of Adelaide houses the leading research activities of three Cooperative Research Centres (CRCs) relevant to research in mineral and energy resources. These are the CRC for Greenhouse Gas Technologies (CO₂CRC), Deep Exploration Technologies CRC (DET CRC) and the Energy Pipelines CRC (EPCRC).

While these CRCs have working links into the Centres and Schools affiliated with IMER, the Institute also works directly with the key researchers in these areas to maximise

benefits to the CRC researchers, the Institute and the University of Adelaide as a whole.

The Australian Federal Government's CRC Program provides funding to build critical mass in research ventures between end-users and researchers which tackle clearly-articulated, major challenges for the end-users. CRCs pursue solutions to these challenges that are innovative, of high impact and capable of being effectively deployed by the end-users.

Energy Pipelines Cooperative Research Centre EP CRC

Program Leader

Associate Professor Peter Ashman

Modern economies are founded on the premise of cheap, abundant and easily transportable energy. Over the past 200 years, fossil fuels – including petroleum, natural gas and coal – have doubled both as primary energy sources and as energy carriers.

This has underpinned society's advances in technology and lifestyle. However, the issues of increasing concentrations of atmospheric carbon dioxide and energy security, has meant society is looking beyond fossil fuels towards more sustainable primary energy sources.

Many alternate energy sources such as wind power, solar energy and geothermal energy have the drawback of locations which are remote from existing electricity transmission networks. The use of electricity as an energy carrier, may also in some cases, introduce additional energy conversion steps which unavoidably result in a loss of overall energy efficiency and thus higher energy costs.

There is a growing interest in both non-fossil-derived carbon based fuels such as methanol or ethanol and non-carbon based energy carriers such as hydrogen or ammonia. There is also interest in the options to either transport

them in new, dedicated pipelines such as H₂ and NH₃ or in existing natural gas pipelines which may be used for blends of H₂ with conventional natural gas.

The Energy Pipelines Cooperative Research Centre (EPCRC) was established in 2010 to undertake research and education of relevance to the energy pipeline industry in Australia. There are 30,000km of high-pressure natural gas transmission pipelines in Australia supplying about 22 per cent of Australia's energy needs. It is clear Australia's energy pipeline network will not be able to support the country's economic prosperity in a carbon and finance constrained future unless new technologies are created to extend the life of the existing, ageing network. New pipelines are also needed with the use of new technologies.

EPCRC is focussed on four research programs: more efficient use of materials for energy pipelines; the extension of safe operating life for both new and existing energy pipelines; additional pipeline design and construction; and public safety and security of supply issues.



Cooperative Research Centre for Greenhouse Gas Technologies CO2CRC

Chief Scientist

Professor John Kaldi

The Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC) is one of the world's leading research organisations focussed on carbon dioxide capture and storage (CCS).

Carbon capture and storage is a hot topic because of its potential to make substantive cuts in CO₂ emissions from large industrial sources such as power stations, aluminium smelting, gas processing and cement plants.

CO2CRC collaborates with leading international and national organisations and CCS experts to conduct world-class research into carbon capture and storage. Industry partners include global and nationally significant organisations such as Anglo American, BG, BHP Billiton, BP, Chevron, Inpex, KIGAM, Mitsui, QER, Rio Tinto, Sasol, Schlumberger, Shell, Solid Energy, Stanwell, Total and Xstrata.

The CO2CRC commenced activities in 1998 and has grown to nearly 200 researchers with an annual budget of over \$22 million. The CO2CRC was recently renewed for funding of the program to 2015. Professor John Kaldi, of the Australian School of Petroleum, continues as a member of the Executive of CO2CRC, and is its Chief Scientist.

The 'jewel in the crown' of the CO2CRC is the CO2CRC Otway Project, Australia's first and to date only, active CO₂ storage facility. Located in the Otway Basin of southwest Victoria, the Otway Project has successfully injected over 60,000 tonnes of CO₂ more than 2000m below the surface.

CO2CRC staff at the University of Adelaide are predominantly involved in storage projects comprising both fundamental and applied areas of research. The prime focus of the research is the selection of storage sites, their adequate characterisation with respect to storage capacity and containment; and an understanding of the physical and chemical processes which take place during and after injection. In addition, using the Otway Project as a field laboratory, the group's research activities provide an understanding of the technologies available for monitoring the movement of stored CO₂ and an assessment of the risks associated with all phases of the process.



Researchers are focusing on the following areas:

- Technologies for assessing sites for CO₂ storage;
- Reservoir and Seal Characterisation and Stratigraphy;
- Geomechanics and Petrophysics;
- Geochemistry and Hydrodynamics;
- Reservoir Engineering;
- Investigation of onshore and offshore natural analogues for CO₂ geosequestration.

EVALUATION OF THE OTWAY BASIN AS A GEOLOGICAL HOST FOR CO₂ STORAGE

RESEARCH HIGHLIGHT

The Australian Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC) is carrying out a field-scale carbon dioxide (CO₂) sequestration demonstration project in the Otway Basin, South-East Australia. This evaluates the Otway Basin as a geological host for CO₂ storage.

During stage 1 of this project CO₂-rich gas (~80 mol% CO₂; ~20 mol% CH₄) was extracted from a gas well. The gas was then injected into a newly drilled well and was safely stored two kilometres below the Earth's surface.

Vadose zone soil gas monitoring has been proposed as one of the sentinel monitoring systems to detect leakage of carbon dioxide from a storage reservoir. In order to effectively monitor soil gases during and after the injection of CO₂ into the geological subsurface, baseline characterisation of the study area took place in 2007 and 2008. The baseline study characterised background soil gas concentration and other chemical attributes, and identified potential zones where leakage may occur. Through the baseline characterisation study, a methodology has been developed to suit the challenges of the study area, field conditions and the nature of the soil gas. The baseline characterisation also allowed a differentiation of the existing CO₂ from

the injected CO₂ when post-injection monitoring took place in 2009-2011 and will continue in 2012 and beyond.

Carbon dioxide, methane and helium were the main gases analysed and for much of the time CH₄ concentrations were too low for accurate analysis. Carbon dioxide concentrations ranged from atmospheric background levels of 0.033% up to about 10% of the total soil gas. The δ¹³C_{CO₂} values are typical for organic matter decomposition as the main source of the CO₂ in the soil gas.

Modern radiocarbon ages, determined from 14C analysis, and low helium concentrations support the conclusion that CO₂ in the soil gas is predominantly from modern organic sources (see Fig. 1).

The findings of the five soil gas surveys carried out between 2007 and 2011 in the CO2CRC Otway Project area are:

- Vadose zone soil gas sampling is an effective method for studying variations in gas chemistry.
- CO₂ composition and isotopic analysis paired with helium and/or tracer analysis is most effective in the determination of the CO₂ source.
- CO₂ concentrations within the soil gas are moderately high, ranging over three orders of magnitude.

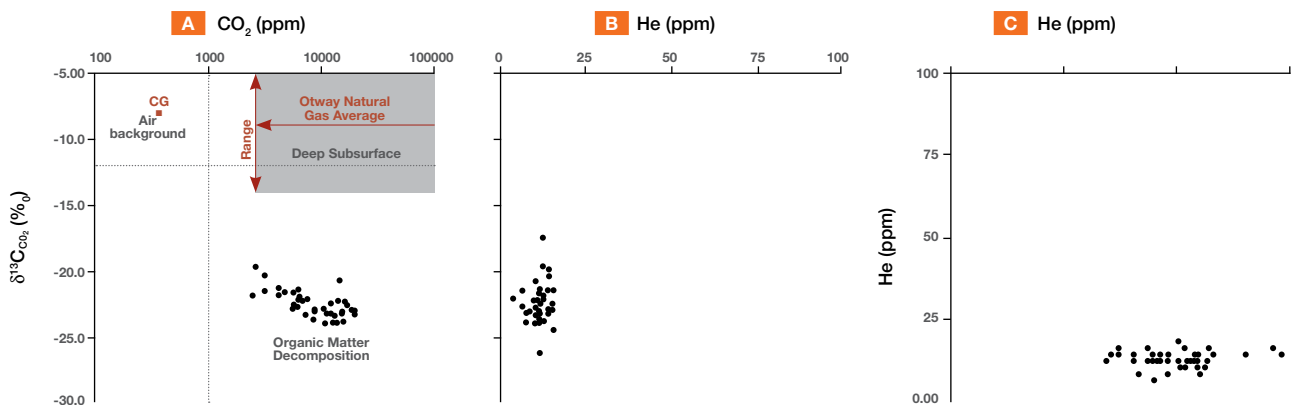
- The source of CO₂ in soil gas is a combination of both organic matter decomposition and weathering of the Port Campbell Limestone.
- Deep subsurface CO₂ is not present in the soil gas samples taken during baseline and assurance monitoring surveys.

REFERENCES

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- Dodds, K, Etheridge, D, Henning, A, Watson, M, Rogers, C, Boreham, C, Stalker, L, Urosevic, M and Kecip, A, 2007. Monitoring and verification in the Otway Basin Pilot Project: approach, results and plans. CO2CRC Presentation PRZ07-0554.
- Schacht, U, Regan, M, Boreham, C and Sharma, S, 2011. CO2CRC Otway Project - Soil gas baseline and assurance monitoring 2007-2010. *Energy Procedia* 4: 3346-3353.

FIGURE 1

(A) CO₂ concentrations vs. δ¹³C_{CO₂} values, (B) He concentrations vs. δ¹³C_{CO₂} values and (C) CO₂ vs. He concentrations of the 2010 survey subset for isotopic and He analysis (Schacht et al., 2011). Cape Grim atmospheric composition (CG) is according to Dodds et al. (2007) and Otway natural gas composition according to Boreham (2001).



Deep Exploration Technologies Cooperative Research Centre DET CRC

Research Leader Professor David Giles

The Deep Exploration Technologies Cooperative Research Centre (DET CRC) was launched late 2010 to meet the increasing long-term global demand for mineral products, a demand which can only be satisfied by discovering new mineral deposits (greenfields exploration) and extending known deposits (brownfields exploration) under deep cover rocks.

Deep mineral exploration through barren cover rocks must become more successful, more cost-effective, more environmentally-friendly and be undertaken with less safety risks, if Australian mining is to be sustainable. DET CRC aims to develop technologies and workflows which will address these issues and be commercialised for routine use in mineral exploration.

The three key research programs of DET CRC relate to drilling; logging and sensing; and targeting.

The **drilling program** aims to reduce cost and environmental impact and increase the safety of mineral exploration drilling by delivering incremental and transformational changes in drilling technology. The end product will be a revolutionary new drilling platform, bringing coil-tube drilling into the mineral exploration sector.

The **logging and sensing program** aims to increase the value of drill holes by real-time down-hole or top-of-hole evaluation of intersected

mineralisation, detect near misses and enable immediate follow-up drilling by real-time refinement of exploration and life-of-mine models.

The **targeting program** aims to ensure drill holes are placed to maximise their success and the knowledge they produce by developing new seismic and geochemical methods for exploration and integrating such into new exploration workflows in drilling, logging and sensing.

IMER members from the School of Civil, Environmental and Mining Engineering and the School of Earth and Environmental Sciences have been involved with DET CRC since its inception.

The University of Adelaide personnel are involved in a number of projects within DET CRC aimed at:

- Overcoming the technical and cost barriers that have prevented the widespread application of seismic methods in mineral exploration;
- Determining the geochemical and mineralogical signature of hypogene mineral systems and the dispersion pathways for the components of those mineral systems within overlying deep cover rocks;
- Developing sampling and analytical workflows which allow the rapid assessment of mineral system footprints in deeply-buried environments during drilling;



- Collecting and integrating regional-scale data to produce mineral potential maps of highly-prospective mineral provinces in South Australia. This data can be used to refine drilling, sampling and analytical methods in the deep exploration search area;
- Investigating the advantages of co-located seismic and magnetotelluric (MT) surveys in terms of mutual constraints and joint inversion that significantly improve geological interpretation over that which can be achieved from a single technique;
- Developing models of the bit-rock interface to improve the design of drill bits and choice of drilling parameters in order to maximise drilling efficiency;
- Establishing an accessible facility, at Bruckunga in the Adelaide Hills, for field testing of new drilling and logging techniques and for vocational drilling.



AFFILIATES The DET CRC Affiliates program is administered by AMIRA International

SUPPLIER AFFILIATES

Australian Drilling Industry Association

CSA Global

Diamant Drilling Services

Diarotech

Downhole Surveys

Easternwell

Fugro

GeoMole

Globaltech

HiSeis

JKTech

Olympus Innov-X

Sandvik

Teakle Composites

PRODUCER AFFILIATES

ABM Resources

Carpentaria Exploration

Heathgate Resources

Minotaur Exploration

Nautilus Minerals

Paladin Energy

Rex Minerals

Tanami Gold

GEOLOGICAL SURVEY AFFILIATES

Geological Survey of New South Wales

Geological Survey of Queensland

Geological Survey of Western Australia

Geoscience Australia

GeoScience Victoria

Northern Territory Geological Survey

Key Major Projects

IMER researchers gained support from prominent global companies, government and research partners in a large number of projects during 2011.

Here are details of key projects either initiated in 2011 or continuing as active projects through the year:

Centre for Energy Technology

The Adelaide Airport Limited Industry Partnership

Sponsor: Adelaide Airport Limited

Chief Investigator: Prof Gus Nathan

Detailed understanding of the behaviour of soot in, and emission from, turbulent flames and fires

Sponsor: Australian Research Council

Chief Investigator: Prof Gus Nathan

Energy from microalgae - industrial scale development and downstream processing of co-products

Sponsor: Australian Research Council

Chief Investigators: Dr David Lewis, Dr Stephen Clarke, A/Prof Peter Ashman

Enhanced mixing of turbulent jet flames via side lateral injection

Sponsor: Australian Research Council

Chief Investigator: A/Prof Bassam Dally

Establishment of a Chair and Associated Activities in Process Safety and Integrity Management (PSIM)

Sponsor: SafeWork SA, Government of South Australia

Chief Investigator: A/Prof Peter Ashman

Establishment of Senior Academic in Process Safety and Integrity Management

Sponsors: Adelaide Brighton Ltd, BHP Billiton, GPA Engineering, Mayne Pharma, Origin Energy, Department for Manufacturing, Innovation, Trade, Resources and Energy, Government of South Australia, Santos Ltd

Chief Investigator: A/Prof Peter Ashman

A fully integrated process for biodiesel production from microalgae in saline water

Sponsor: Asia Pacific Partnership on Clean Development and Climate

Chief Investigator: A/Prof Peter Ashman

Growth optimisation and scale up of specified algal strain

Sponsor: SQC Pty Ltd

Chief Investigator: Dr David Lewis

Investigation of the coupled dependence of concentrated solar radiation and combustion in a novel solar hybrid technology

Sponsor: Australian Research Council

Chief Investigator: Prof Gus Nathan

The mechanics of quiet airfoils

Sponsor: Australian Research Council

Chief Investigator: Dr Con Doolan, Prof Colin Hansen

Metal-organic frameworks as heterogenous catalytic systems

Sponsor: Australian Research Council

Chief Investigators: Dr Christian Doonan, Dr Christopher Sumbly

Multi-dimensional, high-speed laser imaging facility for fluids and combustion

Sponsor: Australian Research Council

Chief Investigators: Dr Zeyad Alwahabi, Prof Assaad Masri

Multiscale models of nanoporous carbons for a sustainable future

Sponsor: Australian Research Council

Chief Investigator: Prof Mark Biggs

A novel approach to controlling boundary-layer separation

Sponsor: Australian Research Council

Chief Investigators: Dr James Denier, Prof Andrew Bassom

Open framework organic materials for CO₂ capture and conversion

Sponsor: Australian Research Council

Chief Investigator: Dr Christian Doonan

Scramjet-based access-to-space systems

Sponsor: Department of Industry, Innovation, Science, Research and Tertiary Education, Australian Government

Chief Investigator: Dr Con Doolan

Tomography of inclined stress corrosion cracking

Sponsor: Energy Pipelines Cooperative Research Centre

Chief Investigator: Dr Erwin Gamboa

Understanding and predicting submarine hydrofoil noise

Sponsor: Australian Research Council

Chief Investigators: Dr Con Doolan, Prof Colin Hansen, A/Prof Anthony Zander, Dr Laura Brooks

Centre for Tectonics, Resources and Exploration

AuScope - Imaging Operations

Sponsor: Department of Industry, Innovation, Science, Research and Tertiary Education, Australian Government

Chief Investigator: Prof Graham Heinson

Carbon sequestration by mineral surface area as a feedback to climate warming in a greenhouse ocean

Sponsor: Australian Research Council

Chief Investigator: Prof Martin Kennedy

Compressional deformation and uplift of Australia's passive southern margin

Sponsor: Australian Research Council

Chief Investigator: Dr Simon Holford

Constraining conditions and timing of orogeny and reworking in the west Musgrave Province

Sponsors: Australian Research Council, Curtin University, Geological Survey of Western Australia

Chief Investigator: Dr David Kelsey

Development of biosensors and bioindicators for gold exploration and processing in Australia

Sponsors: Australian Research Council, Barrick Gold of Australia Ltd, CSIRO Land and Water, Flinders University, Martin Luther-University Halle-Wittenberg, Newmont Australia, South Australian Museum, University of Nebraska-Lincoln

Chief Investigators: A/Prof Frank Reith, Prof Joel Brugger, Prof Joseph Shapter, A/Prof Claire Lenehan

Experimental studies on hydrothermal reaction processes at the molecular level: the role of mineral replacement reactions in ore formation

Sponsor: Australian Research Council

Chief Investigators: Prof Allan Pring, Prof Joel Brugger

The geomicrobiology and (bio) geochemistry of platinum, palladium and rhodium

Sponsor: Australian Research Council

Chief Investigator: A/Prof Frank Reith

High performance EMPA optimised for the microanalysis of sulphides and heavy elements

Sponsors: Australian Research Council, BHP Billiton, Flinders University, Monash University, University of South Australia.

Chief Investigators: Dr Joel Brugger, Prof Martin Hand, A/Prof Heike Ebendorff-Heidepriem, A/Prof Claire Lenehan, Dr Andrew Tomkins, Prof William Skinner, Dr Kathy Ehrig

Iron isotope variation in subduction magmas: links to fluid flux and oxidation of the mantle wedge?

Sponsor: Australian Research Council

Chief Investigator: Prof John Foden

Mitchell Channel architecture and connectivity project

Sponsor: Woodside Energy Ltd

Chief Investigator: Dr Rachel Nanson

Molecular structure and transport properties of hydrothermal fluids under extreme conditions: near-critical, high salinity, high pressure and high volatile contents

Sponsor: Australian Research Council

Chief Investigator: Prof Joel Brugger

Professor of Mining Geology

Sponsor: Department for Manufacturing, Innovation, Trade, Resources and Energy, Government of South Australia

Chief Investigator: Prof Ian Plimer

Reservoir architecture and heterogeneity in marginal marine systems – WAVE Consortium Phase 11

Sponsors: Apache Corporation, Badr Petroleum Co, BG Todd Energy, BHP (Broken Hill Proprietary), Billiton Petroleum, BP Australia, Chevron Australia, ConocoPhillips, Nexen Petroleum Australia Pty Ltd, OMV Group, Shell, Statoil, Todd Energy, Woodside Energy Ltd

Chief Investigator: Prof Bruce Ainsworth

Resistivity of typical rocks at crustal pressure and temperature conditions from combined laboratory and magnetotelluric measurements

Sponsor: Australian Research Council

Chief Investigator: Dr Katherine Selway

The regolith expression of IOCG mineralisation at the Project Mawson area, NE Eyre Peninsula, South Australia (part 1)

Sponsor: Onesteel Manufacturing Pty Ltd

Chief Investigator: Dr Steven Hill

South Australian State Chair of Petroleum Geology

Sponsor: Department for Manufacturing, Innovation, Trade, Resources and Energy, Government of South Australia

Chief Investigator: Prof Bruce Ainsworth

Three-dimensional magnetotelluric and controlled-source electromagnetic modelling and inversion in isotropic and anisotropic media with Gaussian Quadrature Grids

Sponsor: Australian Research Council

Chief Investigator: Prof Graham Heinson

Sonic drilling to provide contamination-free core sampling of rock, unconsolidated sediment (administered by University of Wollongong)

Sponsor: Australian Research Council

Chief Investigator: Dr Rachel Nanson

South Australian Centre for Geothermal Research

Development of the Geothermal Research Facility

Sponsor: Department for Manufacturing, Innovation, Trade, Resources and Energy, Government of South Australia

Chief Investigator: Prof Martin Hand

Developing world-class trace element micro-analytical imaging facilities for South Australia through key analytical infrastructure advances

Sponsor: Premier's Science and Research Fund, Government of South Australia

Chief Investigator: Prof Martin Hand

Research funding for South Australian Centre for Geothermal Energy Research

Sponsor: Department of Trade and Economic Development, Government of South Australia

Chief Investigator: Prof Peter Dowd

South Australian Centre for Geothermal Energy Research 2011 to 2013

Sponsor: Department of Premier and Cabinet, Government of South Australia

Chief Investigator: Prof Peter Dowd

Environmental Impacts of Mineral and Energy Resources Development

Allocating water and maintaining springs in the Great Artesian Basin

Sponsor: South Australian Arid Lands Natural Resources Management Board

Chief Investigators: Dr Jennie Fluin, A/Prof Susan Carthew

Environmental Genomics: Mining, climate change, water, crime and health

Sponsors: Australian Federal Police, Australian Genome Research Facility, Australian Research Council, Biomatters Ltd NZ, Department of Environment and Natural Resources, Government of South Australia, Department for Manufacturing, Innovation, Trade, Resources and Energy, Government of South Australia, South Australian Museum, Government of South Australia, South Australian Water, Government of South Australia

Chief Investigators: A/Prof Jose Facelli, Prof Alan Cooper, Prof David Adelson, Prof Barry Brook

Root distribution and salinity and soil water dynamic in a chenopod shrubland: implications for restoration ecology

Sponsor: Iluka Resources Ltd

Chief Investigator: A/Prof José Facelli

Resource Engineering Program

Acoustic emission monitoring during drilling/rock cutting for optimising drilling performance

Sponsor: Cooperative Research Centre for Deep Exploration Technologies

Chief Investigator: A/Prof Chaoshui Xu

Borehold stability assessment for deep drilling

Sponsor: Cooperative Research Centre for Deep Exploration Technologies

Chief Investigator: A/Prof Chaoshui Xu

Centre for improved business performance

Sponsors: ESSO Australia Pty Ltd, Santos Ltd

Chief Investigator: Prof Stephen Begg

Developing engaging, effective and enlightening practical experiments in geotechnical engineering

Sponsor: Australian Learning and Teaching Council

Chief Investigator: A/Prof Mark Jaksa

Development of innovative technologies for oil production based on the advanced theory of suspension flows in porous media

Sponsors: Australian Research Council, Santos Ltd, University of South Australia.

Chief Investigators: Prof Pavel Bedrikovetski, Prof Anthony Roberts, Dr Andrei Kotousov

Institute for Mineral and Energy Resources (IMER)

Sponsor: Department of Premier and Cabinet, Government of South Australia

Chief Investigator: Prof Peter Dowd

Modelling the capillary entrapment phenomena and integrity of geological reservoirs for clean energy, water and waste management technologies

Sponsors: Australian Research Council

Chief Investigators: Prof Pavel Bedrikovetski, Dr Yildiray Cinar, Dr Andrei Kotousov

Stochastic modelling of fractures in crystalline rock masses for hot dry rock enhanced geothermal systems

Sponsor: Australian Research Council

Chief Investigator: Prof Peter Dowd

Socio-Economic Impacts of Mineral and Energy Resource Development Program

Plausible futures for economic development and structural adjustment - impacts and policy implications for Indonesia and Australia

Sponsor: Australian Centre for International Agricultural Research, Australian Government

Chief Investigator: Prof Christopher Findlay

Cooperative Research Centre for Greenhouse Gas Technologies

CO₂ storage in deltaic and fluvial sedimentary systems

Sponsor: Cooperative Research Centre for Greenhouse Gas Technologies

Chief Investigators: Dr Mark Bunch, Dr Richard Daniel, Dr Saju Menacherry

Understanding CO₂ storage in saline aquifers

Sponsor: Cooperative Research Centre for Greenhouse Gas Technologies

Chief Investigators: Dr Mark Bunch, Dr Saju Menacherr, Dr Richard Daniel

Reactive rocks and their impact on CO₂ storage potential trapping

Sponsor: Cooperative Research Centre for Greenhouse Gas Technologies

Chief Investigator: Dr Ulrike Schacht

Seal geomechanics and retention of CO₂ in the subsurface

Sponsor: Cooperative Research Centre for Greenhouse Gas Technologies

Chief Investigators: Dr Guillaume Backe, Dr Mohammad Rahman, Mr Ernest Swierczek, Prof John Kaldi

Predictive modelling of storage reservoirs

Sponsor: Cooperative Research Centre for Greenhouse Gas Technologies

Chief Investigator: Dr Mark Bunch

Monitoring and verification

Sponsor: Cooperative Research Centre for Greenhouse Gas Technologies

Chief Investigator: Dr Ulrike Schacht

Deep Exploration Technologies Cooperative Research Centre

Acoustic emission monitoring during drilling/rock cutting for optimising drilling performance

Sponsor: Deep Exploration Cooperative Research Centre

Chief Investigator: Prof David Giles

Borehold stability assessment for deep drilling

Sponsor: Deep Exploration Cooperative Research Centre

Chief Investigator: Prof David Giles

Geochemical sampling of deep cover

Sponsor: Deep Exploraion Cooperative Research Centre

Chief Investigator: Prof David Giles

Hypogene alteration

Sponsor: Deep Exploration Cooperative Research Centre

Chief Investigator: Prof David Giles

Joint inversion of 3D Seismic data and magnetotelluric (MT) Data

Sponsor: Deep Exploration Cooperative Research Centre

Chief Investigator: Prof David Giles

Energy Pipelines Cooperative Research Centre

Development of simplified mathematical models and criteria for identification os whether a weld will be susceptible to WMHACC

Sponsor: Energy Pipeline Cooperative Research Centre

Chief Investigator: A/Prof Peter Ashman

Weld metal HACC susceptibility under controlled welding conditions and restraint levels

Sponsor: Energy Pipelines Cooperative Research Centre

Chief Investigator: A/Prof Peter Ashman

ADELAIDE AIRPORT LIMITED (AAL) PROJECT MODEL AN AUSTRALIAN FIRST

INDUSTRY PARTNERSHIP PROJECT

IMER's Centre for Energy Technology (CET) is working in partnership with Adelaide Airport Limited (AAL) to develop clean energy solutions that reduce the carbon footprint of AAL and contribute towards the sustainability of the broader environment.

Research Team: Professor Gus Nathan, Dr Tim Lau, Dr Lei Chen, Associate Professor Eric Hu, Associate Professor Bassam Dally, Dr Maziar Arjomandi.

The partnership began in 2011 to provide leadership in how organisations and people can advance clean energy practices by making AAL the most ecologically sustainable airport in Australia and supporting CET's drive to be a world-leading research centre in clean energy technology.

A key project to reduce AAL's carbon footprint is the development of a transient, thermodynamic model of the Terminal 1 (T1) building. This model accounts for T1's geometry, location, local weather, operation, lighting systems, heating, ventilation and air-conditioning systems. It will be used to accurately assess the costs and benefits of energy-efficiency technologies or practices.

The validated thermodynamic model will be the first in Australia to be successfully used for such a large complex building.

The model will integrate the outcomes of other projects focussed on the potential benefits of indirect evaporative cooling (IEC) technology and the development of a smart mechanical plant control system.

The Partnership also directly supports six projects across the CET which are investigating a range of clean energy technologies to the broader benefit of society. These projects include:

- Improving wind energy utilisation by investigating turbine wake generation and propagation in a collaboration with Korean Maritime University;
- Producing a future clean fuel source, by using catalytic technologies to generate hydrogen from solar energy; and

- Developing a unique laser diagnostic experimental facility to research more efficient and clean burning flames and solar energy-flame hybrid concepts.

The Partnership also supports CET's ongoing and world-leading research to optimise fuel combustion systems such as the Gyrotherm low NO_x burner, developed in partnership with FCT-Combustion.

The Gyrotherm burner technology reached an important milestone in 2011. The 34 burners installed around the world to date are estimated to have now reduced global greenhouse gas emissions by an estimated 29.6M tonnes of CO₂ equivalent. This is equal to the annual CO₂ emissions of South Australia.



Staff and Members

Institute Staff

Executive Director

Professor Stephen Grano

PhD, University of South Australia;
MSc, University of South Australia;
BEng (Hons), University of Queensland
Minerals processing

Deputy Directors

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PhD, BEng (Hons), University of
Adelaide
*Combustion, fluid mechanics, heat
transfer and renewable energy*

Professor Martin Hand

Director, SACGER
PhD, University of Melbourne;
BSc (Hons), University of Newcastle
*Geology, geothermal energy and
tectonics*

Institute Manager

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PhD, BEng (Hons), University of Adelaide
Energy systems and combustion

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*Combustion, fluid mechanics, heat
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PhD, University of Sydney;
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*Combustion, fluid mechanics, heat
transfer and energy systems*

Director, TRaX

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PhD, BSc, University of London
*Geology and mineralogy of sulphide
ore deposits*

Deputy Director, TRaX

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PhD, University of Birmingham;
BSc (Hons), Keele University
*Petroleum geoscience, basin analysis,
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Mineral exploration

Director, SACGER

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PhD, University of Melbourne; BSc
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Geology, geothermal energy and tectonics

Deputy Director, SACGER

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PhD, BEng, RMIT University
Minerals science, rheology

Program Leaders

Resource Engineering Program

Associate Professor Emmanuel Chanda

PhD, Technical University Berlin;
MEng, Colorado School of Mines; BSc,
University of Zambia
*Mine planning and design, process
optimisation*

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PhD, University of Liverpool;
MSc, McMaster University;
BSc (Hons), Imperial College
Sedimentology, sequence stratigraphy

Program of Socio-Economic Impact of Mineral and Energy Resources

Associate Professor John Spoehr

PhD, University of South Australia;
BEcon, University of Adelaide
Economic development

Environmental Impact of Mineral and Energy Resources Program

Associate Professor Sue Carthew

PhD, MSc, BSc (Hons), University of
Wollongong
Conservation biology

Associate Professor José Facelli

PhD, BSc, University of Adelaide
(Incoming Leader 2012)
Plant ecology

CRC Leaders

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PhD, Cambridge University; MSc, BSc,
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Carbon capture and storage

Research Leader, DET CRC

Professor David Giles

PhD, BSc (Hons), Monash University
Mineral exploration

Program Leader, Energy Pipelines CRC

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PhD, MEng, BEng, University of
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*Microalgae, combustion, coal and
geothermal energy*

Researchers

Professors

Bruce Ainsworth

PhD, University of Liverpool;
MSc, McMaster University;
BSc (Hons), Imperial College
Sedimentology, sequence stratigraphy

Pavel Bedrikovetski

PhD, MSc, BEng, Moscow Gubkin
Petroleum University
*Mathematical modelling for formation
damage, waterflooding and IOR/EOR*

Steve Begg

PhD, BSc (Hons), University of Reading
Decision making and project economics

Mark Biggs

PhD, University of Adelaide; BEng (Hons), University of New South Wales
Nanoporous carbons and multiphase fluids

Joel Brugger

PhD, University of Basel; BSc (Hons), University of Fribourg
Experimental geochemistry, mineralogy, spectroscopy

David Chittleborough

Also affiliated with the Environment Institute
PhD, University of Adelaide
Soils and water quality

Peter Dowd

PhD, University of Leeds; MScA, Ecole Polytechnique de l'Université de Montréal; BSc (Hons), University of New England
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PhD, MEcon, Australian National University; BEcon (Hons), University of Adelaide
Reform and industrialisation of the Chinese economy

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Geology and trace elements geology

Colin Hansen

PhD, BEng (Hons), University of Adelaide
Acoustics, aeroacoustics, noise and vibration control

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PhD, Australian National University; BSc, Edinburgh University
Electromagnetic and electrical geophysics

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PhD, Australian National University; BA (Hons), University of Western Australia
Politics and history

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Geochemistry and petroleum systems

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PhD, BSc, University of New South Wales
Combustion and laser diagnostics

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PhD, University of Adelaide, BSc (Hons), DSc, University of Manchester
Climate change and energy

Russell Luxton

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Air conditioning, fluid mechanics

Jamie Mi

Visiting Professor; PhD, University of Newcastle
Fluid mechanics

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Also affiliated with the Institute for Photonics and Advanced Sensing
PhD, MSc, University of Chicago; BSc, Massachusetts Institute of Technology
Laser physics and optical design

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State taxes and fiscal equalization

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Mining geology and mineral exploration

Stephen Priest

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Mineral economics and financial analysis

Allan Pring

Also affiliated with South Australian Museum
PhD, ScD, University of Cambridge; BSc, Monash University
Geology and geophysics

John Sturgul

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Mine design, mineral economics and geostatistics

Associate Professors**Peter Ashman**

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Microalgae, combustion, coal and geothermal energy

Karin Barovich

PhD, MSc, BSc, University of Arizona
Rocks and geological events

Barry Burgan

BEcon (Hons) University of Adelaide
Project and policy evaluation

Ben Cazzolato

PhD, BEng (Hons), University of Adelaide
Structural dynamics, acoustics, signal processing, robotics and control

Alan Collins

PhD, University of Edinburgh; BSc (Hons), University of London
Tectonics and geochronology

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PhD, University of New South Wales; BSc (Hons), University of Melbourne
Advanced fluid dynamics, fluid mixing

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Electrical and Electronic and Communication Engineering

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Thermodynamics and sustainable energy

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Foundations, geotechnical engineering

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Bioprocess engineering and nanotechnology

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Fluid mechanics and combustion

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Engineering design, CAD engineering education research

Michael Liebelt

MEng, MSc, BEng (Hons), BSc, University of Adelaide
Electronics and computer architecture

Greg Metha

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Laser ionisation spectroscopy

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PhD, University of North Carolina; BEcon, Australian National University
Cloud computing, eScience, parallel computation, computational geoscience

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PhD, University of Sheffield; BSc, BEng, University of Leicester
Industrial combustion systems

Mandar Oak

PhD, Cornell University; MA, Delhi School of Economics; BCom, University of Mumbai
Public economics, political economy, applied microeconomics

Brian O'Neill

PhD, BEng (Hons), University of Queensland
Process systems modelling

Frank Reith

PhD, Australian National University; MSc, BSc, BBA, University of Bayreuth
Geomicrobiology, metagenomics and transcriptomics

Andrew Rosser

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Politics, anthropology

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PhD, University of Glasgow; BEng (Hons), University of Adelaide
Electrical machinery and renewable energy

Chaoshui Xu

BSc, Northeast University
Rock fracture modelling, Geostatistics and resource evaluation

Anthony Zander

PhD, BE (Hons), University of Adelaide
Acoustics and vibrations

Senior Lecturers**Dr Zeyad Alwahabi**

PhD, University of Sussex; BSc, Al Mustansiriyah University
Laser diagnostics

Dr Maziar Arjomandi

PhD, MEng, Moscow Aviation Institute; BEng (Hons), Iran University of Science and Technology
Aircraft design, aerodynamics and wind energy

Dr Bunda Besa

PhD, Curtin University; MSc, BSc, University of Zambia
Mine planning and design, mining transport and materials handling

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Building management systems, energy integration and optimisation solutions, energy audits and renewable energy options.

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Materials for energy applications

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Geothermal, tectonics, geomechanics, overpressure, mud volcanoes

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Lecturers**Dr Kathryn Amos**

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3D geomodelling and fracture imaging

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Chaotic laminar fluid mixing

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Stress and geomechanics

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BSc, University of Sydney
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Combustion and gasification of solid fuels

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Fluid mechanics

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University of Kerala; BSc, University
of Calicut
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University of Melbourne
Fluid mechanics

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*Building management systems,
energy integration and optimisation
solutions, energy audits, and
renewable energy options*

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Regolith geology and geochemistry

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Dr Barbara Etschmann

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X-ray absorption spectroscopy

Dr Caroline Forbes

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Proterozoic tectonics

Dr Pascal Grundler

PhD, Ecole Polytechnique Fédérale de Lausanne; DChem, University of Lausanne
Coordination chemistry, physical chemistry, geochemistry

Dr Nathaniel Jewell

PhD, BSc (Hons), University of Adelaide; BSc, Flinders University
Fluid mechanics, operations research, hydrology

Dr Timothy Lau

PhD, BEng (Hons), University of Adelaide
Fluid dynamics

Dr Rosemarie Mohais

PhD, MPhil, BSc, University of West Indies; DipEd, Valsayn Teachers' College
Fluid flow and heat transfer

Dr Danielle Moreau

PhD, MEng (Hons), University of Adelaide
Aeroacoustics, acoustics, active noise control and virtual sensing

Mr Alexander Musson

BSc (Hons), University of Melbourne; BSc, University of Adelaide; BA, ACCD Pasadena Art Center College of Design
Thermal geophysics, geothermal geology

Dr Stephen Pahl

PhD, BEng (Hons), University of Adelaide
Industrial bioprocessing and biotechnology

Dr Zebb Prime

PhD, BE, BSc, University of Adelaide
Robust control theory

Mr Myles Regan

BE, University of Adelaide
Enhanced oil recovery

Dr Ulrike Schacht

PhD, University of Kiel; MSc, BSc, Technical University of Berlin
Siliciclastic reservoir quality and diagenesis

Dr Sattar Seifollahi

PhD, Iran University of Science and Technology; MSc, BSc University of Tabriz
Fracture network modelling

Dr Kate Selway

PhD, BSc (Hons), University of Adelaide
Proterozoic collision

Dr Stephan Thiel

PhD, BEng, University of Adelaide; MEng, Freiberg University of Mining and Technology
Electromagnetics and geothermal exploration

Dr Adrian Tuitt

PhD, BSc (Hons), University of Edinburgh
Seismic interpretation and numerical modelling

Dr Philip van Eyk

PhD, BE (Hons), BSc, University of Adelaide
Combustion and gasification of low-rank coals and biomass

Dr Matthew Welsh

PhD, BA (Hons), BSc (Hons), University of Adelaide
Psychology of decision-making

Dr Zhenjiang You

PhD, BEng, Zhejiang University
Fluid mechanics and heat transfer

Dr Carla Zammit

BSc, BA (Hons), Curtin University
Environmental microbiology and molecular genetics

Dr Manfred Zockel

PhD, MEng, University of Adelaide
Thermodynamics, engines, design and manufacturing

Postgraduate Members

Here is a list of current postgraduate students supervised by IMER members relevant to core IMER research areas and priorities during 2011.

Hamish Adam

Integrating 2d transect and 3d regional mt data

Muhammad Akram

Reducing CO₂ emissions from glue gasses by developing the chemical absorption techniques

Homoud Al Anzi

Anatomy of an intra-shelf basin: oligocene to pliocene seismic stratigraphy of the Bonaparte basin shelf, NW Australia

Mohammed Al-Ghamdi

Detection of reservoir fracturing using seismic attributes

Jade Anderson

Crustal evolution of proterozoic central Australia using an integrated isotopic, metamorphic and geochemical approach

Mohamed Awadalla

Gas leakage detection and mobile robot navigation in pipelines and urban environments

Khadijah Awang

*Evolution in *Cassytha* (Lauraceae)*

Setiawan Bambang

Modified evaluation of liquefaction potential of soils utilising in situ tests

Elizabeth Baruch

Influence of multi-scale rock fabric, mechanical properties and composition on geophysical (log and seismic) properties of gas shales

Marcus Boyd

Investigation of the in-cylinder combustion dynamics of biodiesel fuel

Guiqin Cai

Understanding and modelling metabolic flux network of hydrogen fermentation

Peter Chaplin

Lead acid batteries

Xiao Chen

Numerical study of pressing jet

Xin Xin Chen

Heterotrophically grown microalgae as a feed source for the Australian aquaculture industry

Yang Chen

Controlled supramolecular assembly in aqueous molecular and macroscopic system

Mei Chiin Cheong

Targeted unmixing of particles in suspension

Amanullah Choudhry

Dynamic stall control on wind turbine blades

Mohammad Chowdhury

Investigation of particle agglomeration using laser diagnostics influence of stokes number on particle distribution in a pipe jet

Hilary Coleman

The study of metal complex chemistry for application in sensor chemistry and technology

Kathryn Cutts

Metamorphic analysis of proterozoic terrains in Rodinia

Michael De Rosa

Active control of horizontal axis wind turbines

Jamie Dennis

Qualification and quantification of coal in the patchawarra formation of the southern Cooper Basin: significance to in-situ coal aquathermolysis

Michael Dixon

Optimizing removal of algal toxins using integrated membrane systems

Liang Duanmu

Intelligent automatic control system

Blessing Eboibi

Renewable energy and bioenergy

Blaise Fernandes

Deepwater outcrop analogues

Clayton Fry

CO₂ storage potential of the Officer Basin of South Australia

Alexander Gentleman

Laser spectroscopy of mixed transition metal clusters

Matthew Gray

Geophysical and structure 1 modelling of the musgraves block

Martin Griessmann

Gold-basemetal mineralisation in the Adelaide foldbelt

Kristy Lee Hansen

Effect of leading edge tubercles on airfoil performance

Steven Harding

Stability and fracture of highly non-linear systems

Alan Harrland

Hypersonic inlet for a laser powered propulsion system

Abdolvahab Honari

Effects of stress and temperature on methane adsorption and desorption in coal seams

Katherine Howard

Crustal evolution of the Gawler Craton

Hao Huang

Intelligent control system

Roniza Ismail

Trace element distributions in South Australian IOCG mineral deposits

Richard Jones

Aeroacoustic shape optimisation for aerofoil trailing edge noise

Ashok Kaniyal

Investment strategies for thermal renewable resources

Timothy Kelly

Climate change policy

Kieran Kilgariff

Exploration opportunities: CO₂ CRC's PPL's 11 & 13, Otway Basin Victoria

Alexis Lambeck

Basin analysis and the geochemical and isotopic signature of daleoproterozoic sedimentary successions in northern Australia

Changhwan Lee

3-D reservoir modelling of marginal marine systems

Seung Joon Lee

Structure health monitoring

Kan Li

Geochemistry of in-situ uranium recovery

Qi Lin

Intelligent vision system

Gernot Loidl

Geology and geochemistry of the Endeavor deposit

Mohammad Lotfolah Hamedani

Alteration and mineralisation in the Curnamona Craton and Broken Hill region

Phyllis MacGillivray

Tracking phenological shifts and evolutionary impacts due to climate change

Saleh Mahmoud

Measurements in Sooty Flames (Combustion)

Rachel Maier

Applications of marine magnetotellurics for petroleum exploration

Mohamed Mat Ali

Aeroacoustic interaction of a square cylinder and a flat plate

Abdolrasool Mayahi

Design, fabrication and control of an underwater vehicle

Arash Mirahmadizoghi

Rock mechanics, rock behaviour under three dimensional state of stress, evaluating 3d failure criteria by comparing them with experimental data

Mohammadamin Miremadi

An investigation into the effects of vortices in the heat transfer from a flat plate

Alireza Moazen Ahmadi

Defect detection of rolling element bearings using vibro-acoustic signatures

Mohd Mohamad Hashim

An autonomous mobile robot navigating system

Roslina Mohammad

Response of pressurized pipes due to low speed impact

Morteza Mohammadzaheri

Intelligent control systems

Syed Mohsin

Solar coupling with combustion

Mustarum Musaruddin

Automatic fault analysis in power systems via application service provider

Thi Nguyen

Improved oil recovery using raw water injection

Frances Parkhowell

A biogeochemical and geophysical study of Arkaroola, South Australia

Anne Philcox

Study of reactive intermediates relevant to material combustion chemistry

Ian Powrie

The implications for company and institutional strategy of the risks associated with the sustainable development of the Australian wine industry.

Herath Premarathna

Trace element bio geo chemistry

Qian Qian

Probabilistic stability analysis of rock structures

Thomas Raimondo

Fluid flow in shear zones

Nima Ramezani Taghiabadi

Intelligent trajectory planning

Ladan Sahafi

Intelligent control systems

Melissa Salt

Phytocapping of landfills for final closure

Marianne Sandstrom

Lake Eyre as a modern analogue

Jacques Sayers

Geostatistical representation of fracture systems in mechanical modelling approaches when designing carbon dioxide hoods

Md Hossain Siddiqui

Palaeo environmental study of Murray River wetlands

Sarabjeet Singh

Development of a Wheel-rail dynamics simulation model for predicting acoustic radiation

Yuriy Solomonov

Investigation of friction in water-lubricated bearings

Narasimha Thota

Development and validation of a new method to predict submarine flow induced noise

Manjot Toor

Removal of Toxic Pollutants from Industrial Wastewater by Australian Clay Mineral

Melissa Vallee

Development of an improved petrophysical model based on semi quantitative mineralogy, jurassic-cretaceous succession, Cooper area, Eromanga Basin

Benjamin Vanderhoek

Regolith and landscape evolution in South Australia

Vipasiri Vimonses

Integration of nanotechnology for wastewater treatment

Kim Toan Vu

Impact of film heterogeneity and transport and transport of international trade

Andrew Ward

Anaerobic digestion of algal biomass

Stuart Wildy

Smart sensor technology for structure health monitoring

James Wilkie

NVH Tuning in Power Steering Systems - Plastic Tuner Cable

James Lionel Donald Wilson

Electrical and Electromagnetic Geophysics for Groundwater Exploration

Yongling Zhao

The study of carbon-methanol adsorption cooling tube

Higher Degree Graduates

During 2011 IMER researchers supervised twenty three higher degree graduates in a wide range of research areas. Of this number twenty completed PhDs, and a further three completed Masters.

Here is a list of graduates and their research topics in areas relevant to IMER's focus.

Doctor of Philosophy

Rachael Brick

The formation and exhumation of the world's oldest eclogites

Alexandre Burgun

Synthesis and structure of electro-commutable trinuclear complexes of iron and ruthenium: toward bistable molecules for molecular electronic

Qing Chan

Soot evolution in non-premixed flames

Wai Chan

Quality in drinking water reservoirs

Kathryn Cutts

Metamorphic analysis of proterozoic terrains in rodonia

Michael Dixon

Optimizing removal of algal toxins using integrated membrane systems

Martin Griessmann

Gold-base metal mineralisation in the Adelaide foldbelt

Michael Hatch

The use of shallow geophysical techniques to help characterise hydrological parameters

Katherine Howard

Crustal evolution of the Gawler Craton

Alexis Lambeck

Basin analysis and the geochemical and isotopic signature of daleoproterozoic sedimentary successions in northern australia

Gernot Loidl

Geology & geochemistry of the endeavor deposit

Mohammad Lotfolah Hamedani

Alteration and mineralisation in the Curnamona Craton and Broken Hill region

Rachel Maier

Applications of marine magnetotellurics for petroleum exploration

Mohamed Mat Ali

Aeroacoustic interaction of a square cylinder and a flat plate

Roslina Mohammad

Response of pressurized pipes due to low speed impact

Mustarum Musaruddin

Automatic fault analysis in power systems via application service provider

Herath Premarathna

Trace element bio geo chemistry

Thomas Raimondo

Fluid flow in shear zones

Jacques Sayers

Geostatistical representation of fracture systems in mechanical modelling approaches when designing carbon dioxide hoods

Vipasiri Vimonses

Integration of nanotechnology for wastewater treatment

Masters

Thi Nguyen

Improved oil recovery using raw water injection

Manjot Toor

Removal of toxic pollutants from industrial wastewater by Australian clay mineral

Yongling Zhao

The study of carbon-methanol adsorption cooling tube



Public Seminars and Events

IMER members shared key research findings, outcomes and benefits with business leaders, government and the wider community. Here is a selection of key public presentations during 2011.

Mining the Sun Lecture

The development of solar energy and the key role of the mining sector were themes of a free public lecture in July 2011.

Professor Aldo Steinfeld, one of the world's foremost researchers in solar energy technology, joined the University of Adelaide experts including the Centre for Energy Technology's (CET) director Professor Gus Nathan for the event.

"The mining and resources sector is a vital part of the Australian and South Australian economies and the largest contributor to South Australia's exports," said Professor Nathan.

"But both mining and minerals processing are energy-intensive industries and they contribute significantly to national CO₂ emissions and are vulnerable to energy price increases and carbon pricing mechanisms. New technologies are required to reduce energy consumption, costs and impacts," he said.



Mining the Sun was held by CET in association with the University of Adelaide's Environment Institute and the Royal Institution of Australia.

Speakers included Professor Aldo Steinfeld from the Department of Mechanical and Process Engineering at ETH Zurich; Professor Gus Nathan; and Ms Susie Smith, Manager Climate Change and Sustainability, Santos.

IMER Director Professor Stephen Grano was the moderator.

(Left to right): Professor Aldo Steinfeld, Professor Stephen Grano, Professor Gus Nathan and Ms Susie Smith

IMER Executive Addresses Innovate SA Seminar



Left to right: Innovate SA's Mike Richards, John Karageorgos, Stephen Grano and Enterprise Connect's Mark Osborne.

Institute for Mineral and Energy Resource (IMER) Executive Director Professor Stephen Grano addressed the 6th instalment of the Innovate SA and Enterprise Connect supported Mining Innovation Seminar on November 15, 2011 in Adelaide.

More than 80 guests attended the seminar. Professor Grano led discussion on Ore Pre-Concentration as a means to reduce both energy and water consumption in mining. Another key speaker was John Karageorgos, Senior Principal Process Control Engineer at Mantra Controls. He discussed what the minerals industry is doing to minimise water and energy consumption using automation.

The seminars aim to bring mining industry end-users, technology providers and researchers together in South Australia.

Geological Society of America Presentation

TRaX member Dr David Kelsey presented at the Geological Society of America annual meeting in Minneapolis, USA, during October 2011.

He was invited by the University of Arkansas' Dr Gregory Dumond.

The first was titled '*Linking Accessory Mineral Growth and Breakdown to Mineral Evolution in Metamorphic Rocks – Where are We at for Monazite?*' (from Nuna to Rodinia: Proterozoic Growth and Evolution of Laurentia II).

The second presentation was titled '*Implications for the Tectonic Setting of Long-Lived Grenvillian-Aged Tectonism in the Musgrave Province Central Australia, based on Constraints from Large-Scale Isotopic Homogeneity and Thermobarometry*'.

TRaX Attend Gondwana 14 Conference

TRaX members Associate Professor Alan Collins, Professor John Foden and PhD student Ben McGee attended the Gondwana 14 Conference in Buzios, Brazil in September, 2011.

Associate Professor Collins presented an invited talk entitled '*When did Gondwana Finally Amalgamate?*'.

Gondwana Research Annual Meeting draws TRaX Researchers

TRaX PhD students Udeni Amarsinghe and Andrew Barker presented talks at the International Association for Gondwana Research Annual Meeting in Hyderabad, India in August, 2011.

They were joined with a presentation by Associate Professor Alan Collins and posters presented by TRaX Honours students Emma Alexander and Bonnie Henderson.

Macquarie Private Wealth Seminars

The first of the University of Adelaide Excellence in Research series of Boardroom Dinners hosted by Macquarie Private Wealth was held on September 21, 2011.

The series presents an opportunity to highlight the research from each of the University's five Research Institutes to senior industry, government and private individuals.

SACGER Centre Director Professor Martin Hand presented '*Geothermal Energy in Australia – Let's Go With the Flow*' to 20 University and Macquarie guests over dinner.

APCSEET 2011 in Adelaide

The 8th Asia Pacific Conference on Sustainable Energy and Environmental Technologies (APCSEET 2011) was staged in Adelaide, held on July 10-13, 2011.

The APCSEET 2011 was organised by CET and Associate Professor Eric Hu was chairman of this event.

APCSEET is an international biennial forum that aims to address the challenge of balancing growth with sustainability in economic, social and environmental sectors.

It brings together stakeholders from universities, industries, government and business involved in the invention, design, development and implementation of sustainable technologies. The first APCSEET was staged in Singapore in 1996. Other forums have been held in China, Japan, New Zealand and Thailand.

Professor Pavel Bedrikovetsky

Professor, Australian School of Petroleum

SPE Formation Damage Symposium

Presented two technical papers

1. *Water-Cut Reduction during Waterflood by Induced Fines Migration: Effects of Varying Formation Damage Coefficient*
2. *Modified Mathematical Model for Fines Migration in Oilfields*

Professor Pavel Bedrikovetsky

Professor, Australian School of Petroleum

Brazil Offshore Conference and Exhibition

Productivity Impairment Due to Fines Migration: Steady State Production Regime

Professor Barry Brook

Sir Hubert Wilkins Chair, Climate Change, Ecology & Evolutionary Biology

Committee for Economic Development of Australia (CEDA) – Energy/Sustainability

Our Nuclear Future? The pros and cons of Nuclear Energy

Professor Joel Brugger

ARC QE11 Fellow, School of Earth and Environmental Sciences, Discipline of Geology and Geophysics

The Inaugural Solomon Meeting

Towards a molecular-level understanding of metal transport in hydrothermal fluids: successes and challenges. Frontiers in Mineral Systems

Professor Joel Brugger

ARC QE11 Fellow, School of Earth and Environmental Sciences, Discipline of Geology and Geophysics

Elizabeth and Frederick White Conference

Minerals at Extreme Conditions: Integrating Theory and Experiment

Professor Joel Brugger

ARC QE11 Fellow, School of Earth and Environmental Sciences, Discipline of Geology and Geophysics

Sprigg Symposium

Mt Gee and Mt Painter: Genesis and preservation of a U-rich Palaeozoic epithermal system with a surface expression

Associate Professor Alan Collins

Associate Professor, School of Earth and Environmental Sciences, Discipline of Geology and Geophysics

Sprigg Symposium

Local controls on rifting and inversion in the northern Flinders Ranges

Dr Dennis Cooke

Program Manager - Unconventional Resources, Australian School of Petroleum

Fracture Simulation Workshop

Impediments and possible solutions for success in unconventional reservoirs – An overview of the GeoFrac Consortia

Associate Professor Bassam Dally

Deputy Director, Centre for Energy Technology, Head of School, School of Mechanical Engineering

University of Adelaide, Research Week

Research impacting the future of Australia

Associate Professor Bassam Dally

Deputy Director, Centre for Energy Technology, Head of School, School of Mechanical Engineering

Innovation Showcase 2011 - Mining, Engineering and Defence

Flameless Combustion for High Efficiency and Low Emission

Dr Con Doolan

Senior Lecturer, School of Mechanical Engineering

University of Adelaide, Research Week

The Impact of Wind Energy

Professor John Foden

Professor, School of Earth and Environmental Sciences, Discipline of Geology and Geophysics

Sprigg Symposium

Mt Gee and Mt Painter: Genesis and preservation of a U-rich Palaeozoic epithermal system with a surface expression

Professor David Giles

Research Leader, DET CRC, Director, Centre for Mineral Exploration Undercover

Sprigg Symposium

Local controls on rifting and inversion in the northern Flinders Ranges

Professor Stephen Grano

Executive Director, Institute for Mineral and Energy Resources

NG Mining Summit Australia

Methods and Benefits of Integrating Low Greenhouse Energy Technologies into Mining and Processing

Professor Stephen Grano

Executive Director, Institute for Mineral and Energy Resources

Latin America and Australia: Building on Strengths and Opening New Frontiers

Managing Resources for a Sustainable Future

Professor Stephen Grano

Executive Director, Institute for Mineral and Energy Resources

Latin American Seminar, Panel Chair

Managing Resources for a Sustainable Future

Professor Stephen Grano

Executive Director, Institute for Mineral and Energy Resources

AMCHAM Internode Business Luncheon

SA's Mining Boom and Prospects for Business

Mr Paul Harris

Lecturer, School of Agriculture Food and Wine

The Society for Engineering Agriculture (SEAg) Conference

A method for determining the size of anaerobic digesters

Mr Paul Harris

Lecturer, School of Agriculture Food and Wine

Convener: Bioenergy Australia Conference**Professor Graham Heinson**

School of Earth and Environmental Sciences, Head of Geology and Geophysics

Innovation Showcase 2011 - Mining, Engineering and Defence

4D Imaging of Energy Resources

Professor Graham Heinson

School of Earth and Environmental Sciences, Head of Geology and Geophysics

Magnetotelluric Exploration of South Australia – PIRSA event

Dr Simon Holford

Deputy Director, TRaX

Geological Society of Australia monthly seminar

Seismic volcanology: new insights into extrusive and intrusive igneous processes through analysis of 3D seismic datasets from sedimentary basins

Professor Graham (Gus) Nathan

Director, Centre for Energy Technology

AMCHAM Internode

Business Luncheon

Carbon Tax/Pricing

Professor Graham (Gus) Nathan

Director, Centre for Energy Technology

Australia, Israel Chamber of Commerce Business Luncheon

Energy Efficiency

Professor Graham (Gus) Nathan

Director, Centre for Energy Technology

University of Melbourne, Melbourne Energy Institute

Opportunities and Challenges

Professor Graham (Gus) Nathan

Director, Centre for Energy Technology

Engineers Australia

Opportunities and Challenges

Dr Jordan Parham

Manager, Institute for Mineral and Energy Resources

Innovation Showcase 2011 Mining, Engineering and Defence

Integration of Renewable Energy Solutions in Mining, Mineral Processing and Power Production

Professor Jonathan Pincus

Visiting Professor. School of Economics

Symposium, GST Distribution Review

Mining Revenue

Dr Kate Selway

Research Associate, School of Earth and Environmental Sciences, Discipline of Geology and Geophysics

Sprigg Lecture

The Earth Beneath Your Feet

Dr Kate Selway

Research Associate, School of Earth and Environmental Sciences, Discipline of Geology and Geophysics

Magnetotelluric Exploration of South Australia – PIRSA event

1. *Gawler Craton and Musgraves*
2. *Targets Beneath Cover*

Associate Professor John Spoehr

Executive Director, Australian Institute for Social Research

University of Adelaide, Research Week

The Impact of Wind Energy

Dr Stephan Thiel

Postdoctoral Fellow, School of Earth and Environmental Sciences, Discipline of Geology and Geophysics

Magnetotelluric Exploration of South Australia – PIRSA event

Dr Alex Wawryk

Senior Lecturer, Adelaide Law School

Law Society – Mining Law

Update to the Mining Act 1970 (SA, exploring the 2010 amendments to the Act)

Dr Matthew Welsh

Research Fellow, Australian School of Petroleum

Maths Society of SA Lecture

Felicitous Elicitation: DMing in the O&G Industry

Visitors

The University of Adelaide has welcomed many international and national visitors representing world-leading researchers, industry and government groups and entities. Here is just a selection of some key visitors who have collaborated, conducted research or presented at the University of Adelaide in areas of relevance to IMER.

Leading Alumina Research and Development Managers and Executives Visit IMER

Executives from leading alumina companies visited IMER late November, 2011.

Senior research representatives from Worsley Alumina, Alcan, Queensland Alumina and United Company Rusal, who make up the Alumina Technical Panel (ATP), heard presentations from IMER Executive Director Professor Stephen Grano and IMER Centres including the South Australian Centre for Geothermal Energy Research (SACGER) and the Centre for Energy Technology (CET).

Heads of the University of Adelaide's Schools of Chemistry and Physics and Chemical Engineering gave presentations along with the Australian Centre for Evolutionary Biology and Biodiversity.

Professor Abraham

Fellow, the Society of Automotive Engineers, Purdue University

Professor Jonathan Aitchison

Head of School, School of Geosciences, University of Sydney

Mr Theo Aravanis

Chief Geologist
Rio Tinto Mineral Exploration Pty Ltd

Associate Professor Rosalind Archer

Deputy Head of Department, (Continuum Mechanics), Department of Engineering Science, University of Auckland

Dr Denis Audet

Manager - Qld R & D Centre (QRDC)
Rio Tinto Alcan

Mr Ali Baghaei

Chief Executive Officer, Oceanlinx Ltd

Dr Tony Bagshaw

Consultant, Chemical Systems Pty Ltd

Dr Sanjeeva Balasuriya

Associate Professor of Mathematics
Connecticut College, USA

Dr Rowena Ball

ARC Future Fellow, ANU College of Physical and Mathematical Sciences
The Australian National University

Mr Frank Bierlein

Project Generation Manager
AREVA NC Australia

Professor Reidar Bratvold

Department of Petroleum Engineering,
University of Stavenger

Adjunct Professor Craig Brown

Staff Chemist, Centre for Neutron Research, National Institute of Standards and Technology

Associate Professor Kevin Brown

Partner/Consultant, Geokem NZ
(Geothermal and Environmental Geochemistry)

Professor Georgy Burde

Professor, Department of Solar Energy and Environmental Physics,
Ben-Gurion University of the Negev

Professor Don Bursill AM

Chief Scientist for South Australia

Mr Tom Cawley

Chief Executive Officer, Balance Energy

Dr Li Chen

Research Scientist, Department of Defence Science and Technology Organisation

Professor XiaoQi Chen

Academic and Accreditation Coordinator, University of Canterbury

Dr Benoit Cristol

Consultant, United Company Rusal

Mr Joe Cuccuza

Program Director, AMIRA International

Dr Debi Das

Scientist, Dept of Science and Technology, Govt of India

Mr Mark Dobin

Senior Research Geophysicist
Upstream, ExxonMobil Research Co

Mr Ed Donaldson

Stratigraphic & Reservoir Systems,
ExxonMobil Research Co

Professor Colin Dunn

Independent Consultant, British Columbia Geological Survey

Professor Wilfred Elders

Professor of Geology Emeritus/
Research Geologist, Department of
Earth Sciences, University of California

Professor Amanda Ellis

Deputy Head of Research, Faculty
of Science and Engineering, Flinders
University

Mr John Flexman

Graduate Development Manager,
Petroleum Engineering, BG Group

Mr Thomas Flottmann

Technical Advisor, Origin
Petroleum Corporation

Ms Maria Galatsanos

Vice-President / Director SA,
Aust Chile Chamber Commerce

Mr Rudy Gomez

Executive Chairman, Cartwheel
Resources Pty Ltd

Dr Reine Granstom

Researcher, Lulea University of
Technology

Dr Paul Green

Director, Geotrack International

Dr Sanja Gunawardena

Senior Lecturer, Department of
Chemical and Process Engineering,
University of Moratuwa, Sri Lanka

Dr Don Gunasekera

Visiting Scientist, Centre for Complex
Systems Science, CSIRO Centre for
Complex Systems Science

Mr Coy Hall

Assessment Skill Area Coordinator,
ExxonMobil Exploration

Mr Ian Hardwick

Business Manager, Deep Exploration
Technology CRC

Professor T. Harinarayana

Director, GERMI Research Centre,
National Geophysical Research
Institute, Hyderabad

Professor Andrew Harris

Director of the Laboratory for
Sustainable Technology, The
University of Sydney

Dr Ian Harrison

Director of Research and Development,
Alcoa of Australia

Professor Brian Haynes

Chemical Engineer - The School
of Chemical and Biomolecular
Engineering, The University of Sydney

Mr Ross Haywood

Global Practice Director, Hatch Australia

Mr Jeff Innes

Chief Operating Officer,
Conquest Mining Pty Ltd

Ms Susan Jeanes

Chief Executive, Australian Geothermal
Energy Association Inc.

Mr John Karageorgos

Faculty of Science and Engineering,
Western Australian School of Mines,
Department Minerals Engineering and
Extractive Metallurgy, Curtin University

Mr Brian Kilgariff

General Manager of Prominent Hill
Operations, OZ Minerals

Hon Tom Koutsantonis MP

Minister for Manufacturing, Innovation
and Trade; Minister for Mineral
Resources and Energy; Minister for
Small Business, Government of South
Australia

Mr Adrian Larking

Director of Operations,
Green Rock Energy

Dr Sarah Laurie

Chief Executive Office, Waubra
Foundation; Medical Director, Flinders
University

Dr Peter Leary

Chief Scientist, Institute of Earth
Science and Engineering, NZ

Mr George Levay

Adjunct Senior Research Fellow,
Ian Wark Institute, University of
South Australia

Professor Michael Lee

Chair and Professor of Cognitive
Sciences, University of California,
Irvine

Dr Mike McWilliams

Chief, CSIRO Earth Science and
Resource Engineering

Professor Qin Li

Adjunct Associate Professor,
Department of Chemical Engineering
Curtin University

Dr Jian Wei Li

Faculty of Earth Resources, China
University of Geosciences

Mr Xuehao Liu

MSc Student, Chinese Academy of
Science

Dr Horst Maerten

President, Heathgate Resources

Professor Peter Malin

Director, Institute of Earth Science and
Engineering, University of Auckland

Mr Ken McAlpine

Director of Policy and Government
Relations, Vestas Wind Systems

Mr Alastair McArthur

Project Engineer, Ramp RFID Solutions

Mr Gary Meyer

Consultant, Green Rock Energy

Dr Mo

Dept. of Radio Sciences &
Engineering, Korean Maritime
University

Professor Behdad Moghtaderi

Researcher, School of Engineering,
The University of Newcastle

Dr Hossein Najafian

Researcher, Centre for Engineering
Sustainability, University of Liverpool

Professor Peter Nelson

Professor of Environmental Studies &
Associate Dean Research, Faculty of
Science, Macquarie University

Dr David Nobes

Senior Lecturer in Geophysics -
Near-Surface Geophysics and its
Applications, University of Canterbury

Dr Alan Noble

Engineering Director, Google
Australia and New Zealand

Professor Naotake Ohtsuka

Emeritus Professor, University of
Ryukoku

Dr Craig O'Neill

Manager of the GEMOC Computing
Cluster ARC National Key Centre,
Department of Earth and Planetary
Sciences, Macquarie University

Lyle Pickett

Combustion Research Facility
Researcher, Engine Combustion
Department, US Department of
Energy's Sandia National Laboratories

Mr Jim Poss

President and Chief Executive Officer,
Big Belly Solar, USA

Professor Steve Reddy

Dean Research Science, Curtin
University

Dr Steve Rosenberg

Technical Manager - Development,
BHP Billiton Worsley Alumina Pty Ltd



Professor Sukanta Roy

Scientist and Project Leader, National Geophysical Research Institute Hyderabad

Dr Jim Sait

Senior Research Specialist, Braithwaite Steiner Pretty

Professor Mike Sandiford

Director, Melbourne Energy Institute and Professor of Geology, University of Melbourne

Mr Ian Satchwell

Interim Director, International Mining for Development Centre, Committee for Economic Development of Australia (CEDA)

Dr Keith Scott

Senior Researcher, CSIRO Exploration and Mining

Mr Ibrahim Shahin

Graduate Mechanical Engineer and Development Programme, BG Group

Professor David Sherman

Professor of Geochemistry, University of Bristol

Professor Stuart Simmons

Visiting Research Professor, CERl and Department of Geology and Geological Engineering, Colorado School of Mines

Mr Bogdan Skomra

Research and Development Superintendent, Queensland Alumina Pty Ltd

Mr Robert Smith

Consultant, Greenfields Geophysics

Dr Wayne Stange

Managing Director, AMIRA International

Dr Victoria Steblina

Senior Consultant, Applied Science International

Professor Aldo Steinfeld

Head, Institute of Energy Technology, Eidgenössische Technische Hochschule Zürich

Dr Mark Sykes

Assessment Skill Area 2IC, ExxonMobil Exploration

Professor Denis Testemale

Researcher, Institut Néel, CNRS, France

Professor Jiyuan Tu

Deputy Head of Research and Innovation, RMIT University

Mr Mark Twidell

Executive Director, Australian Solar Institute

Professor Avner Vengosh

Professor of Earth and Ocean Sciences, Nicholas School of Environment, Duke University

Mr Daniel Walsh

Senior Wind Analyst Engineer, Pacific Hydro

Mr Peter Wameyo

Senior Field Technician, Institute of Earth Science and Engineering, NZ

Professor Hongjiang Wang

University of Science and Technology, Beijing

Professor Makoto Watanabe

Faculty of Life and Environmental Sciences, University of Tsukuba

Dr Nicky White

Reader, Dept of Earth Sciences, University of Cambridge

Mr Hao Yuan

PhD student, Technical University of Denmark

Dr Eryong Zhang

Hydrogeologist, China Geological Survey

Professor Dongke Zhang

Director/Winthrop Professor, UWA Centre for Energy, The University of Western Australia

Mr Lin Zuo

PhD Student, Department of Energy Resource Engineering, Stanford University, California

Publications

Books

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