

**T**HIS REPORT summarises GEMOC's 2004 activities including research, technology development, strategic applications and industry interaction, international links and teaching (at both undergraduate and postgraduate levels). The report is required as part of GEMOC's formal annual accounting to the Australian Research Council (ARC). The ARC acknowledges GEMOC as a continuing ARC National Key Centre while GEMOC attracts sufficient income to fund its activities and achieve its annual goals, and submits an Annual Report fulfilling ARC reporting requirements.

Last year we experimented with new ways of presenting the Report and we sent, with all our posted copies, a questionnaire inviting your feedback on your preferences for delivery of our report, with choices including web access only, CD, traditional hard copy, hard copy of Research Highlights, and with composite combinations. The overwhelming response was to keep the hard copy distribution and post a web copy as well. This was also our preference, but the increasing costs of hard copy production (a large proportion of a postdoctoral salary) have made it prudent to go fully electronic. We have prepared the 2004 Report as a CD which we can mail to you, and it is posted on our website ([www.es.mq.edu.au/GEMOC/](http://www.es.mq.edu.au/GEMOC/)) both in downloadable pdf format and as an html version.

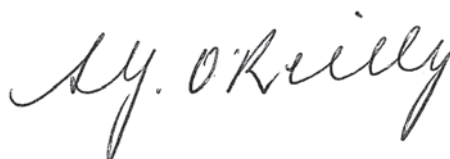
GEMOC's funding continued to access a wide portfolio of income sources ranging from traditional research sources such as the Australian Research Council schemes, non-ARC government sources, delivery of value-added consulting to the mineral exploration industry, industry collaborative projects (both mineral exploration and technology development industries), strategic alliances with technology and instrument manufacturers, commercialisation ventures (such as marketing of GLITTER software with New Wave Research), and international links and alliances that provide reciprocal resources. The latter included significant funding from the Johnson Space Centre, NASA and the Carnegie Institution through the AMASE (Arctic Mars Analogue Svalbard Expedition) Project in the Centre for Physics of Geological Processes at the University of Oslo. Four GEMOC researchers participated in the AMASE program in Spitsbergen in September 2004 (see *Research Highlights* and front cover).

The suite of new instrument rooms and clean geochemical laboratories for GEMOC is now fully operational and provides a world-class facility that, along with the extensive instrument array (see the text and photos in the section on *Technology Development*), attracts many national and international researchers. A successful LIEF bid resulted in the purchase of a Triton Thermal Ionisation Mass Spectrometer to complement the capabilities of the Nu Multi-collector Inductively Coupled Plasma Mass Spectrometers. GEMOC's strategy of driving basic research with parallel strategic and applied goals, requires our high-technology facilities to deliver the relevant developments in technology and analytical methodologies.

GEMOC has achieved tremendous advances in understanding the nature of Earth's lithosphere and its processes and we now plan to plunge deeper and explore the whole mantle and core-mantle interaction with the same interdisciplinary approach, integrating geochemical, geophysical and tectonic information. This new direction will align with the planned experimental studies of deep Earth processes which will be a part of the research program of Professor Bernard Wood, the second Federation Fellow to join GEMOC, who will arrive mid 2005.

Throughout 2004, Macquarie University continued to provide a supportive research framework for GEMOC to operate within.

We look forward to expanding beyond the lithosphere to explore Earth's deeper regions through 2005.

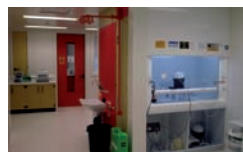


## Director's Preface



[http://  
www.es.mq.edu.au/  
GEMOC/](http://www.es.mq.edu.au/GEMOC/)

# Introducing GEMOC



This Mission Statement has been revised to reflect the evolution of GEMOC's activities to consider Earth Geodynamics beyond the Lithosphere.

## Mission

- to define the processes driving Earth's internal dynamics, and understand how these have generated the present chemical and physical structure of our planet through time, integrating petrological, geochemical and geophysical information
- to deliver new concepts about the spatial and temporal distribution of Earth resources to the mineral and energy industries and the next generation of students

## GEMOC'S STRATEGIC FOCUS

THE MAIN TARGETS of GEMOC's founding activities were defined to be large-scale problems related to lithosphere evolution and understanding the relevance of different types of crust-mantle domains to area selection for mineral exploration. These have broadened to involve whole-mantle perspectives of geodynamics, and far-field and feedback effects involving the lithosphere.

Industry collaboration has increased with funded large-scale projects related to lithosphere evolution and crustal generation studies, delivering new tools and a new framework of terrane analysis to the minerals exploration industry. In addition, we have undertaken new projects related to magma-related Ni deposits and to diamond exploration, capitalising on our depth of intellectual property about the lithosphere and deep Earth processes.

## GEMOC'S CONTEXT

**A SHORT HISTORY OF GEMOC:** The National Key Centre for the Geochemical Evolution and Metallogeny of Continents (GEMOC) formally commenced in January 1996 and was funded under the ARC Key Centre scheme for 6 years. Under the government regulations for this round of Key Centres, there was no provision for extension of Centre funding beyond the original six-year term. A detailed business plan was required in the application to demonstrate how the Centre could continue and maintain its identity after the Commonwealth funding term. This business plan has succeeded and the evolved GEMOC started its new phase in 2002 with an independent well-funded base for the next five years.

**GEMOC'S FUNDING BASE FROM 2002:** This funding, like a good investment portfolio, has a healthy, risk-minimising diversity ranging across competitive traditional schemes such as those available from the Australian Research Council, to substantial industry collaborative projects, provision of value-added products to the mineral exploration industry (see the section on *Industry Interaction*) and one-off opportunities such as the competitive DEST Systemic Infrastructure Initiative in 2002 that granted over \$5 million to enable GEMOC's Technology Development Program to stay at the forefront (see the section on *Technology Development*).



*The hazards of Arctic fieldwork – the GEMOC team under attack by angry Arctic terns, on their way to collect xenoliths on the Sverrefell volcano, NW Spitsbergen (cover photo).*

**GEMOC'S LINKAGES AND ALLIANCES:** GEMOC was initially based on the pre-1995 collective profiles of the core participants at Macquarie and the networked group at ANU (Faculties), with collaborative links to CSIRO, AGSO (now Geoscience Australia (GA)) and colleagues at other Australian universities. GEMOC has significantly evolved and expanded from its original base with shifts in the original linkages and expansion in collaborations. Interaction with CSIRO and GA has grown and transformed over the six years. Strong new national and international collaborative research links and programs have emerged and robust ongoing engagement with industry (mineral exploration and technology manufacturing) partners through collaborative projects has fulfilled one of GEMOC's original goals.

### **SCIENTIFIC PHILOSOPHY**

GEMOC's distinctiveness lies in its interdisciplinary and integrated approach to interpreting Earth's lithosphere as a 4-dimensional dynamic system (in space and time).

This approach links...

*petrology and geochemistry*

*experimental petrology*

*geophysics*

*petrophysics*

*tectonics*

*numerical modelling*

within the important contexts of...

*time (the 4th dimension) and thermal state*

to understand how Earth's core-mantle system controls crustal tectonics, and the assembly and destruction of continents through time.

**“GEMOC's distinctiveness lies in its interdisciplinary and integrated approach to interpreting Earth's lithosphere as a 4-dimensional dynamic system (in space and time)”**

## STRATEGIC OUTCOMES

These are modified from the founding strategic aims in 1995 as our understanding and development of novel methodologies to address these aims have evolved.

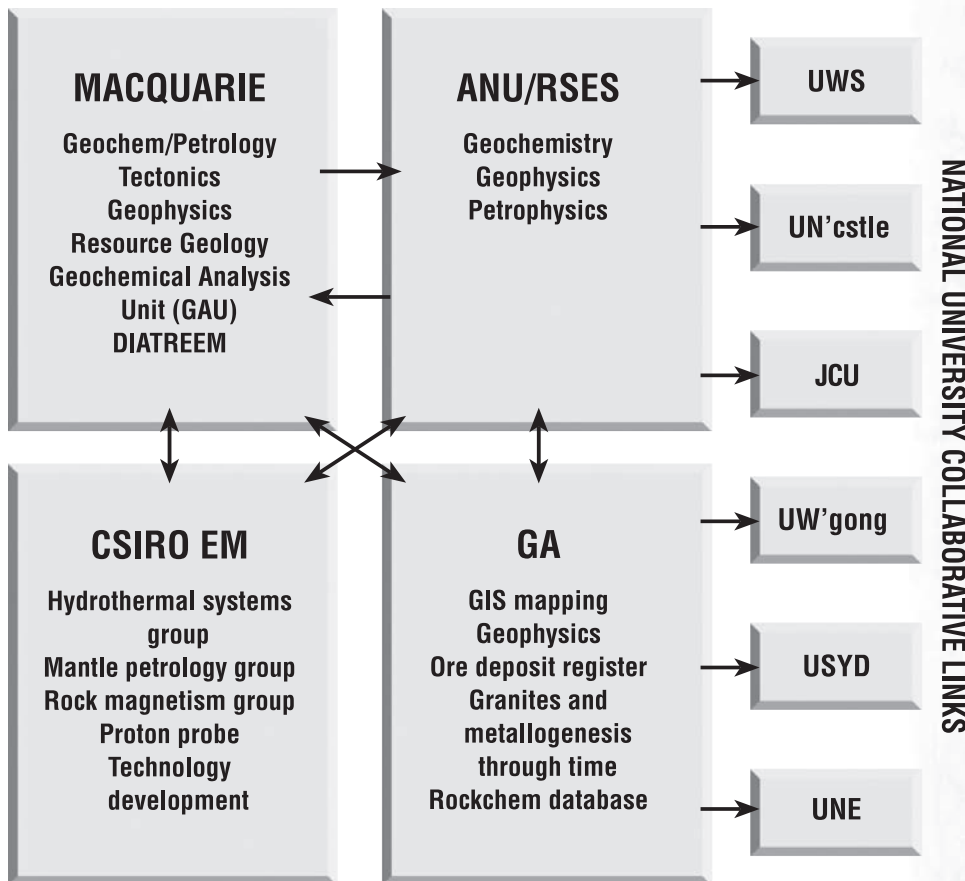
- **fundamental insights into the processes that create and modify the continental mantle and crust through time**
- **a better understanding of the assembly of the Australian continent and its geological architecture through work in Australia and global analogues**
- **results and concepts exportable to other terrains, globally and other potentially resource-rich areas of interest to Australian exploration companies**
- **a new conceptual framework for understanding the localisation of economic deposits, that will influence exploration strategies for world-class ore deposits, and improve the competitiveness of the Australian exploration industry both on- and off-shore**
- **a realistic 3-D geological framework for the interpretation of lithospheric-scale geophysical datasets**
- **a training program for senior undergraduate and postgraduate students (and continuing education) that will help maintain the technological edge of the Australian mineral industry and improve the industry's ability to rapidly assimilate new concepts and methodologies**
- **new analytical strategies for determining the chemical and isotopic compositions of geological materials (including fluids)**
- **new experimental petrology approaches to probing the nature of the deep Earth (core and lower mantle)**
- **development of *in situ* analytical methods (including dating) to maximise information encoded in mineral zoning and to enhance interpretation of data using spatial contexts**
- **strategic and collaborative alliances with technology manufacturers in design and application innovation**

*This report documents achievement of these goals*

**T**HE HOST INSTITUTION for GEMOC is Macquarie University (in the Department of Earth and Planetary Sciences).

There is a close collaboration with CSIRO Exploration and Mining (EM) (North Ryde), State Geological Surveys, GA (Geoscience Australia) and ANU/RSES across an increasingly broad range of projects.

## GEMOC participants



Collaborative research, teaching and technology development links have been established with other universities nationally and internationally and these evolve as new alliances become relevant to new directions.

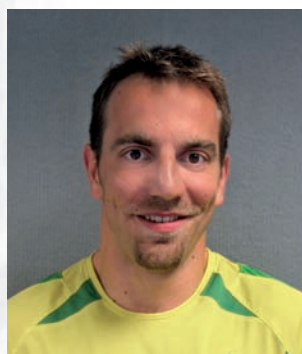
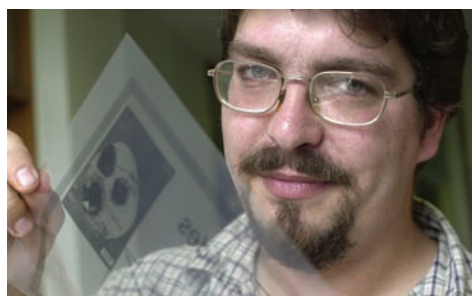
GEMOC has developed ongoing collaborative relationships with national and international industry and end-users such as Geological Surveys globally (eg Australian states, Canada, Norway).

GEMOC has a wide network of international research and teaching development partners and collaborators.

***A full list of GEMOC participants and their affiliations is given in Appendices 1 and 3 at [www.es.mq.edu.au/GEMOC/](http://www.es.mq.edu.au/GEMOC/)***

#### CHANGES IN 2004

**Dr Olivier Alard** commenced an ARC Postdoctoral Fellowship. This project will develop novel methods for analysing metal stable isotopes (MSI: Mg, Fe, Cu, Zn, Ga) and applying these to define their isotopic composition in Earth's key reservoirs and in reference materials such as the chondritic meteorites; and to quantify and understand the causes of MSI fractionations during geological processes. A unique combination of in-situ and solution techniques will be aimed at establishing a conceptual and theoretical framework for the use of MSI in geosciences.



**Dr Anthony Dosseto** commenced an ARC Postdoctoral position. He is currently using U-series disequilibria to study Australian river systems and soils. The objective is to better understand how soils develop and sediments are transferred under the various conditions that constitute the Australian climate: from desert to wet tropical. Other projects are under way in the Caribbean Islands and South American river systems.

**Dr Helen Williams** was appointed the GEMOC-Nu Fellow (commencing 2005) with 3-year funding from Nu Instruments to investigate isotopic systems relevant to the evolution and composition of the Earth, using both conventional and *in situ* analytical techniques.



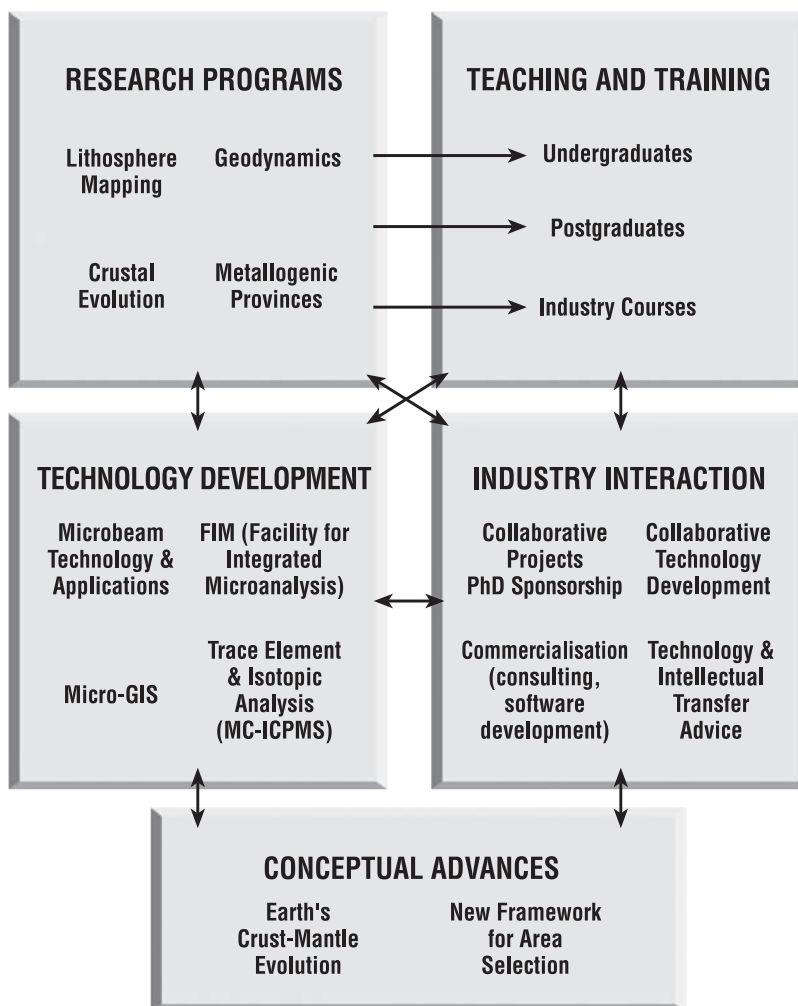
**Professor Bernard Wood** was awarded a Federation Fellowship. The project ("Origin and evolution of the Earth's chemical reservoirs") aims to understand the processes by which the Earth separated into its chemically distinct layers (core, mantle, crust, atmosphere, oceans) and to determine the nature of the continuing interactions



between the surface environment in which we live and the deep interior. Experimental study of these processes will involve establishment of a world-class facility for materials synthesis at high pressures and temperatures. This facility will provide the means to simulate the processes occurring within the Earth and will enable synthesis of new high-density materials of technological interest. This is only the second Federation Fellowship to be awarded in the Geosciences and the other one was to Professor Simon Turner, also in GEMOC in the Department of Earth and Planetary Sciences.

**G**EMOC'S PROGRAMS are set up to be interactive. Basic research strands are supported by parallel applied collaborative research with industry partners: these provide the impetus for technology development. This is, in turn, supported by strategic alliances with front-line instrument designers and manufacturers (eg Nu Instruments, Agilent Technologies, New Wave Research). Teaching and training benefit directly from these new advances. Technology development has been transferred to relevant end-users, applied in postgraduate research programs, and is the essential core that provides the data underpinning the conceptual advances about lithosphere architecture and evolution in GEMOC.

## GEMOC programs



# GEMOC structure

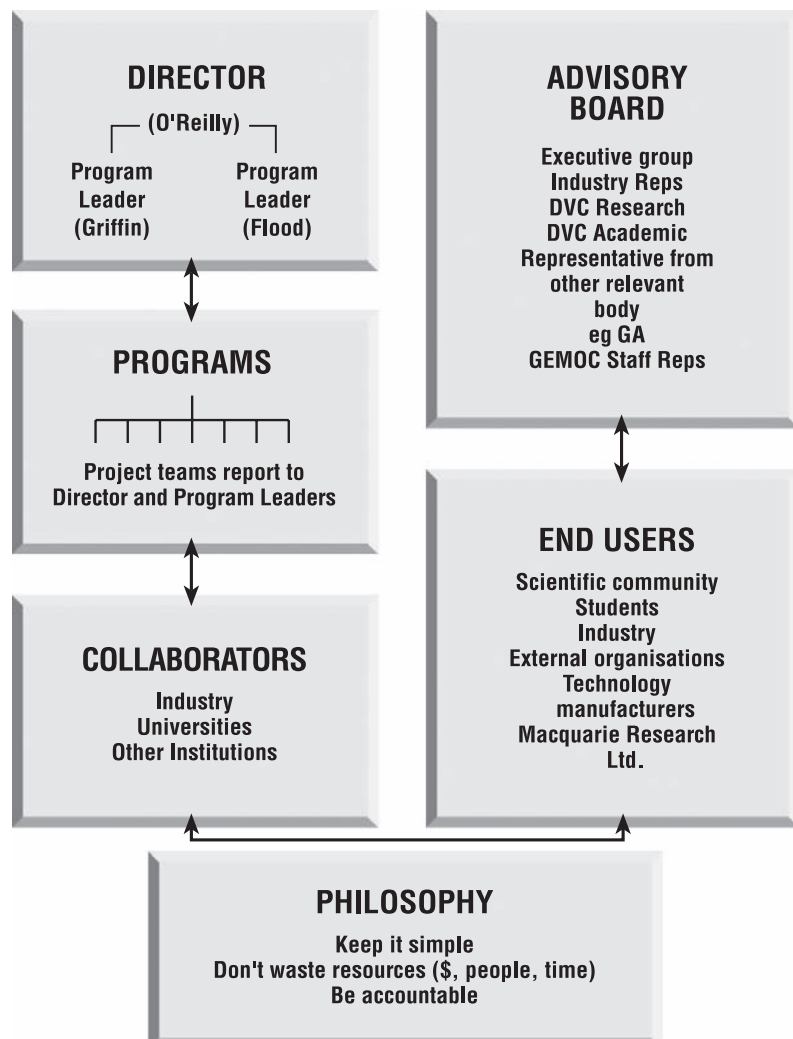
**T**HE ORGANISATIONAL STRUCTURE of GEMOC is designed for efficiency, flexibility and interaction. The financial management operates within Macquarie University's Finance System and within Access Macquarie for commercialised products, consulting and some strategic collaborative research projects. The Teaching Program is incorporated into the teaching activities and strategies of the Department of Earth and Planetary Sciences at Macquarie to ensure that GEMOC interfaces in a positive way with the existing structures while retaining a clear identity and funding unit.

GEMOC has been reconfirmed as a Centre of Excellence and research concentration within Macquarie University, and three designated Areas of Excellence within Macquarie University's Research and Research Teaching Management Plan lie within GEMOC:

- lithosphere and planetary evolution and metallogeny
- isotopic and global geochemistry
- paleomagnetism, geodynamics and geophysical modelling

All of these align with GEMOC's mainstream foci. This University recognition allows for ongoing appropriate staffing and support arrangements.

## MANAGEMENT STRUCTURE





## 2004 MANAGEMENT ROLES

**Professor Suzanne O'Reilly** is Director of GEMOC.

**Ms Leigh Newton** was GEMOC Administrator.

**Dr Richard Flood** is the coordinator of Teaching Programs at Macquarie and Head of the Department of Earth and Planetary Sciences from December 1999 (re-elected in 2002).

**Professor William Griffin** is Adjunct Professor at Macquarie University and is the Program Leader responsible for Technology Development and Industry Interaction.

**Professor Simon Turner** leads the development of the U-Series Geochemical Program.

**Dr Norman Pearson** is Manager of the Geochemical Analysis Unit at Macquarie.

**Dr Kelsie Dadd** is responsible for implementation of GIS-based teaching methodology in the Teaching Program and for promotional activities to attract students.

**Dr Simon Jackson** assists with ICPMS and laser microprobe development at Macquarie.

**Ms Sally-Ann Hodgekiss** is the GEMOC graphics and design consultant at Macquarie.

## ADVISORY BOARD MEMBERS

**Professor Suzanne O'Reilly (Director)** – *EPS Macquarie*

**Professor William Griffin (Program Leader: Technology Development)**  
– *EPS Macquarie*

**Dr Richard Flood (Program Leader: Teaching)** – *EPS Macquarie*

**Professor Jim Piper** – Deputy Vice-Chancellor (Research), *Macquarie*

**Professor John Loxton** – Deputy Vice-Chancellor (Academic), *Macquarie*

**Dr Kelsie Dadd** – *GEMOC, EPS Macquarie*

**Adjunct Professor Michael Etheridge** – Leader, Risk Assessment Group, interfaces with GEMOC's Tectonic Research program and the Predictive Mineral CRC, links with the Exploration Industry and Management Roles, *EPS Macquarie*

**Dr Russell Korsch** – *representative of Geoscience Australia (GA)*

**Dr Richard Glen** – *representative of Geological Survey of New South Wales*

**Dr Paul Heitherseay** – *representative of PIRSA*

**Dr Jon Hronsky** – *industry member WMC (Perth)*

**Dr Steve Walters** – *industry member GeoDiscovery*

**Dr Simon Shee** – *industry member DeBeers Australia Exploration Ltd*

# GEMOC communications 2004



“From 2003 the Annual Reports are available as downloadable pdf files on the GEMOC website as well as in html format. All previous Annual Reports are available in html format.”

Sonja Aubach  
discussing her popular  
poster presentation  
at the IGC held in  
Florence.



**G**EMOC WEB RESOURCES provide past Annual Reports, updated details on methods for new analytical advances and software updates (GLITTER), synthesised summaries of selected research outcomes (eg studies of eastern China lithosphere) and items for secondary school resources on the lithosphere and on diamond occurrence. In addition, undergraduate teaching is web-based. From 2003 the Annual Reports are available as downloadable pdf files on the GEMOC website as well as in html format. All previous Annual Reports are available in html format.

## **PARTICIPATION IN WORKSHOPS, CONFERENCES AND INTERNATIONAL MEETINGS IN 2004 (and beyond)**

GEMOC staff and postgraduates increased their profile at peak metallogenic, geodynamic and geochemical conferences as convenors or invited speakers, or presenters, with 50 presentations. International fora included: the AGU Joint Assembly in Montreal, the 32<sup>nd</sup> Geological Congress in Florence, the 14th V. M. Goldschmidt Conference, the de Beers International Diamond Workshop in Warwick, the 2004 Western Pacific Geophysics Meeting in Hawaii, the 2004 IAVCEI General Assembly, the International Society of Economic Geologists (SEG) 2004 Predictive Discovery Undercover Conference in Perth and the American Geophysical Union Fall Meeting. A full list of abstract titles for Conferences and Workshops attended is given in *Appendix 4* and on the GEMOC website where full-text versions of most of the abstracts can also be found.

Professor Simon Turner continued to lead the organisation of the 2006 International Goldschmidt Conference to be held in Melbourne (see *Appendix 8*).

Professors Sue O'Reilly and Bill Griffin were co-convenors for the Special Session “Geophysical and geochemical imaging and modelling of continental roots and beyond: implications for the formation and evolution of continents” at the International Geological Conference in Florence in 2004. They were also invited speakers in the session on mantle geochemistry.

Professor Bill Griffin gave a keynote talk at the Symposium on “Seismic heterogeneity in the Earth’s mantle: thermo-petrologic and tectonic implications” in Copenhagen in February 2004.

Professors Bill Griffin and Sue O'Reilly (with Sonal Rege) gave an invited account of GEMOC’s work on diamond trace-element analysis at the de Beers’ International Diamond Workshop in Warwick, UK in June 2004.

Dr Norman Pearson gave a Plenary Talk at the “Inaugural Symposium Celebrating the Opening of the W.M. Keck Isotope Laboratory”, University of California, Santa Cruz in June, titled “More ions in the fire: developments in *in situ* high-precision isotope ratio measurement using laser ablation MC-ICPMS”.

Professor Bill Griffin presented a two-day workshop on the *TerraneChron*<sup>TM</sup> methodology and its application to crustal evolution, at the request of WMC Resources (Perth).

Professor Mike Etheridge gave an invited keynote talk on “Improving Exploration Performance” and Professor Sue O’Reilly presented an invited keynote talk on *TerraneChron*<sup>TM</sup> at the International Society of Economic Geologists meeting in Perth in September 2004, both in the session on “Research, Exploration and Predictive Mineral Discovery”.

Professor Sue O’Reilly accepted nomination to the organising committee for the International Geological Congress (IGC) to be held in Brisbane in 2012 after the successful bid by Australia at the 32 IGC in Florence (by the Australian Bid Committee of which she was a member).

Professor Bill Griffin is a member of the program committee for the Goldschmidt Conference to be held in Melbourne in 2006.

A highlight in 2004 was the invitation to four GEMOC researchers (O’Reilly, Griffin, Pearson, Powell) to join the international AMASE (Arctic Mars Analogue Svalbard Expedition) team (with members from the University of Oslo, the Carnegie Institution and the Jet Propulsion Laboratory) on the Arctic island of Spitsbergen to unravel the significance of deepseated fluids detected in volcanic rocks and in mantle xenoliths. Carbonate minerals formed in the xenoliths and in volcanic vents at the surface form tiny round structures very similar to those seen in some Martian meteorites and controversially described as evidence for life on Mars (see *Research Highlights*).

Dr Norman Pearson is convenor of the symposium “European Geosciences Union” for the European Geosciences Union (EUG) Conference in Vienna, April 2005. He is also a Keynote Speaker at this conference.

Dr Norman Pearson is convenor of the session “Isotopic ratio measurement using microbeam methods: Where do we stand and where are we going?” for the 15<sup>th</sup> Annual Goldschmidt Conference in Moscow (Idaho , USA), 2005.

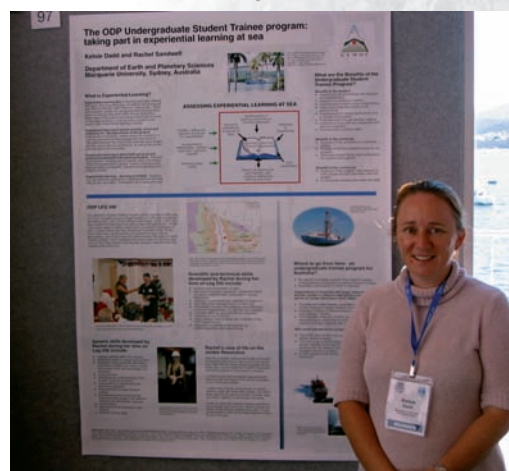
Dr Simon Jackson is the presenter of a Short Course on laser ablation techniques at the Agilent ICP-MS User Group Meeting, Adelaide, April 2005.

## VISITORS

GEMOC fosters links nationally and internationally through visits of collaborators to undertake defined short-term projects or short-term visits to give lectures and seminar sessions. Formal collaborative arrangements are facilitated by ARC Linkage grants with reciprocal funding from international collaborators.

Australian and international visitors are listed in *Appendix 3*. They have participated in:

*collaborative research, technology exchange, seminars, discussions and joint publications, collaboration in postgraduate programs.*



*Kelsie Dadd at the 17th AGC conference held in February 2004.*



*Elena Belousova and fellow attendees at the 17th AGC.*

# Is **GEMOC** making a difference?

“Tools are now developed to address long-standing fundamental questions about Earth’s geological evolution and to inform area selection in exploration”

## Research examples:

- Unique methodology for geochemical imaging of the lithosphere (4-D Lithosphere Mapping) developed to maturity and now being extended to whole-mantle perspectives. This has given a new understanding of lithosphere formation mechanisms and changes through time, and has delivered new concepts for exploration targeting to the mineral exploration industry
- Unique methodologies developed for dating mantle formation events (from 4.6 billion years ago) and times of overprinting tectonic events (Re-Os *in situ* dating of mantle sulfides and *TerraneChron*<sup>™</sup> using zircon geochemical fingerprints)
- Two Federation Fellows in Geoscience attracted to Australia
- ✳ *Unique methods for testing mantle and crust coupling over Earth history have emerged – and these are also keys to new exploration methods*

## Highlights of technology development outcomes:

- Focus on *in situ* analysis of important elements to parts per billion
- Unique method (*in situ* Re-Os) to date mantle events
- Unique method to track crustal histories (U-Pb dating and Lu-Hf and trace-element fingerprinting of zircons, rutiles): *TerraneChron*<sup>™</sup>
- Delivery of rapid, cost-effective and user-friendly new methodologies and software in geochemical analysis (eg GLITTER)
- Establishing the rates of geological processes both for the deep Earth and for surface processes using Uranium decay series dating
- ✳ *Unique geochemical analysis infrastructure built up over last decade (see Technology Development section).*
- ✳ *Tools are now developed to address long-standing fundamental questions about Earth’s geological evolution and to inform area selection in exploration*

## Highlights of teaching outcomes:

- Industry-standard training with development of new degree programs (eg Environmental Geoscience, Marine Geoscience)
- Hands-on undergraduate training in use of state-of-the-art techniques (GIS databases, imaging, geochemical techniques, geophysical measurements) with industry-standard instrumentation
- Vigorous postgraduate group with active international postgraduate exchange programs: (eg China, France, Norway, Italy)
- Short-course programs for end-user information and technology exchange

## Highlights of industry interaction outcomes:

- Changing the mineral exploration paradigm by delivering new concepts for exploration globally and in Australia derived from basic research and technology development
- Development of active partnerships in strategic and applied research with industry (exploration companies and technology manufacturers)
- Funded Industry initiatives (eg GEMOC-Nu Instruments 3-year Fellowship - see *Industry Interaction*)
- Development of value-added consultancies and collaborative research programs using GEMOC’s geochemical technologies and database