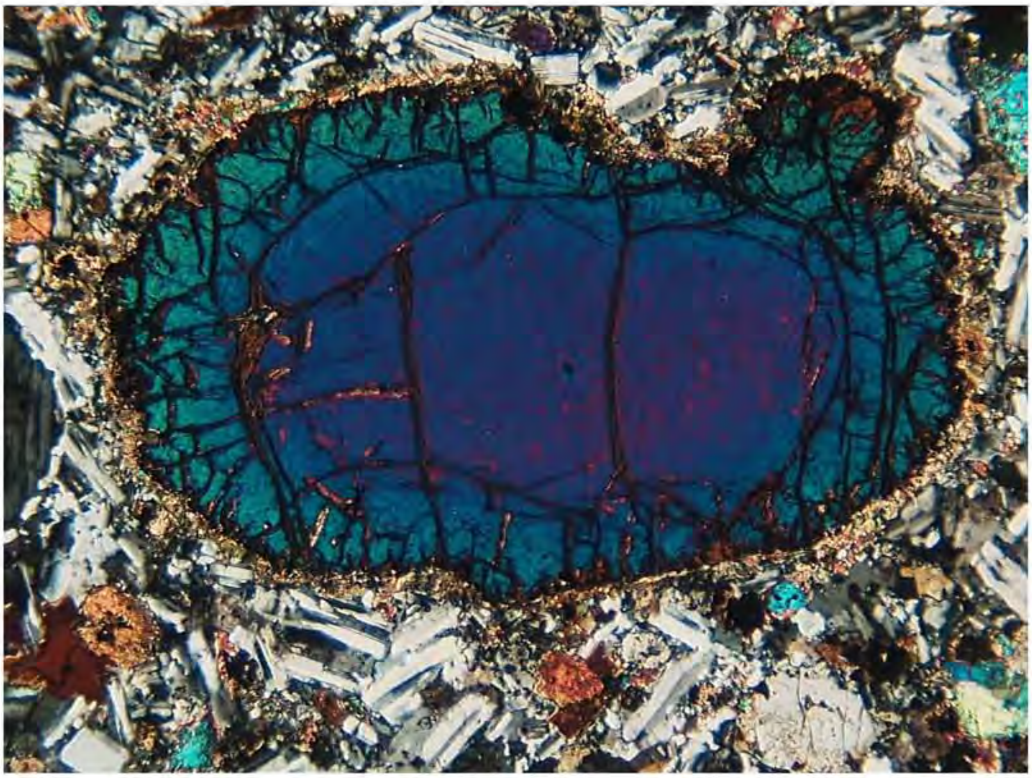
Research School of Earth Sciences Annual Report 2008



Microphotograph (X Nicols) of an olivine xenocrist embedded in a diorite matrix consisting of plagioclase, clinopyroxene, amphibole, biotite and quartz. The olivine grain is surrounded by a small corona of orthopyroxene. The change in interference colors from core to rim is related with an increase in fayalite component in olivine. Image - Jörg Hermann

THE AUSTRALIAN NATIONAL UNIVERSITY

Research School of Earth Sciences
2008 Annual Report - Contents

Director's Introduction 2008

2008 was the first year in which the Research School of Earth Sciences was engaged with the full range of educational activity from undergraduate, honours, Masters by coursework and higher degree research. All education activities are carried out in the *Earth and Marine Science Education Program* and all courses now appear with a single code EMSC irrespective of their origins in the former Research School or Department. I would like to thank the Associate Director – Education, Professor S Cox, for steering the education activities of the School successfully through the year. We have had high numbers in first year in courses shared with the Fenner School and a large Honours class. Most undergraduate teaching is carried at the D.A. Brown Building (#47), but Honours and Masters teaching is concentrated at the Jaeger Building (#61).

The integration of research activities between the D.A. Brown and Jaeger buildings has worked quite well and some rearrangements of facilities are planned to make the best use of technical resources. Movements of staff have been two way and many members of the school keep fit by walking (or cycling) between the two buildings.

The administrative structure in the University continues to evolve. As a result of a University Review of Biological Sciences, the College of Science and the College of Medicine and Health have been reconfigured into the College of Physical Sciences and the College of Medicine, Biology and Environment with a joint college administration for the major functions. The Dean of Science - Prof Byrne is responsible for Education in Science across both colleges. Prof Byrne who is a nuclear physicist also has the role of Director of the College of Physical Sciences within which RSES sits. The full details of the administrative changes are still being worked out, but there has been a subtle but significant shift in the position of the School. Budgetary and Strategic issues are now expected to be worked in a College context.

Members of the School received many honours during the year:

- Prof. B.L.N. Kennett was awarded the Gold Medal in Geophysics from the Royal Astronomical Society and the Peter Baume award for exceptional merit from ANU.
- Prof. R. Grun was elected a Fellow of the Society of Antiquaries of London and the Australian Academy of the Humanities.
- Professor H. O'Neill was elected a Fellow of the Australian Academy of Science
- Prof. M. McCulloch has been made a Fellow of the Geochemical Society
- Prof. G. Lister was elected a Fellow of the Geological Society of America
- The SHRIMP team, comprising Dr John Foster, Dr Peter Holden, Mr Peter Lanc, Mr Ben Jenkins, and Mr Norm Schram, received a Vice Chancellor's Award for Innovation and Excellence in Service Quality

With the election of Prof R. Grun to the Australian Academy of the Humanities for his contributions to archaeology we now have fellows in three Australian Academy (Academy of Science, Academy of Technological Science, Academy of the Humanities) which is unusual for a Science based School.

As a fitting tribute to his very distinguished career in Earth Sciences, Em. Prof S.R. Taylor has been appointed as an Honorary Companion of the Order of Australia. In the internal promotion round for 2008 Drs V. Bennett and M. Norman were promoted to Level D.

The number of grants funded through the Australian Research Council was down once more in 2008, but there was continuing success in the areas of earth physics and climate change.

Two successful LIEF grants will see renewal in mass-spectrometers for environmentally oriented work.

2008 has seen the establishment of the Australian Office for the Integrated Ocean Drilling Program (IODP) at RSES and Prof Neville Exon appointed as Program Scientist. Australian membership of IODP is supported by a multi-year ARC LIEF grant and contributions from a wide-ranging consortium across the country. The IODP membership brings a substantial foreign currency exposure (US$1.4M per year). Fortunately this year's partial subscription (~US$1M) was paid near the top of the A$ rate against the US$ before the recent precipitate decline. The Terrawulf II computer cluster funded through AuScope was formally launched in June, this 384 core system is being used for a wide range of research including atmospheric effects in GPS, through ocean modelling to studies of the Earth core and geodynamo.

The Jaeger 5 extension building with the ground floor SHRIMP stable and second floor offices for the Planetary Sciences Initiative was completed in mid-year. The energy efficient building provides a contrast and complement to the rest of the Jaeger complex. SHRIMP II was successfully moved to the ground floor working area to join SHRIMP RG in the original space. SHIRIMP SI grows in place in the floor and already the general form can be visualised. The offices above are in use and we have gained a valuable area for teaching and small meetings. We have received permission to call this the "D.H. Green Room" in honour of the former Director of the School who has recently 'retired' to Tasmania.

The Campus Planning and Development committee has approved the design for the replacement of the rear section of the Old Hospital Building (OHB-B) that provides an interesting contrast to the Heritage listed OHB-A. This "Jaeger-8" project now awaits release of funding. It will include additional teaching space and a clear front entrance to the School.

Research at RSES mobilises a wide range of geological, geochemical and geophysical techniques and expertise to try to understand the nature of the Earth and its environment. The research is organised through the four main Research Areas: Earth Chemistry, Earth Environment, Earth Materials & Processes and Earth Physics. These research areas link groups with a common style of activity or equipment. Much cross-area cooperation occurs, and many activities transcend area boundaries.

The following pages provide an account of many facets of the research activity of RSES undertaken in 2008.

B.L.N. Kennett
Director, RSES

Honours & Awards

Ms J.N. AVILA received a travel grant award, from the Graduate University for Advanced Studies Sokendai, to attend the 71st Annual Meeting of the Meteoritical Society, Matsue, Japan.

The special volume of the Australian Journal of Earth Sciences "Geochronology in Australia", edited by J. R. De Laeter, A. J. W. Gleadow and I. McDougall, was dedicated to Dr W. COMPSTON.

Prof P. DE DECKKER was awarded the Christoffel Plantin Medal for his achievements in many aspects of science. This Belgian award is offered annually.

Dr N. EXON received the Stillwell Award for the best written paper in the Australian Journal of Earth Sciences in 2006, at the Australian Geoscience Convention in Perth in July.

Mr R.J.M. FARLA has received the Paterson Fellowship award 2009. In August 09 he will visit the David KOHLSTEDT laboratory at the University of Minnesota then proceed to meet Dr S. Karato at Yale University. He will attend the international conference Deformation, Rheology and Tectonics (DRT) early September 09.

Dr M. FORSTER was awarded an ARC Fellowship – Australian Research Fellow (ARF) - starting on August 2008 till August 2013.

Ms C. GREGORY received the Robert Hill Memorial Prize from the Research School of Earth Sciences for excellence in scientific communication.

Prof R. GRÜN was elected Fellow to the Society of Antiquaries, London, and the Australian Academy of the Humanities.

Mr J. HIESS received an ICOG7 Travel Award to attend the 18th Annual V.M. Goldschmidt Conference, Vancouver, Canada, 13-18 July.

Prof T.R. IRELAND was awarded Fellowship of the Meteoritical Society.

C. JONES received a renewal of the National Defense Science and Engineering Graduate Fellowship from the US Department of Defense (3rd year of support)

Prof B.L.N. KENNETT received the Gold Medal in Geophysics from the Royal Astronomical Society, London for his work in seismology.

Prof B.L.N. KENNETT was awarded the Peter Baume Award from ANU. This is the University's most prestigious staff award and was presented in recognition of "his exemplary record of research achievement and leadership".

Prof K. LAMBECK contributed to the award of the Nobel Peace Prize for 2007 to the Intergovernmental Panel on Climate Change (IPCC), as a substantial contributor to the IPCC since the inception of the organization.

Prof G. LISTER was awarded the Carey Medal by the Geological Society of Australia, and was made a Fellow of the Geological Society of America.

Dr J. LONG (Museum Victoria; Adjunct Professor, RSES) received the Australasian Science prize for 2008 for his research on live birth in the Devonian Period published in Nature.

Prof H. St.C. O'NEILL was elected a Fellow of the Australian Academy of Sciences

Prof M.T. McCULLOCH was made a Fellow of the Geochemical Society in July 2008 for outstanding contributions to Geochemistry.

Prof M.T. McCULLOCH was made a Fellow of the Australian Geological Society in July 2008 for outstanding contributions to the Earth Sciences.

Mr I. MOFFAT was appointed a member of the Australian Institute of Aboriginal and Torres Strait Islander Studies

A. ROSENTHAL received financial support from the conference organisers for travel to the 9th International Kimberlite Conference in Frankfurt/Main, Germany.

KEITH SCOTT received an Honorary Fellowship Award from CRC LEME for "Outstanding contributions to the development and promotion of regolith science".

Prof S. R. TAYLOR was appointed as an Honorary Companion (AC) of the Order of Australia. The award is Honorary because he is a New Zealand Citizen.

Dr E. M.TRUSWELL was elected a Fellow of the Geological Society of Australia.

ACADEMIC STAFF

Director and Professor
B.L.N Kennett, MA PhD ScD Cambridge, FAA, FRS

Distinguished Professors
B.L.N Kennett, MA PhD ScD Cambridge, FAA, FRS

Professors
R.J. Arculus, BSC PhD Durham, FAIMM
I.H. Campbell, BSc UWA, PhD DIC London
S.F. Cox, BSc Tasmania, PhD Monash
P. DeDekker, BA (Geology) MSc (Hons) Macquarie, PhD DSc Adelaide
D.J. Ellis, MSc Melbourne, PhD Tasmania
N. Exon, BSc (Hons) NSW, PhD Kiel
R.W. Griffiths, BSc PhD ANU, FAIP, FAA
R. Grün, DiplGeol, Dr.rer.nat.habil Köln, DSc ANU, FAAH
T.R. Ireland, BSc Otago, PhD ANU
I.N.S. Jackson, BSc Qld, PhD ANU
G. Lister, BSc Qld, BSc (Hons) James Cook, PhD ANU
M.T. McCulloch, MAppSc WAIT, PhD CalTech, FAA
H.St.C. O'Neill, BA Oxf, PhD Manchester, FAA
B.J. Pillans, BSc PhD ANU, HonFRSNZ
M.S.Sambridge, BSc Loughborough, PhD ANU, FRAS

Senior Fellows
I. Buick, BSc (Hons), MSc Adelaide, PhD Cambridge (to 2 July 2008)
G.F. Davies, MSc Monash, PhD CalTech
S. Eggins, BSc UNSW, PhD Tasmania
C.M. Fanning, BSc Adelaide
M.K. Gagan, BA UCSantaBarbara, PhD James Cook
M. Honda, MSc PhD Tokyo
R.C Kerr, BSc Qld, PhD Cambridge , FAIP
C. Lineweaver, BSc Munich, PhD Berkeley
J.A. Mavrogenes, BS Beloit, MS Missouri-Rolla, PhD VirginiaPolyTech
D.C. McPhail, BSc. (Hons) MSc British Columbia, PhD. Princeton
I.S. Williams, BSc PhD ANU
G.C. Young BSc (Hons) ANU, PhD London

Fellows
Y. Amelin, MSc, PhD Leningrad State University
R. Armstrong, BSc MSc Natal, PhD Witwatersrand
V.C. Bennett, BSc PhD UCLA
J.J. Brocks, Dip Freiburg, PhD Sydney
J. Hermann, Dip PhD ETH Zürich
A.M. Hogg, BSc ANU, PhD UWA
G. Hughes, BE ME Auckland, PhD Cambridge
M. Norman, BS Colorado , PhD Harvard

B.N. Opdyke, AB Columbia, MS PhD Michigan
R. Rapp, BA (Geological Sciences) State University of New York, PhD (Geology) Rensselar Polytechnic Institute (to 2 November 2008)
N. Rawlinson, BSc PhD Monash
M.L. Roderick BAppSc QUT, PGDipGIS Qld, Phd Curtin
D. Rubatto, BSc MSc Turin, PhD ETH
H. Tkalcic, Dip Engineering in Physics, Zagreb, PhD California
P. Tregoning, BSurv PhD UNSW
G. Yaxley, BSc PhD Tasmania

Research Fellows

L. Ayliffe, BSc (Hons) Flinders, Graduate Dipolma (Oenology) Adelaide, PhD ANU
A.L. Dutton, BA (Mus) Massachusetts, MSc PhD Michigan
M. Ellwood, BSc (Hons) Otago, PhD Otago
S. Fallon, BA MS San Diego, PhD ANU
M. Forster, BSc MSc PhD Monash
P. Treble, BSc Woll, BSc PhD ANU (to 1 July 2008)
J. Trotter, BSc MSc Macquarie, PhD ANU (from 18 September 2008)

Postdoctoral Fellows

P. Arroucau, PhD Nantes University
M. Aubert, PhD, Université du Québec, Institut National de la Recherche Scientifique
M.A Bonnardot, MSc De Savoie, PhD Nice-Sophia Antipolis
J.M. Desmarchelier, BSc PhD Tasmania (to 1 January 2008)
K. Fitzsimmons, Bsc (Hons), Dip Modern Languages Melbourne, PhD ANU
F. Fontaine, DEUG (Hons) Reunion, MSc PhD Montellier II(to 28 August 2008)
A. Halfpenny, M.E.Sc PhD Liverpool,
J. Huang, BSc Peking, PhD Academy of Sciences China
F. Jenner, BSc (Hons) Oxf Brookes, PhD ANU (from 17 January 2008)
S. Jupiter, A.B Harvard, PhD California (to 19 April 2008)
S. Micklethwaite, BSc PhD Leeds (to 1 July 2008)
S. Pozgay, BA Boston A.M PhD Washington (from 7 January 08)
S.W. Richards, BSc PhD Newcastle (to 11 August 2008)
M. Salmon, BSc (Hons) PhD, Victoria University of Wellington
M. Ward, BSc (Hons) Florida, C.A.S Cambridge, PhD Florida State (from 4 September 08)
B. Walther, B.A B.S Texas, PhD Woods Hole Oceanographic Institution (from 2 June 2008)
M.H. Wille, Dimp Geosciences, Muenster, PhD Bern
J Zhang

Senior Visitors

K.S.W. Campbell, MSc PhD Queensland, FAA *
J.M.A Chappell, BSc MSc Auckland, PhD ANU, FAA, HonFRSNZ *
W.Compston, BSc PhD Dsc(Hon) WAust, FAA, FRS*
D.H. Green, BSc MSc DSc, DLitt(Hon) Tas, PhD Camb, FAA, FRS*
K. Lambeck, BSurv NSW, DPhil, DSc Oxf, FAA, FRS*
I. McDougall, BSc Tas, PhD ANU, FAA*
R. Rutland, BSc, PhD London, FTSE*

S.R. Taylor, BSc (Hons) MSc New Zealand, PhD Indiana, MA DSc Oxford, HonAC
J.S. Turner MSc Syd, PhD Camb, FIP, FAIP, FAA, FRS*
* Emeritus Professor

Research Officers

A.G. Christy, BA(Hon) MA PhD Cambridge
J.D. Fitz Gerald, BSc James Cook, PhD Monash
P. Holden, BSc Lancaster, PhD St. Andrews
J. Kurtz, BSc MSc Louisiana State, PhD Arizona State
G. Luton, Bachelor of Surveyor UNSW (from 7 July 2008)
H.W.S. McQueen, BSc Qld, MSc York, PhD ANU
R. Rapp, BA (Geological Sciences) State University of New York, PhD (Geology) Rensselar Polytechnic Institute (from 3 November 2008)

Research Assistants

A. Arcidiaco, BAppSc GradDip SAInst
B.J. Armstrong, BSc UNISA
R.W.L Martin, BSc ANU
P. Rickwood, BSc (Comp Sci) (Hons) UNSW
Y. Shan, BSc Wuhan Cehui Technical University, MSc Wuhan Cehui Technical University, PhD UNSW
C. Tarlowski, MSc Moscow, PhD Warsaw
D. Zwartz, BSc (Hons) Victoria University of Wellington, PhD ANU (to 11 July 2008)

POST-GRADUATE STUDENTS

PhD Candidates

J. Avila, MSc Universidade Federal Do Rio Grande do Sul, Brazil
F. Beavis, BA/BSc (Hons), ANU
R. Berdin, BSc MSc Philippines
T. Bodin, MSc Louis Pasteur University
R. Brodie, BSc QLD
J. Brownlow, BSc (App Geology), UNSW
B. Choo, BSc Murdoch Univ
M. Coman, BSc (Hons) ANU
M. Crawford, BSc (Hons) UQ
A. Cross, BAppSc GDipAppSc MAppSc Canberra
J. Dawson, BSc BS MSc Melbourne, Grad Cert UWS
A. De Leon, BSc (Hons) University of Melbourne
J.P. D'olivo Cordero, MSc UABC Mexico
G. Estermann, MSc Vienna
T. Ewing, BSc (Hons), MSc University of Canterbury
R. Farla, Doctoraal Degree Utrecht University
A. Fyfe, BSc, La Trobe University, Hons, Australian National University
C. Gouramanis, BSc (Hons) La Trobe University, BSc ANU
C. Gregory, BSc Monash, BSc (Hons) ANU
J. Hiess, BSc (Hons) Canterbury
A. Higgins, BSc (Hons) ANU
J. Hoffmann, BA BSc (Hons) Monash University

S. Hui, BSc Australian National University
R. Ickert, MSc (Hons) Simon Fraser University
J. Jasonsmith BSc. (Ecology) - University of Otago; B.App.Sc. (Hons, Environmental Chemistry) - University of Canberra
H. Jeon, MSc Seoul National University
R.C. Joannes-Boyau, MSc University-Bordeaux
J. Jones, Dip Gemmology GAGTL, London, BSc (Hons) Auckland University
J. Kang, BSc MSc Korea University
T. Kelly, BSc University of Tasmania, BSc (Hons) Australian National University
E. Kiseeva, BSc and MSc St Petersburg State Mine Institute
I. Kovacs, MSc Eötvös
S. Lewis, BSc (Hons) Monash University
H. Li, BSc MSc Peking University
G. Mallman, BA MS Brazil
J. Mazerat, BSc MSc Bordeaux University
I. McCulloch, BSc UNSW, GradDip ANU
S. McKibbin, BSc University of Newcastle
N. Mikkelson, BSc (Hons), ANU BArts, ANU
P. Millsteed, Dip 1 cert in Gemmology ACT Institute of Technology, BSc UC
I. Moffat, BA BSc (Hons) University of Queensland
M. O'Byrne, BSc (Hons) Grad Dip ANU
A. Papuc, BSc (Hons) Australian National University
J. Park, BSc MSc Korea University
C. Pirard, BSc, MSc University de Liege
J. Robertson, DipABRSM (Piano Perf) Royal Schools of Music, BSc (Hons) University of Otago
D. Robinson, BSc (Hons) Flinders, Grad Cert UWS
J. Rogers, B.Sc. (Maths) UK, B.A. (anthropology) ANU, B.Sc (Hons) (geology) ANU
A. Rosenthal, MSc University in Freiberg, Germany
A. Sadekov , BC MG Moscow State
R. Schinteie, Cert Arts MSc BSc GripDip University of Auckland
Shirtliff, Gregory BA BSc (Hons) ANU
N. Sinclair, BA/BSc Deakin University, BSc (Hons) ANU
M. Smith, BAppSc, Grad Dipl, MAppSc, Ballarat University
P. Smythe, BSc University of Wollongong, Hons (Physics) ANU
H. Sparks, BSc UBC, BSc (Hons) ANU
A. Stepanov, BSc MSc Novosibirsk State University
K. Stewart, BSc ANU
J. Sutton, MSc B.Tech University of British Columbia, BSc University of Northern British Columbia
N. Tailby, BSc (Hons) ANU
S. Tynan, BA/BSc (Hons) ANU
D. Valente, BSc (Hons) La Trobe
D. Viete, BSc BE (Hons) Monash
L. Wallace, BSc (Hons) Univ Tasmania
L. White, BSc (Hons) University of New South Wales
D. Wilkins, BA/BSc (Hons) ANU.

MPhil Candidates

L. Bean, BSc Dip. Ed. Sydney Uni, Grad Dipl. ANU
R Beattie, BA Macquarie
G Bell, BA (Hons), BSc ANU
A. Deonath, MSc Indian School of Mines
K. Dowell, BSc (Hons), ANU
I. Itikarai, BSc UPNG Papua New Guinea
A. Maulanai, BSc (Hons) Hasanuddin Univ., Indonesia
M. Nash, B.Comm UC, BSc ANU
R. Shi, BSc China University of Geosciences
M. Umar, BSc Syiah Kuala University, MSc ITB, Indonesia

HONOURS STUDENTS

Geology Honours

R. Bailey
S. Biddlecombe
K. Boston
J. Burke
A. David
C. Firth
A. Green
Jia-Urnn Lee
R. Mann
S. McAlpine
J. McDonald
G. Nash
T. O'Kane
N. Pittman
E. Reynolds
A. Robertson
I. Stenhouse
C. Thompson
J. Thorne

Physics of Earth Honours

A. Barker
D. Hutchinson

BGOS Honours

L. Soroka

Masters Students

N. Brown
R. Chopping
S. Chow
R. Costelloe
P. Crosthwaite

J. Gu
J. Hunt
P. Ivanov
R. Morris
H. Tassell

PhD THESES SUBMITTED

Melissa Coman - Convection Forced by Horizontal Variations in Heating with two Plumes or Sill. Supervisor: Prof Ross Griffiths, Advisers: Dr Graham Hughes, Dr Ross Kerr, Dr Andrew Hogg, Dr Trevor McDougall

John Dawson – Satellite Radar Interferometry with Application to the Observation of Surface Deformation in Australia. Supervisor: Dr Paul Tregoning, Advisers: Dr Kurt Lambeck, Dr Herb McQueen, Dr Richard Coleman

Gisela Estermann – Contribution of Mountain Glacier Melting to Sea – Level Changes: Recent Past and Future. Supervisor: Prof Kurt Lambeck, Advisers: Dr Paul Tregoning, Dr Herb McQueen, Dr John Church

Courtney Gregory – Allanite Chemistry and U-Th-Pb Geochronology. Supervisor: Dr Daniela Rubatto, Advisers: Dr Joerg Hermann, Prof Trevor Ireland, Ms Charlotte Allen, Dr Ian Williams

Jospeh Hiess – Early Crustal Petrogenesis: Integrated in Situ U-Pb, O, Hf and Ti Isotopic Systematics of Zircon from Archaean Rocks, West Greenland. Supervisor: Dr Victoria Bennett, Advisers: Dr Allen Nutman, Prof Trevor Ireland, Dr Joerg Hermann, Dr Ian Williams

Istvan Kovacs – Water in the Nominally Anhydrous Minerals of the Upper Mantle: Analytical and Experimental Developments. Supervisors: Prof Hugh O'Neill, Dr Joerg Hermann, Advisers: Prof David Green, Prof Trevor Ireland, Dr John Fitzgerald

Guilherme Mallman – Mantle Redox State and Its Effect on Trace-Element Partitioning During Basalt Petrogenesis. Supervisor: Prof Hugh O'Neill, Advisers: Dr Victoria Bennett, Dr Gregory Yaxley, Dr Carl Spandler
Tjipto Prastowo - Mixing in Buoyancy-Driven Exchange Flows. Supervisor: Prof Ross Griffiths, Advisers: Dr Graham Hughes, Dr Michael Gagan, Dr J.R Taylor, Dr Ross Kerr

Aleksey Sadekov – Advancing Planktonic Foraminifera Mg/Ca Thermometry: A Microanalytical Perspective. Supervisor: Dr Stephen Eggins, Advisers: Prof Patrick De Deckker, Prof Malcolm McCulloch, Dr Michael Gagan, Dr George Chaproniere

Heather Sparks – Supervisor: Dr John Mavrogenes, Dr Joerg Hermann, Dr Christopher McFarlane, Dr Andrew Berry

Dianne Valente – The Geology, Geochemistry and Geochronology of the El Abra Mine, Chile and the Adjacent Pajonal-El Abra Suite of Intrusions. Supervisor: Prof Ian Campbell, Advisers: Dr John Mavrogenes, Dr Victoria Bennett, Dr Joerg Hermann

MASTERS SUB-THESES SUBMITTED

James Hunt – Revision of osteolepiform sarcopterygians (lobe-finned fishes) from the Middle Devonian Hatchery Creek fish assemblage, Wee Jasper, Australia. Supervisor: Dr Gavin Young.

STUDENT AWARDS

A.L. Hales Honours Year Scholarship: Graham Nash and David Hutchinson
Mervyn and Katalin Paterson Fellowship: Robert Farla
Robert Hill Memorial Prize: Courtney Gregory
A.E. Ringwood Scholarship: Huijuan Li
John Conrad Jaeger Scholarship: Lloyd White

SUMMER RESEARCH SCHOLARSHIPS

Ms D. Dass (Australian National University, Canberra) under the supervision of Michael Ellwood
Ms N. Lim (Australian National University, Canberra) under the supervision of Patrick De Deckker
Ms E. Newland (RMIT, Melbourne) under the supervision of Michael Ellwood
Ms R. Norman (Australian National University, Canberra) under the supervision of Stephen Eggins
Mr Y. Zhao (Australian National University, Canberra) under the supervision of Brian Kennett

STUDENT INTERNSHIPS

Mr A. Arad of RMIT; Supervisor Dr Hrvoje Tkalcic
Ms J. Arthur of Australian National University; Supervisor Prof Ian Campbell
Mr J. Bennett of Australian National University; Supervisor Dr John Mavrogenes
Ms S. Doos of Australian National University; Supervisor Prof Hugh O'Neill
Ms K. James of Australian National University; Supervisor Dr Michael Ellwood
Ms E. Johnson of University of Newcastle; Supervisor Prof Gordon Lister
Mr A. Lukomskyj of Australian National University; Supervisor Dr Ulrike Troitzsch
Ms S. NGO of Australian National University; Supervisor Dr Hrvoje Tkalcic
Ms D. Tanner of Australian National University; Supervisor Prof Gordon Lister
Mr Y. Zhao of Australian National University; Supervisor Prof Brian Kennett

GENERAL STAFF

School Manager
Michael Avent, Grad Cert Mgmnt, Grad Dip Admin, University of Canberra

Executive Assistant to the Director
Marilee Farrer

Building and Facilities Officer
Eric Ward, Cert V Frontline Management, Quest/ANU

Assistant Building and Facilities Officer
Nigel Craddy (from 10 June 2008)

Finance Manager
Teresa Heyne, BComm, Deakin University

Finance Officers
Sheryl Kluver, Assoc Diploma in Graphic Communications, Australian Army (to 6 May 2008)
Natalie Fearon (from 6 May 2008)

Human Resources Officer
Nathalie Garrido, Cert III Tourism & Events Management, CIT

Student Officer
Maree Coldrick

School Administrative Assistant and Student Officer
Rebecca Kelly, Cert II Business (Office Administration), QUEST Solutions

Information Technology Manager
Paul Davidson, BSc, MSc, Auckland, PhD, ANU

Information Technology Officer
Duncan Bolt, BSc Sydney
Brian Harrold, BSc ANU

Graphics Support Officer
Brad Ferguson, BDesign(Photography) CIT

Receptionist & Finance Assistant
Natalie Fearon (from 5 May 2008)
Sally Provins (from 16 June 2008 to 2 August 2008)
Josephine Margo (from 18 August 2008)

Area Administrators

Earth Chemistry

Robyn Petch

Earth Environment

Susanne Hutchinson, BA, La Trobe University

Earth Materials

Kay Provins

Earth Physics

Denise Steele (to 5 May 2008)

Sheryl Kluver, Assoc Diploma in Graphic Communications, Australian Army (from 6 May 2008)

Prof Kurt Lambeck

Danica Fouarce, BEnv.Des, BA Hons, University of WA

IODP

Alena Almassy (from 12 August 2008)

School Librarian

Chris Harney, Dip CIT, BA (Communications Information) University of Canberra

Technical Officers

Charlotte Allen, AB Princeton MSc Oregon , PhD VirginiaTech
Anthony Beasley, AssocDip CIT
Nick Best
Brent Butler, Cert III Mechanical Engineering Sydney Institute
Joseph Cali, BAppSc QIT
David Cassar
David Clark
Aron Coffey (from 18 September 2008)
Wayne Cook, Cert Geoscience (field hands) CIT, BSc ANU (to 9 August 2008)
Derek Corrigan
Joan Cowley, BSc ANU
Daniel Cummins
John D. Fitz Gerald, BSc James Cook, PhD Monash
John Foster, BSc Sydney, MSc PhD ANU
Daniel J Hunt, Adv Diploma Mechanical Engineering (Trainee)
Ben Jenkins, BSc UTS, PhD ANU
Damien Kelleher, AssocDip Cartog CIT (to 14 February 2008)
Leslie Kinsley, BSc GradDipSc ANU
Harri Kokkonen, BAppSc CCAE
Richard Krege, MSc Australian Defence Force Academy, BSc Charles Stuart University, BE University of Canberra (from 7 April 2008)
Andrew Latimore
Qi Li
Linda McMorrow, AssocDip Science NTU
Graham Mortimer, BSc PhD Adelaide
Hayden Miller, Advanced Diploma in Mechanical Engineering, CIT (from 1 September 2008)
Samuel Mertens, BA (Hons)
Andrew Myers, (to 8 March 2008)

Charles Norris, BSc ANU (to 3 January 2008)
Shane Paxton
Anthony Percival
Sisounthon (Tony) Phimphisane
Tristan Redman - Trainee
Hideo Sasaki - Trainee
Scott Savage
Norman Schram, Dip EIE SAIT
Dean Scott
Heather Scott-Gagan, BSc Sydney
David Thomson
Ulrike Troitzsch Diplom (Technische Universität Darmstadt), PhD ANU
Carlyle Were
Andrew Welsh, BAppSc CCAE (to 7 August 2008)
Andrew Wilson
Geoffrey Woodward
Igor Yatsevich, BEng Tashkent Polytec Inst, PhD Russian Academy of Sciences
Xiaodong Zhang, PhD LaTrobe

Fitting and Machining Apprentice

Ben Tranter, Cert II in Automotive Radiator Services John Batman Institute of TAFE, Automotive Climate Control / Air conditioning Casey Institute of TAFE (from 11 March 2008)

Earth Chemistry

The chemistry and isotope chemistry of natural materials is highly indicative of provenance and process throughout geological history. Our studies range in time from the earliest solar system through to processes that are actively taking place today, and in scope from planetary systems to individual molecules. Active areas of research centre on planetary studies, metamorphic and igneous geochemistry and geochronology, geochemistry of life processes, and chronology of all processes encompassed.

Most of our analytical work involves detailed analysis on the microscale, or concentrating trace elements from larger samples for high precision analysis. Isotopic systems can reveal both the nature of the processes involved (stable isotopes) as well as the timing of events (radiogenic isotopes), while chemical abundances can reflect protolith contributions and processes affecting various systems including biologic systems. As revealed in this year's research contributions, analytical work can be applied to topics in tectonics, ore genesis, metamorphic petrology, paleoclimate, paleoecology and regolith dating.

Highlights

The J5 building extension was completed in 2008. The project involved doubling the length of the extant building and adding a second floor to house offices, a seminar room (The D. H. Green Room), and geochemistry laboratories. Starting in July, SHRIMP II was moved from J3 to its new position in the J5 SHRIMP building and is now operational again. Construction of SHRIMP SI has now recommenced and is proceeding well with expectations of testing in mid 2009. The fit out of the J5 chemistry laboratories is underway with installation of extraction hoods nearly complete. These laboratories will be established under the direction of Dr Yuri Amelin. The completion of the office space upstairs sees a focal point for the Planetary Science Institute at RSES.

Personnel

Dr Stewart Fallon joined Earth Chemistry in 2008. In January 2009, Dr Vickie Bennett will be taking leave of absence from RSES to take up a position at Johnson Space Center, Houston.

The SHRIMP team, comprising Dr John Foster, Dr Peter Holden, Mr Peter Lanc, Mr Ben Jenkins, and Mr Norm Schram, received a Vice Chancellor's Award for Innovation and Excellence in Service Quality for 2008.

PhD studies were completed by Diane Valente, Courtney Gregory, and Joe Hiess. Congratulations Doctors.

Postgraduate studies were commenced by Ms Heejin Jeon [supervised by Dr Ian Williams], Mr Alexandr Stepanov [Dr Daniela Rubatto], Mr Jung Woo Park [Professor Ian Campbell].

U-Pb ages of angrites

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Angrites form a small but remarkable group of meteorites. These very old differentiated achondrites experienced much less secondary processing than most meteorites, and their peculiar mineralogy and geochemistry facilitates precise dating with several isotopic methods. The group includes a variety of the specimens, ranging from "basaltic" rocks with prominent vesicles that formed rapidly quenched melts, to plutonic igneous rocks with cumulate textures and annealed plutonic rocks. Recent findings of new angrites, mainly in the deserts of northwest Africa and in Antarctica, increased their number from one in 1970's (Angra dos Reis, or AdoR, originally the prototypical meteorite of this group, which is now considered an anomalous angrite) to 16 in 2008.

Angrites are singularly well suited to serve as benchmarks of the early Solar System chronology. The ages of some of these meteorites were determined in 1970's to early 90's, and AdoR has been long known as one of the oldest rocks in our Solar System, but precision and accuracy of these dates are insufficient for constructing a detailed timescale of the early Solar System events. The ages of recently found angrites were not known at all. Recent developments in Pb isotopic analysis of meteorites: using ^{202}Pb-^{205}Pb double spike optimized for isotopic dating, and a new procedure for efficient removal of common Pb, provides a background for revisiting and refining chondrite chronology.

Precise U-Pb ages for seven angrites are determined with double spike (^{202}Pb-^{205}Pb) thermal ionization mass spectrometry. The data for three angrites with well preserved U-Pb isotopic systems are shown in Fig. 1. The implications of these ages are threefold. First, they demonstrate that AdoR and LEW are not coeval, and the group of "slowly cooled" plutonic angrites is genetically diverse. Second, the new age of LEW suggests an upward revision of ^{53}Mn-^{53}Cr "absolute" ages by 0.7 Ma. Third, a precise age of D'Orbigny allows consistent linking of the ^{53}Mn-^{53}Cr and ^{26}Al-^{26}Mg extinct nuclide chronometers to the absolute lime scale.

Furthermore, these data show that the angrite parent body underwent prolonged high temperature igneous (both volcanic and plutonic) activity and metamorphism for at least 7 Ma during a period very early in solar system history. It is difficult to conceive of a thermal mechanism by which this could be accomplished unless the parent body was a relatively large, differentiated planet.

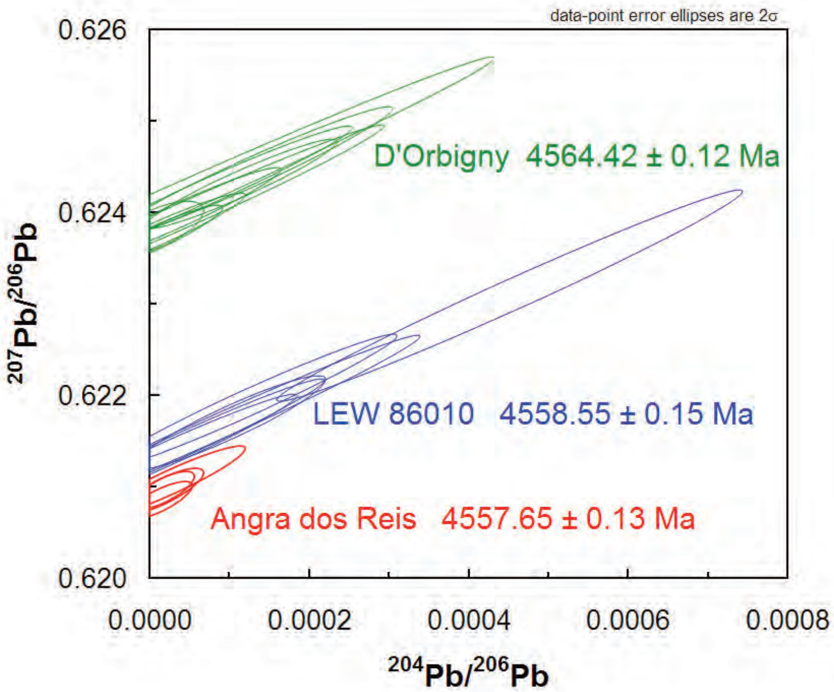

Figure 1. *Pb isotopic data for pyroxenes from Angrites AdoR and LEW 86010, and pyroxenes and whole rock fractions from D'Orbigny, plotted in a* $^{207}Pb/^{206}Pb$ *vs.* $^{204}Pb/^{206}Pb$ *isochron diagram, and the weighted average* $^{207}Pb^{*}/^{206}Pb^{*}$ *ages.*

Tungsten isotopic compositions of presolar silicon carbide grains: implications for ^{182}hf-^{182}w and ^{187}re-^{187}os chronometers

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The *s*-process nucleosynthesis in the Hf-Ta-W-Re-Os path has received considerable attention lately (Fig. 01). New neutron capture cross-sections for ^{174,176,177,178,179,180,182}Hf, ^{185}W and ^{186,187,188}Os have been reported (Sonnabend et al., 2003; Mosconi et al., 2006; Wisshak et al., 2006; Vockenhuber et al., 2007), and small anomalies in W and Os isotopes have been observed in primitive meteorites (Brandon et al., 2005; Yokoyama et al., 2007; Qin et al., 2008). However, as suggested by Vockenhuber et al. (2007) and Sonnabend et al. (2003), model calculations for *s*-processes nucleosynthesis appear to underestimate ^{182}W and overestimate ^{186}Os, and this may have implications for the ^{182}Hf-^{182}W and ^{187}Re-^{187}Os chronometers. Tungsten isotopes are particularly important because they are affected by several branching points (^{182}Ta, ^{181,182}Hf, and ^{185}W), which also affect Re and Os isotopes. Here we report W isotopic measurements in presolar SiC grains in order to provide additional constraints on *s*-process nucleosynthesis.

^{182,183,184,186}W and ^{180}Hf were measured with SHRIMP RG at ANU in an aggregate of presolar SiC grains (KJB fraction) extracted from the Murchison meteorite (Amari et al., 1994). Tungsten isotopes were measured as WO^+ ions, which have a higher yield than the atomic species ($WO^+/W^+ \sim 3$). An O^- primary ion beam of 5 nA was focused to sputter an area of 20 mm in diameter. SHRIMP RG was operated at a mass resolving power of m/_m= 5000 (at 1% peak). At this level, isobaric interferences were well resolved from the WO^+ species. NIST silicate glasses and synthetic SiC were used to monitor instrumental mass fractionation and isobaric interferences.

The W isotopic compositions are anomalous in comparison to those observed in normal solar system materials. The SiC grains appear to be enriched in ^{182}W and ^{184}W relative to ^{183}W, as expected for *s*-process nucleosynthesis in AGB stars (e.g. Qin et al., 2008). However, an unexpected enrichment in ^{186}W is observed. The low ^{180}Hf/^{183}W ratios determined here imply a low contribution from radiogenic ^{182}W after SiC condensation, otherwise the ^{182}W excesses would be even higher. The enrichment in ^{182}W appears to be plausible, given the observation that the calculated *r*-process residue of ^{182}W ($N_r = N_{\odot} - N_s$) has a significant positive deviation from the smooth *r*-abundance distribution (Wisshak et al., 2006; Vockenhuber et al., 2007). A lower *r*-process component of solar ^{182}W would imply a shorter time interval between the last *r*-process contribution to solar ^{182}Hf and the formation of solid parent bodies (Vockenhuber et al., 2007).

As discussed by Sonnabend et al. (2003), the stellar *s*-process model shows a 20% overproduction of ^{186}Os, and consequently it underestimates the *s*-process contribution to ^{187}Re. The enrichment observed in ^{186}W requires the activation of the ^{185}W branching point during AGB thermal pulses, when marginal activation of the ^{22}Ne(α,*n*)^{25}Mg source produces neutron densities as high as N_n= 5 x 10^9 neutrons cm^{-3} (Lugaro et al., 2003), bypassing ^{186}Os. This result is in disagreement with ^{96}Zr depletions in SiC grains, which indicate that the ^{22}Ne(α,*n*)^{25}Mg source was weak in their parent stars (Nicolussi et al., 2003). However, the overabundance of ^{186}Os could also be the result of uncertainties in the nuclear physics data.

Amari S. et al. 1994. Interstellar grains in meteorites. I. Isolation of SiC, graphite, and diamond; size distributions of SiC and graphite. *Geochimica et Cosmochimica Acta* 58: 459-470.

Brandon A. et al. 2005. Osmium Isotope Evidence for an s-Process Carrier in Primitive Chondrites. *Science* 309: 1233-1236.

Lugaro M. et al. 2003. Isotopic Compositions of Strontium, Zirconium, Molybdenum, and Barium in Single Presolar SiC Grains and Asymptotic Giant Branch Stars. *Astrophysical Journal* 593: 486-508.

Mosconi M. et al. 2006. Experimental challenges for the Re/Os clock. *Nuclei in the Cosmos IX*: 381-387.

Nicolussi G. et al. 1997. s-Process Zirconium in Presolar Silicon Carbide Grains. *Science* 277: 1281-1283.

Qin L. et al. 2008. Tungsten Nuclear Anomalies in Planetesimal Cores. *Astrophysical Journal* 674: 1234-1241.

Sonnabend K. et al. 2003. The s-Process Branching at ^{185}W. *Astrophysical Journal* 583: 506-513.

Vockenhuber C. et al. 2007. Stellar (*n*, _) cross sections of ^{174}Hf and radioactive ^{182}Hf. *Physical Review C* 75: 15804.

Wisshak K. et al. 2006. Fast neutron capture on the Hf isotopes: Cross sections, isomer production, and stellar aspects. *Physical Review C* 73: 45807.

Yokoyama T. et al. 2007. Osmium isotope evidence for uniform distribution of *s*- and *r*-process components in the early solar system. *Earth and Planetary Science Letters* 259: 567-580.

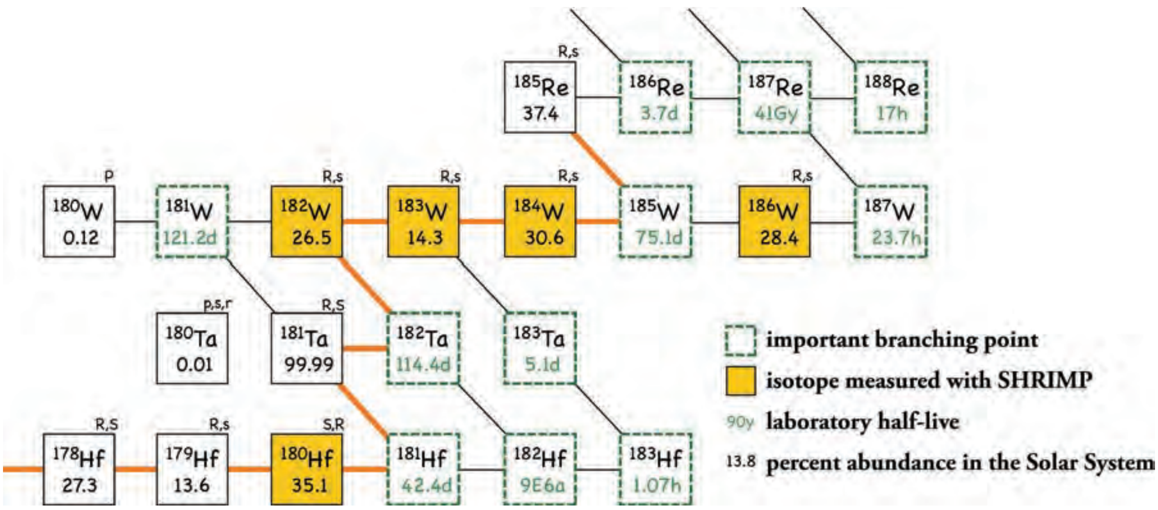

Figure 1.

Small continents on the Hadean Earth: New Isotopic Evidence from combined Hf and ^{142}Nd Isotopic Signatures

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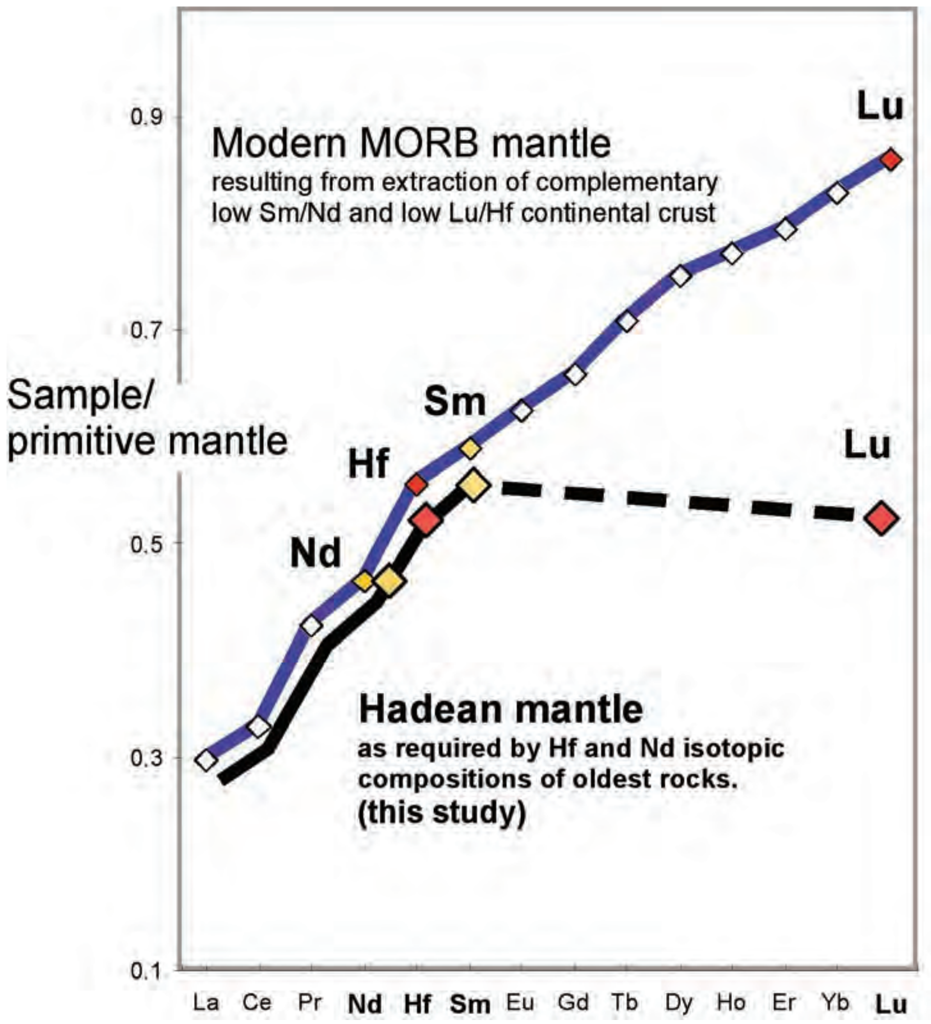
Questions of the antiquity and volumes of Earth's ancient continental crust have been actively debated for more than 100 years and remain controversial. One view is that massive amounts of continental crust formed very early in Earth's history and persisted to the present, with new crustal growth balanced by recycling into the mantle. In direct contrast are models calling for progressive growth of the continental mass over geologic time, with small volume early continents. These debates take on added significance when considered in conjunction with potential early life habitats and the timing and mechanisms of formation of Earth's major chemical domains after the initial stages of planetary accretion.

We have taken a new perspective on Earth's early history by combining information from two isotopic systems (^{176}Hf/^{176}Hf formed from decay of ^{176}Lu; half-life=37.1 Gy) and ^{142}Nd/^{144}Nd (formed by decay of now extinct ^{146}Sm; half life =103 My), whose signatures are preserved in the oldest rocks. The analysed samples include 3.63 -3.87 Ga (billion years old) rare, early crustal relicts from southwest Greenland, Western Australia, and China. Hafnium isotopic data from well-characterised and U-Pb dated zircons extracted from these rocks show that the oldest rocks have initial Hf isotopic compositions that are the same as bulk Earth and primitive meteorite compositions (Hiess et al, in review), indicating that the source of these rocks did not experience early Lu/Hf modification. In contrast the ^{142}Nd isotopic compositions measured from the same rocks as yielded the zircons, are distinct from both modern rocks and from primitive meteorites (Bennett et al., 2007) requiring Hadean Sm/Nd fractionation.

Modelling of the trace element pattern of the Hadean (>4.0 Ga) mantle, as defined from the combined isotopic data, shows that it could not have been generated by extraction of average low Sm/Nd, low Lu/Hf continental crust (Figure 1). This is in contrast to the modern Earth, where the continental crust and the upper mantle have complementary isotopic and trace element characteristics. Thus, continent formation could not have been the primary mechanism of differentiation on the Hadean Earth. Furthermore, owing to the effectiveness of crust formation at changing Lu/Hf ratios, the near-chondritic Hf isotopic data require that the preserved earliest continents were of very limited extent, likely less than 5% of the present day continental mass. The chemistry of the Hadean mantle as recorded by the short and long half-life isotopic systematics of the oldest rocks points towards models of early silicate differentiation in a global terrestrial magma ocean.

Bennett, VC, Brandon AD and Nutman AP (2007) Coupled ^{142}Nd-^{143}Nd Isotopic Evidence for Hadean Mantle Dynamics. *Science* **318**: 1907-1910.

Hiess J, Bennett VC, Nutman AP. and Williams IS (In revision) In situ U-Pb, O and Hf isotopic compositions of zircon from Eoarchaean rocks, southern West Greenland: New Views of old Crust. *Geochimica et Cosmochimica Acta.*



Modern MORB mantle
resulting from extraction of complementary
low Sm/Nd and low Lu/Hf continental crust
Hadean mantle
as required by Hf and Nd isotopic
compositions of oldest rocks.
(this study)
Sample/
primitive mantle
Lu
Sm
Hf
Nd
Lu
0.9
0.7
0.5
0.3
0.1
La
Ce
Pr
Nd
Hf
Sm
Eu
Gd
Tb
Dy
Ho
Er
Yb
Lu

Figure 1.

Integrating community proteogenomics and lipid biogeochemistry to unravel ancient evolutionary history

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The first appearance of a metabolic pathway that allowed microorganisms to exploit a new and previously untapped energy source, such as methanogenesis, sulfate reduction and photosynthesis, must have had profound effects on the chemical composition of the atmosphere and oceans. It is a captivating goal of geobiology to determine when such physiologies first appeared in Earth history and to correlate these events with the associated chemical and isotopic changes in the rock record. One of the best methodologies to track the first appearances of microorganisms in the geological record is the search for biomarker molecules. Biomarkers can be preserved in billion years old sedimentary rocks and are often the only direct methodology to study ancient microbial ecosystems. If we want to match biomarkers from ancient rocks with the organisms that produced them we rely on information about lipids detected in extant organisms grown in cultivation. However, currently the vast majority of all microorganisms defies isolation, and their lipid biosynthetic capacities, as well as their roles in ecosystems, remain largely obscure. Consequently, our knowledge about the distribution of biomarkers in nature remains highly fragmentary.

Figure 1 shows how environmental genomics and proteomics on natural microbial consortia may help to solve the problem. It summarizes how these methodologies could be combined with lipid biogeochemistry to assemble a phylogenetic tree of the three domains of life where all nodes are (roughly) dated, all branches are annotated with a complete set of lipids that are produced by each lineage, and each lineage is linked to the sequences of the genes required for their biosynthesis. Development and use of phylogenetic trees for lipid genes and their products should provide quantitative data about the frequency of lateral gene transfer and convergent evolution in lipid biosynthetic pathways, and should allow us to determine a level of confidence with which a biomarker from a well-dated ancient rock can be assigned to a particular biological origin.

Ram R. J. et al. and Banfield J. F. (2005) Community proteomics of a natural microbial biofilm. *Science* **308**, 1915-1920.

Tyson G. W. et al. and Banfield J. F. (2004) Community structure and metabolism through reconstruction of microbial genomes from the environment. *Nature* **428**, 37-43.

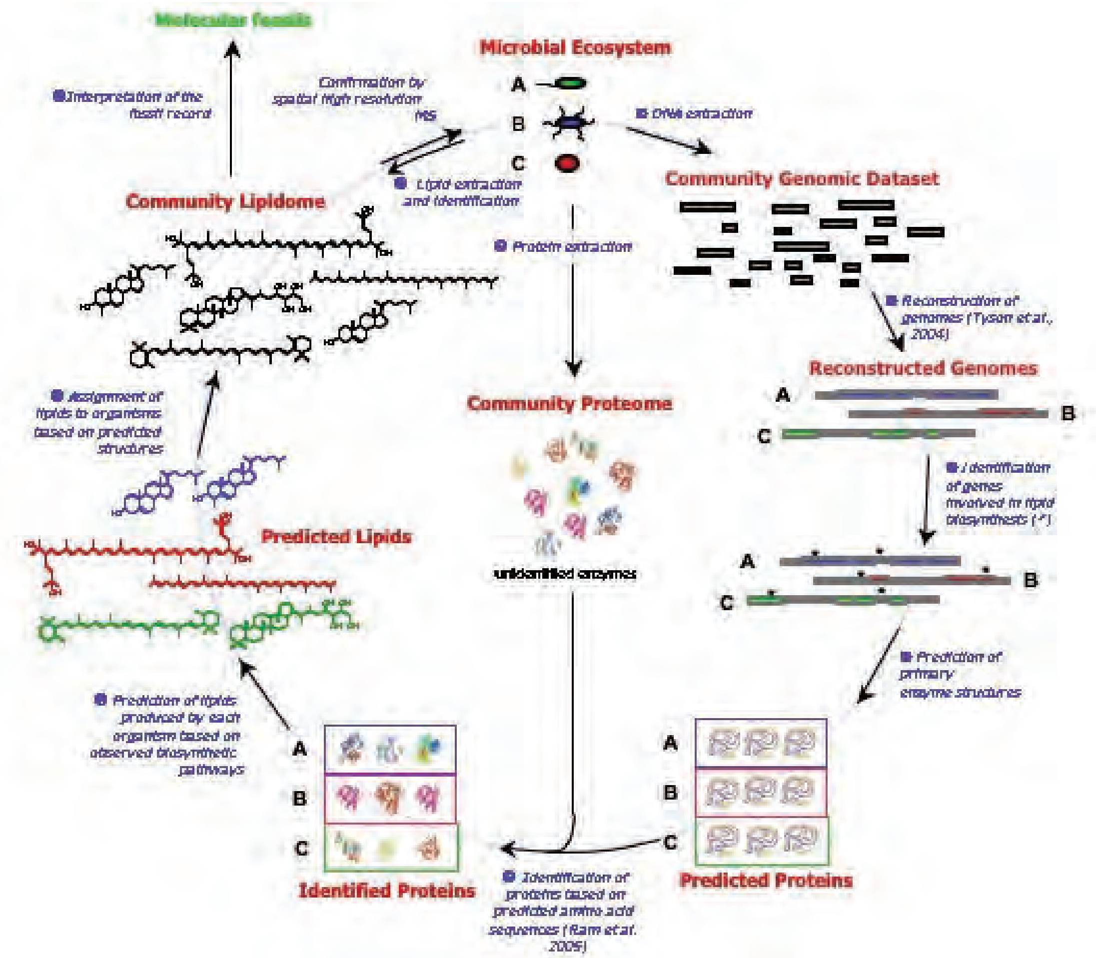

Figure 1. *With nearly completely reconstructed genomes and the knowledge which genes were expressed at the time when the sample was taken, it should, in principle, be possible to assign each lipid detected in a 'community lipidome' to an organism or group of organisms in the consortium, even if these organisms can not be isolated and grown in culture: DNA is extracted from a natural sample, fragments are sequenced (①) and sequences assembled to reconstruct (near) complete genomes of all dominant (>5% relative abundance) bacteria and archaea (②). Genes involved in lipid biosynthesis are identified (③) and primary protein structures predicted based on base sequences (④). Proteins involved in lipid biosynthesis that were extracted from the same environmental sample (⑤) can then be identified based on predicted primary protein structures and assigned to individual organisms (⑥). Based on enzymes that are part of well-studied lipid biosynthetic pathways and that were detected in the environmental sample, it should be possible to predict major lipid end-products (⑦) and, thus, to assign actual lipids in the environment to individual organisms or group of organisms (⑧, ⑨). The identification of lipids of organisms that defy isolation may significantly improve our understanding of the sources and environmental significance of fossils lipids in the geological record (⑩).*

Supercontinents, supermountains and the rise of atmospheric oxygen

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Atmospheric oxygen concentrations in the Earth's atmosphere rose from negligible levels in the Archaean Era to about 21% at present day. This increase is thought to have occurred in six steps, 2.65, 2.45, 1.8, 0.6, 0.3 and 0.04 billion years ago, with a possible seventh event identified at 1.2 billion years ago. The timing of these steps correlates with the amalgamation of Earth's landmasses into supercontinents. We suggest that the continent-continent collisions required to form supercontinents produced chains of supermountains. These supermountains eroded quickly and released large amounts of nutrients such as iron and phosphorous into the oceans, leading to an explosion of algae and cyanobacteria, and thus a marked increase in photosynthesis, and the photosynthetic production of O_2.

Enhanced sedimentation during these periods promoted the burial of a high fraction of organic carbon and pyrite, thus preventing their reaction with free oxygen, and leading to sustained increases in atmospheric oxygen.

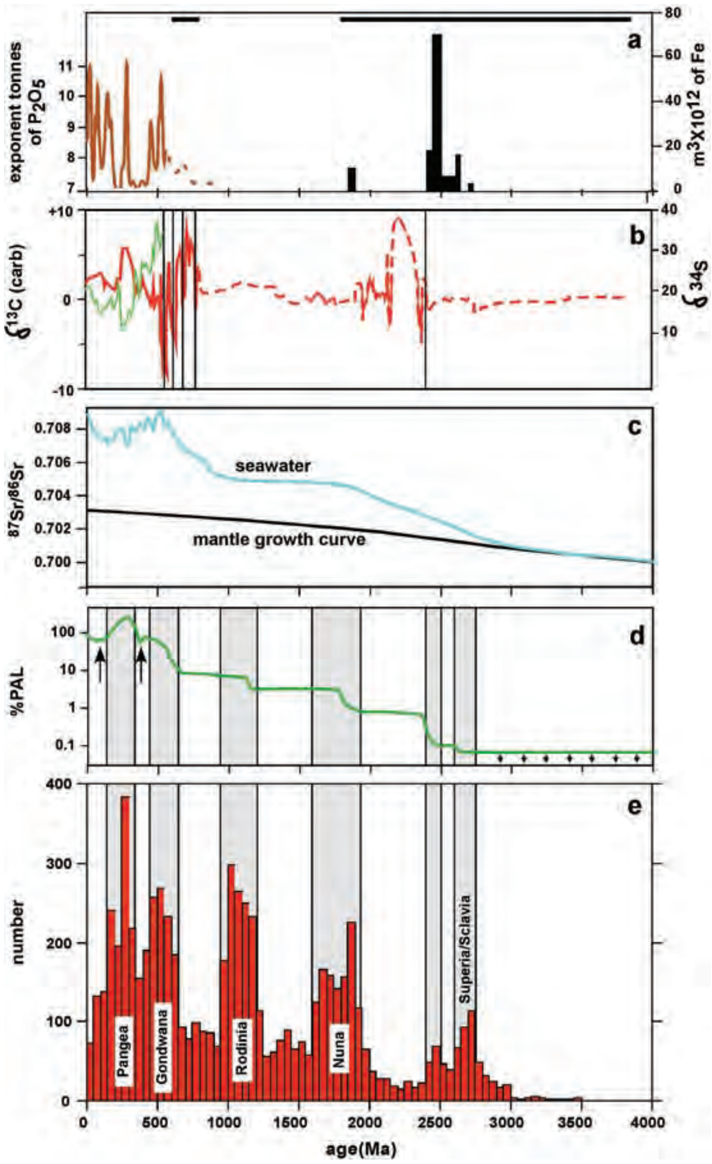

Figure 1. *Supercontinent ages compared with variations in atmospheric O_2 and related variables. a, Tonnes of P_2O_5 in phosphate deposits and Fe in iron formations. b, $^{13}\delta C$ in marine carbonates (red) and $^{34}\delta S$ in sulfate (green). Black lines correspond to ice ages. c, $^{87}Sr/^{86}Sr$ in seawater. d, Atmospheric O_2 showing the steps described in the text. Arrows point to periods of low atmospheric O_2. e, U/Pb ages of 5246 concordant detrital zircons from 40 major rivers supplemented by 1136 Australian dune zircons and 583 from Antarctic Palaeozoic sediments.*

Hf isotopes in rutile measured in-situ by LA-MC-ICPMS

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Hf isotopes are commonly measured in zircon and used to trace input from different mantle reservoirs and crustal components. In contrast, the Hf isotope systematics of rutile (TiO_2), a common accessory mineral in a variety of geological settings, are relatively unexplored.

The recent studies of Choukroun et al. (2005) and Aulbach et al. (2008) have revealed that rutile records a much greater range of $^{176}Hf/^{177}Hf$ ratios than is seen for zircon. These studies have also highlighted the potential for the in-situ measurement of Hf isotopes in rutile using Laser Ablation Multi-Collector Inductively Coupled Mass Spectrometers (MC-LA-ICPMS). However, as yet no detailed study of the accuracy of these in-situ measurements for rutile has been made. As rutile contains very low levels of Hf compared to zircon, proving the reliability of in-situ Hf isotope measurements is a critical first step in exploring the potential of this method to contribute to petrological studies.

We have used a number of approaches to assess the accuracy, precision and limitations of in-situ analysis for Hf isotopes in rutile, as well as refining analytical and data reduction methods for analysis of low levels of Hf. Some novel adaptations have been made, such as the use of synthetic rutiles doped with Hf to monitor change in mass bias over the course of a session and provide an external correction factor where required.

The accuracy of Hf isotope measurements for rutile on our Neptune MC-ICPMS in laser ablation mode is demonstrated by comparison with solution MC-ICPMS values for a rutile containing c.30ppm Hf. The $^{176}Hf/^{177}Hf$ values obtained from the two methods were in excellent agreement. Accuracy is confirmed by the agreement of $^{176}Hf/^{177}Hf$ values for plutonic rutile and zircon – which should record the same Hf isotope signature in an igneous system – from a single trondjhemite sample.

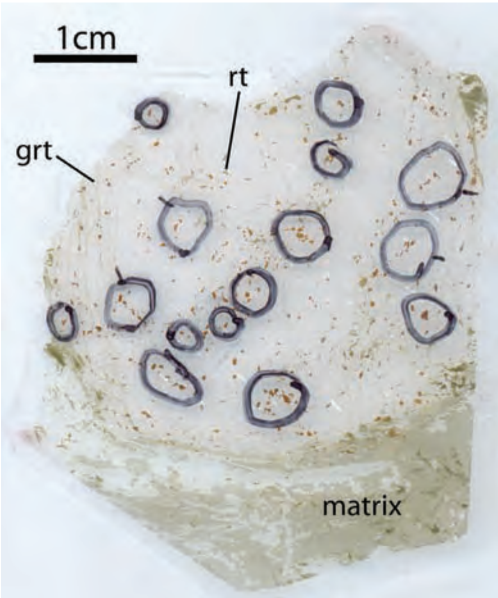
The precision of individual rutile analyses is lower for laser ablation than for solution analyses, but combining populations of 10 to 15 analyses to give a weighted mean significantly improves the precision. This level of precision has proved ample to distinguish between different rutile samples, or between rutile and other minerals that record a different Hf isotope signature.

It is already clear that in-situ Hf isotope measurements for rutile may have exciting applications to petrological problems. An early case study on rutile and zircon from the Duria garnet peridotite has demonstrated that Hf isotope analysis of metamorphic rutile can provide complementary information to isotopic information obtained from zircon. LA-MC-ICPMS analyses of zircon and rutile from the Duria peridotite revealed clearly distinct Hf isotopic ratios for the two minerals: the rutile records a mantle signature, whereas zircon isotopic ratios provide evidence for crustal input. This is in keeping with the metamorphic history of the peridotite as determined by Hermann et al. (2006) based on petrographic analysis and trace element geochemistry. The ability to analyse Hf isotopes in rutile therefore allows us to access isotopic information about parts of the metamorphic history that are not recorded by zircon.

Aulbach S, O'Reilly SY, Griffin WL, Pearson NJ (2008) The eclogite mantle reservoir: $^{176}Hf/^{177}Hf$, Nb/Ta and Zr/Hf of rutile. *Nature Geoscience* **1**:468-472

Choukroun M, O'Reilly SY, Griffin WL, Pearson NJ, Dawson JB (2005) Hf isotopes of MARID (mica-amphibole-rutile-ilmenite-diopside) rutile trace metasomatic processes in the lithospheric mantle. *Geology* **33**(1):45-48

Hermann J, Rubatto D, Trommsdorff V (2006) Sub-solidus Oligocene zircon formation in garnet peridotite during fast decompression and fluid infiltration (Duria, Central Alps). *Mineralogy and Petrology* **88**(1-2):181-206



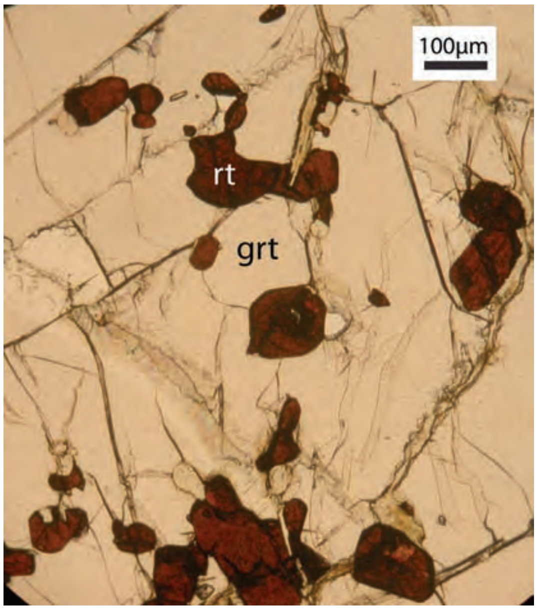


Figure 1. (left) Large thin section of garnet (grt) megacryst including numerous large rutiles (rt). Using LA-MC-ICPMS, Hf isotopes can be measured in-situ for rutiles in this thin section. Areas of interest for analysis have been circled in black pen.

Figure 2. (Right) Close-up photo of rutiles (rt) included in garnet (grt) in the thin section shown in Fig. 1.

A simple radiocarbon dating method for determining the age and growth rate of deep-sea sponges

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[2] *National Centre for Aquatic Biodiversity & Biosecurity, National Institute of Water & Atmospheric Research (NIWA) Ltd, Auckland, New Zealand*

While radiocarbon-dating is a well established technique in aging marine carbonates, the ability to reliably age siliceous organisms remains largely unexplored. Attempts have been made to carbon date the proteinaceous material bound within fossil diatoms frustrules isolated from sediment cores [1,2] and siliceous sponges [3]. The proteinaceous material bound within siliceous spicules is potentially a new and exciting way to age sponges and to date sediments devoid of carbonate material. Indeed the carbon dating of siliceous spicules in the Southern Ocean where carbonates are absent, or not well preserved, could help to validate paleoceanographic and paleoclimatic proxies and further elucidate physical and chemical changes within the oceans interior.

As filter-feeding organisms ubiquitous to the world's oceans, marine sponges obtain carbon from the food they consume, incorporating low levels (0.05%) into the spicules they produce. The carbon intrinsically incorporated into the spicule matrix from the surrounding water, is protected from contamination and can potentially provide dates in opal rich sediment cores as well as providing information on extension rates in living siliceous organisms. The following is an interpretation of ^{14}C analysis by accelerator mass spectrometry to constrain currently unknown growth rates of deep-sea sponges.

The Ross Sea sponge (TAN0402/67) was sub-sampled and cleaned using either sequential acid digestion alone, or acid digestion followed by roasting. Samples cleaned using sequential acid digestion alone needed to be placed inside a second quartz tubes to confer sufficient strength for combustion. In certain cases, these samples contained significantly more carbon than anticipated (Figure 1a). Elevated percentage carbon is attributed to insufficient removal of contaminant carbon (sponge tissue) by omitting the pre-roasting step.

The results for the percentage of carbon extracted and $\Delta^{14}C$ for samples where pretreatment included incremental increases in roasting temperatures is presented in Figure 2b. These results indicate that the optimal roasting is >400 °C. Above this temperature all the external carbon is removed yielding low but consistent results for both percentage carbon recovered and the radiocarbon $\Delta^{14}C$ results for proteinaceous material bound within the siliceous matrix (Figure 1b). The age results for sponge TAN0402/67 collected from the Ross Sea are presented in Figure 1c. A linear increase in age versus length was obtained for this sponge, although there is a significant water reservoir affect on the radiocarbon results.

The estimate $\Delta^{14}C$ value for organic carbon consumed by the sponge is about −150‰ based on modern organic carbon sedimentation in the Ross Sea. Our $\Delta^{14}C$ results for the outer part of the sponge, at about −140‰, are close to the modern organic carbon sedimentation value thereby confirming that the sponge faithfully records the $\Delta^{14}C$ signature of the organic carbon it consumes. After correcting for the reservoir age of the water, the extension rate for this sponge is around 2.9 mm yr^{-1}. Using this extension rate and a length 15 cm along the axis of growth, we estimate that sponge TAN0402/67 is around 440 years old. This novel technique for elucidating extension rates in sponges and more broadly for dating siliceous organisms is testament to the broad applications of $^{14}C/^{12}C$ ratios by accelerator mass spectrometry as both a paleo- and modern oceanographic tool.

Hatté, C., Hodgins, G., Jull, A.J.T., Bishop, B. and Tesson, B., 2008. Marine chronology based on 14C dating on diatoms proteins. Marine Chemistry, 109(1-2): 143-151.

Zheng, Y., Anderson, R.F., Froelich, P.N., Beck, W., McNichol, A.P. and Guilderson, T., 2002. Challenges in radiocarbon dating organic carbon in opal-rich marine sediments. Radiocarbon, 44(1): 123-136.

Ellwood, M.J., Kelly, M. and Richer de Forges, B., 2007. Silica banding in the deep-sea lithistid sponge Corallistes undulatus: Investigating the potential influence of diet and environment on growth. Limnology and Oceanography, 52(5): 1865–1873.

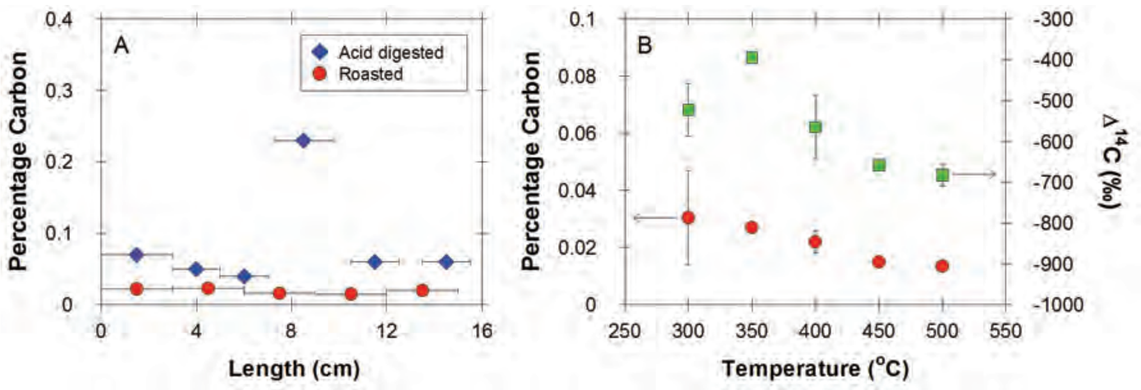

Figure 1. A) Percentage carbon versus length for samples oxidised with sequential acid digestion (acid digested) and acid digested followed by combustion at 450 °C for 12 hours (Roasted). B) Percentage carbon and $\Delta^{14}C$ versus roasting temperature. Sample points are the mean of two replicates while the error bars indicate the range.

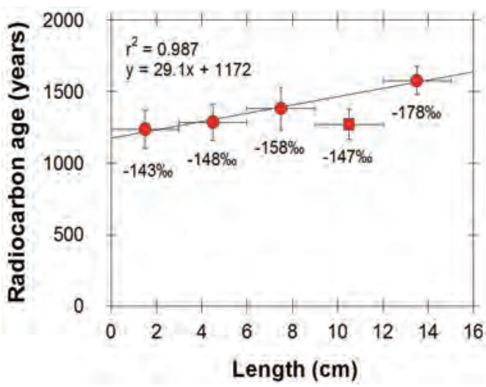

Figure 2. Radiocarbon age versus length along the axis of growth for samples removed from sponge TAN0402/67. The red square indicates a sample that was not included in the calculation of sponge extension rate.

Argon enters the retentive zone: Reassessment of diffusion parameters for K-feldspar

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$^{40}Ar/^{39}Ar$ apparent age spectra have been measured for unusually retentive potassium feldspars from the South Cyclades Shear Zone, Ios, Greece. The data obtained helped constrain the age and duration of the operation of this crustal-scale shear zone. We investigated traditional methods used to analyse Arrhenius plots by simulating the effect of step-heating experiments on argon loss. Fractals were used to define theoretical distributions of diffusion domain size and volume, allowing recognition of a Fundamental Asymmetry Principle (FAP) which is required if line fitting is to be consistent with the multi-domain diffusion hypothesis. The FAP means that a fitted line must divide the population by rank order. Points from data obtained earlier in the sequence of step heating experiments must lie on the fitted line, or to the right of it. Points from data obtained later in the sequence must lie on the fitted line, or to the left of it. Applying the FAP has lead to the estimation of higher activation energies.

To understand whether these results are limited, for example, to the K-feldspars from this study, data from previously published papers was examined (Fig. 1a), including data from the UCLA archive. The results obtained, using multi-domain diffusion modelling (Lovera *et al.* 1997) led us to an in depth look at the method and the fundamentals behind these methods. Analysis of Arrhenius data should take account of the Fundamental Asymmetry Principle since this is an inherent part of any multi-domain diffusion model. Results showed that if the Fundamental Asymmetry Principle is not applied (Fig. 1a b), numerical analysis will invariably underestimate the value of activation energy used in simulating the effect of step-heating experiments on fractal volume-size distributions (Fig. 1c d).

It was found that the application of the Fundamental Asymmetry Principle, determined from modeling using *eAr software* makes a considerable difference in respect to the magnitude of the activation energies estimated. The average of activation energy for K-feldspar is significantly higher than previously reported. These results imply that the Argon Partial Retention Zone for the most retentive domains in K-feldspar can expand into the ductile regime (i.e. with temperatures ~400-450°C), as recorded for the South Cyclades Shear Zone (Fig 1e). This means that K-feldspar can routinely be used as a geochronometer to estimate the timing and duration of events in complexly deformed terranes.

Baldwin SL, Lister GS, (1998) Thermochronology of the South Cyclades shear zone, Ios, Greece: effects of ductile shear in the argon partial retention zone. *JGR*, **103**, 7315–7336.

Lovera OM, Grove M, et al (1997) Systematic analysis of K-feldspar $^{40}Ar/^{39}Ar$ step heating results: I. Significance of activation energy determinations. *Geo Cosmochimica Acta,* **61**: 3171-3192.

Forster MA, Lister GS (2008) Argon enters the retentive zone: reassessment of diffusion parameters for K-feldspar in the South Cyclades Shear Zone, Ios, Greece. *Lithos, in press.*

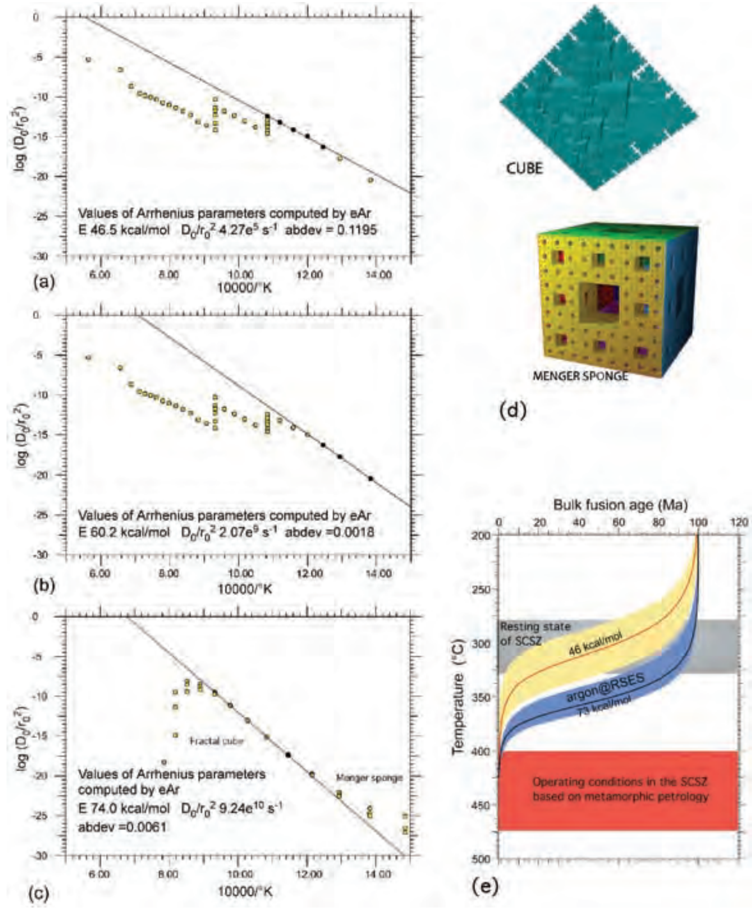

Figure 1. *Arrhenius plots where (a) activation is calculated at 46.5 kcal/mol (Baldwin & Lister 1998). The fundamental asymmetry principle (FAP) has not been followed in this calculation and the activation energy incorrect; (b) when the FAP is applied to this same plot the calculated activation energy is much higher, 60.2 kcal/mol; (c) mathemical calculation using the fractual cube and Menger sponge (d) (http://members.cox.net/fathauerrecent/FractalCrystal.html) (http://en.wikipedia.org/wiki/Menger_sponge) used in the mathematical representation of the Arrhenius plot; (e) A Temperature / Time plot show the region where the shear zone is at rest and where the shear zone operated, temperature calculated from mineral paragenesis.*

Behaviour of allanite during incipient partial melting in the Southern Central Alps

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[2] *Institute of Geological Sciences, University of Bern, CH-3012 Bern, Switzerland*

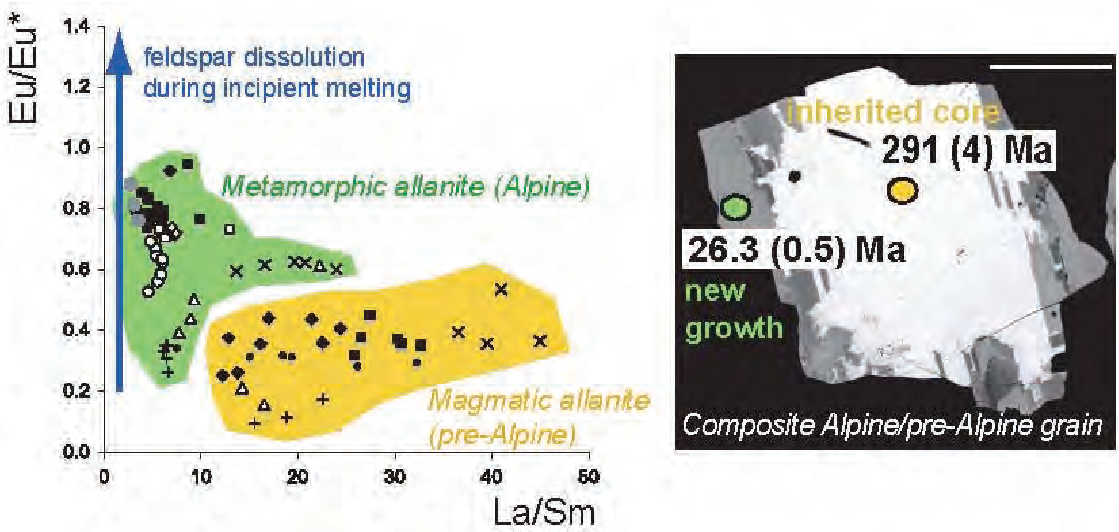
The chemical and U-Th-Pb isotopic behaviour of accessory allanite during incipient partial melting was investigated in a field-based study of upper-amphibolite facies migmatites in the southern Central Alps (Switzerland). Orthogneiss and leucosome sampled from the core of the migmatite zone (peak T of ~680-720°C) to its limit (T ~650°C), contained both zircon and allanite, which permitted a comparison of U-Th-Pb systematics in these phases.

Allanite found in orthogneiss showed complex internal zoning (see backscatter electron or BSE image in Fig. 1), suggestive of multi-stage growth. Bright BSE cores with high La/Lu and Th/U and low Eu/Eu* chemical signatures yielded Permian ages and thus were inherited from the pre-Alpine magmatic protolith. In contrast, chemically distinct overgrowths and single grains gave age populations between 30 ± 1 Ma and 23 ± 1 Ma in line with an Alpine metamorphic origin. Textural and inclusion relationships with major melt-formed minerals and their LREE-depletion supports the interpretation that allanite was an anatectic phase. Further evidence is provided by comparing magmatic and metamorphic mineral Eu compositions (Fig. 1).

Plagioclase did not impose a negative Eu anomaly on co-existing metamorphic phases because 80-90 % of the bulk-rock Eu was actually hosted in metamorphic allanite and titanite. To account for this, it is suggested that metamorphic allanite and titanite formed during feldspar breakdown, which would have occurred above the wet solidus for this system (i.e. at T > 650°C).

The inheritance of Permian cores provides first hand evidence for minimal Pb diffusion in allanite during Alpine partial melting (i.e. ~7 million years above 650°C). Importantly, in samples where co-existing zircon had rare or limited metamorphic overgrowths (i.e. at T < 700°C), allanite was the only accessory mineral chronometer that recorded the Alpine event. The U-Th-Pb system in allanite therefore presents a solid, complementary approach for the geochronology of low-temperature (~650-700°C) partial melt processes in the crust.

Accepting allanite as a melt-product, the youngest U-Th-Pb age obtained from a discordant leucosome indicates that the Alpine melting regime lasted over several million years (until 23 Ma) and later than previously accepted. Combined with previous constraints, the prolonged high temperature evolution down to 23 Ma requires a subsequent period of fast cooling (~100 ± 20°C/Ma) for the studied samples.



Eu/Eu*
feldspar dissolution
during incipient melting
Metamorphic allanite (Alpine)
Magmatic allanite
(pre-Alpine)
La/Sm
Inherited core
291 (4) Ma
26.3 (0.5) Ma
new
growth
Composite Alpine/pre-Alpine grain

Figure 1

An inclusion suite of "granitic" phases within 3.81 Ga tonalite zircons: Restrictions for studying Hadean crustal evolution with detrital zircons

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Petrogenetic interpretation of Hadean detrital zircons is problematic, because their source rocks are no longer preserved. Tonalites represent the dominant component of Eoarchaean (3500–4000 Ma) crustal rocks and therefore form an important reference point for the interpretation of Hadean detrital zircons, and Earth's earliest crustal evolution.

We conducted an electron microprobe survey of inclusions contained within igneous zircons from the best-preserved ca. 3810 Ma meta-tonalite sample G97-18 from West Greenland. Crystalline inclusions were K-feldspar, plagioclase, quartz, hornblende, biotite, ilmenite and apatite. Additionally, one globular polymineralic inclusion interpreted as crystallised melt occurs at the surface of a polished grain mount (Fig. 1). This consists of plagioclase + quartz + K-feldspar around a biotite lath. Other similar, but rare globular inclusions were seen buried within other zircons below the polished surface. These phases, particularly the presence of K-feldspar and plagioclase in broadly equal amounts, suggest the zircons crystallised from a residual granitic (sensu-stricto) melt, as opposed to a tonalitic melt. SHRIMP U-Pb dating of zircons with inclusions indicates that they grew at ca. 3810 Ma, the accepted igneous age of the rock.

This inclusion suite is compatible with the low Ti-in-zircon temperatures for G97-18 igneous zircon (Hiess et al., 2008). Therefore, low Ti-in-zircon temperatures and "granitic" inclusions reported for Hadean detrital zircons do not necessitate crystallisation from low temperature granites. Such features could also be found within Hadean zircons that crystallised late from a higher temperature zircon-undersaturated melt of tonalitic composition.

Hiess J, Nutman AP, Bennett VC, Holden P (2008) Ti-in-zircon thermometry applied to contrasting Archean igneous and metamorphic systems. *Chemical Geology* **247**: 323-338.

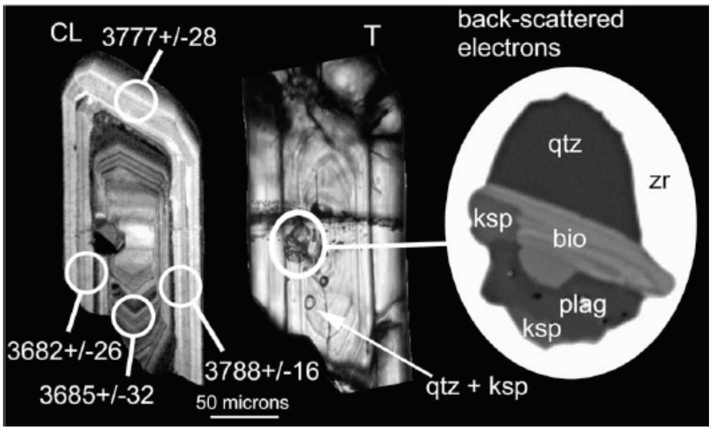

Figure 1. Cathodoluminescence (CL) and transmitted light (T) images for a single globular polymineralic inclusion exposed at the mount surface (at least one more appears to be present at depth in other grains), interpreted as a crystallised melt inclusion. Shown to the right is an enlarged back-scattered electron image of the globular inclusion. Note that the lower edge of the biotite is altered to chlorite. Errors on SHRIMP $^{207}Pb/^{207}Pb$ ages (Ma) are 2_.

Links between abiogenic-methane and gold, indicated by Ar, Ne and Cl in fluid inclusions

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[1] *The School of Earth Sciences, The University of Melbourne, VIC 3010, Australia*
[2] *Research School of Earth Sciences, Australian National University, Canberra, ACT 0200, Australia*
[3] *CSIRO, ARRC, 35 Stirling Highway, Kensington, WA 6151, Australia*
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The processes that mobilise gold through the Earth's crust and concentrate it in ore deposits have been widely debated. Most workers emphasise the importance of CO_2-H_2O fluids and phase separation or wall-rock reaction as depositional mechanisms. However, the possible importance of mantle components and the significance of CH_4-dominated fluid inclusions have been subject to speculation. The Yilgarn Terrane of Western Australia is richly endowed with gold-only ore deposits that have a low concentration of base metals, and are associated with quartz ±carbonate veins in regionally-significant, mid-crustal (3-15 km), shear zones that formed in an arc or back arc setting. Recent mapping of mineral alteration assemblages in the world class St Ives Gold Camp, in Western Australia, has shown high grade gold occurs preferentially at the intersection of 'oxidised' pyrite-magnetite-hematite-anhydrite bearing veins that are dominated by H_2O-CO_2 fluid inclusions; and 'reduced' pyrrhotite-pyrite bearing quartz veins that are dominated by CH_4 fluid inclusions

H_2O- and CO_2-dominated fluid inclusion assemblages have maximum $^{40}Ar/^{36}Ar$ values of ~21,000 (Fig. x-a) and ppb 36Ar concentrations, consistent with the involvement of magmatic fluids. Based on the fluid inclusion abundances, this suggests Cl must be present as HCl in CH_4 as well as NaCl in rare H_2O fluid inclusions. Provided Cl has a lower abundance in CH_4 than in the H_2O-CO_2 fluid inclusions, this measurement also suggests CH_4 has the lowest ^{36}Ar concentration. As wall-rock reaction increases the ^{36}Ar concentration of the volatile phase, this inference precludes a CH_4 source by localised reduction of CO_2. Instead, the high $^{40}Ar/^{36}Ar$ value favours an abiogenic CH_4 origin in the deep-crust or mantle. The Ne isotope data reveal a mantle component in pre- to early-gold pyrites, but the quartz-hosted H_2O and CO_2 fluid inclusions are dominated by atmospheric and crustal Ne (Fig. x-b). If all these fluids had a magmatic origin, this pattern is consistent with the changing style of regional magmatism from bimodal (mafic-flesic) prior to mineralisation to dominantly Ca-poor granite during the main-stage of gold deposition. The maximum $^{21}Ne/^{22}Ne$ value of 0.55 determined for CH_4-dominated fluid inclusions corresponds to the maximum $^{40}Ar/^{36}Ar$ value of ~50,000. The highest $^{21}Ne/^{22}Ne$ values require a source in which U is hosted by a mineral with an O/F value of greater than the upper-crustal average for U minerals. If CH_4 was generated by serpentinisation of deep-crustal mafic intrusions, the Ne data would be consistent with precursor H_2O-CO_2 fluids derived from lower-crustal rocks in which zircon or pitchblende were important U hosts.

These Ar and Ne data suggest CO_2-H_2O was derived from a lower crustal magmatic source and conclusively demonstrate that CH_4 had an independent 'abiogenic' origin. As CH_4 fluid inclusions or graphite are found in many gold-only ore deposits, we suggest that oxidation of abiogenic CH_4, possibly sourced from as deep as the Earth's mantle, has been a critical and overlooked control on the formation of many of the planets largest gold deposits.

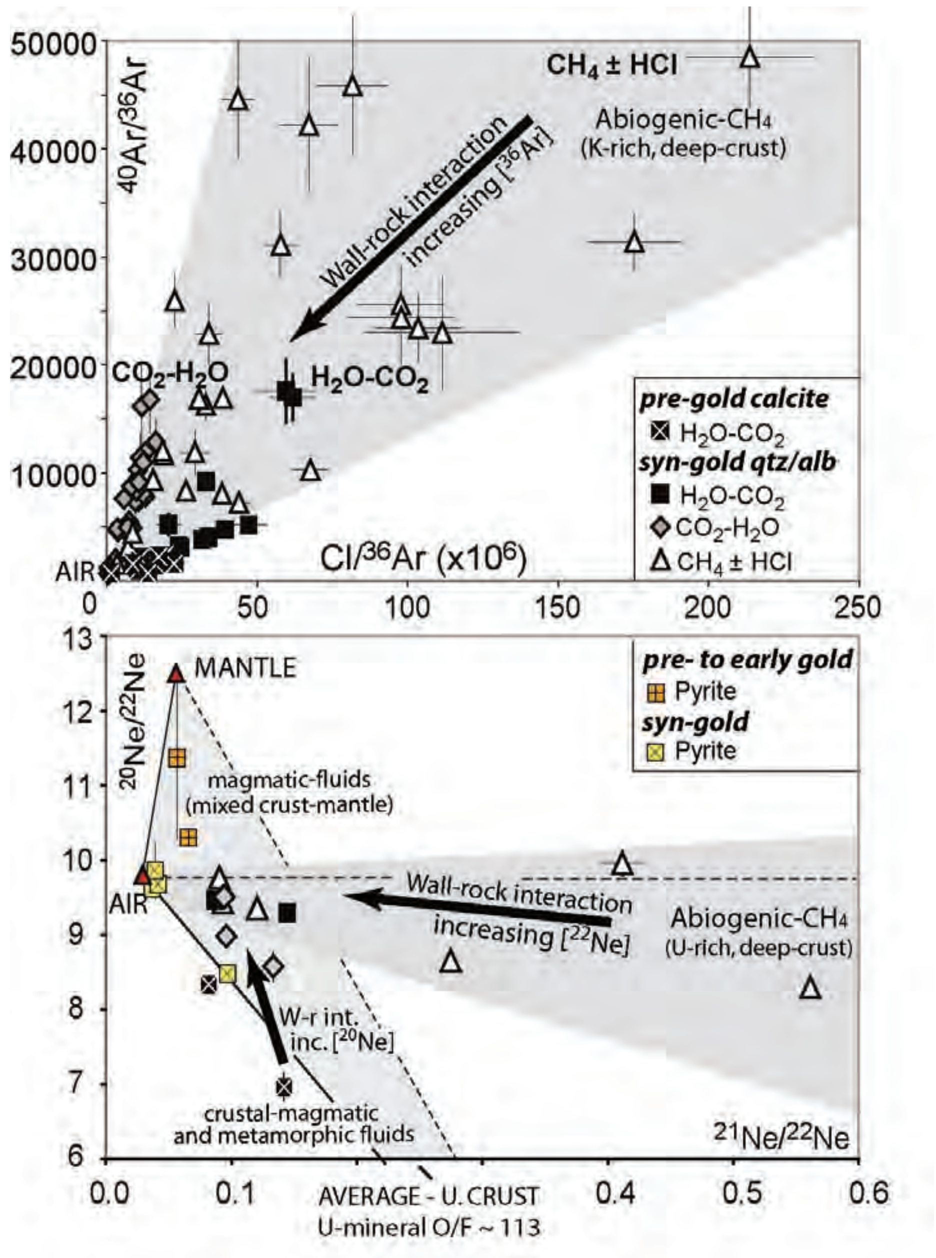

Figure 1. Fluid inclusion noble gas data for pre- to syn-gold minerals of the St Ives Gold Camp, Western Australia: a) Cl/^{36}Ar versus ^{40}Ar/^{36}Ar; b) ^{21}Ne/^{22}Ne versus ^{20}Ne/^{22}Ne. The high Cl/^{36}Ar values determined for CH_4 fluid inclusions suggest Cl is present as HCl and imply a parts per trillion ^{36}Ar concentration. CO_2-H_2O fluid inclusions have higher ^{36}Ar concentrations. The convergence of mixing trends and increase in ^{36}Ar concentration is interpreted to result from fluid interaction with mafic host-rocks rich in seawater-derived noble gases. Note that few of the deeply-derived fluids have Ne isotope compositions within the light grey envelope that could be explained by mixing atmospheric or mantle Ne with 'average-crustal' Ne. This suggests Ne-isotope heterogeneity in the lower crust; assuming an atmospheric intercept, the best fit slope for CH_4 indicates a source region in which U-minerals have an O/F value of close to the average crustal O/F value of 752.

Contamination-free biomarker analysis of shales using oxidative microwave digestion

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Research School of Earth Sciences, Australian National University, Canberra, ACT 0200, Australia

Surficial contamination of drill core and outcrop samples with anthropogenic hydrocarbons is a common phenomenon and can compromise the analyses of molecular fossils, particularly of lean and very ancient samples. A survey studying the molecular content of the exterior and interior portions of 26 rock samples from a wide range of drill cores and outcrops, found that all samples were surficially contaminated with petroleum products [1]. For compact and impermeable rock samples, surficial contaminants can be removed by trimming of surfaces [1]. However, we demonstrated that this is not possible for fissile and fractured samples where contaminants may have entered fissures and cracks. We tested whether contaminant hydrocarbons can be removed with solvents by extracting intact pieces of diesel stained shale with dichloromethane using an Automated Solvent Extractor (ASE). After 3 extraction cycles only ~40% of the diesel was removed, demonstrating that solvent rinsing does not efficiently eliminate surficial petroleum products. In a second experiment, we subjected diesel stained shale with hot concentrated nitric acid in a microwave digestion oven. This treatment successfully removed 98.5 to 100% of the contaminant hydrocarbons from the shale.

We further tested the microwave digestion technique on a Precambrian shale. Figure 1 shows the hydrocarbons of this sample after heating of the rock in concentrated nitric acid at 180°C for 30 minutes. The treatment successfully removed nearly 100% of all contaminants while the indigenous diamondoid and polyaromatic hydrocarbons were retained. The experiments demonstrate that our oxidative microwave digestion technique is highly efficient for the removal of surficial hydrocarbons and other contaminants.

Brocks J. J., Grosjean E., and Logan G. A. (2008) Assessing biomarker syngeneity using branched alkanes with quaternary carbon (BAQCs) and other plastic contaminants. Geochim. Cosmochim. Acta **72**, 871-888.

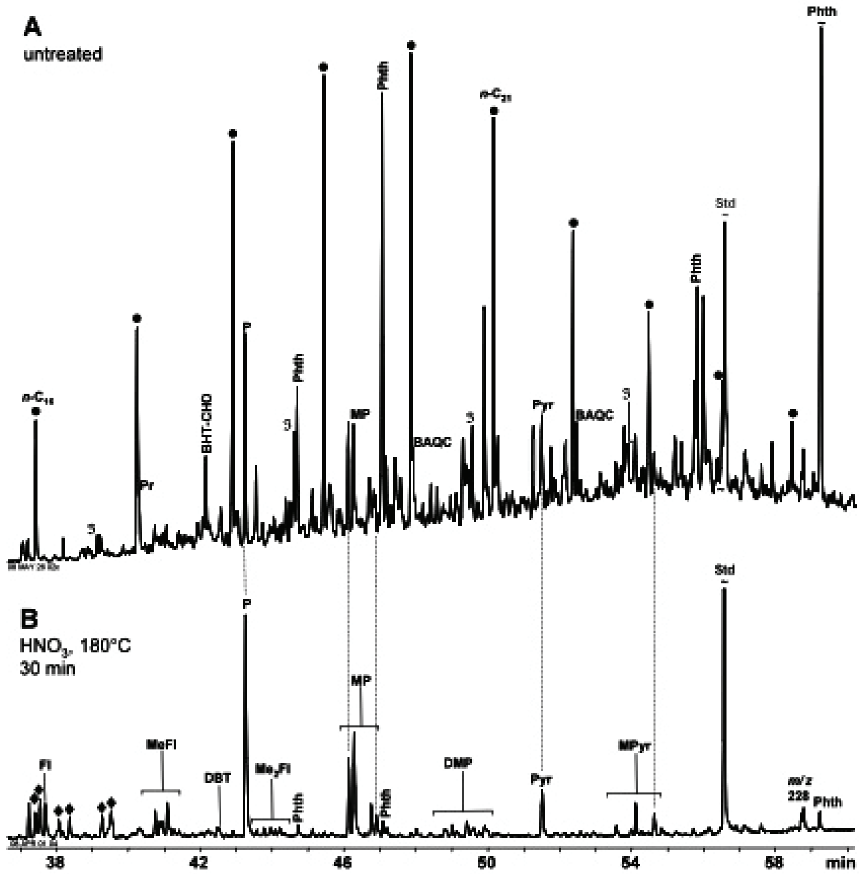

Figure 1. Mass chromatograms of the hydrocarbons of a 1.6 billion year old sample from the McArthur Basin in northern Australia. **(A)** Untreated sample showing a mixture of contaminants and indigenous biomarkers. **(B)** Predominantly indigenous hydrocarbons after treatment of the rock sample with hot nitric acid. BAQC = 5,5-diethylalkanes (branched alkanes with quaternary carbon); BHT-CHO = 3,5-di-tert-butyl-4-hydroxybenzaldehyde; Fl = fluorene; DBT = dibenzothiophene; DMP = dimethylphenanthrenes; MeFl = methylfluorenes; Me2Fl = dimethylfluorenes; MP = methylphenanthrenes; MPyr = methylpyrenes; P = phenanthrene; Phth = phthalates; Pyr = pyrene; Std = standard; ♦ = alkyl diadamantanes; ⬟ = alkylcyclopentanes; • = n-alkanes.

The Mystery of the Missing Solar Wind Oxygen in Lunar Soil

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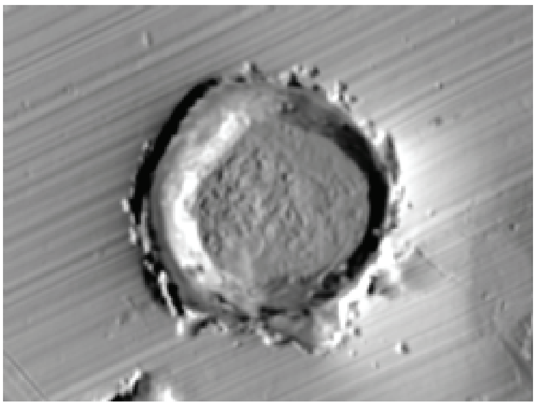
[2]*Research School of Astronomy and Astrophysics, Australian National University, Canberra, ACT 0200, Australia*

We have previously reported an isotopically heavy component (5‰ enriched in ^{17}O and ^{18}O) in the lunar soil that is preserved in the top few hundred nanometers of lunar metal grains. The location of this component appears consistent with the site expected for solar wind oxygen. However, McKeegan and colleagues reported at the Lunar and Planetary Science Conference this year that solar wind appears enriched in ^{16}O. We have carried out measurements on a larger number of grains from a variety of soils in an attempt to elucidate this discrepancy. Many more grains have been discovered with ^{17}O, ^{18}O enrichments with surprisingly few having ^{16}O-rich compositions, and none around the 6‰ enriched composition reported by McKeegan et al. (2008). Further analyses by Hashizume and Chaussidon (2008) also reveal ^{17}O, ^{18}O-rich compositions in modern lunar soils, while ^{16}O rich compositions in ancient soils are typically mass-dependently fractionated. The question then arises, what happened to the solar wind oxygen on the surface of the Moon.

We have measured Ne isotopic compositions in olivine grains from the lunar soils and these are consistent with solar wind implantation. It should therefore be expected that solar wind oxygen should be present in the surfaces of these grains. We cannot measure olivine grains for implanted solar-wind oxygen because of the high intrinsic concentration of oxygen in olivine. The issue is either the high density of the lunar metals biasing metal grains from exposure to the solar wind, or an issue of preservation. To address this, we will attempt to measure Ne in these metal grains to ascertain their exposure history. The solar wind exposure takes place at lunar surface temperatures of around 100°C. At such temperatures, oxygen diffusion is probably a major issue in retention in the lunar grains, particularly with the high flux of hydrogen carried by the solar wind. These issues will be examined with experiments on oxygen diffusion in metals under appropriate physical conditions.



While solar wind appears poorly represented in the metal grains, the component enriched in ^{17}O and ^{18}O is quite widespread. This component may be carried in cometary water, which is expected to have an isotopically heavy composition. The preservation of this component may be related to subsurface reaction of water with Fe metal.

Preliminary zircon U-Pb dating of late Paleozoic granites across the boundary between the Lachlan and New England fold belts

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Lachlan and New England fold belts are major tectonic components of eastern Australia. Because the boundary between them is totally covered by the huge Sydney basin, their tectonic relationship is unclear. However, the Carboniferous granites in the north-eastern Lachlan Fold Belt show similarities in age and composition with granites (Chappell et al., 1988) and volcanics (Shaw and Flood, 1993) in the New England Fold Belt. Based on these data, we could infer that the two fold belts might share the same basement and lower crustal structure. Therefore, our purpose is to trace the geologic history and decipher their relationship under the crust through the signature recorded in similar aged granites (Carboniferous to Permian) across the boundary between the Lachlan and New England fold belts. The combination of *in situ* U/Pb - O - Hf isotopic data for zircon will be a key for this study (e.g., Kemp et al., 2007).

Although a large amount of isotopic work on the granites of the Lachlan Fold Belt has been done over 30 years, there is little published work for the Carboniferous granites. Zircon from the Oberon, Bathurst and Gulgong batholiths has been dated. The ages of the granites dated so far range from ~340 to ~330 Ma. There is no simple age trend north to south, but the granites immediately west of Lithgow do appear to become younger from west to east.

Zircon has also been studied from the Banalasta (~290 Ma) and Inlet (~250 Ma) granites of the Bundarra and Moonbi supersuites, respectively, in the New England Fold Belt. Zircons of Banalasta show Carboniferous cores around 330 Ma old, while those of Inlet have no old cores at all. These preliminary results are not enough to conclude, but a beautiful story would be envisaged soon because O and Hf isotopic analyses for dated zircon grains are in progress now.

Shaw, S.E. and Flood, R.H., 1993. Carboniferous magmatic activity in the Lachlan and New England Fold Belts. In: Flood P.G. & Aitchison J.C. eds. New England Orogen eastern Australia NEO'93 Conference, pp. 113–121. University of New England, Armidale.

Kemp, A.I.S., Hawkesworth, C.J., Foster, G.L., Paterson, B.A., Woodhead, J.D., Hergt, J.M., Gray, C.M. and Whitehouse, M.J., 2007, Magmatic and Crustal Differentiation History of Granitic Rocks from Hf-O Isotopes in Zircon, *Science*, **315**: 980-983.

Chappell, B.W., White, A.J.R., and Hine, R., 1988, Granite provinces and basement terranes in the Lachlan Fold Belt, southeastern Australia, *Australian Journal of Earth Sciences*, **35**, 505-521.

Figure 1. *Typical feature of Bathurst and Gulgong batholiths that contain big pink feldspar crystals.*

Evolution of the Angrite Parent Body and Concordancy of Isotope Chronometers in Angrite Meteorites

Seann J. McKibbin[1], Trevor R. Ireland[1], Yuri Amelin[1], Hugh St. C. O'Neill[1]

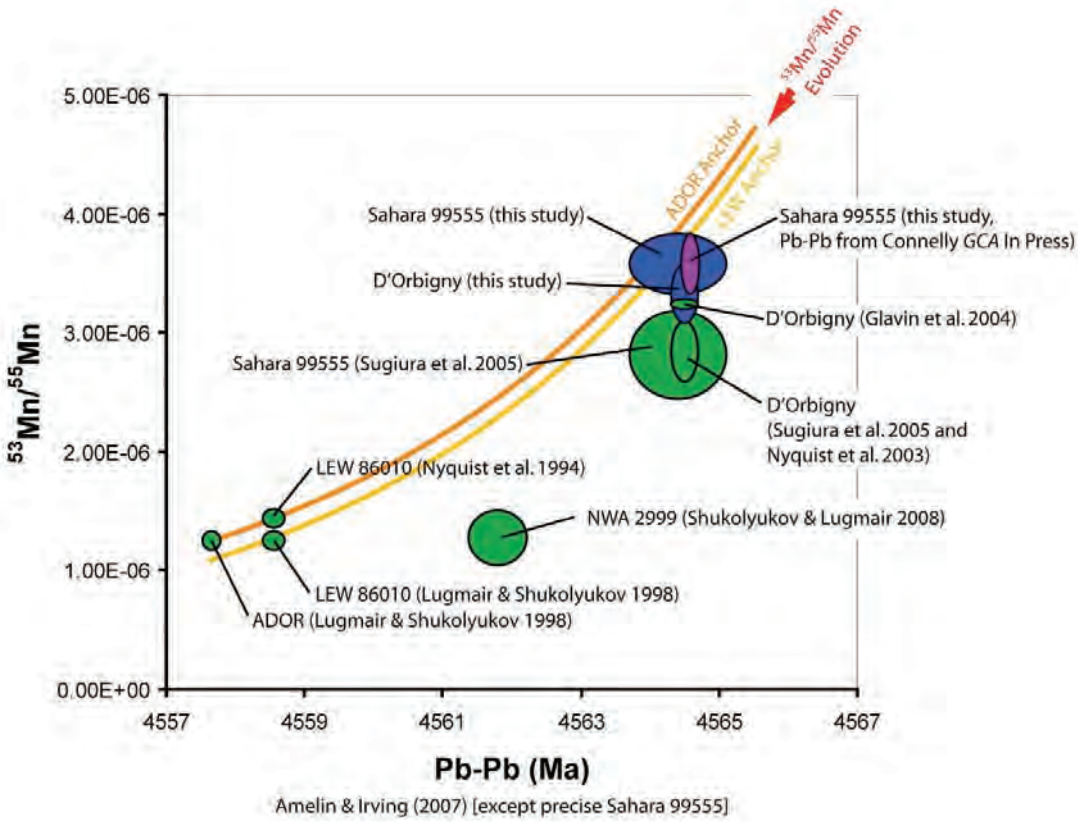
[1] *Research School of Earth Sciences, Australian National University, Canberra, ACT 0200, Australia*

The small achondrite meteorite clan classified as angrites have unique mineralogy, chemistry and oxygen isotopic compositions that strongly suggest they share a single parent body. They come in two broad petrologic groups: quenched 'volcanics' such as D'Orbigny and Sahara 99555, and 'plutonics/metamorphics' like LEW 86010. They are particularly suited to isotopic dating using the Pb-Pb chronometer and the short-lived (extinct) Mn-Cr system ($^{53}Mn \rightarrow {}^{53}Cr$, $t_{1/2}$ = 3.74 My) from which age differences between meteorites can be obtained. The angrites have yielded ages in these systems spanning a period of Solar System history critical to understanding of protoplanet formation (~4564.5 to ~4557.5 Ma from Pb-Pb).

However, concordancy between the two decay systems has been poor, with Pb-Pb isotopes recording up to 7 My of evolution between early volcanic and later plutonic varieties, while the Mn-Cr ages preserve a difference in ages of only ~5.5 My for the same meteorites [1]. To investigate this discrepancy, the Mn-Cr systematics of D'Orbigny and Sahara 99555 have been reinvestigated using the SHRIMP-RG ion-probe. Results support an early Mn-Cr age for both meteorites, and reinforce the discordancy between D'Orbigny and LEW 86010 in the Mn-Cr/Pb-Pb systems. However, the new result for Sahara 99555, along with improved agreement in the community over its Pb-Pb crystallisation age, suggests that this meteorite is concordant when compared with the younger LEW 86010 (Figure 1). This means that the two meteorites sample a common isotopic reservoir evolving in time, with no complications from diffusive closure occurring in different minerals at different times, and no later disturbance.

The emerging consensus is that angrite basalts crystallised from lava flows or a magma ocean around 4564.5 Ma, and magmatism and thermal activity continued until at least 4557.5 Ma as the protoplanet cooled. Further work will centre on angrites NWA 4590 and NWA 4801, which have not yet been dated using the Mn-Cr system.

Wadhwa M, Amelin Y, Bizzarro M, Kita N, Kleine T, Lugmair G, Yin Q (2007) Comparison of short-lived and long-lived chronometers: Towards a consistent chronology of the early Solar System. *Workshop on the Chronology of Meteorites and the Early Solar System* pp. 173. LPI Contribution No. 1374, Lunar and Planetary Institute, Houston.



5.00E-06
4.00E-06
3.00E-06
2.00E-06
1.00E-06
0.00E+00
4557
4559
4561
4563
4565
4567
^{53}Mn/^{55}Mn
Pb-Pb (Ma)
^{53}Mn/^{55}Mn Evolution
ADOR Anchor
LEW Anchor
Sahara 99555 (this study)
Sahara 99555 (this study, Pb-Pb from Connelly GCA In Press)
D'Orbigny (this study)
D'Orbigny (Glavin et al. 2004)
Sahara 99555 (Sugiura et al. 2005)
D'Orbigny (Sugiura et al. 2005 and Nyquist et al. 2003)
LEW 86010 (Nyquist et al. 1994)
NWA 2999 (Shukolyukov & Lugmair 2008)
LEW 86010 (Lugmair & Shukolyukov 1998)
ADOR (Lugmair & Shukolyukov 1998)
Amelin & Irving (2007) [except precise Sahara 99555]

Figure 1.

Copper concentrations in silicate mineral phases of the Boggy plain zoned intrusion

Jung Woo Park[1] and Ian H. Campbell[1]

[1] *Research School of Earth Sciences, Australian National University, Canberra, ACT 0200, Australia*

Understanding copper geochemistry in an evolving magmatic system is important because it may give the information about the relationship between copper mineralization and the magma and the variation of physical and geochemical condition, e.g. oxidation state and sulfur and water contents, of the magma.

Copper is a distinctively chalcophile element and therefore it strongly partitions into sulfide melts if the magma is S-saturated. However, depending on the physical and chemical condition of magma, dissolved copper in the magma as Cu^{+1} or Cu^{+2} can be trapped in a silicate mineral as an intrinsic element. Cu^{+2} is likely to be substituted for Fe^{+2} or Mn^{+2} in Fe-Mg silicates and Cu^{+1} for Na^{+1} in feldspar or hornblende because of their similar charge and radius (Stanton, 1994). Ewart et al. (1973) obtained 11-53 ppm copper in pyroxenes and 0-27 ppm in plagioclases of the Tonga-Kermadec volcanic island chain and found the copper levels in the plagioclases have positive correlation with whole-rock copper concentration. Wedepohl (1974) lists mean copper contents of 9.4-18, 9-17 and 2-45 ppm in amphibole, biotite and plagioclase of granitic rocks respectively.

Copper concentrations in silicate minerals were analyzed by LA-ICPMS in order to document variations in copper contents in the selected minerals during differentiation of the Boggy Plain magma, and their relationship with whole rock copper concentration.

Copper concentration in plagioclase are slightly higher in the mafic rocks of FeO^t+MgO>14.5 per cent, and copper contents of the northern gabbro which contains the highest whole rock copper concentration is distinctively enriched in copper compared with the felsic rocks of Boggy Plain zoned pluton (Figure 1). Except for several anomalously high copper values, the majority of them of plagioclases from outer/inner granodiorite and adamellite (FeO^t+MgO<14.5 %) are lower in order of 2-5 than them of mafic rocks. The mean copper contents of intermediate-felsic rocks range from 0.2 to 1 ppm showing a flat trend along with further magma differentiation. The Average values of copper concentration in plagioclase of Boggy Plain zoned pluton (0.18-2.2 ppm) is significantly less than that of the El Abra-Pajonal suite intrusion (0.4-69.1 ppm; Dianne 2008). This difference between the two suites can be partly explained by higher whole rock copper contents (12.5-5493 ppm) of the El Abra-Pajonal suite intrusion.

In order to estimate the amount of copper hosted by silicates phase, copper concentrations in other major silicate minerals are measured and mass balanced. This analysis yields silicate selective copper abundances ranging from 0.5 to 7.3 percent of whole-rock copper abundance. It indicates that the subtraction of copper by silicate crystallization is insufficient for the observed decrease of whole-rock copper in Boggy Plain rocks of FeO^t+MgO<14.5 per cent and the additional mechanism is required, e.g. the formation of Cu-bearing sulfide or Cu loss in vapor phase.

Ewart F, Bryan W, Gill, J. (1973) Mineralogy and geochemistry of the younger volcanic islands of Tonga, SW Pacific. *Journal of Petrology* **14**: 429-465

Dianne LV (2008) The geology, geochemistry and geochronology of the El Abra mine, Chile, and the adjacent Pajonal-El Abra suite of intrusions, Unpublished Ph.D. thesis, The Australian National University, 777 p.

Stanton RL (1994) Copper. In *Ore elements in arc lavas*: New York, Oxford University Press, p. 53-74.

Wedepohl, K.H. (1974). Copper. In *Handbook of geochemistry* (ed. K. H. Wedepohl). Springer-Verlag, Berlin.

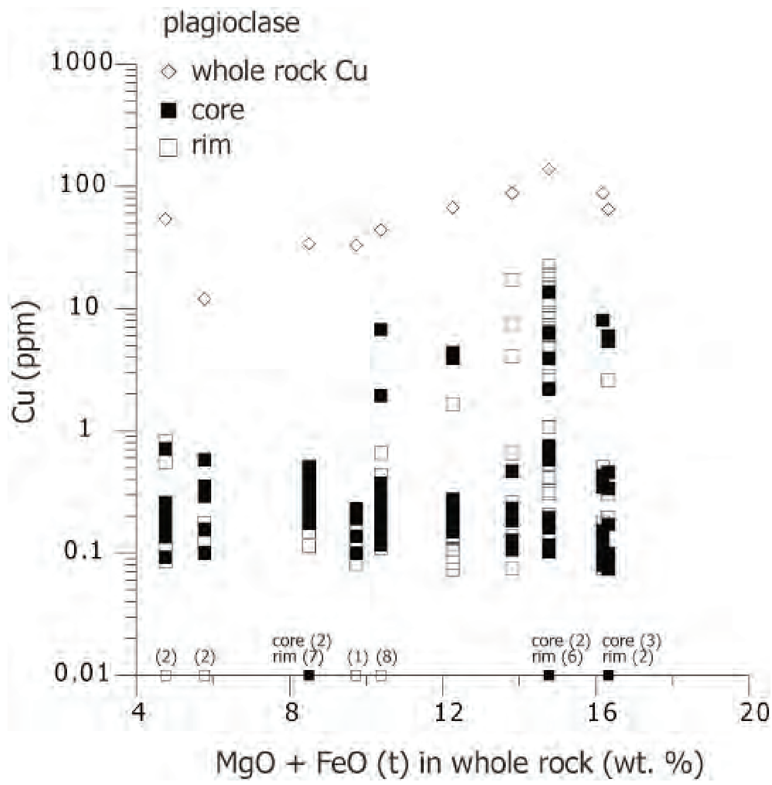


Figure 1. *Copper concentration in plagioclase of the Boggy Plain zoned pluton. Values below detection limits are on the x-axis and numbers in the brackets are number of analysis points of them.*

Dating the allanite-monazite metamorphic reaction

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U-Pb geochronology is one of the most widely used methods for the investigation of the timing of crustal processes. One main limitation of the application of U-Pb geochronology to metamorphism is the lack of direct links between the age measured and the conditions at which the dated minerals formed. In this respect, dating metamorphic reactions that can be placed in pressure-temperature space is particularly appealing.

One metamorphic reaction between U-Pb minerals that has been widely reported is the mutual replacement of allanite and monazite (figure 1 and 2). With the recent set-up of a protocol for accurate dating of allanite by SHRIMP ion microprobe (Gregory et al. 2007) it has become possible to date this reaction in-situ. We applied this method to the two geological settings where allanite-monazite reactions are most commonly documented.

1) Monazite replacing allanite is observed in prograde greenschist to amphibolite facies metamorphism of metapelites in the Central Alps (Fig. 1). Petrographic observations and thermobarometric calculations allow placing the reaction at T = 560-580°C, whereas initial allanite formation occurred at T = 430-450°C. In-situ SHRIMP U-Th-Pb dating of allanite (31.5 ± 1.3 and 29.2 ± 1.0 Ma) and monazite (18.0 ± 0.3 and 19.1 ± 0.3 Ma) constraints the time elapsed between 430-450°C and 560-580°C, which implies an average heating rate of 15-8 °C/My (Janots et al., in press).

2) During subduction-related metamorphism, the replacement of monazite by allanite is associated to increasing pressure. This is observed in the silvery micaschists of the Gran Paradiso Massif, Western Alps where microstructural relationships among major and accessory minerals indicate the following prograde sequence of U-Th bearing accessory minerals: florencite -> monazite -> allanite (Fig. 2). Thermobarometric calculations indicate that the allanite-bearing peak assemblage was stable at P = 2.3 ± 0.4 GPa and T = 570 ±30 °C, while monazite formed earlier at pressures over 2.0 GPa. SHRIMP dating of allanite yielded 34.5 ± 0.8 Ma, interpreted as the age of the high-pressure metamorphic peak. Prograde monazite yielded an age of 37.5 ± 0.9 Ma, implying a minimum duration of ~3 Ma for the Alpine subduction event (Gabudianu Radulescu et al., in press).

Gregory C, Rubatto D, Allen C, Williams IS, Hermann J, Ireland T (2007) Allanite micro-geochronology: a LA-ICP-MS and SHRIMP U-Th-Pb study. *Chemical Geology* **245**:162-182

Janots E, Engi M, Rubatto D, Berger A, Gregory C, Rahn M (in press) Metamorphic rates in collisional orogeny from in situ allanite and monazite dating. *Geology*

Gabudianu Radulescu I, Rubatto D, Gregory C, Compagnoni R (in press) The age of HP metamorphism in the Gran Paradiso Massif, Western Alps: a petrological and geochronological study of "silvery micaschists". *Lithos*

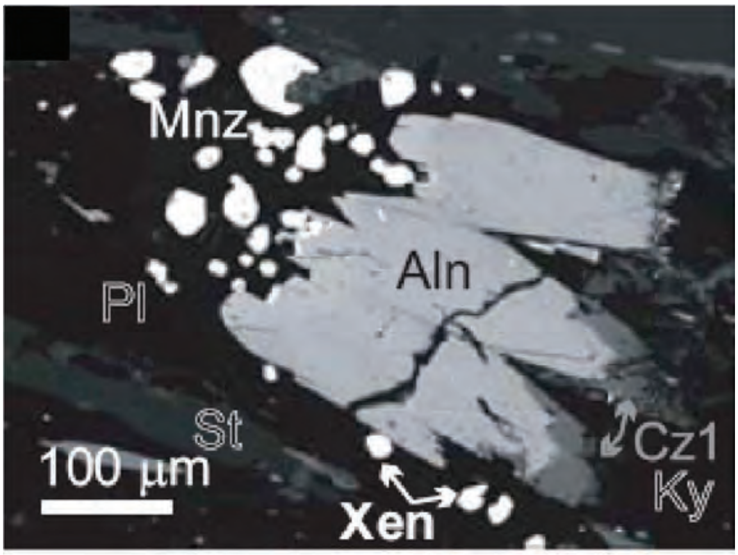

Figure 1.

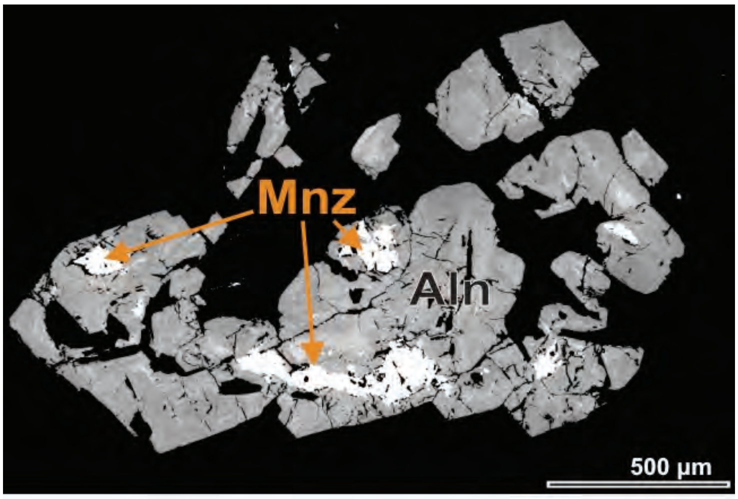

Figure 2:

Molecular Fossils of the Neoproterozoic-Cambrian Interval: Lipid Biomarker Geochemistry and Ancient Microbial Ecosystems

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Numerous microorganisms survive and flourish in environments that are often considered "extreme" from an anthropogenic view point. Such environments include hydrothermal vents, hydrocarbon seeps, and acid hot springs. Hypersaline environments are another type of setting where microorganisms live under salinity regimes exceeding those of seawater. In order to understand the evolution of ecosystems from such settings, Neoproterozoic and Cambrian halite-bearing evaporites were investigated for their lipid biomarker content. This time frame encompasses tremendous environmental and biotic changes (e.g., major glaciations, oxygenation of the deep ocean, evolution and radiation of microorganisms, and the first appearance of animals). While previous work identified potential halophiles in the Cambrian and Precambrian, we aim to present a more detailed investigation of biotic evolution over a significant period of geologic time.

In order to assess changes in microbial ecosystems over geologic time, it is important to focus on a variety of different environmental settings. Dissimilar environments offer different ecological niches which organisms can exploit. Such niches may respond differently to environmental changes over time.

Thus far, the results look very promising and has let to the discovery of lipid biomarkers that are over 1 billion years old. I am also trying to investigate rock samples from that period that originated in shallow water, particularly hypersaline facies. So far, most investigations concentrated on deep water facies. I have collected rock samples from drill cores (Figure 1) held at Australian drill core repositories. These rocks are from shallow water facies and contain numerous evaporate (salt-bearing) sequences.

A major theme in any chemical work dealing with ancient life is the interpretation of molecules as original contemporaneous components of a rock sample or as more recent additions in the form of contamination. Therefore, I investigated techniques aimed at removing potential contaminants from rock samples. Thus far, the techniques have worked very well and helped me determine which biomarkers were likely derived from the Precambrian-Cambrian interval and which samples are contaminants (e.g. from the use of drilling fluids, fingerprints etc).

Figure 1.

In situ oxygen isotopic analyses of zircon from granites of the Bega Batholith, south-eastern Australia

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The oxygen isotopic composition of granites is a sensitive indicator of both their source materials and the low-temperature processes that occurred as or after the magma cooled. Oxygen isotopes have been used extensively, particularly in the USA, for studies of granite genesis. Granite O isotopic compositions are normally measured on whole rocks or major minerals, but these are susceptible to late alteration. A major recent advance in the study of granite O isotopes has been the recognition that the O isotopic composition of zircon accurately reflects the O composition of the melt from which it precipitated (e.g. Monani & Valley, 2001). Because zircon grains are commonly strongly zoned and in many cases contain older cores, the ideal method of measuring the isotopic composition of the melt-precipitated components is *in situ* analysis by secondary ion mass spectrometry.

Over the past few years, the SHRIMP II ion microprobe has been progressively upgraded for the high precision isotopic analysis of light elements, including O. In addition, sample mounting procedures have been modified and analytical protocols developed to minimise variations in instrumental mass fractionation (Ickert et al., 2008). The resulting ability to measure the O isotopic composition of single 25 µm spots on a crystal with a precision and accuracy of better than 0.4‰ has opened up a range of new opportunities for the study of granite petrogenesis in Australia.

The Bega Batholith, SE of Canberra, consists of ~130 plutons of I-type granite covering ~8900 km^2. These have been grouped into a series of suites that show remarkably systematic regional changes in chemical and isotopic composition. East to west, across the elongation of the suites and the batholith as a whole, in granites of any given general bulk composition there is, for example, a systematic decrease in Na, Sr, (Al, P) and increase in Ca, Sc, (Rb, V). East to west, the granites become more isotopically evolved, initial $^{87}Sr/^{86}Sr$ rising from 0.704 to 0.709 and εNd falling from +4.3 to -8.7 (Chappell et al., 1990). It is generally agreed that these changes are due to a westerly increasing sediment component in the magmas, but whether that originates in the lower or upper crust or mantle, and whether the magmas also contain a juvenile mantle component, are matters of vigorous debate.

The early O isotopic work done on eastern Australian granites by O'Neil and Chappell (1977) and O'Neil et al. (1977) showed a clear distinction between the whole-rock O isotopic compositions of the I- and S-type granites, consistent with the proposed contrasts in their source materials. Later Chappell et al. (1990) reported mean whole rock d^{18}O values for seven supersuites from the Bega Batholith ranging from 8.2 to 10.0‰. The range in individual granite compositions exceeded 6‰, some values reflecting the effects of late magmatic and/or post emplacement interaction with meteoric water.

A major study of the age and O isotopic composition of selected granites from the Bega Batholith is now nearing completion. Analyses of over 600 zircons from 30 plutons representing a range of bulk chemical compositions, mainly from the eastern and western sides of the batholith, has shown that there is a broad trend for the granites to be younger in the east than in the west. Contrary to expectations, however, with a few notable exceptions, the mean isotopic composition of the O in the granite zircons shows no clear regional trend. The range of mean O isotopic compositions of the zircons is much smaller than the range of whole rock compositions, consistent with the expectation that the zircon isotopes are much more resistant to alteration than those in the whole rock, thereby more closely reflecting the original O isotopic compositions of the magmas. The radiogenic and stable isotopic systems in the granites appear to be for the most part decoupled.

The next stage of this project will be to measure the Hf isotopic compositions of the same spots on the same grains as have been analysed for O. In combination with the O isotopes, this is expected to give a clearer indication of the relative contribution of bulk juvenile and crustal components to the magmas.

Chappell, B.W., Williams, I.S., White, A.J.R. & McCulloch, M.T. (1990) Excursion Guide A-2, Granites of the Lachlan Fold Belt. *BMR Record* **1990/48**: 93 pp.

Ickert, R.B., Hiess, J., Williams, I.S., Holden, P., Ireland, T.R., Lanc, P., Schram, N., Foster, J.J. & Clement, S.W. (2008) Determining high precision, in situ, oxygen isotope ratios with a SHRIMP *II*: Analyses of MPI-DING silicate-glass reference materials and zircon from contrasting granites. *Chemical Geology* **257**: 114–128.

Monani, S. & Valley, J.W. (2001) Oxygen isotope ratios of zircon: magma genesis of low d18O granites from the British Tertiary Igneous Province, western Scotland. *Earth and Planetary Science Letters* **184**: 377–392.

O'Neil, J.R. & Chappell, B.W. (1977) Oxygen and hydrogen isotope relations in the Berridale batholith. *Journal of the Geological Society, London* **133**: 559-571.

O'Neil, J.R., Shaw, S.E. & Flood, R.H. (1977) Oxygen and hydrogen isotopic compositions as indicators of granite genesis in the New England Batholith, Australia. *Contributions to Mineralogy and Petrology* **62**: 313-328.

Earth Environment

As for other parts of the School, the size of the Group increased substantially due to the amalgamation of RSES with the former Department of Earth and Marine Sciences. Several members of staff joined the Group [De Deckker, Ellis [partim], Opdyke and Young] together with their students and technical staff.

Members of the Earth Environment group undertake research on environmental and climate change with particular emphasis on the interactions between humans and the environment. The group specialises in the development of diagnostic environmental proxies within an absolute chronologic framework that spans a few decades to several hundred thousand years of Earth history. The purpose is to document and understand past changes that have particular relevance to help predicting future ones. With the considerable current awareness and concern about environmental changes, the relevance of the group's research is paramount and of direct relevance to society. The future of the Great Barrier Reef is one of these concerns with biogenic carbonate build ups and ocean acidification.

Our researchers and their students and collaborators [Eggins, McCulloch, Opdyke, Trotter and Walther] are involved in growing organisms such as the marine microscopic, calcitic foraminifera under controlled conditions and also determining changes in calcification and temperature in shallow and deep-sea corals. Several of those people are also conducting research to determine proxies for pH changes in the oceans. Experimental research, monitoring and data gathering dealing with silica budgets in the Southern Ocean are the concern of other research teams [Ellwood and Wille]. Gagan, Treble and Ayliffe are involved in investigations on speleothem spanning different ages with the aim of determining past climatic signals. Some of that work concerns links between human evolution and climate in Indonesia. Gagan, Sosdian and students are also involved in isotopic analyses on shallow water corals from a variety of localities.

De Deckker continues his work on Holocene sequences, both from marine and lacustrine origins using biogenic carbonates, and is also involved in fingerprinting the geochemistry and microbiology of aeolian dust.

Another aspect of the Group's research deals with human impacts on environment, across very different time scales. Of principal concern is the impact of terrigenous sediments and nutrients on reefal systems [McCulloch and Trotter] and in estuaries [Ellis] over short time scales. Grün and colleagues [Aubert and Eggins] deal with much longer time scales and on sites that are important to cultural and environmental history such as the Willandra Lakes World Heritage area, in particular, developing new techniques for dating human teeth and bones.

Landscape evolution is also an important focus of several members of the Group. Pillans, Fitzsimmons and Barrows are further developing dating techniques, such as palaeomagnetism, optically stimulated luminescence and cosmogenic nuclides to characterise geomorphic changes, denudation and weathering changes.

In situ oxygen isotope analysis of faunal material using a secondary ion micro-probe: a new tool for palaeoecology and archaeology.

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We have applied *in situ* oxygen isotope analysis on Neanderthal and herbivore teeth from the archaeological site of Payre as well as fossil fish otoliths from Australia. The high resolution of the oxygen isotope analysis allows weekly to bi-weekly resolution of human teeth. We observed large variations in the oxygen isotopic composition in the enamel of herbivore teeth, which were on a scale expected from seasonal variations. The range of isotopic variations in Neanderthal tooth enamel was much smaller, perhaps reflecting a more restricted range of diet and/or more uniform sources of drinking water when the teeth were growing. The application of fish otoliths from the Australian Willandra Lakes World Heritage area showed significant isotopic variations indicating seasonal variations but also a general trend towards heavier oxygen isotopes, which may be due to an enrichment in heavy isotopes as a result of increased evaporation (Fig 1). We will pursue with the oxygen isotope research on fish otoliths as these seem ideal archives of past environmental conditions.

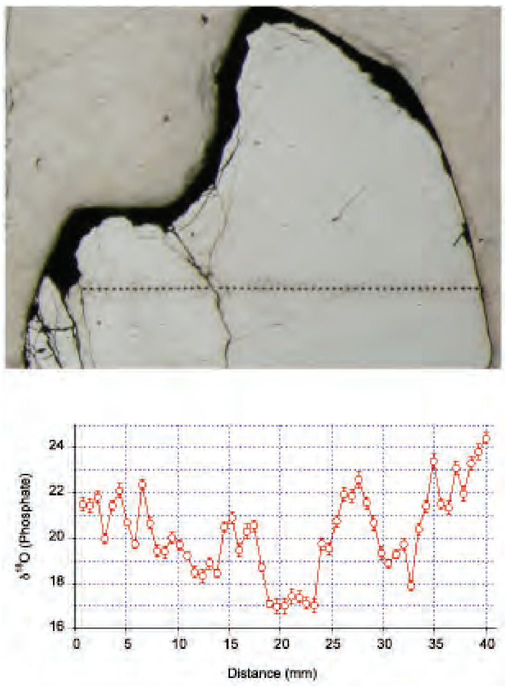

Figure 1. *Oxygen isotopic compositions of a fossil otolith from the Australian Willandra Lakes World Heritage area showing a general trend to heavier oxygen isotopes, indicating an enrichment in heavy isotopes due to increased evaporation*

Past glacial cycle monsoon variation recorded in speleothems from Flores, Indonesia.

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[1] *Research School of Earth Sciences, The Australian National University, Canberra, ACT 0200, Australia.*
[2] *Radiogenic Isotope Laboratory, Centre for Microscopy and Microanalysis, University of Queensland, St. Lucia, Queensland 4072, Australia.*
[3] *Environmental and Climate Change Research Group, University of Newcastle, Callaghan, NSW 2308, Australia.*
[4] *School of Earth Sciences, The University of Melbourne, Victoria 3010, Australia.*
[5] *Research and Development Center for Geotechnology, Indonesian Institute of Sciences, Jalan Cisitsu No. 21/154 D, Bandung 40135, Indonesia.*

Tropical speleothems are ideal archives of changes in past rainfall as they can be dated precisely with the U-Th technique and their d^{18}O values can be interpreted in terms of rainfall intensity as tropical rainfall d^{18}O values are inversely proportional to rainfall amount (Dansgaard, 1964). Here we present some preliminary d^{18}O results over the past ~90ka from speleothems from the island of Flores, Indonesia. Located at the southern-most extent of the Intertropical Convergence Zone (ITCZ) in the Austral summer and just within the current southern boundary of the Western Pacfic Warm Pool (WPWP) Flores is ideally situated to record changes in each of these major climate systems.

Several stalagmites and flowstones were collected from deep within Liang Luar Cave (8°32'S, 120°27'E) in 2006 and 2007. Oxygen isotope results of two stalagmites and two flowstone cores are shown in Figure 1. As can be seen good agreement is observed between the oxygen isotopes of the faster growing stalagmites and the much slower growing flowstones where they overlap in age. This suggests that speleothem calcite is being deposited under conditions of near isotopic equilibrium in this cave environment.

Although much work still remains to firmly establish the chronology of the >50ka flowstone record, some interesting trends are emerging from the younger portion of our speleothem record. In contrary to what might be expected, monsoon intensity appears not markedly reduced during past cool phases such as the LGM and stage 3 compared to the Holocene. Rather at times of lowered sea level, monsoon intensity appears more directly coupled to southern hemisphere insolation changes compared to times of high sea level, Fig. 1. This effect could be the result of increases in the degree of continentality experienced at times of low sea level, and consequent greater impact of insolation changes on monsoon strength.

Dansgaard W. (1964) Stable isotopes in precipitation. *Tellus* **16**:436-468
Sturman A, Tapper N. (1996) *The Weather and Climate of Australia and New Zealand*. Oxford University Press: Oxford

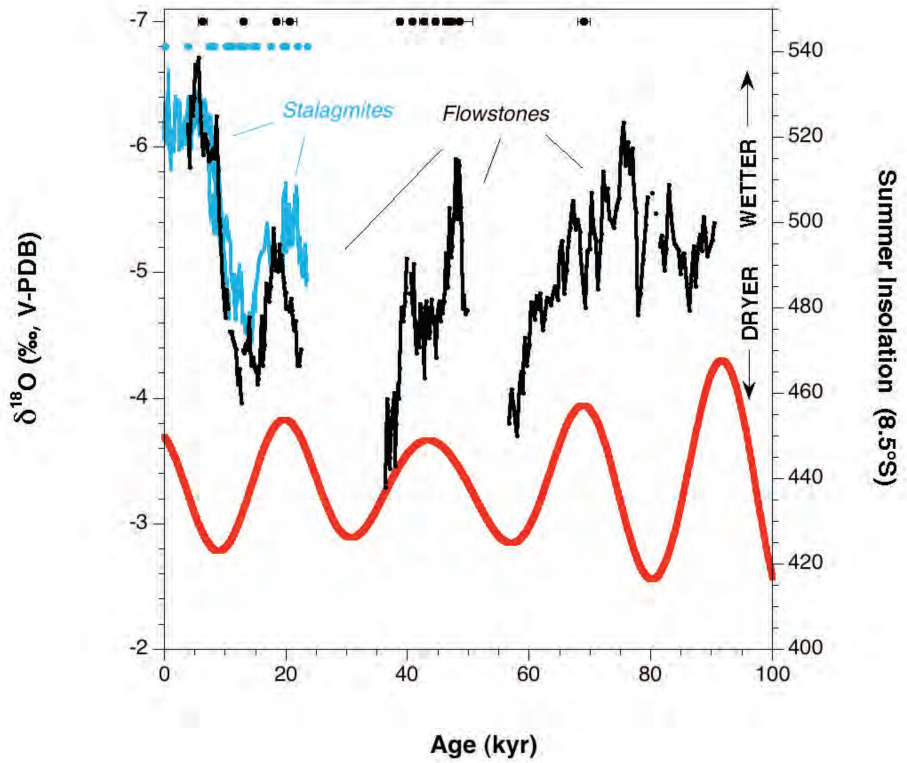

Figure 1. *Speleothem d18O records from Flores (8°32'S, 120°27'E) (stalagmites (blue) & flowstones (black)) compared with summer insolation at 8.5°S (red). d18O values are not corrected for the effects of changes in global ice volume or regional temperatures. Ice volume changes would amount to corrections of ~+1‰ (at 20ka) and ~+0.6‰ (at 50k) to speleothem calcite d18O values. Temperature reductions of ~2-3.5°C (such as was likely experienced during the LGM at the site) would also result in further corrections of +0.4‰ to +0.7‰ calcite d18O values.*

Geochemical and microbiological fingerprinting of airborne dust that fell in Canberra, Australia in October 2002

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During the night of October 22-23, 2002, a large amount of airborne dust fell with rain over Canberra, located some 200 km from Australia's east coast, and at an average altitude of 650m. It is estimated that during that night about 6 g.m^{-2} of aeolian dust fell. We have conducted a vast number of analyses to "fingerprint" some of the dust and used the following techniques: grain size analysis, SEM imagery, major, trace and rare earth elemental, plus Sr and Nd isotopic analyses, organic compound analyses with respective compound-specific isotope analyses, pollen extraction to identify the vegetation sources, molecular cloning of 16S rRNA genes in order to identify dust bacterial composition. DNA analyses show that most obtained 16S rRNA sequences belong mainly to three groups: *Proteobacteria* (25%), *Bacteriodetes* (23%), and *gram-positive bacteria* (23%). In addition, we investigated the meteorological conditions that led to the dust mobilisation and transport using model and satellite data.

Grain sizes of the mineral dust show a bimodal distribution typical of proximal dust, rather than what is found over oceans, and the bimodal aspect of size distribution confirms wet deposition by rain droplets. The inorganic geochemistry points to a source along/near the Darling River in NW New South Wales, a region that is characteristically semi-arid, and both the organic chemistry and palynoflora of the dust confirm the location of this source area. Meteorological reconstructions of the event again clearly identify the area near Bourke-Cobar as being the source of the dust. This study paves the way for determining the export of Australian airborne dust both in the oceans and other continents.

De Deckker, P., R. M. M. Abed, D. de Beer, K. Hinrichs, T. O'Loingsigh, E. Schefuß, J. W. Stuut, N. J. Tapper, and S. van der Kaars, 2008, Geochemical and microbiological fingerprinting of airborne dust that fell in Canberra, Australia, in October 2002, Geochem Geophys. Geosyst., **9**, Q12Q10, doi:10.1029/2008GC002091.

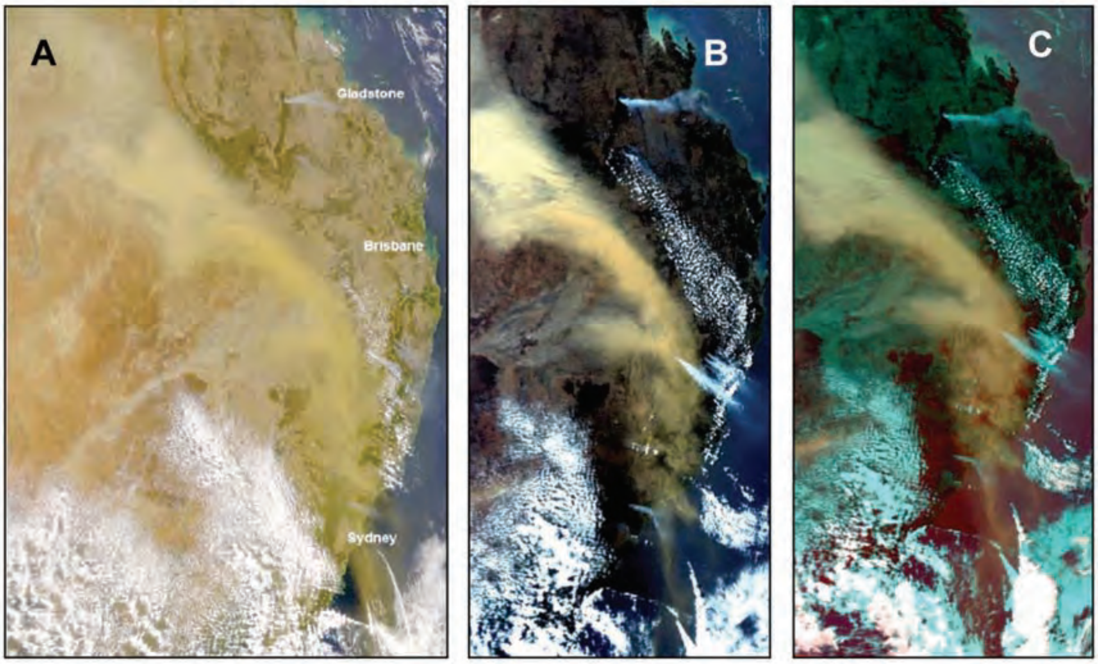

Figure 1. (A) SeaWiFS satellite image 09:00 hours local eastern standard time (EST) on 23 October 2002 (taken from McTainsh et al., 2005), showing the main dust plume passing over eastern Australia (note the smoke plumes from bushfires in south east Queensland and central east NSW, which indicate wind directions at the time of the event), (B): 13:25 hours EST – MODIS colour-optimised Red-Green-Blue image and (C) processed with the Miller Dust Enhancement Algorithm.

Phasing and amplitude of sea level and climate change during the penultimate interglacial

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[2] *CEREGE, CNRS and Universite Aix-Marseille III, Europole de l'Arbois, 13545 Aix-en-Provence Cedex 4, France*
[3] *ENEA - Special Project Global Change, Rome 00060, Italy*

Direct markers of sea level position during the Quaternary are often limited to archives near or above present sea level, such as corals which grew near the sea surface during interglacial highstands. Submerged speleothems provide a means to access the history of sea level oscillations across a range of depths below present sea level. Because the dense calcite comprising speleothems is less susceptible to alteration than corals, this archive also has the potential to extend reconstructions of sea level position farther back in time. A collection of unique speleothems from Argentarola Cave, Italy have been recovered which contain alternating layers of spelean calcite (formed during subaerial exposure) and *Serpulid* calcite (formed during cave submergence by seawater). We have extended the sea level reconstruction from Argentarola farther back in time and have examined additional specimens from different depths to complement the existing dataset [1,2]. This work has resolved the timing and magnitude of multiple sea level highstands during marine isotope stage (MIS) 7.

We have generated 36 U-Th ages of the speleothem calcite to constrain the timing of cave submergence by seawater, represented in these specimens by the marine serpulid overgrowths. Our data show that sea level highstands above -18 m were attained ~5,000-8,000 years prior to northern hemisphere (NH) insolation maxima during MIS 7.5 and 7.1. In contrast, MIS 7.3 commences within 1,000 years of the NH insolation maximum and peaks near -18 m, despite having the strongest insolation forcing of the triplet. This delayed phasing and dampened amplitude of the MIS 7.3 highstand is attributed to extensive glaciation during MIS 7.4 and highlights the significance of cryosphere response time to the climate system.

[1] E. Bard, F. Antonioli and S. Silenzi, (2002) Sea-level during the penultimate interglacial period based on a submerged stalagmite from Argentarola Cave (Italy). *Earth and Planetary Science Letters* **196**: 135-146.

[2] F. Antonioli, E. Bard, E.-K. Potter, S. Silenzi and S. Improta (2004) 215-ka History of sea-level oscillations from marine and continental layers in Argentarola cave speleothems (Italy). *Global Planetary Change* **43**: 57-78.

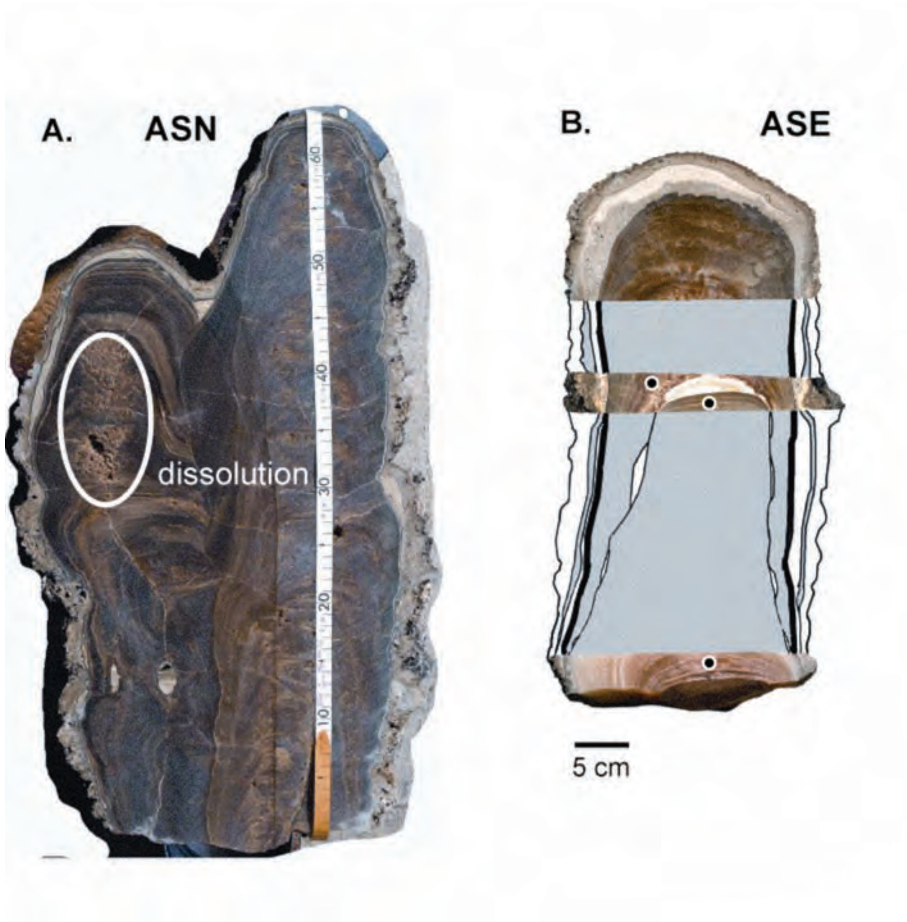

Figure 1. Marine serpulid overgrowths present in two stalagmites were dated by bracketing U-Th ages of speleothem calcite above and below the marine layers. A. Argentarola stalagmite N (ASN). Large scale dissolution is visible in part of the speleothem (below the areas we sampled). B. Argentarola stalagmite E (ASE) drawing spliced together with photographs. Sample positions denoted by black circles in ASE.

Winter-time dissolved iron and nutrient distributions in the Subantarctic Zone from 40-52S; 155-160E

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In the Southern Ocean, mesoscale iron fertilization experiments have clearly demonstrated that iron plays a pivotal role in controlling primary production in polar and subpolar High Nitrate Low Chlorophyll (HNLC) waters. There has been considerable debate about the relative magnitude of different iron sources to surface waters in these regions, such as upwelling, dust or entrainment from island and continental self sediments. However, despite the rapidly emerging field of iron biogeochemistry, there are few vertical profiles of dissolved iron concentration, and almost no winter iron data.

During 2006 we generated the first comprehensive winter dataset for dissolved iron and nitrate distributions (0-1000 m depth) between 40 °S - 52 °S, which transects the Subantarctic zone (SAZ), west of New Zealand (Figure 1).Surface iron concentrations (<0.2 nmol Fe kg^{-1}) were conspicuously low, i.e., probably biologically limiting even at winter-reserve levels, at frontal zones between 43 °S (Subtropical Front) and ~51 °S (Subantarctic Front) (Figure 2). A fivefold range in iron:nitrate molar ratios was observed along the transect, with Subtropical waters, where blooms occur, having the highest ratios in subsurface waters. The major wintertime supply of dissolved iron in the SAZ is from Ekman advection of waters from the south (but calculated source water dissolved iron is ~0.2 nmol Fe kg^{-1}), suggesting that mixed-layer dissolved iron concentration is controlled by how long these southern waters remain at the surface (~3 years).

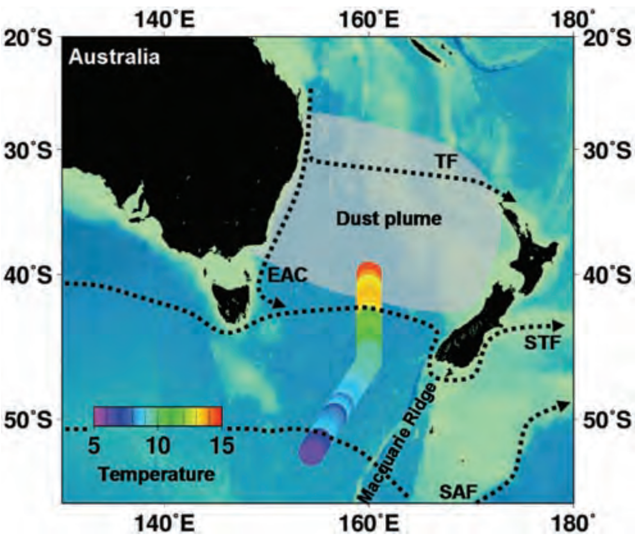

Figure 1

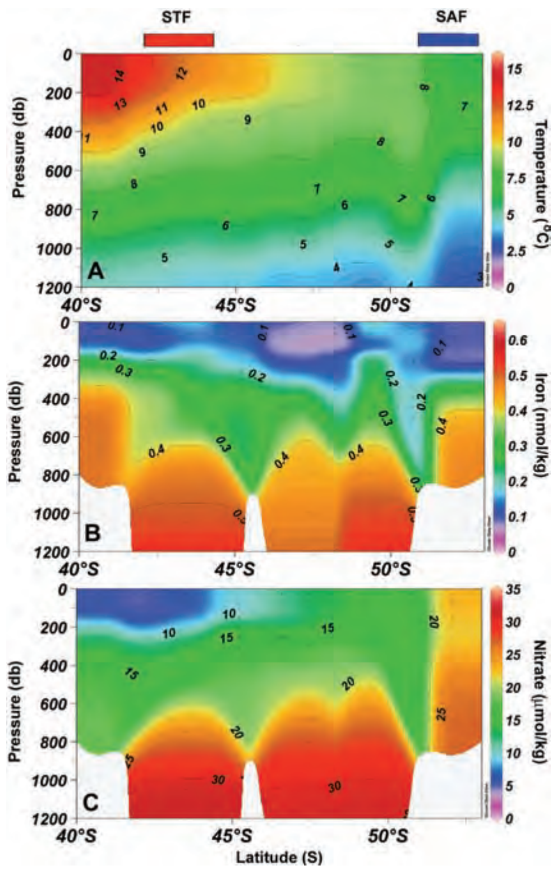

Figure 2

Reconstructing the history of drought and aridity in Australia: Evidence from Lake George

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Australia is the driest inhabited continent on Earth. However, evidence preserved in the landscape suggests that arid and drought conditions have varied in intensity through time and space. Aridity during the late Quaternary presided over considerable expansion of desert dunefields across Australia (e.g. Fitzsimmons et al. 2007a, b), the drying of lake basins, and increased dust transport.

It is unclear how the present relatively arid, warm conditions relate to the cold, dry climate responsible for desert expansion during the late Quaternary, or to the current severe droughts. This knowledge gap is primarily due to the fact that there are few systematic records of regional aridity and drought in Australia. The key to understanding the development of aridity is to produce a chronological framework for terrestrial aridification. Recent and continuing work at the luminescence dating laboratory in the Research School of Earth Sciences aims to produce such a chronological framework, focusing on key sites which preserve landscape features responsive to aridity, such as dunes and lake shorelines.

Lake George is the largest freshwater lake in mainland Australia when full, and provides one of the most complete records of Quaternary sedimentation in the southeastern part of the continent. The lake is presently ephemeral in response to drought conditions, but sediments within the basin preserve evidence of multiple permanent and dry lake conditions in the past. Cross bedded gravels exposed in the southern part of the lake basin indicate the existence in the past of a substantial water body with water depth in excess of 20 m. Stratigraphic sequences and lake shorelines at the northern end of the lake record multiple periods of lake filling. Lacustrine sediments within the northern part of the lake basin are overlain by a thin veneer of alluvial material and aeolian dust representing shoreline retreat late in the Holocene.

Optically stimulated luminescence (OSL) dating has been applied to the various geomorphic features associated with the lake, with an examination of aeolian, fluvial and lacustrine sediments. The single aliquot regenerative dose (SAR) OSL dating protocol has been applied using both single aliquots and single grains for samples from the different geomorphic settings. We are presently seeking to extend the chronology beyond the limits of conventional SAR OSL dating through the use of thermally-transferred OSL (Tsukamoto et al. 2008), and are contributing to the development of this new technique.

We are working to reconstruct past lake levels based on the sedimentology of the dated units, and to relate these to environmental change in the region during the Late Quaternary. The preliminary OSL chronology shows a striking correlation between lake filling events at Lake George and permanent lake conditions/ high water tables across humid, semi-arid and arid Australia (Figure 1). The Holocene and oxygen-isotope stage 5 filling events at Lake George correspond to warm sea-surface temperatures (Barrows et al. 2007). Lake filling events also appear to correspond to relatively humid periods between major arid episodes in the desert dunefields of central Australia, also identified by OSL dating in the luminescence laboratory at the Research School of Earth Sciences (Fitzsimmons et al. 2007a).

Barrows, T.T., Juggins, S., De Deckker, P., Calvo, E., Pelejero, C. (2007) Long-term sea-surface temperature and climate change in the Australian-New Zealand region. *Paleoceanography* **22**: PA2215.

Fitzsimmons, K.E., Rhodes, E.J., Magee, J.W., Barrows, T.T. (2007a) The timing of linear dune activity in the Strzelecki and Tirari Deserts, Australia. *Quaternary Science Reviews* **26**: 2598-2616.

Fitzsimmons, K.E., Bowler, J.M., Rhodes, E.J., Magee, J.W. (2007b) Relationships between desert dunes during the late Quaternary in the Lake Frome region, Strzelecki Desert, Australia. *Journal of Quaternary Science* **22**: 549-558.

Tsukamoto, S., Duller, G.A.T., Wintle, A.G. (2008) Characteristics of thermally transferred optically stimulated luminescence (TT-OSL) in quartz and its potential for dating sediments. *Radiation Measurements* **43**: 1204-1218.

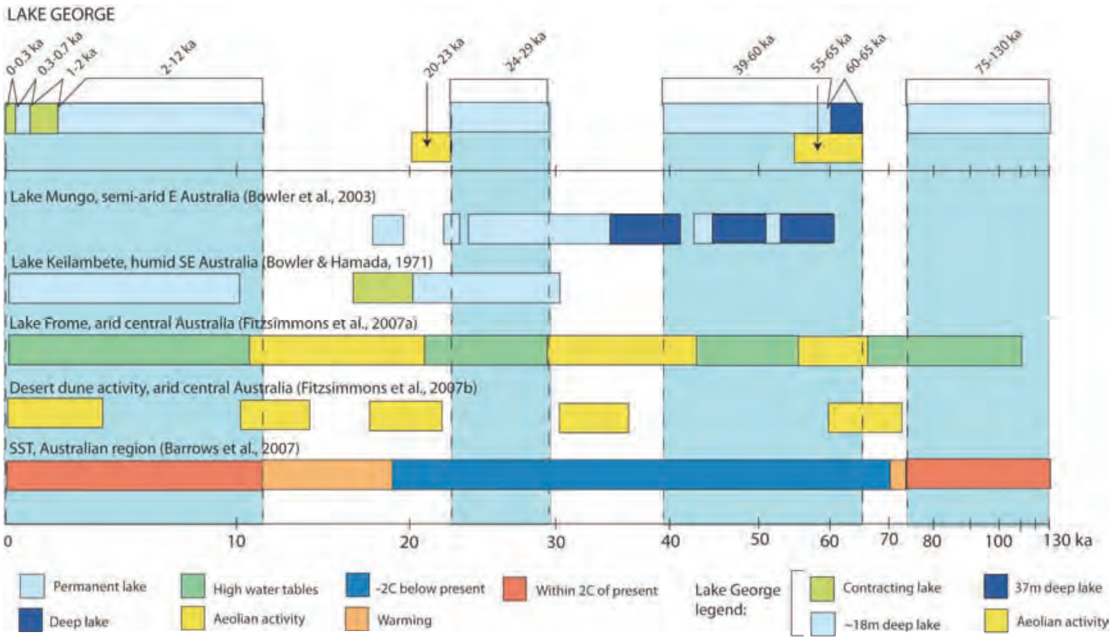

Figure 1. *Summary of late Quaternary lake level change at Lake George, southeastern Australia, and comparisons with palaeoenvironmental records from Lakes Mungo (semi-arid) and Keilambete (humid), groundwater levels and dune activity at Lake Frome (arid), desert dune activity (arid zone) and sea-surface temperatures in the Australian-New Zealand region.*

Speleothem carbon-isotope response to an explosive volcanic eruption ~12 ka ago near Liang Bua, Flores, Indonesia

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[2] *Centre for Microscopy and Microanalysis, The University of Queensland, Brisbane, Qld. 4072, Australia*
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Knowing what caused the surprisingly recent extinction of the dwarf hominin *Homo floresiensis* ("the Hobbit") ~18-12 ka (thousand years ago) on the island of Flores in eastern Indonesia is an intriguing question of great international interest. At present, we do not know if predation by modern humans or severe climate change pushed the Hobbit beyond its adaptive capability. However, a prominent volcanic ash layer overlies remains of the Hobbit recovered from Late Pleistocene sediments in Liang Bua cave, suggesting that an explosive volcanic eruption could have altered the local ecosystem at ~12 ka, and played a role in the Hobbit's demise (Morwood et al., 2004).

Interestingly, out of the ~850 volcanic sulfate signals recorded by the GISP2 (Greenland) ice core over the past 100 kyr, including the Toba super-eruption ~73 ka (Zielinski et al., 1997), the largest and most abundant volcanic signals occur between 17 ka and 6 ka, when the Hobbit became extinct (Fig. 1a). It is thought that crustal stresses associated with post-glacial sea-level rise may have significantly increased explosive volcanic activity in island arc systems, such as Indonesia, during this period.

In 2006, our ARC *Discovery* grant team (Gagan et al., 2006) collected several speleothems (cave calcite deposits) from Liang Luar cave (located ~1 km from Liang Bua) that show clear dark laminae at ~12 ka, which may be indicative of volcanic ash. High-resolution analysis of carbon-isotope ratios ($^{13}C/^{12}C$) in the speleothem calcite shows a sharp increase in ^{13}C at ~12 ka, suggesting that vegetation cover may have been substantially reduced for ~300 years (Fig. 1b).

On tropical islands, like Flores, isotopically light carbon derived from oxidation of abundant soil organic matter dominates speleothem $^{13}C/^{12}C$ because forested tropical soils have CO_2 partial pressures 1-2 orders of magnitude greater than that of the overlying atmosphere (Kessler and Harvey, 1999). Therefore, an abrupt reduction in vegetation cover, soil productivity, and soil CO_2 production following local deposition of volcanic ash would reduce the supply of isotopically light carbon to the cave drip-water, thus raising speleothem $^{13}C/^{12}C$.

Explosive island arc volcanic eruptions are rich in sulphur, so our follow-up approach will be to measure S concentrations in speleothem calcite (using SHRIMPII at RSES) as an indicator of sulfate rain-out. It is also possible that fresh volcanic ash above caves could be detected by LA-ICP-MS measurements of leachable metals (e.g. Ni, Cu, Zn, Mo, Ti, Co, Rb) and rare earth elements in speleothem calcite. Precise U-series dating of these multi-proxy records will shed light on the timing of large volcanic eruptions and the innate ability of humans to adapt to natural catastrophes and environmental change.

Gagan MK, Zhao J-x, Drysdale RN, Hantoro WS, Schmidt GA, ARC *Discovery* Grant DP0663274 (2006-2008): Monsoon extremes, environmental shifts, and catastrophic volcanic eruptions: Quantifying impacts on the human history of southern Australasia.

Kessler TJ, Harvey CF (1999) The global flux of carbon dioxide into groundwater. *Geophysical Research Letters* **28**: 279-282.

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Zielinski GA, Mayewski PA, Meeker LD, Whitlow S, Twickler MS (1996) A 110,000-yr record of explosive volcanism from the GISP2 (Greenland) ice core. *Quaternary Research* **45**: 109-118.

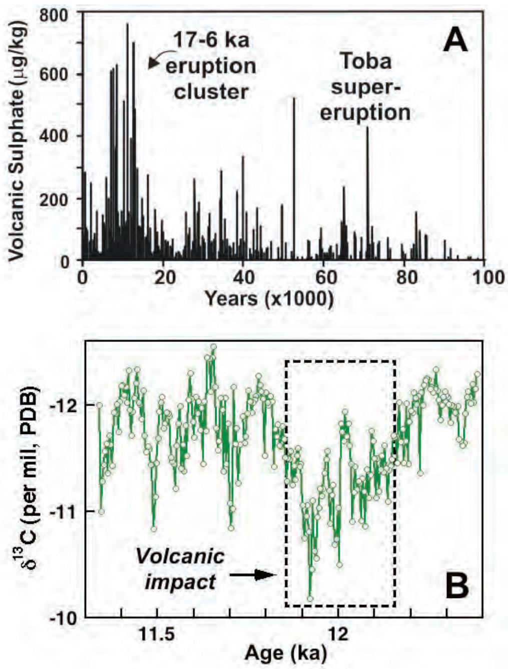

Figure 1. Volcanic impacts. *(A) 100-kyr volcanic sulphate record from the GISP2 (Greenland) ice core (after Zielinski et al., 1997). The Toba super-eruption (~73 ka) and abundant volcanic signals between 17 ka and 6 ka coincide with key turning points in human history.* ***(B)*** *4-year resolution speleothem $^{13}C/^{12}C$ record from Liang Luar cave, Flores, showing potential decrease in vegetation cover lasting ~300 years (dashed box) at the time of ~12 ka volcanic eruption, and disappearance of the Hobbit.*

The relevance of parametric U-uptake models in ESR age calculations

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Ever since the inception of ESR dating of tooth enamel, it was clear that the unknown uranium uptake history has to be addressed in dose rate calculations. Various parametric models have been proposed for the reconstruction of U-uptake in dental tissues, notably early (EU), linear (LU) and very recent (RU) uptake. The EU model has some physical meaning, it presents the closed system and provides the minimum age. The RU model is physically less meaningful, but provides the maximum age. The main virtue of these parametric models lies mainly in their reasonable simple computability. Nevertheless, many publications have either favoured a particular U-uptake model, for the convenience of being able to explain a dating result, or claimed that the correct age of the sample lied somewhere between the EU and LU results. However, without any knowledge of the U-uptake history, it is only safe to assume that the correct age of a sample lies somewhere between the EU and RU calculations. Depending on the contribution of the U in the dental tissues to the total dose rate, this difference ranges between negligible and utterly enormous.

U uptake can be modelled by combining ESR and U-series data. Although the explicit U-uptake in nature may occur in multiple phases, two models can bracket virtually all possible scenarios, as long as no U-leaching occurs. Grün et al. (1988) used a smooth diffusion function: $U(t) = U_m (t/T)^{p+1}$, where U(t) is the uranium concentration at the time t, U_m the measured, present day U-concentration, T the age of the sample and p the uptake parameter. This system provides minimum age estimates for given ESR/U-series data sets. A delta function, where U_m is accumulated instantly at the apparent closed system U-series age of the dental tissue, provides the maximum age. For younger samples, the differences between these two models are relatively small, which means that the explicit U-uptake history has little effect on the age calculation. For older samples (> 700 ka), with larger differences between the closed system U-series and ESR age estimates, the differences may be large (by more than a factor of 2).

To get more general insights into the general behaviour of U-uptake, published p-values were compiled and separated into two groups, from cave sites (and rock shelters) and open air sites. For the cave sites, most of the p-values of the dentine fall between about -1 and 1, but still a significant number give higher values (Figure 1A). All enamel values fall within -1 and 0.5 (Figure 1B). Note, however, that many of the teeth with high p-values in the dentine had not their enamel analysed (partly because of low U-concentrations). Most of the measured p-values in cement, p(CE), indicate a more rapid accumulation in cement than dentine (Figure 1C). This is expected, as the cement is located on the outside of the tooth. The relationship between p(EN) and p(DE) is random, most values lying in a band of 0.5 around the 1:1 line. The results on the open air sites are markedly different (Figure 2). Most p(DE) and p(EN) lie outside the -1 to 0 range (Figures 2A and B). A large number of results show p-values of > 2. There is no trend whether enamel or dentine experienced a faster uptake (Figure 2C).

The p(CE) values are reasonably close to p(DE). For open air sites it is impossible to define a range of p-values that could be used for general approximations. It is even not possible to claim that the correct uptake is somewhere between EU and RU, because there is a significant number of sites where model violations have been observed (the closed system U-series age is older than the corresponding ESR age) or U-leaching (with $^{230}Th/^{234}U$ ratios lying outside the isotope evolution diagram). In the former case it is not unequivocally clear whether U-leaching has occurred of whether the ESR results underestimate the correct age because of problems with the distributions of the orientated and non-orientated CO_2^- radicals (Grün et al. 2008a), thermal transfer processes (Joannes-Boyau and Grün, submitted), reworking of samples, or the usual vagrancies in dose rate estimation. Leaching has been observed in a range of sites (Grün et al. 2008b, Grün, unpublished data).

The differences between cave and open air sites can probably be explained through the different sedimentological histories of the sites. Caves are systematically excavated because archaeologists know that ancient humans preferred to live in rock shelters and caves. Until excavated, the sedimentary stack is usually undisturbed. In contrast, many open air sites are discovered because erosion, starting at some time in the past, had provided an indication that a site was present. Erosion causes changes in the hydrological environment, e.g., by re-activation of drainage and changing the ground water table. This is accompanied with renewed U-mobilisation. Not surprisingly, many U-series age estimates of open air sites seem to reflect this change in the hydrology rather than the age of the sample.

To conclude, the statement that the correct ESR age of a sample probably lies somewhere between the EU and LU uptake age calculations is incorrect. It is not even true that the correct age lies always somewhere between the EU and RU model calculations, because there have been occasions of model violations and U-leaching. Any ESR dating study on teeth with substantial U concentrations in the tissues requires U-series age estimates. Anything else is simply a tenesmic approach to dating.

Grün, R., Aubert, M., Joannes-Boyau, R., Moncel, M.H. (2008a) High resolution analysis of uranium and thorium concentrations as well as U-series isotope distributions in a Neanderthal tooth from Payre using laser ablation ICP-MS. *Geochimica Cosmochimica Acta* 72: 5278-5290.

Grün, R., Joannes-Boyau, R., Stringer, C. (2008b) Two types of CO_2^- radicals threaten the fundamentals of ESR dating of tooth enamel. *Quaternary Geochronology* 3: 150-172.

Grün, R., Schwarcz, H.P. and Chadam, J.M. (1988) ESR dating of tooth enamel: Coupled correction for U-uptake and U-series disequilibrium. *Nuclear Tracks and Radiation Measurements* 14: 237-241.

Joannes-Boyau, R., Grün, R. (submitted). Thermal behaviour of orientated and non-orientated CO_2^- radicals in tooth enamel. *Radiation Measurements.*

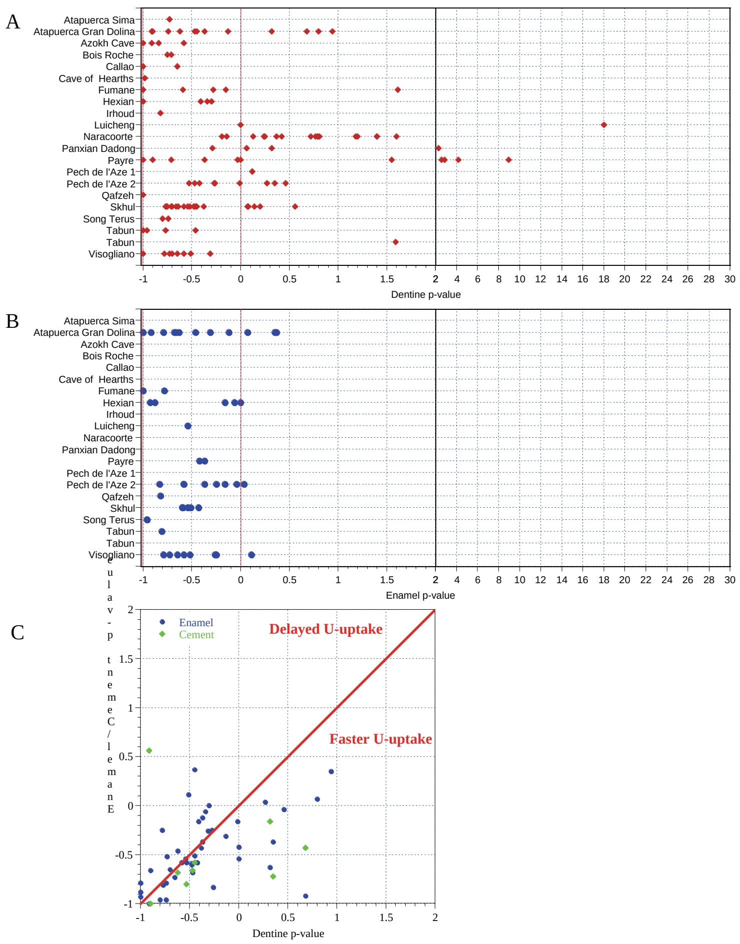

Figure 1.
Compilation of p-values from cave sites
A: p-values from dentine
B: p-values from enamel
C: Relationship between p(EN), p(CE) and p(DE).

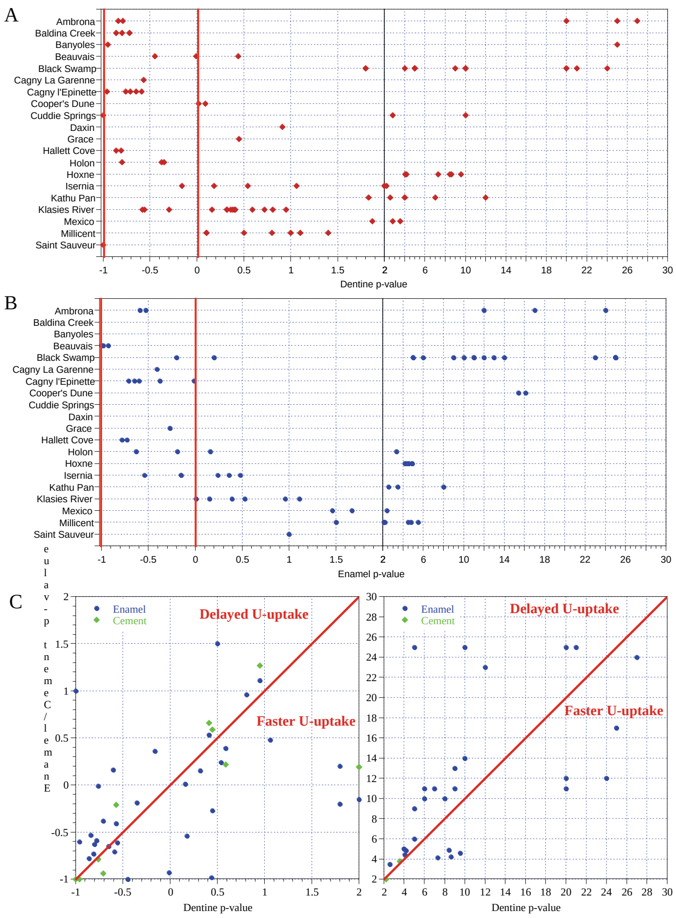

Figure 2.
Compilation of p-values from open air sites
A: p-values from dentine
B: p-values from enamel
C: Relationship between p(EN), p(CE) and p(DE).

Warming and Acidifying Ocean and Coral growth

Jung Ok Kang[1] and Malcolm T. McCulloch[1]

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Coral reefs generally are developed within relatively narrow area when environmental controls on the growth of corals including seawater temperature, light, and aragonite saturation states, water motion, and water quality are satisfied. Increasing atmospheric carbon dioxide concentration has been affected on coral reefs mainly through two kinds of mechanisms. Firstly, global warming or climate change has caused rising seawater temperature and extraordinally warm temperature cause corals to bleach. This process has already had a serious impact on the world's coral reefs, with almost 30% of corals having disappeared since the beginning of the 1980s by bleaching events (Hoegh-Guldberg, 2005). Besides, the rise in the concentration of carbon dioxide in the atmosphere has an influence on coral reefs since a decrease of ocean acidity by increasing atmospheric carbon dioxide lower the aragonite saturation states of seawater, declining available carbonate ions of seawater to calcification.

Several experimental and modelling studies were performed under conditions expected in the 21st century and the results show that acidifying ocean will compromise coral calcification. Thermodynamic calculation shows that a doubling of carbon dioxide in seawater will be a decline in carbonate ion concentration of 25-35% to the preindustrial concentration (Landon et al., 2000). Moreover, the worst cast of modelling study argues that total preindustrial to 2100 calcification decrease could be as high as 17% to 35% depending on the regions (Kleypas et al., 1999). The shapes of the calcification versus aragonite saturation curve which are from laboratory studies and crucial in predicting future changes in coral reef, however, still have many uncertainties because the data is scare and is constrained with a first approximation of the general response of coral reefs. In addition, time of exposure to manipulating conditions is too short to apply to the real world and the synergistic interaction of elevated temperature and lowering aragonite saturation state is unknown.

Therefore, my project aims to understand how anthropogenic climate change and increasing ocean acidity affect coral reefs in real and various paleo-evironmental proxies will be used to provide the evidences of the changes in coral-reef pH representing ocean acidity and sea surface temperature indicating global warming and the responses on coral calcification rate. For the first place, the massive corals of genus *Porites* were collected from Southern Great Barrier Reef in October of this yesr (Figure 1). Since they are long lived, distributed widely throughout the Indo-Pacific Ocean, from inshore to offshore waters, their skeletal records are useful as a tool for detecting long-term changes in environmental conditions in ocean surface waters. At the same time, the determination of calcification rate for *Porites* corals collected in 2006 from Pompey complex is in progress.

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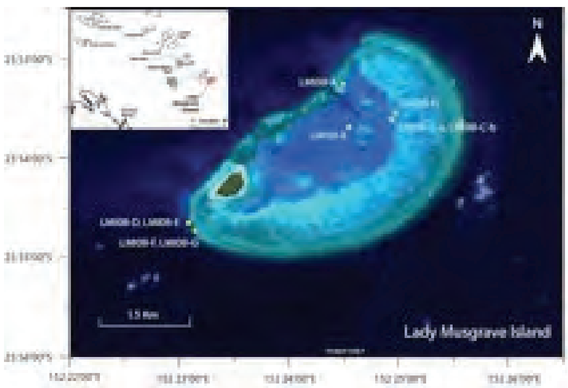
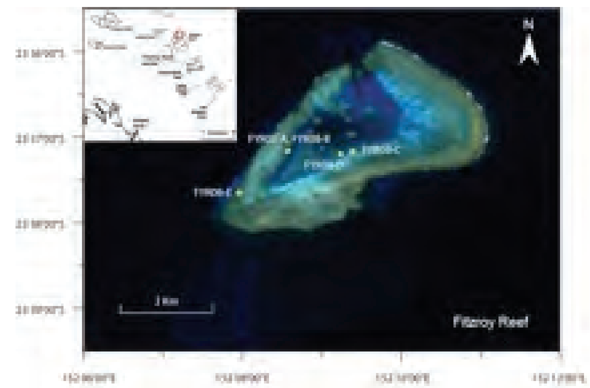
Kleypas JA, Buddemeier RW, Archer D, Gattuso J-P, Opdyke BN (1999) Geochemical consequence of increased atmospheric carbon dioxide on coral reefs. *Science* **284**: 118-120

Langdon C, Takahasi T, Sweene C, Chipma D, Goddard J, Marubini F, Arceve H, Barnett H, Atkinson MJ (2000) Effect of calcium carbonate saturation state on calcification rate of an experimental coral reef. *Global Biogeochemical Cycles* **14**: 639-654





Landscape evolution and palaeoenvironment reconstruction of the Lake Mulurulu Lunette, Willandra Lakes World Heritage Area, NSW

Tegan E Kelly, Rainer Grün, Ian Moffat, Maxime Aubert, Tim Barrows.

Research School of Earth Sciences, Australian National University, Canberra, ACT 0200, Australia

The Willandra Lakes are a dry lake system consisting of a number of ancient lakes in the western region of the Murray basin. The area has significant scientific value, providing detailed palaeoenvironmental and palaeoclimatic records of arid, ice-age Australia as well as a rich and unique archaeological record. Lake Mungo, resting place of Australia's oldest dated aboriginal remains, has been a popular lake for study, while Lake Mulurulu, the northern-most lake in the system, is relatively understudied, despite its abounding potential. The aim of the current study is to combine isotope palaeoecology, geochronology, stratigraphy and sedimentological techniques to study the Mulurulu Lake lunette, thus creating a detailed geomorphological and palaeoenvironmental history of the lake, putting the aboriginal occupation of the area into an environmental context.

Techniques being utilised in the study include stable isotope analyses of wombat teeth, mollusk shells, emu egg shells and fish otoliths to provide palaeoenvironmental records of the area (e.g. Fig 1). This information is put into a geochronological context through ESR dating of wombat teeth, radiocarbon dating of mollusk shells and otoliths and AAR dating of egg shells. Detailed stratigraphic and sedimentological analyses (e.g Fig 2) further provide information about the history of the lake, and are also put into a geochronological context, through OSL dating of sediments.

Research questions being addressed include the history of the current deflation regime at the site, past seasonality and wetting-drying cycles in the region, climate change, timing and reasons for local species extinctions and how these factors relate to the human occupation of the area. Additionally, by utilising independent methods of palaeoenvironment reconstruction (i.e. stratigraphy and geochemistry) and geochronology (i.e. ESR and OSL), the competency and reliability of the techniques are tested.

The study is backed by an ARC-Linkage grant and is being conducted in collaboration with a number of other researchers from ANU, Latrobe, Bond and UQ universities as well as the local aboriginal groups (3TTG inc.) from the area. Associated work is being conducted on other lake lunettes in the region and the overall project integrates geological, geochronological, archaeological, palaeontological and palaeoenvironmental research at the Willandra Lakes World Heritage Area, providing a thorough analysis and understanding of one of Australia's most significant and unique areas of cultural and environmental history.

Figure 1. a) An otolith (fish ear bone) in cross-section, showing growth lines. b) ^{18}O isotope ratios along a transect of an otolith, measured using the SHRIMP II. The increasing values indicate increasing evaporation and hence aridity, while the fish was growing. c) The transect that these data represent. (Courtesy of Maxime Aubert)

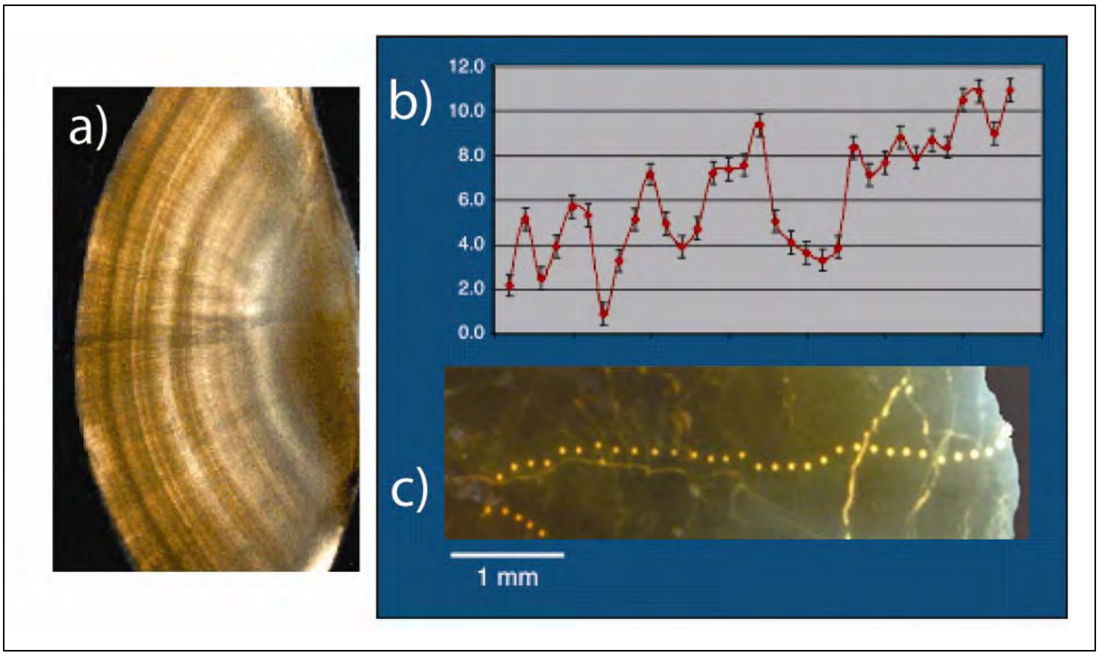
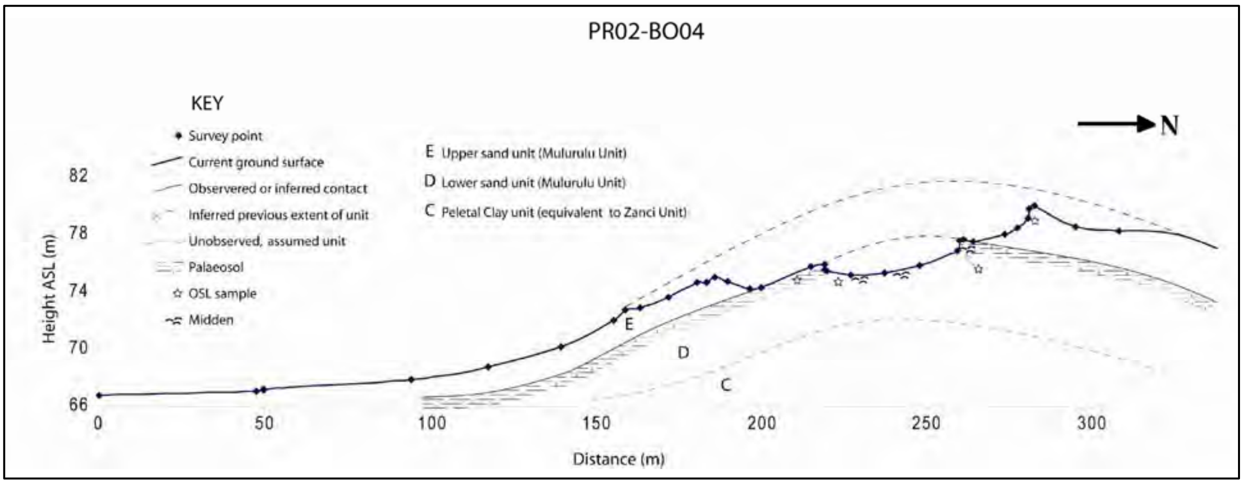


Figure 2. An example profile of the Mulurulu lunette. Approx. 5x vertical exaggeration.



Modelling climate and water isotope variability in southern Indonesia with GISS ModelE-R

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Water isotope records collectively provide some of the most extensive proxy evidence for past climate. However, a known or assumed relationship between water isotopes and climate is required for the interpretation of these records. Climate variability on annual to orbital timescales impacts the hydrologic cycle and influences water isotope distribution, with varying impacts on individual climate variables and water isotopes. As such, the relationship between water isotopes and climate may not remain constant through time. The goal of this study is to examine the relationship between climate and water isotope variability in southern Indonesia to facilitate understanding of late Quaternary changes in monsoon rainfall recorded by oxygen isotopes in speleothems.

We assess the relationship between water isotopes and climate and infer the primary mechanisms controlling water isotope variability on various time scales using multiple simulations of current and past climate (Holocene through glacial). The GISS ModelE-R, a fully coupled atmosphere-ocean GCM equipped with water isotope as well as other tracers, is ideal for tracing the source of water isotope variability. We investigate the mechanisms controlling water isotope variability through the addition of isotopic tracers that allow us to explicitly track water vapour and precipitation sources to a region.

We find that the relationship between water isotopes and climatic variables is different at various timescales and that this relationship can change during abrupt climate excursions. Model results support the interpretation of isotopic variability in tropical speleothem records and allow a greater understanding of late Quaternary changes in precipitation. For example, model simulations of precipitation variability in southern Indonesia show a significant northward shift in precipitation source region during the middle Holocene (Figure 1). This change in source area of precipitation likely results from a southward shift in the position of the Intertropical Convergence Zone through the Holocene (Wanner et al., 2008), which would have altered the isotopic composition of rainfall recorded in speleothems in southern Indonesia.

Ultimately, model outputs indicate that the isotopic composition of rainfall delivered to a speleothem site is dependent on numerous dynamic variables, including rainfall amount, precipitation source region and transport trajectory from source to rainout. Model simulations of water isotope variability greatly assist in interpreting oxygen isotopes variability within speleothem records of the palaeomonsoon.

Wanner, H., Beer, J., Bütikofer, J., Crowley, T. J., Cubasch, U., Flückiger, J., Goosse, H., Grosjean, M., Joos, F., Kaplan, J. O., Küttel, M., Müller, S. A., Prentice, I. C., Solomina, O., Stocker, T. F., Tarasov, P., Wagner, M. & Widmann, M. (2008) Mid- to Late Holocene climate change: an overview. *Quaternary Science Reviews,* 27, 1791-1828.

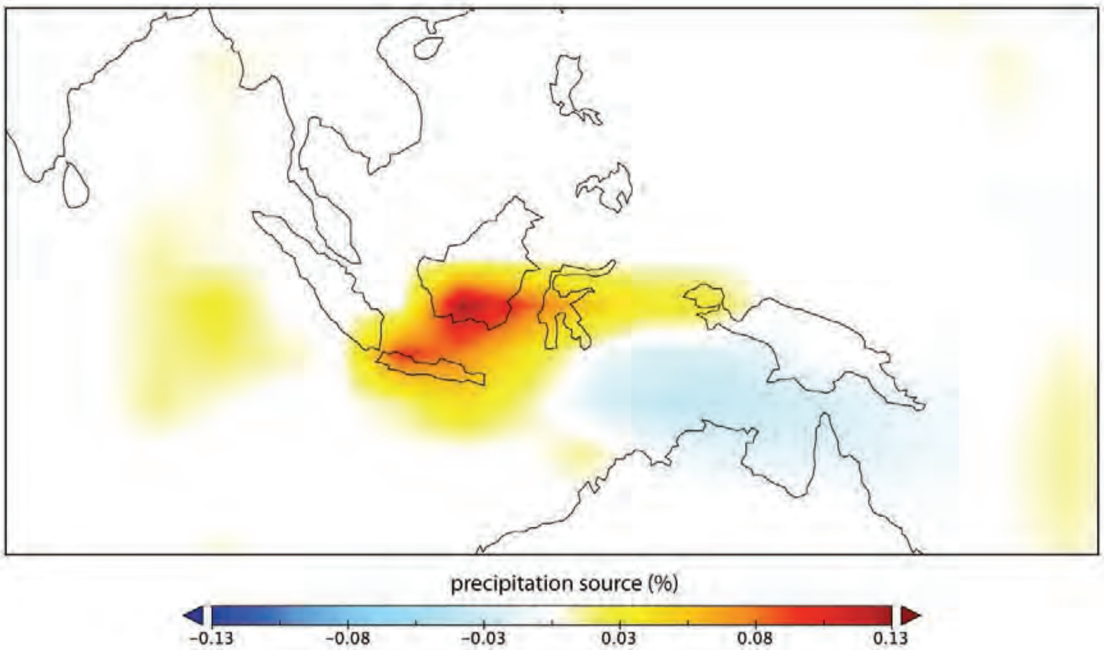

Figure 1. Difference in precipitation source region to southern Indonesia between 6 kyr and modern GISS ModelE-R simulations.

Ocean Acidification in the Great Barrier Reef

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Over the past century atmospheric CO_2 has risen by over 30%, from pre-industrial values of ~280 ppm to present-day levels of over 380 ppm, and is continuing to rise at an unprecedented rate of ~2 ppm per year. If unabated, this rate of increase will result in a doubling of CO_2 by sometime later this century. Unlike the atmosphere where CO_2 causes warming through its strong physical interaction with infrared radiation, in the oceans it is a highly reactive species causing a major perturbation to the chemistry of surface waters. This perturbation arises from dissolution of CO_2 in surface waters resulting in an increase in the concentration of carbonic acid, and a reduction in seawater *p*H or what has become known as 'ocean acidification'. This in turn is leading to an overall decrease in the carbonate ion concentration, the key component controlling calcification in marine organisms.

Ocean acidification is thus of major concern not only because it will ultimately lead to dissolution of calcium carbonate organisms as aragonite undersaturation is approached, but also because the rate of coral calcification appears to be directly proportional to the degree of carbonate ion concentration, even in oversaturated conditions. Thus coral reefs will be at risk as calcification decreases while bio-erosion and chemical dissolution increases. Unfortunately, very little is known about the regional variability of ocean acidification on decadal to centennial time scales, especially since the industrial era. Our current knowledge of ocean acidification is mainly dependent on model calculations and unlike other key climatic indices, such as temperature and salinity, seawater pH has seldom been recorded in marine observations due to the non-routine nature of the measurements. Accordingly, long-term continuous seawater pH records are scarce, with records of several decades now only becoming available from the off-shore sites of Hawaii and Bermuda. This lack of knowledge hinders attempts to properly evaluate not only the current status of ocean acidification, but importantly future trends and likely impacts on calcification of marine biota.

Boron isotope systematics in marine carbonate provide an alternative solution acting as a potential long-term proxy for seawater pH, due to an isotopic fractionation between the boric acid and borate ion species, with their relative proportions being controlled by seawater pH. However in order to utilize this system, high precision measurements of B isotopic compositions are needed to determine the relatively small shifts in seawater pH that are predicted since the commencement of the industrial era. We have pioneered this approach using B measurements in the carbonate skeleton of long-lived (~200 year) *Porites* corals from the Great Barrier Reef.

Our initial results indicate that the long-term pre-industrial variation of seawater pH in this region is partially related to the decadal-interdecadal variability of atmospheric and oceanic anomalies in the Pacific. The 1998 oscillation is co-incident with a major coral bleaching event indicating the sensitivity of skeletal _^{11}B compositions to loss of zooxanthellate symbionts. Importantly, from the 1940's to the present-day, there is a general overall trend of ocean acidification with pH decreasing by about 0.2 to 0.3 units. Correlations of _^{11}B with _^{13}C during this interval indicate that the increasing trend towards ocean acidification over the past 60 years in this region is the result of enhanced dissolution of CO_2 in surface waters from fossil fuel burning at a significantly larger than anticipated from model calculations.

This suggests that the increased levels of anthropogenic CO_2 in atmosphere has already caused a marked trend towards acidification in the coral reefs during the past decades. Observations of surprisingly large decreases in pH across important carbonate producing regions, such as the Great Barrier Reef of Australia, raise serious concerns about the impact that Greenhouse gas emissions may already be having on coral calcification in the Great Barrier Reef.

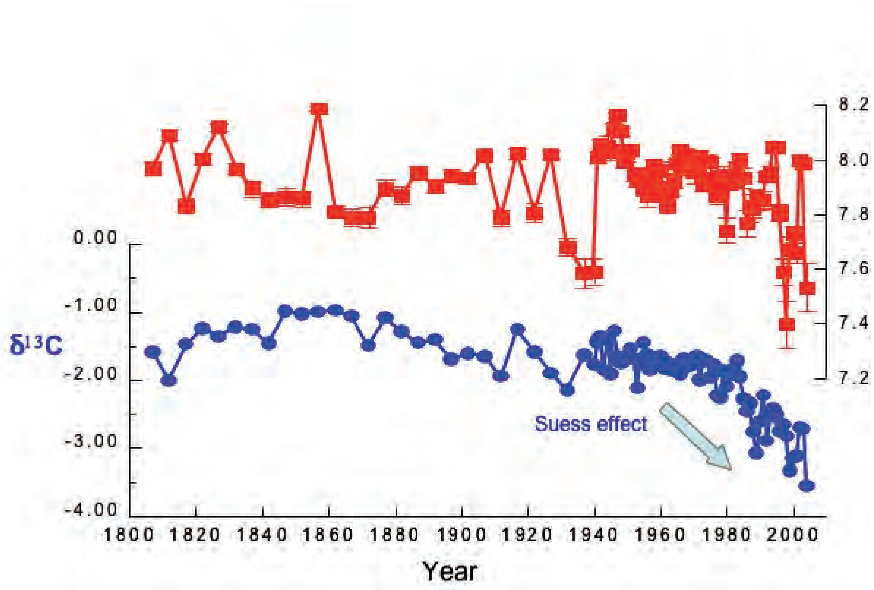

Figure 1.

Weathering history of rock art on Burrup Peninsula, Western Australia

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[3] *School of Earth & Environmental Sciences, University of Wollongong, NSW 2522, Australia*

In July 2007 the renowned Aboriginal rock art of the Dampier Archipelago (including Burrup Peninsula) in Western Australia was included in the National Heritage List. Some hundreds of thousands of rock engravings (petroglyphs) were made on weathered rock surfaces by pounding, pecking, abrading and scoring using rock tools. It is claimed that the Dampier Archipelago contains the largest known rock art gallery in the world. Industrial development at the nearby port of Dampier has stimulated research to underpin conservation strategies for the rock art.

The weathered, outer layers of rocks (dominantly granophyre) on the Burrup Peninsula consist of a thin, discontinuous surface varnish (up to ~200 microns thick) and underlying weathered zone or rind (up to ~1 cm thick), mainly composed of hematite, kaolinite, quartz, K-feldspar and phosphates. These are the typical insoluble residues from rock weathering and they are at the surface simply because they are very slow to dissolve in rain water. The dark reddish- to blackish-brown colour of the rock varnish contrasts with the pale brown colour of the underlying weathering rind. The pale weathering rind is exposed in the majority of petroglyphs, providing a distinctive colour contrast with surrounding dark coloured varnish.

Laser ablation-ICPMS depth profiling of the rock varnish indicates geochemical microlamination that may be related to changing long-term environments as described by Liu & Broecker (2008) in their study of rock varnish microlamination in the western USA. Together with our field observations, the geochemistry of the varnish is consistent with an origin from direct chemical precipitation of dissolved elements in rain water, rather than from leaching of the underlying rock or from slow diagenesis of dust particles deposited on the rock surfaces – see discussion by Thiagarajan & Lee (2004).

From our field observations, we identify three modes of physical rock breakdown each of which impinges on the long term stability of rock surfaces and associated petroglyphs:

1. Flaking of thin (mm-scale) surface layers associated with the development of a weathering rind and/or rock varnish.
2. Fracturing along major rock joints (cm- to m-scale), resulting in block fall from steep slopes and cliffs. Note, however, that in between the very infrequent block fall events, erosion will likely be dominated by mm-scale flaking.
3. Fire-induced fracturing around the margins of rock outcrops caused during burning of adjacent vegetation (Dragovitch 1994).

Overall, our results indicate that the weathered granophyre rock surfaces containing petroglyphs, on Burrup Peninsula, are extremely resistant to erosion over thousands of years. Major contributing factors include low rainfall, resistant rock and the presence of stable secondary minerals on rock surfaces. We are currently undertaking a program of cosmogenic nuclide measurements to quantify rates of erosion on rock surfaces associated with petroglyphs.

Dragovich D (1994) Fire, climate, and the persistence of desert varnish near Dampier, Western Australia. *Palaeogeography, Palaeoclimatology, Palaeoecology* **111**: 279-288.

Liu T, Broecker WS (2008) Rock varnish evidence for latest Pleistocene millenial-scale wet events in the drylands of western United States. *Geology* **36**: 403-406.

Thiagarajan N, Lee C-TA (2004) Trace-element evidence for the origin of desert varnish by direct aqueous atmospheric deposition. *Earth and Planetary Science Letters* **224**: 131-141.

Figure 1.

Silicon isotopic composition of marine sponges: Understanding isotopic variations using a mass balance approach

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In this study, relationships were investigated between coupled sponge and seawater samples for Si isotope fractionation compared with equivalent Si concentrations from the water column. The Southern Ocean was chosen for field work as it is the only oceanic area where diatom productivity is dominant and it is a useful natural laboratory for oceanic Si research with concentration gradients stratified by latitude and depth (higher concentrations at lower latitudes and depths). Accordingly, siliceous sponges from both the Hexactinellid and Demosponge classes were sampled at a variety of latitudes and depths. Results were compared to a new model that assumes variable Si isotope fractionation dependent on the Si concentration of seawater. The new model offers a new perspective on what controls biological fractionation in biogenic opal and in turn, will yield a novel interpretation of the paleo-oceanic distribution of Si.

Figure 1. *Iceberg near Antarctica in the Southern Ocean.*

Calibrating the speleothem O isotope signal to rainfall

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Oxygen isotopes ($\delta^{18}O$) are the most commonly used paleoclimate proxies in speleothems (see McDermott, 2004) and are being used in current research by Dr Treble to reconstruct records of natural rainfall variability for southwest Western Australia. This region has suffered a significant decrease in rainfall since the 1970s and longer records are needed to understand why. The relationship between speleothem $\delta^{18}O$ and rainfall was reported in a previous publication (Treble et al., 2005) and was further examined in detail by Fischer and Treble (2008). The findings of this latter study challenge the common expectation with climate proxies is that we can apply short-interval calibrations to interpret trends in proxy data back in time. These findings have wide application to the interpretation of speleothem $\delta^{18}O$ records in general, and are summarised here.

Two datasets were originally used to examine the relationship between speleothem $\delta^{18}O$ and rainfall. The first are measurements of $\delta^{18}O$ in daily rainfall events for 2001 which show that larger rainfall events contain less of the heavier isotope, ^{18}O. The second are measurements of speleothem $\delta^{18}O$ between 1911-1992 which can be closely compared with changes in the instrumental period (Figure 1, upper panel; Treble et al., 2005). The speleothem record showed that $\delta^{18}O$ rose after 1970, consistent with the decrease in the frequency of large rainfall events. But importantly, the speleothem record showed that this simple inverse relationship between rainfall amount and $\delta^{18}O$ did not hold, evidenced by the higher $\delta^{18}O$ values between 1930-55 when there was no decrease in rainfall.

This key finding led to the publication, Fischer and Treble (2008), where the simple rainfall amount-$\delta^{18}O$ regression model was improved to include inter-annual climate variance. The new model was modulated by dominant modes of inter-annual climate variability or climate indices (calculated as the principal components of sea level pressure over the study period). The new model produced a positive shift in $\delta^{18}O$, similar to that in the speleothem record between 1930-55. This suggests that the dominant modes of interannual variability can cause shifts in vapour source regions (or other effects), which can affect $\delta^{18}O$ independent of amount-type effects. In southwest Australia, it appears that the interannual mode most responsible for isotopic changes related to vapour source, is Zonal Wave 1 (ZW1). An EOF-based reconstruction of ZW1 over the last century suggests that a negative ZW1 state from 1930-55 favoured the advection of ^{18}O-enriched moisture from low latitudes, while a positive ZW1 state post-1970 resulted in more ^{18}O-depleted moisture advected from the sub-polar region (Figure 1, lower panel).

As a result of the study summarised here, we now have an improved regression model for $\delta^{18}O$ rainfall in southwest Australia that replicates key patterns at daily to interdecadal timescales. This is a statistical forward model and thus it can be used to compare paleoclimate simulations to proxy data. The inversion of the model will require a multi-proxy approach (e.g., isotopes and rainfall amount-sensitive trace elements), because the new model relies on two predictors ($d^{18}O$ depends on both precipitation amount and vapour source). In general terms, this study illustrates the importance of understanding the multiple factors which influence speleothem $\delta^{18}O$ and demonstrate for the first time, the effect of interannual climate modes on rainfall $\delta^{18}O$.

Fischer, M.J., Treble, P.C. (2008) Calibrating climate-delta O-18 regression models for the interpretation of high-resolution speleothem delta O-18 time series. *Journal Of Geophysical Research-Atmospheres* **113(D17)**: D17103.

McDermott, F. (2004) Palaeo-climate reconstruction from stable isotope variations in speleothems: a review. *Quaternary Science Reviews* **23(7-8)**: 901-918.

Treble, P.C., Chappell, J., Gagan, M.K., McKeegan, K.D., Harrison, T.M. (2005) In situ measurement of seasonal delta O-18 variations and analysis of isotopic trends in a modem speleothem from southwest Australia. *Earth And Planetary Science Letters* **233(1-2)**: 17-32.

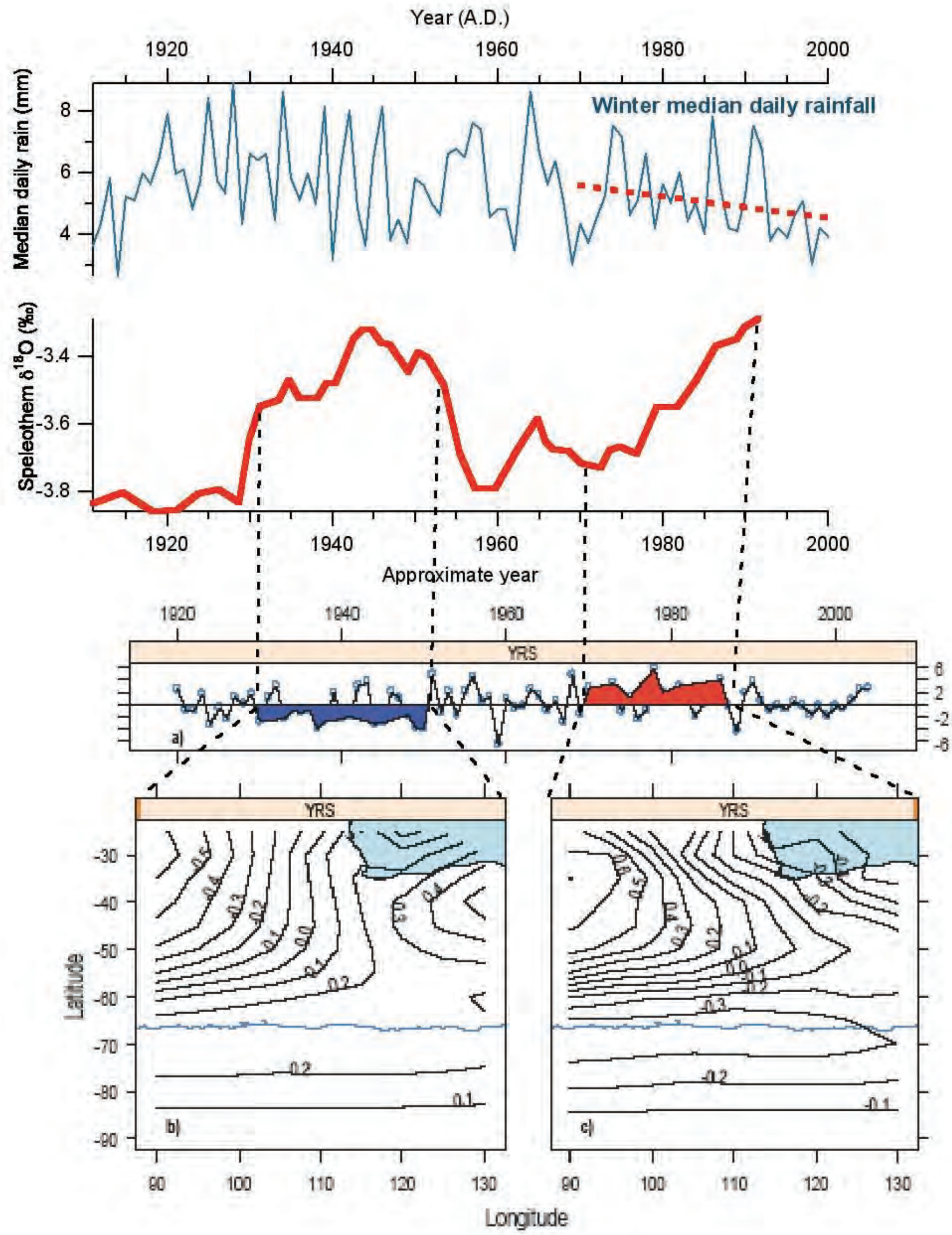

Figure 1.

Did Cooling Oceans Trigger Ordovician Biodiversification? Evidence from Conodont Thermometry

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The Ordovician Period, long considered a Supergreenhouse state, saw one of the greatest radiations of life in Earth's history. Previous temperature estimates of up to ~70°C have spawned controversial speculation that the oxygen isotopic composition of seawater must have evolved over geological time. We present a very different global climate record determined by *in situ* ion microprobe (SHRIMP) oxygen isotope analyses of Early Ordovician–Silurian conodonts. This record shows a steady cooling trend through the Early Ordovician reaching modern equatorial temperatures that were sustained throughout the Middle and Late Ordovician. This favourable climate regime not only implies that the oxygen isotopic composition of Ordovician seawater was similar to today, but that climate played an overarching role in promoting the unprecedented increases in biodiversity that characterized this period.

Published in Science, July 2008:

Trotter, J., Williams, I., Barnes, C., Lecuyer, C., Nicoll, R. (2008) Did cooling oceans trigger Ordovician Biodiversification? Evidence from conodont thermometry, Science, Vol 321, 25 July, 550-554.

Figure 1. *Portion of a polished epoxy mount showing ion microprobe pits, excavated during in situ oxygen analysis using the SHRIMP II, in conodonts and a Durango apatite grain (centre).*

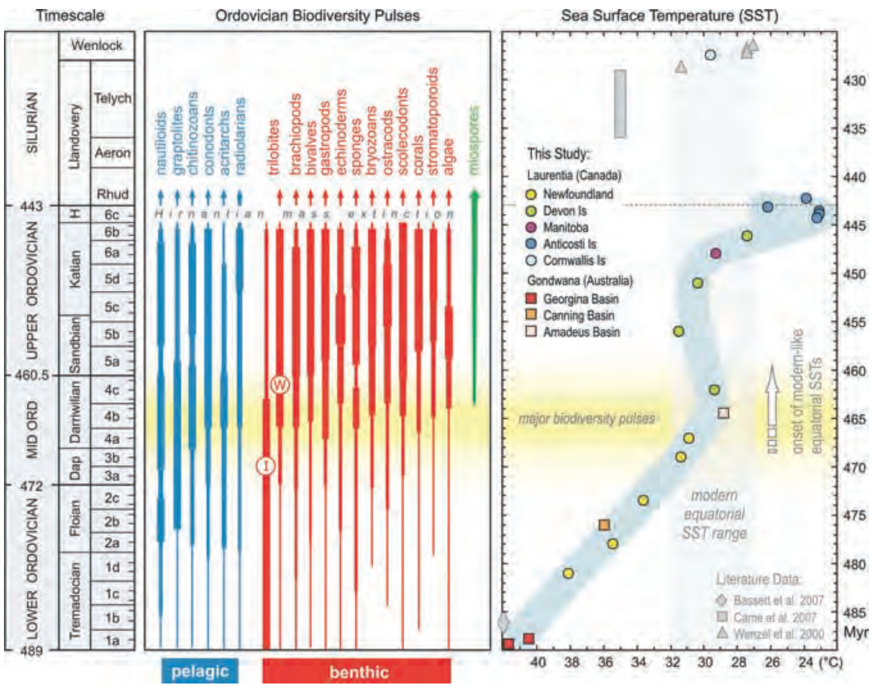

Figure 2. *Generalized global biodiversity pulses and tropical seawater temperature trend through the Ordovician.*

Silicon and Boron isotopic signatures in marine sponges

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The Southern Ocean is widely regarded as playing a key role in influencing atmospheric pCO_2 over glacial-interglacial timescales; the mechanism by which this influence is exerted is, however, poorly constrained. Diatom production constitutes about 40% of the total oceanic primary production, making them key players in the modulation of atmospheric CO_2 concentrations and global climate. Additionally better understanding of changes in the surface and deep water carbonate system (eg pH, alkalinity) would provide invaluable insight into the driver(s) of millennial scale climate change. Here, the boron and silicon isotope composition of biogenic silica (siliceous sponges), is being investigated as a potential seawater pH and paleo-productivity proxy.

Relationships were investigated between coupled sponge and seawater samples for Si isotope fractionation compared with equivalent Si concentrations from the water column. Our new results and the subsequent new model offers a new perspective on what controls biological fractionation in biogenic opal and in turn, will yield a novel interpretation of the paleo-oceanic distribution of silicon.

Boron analysis of siliceous sponges aims to examine the nexus between seawater pH, biogenic silica and boron, and thus the utility of boron in siliceous organisms (namely sponges and diatoms) as a pH proxy. First order Comparison between boron and silicon signatures obtained from the same sponge material suggest a coupling between Silicon and Boron system in marine sponges.

Oldest complete vertebrate eye preservation from the fossil record

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The XCT scanning facility in the ANU Research School of Physical Sciences & Engineering has been used on a unique fossil specimen from the 400 million-year-old limestones at Burrinjuck near Canberra (Early Devonian in age). The image below shows the complete eye capsule of an extinct placoderm (armoured) fish, reconstructed from the XCT scanning data using the ANU-developed *Drishti* program. The specimen was originally removed, perfectly preserved, from limestone using acetic acid. Burrinjuck is one of only a few vertebrate fossil localities in the world where extremely thin layers of 'perichondral' bone investing the surface of a cartilage can be preserved and extracted intact. The cartilage at the back of the eyeball was fused to the sclerotic bones forming a ring around the eye opening. The soft part of the eye was completely encapsulated, and all the nerves and blood vessels passing between the eye and the brain are preserved as openings or canals through the cartilage. The new CT scans permit the internal structure of the eye capsule to be studied in great detail.

One of the issues concerning structure of the vertebrate eye is the homology of the six extraocular muscles controlling eye movement. In every vertebrate species these are always innervated by the same three cranial nerves (III, IV, VI). However there are consistent differences of pattern between all living jawless and jawed vertebrates, which are assumed to have evolved at the branching point between these two major groups.

Previously there was no direct evidence of this from the fossil record, but analysis of the nerve canals and muscle attachment points in the placoderm eye capsule, compared to preserved braincase specimens from Burrinjuck, suggested that this extinct group had an extraocular muscle arrangement unknown in any other vertebrate species, living or extinct. This research was published in the Royal Society journal *Biology Letters*, the image below being used on the cover of the journal.

The structure of the vertebrate eye has been used for centuries as an example of biological complexity that proved an 'intelligent designer' created life on the planet. Modern proponents of 'Intelligent Design' present the vertebrate eye as an example of 'irreducible complexity'. Charles Darwin argued in *The Origin of Species by Means of Natural Selection* (1859) that the evolution of complex organs could be explained by natural selection, but the absence of known intermediate stages was due to incompleteness of the fossil record. In an invited contribution to a special issue on eye evolution for the American journal *Evolution: Education and Outreach* I elaborated on the eye capsule evidence, and illustrated a number of other specimens from the famous Burrinjuck fossil locality that demonstrate the structure of the brain in early vertebrates.

This research is supported by ARC Discovery Grant DP0772138.

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Young, G.C. 2008a. Number and arrangement of extraocular muscles in primitive gnathostomes - evidence from extinct placoderm fishes. *Biology Letters*, **4**: 110-114. [doi:10.1098/rsbl.2007.0545]

Young, G.C. 2008b. Early evolution of the vertebrate eye - fossil evidence. *Evolution: Education and Outreach* (2008) **1**(4): 427-438 [doi:10.1007/s12052-008-0087-y]

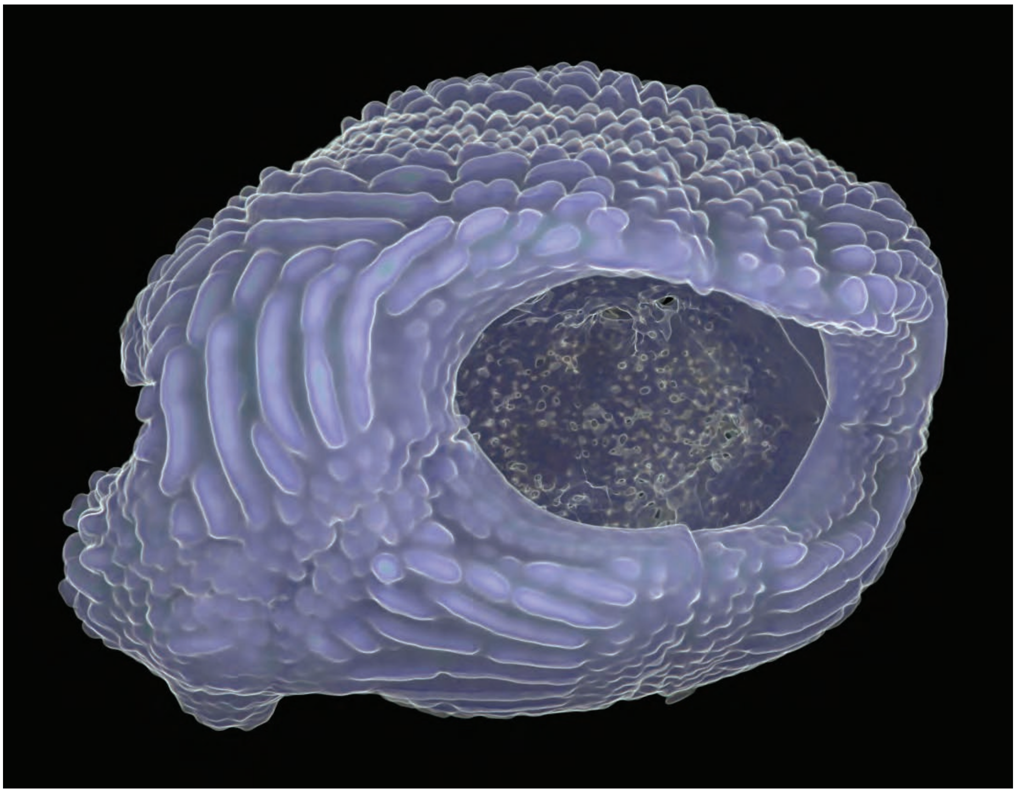

Figure 1. *A 3-D image created by the Drishti program from XCT scanning data of the acid-extracted eye capsule of the placoderm Murrindalaspis from Burrinjuck, NSW (micro X-ray tomography by Dr T. Senden; 3-D rendering using Drishti software by Dr A. Limaye)*

Earth Materials and Processes

The Earth Materials and Processes area comprises groups in Experimental Petrology, Rock Physics, Thermochronology, and Structure & Tectonics. Our research centres around laboratory based measurements under controlled conditions, simulating those occurring in nature, but these activities are complimented by a rich array of analytical equipment and are supported by extensive field-based observations, often in collaboration with scientists from other institutions, nationally and internationally. Through such investigations we are developing understanding of the structure and chemical composition of planetary interiors, and the processes by which they evolve. Our interests start at the very beginning of solar system history with how the Earth and other rocky planets accrete, but also covers the ongoing processes of mantle convection, volcanism, metamorphism, global tectonics and the formation of ore deposits.

Areas of current research activity include:

- The making of terrestrial planets. Chemical constraints on the accretion of the Earth and similar planets from the solar nebula, and the processes of core formation; mineralogical and chemical properties of the deep mantle and their influence on global tectonics.

- The nature of the Earth's upper mantle. Experimental studies and thermodynamic modelling of the phase equilibria relevant to upper mantle melting and ultra-high-pressure metamorphism associated with crustal thickening and subduction; experimental and microstructural studies of phenomena associated with lattice defects and grain boundaries including incorporation of water into nominally anhydrous minerals and microscopic mechanisms of seismic wave attenuation; experimental studies and modelling of grain-scale melt distribution and its implications for melt transport, rheology and seismic properties.

- Coupling between fluid flow and fault mechanics in the continental crust Experimental studies of the role of fault healing and sealing processes in controlling the time dependence of fault strength and permeability at high temperatures and pressures; complementary field-based and modelling studies exploring fluid-driven growth of shear networks with applications to understanding the development of lode gold systems, especially in the Western Australian goldfields.

- Oxidation state and coordination of metal ions at high temperatures. Studies of crystals, melts and hydrothermal solutions by X-ray absorption spectroscopy, using synchrotron radiation. Studies of silicate glasses and melts to very high temperatures under controlled redox conditions. Analysis of hydrothermal solutions trapped in synthetic fluid inclusions is providing important basic information on metal complexes at high temperatures.

Experimental Petrology Introduction

The Experimental Petrology Group uses a laboratory-based experimental approach combined with field observations to study the Earth, its origin, evolution and mineral wealth. The group operates a wide range of experimental apparatuses for generating the high temperatures and pressures that are needed to reproduce the natural conditions within the Earth. The equipment includes: high temperature furnaces capable of reaching 1800°C, several of which are equipped for precise control of oxygen and sulfur fugacities by gas mixing; eleven solid-media piston-cylinder devices for generating pressures to 6 GPa and temperatures in excess of 2000°C, a multi-anvil apparatus, which can presently achieve pressures of 27 GPa; and a well-equipped hydrothermal laboratory.

These high-temperature, high-pressure apparatuses are complimented by an array of microbeam analytical techniques, including a Cameca SX100 electron microprobe; laser-ablation ICP-MS, which is now being used regularly to analyse trace-elements in experimental run products; a STOE STADIP powder X-ray diffractometer; and FTIR spectroscopy for the determination of H2O, CO2 and other volatile species in minerals and glasses. To complement this latter facility, the group acquired a Agilent 6850 Gas Chromatograph, which has been combined with a capsule-piercing device to enable the extraction and analysis of small quantities of C-O-H fluids from high-pressure experimental run products.

As well as the conventional 1/2 inch and 5/8 inch apparatus for use to 4 GPa, the group's piston-cylinder laboratory also runs a high-pressure device that is now operating regularly at 6.5 GPa; the laboratory also has two large-capacity piston-cylinder devices that take 30 mm and 50 to 65 mm diameter pressure assemblies respectively, enabling pressure to be controlled extremely accurately, and which are capable of synthesising relatively large volumes of high pressure phases for detailed mineralogical studies. A novel diamond composite hard material, developed in these apparatuses and now under commercial production, offers promise as an anvil material to extend the pressure range of the multi-anvil apparatus above 26 GPa, thereby allowing detailed experimental exploration of the pressure-temperature regime of the Earth's lower mantle. To further this research the multi-anvil apparatus has now been refurbished and provided with full computer control of pressure and temperature.

In recent years the group has become increasingly involved in developing methods to characterise geologic materials by X-ray absorption spectroscopy (XANES) and related techniques that use synchrotron radiation. Research in this area is presently concentrating on oxidation states in silicate melts, including in-situ measurements at temperatures to 1500°C, and speciation in ore-forming hydrothermal solutions. Members of the group continue to investigate conditions and processes in the Earth's upper mantle (Professors David Green and Hugh O'Neill, Dr Robert Rapp), and metamorphism in the continental crust (Dr Joerg Hermann), as well as the physical chemistry of ore-forming solutions (Drs John Mavrogenes, Katy Evans).

On twinning and microstructures in calcite and dolomite

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Electron diffraction of the rhombohedral carbonate minerals can show additional diffraction spots which have been ascribed to various metastable Ca-Mg ordering schemes that remain unknown as macroscopic minerals. We have found that such reflexions can be produced by nanoscale twin domains which appear to be widespread in both biogenic and abiogenic carbonates. Because of the many metrical pseudosymmetries in the calcite structure, such twins can produce diffraction resembling that of commensurate modulated structures. Twin nanodomains on {104}, in particular, can produce the diffraction patterns of any of the supposed "g", "m" and "n" superstructures, provided only that the usual carbonate orientational order is lost in the twin. Thus, these superstructures may not actually exist, and controversies surrounding their occurrence may not be irrelevant. {018} twins are also common, and diffract similarly to a fivefold superstructure.

Larsson A-K, Christy AG (2008) On twinning and microstructures in calcite and dolomite. *Amer. Mineral.* **93**: 103-113.

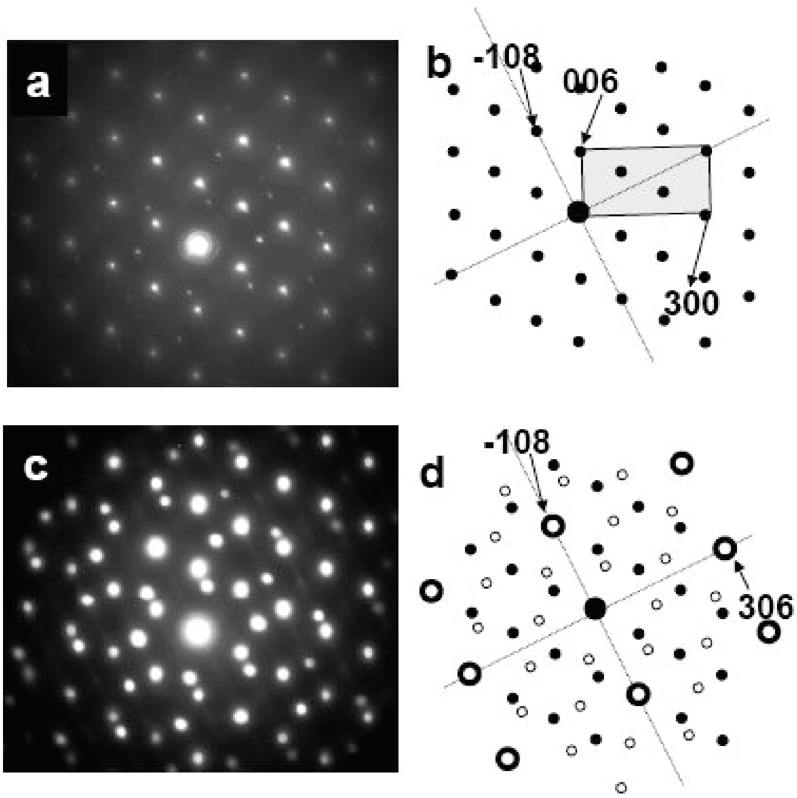

Figure 1. Electron diffraction patterns of a calcite crystal from a sea urchin shell. (a) Selected area is about 1 mm diameter, weak diffraction can be seen that is additional to that of the host crystal. (b) Indexed, consistent with viewing direction [010]. (c) Smaller selected area of 100 nm diameter, enhancing reflexions from a small {018} twin domain which gives trhe appearance of a fivefold superstructure.

Multiple element diffusivities in natural olivine xenocryst from high-Mg diorite

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Despite solid-state diffusion being central to many geological processes, little is known about the factors controlling the rates of diffusion of different species in silicate minerals. Theoretical modeling of diffusivities in silicates suffers from a general lack of empirical data against which the modeling can be tested.

Olivine xenocrysts (0.5-3 mm in diameter, up to 20% in volume) were found in the chilled margin of one of the plutons of high-Mg diorite from Handan-Xingtai, central North China block, which was formed at an intracontinental setting. These hybridized high-Mg dioritic rocks formed during cooling from ~ 1000°C. One crystal with favorable dimensions and orientation, and despite some dissolution still retaining a crystal face, indicating minimal dissolution (Fig. 1), was selected for detailed study. Concentration profiles of Mg, Fe, Mn and Ni were determined by electron microprobe. The olivine was normally zoned in Mg/Fe, with Fo# [100*Mg/(Mg + Fe^T)] decreasing from core (89.1-93.2) to rim (73.2-81.4). Element mapping with the electron microprobe showed a gradual change of Fe, Mg, and Mn contents (Fig. 2). Concentration profiles of trace elements (Li, Na, Al, P, Ca, Sc, Ti, V, Cr, Mn, Co, Ni and Y) were then determined along the same or similar profiles by laser-ablation inductively-coupled plasma mass spectrometry (LA-ICP-MS). The profiles were acquired using different spot sizes as well as continuing scans using a 7 x 70 µm slit (Fig. 2).

The obtained data (Fig. 3) allow trace diffusion coefficients to be evaluated relative to Mg-Fe interdiffusion under conditions that cannot be accessed in the laboratory. The effective diffusion coefficients of many trace elements (Li, Ca, Sc, Mn, Co, Ni and Y) fall within a factor of three of each other and of the mean Mg-Fe interdiffusion coefficient, in agreement with results from laboratory experiments at higher temperatures (Spandler et al. 2007). By contrast, the profiles for Na, Ti and V imply much faster diffusion rates, while P shows no discernible diffusion. The Al and Cr profiles, which are well correlated with each other, are highly complex and variable on a small length scale. These data show that the diffusion coefficients of cations in olivine are not simple functions of either ionic charge or ionic radius. Using published Mg-Fe interdiffusion coefficients (Dohmen and Chakraborty, 2007), the characteristic residence time of the olivine xenocryst is modeled to be about 10^2 to 10^3 years.

Dohmen R, Chakraborty S (2007) Fe-Mg diffusion in olivine _: point defect chemistry, change of diffusion mechanisms and a model for calculation of diffusion coefficients in natural olivine. *Physics and Chemistry of Minerals* **34**, 409-430, doi: 10.1007/s00269-007-0158-6

Spandler C, O'Neill, HStC. Kamenetsky V.S. (2007) Survival times of anomalous melt inclusions from element diffusion in olivine and chromite. *Nature* **447**, 303-306. doi: 10.1038/nature05759.

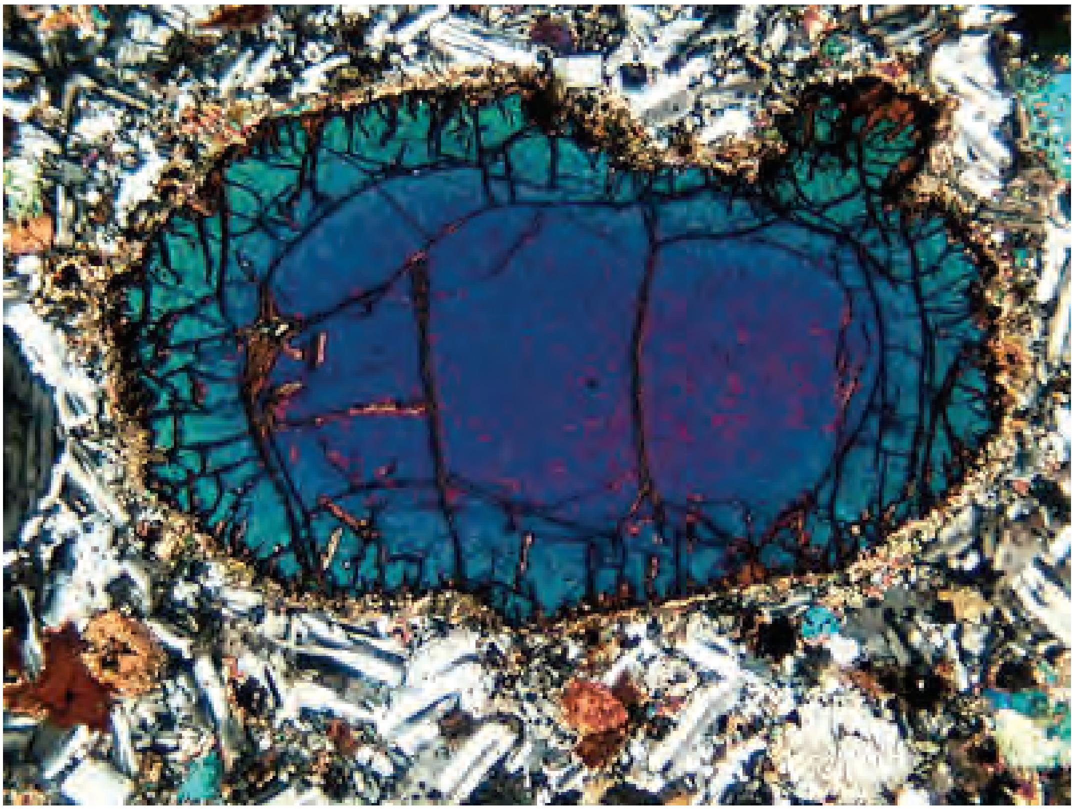

Figure 1. Microphotograph (X Nicols) of an olivine xenocrist embedded in a diorite matrix consisting of plagioclase, clinopyroxene, amphibole, biotite and quartz. The olivine grain is surrounded by a small corona of orthopyroxene. The change in interference colors from core to rim is related with an increase in fayalite component in olivine.

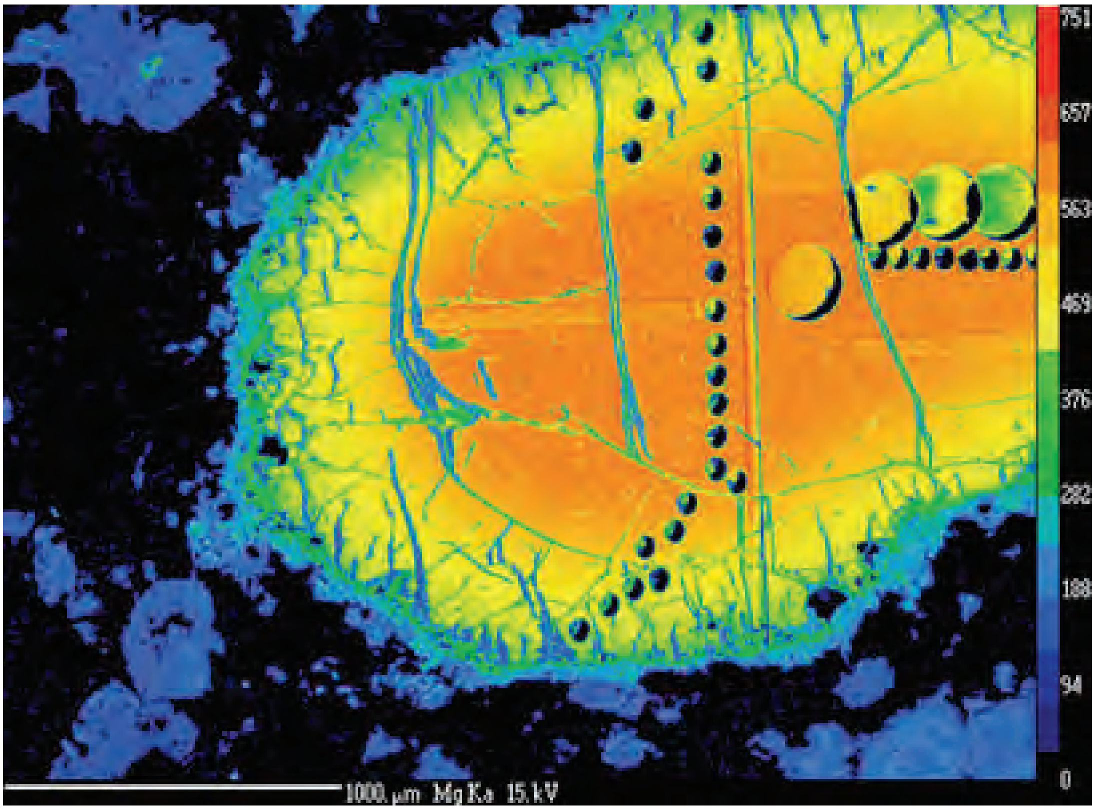

Figure 2. Mg distribution X-ray map of the investigated olivine. Mg continuously decreases from core to rim. Also shown are the different ablation pits (180 µm, 70 µm spot size) and the tracks from the LA-ICP-MS analyses.

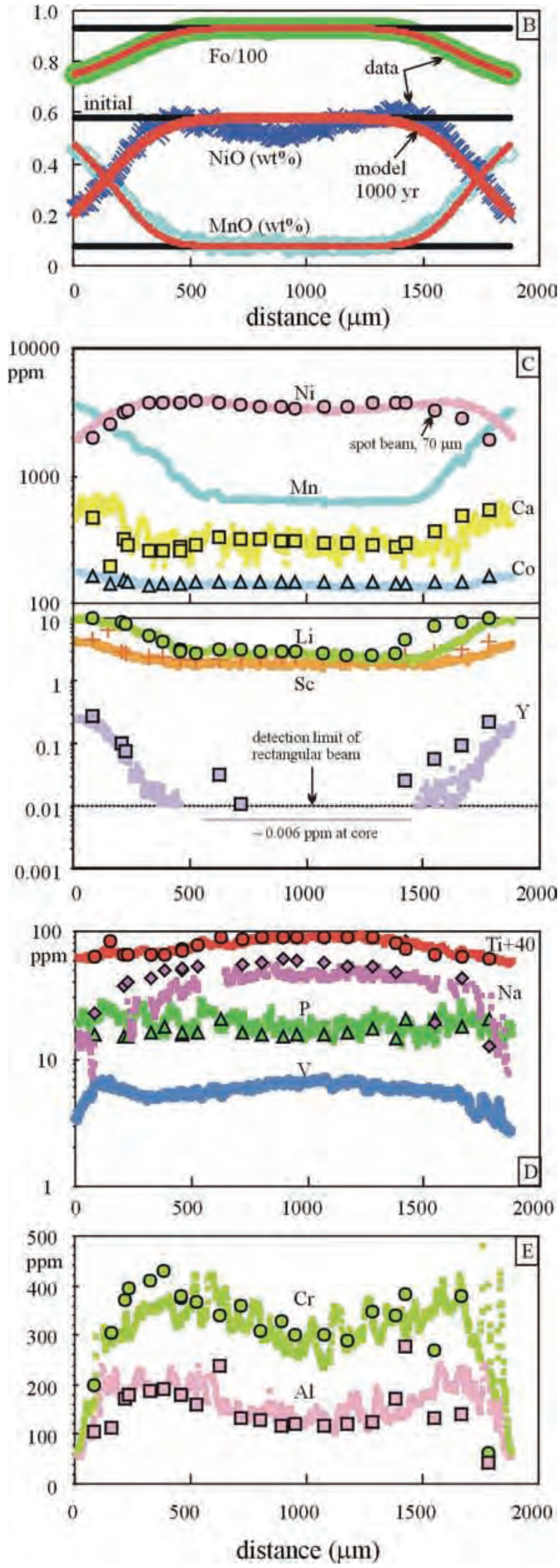

Figure 3. Profiles through the olivine grain. B) Major element data for the forsterite content and NiO and MnO in wt.% from electron microprobe analysis. The red line refers to modeled diffusion profiles indicating that the olivine had a ~1000 year residence time at 950-1000°C. C), D) and E) Trace element profiles in olivine determined with LA-ICP-MS analyses (all values in ppm). Continuous lines were measured in scan mode whereas symbols refer to single spot analyses. Note the similar diffusion behavior of ions with different charges such as Li (1+), Mn (2+) and Y (3+).

Determination of Selenium Concentrations in NIST SRM 610, 612, 614 and Reference Materials using the Electron Probe, LA-ICP-MS and SHRIMP II

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Hugh St.C. O'Neill and Charlotte M. Allen

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Selenium (Se) is a trace element with distinctive geochemical properties, which have yet to be exploited in petrology because of the analytical difficulties associated with its low concentrations in geological materials. Selenium (Se) has 6 naturally occurring stable isotopes; ^{74}Se, ^{76}Se, ^{77}Se, ^{78}Se, ^{80}Se and ^{82}Se and is both volatile and strongly siderophile. Constraining the range of Se concentrations in mantle-derived rocks is important to studies of planetary differentiation, partial melting models and recycling of lithospheric components into the mantle.

The abundance of Se in the mantle is not well known, but has been estimated to be 79 ppb by assuming chondritic Se/S (Palme and O'Neill 2003). Due to the time-consuming and often complicated sample preparation techniques used by previous studies (see Johnson and Bullen 2004 for a comprehensive review) and the high levels of analytical sensitivity required, little is known about the behaviour of Se in igneous systems.

In situ analysis of geological materials such as natural volcanic glasses and minerals, using LA-ICP-MS, allows the rapid measurement of major and trace element data for a wide range of elements that are below the detection limits of the electron microprobe (EMP). The quantification of LA-ICP-MS data of unknown samples is dependent on the analysis of calibration materials, such as NIST SRM 610 and 612. Currently, no published value is available for the concentration of Se in NIST SRM 612. We have used a combination of EMP, Sensitive High Resolution Ion Microprobe II (SHRIMP) and/or LA-ICP-MS techniques to measure the concentration of Selenium (Se) in NIST SRM 610, 612, 614 and a range of reference materials. The new reference value for Se in NIST 612 was then to measure the concentrations of Se in natural volcanic glasses.

Johnson, T. M., Bullen, T. D. (2004). Mass-Dependant Fractionation of Selenium and Chromium Isotopes in Low-Temperature Environments. In: Johnson, C. M., Beard, B. L., Albarède, F. (Editors), Geochemistry of non-traditional stable isotopes. Reviews in Mineralogy and Geochemistry. Mineralogical Society of America, pp 289-317.

Palme, H, O'Neill, H. St.C. (2003). Cosmochemical Estimates of Mantle Composition, Treatise on Geochemistry. Elsevier Ltd., pp. 1-38.

XANES Analysis of Ni & Co in silicate glass: A Preliminary Investigation of Pressure Induced Changes in Their Coordination Environment

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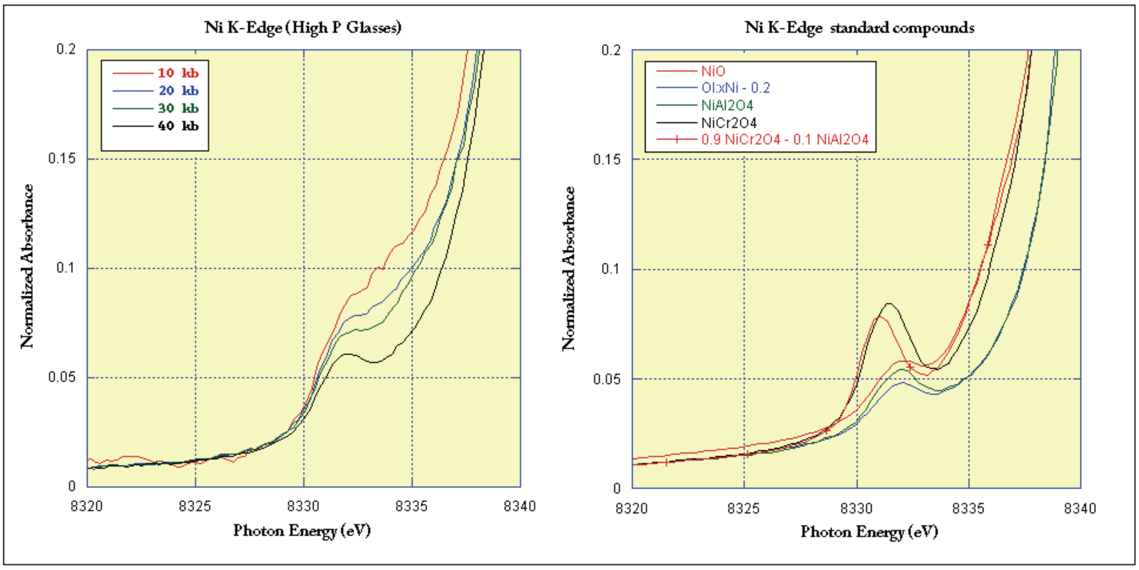
The XANES region of the x-ray absorption spectrum (typically within 30-50 eV of the absorption edge) is strongly sensitive to both formal oxidation state and local coordination chemistry of the element under analysis. Pre-edge features in many transition-metal k-edge spectra provide a qualitative means to determine their coordination environment. Whilst s-p (orbital) is the primary transition for Ni and Co (1s core electron) K-edge spectra, elements of their pre-edge features reflect the degree to which local geometry around the absorbing atom allows hybridization of p-d orbitals, increasing the availability of transition states for the 1s core photo-electron and hence the pre-edge absorption intensity. The extent (if any) to which the intensity and shape of these pre-edge peaks are seen to vary with pressure, indicates a change in allowable hybridization associated with shifts between octahedral, distorted octahedral and tetrahedral symmetry.

To examine the possibility of pressure induced changes in the coordination chemistry of Ni and Co in silicate melt (taking silicate glass as the closest available analogue to a liquid melt structure) a series of high pressure experiments was conducted using a piston-cylinder apparatus (at 1500^{o}) to produce uniform high pressure glasses at 10, 20, 30 & 40 kb for each element. XANES analysis of the experimental glasses was carried out at the KEK PF synchrotron, Tsukuba, Japan. After the appropriate data reduction, our results indicate that whilst Co shows no apparent shift in its coordination environment over the applied pressure range, a systematic change in the coordination symmetry of Ni can be seen to occur toward the upper 40 kb limit of the study. This shift to a lower pre-edge peak intensity at higher pressures suggests a transition from tetrahedral coordination, where increased p-d hybridization occurs at lower pressures, toward a more centro-symmetric octahedral symmetry reflected by the lower intensity 40 kb peak. Further experiments are planned to examine this shift over an expanded pressure range.


Ni K-Edge (High P Glasses)
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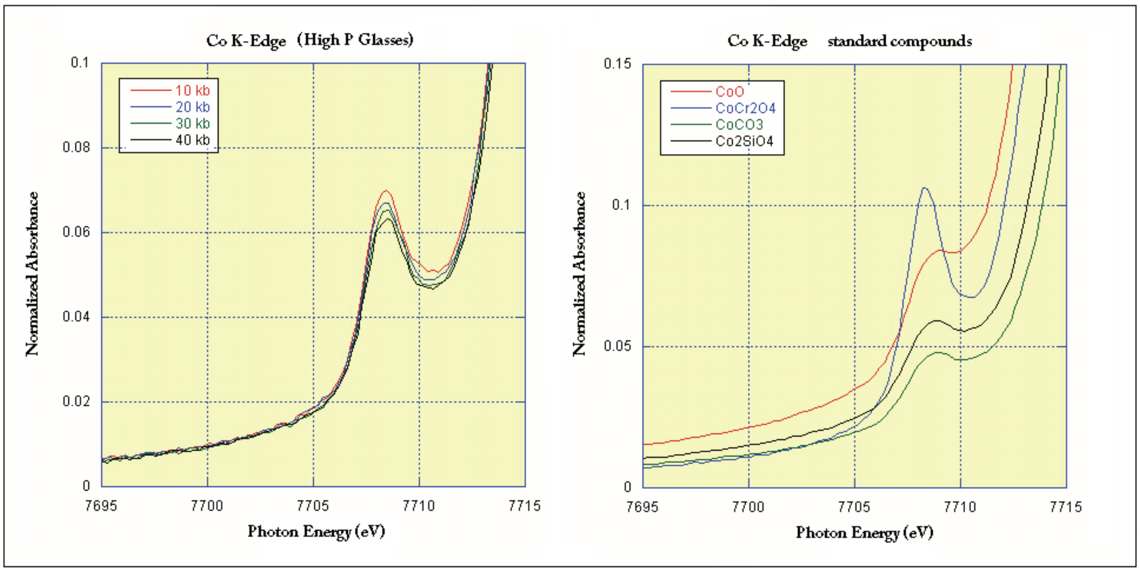
Co K-Edge (High P Glasses)
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CoCO3
Co2SiO4
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Photon Energy (eV)

Trial to establish muscovite-paragonite solvus by synthesis experiments

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[1] *Research School of Earth Sciences, Australian National University, Canberra, ACT 0200, Australia*

Since the pioneering work of Eugster and Yoder (1955), numerous efforts have been made to study the nature of Ms-Pa solvus and its application as geothermometry by experimental work (Flux & Chatterjee, 1986 and references therein). Guidotti (1994) stated: "Unfortunately, field, experimental and thermodynamic investigations of Pg-Ms equilibria have yielded conflicting results".

In this study, we planned to obtain Ms-Pa solvus brackets at various T and 20 kbar by hydrothermal treatment of a variety of gel starting materials using Piston-Cylinder apparatus. Paragonite can be stable at a wider temperature interval at 20 kbar and high pressure will contribute to a faster and closer approach to the equilibrium.

The XRD spectra of all the runs accord with the spectra of 2M1 polytype mica. Through a calibration curve expressing cell volume *V* (Å) as a function of X_{ms}, we can obtain the compositions of predominant K-rich mica which are plotted in Fig 1. For run C3170 at 700°C, 20kbar, single phase mica was formed (blue circle in Fig 1), of which similar compositions were got from probe (X_{ms}=0.645) and XRD (X_{ms}=0.622). For runs at 650°C, 20kbar with 50%Ms+50%Pa as starting material, two phases of micas coexist, and the composition for K-rich mica is around X_{ms}=0.58. K-rich mica with X_{ms}=0.6587 was formed and Na-rich mica decomposed to Jadeite and Kyanite in run D1004 at 600°C, 20kbar. We obtain a graphical Ms limb of the solvus which locates at lower temperature than it should be according to the models in Chatterjee & Flux (1986) and Roux & Hovis (1996).

Eugster HP, Yoder HS (1995) Micas: The join muscovite-paragonite. *Carnegie Inst. Washington Yearbook* 54, 124-126

Guidotti CV, Sassi FP, Blencoe JG, Selverstone J (1994) The paragonite-muscovite solvus: I P-T-X limits derived from the Na-K compositions of natural, quasibinary paragonite-muscovite pairs. *Geochimica et Cosmochimica Acta* 58, 2269-2275

Chatterjee ND, Flux S (1986) Thermodynamic mixing properties of muscovite-paragonite solid solutions at high temperatures and pressures, and their geologic applications. *Journal of petrology* 27, 677-693

Roux J, Hovis GL (1996) Thermodynamic mixing models for muscovite-paragonite solutions based on solution calorimetric and phase equilibrium data. *Journal of petrology* 37, 1241-1254

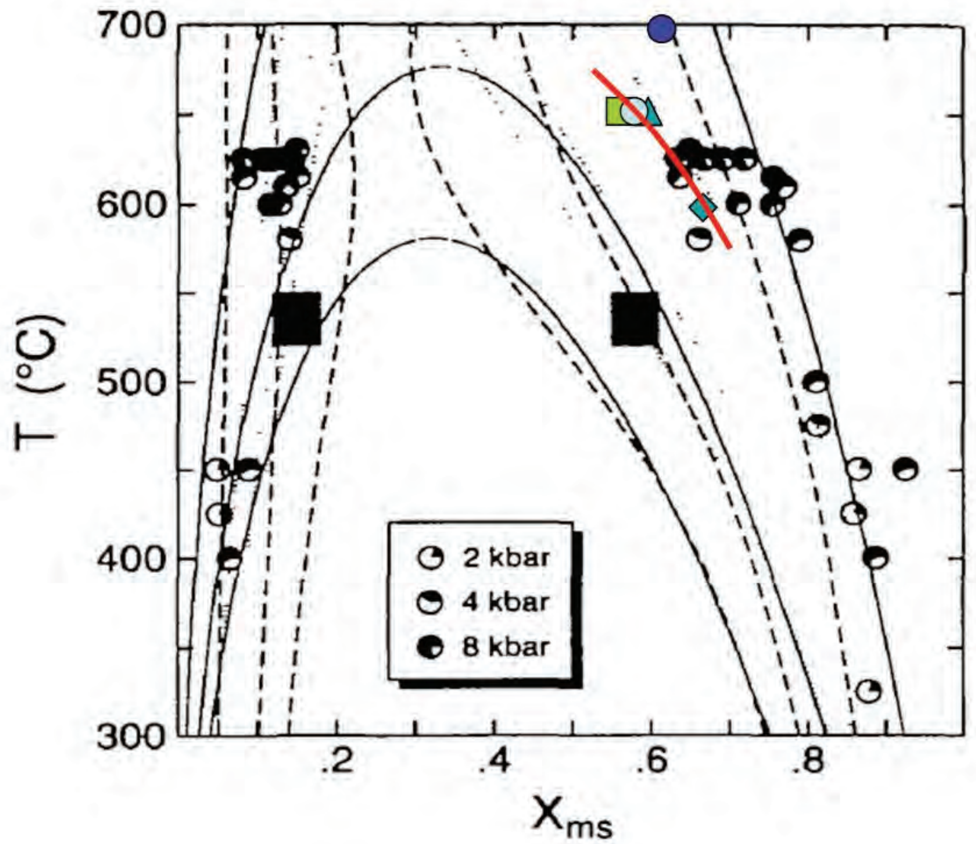

Figure 1. Comparison of results in this study with the solvi calculated at 2, 6 and 15 kbar using Model D (continuous lines), Model A (dashed lines) and chatterjee & Flux (1986) (dotted lines). The rectangular boxes and circles are compositions for natural micas from Grambling (1984) and Guidotti et al. (1994). (from Roux & Hovis, 1996)

The redox state of terrestrial basalts determined by V/Sc olivine-melt partitioning data

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[2] *Mineralogisch-Petrologisches Institut, Universität Bonn, Poppelsdorfer Schloss, Bonn 53115, Germany*

The dependence of the partitioning of V between olivine and silicate melt ($D_V^{ol/m}$) on oxygen fugacity was used to estimate directly the redox state of primitive terrestrial basaltic and picritic magmas at that stage in their evolution when they begin to crystallize olivine. The effect of other variables was accounted for by rationing $D_V^{ol/m}$ to $D_{Sc}^{ol/m}$, because the partitioning of Sc, a redox insensitive element having approximately the same incompatibility at terrestrial oxygen fugacities, is shown to depend rather similarly on melt composition. The method was calibrated on basaltic compositions equilibrated in the laboratory (one atmosphere) at QFM and QFM-2.7 between 1300 and 1400°C. We demonstrated that this method can be effective over the entire range of redox conditions observed in geological and cosmochemical materials, and therefore may serve as a universal redox indicator in olivine-phyric mafic volcanic rocks. Our preliminary assessment indicates accuracy in relative oxygen fugacity between 0.2 to 0.5 log units, but precision typically better than ±0.2 log units. The method was applied to 41 mid-ocean ridge (MORB), 25 ocean island (OIB), and 13 island arc (IAB) recent primitive basalts and picrites. The data indicate that MORBs and OIBs record a very restrict range of redox conditions, between QFM and QFM+1, with no clear distinction between them. However, IABs record consistently more oxidizing conditions, ranging from QFM+0.5 to QFM+3 (average at QFM+1.7). Except for MORBs, for which the data cluster exactly on the maximum redox condition ever reported, the results presented here are in good agreement with previous estimations using various methods in minerals and melts.

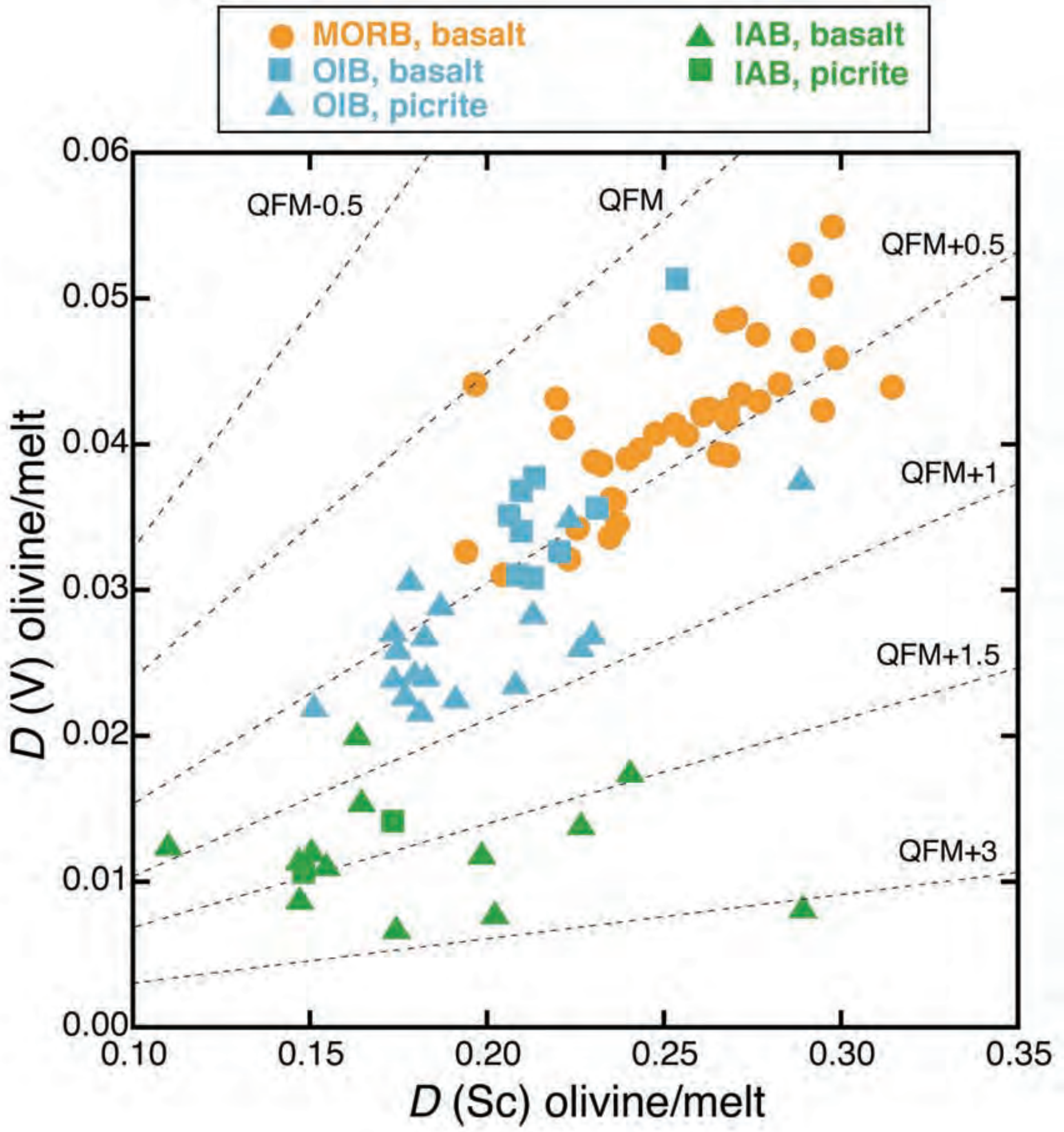

Figure 1. Partition coefficients obtained empirically for V and Sc between olivine phenocryst and silicate melt (glass or matrix). The positive correlation between is indicative of effects (possibly melt composition) other than oxygen fugacity. The dashed lines, illustrating values of oxygen fugacity relative to the QFM buffer, were calculated based on the experimental partitioning data.

Experimental investigation of fluid transfer in sub-arc mantle conditions

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[1] *Research School of Earth Sciences, Australian National University, Canberra, ACT 0200, Australia*

Fluid transport from the subducted slab to the locus of partial melting in the mantle wedge in volcanic arcs is a process which is still strongly debated. Two end member mechanisms are considered: 1) porous fluid transfer through the mantle or 2) focused fluid flow in dykes/channels. These two processes are very different and the composition of reacted fluids arriving at the locus of partial melting in the mantle wedge must have different trace element signatures depending on which process is involved.

The main goal of this experimental study is to constrain the change in composition of the fluid as a result of these two ways of fluid transport. Experiments were performed on natural San Carlos olivine representing a simplified mantle and various pre-synthesized, trace element doped, hydrous felsic glass identified as slab-extracted melts (Fig.1)(Hermann & Spandler, 2008). Synthesis piston cylinder experiments were carried out in gold capsules for a week in the range 700°-1100°C and 35kbar which represent average values for the extraction of slab-fluids into the mantle (Fig.2).

Porous fluid transport was simulated by mixing a 1 to 4 ratio of fine grained hydrous felsic glass with fine grained olivine. One end of the capsule was filled with carbon spheres in order to collect the reacted quenched fluid at the end of the run. These mixed charges show an olivine-orthopyroxene-biotite±garnet± amphibole assemblage in equilibrium with a fluid (Fig. 1a). Fluid traps collected in K_2O-rich experiments (amphibole barren) were analyzed with laser ablation ICP-MS. Fluid composition was calculated using Ce as internal standard and normalized on the initial felsic glass. It appears that the crystallization of phlogopite has a strong impact on the composition of the fluid. The K_2O/H_2O ratio is considerably diminished (Fig. 2) and the LILE have a strong affinity to follow potassium in phlogopite whereas LREE, MREE and HFSE tend to be enriched into the fluids. In the case of the H_2O-rich experiments, the presence of amphibole and biotite modify the system. Fluids are less abundant and most of the initial starting material is retained in a hydrous peridotitic mix.

Focused fluid was simulated by a layered experiment of hydrous felsic glass overlying coarse olivine grains. A carbon spheres fluid trap was placed over the olivine layer. Significant differences are observed in this type of experiment compared to the mixed experiments. A reaction zone consisting of an orthopyroxenite layer ±garnet only occurs at the interface between olivine and the felsic glass and neither phlogopite nor amphibole has been observed (Fig.1b). In consequence, the glass composition is very similar to the starting composition and the shielding provided by the garnet-orthopyroxenite reduced strongly interactions with olivine, keeping the K_2O/H_2O high. LILE remain high in the quenched glass and REE and HFSE are less affected with respect to the initial starting glass.

These two types of experiments show that there are strong differences in transport behaviour of LILE in the mantle wedge dependent on the fluid flow mechanism. The high K_2O/H_2O and LILE contents observed in arc lavas suggest that fluid transfer in sub-arc conditions can occurs by channelled flow. In case of porous flow, fluids are strongly affected by the crystallization of biotite and LILE are retained in the residue (Fig. 2). However, the melting of such hydrous peridotite residues containing both micas and amphiboles could potentially lead to the formation of arc lavas as well.

Hermann J, Spandler C (2008) Sediment melts at sub-arc depths: an experimental study. *Journal of Petrology* **49**:717-740

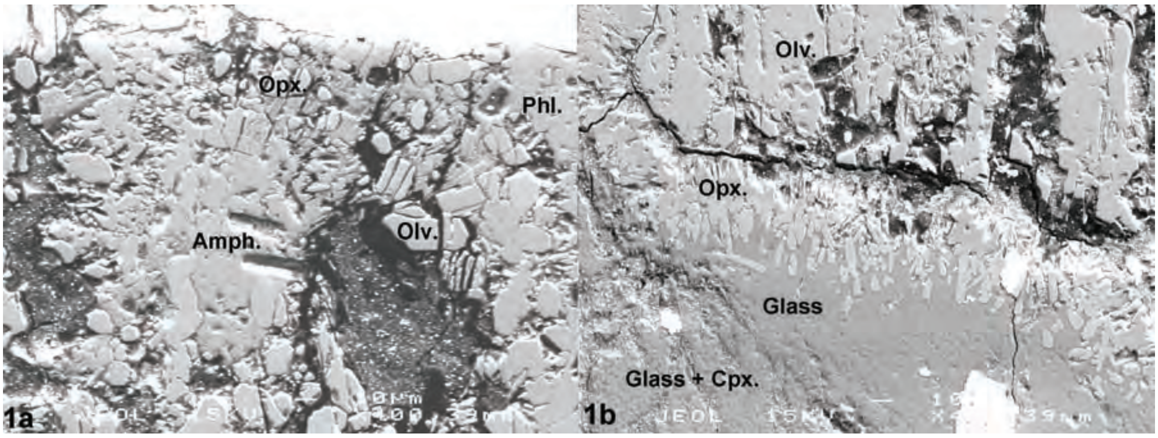

Fig.1. 1a. H_2O-rich mixed experiment showing anhydrous phases (Olivine, Orthopyroxene) and hydrous phases (Biotite, Amphibole) 1b. H_2O-rich layered experiment showing the contact zone between the olivine and the glass, forming an orthopyroxene layer.

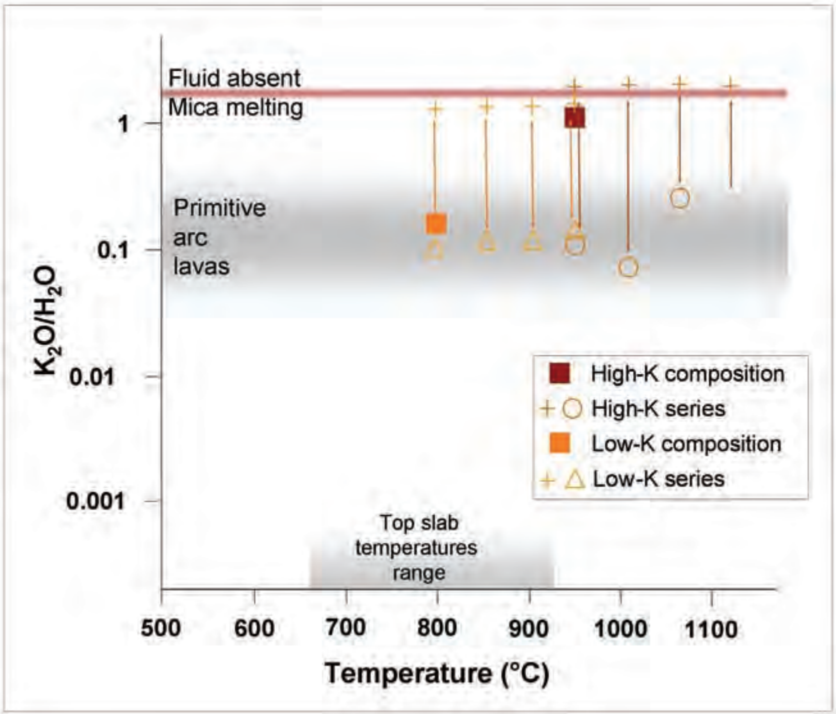

Fig.2. Composition of the different K-bearing phases of these sets of mixed experiments. Full squares are starting compositions; crosses are phlogopite K_2O/H_2O ratios; circles are quenched fluids and triangles give the amphibole composition.

Archean granitoid magmatism and the chemical evolution of the cratonic lithosphere

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[2] *Laboratoire Magmas et Volcans, Universite de Blaise Pascal, Clermont-Ferrand, France*
[3] *Department of Geology, University of Stellenbosch, Matteland, South Africa*

Although there is indirect evidence for the existence of continental crust on Earth more than 4.0 Ga ago (Harrison et al., 2005), no intact, preserved fragments of continents have been found. This begs the question when and how did the first truly "nondestructible" continents form? The development of deep (>200 km), old and chemically refractory roots to the continents in the underlying lithospheric mantle appears to be a critical stage in the physical and chemical evolution of Earth's cratons, the old and stable nuclei of the continents. Without roots in the underlying sub-cratonic lithospheric mantle, the preservation of large continental masses over billions of years may not have been possible. Ongoing experimental and field-based petrologic research over the past several years has led to an improved understanding of the genetic links between granitoid magmatism on the early Earth and the development of their roots in the cratonic lithosphere.

It is well established from studies of Archean (~2.5-4.0 Ga old) granite-greenstone and high-grade gneiss terranes around the world that the granitoid plutons comprising the "continental" component in these areas are dominated by rocks of the trondhjemite-tonalite-granodiorite (TTG) suite of granitoids. A number of experimental studies have previously shown that TTG "magmas" can be generated by low-moderate degrees of partial melting of hydrous "metabasaltic" crust in the garnet-amphibolite-eclogite facies (e.g., Rapp and Watson, 1995; Rapp et al., 2003), and thus tectonic processes that lead to overthickening or recycling (subduction?) of secondary basaltic (oceanic?) crust could also culminate in TTG-forming dehydration melting reactions. In the meantime, detailed field-based petrologic and geochemical studies in a number of granite-greenstone terranes (e.g., the Superior Province of Canada and the Pilbara of Australia; see Smithies and Champion, 2000) had identified another suite of Late Archean "post-kinematic" granitoid intrusives (the "sanukitoid" suite), that possessed "primitive" (i.e., mantle-like) characteristics overprinted onto an overall "TTG-like" geochemical signature, suggesting a hybrid lineage with a significant mantle contribution somewhere along the way.

In an effort to constrain the petrogenesis of sanukitoid magmas, we began a series of high-pressure laboratory experiments at 3-5 GPa in which TTG melts were allowed to react with (and assimilate) a peridotite mineral assemblage (Rapp et al., 1999). Our latest results show that primitive (high-magnesium) granitoids (andesites) comparable to Late Archean sanukitoids result from the equilibration of TTG melts with olivine-bearing mantle phase assemblages (Rapp et al., 2009). The resulting olivine-free garnet pyroxenite and garnet websterite reaction residues are currently being characterized in terms of their major- and trace-element compositions, for subsequent comparison with mantle xenoliths from the subcratonic mantle lithosphere.

Harrison, TM, Blichert-Toft, J, Muller, W, Albarede, F, Holden, P, Mojzsis, SJ (2005) Heterogeneous Hadean Hafnium: evidence of continental crust at 4.4 to 4.5 Ga. Science 310, 1947-1950.

Rapp, RP, Watson, EB (1995) Dehydration melting of metabasalt at 8-32 kbar: Implications for continental growth and crust-mantle recycling, *Journal of Petrology* **36**, 891-931.

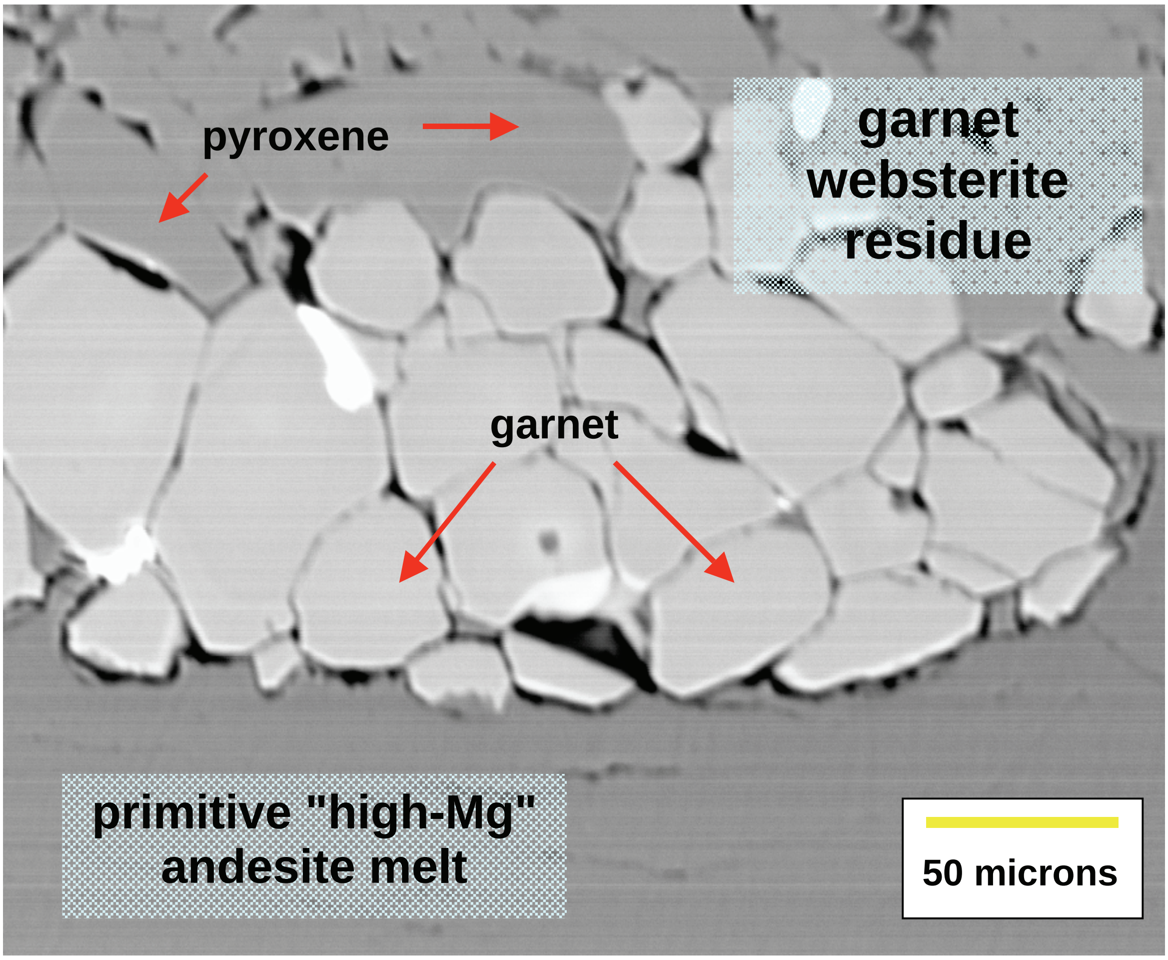
Rapp, RP, Shimizu, N, Norman, MD, Applegate, GS (1999) Reaction between slab-derived melts and peridotite in the mantle wedge: experimental constraints at 3.8 GPa. *Chemical Geology* **160**, 335-356.

Rapp, RP, Shimizu, N, Norman, MD (2003) Growth of early continental crust by partial melting of eclogite. *Nature* **425**, 605-609.

Rapp, RP, Yaxley, GM, Norman, MD (2008) Genetic relations between Archean granitoid magmatsim and the chemical evolution of subcratonic lithospheric mantle: experimental constraints at 3-4 GPa. *Lithos* Special Volume: 9th International Kimberlite Conference (submitted).

Smithies, R.H. and Champion, D.C. (2000). The Archaean high–Mg diorite suite:

links to tonalite–trondhjemite–granodiorite magmatism and implications for Early Archaean crustal growth. *Journal of Petrology* **41**, 1653–1671.



Synthesis and crystal structure of $CuZrTiO_5$: a new inorganic compound

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[1] Research School of Earth Sciences, Australian National University, Canberra, ACT 0200, Australia
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A new inorganic compound, $CuZrTiO_5$, was discovered as a by-product of high-PT experiments with rutile [TiO_2] and baddeleyite [ZrO_2] that were fluxed with CuO. The compound was synthesized in pure form by sintering from the oxides at 1000°C under atmospheric pressure. It is bright green (Figure 1) and strongly pleochroic.

Its composition was confirmed with energy-dispersive x-ray analysis in the scanning electron microscope, and its crystal structure investigated with single-crystal and powder X-ray diffraction.

$CuZrTiO_5$ is orthorhombic, and crystallizes in space group $P2_12_12_1$, with unit cell dimensions a = 3.5871(3) Å, b = 6.6968(4) Å, c = 14.6679(9) Å, cell volume V = 352.35(4) Å, Z = 4, based on a single crystal refinement resulting in R = 0.032 and R_w = 0.079.

The crystal structure is topologically similar to that of In_2TiO_5 (*Pnma*) (Gaedwang et al.1993) but differs in space group and cation coordination (Figure 2). In $CuZrTiO_5$, the two types of In are replaced by Cu and Zr. While $CuZrTiO_5$ has relatively regular TiO_6 polyhedra (Ti-O = 1.84 - 2.18 Å), Zr is in 7+1 coordination (6 O at 2.10 - 2.27 Å and one at 2.811 Å) and Cu shows the 4+2 coordination characteristic of the Jahn-Teller effect. Four O surround Cu in an approximate square at 1.915 - 2.029 Å, while two more distant neighbours lie on opposite sides of the square at 2.565 and 2.591 Å.

In $CuZrTiO_5$, the cations are ordered into layers parallel to (001) of either pure Cu or alternating zigzag chains of Ti and Zr. This layered structure causes the distinct {001} cleavage of $CuZrTiO_5$ observed in the electron microscope (Figure 3).

Gaewdang T, Chaminade JP, Gravereau P, Garcia A, Fouassier C., Hagenmuller P, Mahiou R (1993) Crystal structure and luminescent properties of indium titanate. *Materials Research Bulletin* **28**:1051-1060.

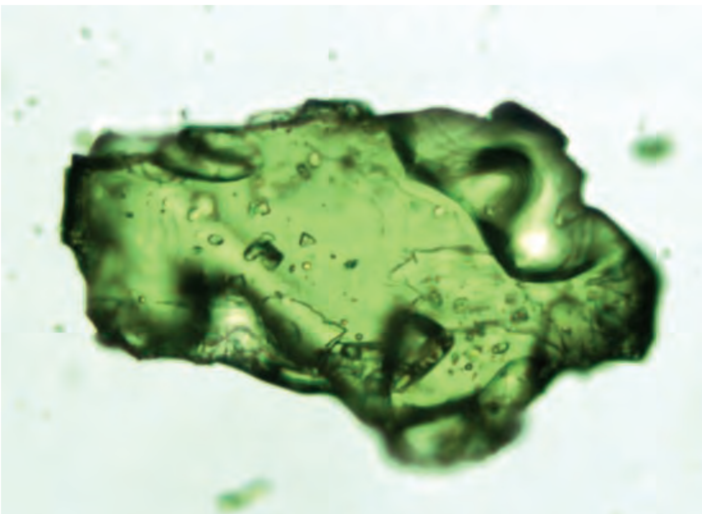

Figure 1.

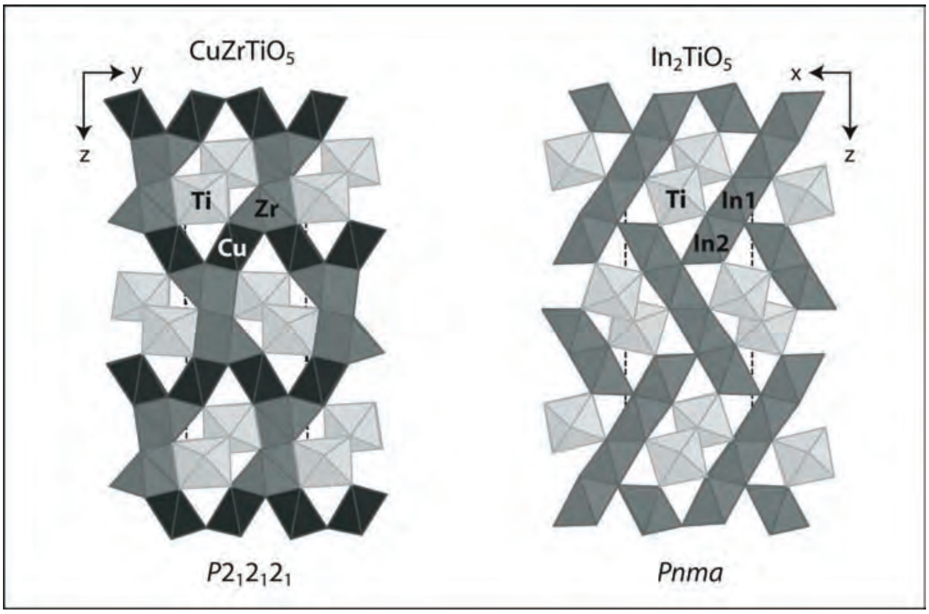

Figure 2.

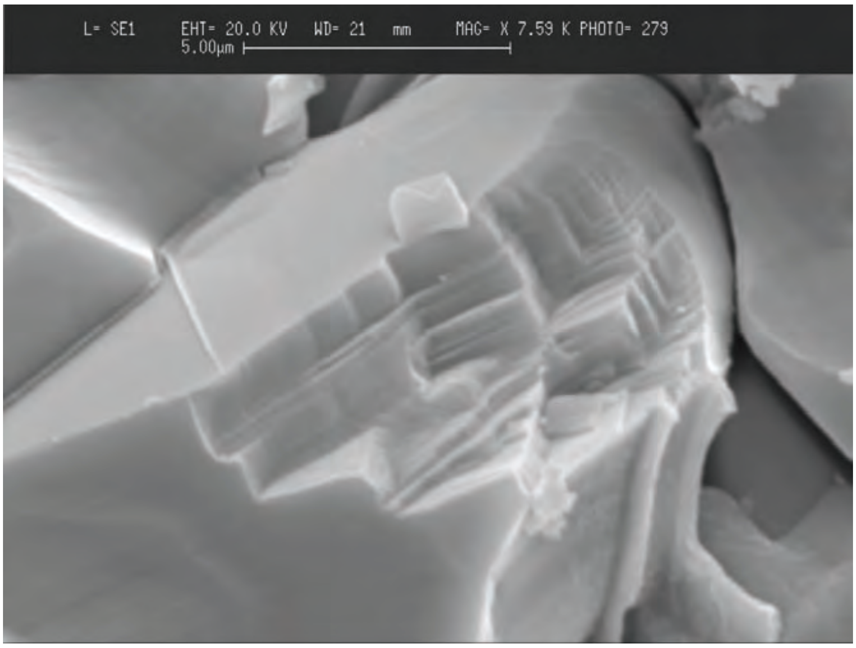

Figure 3.

Coupling between deformation processes and fluid flow in the Earth's crust

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Research School of Earth Sciences, The Australian National University, Canberra, ACT, 0200

Experimental, field-based, microstructural and numerical modelling approaches are being used to explore several aspects of coupling between deformation processes, fluid transport and reaction, especially in fracture-controlled flow regimes.

In 2008, *field-based, modelling, microstructural and microchemical studies* are being used to further explore the growth of faults and fracture networks, and what factors lead to fluid flow becoming localised in certain parts of fracture controlled hydrothermal systems. The research has implications for understanding the localisation of hydrothermal ore deposits within fracture systems, and with minerals industry support, is providing new tools to help enhance exploration strategies. The work is also providing fundamental insights about the roles of reactive pore fluids in controlling fault mechanics and the growth of fracture networks.

Field and modelling studies, in the North Carlin gold systems in Nevada, have evaluated the role of co-seismic static stress changes in governing the distribution of aftershock activity in controlling localisation of fluid flow and related gold mineralisation within particular parts of fault networks.

A study of an Archaean, mesothermal gold system near Kambalda (WA), has shown how, during fault-valve behaviour near the base of the continental seismogenic regime, the relative rates of recovery of shear stress and pore fluid factors after slip events, impact on the internal structure of fault zones, as well as the nature and distribution of gold mineralisation.

In intrusion-related hydrothermal systems, the evolution of fluid pathways and the geometry, distribution, and other characteristics of vein systems, are governed by interactions between stress and fluid pressure states, and by the orientation of stress fields during and after magma emplacement. Stress states and the orientations of stress fields within active intrusive systems respond very dynamically to repeated cycles of inflation and deflation of fluid pressures due to migration of magma and hydrothermal fluids. Repeated variations in stress magnitudes and orientations can also be driven by sudden co-seismic stress relief and more gradual interseismic stress recovery associated with episodic, large earthquakes in convergent margin settings. Additionally, geodetic and seismological studies have demonstrated that episodic fluid migration, as well as cyclic changes in the orientations and magnitudes of stresses, occur on time-scales of years to decades in contemporary magmatic systems. This occurs especially in response to eruption cycles, emplacement of dyke swarms, and effects of nearby earthquakes. Indeed, stress change due to magma migration is likley to be a major driver of seismicity, and associated development of fracture-controlled fluid pathways, up to 15 km from the sites of magma movement. Small dynamic stress changes associated with remote, but large, earthquakes can also trigger microseismicity and attendant fracture propagation and fluid movement in magmatic systems.

A new project, as part of the ANU node of the Centre of Excellence in Ore Deposits, is using this modern understanding of the dynamics of magmatic systems as a basis for undertaking structural, microstructural and alteration studies to analyse the evolution of stress and fluid pressure states during the development of vein systems and faults in intrusion-related hydrothermal systems. The broad goal is to understand how the dynamic evolution of fracture-controlled fluid pathways impacts on the styles of flow and ore deposition, as well as the distribution of mineralisation. In 2008, attention has focussed on the giant Porgera gold deposit (in the far western PNG highlands). Projects on other intrusion-related systems are being developed for subsequent years. A key early result is that fluid flow, in such fracture-controlled hydrothermal systems, is probably controlled by episodic breaching of substantially overpressured, magmatic fluid reservoirs at depth. Fluid pressure fluctuations are associated with repeated cycles of reservoir breaching and episodic, fluid-driven growth and sealing of fracture networks. These processes have important implications for ore deposition. In particular, large, transient hydraulic gradients promote rapid flow and potentially severe chemical disequilibrium in the ore fluid.

The mechanical and fluid pressure evolution of the Argo fault zone, St Ives goldfield, Western Australia: an example of an Archaean, shear-hosted, mesothermal gold system

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The development of low displacement, moderate to high-angle reverse faults during the formation of the Argo gold deposit, within a tholeiitic gabbro host-rock, involved a four stage evolution of deformation and associated hydrothermal alteration. Fault zone evolution and Au mineralization were associated with high fluid flux, fault-valve behaviour in a severely-misoriented fault zone. The far-field maximum principal stress was approximately east-west and horizontal, and the far-field minimum principal stress was sub-vertical. The fault system developed at approximately 400°C in a transitional brittle-ductile regime, near the base of the continental seismogenic regime. Initial Stage 1 deformation involved ductile shear and the development of potassic (biotite-rich) alteration assemblages and associated reaction-weakening in shear zones; few quartz extension veins were formed. Stage 2 is marked by onset of predominantly brittle shear failure at elevated pore fluid factors, and was associated with widespread development of matrix-supported, dilational breccias in fault zones, and a change to sodic (albite-carbonate-quartz) alteration styles. Extension veins have limited development. Stage 3 is also dominated by brittle shear failure, and characterized by a change to quartz-carbonate assemblages in fault-fill veins and breccias. In contrast to Stage 2, large arrays of extension veins are well-developed adjacent to faults. In Stage 4, widespread sub-horizontal quartz-carbonate-biotite extension veins were developed, but shear failure was limited.

Failure mode diagrams in pore fluid factor ~ differential stress space (Figure 1) illustrate how the structural evolution and styles of mineralisation in the Argo fault system reflect a response to progressive changes in relative rates of change of pore fluid factor and differential stress during individual fault-valve cycles. High fluid fluxes and rapid rates of recovery of fluid pressures, relative to rates of recovery of shear stress after slip events, have maintained the system at near-lithostatic fluid pressures and very low differential stresses during gold mineralization.

The structural and rock mechanics study has been complemented by detailed microstructural, microchemical and stable isotope studies of hydrothermal alteration and vein mineral assemblages to characterise variations in the intensity and style of alteration in space and time in the Argo shear system. This work, together with analysis of gold grade distribution, is providing new insights about structural and geochemical controls on gold deposition at scales ranging from the deposit scale, down to metre-scales.

Laboratory studies of Dislocation Damping

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Last year we presented some preliminary results on dislocation annealing in fine-grained synthetic olivine [1]. Since analyses of these results showed that dislocations can be preserved over laboratory timescales, the first experiments to search for dislocation damping in polycrystals have now been conducted.

Two similar deformed synthetic olivine specimens have been investigated so far. The first specimen, 6618, has been deformed in compression up to 2.3% strain, the second, 6646, to 22%. The resulting dislocation densities are 2.3 and 3.6 μm^{-2} respectively. The specimens were exposed to a maximum temperature of 1100°C, and to oscillating torques of 1 – 1000s periods at each temperature decrement, generating maximum shear strains of around 10^{-5}. The strains are sensed from displacements measured with parallel-plate capacitance transducers.

The first attenuation experiment in torsion on specimen 6616 yielded a surprise null result. This led to some calculations for resolved shear stresses in relation to deformation in compression or torsion and assuming that, at high temperatures, the dominant slip system for olivine involves slip in the [100] direction on the (010) glide plane. The main results are shown in figure 1 for [100](010) slip in a single crystal olivine. The two panels (a) and (b) represent deformation in compression and torsion respectively. The parameters α, and β (and γ) are the direction cosines relative to the crystal axes $[\alpha,\beta,\gamma]$ and some major crystal directions are labelled. In uniaxial compression, the resolved shear stress as indicated by the contours in (a) has its maximum value of 0.5 for compression parallel to $[110]_c$. The contours in panel (b) describe the azimuth-dependent resolved shear stress for different torsion axes. Note that torsional deformation around the $[110]_c$ is the least favoured orientation for stressing [100](010). In contrast, a cylinder axis parallel to $[111]_c$ (ie making equal angles with all 3 principal unit-cell axes) is a good trade-off if a single crystal were to be deformed in compression then transferred to attenuation measurements in torsion. For the case of polycrystalline olivine, preliminary calculations show that prior torsional deformation should increase the anelastic strain by 6-fold relative to prior compressional deformation.

Figure 2 shows measurements of Q^{-1} for both deformed specimens with different dislocation densities in comparison to a similar synthetic but undeformed olivine specimen. Only specimen 6646 with the higher dislocation density shows enhanced attenuation and only at the highest temperatures (> 1000°C). In nature, dislocation density should be in equilibrium with the prevailing tectonic stresses in the upper mantle. Dislocation damping will become progressively more important as the grain-boundary dissipation decreases with increasing grain size. Accordingly, dislocation damping could dominate in melt-free material under upper-mantle conditions.

Since the resolved shear stress calculations indicated the need, prior torsional deformation experiments will be done through a collaboration with the University of Minnesota in 2009. Also for single crystals we plan to investigate the possibility of deforming along $[111]_c$ in compression. For both materials, subsequent measurement of the forced torsional behaviour will proceed at ANU.

[1] Farla RJM, Kokkonen H, Fitz Gerald JD, Barnhoorn A, Faul UH and Jackson I (2008) Dislocation recovery in fine-grained synthetic olivine. In preparation for submission to *Physics and Chemistry of Minerals.*

Fig. 1

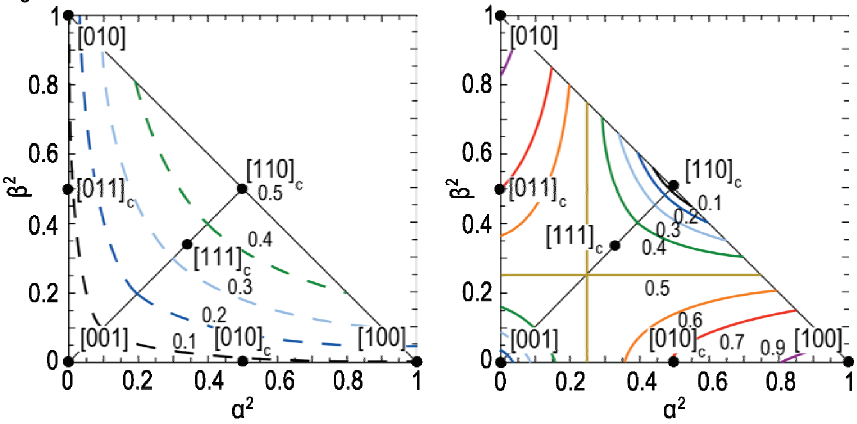

Figure 1. Calculations showing the resolved shear stress (contours) for uniaxial compression (left) and torsion (right}

Fig. 2

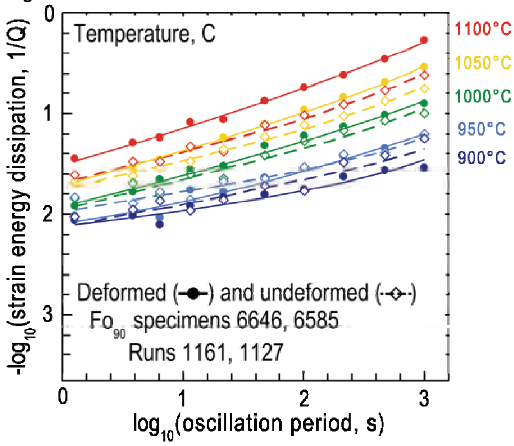

Figure 2: *Q^{-1} data for a deformed (6646) and undeformed specimen (6585).*

Development of fracture-controlled flow regimes and gold mineralisation, Porgera gold deposit, PNG

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Within the framework of the rapidly developing understanding of the dynamics of stress and fluid pressure regimes in contemporary, active magmatic systems, this project is exploring how stress states, stress field orientations and fluid pressures evolved during the development of the large, intrusion-related, hydrothermal gold system at Porgera in the highlands of Papua New Guinea. Fieldwork is being used to document the geometries and styles of vein systems, their overprinting relationships, and relationships to growth of fault networks. This is allowing us to examine how stress states, fluid pressure regimes, and the orientations of stresses evolved during the multi-stage evolution of the hydrothermal system. We are also evaluating what processes drove the growth of fracture-controlled flow networks and the evolution of fluid pathways. A key goal is to understand how the evolution of fracture-controlled fluid pathways and reactions impacts on the distribution of economic mineralisation in multi-stage, intrusion-related hydrothermal systems.

Work in 2008 has focussed on developing a 4D understanding of the evolution of vein distribution, geometries and internal textures during five distinct stages of vein development. The Porgera gold deposit exhibits at least two gold-bearing vein formation stages. The development of the richest vein-hosted Au mineralisation is associated with the growth of several low-displacement faults, which exhibit a complex kinematic evolution involving both dextral and normal slip histories during mineralisation.

The varied internal structures of Au-bearing veins and fault zones, such as textural and mineralogical zoning, in some cases provide evidence for multiple opening and sealing events (Figure 1). Flow in such fracture-controlled hydrothermal systems is unlikely to have been continuous. Instead, flow is interpreted to have occurred as numerous, episodic pulses associated with repeated cycles of breaching of the overpressured, magmatic fluid reservoir by failure events. Breaching events are followed by propagation of fracture arrays driven by migration of a fluid pressure pulse, then progressive sealing of fractures as flow rates decay. Ongoing work is focusing on defining the architecture of major, ore-producing fluid pathways.

Figure 1. a. The internal structure of a composite Stage 1 and Stage 2 vein. Section 1 and 3 represent the Stage 2 mineralisation, which exhibits crustiform quartz interlayered with roscoelite-rich layers. The gold is associated with the roscoelite-rich bands and a patch of gold is marked by the white arrow. Section 2 shows the Stage 1 vein.

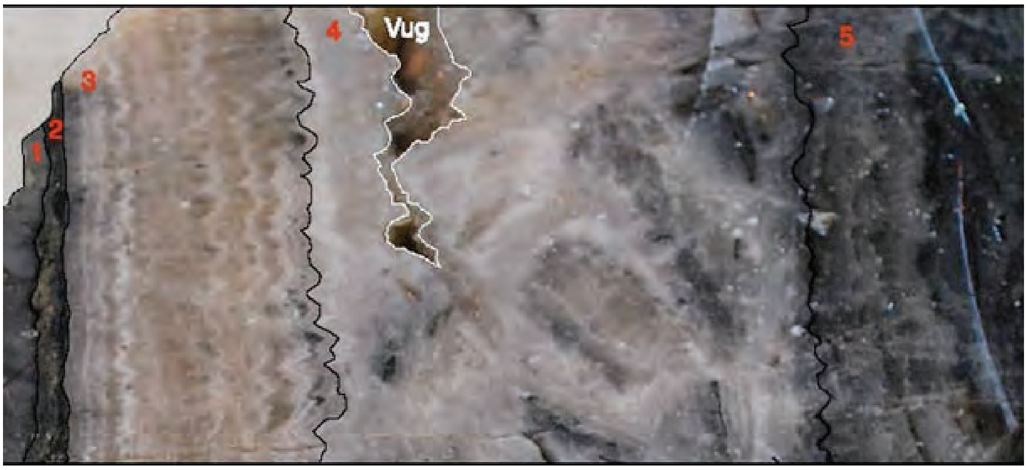

Figure 2. Internal texture of a complex Stage 2 vein. Section 1 shows the wall rock. Section 2 is a pyrite-rich layer. Section 3 exhibits quartz-rich, crustiform banding which grades out into section 4 which shows a dilatational breccia containing wall-rock and quartz-rich clasts with a crustiform overgrowth. Section 4 also exhibits a vuggy centre to the vein. Section 5 exhibits crustiform banding and was in contact with the wall rock.

Viscoelasticity, poroelasticity and seismic properties

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At sufficiently high temperatures in the Earth's interior, the mechanical behaviour changes from elastic to viscoelastic with profound implications for mantle rheology and also seismic wave speeds and attenuation. Such viscoelastic behaviour results from the stress-induced migration of vacancies and dislocations (extended defects reflecting prior or current deformation: see also Farla et al.). Equally, the stress-induced flow of fluids within cracked/porous media results in departures from elastic behaviour, termed poroelasticity. The following are highlights for 2008 of our ongoing study of rheology and seismic properties:

Hot-pressing and high-temperature deformation of titaniferous olivines (with U.H. Faul of Boston University): Work has continued this year towards an understanding of the influence of trace impurities on the rheology of fine-grained polycrystalline olivine. Specimens have been hot-pressed at 1300°C from sol-gel-derived Fo_{90} olivine precursors containing 0.1 wt % each CaO and TiO_2, and deformed at 1200-1300°C in compressive creep tests at progressively higher stress reaching ~300 MPa. Preliminary indications are that these materials (Fig. 1) undergo much more rapid grain growth than their Ti-free counterparts and are significantly weaker.

Seismic-wave dispersion and attenuation (with U.H. Faul, S.J.S. Morris of UC Berkeley, and D.R. Schmitt of the Univ. of Alberta): Our torsional forced-oscillation method for the study of high-temperature viscoelastic relaxation has recently been refined to take account of (i) compliance associated with frictional coupling between the specimen and neighbouring torsion rods, and (ii) significantly viscoelastic behaviour of the alumina control specimen [1]. Our published data concerning the shear modulus G and dissipation 1/Q for fine-grained melt-free and melt-bearing olivine have been re-processed with this improved strategy. Allowance for the compliant frictional coupling results in systematically higher G and lower 1/Q - especially for relatively coarse-grained (low-loss) materials tested at the highest temperatures (≥1200°C) and longest periods (>100 s). These effects are offset to some degree by allowance for the appreciably viscoelastic behaviour of the high-grade polycrystalline alumina control specimen. The interim result is an enhanced grain-size sensitivity of the viscoelastic relaxation (Fig. 2) meaning higher wavespeeds and lower attenuation on extrapolation to upper-mantle grain sizes. Additional experimental data for medium-coarse-grained materials are needed to underpin more robust extrapolation. Planned changes to the experimental procedure involving more active gripping of the cylindrical specimen and use of a single-crystal alumina control specimen may increase the signal/noise ratio for such low-loss materials. In a new initiative, our 'attenuation apparatus' is currently being modified to allow forced-oscillation measurements in extension/flexure, as well as torsion. Such measurements will allow the probing of poroelastic effects in cracked and fluid-saturated media that are analogues for upper-crustal rocks.

Modelling of elastic properties and equation of state (with B.L.N. Kennett): The thermodynamically consistent finite-strain model of Stixrude and Lithgow-Bertelloni (*GJI*, 2005) provides an attractive framework for the assessment and assimilation of experimental data concerning elastic properties and equation of state. The model requires the specification of 9 parameters: molar volume, (isotropic) bulk and shear moduli and their pressure derivatives, the effective Debye temperature, and the Grüneisen parameter and its volume and shear strain derivatives. We have explored the feasibility of using Sambridge's Neighbourhood Algorithm strategy (*GJI*, 1999) to undertake a guided search of the model space that is constrained simultaneously by diverse experimental datasets as an alternative to iterative least-squares fitting. This approach has been tested on data for MgO including measurements of specific heat and thermal expansion, static and shock compression, and the pressure and temperature dependence of elastic wavespeeds. The search converged on a unique model that adequately represents most of the experimental data, but not before revealing tensions between marginally incompatible datasets.

[1] Jackson, I, A. Barnhoorn, Y. Aizawa and C. Saint. Improved experimental procedures for the study of high-temperature viscoelastic relaxation, *Phys. Earth Planet. Interiors* (in press).

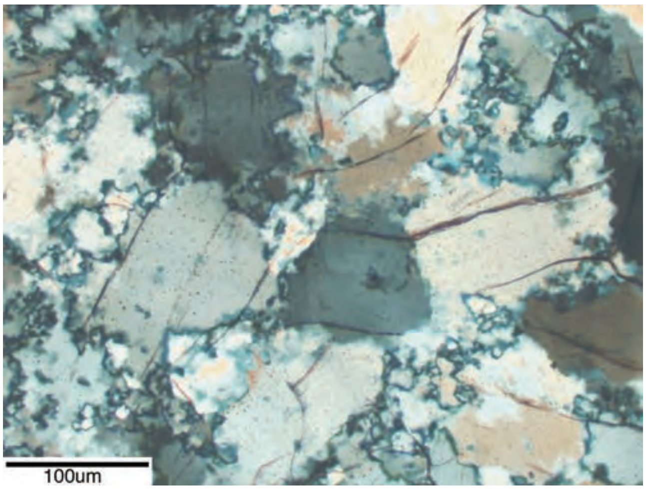

Figure 1

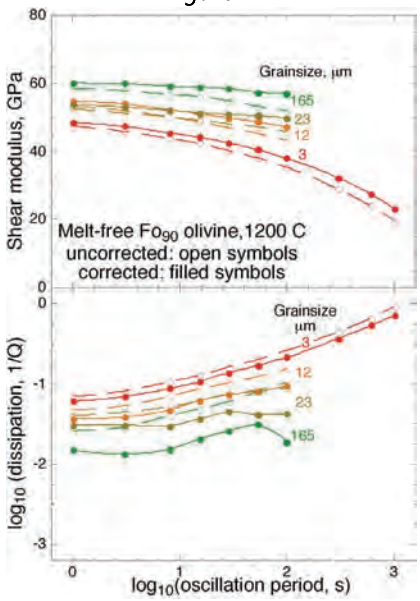

Figure 2

Exploration potential of stress transfer modelling in fault-related mineral deposits

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This project applies the principles of the triggering mechanisms and triggering effects of active fault systems to understand gold mineralisation in ancient fault systems. Earthquakes generate small elastic stress changes, which in turn trigger other earthquakes and many thousands of aftershocks. Each aftershock is a fault slip event that enhances the permeability of the crust and high-frequencies of aftershocks tend to occur on faults with the same dimensions as those faults that host gold mineralisation in Australian gold camps. Previously, we have shown that at crustal depths of 10-20 km, orogenic-type gold deposits occur where co-seismic stress changes around a fault are likely to have triggered clusters of aftershocks (Micklethwaite and Cox, 2004, 2006; Micklethwaite, 2007). Therefore Stress Transfer Modelling helps us understand the dynamics of ancient fault systems and acts as a valuable predictive tool for the exploration industry.

Stress Transfer Modelling is now being extended to gold mineralised fault systems that developed in near-surface crustal environments (1-6 km) during episodes of normal faulting and high geothermal gradients, such as the Carlin-type gold deposits.

Both earthquakes and intrusive events generate small elastic stress changes in the crust, which have been linked to the triggering of thousands of aftershocks and the enhancement of permeability. We developed stress transfer modelling (STM) to understand the dynamics of ancient fault systems and act as a valuable predictive tool for the exploration industry (Micklethwaite and Cox, 2004, 2006; Micklethwaite, 2007). We have also been able to link co-seismic stress changes to wall rock damage generation and permeability, using Damage Mechanics Theory (Sheldon and Micklethwaite, 2007).

In 2008, we applied STM to near-surface hydrothermal environments (0.5-2 km; Carlin goldfield, Nevada), and deep hydrothermal environments (15-25 km; Agnew goldfield, West Australia). In the Carlin goldfield, mineralisation is broadly stratiform but also related to the upper tips of ~5 km-long normal dip-slip faults. Debate exists as to whether fluid migration was controlled by active fault processes, reaction-enhanced porosity generated in specific lithologies, or convection through fracture networks that were indefinitely open due to the low confining stresses of near-surface environments. In the Agnew goldfield, mineralisation forms a linear trend of pod-like bodies on the western limb of a regional fold. Fault rocks containing ore-grade mineralisation are dominated by ductile shear textures, with only small percentages of brittle deformation textures such as breccias and veins. Metamorphic grades suggest the goldfield formed in the mid-crust possibly at the base of a structure, but it was not clear whether visco-elastic creep processes, or co-seismic damage controlled fluid migration and mineralization.

In both case studies, STM predictions were made in three dimensions, and it was demonstrated that mineralization could be matched by the unique stress patterns generated at the tips of fault ruptures; indicating co-seismic elastic stress changes are a first-order control on permeability enhancement and mineralisation. This potentially represents a breakthrough for Carlin-related research and promises to resolve a long-standing debate.

Micklethwaite, S. and Cox, S.F., 2004. Fault segment rupture, aftershock-zone fluid flow, and mineralization. *Geology*, 32, 813-816.
Micklethwaite, S. and Cox, S.F., 2006. Progressive fault triggering and fluid flow in aftershock domains. *Earth and Planetary Science Letters*, 250, 318-330.
Micklethwaite, S., 2007. The significance of strings and clusters of fault-related mesothermal lode gold mineralization. *Economic Geology*. 102, issue 6, 1157-1164.
Sheldon, H.A. and Micklethwaite, S., 2007. Damage and permeability around faults: Implications for mineralization. *Geology*, 35, 903-906.

Mineralisation

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Tectonic plate boundaries are the preferred location for economic mineralization, which appear to have been emplaced at specific time. This two-folded project proposes to re-examine tectonic evolution of the lithosphere along convergent and divergent boundaries. This project involves the development and application of the tectonic reconstruction tool, *Pplates*, in collaboration with Joe Kurtz and is also undertaken with the support from the DeBeers group.

Along convergent margins, subduction of lithospheric anomalies like seamount chain or oceanic plateau has the potential to vastly impact on the motion of tectonic plates. A famous example is the collision of the Ontong Java oceanic plateau along the New Guinea subduction zone to the north of Australia, which induced a drastic plate reorganisation involving subduction reversal in the SW Pacific. Based on previous works (Bonnardot et al., 2008), the first part of the project focuses on understanding the 3D geometry of slabs related to seafloor heterogeneities subduction and in particular, it focuses on the identification of slab tears, which may have a fundamental effect on the upper plate tectonic regime and on the porphyry deposits emplacement. We are currently revising the slab geometry in the Tonga, Sumatra and the South America subduction zones in regards to the tectonic evolution of the overriding plate, based on the analyse of the seismicity distribution and the stress regime within the involved lithospheric plates.

The second part of that project focuses on intracontinental rifting processes and aims at understanding the tectono-magmatic structures associated with anorogenic alkaline trends, for instance the relationship between transform faults/structural pattern of the mid-oceanic ridge and kimberlite emplacement.
Outcomes will allow refining plate motion in global tectonic reconstruction, as it will result in better quantifying the intraplate deformation that occurs during rifting initiation.

Bonnardot M.-A., Régnier M., Christova C., Ruellan E., Tric E. 2008. Seismological evidence for a slab detachment in the Tonga subduction zone. *Tectonophysics*, doi:10.1016/j.tecto.2008.10.01

Tectonic mode switches and the nature of orogenesis

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The birth and death of many mountain belts occurs in lithosphere that over-rides major subduction zones. Roll-back creates a gravitational potential well into which the orogen collapses. This motion, coupled with stress guides, can "pull" an orogen apart. A slowing of roll-back (or of hinge retreat) means that the subduction flexure may subsequently begin to be "pushed back" or be "pushed over" by the advancing orogen. The consequence of such changes in relative motion is that orogenic belts are affected by abrupt tectonic mode switches. The change from "push" to "pull" leads to a sudden change from horizontal extension to horizontal shortening, potentially throughout the entire mass of the orogenic lithosphere that over_rides the subducting slab. The sequencing of these tectonic mode switches affects the thermal evolution of the orogen, and thus fundamentally determines the nature of orogenesis. In consequence high pressure metamorphic rocks are found in orogens characterized by push-pull sequences while high temperature metamorphic rocks are found in orogens characterized by pull-push sequences (Lister and Forster, 2008).

However the real complexity evident in the evolution of any orogen begins to emerge once we begin to consider movement in three dimensions. Motion orthogonal to an arcuate mountain front is typical of the geometry of collapse, where the orogen has spread over or been pushed over the adjacent foreland. For example it can reasonably be inferred that the Tibetan crust collapsed southward to create the modern arcuate shape of the southern boundary of the Himalayan mountain chain (see Figure below). In fact the mountain front defines an almost perfect small circle, with a radius of 1696 $\pm$ 55 km (Bendick and Bilham, 2001). GPS measurements suggest this flow is still occurring: present day movement is taking place in directions orthogonal to the modern arc (Jade et al., 2004). England and Molnar (2005) provide a convincing argument that crustal flow in Tibet is driven by the gravitational potential energy of the collapsing orogen: in their words, the orogen behaves more like a 'fluid' than a 'plate'. Forward motion of the Indian indentor is accommodated in the west by the left-lateral Chaman fault zone on the boundary between Afghanistan and Pakistan, and in the east (in Myanmar) by the right-lateral Sagaing fault zone.

The main focus of the India-Asia collision is now in the NW, under the ranges of the Hindu Kush. The impact of an indentor can be inferred from the paired clusters of strike-slip faults. In the South, the small-circle geometry of the Himalayan mountain front is diagnostic of the fluid-like behaviour of this collapsing orogen, reflecting the impact of radiating viscous flow driven by the gravitational potential energy of the collapsing Tibetan Plateau. Thrusts radiate orthogonally from the orogenic welt defined by the Tibetan plateau, southward, northward, and eastward. The effects of eastward flow of the collapsing Tibetan Plateau is particularly evident in the fold and thrust belt in Sichuan Province, the locus of several catastrophic earthquakes (yellow dots in Figure).

In contrast, in the Myanmar crust, there are two almost orthogonal competing movement patterns. Shortening occurs in the foreland fold and thrust belt because this zone accommodates WSW directed motion of crust flowing out from the Myanmar hinterland. The Sagaing wrench fault zone marks the locus of accumulating right-lateral offsets, periodically accommodating distortions caused by relative plate motion. At the same time concentric left-lateral strike-slip faults accommodate flow around the eastern syntaxis, causing distortion of the Sagaing Fault. These concentric left-lateral strike-slip faults are most evident in the green lines that show the trend of fault plane slip vectors associated with left-lateral strike-slip earthquakes. As we move from north to south in a semicircle around the eastern syntaxis the movement direction associated with these earthquakes changes from towards ~90° to towards ~250°. This is a movement pattern that suggests mass flow in the deeper crust driven by the WSW-directed roll-back of the tearing Myanmar slab that lies beneath this zone.

Bendick, R., Bilham, R., 2001. How perfect is the Himalayan arc? Geology 29, 791-794, doi:10.1130/0091-7613(2001)029<0791:HPITHA>2.0.CO;2

England, P., Molnar, P., 2005. Late Quaternary to decadal velocity fields in Asia. Journal of Geophysical Research _110, B12401, doi:10.1029/2004jb003541.

Jade, S., Bhatt, B.C., Yang, Z., Bendick, R., Gaur, V.K., Molnar, P., Anand, M.B., Kumar, D., 2004. GPS measurements from the Ladakh Himalaya, India: preliminary tests of plate-like or continuous deformation in Tibet. Geol. Soc. Amer., Bull. 116, 1385–1391, doi:10.1130/B25357.1

Lister, G. and Forster, M. 2008. Tectonics mode switches and the nature of orogenesis. Lithos, in press.

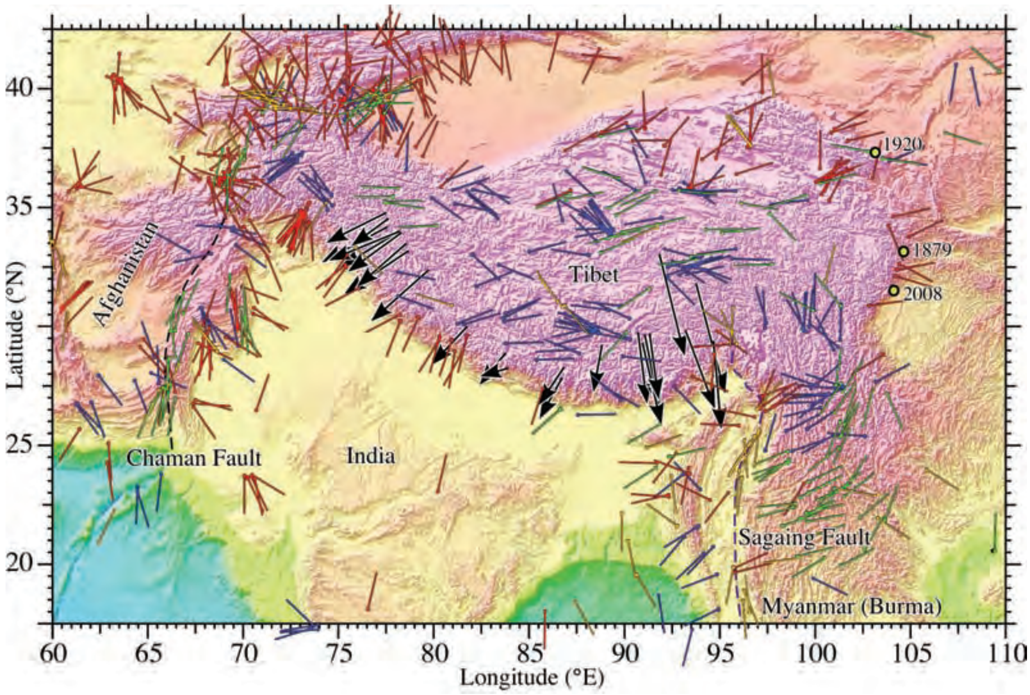

Figure 1. Geometry of a mountain front reflecting the impact of collapse driven by the gravitational potential energy of the orogen. Arrows show GPS motions relative to India (after Jade et al., 2004). The coloured slip lines stem from epicenters of 575 earthquakes in the period 1976-2006 in the depth range 0-60 km, as recorded in the Harvard Centroid Moment Tensor database (http:/ www.seismology.harvard.edu/CMTsearch.html). Map produced using Program eQuakes superimposed on images derived from NOAA (http://ibis.grdl.noaa.gov/cgi-bin/bathy bathD.pl). Each slip line shown represents a choice of one of two conjugate fault plane solutions derived from the centroid moment tensor: each choice based on details of the local geology. Thrusts (red), normal faults (blue), left-lateral strike-slip faults (green) and right lateral (yellow). Motion orthogonal to the mountain front is typical of the geometry of collapse where the orogen has spread over, or been pushed over the adjacent descending slab. Left-lateral Chaman fault zone (dashed) in the west (a). Right-lateral Sagaing fault zone (dashed) in the east (b).

Episodic emplacement of the Ladakh and Karakoram Batholiths

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Preliminary U-Pb SHRIMP dating of zircon grains from the Ladakh and Karakoram batholiths confirms some of the previously published ages for the two batholiths, but also indicates that older crust (possibly associated with the Tibetan slab) may have been involved with the Karakoram Bathoiith.

Samples of the Ladakh Batholith were collected from Khardung La and Chang La in Ladakh, NW India. These samples obtained an age of circa 58 Ma, similar to the age data published by earlier workers (e.g. Singh et al. 2007). This confirms that there was a strong phase of magmatism in the Ladakh Batholith at approximately 58 Ma.

Samples of the Karakoram Batholith were collected near Tangste Gompa and obtained an age of circa 32 Ma. One zircon grain from this sample also gave a late Permian age, which could indicate that older crust is associated with the Karakoram Batholith. One sample of a cross-cutting dyke collected in the Tangste Gorge (Figure 1 and 2) gave an age of circa 18 Ma. This is consistent with earlier published data that was associated with movement on the Karakoram Fault. Another sample of the Karakoram Batholith obtained an age of circa 102 Ma. Again, this is consistent with a date published for the same Batholith in Pakistan.

This study confirms many of the earlier published dates of the Ladakh and Karakoram batholiths. However, our preliminary work also shows that attention must be paid to younger phases of magmatism that cross-cut older phases of magmatism.

Singh, S. Kumar, R., Barley, M. E., Jain, A. K. 2007. SHRIMP U-Pb ages and depth of emplacement of Ladakh Batholith, Eastern Ladakh, India. *Journal of Asian Earth Sciences* **30**: 490-503

Figure 1. Aplite dyke cross-cutting an earlier migmatitic phase of the Karakoram Batholith, Tangste Gorge, Northwest India.

Figure 2. Tangste Gorge, Ladakh, Northwest India

Earth Physics

Research into the structure and dynamics of the Earth uses a range of physical and mathematical techniques and is grouped into the three main themes of Seismology and Mathematical Geophysics, Geophysical Fluid Dynamics, and Geodynamics and Geodesy. The work spans observational, theoretical, laboratory, computational and data oriented studies, all directed towards understanding the structure and physical processes in the earth's interior, the crust or the earth's fluid envelope.

Two members of the Earth Physics academic staff received awards this year. Prof B.L.N. Kennett received the Gold medal in Geophysics from the Royal Astronomical Society, London, for his work in seismology and the Peter Baume Award from ANU for his exemplary record of research achievement and leadership. Prof K. Lambeck contributed to the award of the Nobel Peace Prize for 2007 to the Intergovernmental Panel on Climate Change (IPCC), as a substantial contributor to the IPCC since the inception of the organization.

PhD theses were submitted by T. Prastowo ("Mixing in buoyancy-driven exchange flows"), M. Coman ("Convective circulation forced by horizontal gradients in heating"), J.Dawson ("Satellite radar interferometry with application to the observation of surface deformation in Australia")and G. Estermann ("Contribution of mountain glacier melting to sea-level changes: Recent past and future"). New Postdoctoral academic staff commencing during 2008 include M. Ward in ocean modeling, S. Pozgay and A. Coffey in seismology, G. Luton on geodesy and S. Bonnefoy in computational geophysics.

RSES is taking a major role in Component 13 of the National Cooperative Research Infrastructure Strategy (NCRIS): "Structure and Evolution of the Australian Continent", which is managed through 'AuScope'. RSES hosts activities in Earth Imaging through support of portable instrumentation and transects, Geospatial through gravity measurements and testing of portable equipment for satellite laser ranging, and Simulation & Modelling through 'pPlates' software for tectonic reconstruction. As a linked activity between three AuScope components (Imaging, Geospatial and Access and Interoperability), the Terrawulf II cluster computer at RSES provides capability in geophysical inversion and the computation reduction of observational data.

Acting Director Prof. Ross Griffiths launching the Terrawulf II computational facility in June at RSES. TII is the latest in a long line of Geoscience computational facilities at RSES stretching back 30 years. Projects initiated in 2008 range from atmospheric effects in GPS, through ocean modeling to studies of the Earth core and geodynamo.

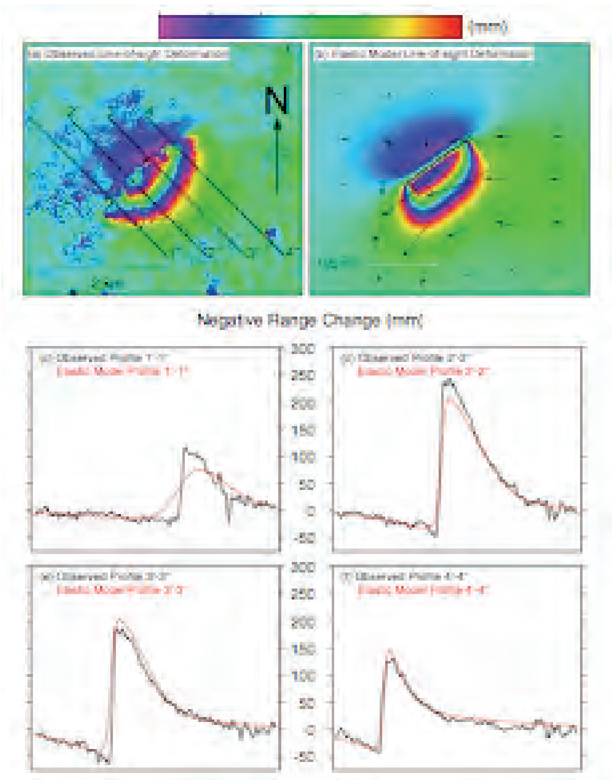
Centre for Advanced Data Inference

In the Centre for Advanced Data Inference a new, more powerful compute cluster, Terrawulf II, was commissioned early this year. The new cluster was made possible by NCRIS funding combined with support from RSES. Terrawulf II consists of 96 dual processor dual core 2.8GHz Opteron systems with 8GB of memory per node, connected with Gigabit Ethernet. Half of the nodes are also connected through higher bandwidth switches, which significantly extend the range of potential applications of the cluster to both `tight' and `loosely' coupled codes. The Terrawulf II cluster is integrated into the AuScope grid and used for a broad range of geoscience data processing as well as continuing development of state of the art inversion and data inference software.

Geodynamics and geodesy

The geodynamics group within Earth Physics is involved in the Geospatial component of AuScope. NCRIS funding in this strand has enabled investment in geodetic infrastructure throughout Australia, including three new Very Long Baseline Interferometry (VLBI) sites, a national Global Navigation Satellite System (GNSS), terrestrial gravimeters, a test of a mobile Satellite Laser Ranging (SLR) system and a contribution towards the new Terrawulf II compute cluster. Members of the geodynamics group are involved in the AuScope Executive Committee, the Geospatial Steering Committee as well as the gravity, VLBI and Grid Computing subcommittees charged directly with the acquisition and deployment of the infrastructure. The ANU component of the above equipment includes an FG5 absolute gravimeter (acquired in April 2008), a relative gravimeter (acquired in July 2008), a gravity technician and a SLR technician. Dr Jason Zhang, the SLR technician, was involved in instrument testing at Burnie, Tasmania early in 2008 while Mr Geoff Luton has been involved in FG5 observations in Melbourne, Hobart and Western Australia.

The InSAR analysis of small, shallow earthquakes in Western Australia demonstrated the capability of the technique to not only estimate fault plane location, orientation and depth but also to estimate the distribution of slip on the fault plane (Dawson et al., 2008). The stress drop for the Mw=4.7 Katanning earthquake was found to be 14-27 MPa, significantly smaller than expected for such as small event. This suggests that the seismic hazard of small earthquakes might be higher than previously thought.



Observed and modelled interferograms of deformation caused by the Katanning rthquake. Observed and modelled changes in round-satellite distance is shown across four different profiles (Dawson et al., 2008).

A combination of surface deformation from GPS and inferred deformation from changes in the Earth's gravity field from the Gravity Recovery and Climate Experiment (GRACE) have been undertaken to separate short-term hydrological variations from longer-term glacial isostatic adjustment as a result of melting of polar ice sheets since the Last Glacial Maximum. Coupled with continued advances in the analysis strategies of the raw GPS observations, these studies have revealed that both the GPS and GRACE estimates of surface deformation agree at the 1-2 mm level and mm/yr level, enabling highly accurate estimates of crustal deformation to be made.

Successful field experiments have been undertaken using the new gravimeters in Melbourne, Hobart and several sites in Western Australia. The GPS field programme in Papua New Guinea concluded this year while coral sampling in the Ningaloo Reef region continued in order to understand past levels of relative sea level.

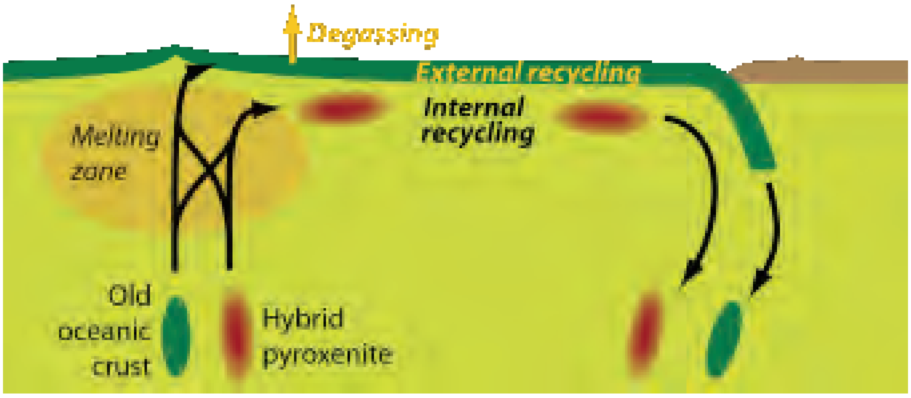
Geophysical fluid dynamics.

Highlights of work in geophysical fluid dynamics this year included laboratory and theoretical fluid dynamics studies modelling lava flows, where cooling, solidification and yield-strength are important factors. Experiments have focused on the flow of yield-strength fluid that is also cooling and solidifying as it flows down a sloping channel. A variety of inertial, viscous, plastic and cooling-controlled flow regimes have been found.

The geophysical fluid dynamics laboratory has also seen a renewed effort to understand the three-dimensional flow in mantle subduction zones, including the influences of an over-riding plate, back-arc spreading, the effects of a thick keel on the over-riding plate, and the behaviour of a hot mantle plume ascending under the over-riding plate. This work relied on an extended visit by Prof Kincaid and a student from the University of Rhode Island. The interaction of ascending mantle plumes and subduction zones is being examined with a view to explaining the distribution and ages of the Columbia River Basalts and volcanism of the Yellowstone hotspot. The work has shown that previously unsuspected patterns of volcanism can be produced and many aspects of the volcanism, including the age distributions, around Yellowstone and the Lava High Plains of the northwest USA can be explained by interaction of a plume and subduction zone.

Lessons learnt from several years of numerical modelling of the combined chemical and thermal evolution of the mantle are now bearing fruit in two directions. The models are being extended to Venus' mantle to test whether the 'basalt barrier' mechanism, reported last year, can explain the outburst of volcanism that completely resurfaced Venus about 500 Myr ago. Initial results are promising.

The insights from the numerical modelling have also fed into a new hypothesis to reconcile mantle chemistry with mantle dynamics. The idea is that only a fraction of the melt generated under a mid-ocean ridge actually reaches the surface. The remaining melt is trapped in the mantle, and carries the so-called incompatible elements. This hypothesis removes the need for a postulated deep, hidden reservoir containing 'missing' incompatible elements. It can also explain the presence of enigmatic 'unradiogenic' helium and other noble gases that emanate from some hotspot volcanos.

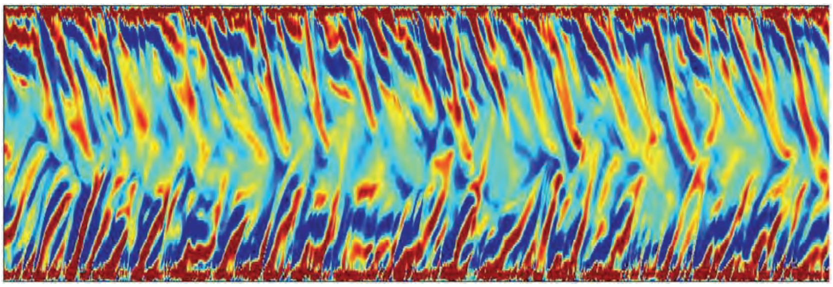


Cartoon of how noble gases may be partially retained in the mantle despite losses due to melting under mid-ocean ridges. Some of the melt is trapped, in the form of hybrid pyroxenite, and recycled internally without losing its gases. The melt that reaches the surface forms oceanic crust that degasses.

Studies of the fundamental dynamics of the ocean's meridional overturning circulation continued in the geophysical fluid dynamics laboratory. A new approach to the energetics of the circulation developed this year has elucidated the way in which energy supplied to irreversible turbulent mixing from the winds and tides must be in balance with the available potential energy supplied by the surface buoyancy fluxes. The two are closely tied, the buoyancy fluxes providing the driving force while the turbulent mixing maintains the stratification, and hence the strength of the forcing and the consequent rate of overturning. Numerical solutions have revealed the presence of significant internal gravity wave activity generated by the convection. It will require further work to determine whether there is likely to be substantial wave generation under oceanic conditions, and whether the wave energy can contribute to the vertical mixing. The steady-state dynamics were also examined in experiments with the case of a large ocean basin connected to a marginal sea by flow over a topographic sill. The exchange flow can influence the circulation and stratification in the ocean.

A video clip (available on-line) of flow in the laboratory convection model, in which the base is heated near both ends and cooled over the central half. The right hand section of the base is heated by an applied heat input 10% smaller than that applied to the left hand section of the base. Hence the plume at the left hand end is stronger than that at the right end and fills the top of the box. In the oceans this is analogous to the strongest sinking region producing the bottom waters.

In other experiments the response to small changes in the surface boundary conditions, such those as implied by global warming, has been investigated. The conditions leading to a potential shutdown of the deep sinking leg of the overturning circulation in simplified cases have been outlined. A first set of experiments with periodic oscillatory surface forcing is also providing insights into whether the global circulation is influenced by fluctuations having periods from the annual seasonal cycle (which is known to force variations in the deep sinking of cold waters) to millennia (which is the time scale for complete equilibration of the stratification to new surface conditions).

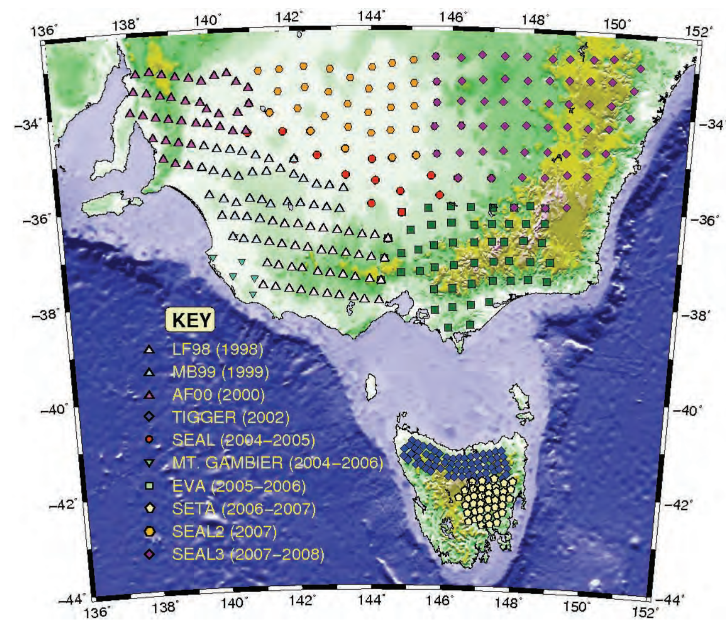


Hovmöller plot of the vertical velocity along a horizontal section at mid-depth from a 2-D numerical simulation of horizontal convection. Time increases upwards; blue represents upwelling motion, green approximately no motion, and red downwelling motion. Regions of high latitude sinking are situated in this case at both the left and right hand ends of the horizontal section, and excite strong wave modes that propagate towards 'low latitudes' at the centre of the section. These waves and their interactions appear to be responsible for much of the variability in the circulation.

In another laboratory study, the dynamics of wakes behind islands and headlands were shown to be sensitive to eddy disturbances or turbulence carried from upstream of the topographic feature. The incident disturbances cause a faster dissipation of wake instabilities with distance downstream, hence a smaller recirculation region. This study is currently being extended to a practical application involving the dispersion of wastewater released into a major estuary in which there is a separation of the flow in the main channel and a relatively slow flushing of a shallow region to one side. Preliminary experiments in a water flume are exploring the roles of wastewater outflow location and tides on the flushing time.

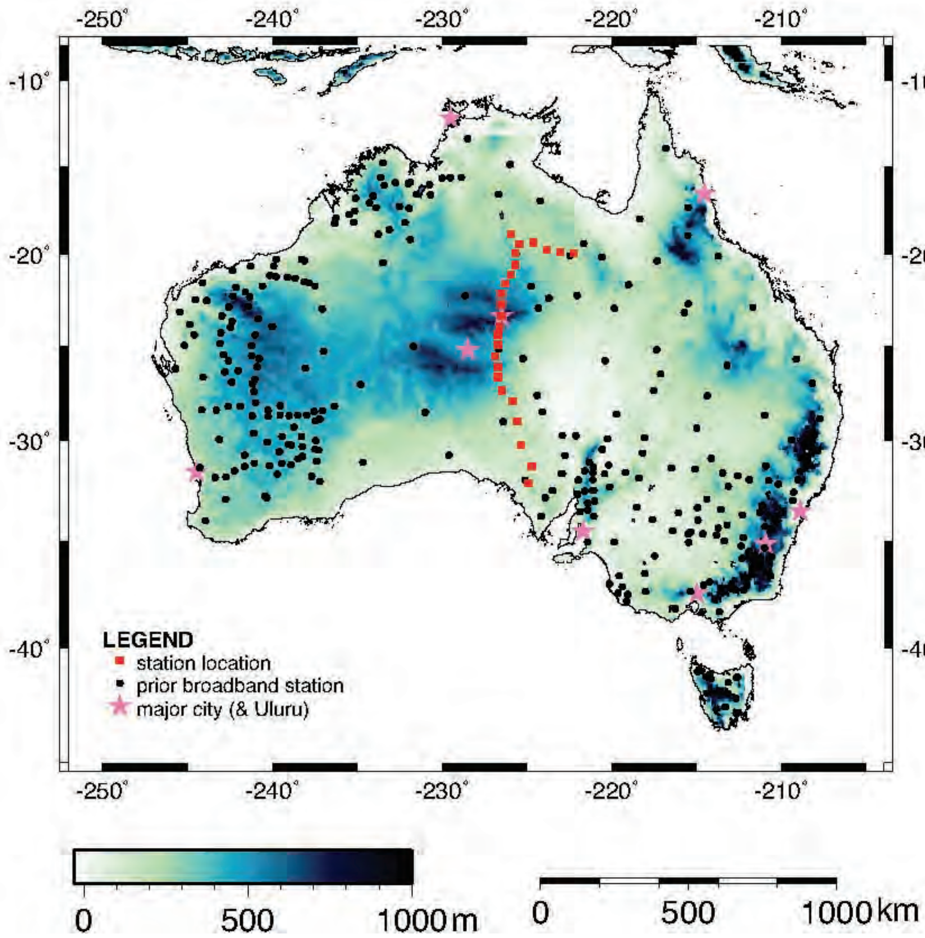
Seismology.

2008 was an eventful year for seismic experiments, with the deployment of two new arrays, and the continued maintenance of the SEAL3 array which was deployed in late 2007. SEAL3 comprises 57 3-component short period stations distributed throughout southeast New South Wales at a spacing of approximately 50 km. With a recording period in excess of 1 year, this study has substantially contributed to the cumulative coverage of passive seismic data in southeast Australia. To date, nearly 400 sites have been occupied in Tasmania, Victoria, South Australia and New South Wales. Teleseismic tomography, ambient noise tomography, receiver functions and core phase studies are currently in progress using SEAL3 and pre-existing data.



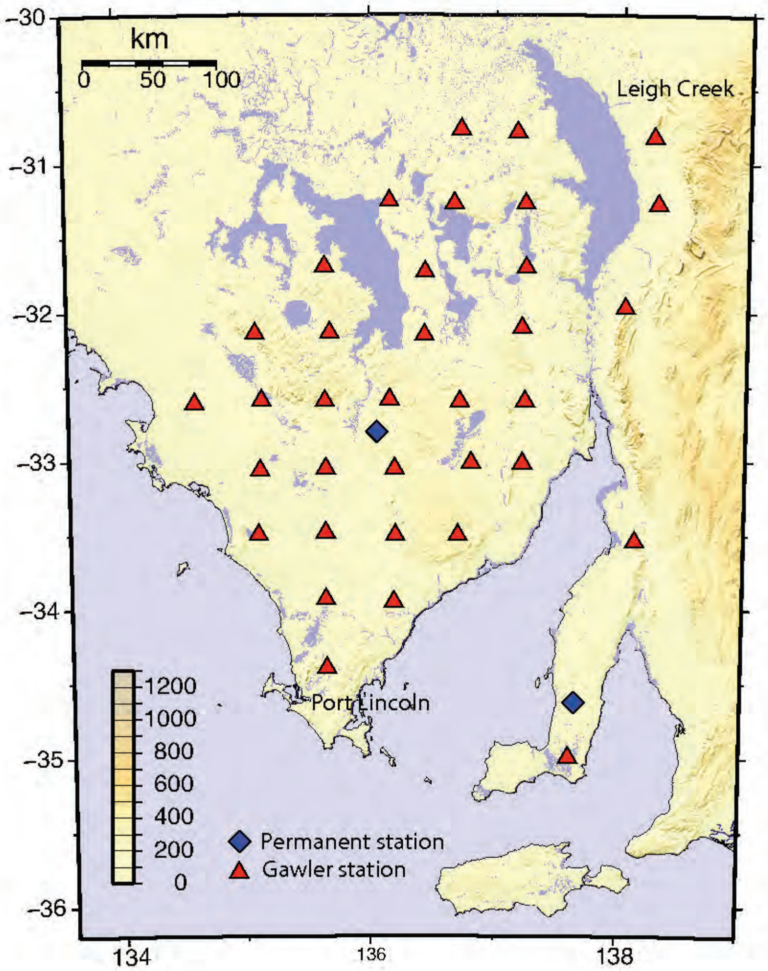
Location of all short period seismic arrays deployed in southeast Australia over the last 10 years.

In order to determine the nature of the transition at lithospheric depths between the northern and southern Australian cratons, a transect of 25 broadband seismic stations was deployed between the Eyre Peninsula in South Australia and Tennant Creek in the Northern Territory. The installation took place in August-September 2008, with all stations expected to remain in operation for at least one year. With a site spacing of between 60-90 km, receiver functions, shear wave splitting and traveltime inversion can be utilized to help address fundamental questions relating to the anomalously slow velocities beneath the central Australian intercratonic structures, and how they propagate with depth.



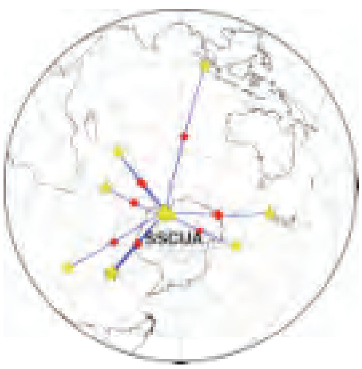
Bilby array comprising 25 boradband seismometers deployed in central Australia.

In June-July 2008, an array of 35 short period seismometers was installed across the Gawlor Craton in South Australia for an eight month period. Station spacing is approximately 50 km and the area covered runs from Port Lincoln in the Eyre Peninsular to Leigh Creek just west of the Flinders Ranges. The primary aim of this array is to increase passive data coverage in this part of Australia for seismic imaging, which includes teleseismic tomography and receiver function analysis. Local earthquakes, which are relatively plentiful in this part of Australia, will also be exploited to improve structural constraints. The eastern edge of the Gawler craton is currently of particular interest for the supply of geothermal energy and there are many ongoing industry projects in the area. Geoscience Australia completed a deep seismic reflection transect across the top of the Eyre Peninsular just prior to the deployment of the Gawler array. This array will provide broad scale earth imaging required for more detailed studies.



Short period array deployed across the Gawler craton in mid 2008.

In 2008 the conversion of a large portion of our seismic data from past experiments to an international standard format called "miniseed" was accomplished. This is the first step in building a continuous archive of data, which is now easily accessible by local researchers through a java acquisition tool called Seismic Data Centre (SDC). About one half of our data has been converted and it is a work in progress. In other projects it was shown that it is not feasible to use 1D structural model for Australia when inverting for source parameters of large earthquakes surrounding Australia, and that a 3D model will be needed for the computation of Green's functions. This work is important in the context of the Tsunami warming for Australia. Work also commenced on the lithospheric structure of the Balkans peninsula using receiver functions, and an interactive tool (java) for forward modelling of receiver functions was completed. A large dataset from Antarctica was used to examine current hypotheses about the core anisotropy and structure showing in particular that the Antarctic data do not support the existence of significant heterogeneity in the outer core Taylor cylinder.



Distribution of events (stars) with clear PcP arrivals recorded at SSCUA stations in Antarctica (triangles). The red diamonds are bouncing points of the PcP waves at the CM

Ambient noise tomography in Southeast Australia

Pierre Arroucau[1], Nick Rawlinson[1] and Malcolm Sambridge[1]

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Previous studies have demonstrated that the Green's function of the medium between two stations can be extracted from the cross-correlation of the seismic ambient noise wavefield recorded at these stations. This class of technique is now progressively becoming a standard seismic investigation tool and has successfully been used for tomographic imaging purpose in many parts of the world. Saygin (2007) obtained encouraging results for the Australian continent using broadband records, and showed that Rayleigh wave group velocity contrasts within Australia correlated well with its major geological units.

In the last decade, dense rolling short-period seismic array deployments have been carried out by RSES in Southeast Australia (WOMBAT-SE). With an interstation distance of a few tens of km, several months of continuous records and a cumulative total of approximately 400 stations, these temporary arrays provide an unique opportunity for high-resolution ambient noise imaging in the region, which can address fundamental questions regarding the structure and tectonic evolution of the Lachlan and Delamarian orogens, which underpin the southern half of Palaeozoic eastern Australia.

Dispersion curves constructed form the cross-correlation of the vertical component, by means of frequency-time analysis for periods ranging between 1 to 20s, have been used to extract Rayleigh wave group traveltimes. An iterative non-linear tomographic scheme based on the fast marching method, a grid-based eikonal solver, and a subspace inversion method, was used to map the traveltimes as variations in Rayleigh group wavespeeds at different frequencies.

Saygin, E, (2007) Seismic Receiver and Noise Correlation Based Studies in Australia. *PhD Thesis, The Australian national university*, 175p.

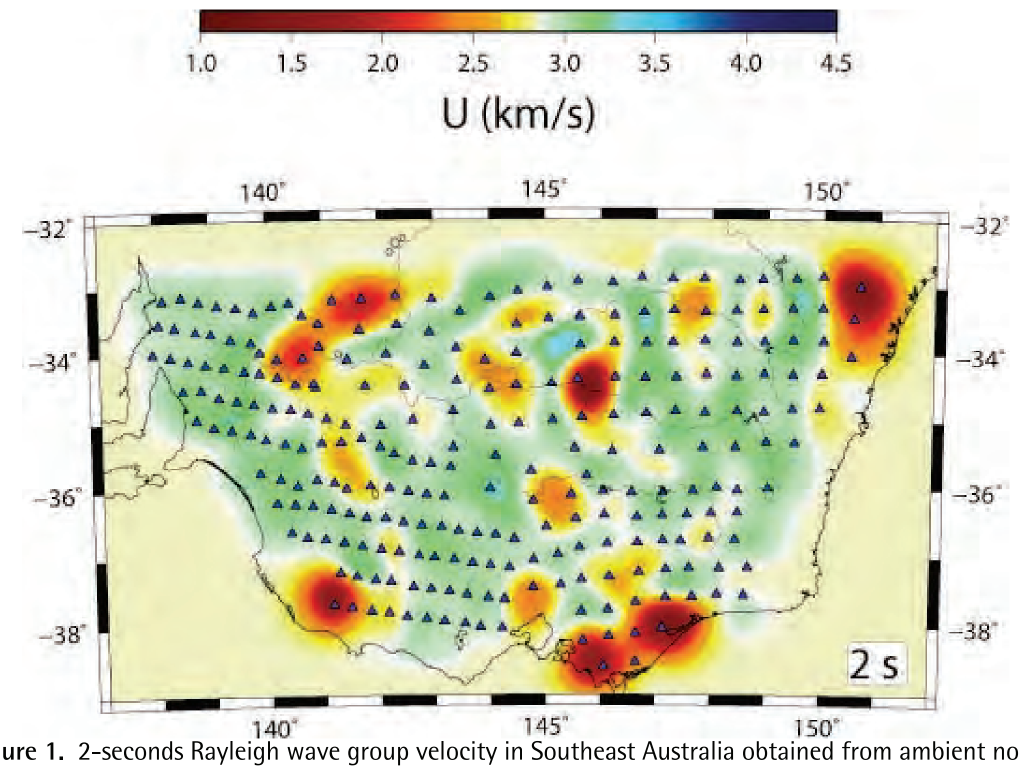

Figure 1. 2-seconds Rayleigh wave group velocity in Southeast Australia obtained from ambient noise cross-correlation of the vertical component for simultaneously recording pairs of stations. The stations used belong to 10 temporary arrays of short-period instruments deployed in the last decade.

Seismic Tomography With a Transdimensional Markov Chain

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In seismic tomography, the Earth's interior must be parametrized in some fashion. This is typically done using uniform local cells, and the inversion process consists of finding seismic wave speeds within each cell. The number of cells (and size) has to be chosen according to a compromise between model resolution and model uncertainty. Usually, seismologists choose to have a large number of cells and then face the problem of non-uniqueness by imposing constraints on the solution that are independent of the observations, i.e. by employing regularization procedures like spatial smoothing and norm damping. The type and weighting applied to regularization terms often forms a subjective choice of the user. Another aspect is that the strength of damping and smoothing is determined globally which raises the possibility that, while the ill-constrained regions are being suitably damped, the well constrained regions may be over-smoothed with resulting loss of information from the data.

Our work this year has been devoted to using some new ideas in nonlinear inversion to determine the model dimension (i.e. the number of cells) during the inversion. Treating the number of unkowns as an unknown itself has received little attention in geophysics. However, for more than 10 years, Markov chain Monte Carlo (MCMC) methods that admit transitions between states of differing dimension have been actively developed in the area of Bayesian statistics.

We have developed an approach which uses Voronoi cells instead of a regular mesh for an Earth parametrization (see Figure 1). The Voronoi cells are defined by their centres which are able to move. That is, the number and the position of the cells defining the geometry of the velocity field, as well as the velocity field itself are unknowns in the inversion. The inversion is carried out with a fully non-linear parameter search method based on a trans-dimensional Markov chain.

At each step of the chain, a change from the current model is proposed : we either change the velocity or the position of one random cell. The algorithm also allows jumps between dimensions by adding or removing random cells. The forward problem is computed and provides new estimated travel times. The new misfit to observed travel times is compared to that of the current model. The proposed model is either accepted or rejected using a predefined probabilistic threshold.

The Markov chain produces an ensemble of models with different dimensions which carries relevant statistic information about the unknown velocity field. The method takes as a solution the average of this family of models. Each model in the ensemble has a different parametrization but the average is continuous without obvious 'parametrization' artefacts. The standard deviation of the ensemble forms a continuous map and can be used as a proxy for the error for the solution model.

The method has been tested on synthetic situations where the ray coverage is not uniform and where the parametrisation is an issue (see Figure 2). A major advantage is that explicit regularisation of the model parameters is not required, thus avoiding global damping procedures and the need to find an optimal regularisation value. The technique has also been tested on real data and gives promising results.

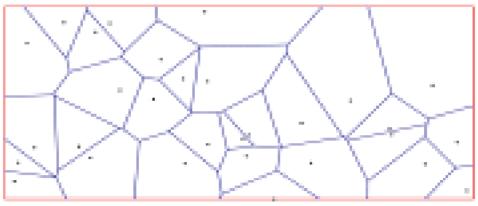


Figure 1: Voronoi cells about 30 pseudo random points on the plane. The cell nuclei have been drawn from a 2-D uniform distribution over the spatial domain delimited by the red rectangle. The cell boundaries are defined as the perpendicular bisectors of pairs of nuclei. Any point inside a cell is closer to the nucleus of that cell than any other nucleus.

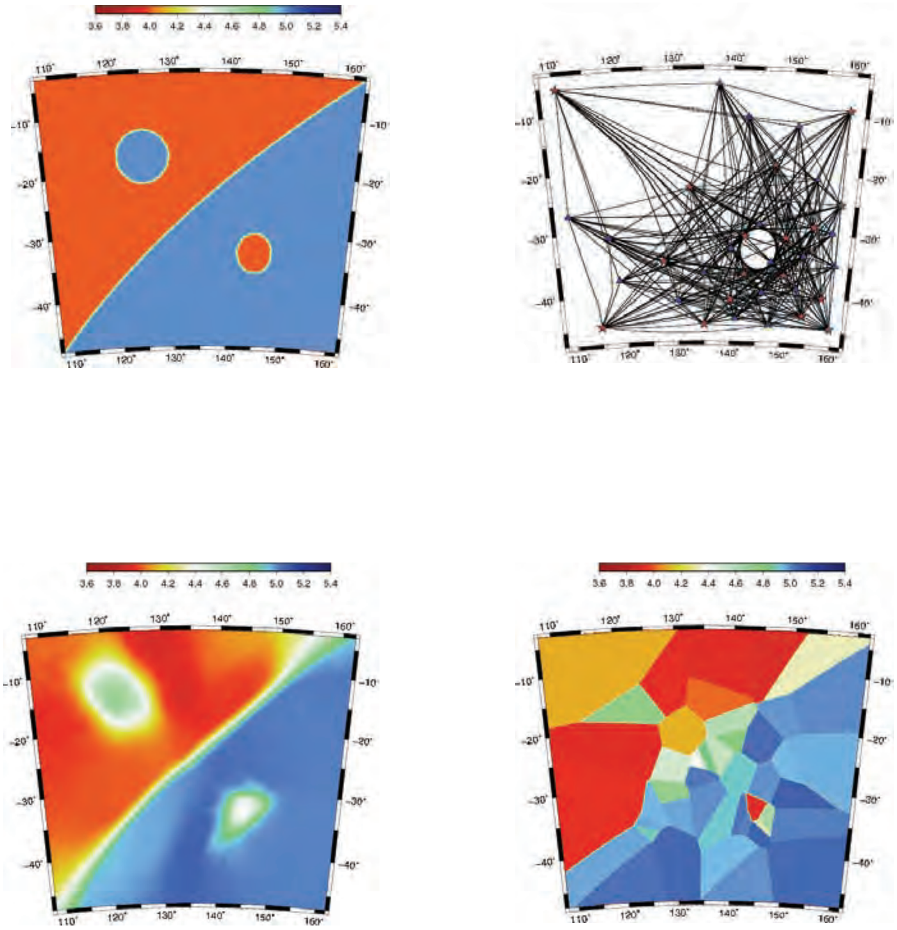


Figure 2 : Upper left map shows the true model. The upper right map shows the ray geometry. The lower left map shows the model sampled with the best fit to the data and the lower right map shows the average estimated solution.

Terrawulf II

Malcolm Sambridge[1], Herb McQueen[1], Shinta Bonnefoy[1]

[1] *Research School of Earth Sciences, Australian National University, Canberra, ACT 0200, Australia*

TerraWulf is a networked cluster of computers set up in RSES to provide convenient high end computing power for a range of demanding geoscience problems. A major upgrade of the TerraWulf compute cluster was recently made possible by funding support from the National Collaborative Research Infrastructure Strategy (NCRIS) under the AuScope umbrella. Contributions from the AuScope Geospatial, Imaging and Structure, and Access and Interoperability components combined with support from RSES have enabled the construction of a new and more powerful cluster. The hardware was delivered and assembled in 2007 and commissioning and benchmarking continued through the first half of 2008.

On Friday 27th June 2008 TerraWulf II was launched at the Research School of Earth Sciences by Acting Director Prof. Ross Griffiths. It has a total of 24 Tb of disk storage and 1Tb of RAM and was built to tackle large complex computational problems in the Earth Sciences using parallel processing techniques. 'TII', is the latest in a long line of Geoscience computing platforms at the RSES which stretch back more than 30 years. Projects initially identified for TII include applications in seismic imaging of Earth structure, geospatial data analysis and mathematical geophysics. TII is open for access by the Australian Earth Science community for projects consistent with the AuScope vision to '...characterise the structure and evolution of the Australian continent from surface to core in space and time.' It is accessible directly through a local account and via the AuScope grid.

The main cluster consists of 96 nodes (384 processor cores) connected through Gigabit and Infiniband switches which support a range of potential applications of the cluster including both `tight' and `loosely coupled' codes. Each node is an IBM System x3455 with 2 AMD Opteron Dual-core 2.8 GHz processors, 160 GB local disk and 9GB to 17GB RAM. All the nodes are interconnected through SMC8848 Gigabit Ethernet switches, and half of the cluster is also inter-connected via three 24port Voltaire ISR9024S Infiniband switches providing 10Gbit inter-process communication. Compute nodes are configured with Open SUSE 10.3 and two kinds of MPI environment, MPICH2 and VLTMPI, have been installed to enhance paralled processing applications. It is accessible directly through a local account and via the AuScope grid.

The TerraWulf II cluster is now running a variety of geoscience data processing, technique development, simulation and analysis codes. Current projects include studies of atmospheric effects in GPS analysis, ocean overturning circulation and Earth's inner core structure & geodynamo, as well as multi-arrival wavefront tracking seismic tomography, inversion of airborne electromagnetic data, development of nonlinear inversion methods, implementation of earthquake source parameter inversion, and high-resolution ambient noise tomography.

Figure 1.

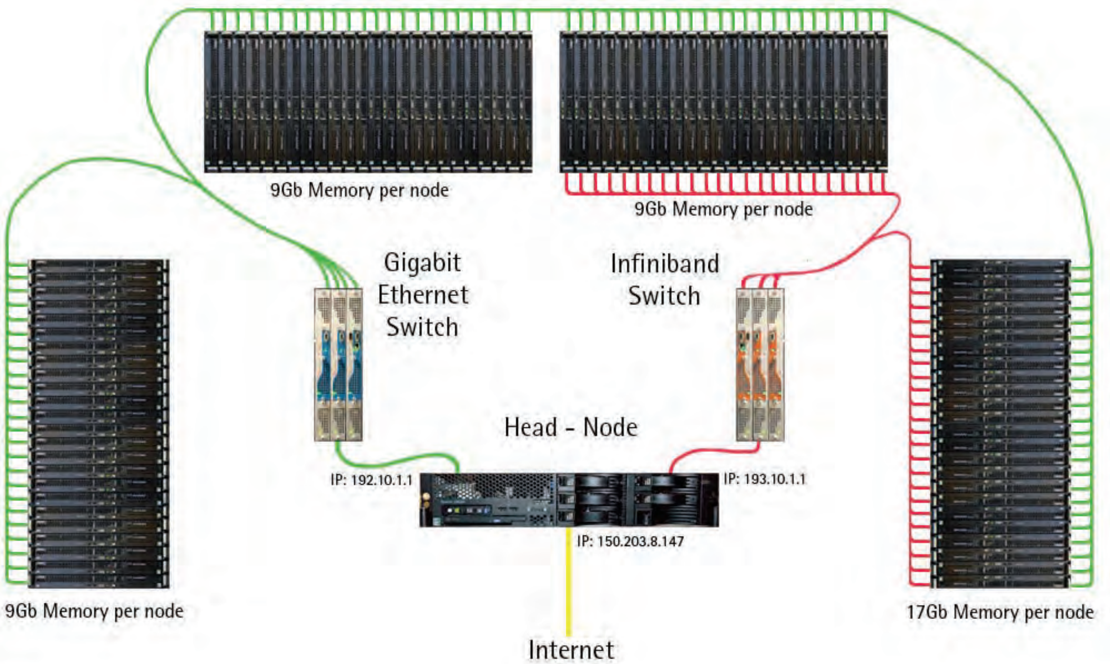


Figure 2.

Holistic inversion of time-domain airborne electromagnetic data

Ross Brodie[1] and Malcolm Sanbridge[1]

[1] *Research School of Earth Sciences, Australian National University, Canberra, ACT 0200, Australia*

Since the research on this project resumed in August 2008 we have been investigating the feasibility of applying our holistic inversion technique to time-domain airborne electromagnetic (AEM) data. Holistic inversion was originally developed to invert frequency-domain AEM data to solve for continuous 3D survey wide conductivity model while simultaneously solving for systematic calibration errors (e.g., scaling effects, phase shifts and zero-level bias) which often degrade frequency-domain data (Brodie and Sambridge, 2006).

One of the challenging 'calibration' issues in fixed-wing time-domain AEM is the fact that the position and attitude of the receiver coils, which are towed ~120m behind and ~40m below the aircraft, cannot be accurately measured under normal operating conditions. This receiver geometry information is a critical input into quantitative modelling and inversion routines. Conventionally the receiver coils' position are estimated from the measured AEM data during the routine data processing. However this requires assumptions to be made about the conductivity of the subsurface and the attitude of the receiver coils. When these assumptions are poor the estimated receiver position is not accurate, which results in the data not being able to be fitted and/or inaccurate conductivity models being estimated from subsequent inversions. More recently it has been demonstrated that a better approach is to simultaneously invert for the system geometry and the conductivity model (Lane et al., 2004).

The fixed-wing time-domain holistic inversion we improve on this by inverting not just one sample of AEM data at a time but a whole flight line of data. Figure 1 shows a schematic outline of the elements of the inversion formulation. We solve for layer conductivities, the transmitter to receiver in-line (D_x) and vertical separations (D_z), and the receiver pitch (R_p). All of these are parameterized as along line 1D cubic B-splines. Splines are an ideal choice because they are able to naturally represent the smooth and continuous along line variation of receiver geometry that occurs in reality. In doing so we are able to exploit the along line coherency, which is not accessible to the conventional sample by sample inversion, to improve upon the accuracy and stability of the inversion.

As a demonstration of the improvement that the new method offers, we have inverted a flight line of data that was acquired with the TEMPEST system using the two techniques. Figure 2 shows the results using a conventional inversion in which we solve for the layer conductivities independently for each airborne sample point and stitch the results together post-inversion to form a conductivity section. We did not solve for the receiver geometry. Figure 3 shows the results for the holistic method where we inverted the whole line at once to solve for the layer conductivities and three receiver geometry parameters, each parameterized as along line splines.

In the holistic inversion the data was able to be fitted to the expected misfit value of 1. However they were not able to be fitted in the conventional inversion due to inaccurate receiver geometry estimates made during the data processing. The holistic inversion conductivity section does not have the numerous vertical artefacts that are apparent in the conventional inversion section. This makes it more geologically realistic and continuous, and thus easier to interpret/trace subtle features. As a means of gauging the relative accuracy of the methods via independent ground truth two downhole conductivity logs (GW800232 and LMQ03) are plotted over the conductivity sections in the same color lookup scheme. It can be seen that in the vicinity of both logs the holistic inversion more accurately reproduces the downhole logs.

Brodie RC, Sambridge M (2006) A holistic approach to inversion of frequency-domain airborne EM data. *Geophysics* **71**: G301–G312

Lane R, Brodie RC, Fitzpatrick A (2004) Constrained inversion of AEM data from the Lower Balonne Area, Southern Queensland, Australia. *CRC LEME open file report* **163**

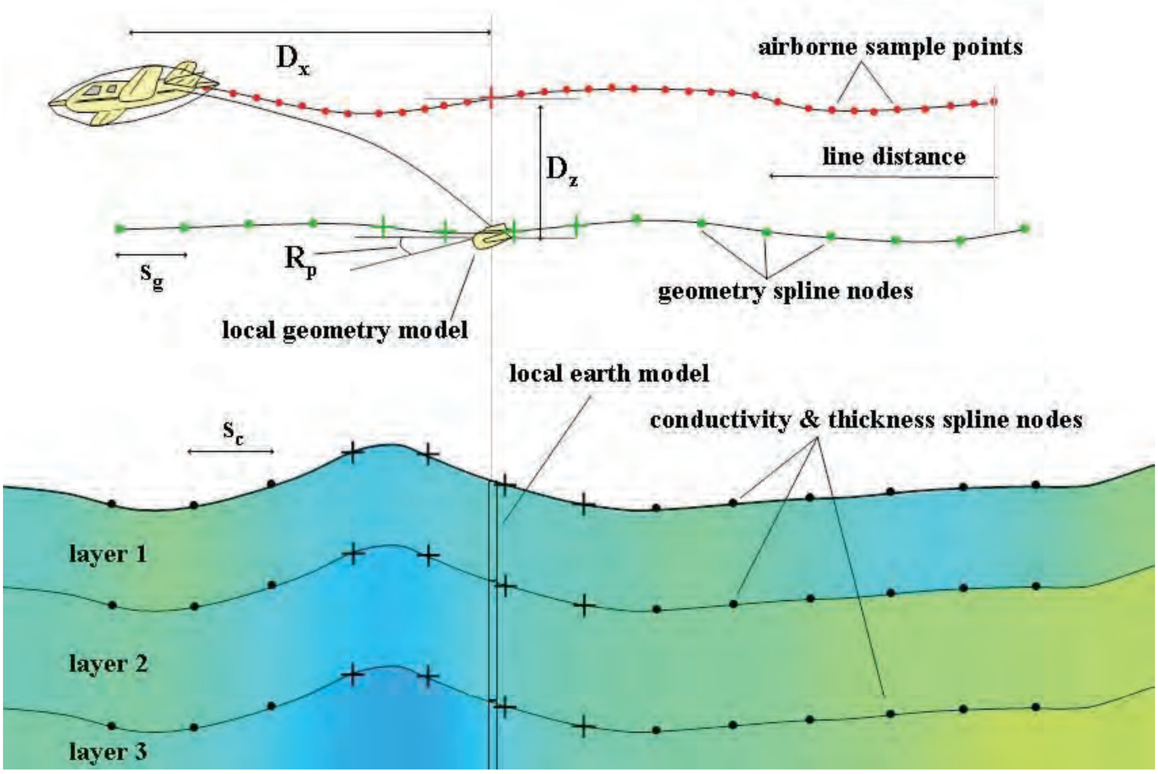


Figure 1.

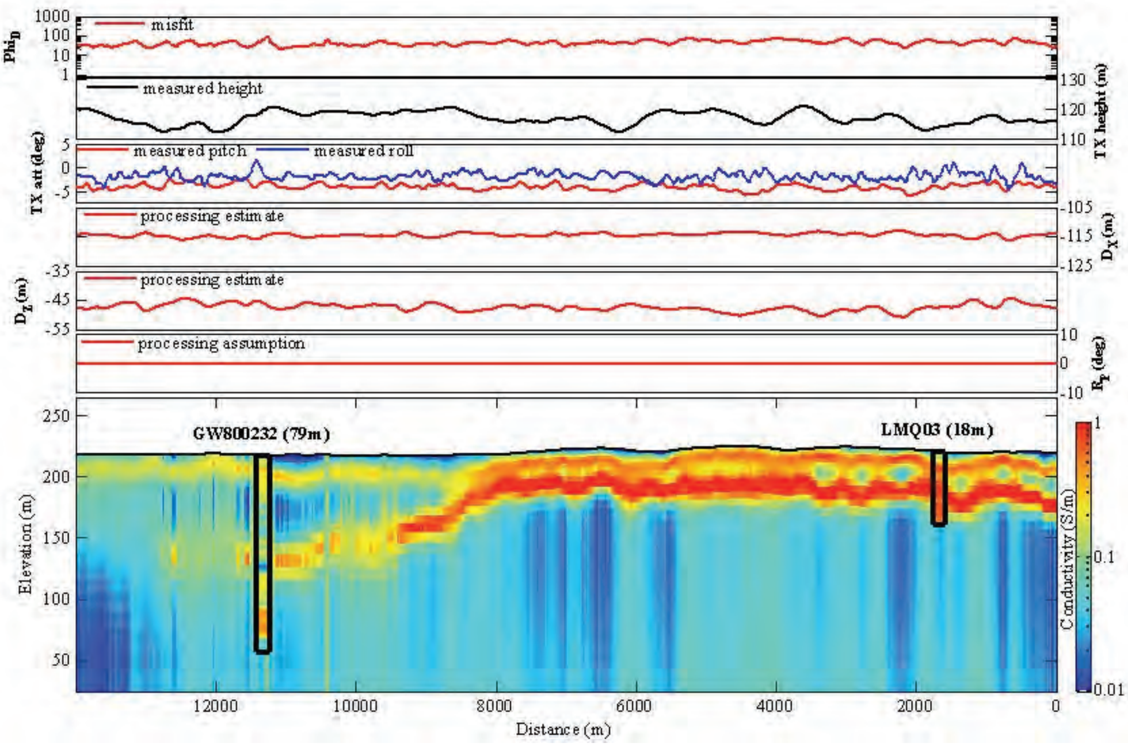
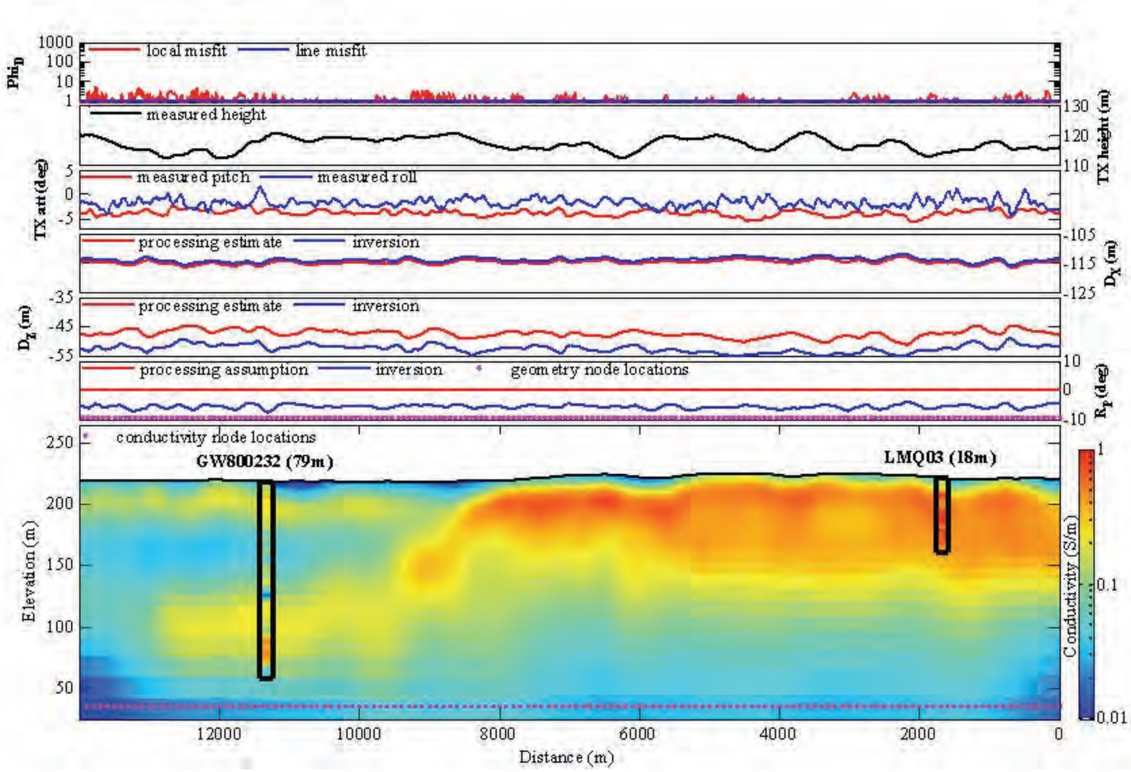


Figure 2.



local misfit
line misfit
Phi_D
1000
100
10
1
measured height
TX height (m)
130
120
110
measured pitch
measured roll
TX att (deg)
5
0
-5
processing estimate
inversion
D_X (m)
-105
-115
-125
processing estimate
inversion
D_Z (m)
-35
-45
-55
processing assumption
inversion
geometry node locations
R_P (deg)
10
0
-10
conductivity node locations
GW800232 (79m)
LMQ03 (18m)
Elevation (m)
250
200
150
100
50
Conductivity (S/m)
1
0.1
0.01
12000
10000
8000
6000
4000
2000
0
Distance (m)

Figure 3.

Mantle Evolution, Dynamical and Chemical, Earth and Venus

Geoffrey F. Davies and Andreea Papuc

Research School of Earth Sciences, Australian National University, Canberra, ACT 0200, Australia

Numerical modelling of mantle dynamics is leading to important insights into the history of Earth and Venus.

A series of studies of how mantle convection stirs chemical tracers has established a quantitative basis for a new hypothesis regarding the abundance of trace elements in the mantle, including the enigmatic noble gases. Because the mantle is heterogeneous, being a mixture of subducted oceanic crust and peridotitic mantle, the extraction of melt at mid-ocean ridges is expected to be inefficient. A cartoon of melting under ridges is shown in the Figure. The inefficient extraction implies that the abundance of incompatible trace elements in the mantle is higher than has been estimated in the past. Geophysical constraints indicate the abundance is 2-3 times previous estimates. This removes the need for a 'hidden' reservoir, clarifies the relationship between continental crust and the mantle, and helps to resolve a discrepancy between estimates of radioactive heating and models of the thermal evolution of the mantle.

The source of 'unradiogenic' helium, i.e. helium that has a low $^4He/^3He$ ratio, from Hawaii and other hostpots has been an enduring puzzle for which the new hypothesis offers a resolution. Melting of the heterogeneous mantle is expected to produce a 'hybrid pyroxenite' that contains much of the mantle's complement of incompatible elements, including the noble gases. It is also likely to be denser than average mantle, like subducted oceanic crust. Numerical models have shown that such denser components tend to partially settle to the bottom, plausibly explaining the seismological D" region at the base of the mantle. Whereas subducted oceanic crust is expected to contain little noble gas, the hybrid pyroxenite should contain substantial noble gas. Furthermore the material in D" has a longer residence time, according to the numerical models, so it will degas more slowly, meaning the content of primordial ^3He will be higher. D" is already believed to be the source of mantle plumes, so the new hypothesis offers a straightforward explanation of mantle helium observations. A simple quantitative model, based on results from numerical models, then successfully explains the helium, neon and argon observations from mid-ocean ridge basalts and oceanic island basalts.

These results, if substantiated, go far to reconciling mantle geochemistry with the dynamical picture of the mantle based on geophysical evidence and numerical modelling. It has been unclear for at least three decades how this could be achieved.

Work reported last year on numerical models that yield episodic layering and overturns in Earth's early mantle is now being extended to Venus. Venus was volcanically resurfaced about 500 Myr ago. PhD student Andreea Papuc's project is to investigate whether conditions in Venus' mantle today are conducive to layering and overturn, as Earth's mantle was early in Earth history. Layering occurs because of the 'basalt barrier' mechanism, in which subducted oceanic crust tends to accumulate at 660 km depth because it is buoyant between 660 and 750 km depth, but negatively buoyant at other depths. Initial results show that overturns are indeed still likely in Venus, mainly because of its hotter surface and lack of plate tectonics. Venus' slightly smaller size, gravity and mantle density also seem to favour layering, though it is not yet clear why. The effects of different lithosphere strengths are yet to be investigated, and the goal is to do evolutionary models of Venus. It will be important for understanding Venus' atmosphere and geochemistry to know whether and how often earlier resurfacing events might have occurred.

Davies, G. F. (2008) Inefficient melt extraction from a heterogeneous, mildly depleted mantle: no hidden reservoir, Earth Planet. Sci. Lett., submitted.

Davies, G. F. (2008) Noble gases in the dynamic mantle, Earth Planet. Sci. Lett., submitted.

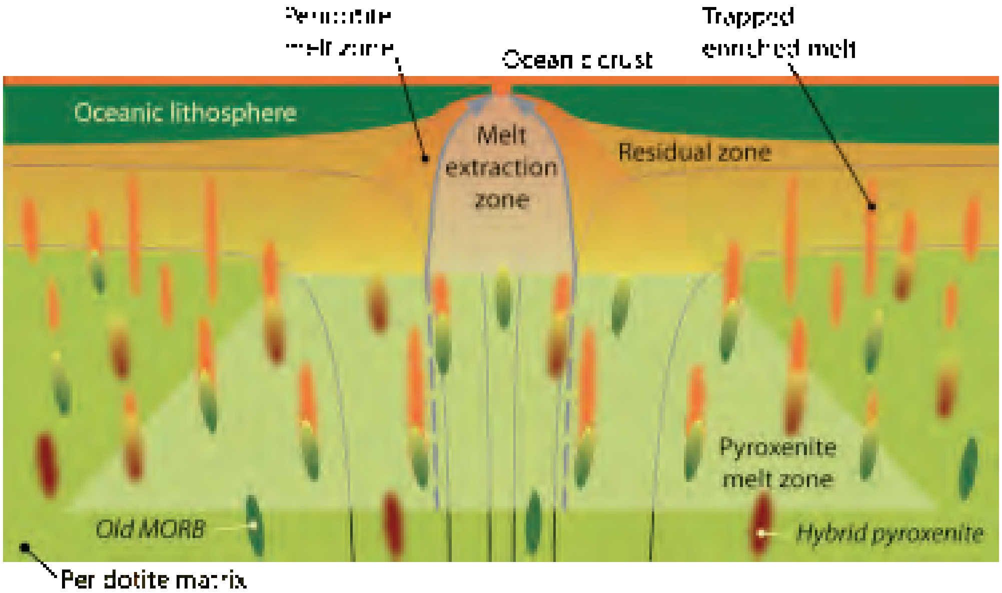


Figure 1. Melting under a mid-ocean ridge in a heterogeneous mantle.

Detecting Australian Earthquakes with InSAR

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[2] *Geoscience Australia, Canberra, Australia.*

Analysis of Interferometric Synthetic Aperture Radar (InSAR) images has detected two shallow, intraplate earthquakes over the past three years. Each of these small earthquakes occurred in the top ~1 km of the crust and caused sufficient surface deformation that the location and fault parameters (orientation, dip, slip direction) could be estimated. These are the smallest magnitude earthquakes ever imaged by the InSAR technique (Dawson et al., 2008).

The Mw 4.7 October 2007 Katanning earthquake ruptured ~1 km2 with an average slip of ~ 42 cm. This implies a static stress drop of 14-27 MPa which is much higher than previously expected for such a small event. The quality of the InSAR deformation estimates is sufficiently high that the depth of the event can be estimated with a precision of ~10 m. It was even possible to invert for the distribution of slip on the fault plane – the first time that this has been achieved for such a small event. These results have been published by Dawson et al. (2008).

The fine spatial resolution and accuracy that InSAR analysis can provide to the study of earthquakes in Australia opens up exciting new possibilities. Given the vastness of the Australian continent, it is likely that most earthquakes will not occur close to a seismic station. Therefore, the accuracy with which seismic data can be used to locate earthquakes is limited. Given that InSAR observations are made remotely from space platforms, the deformation from any shallow earthquake (ie < 5 km depth) can be captured by InSAR provided an image of the region exists prior to the earthquake. It is even conceivable that the highly accurate locations estimated by InSAR could be used as constraints in seismic inversions for crustal rheology modelling and/or as master event locations in a bootstrapping process to relocate other Australian earthquakes.

Dawson, J., P. Cummins, P. Tregoning, and M. Leonard, 2008. Shallow intraplate earthquakes in Western Australia observed by InSAR, *J. Geophys. Res.* 113, B11408, doi:10.1029/2008JB005807.
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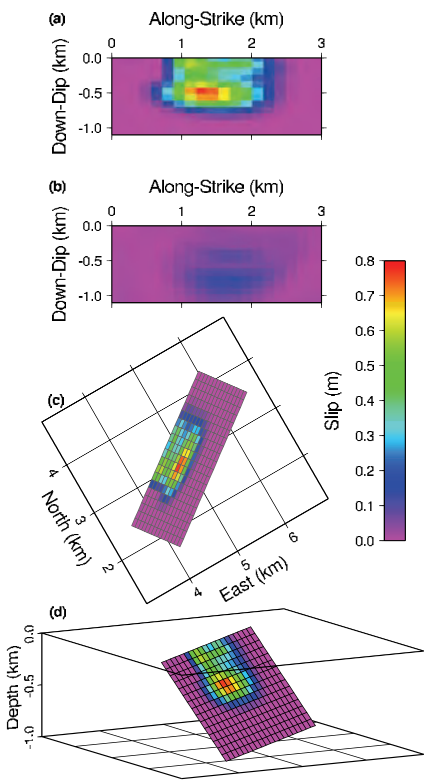

Figure 1. Slip distribution estimate of the Katanning earthquake, October 2007. A) Estimated slip. View is normal to the fault plane. b) 1_ uncertainties of the slip. c) Plan view of the rupture in an arbitrary local coordinate system. d) Viewing azumuth and elevation is 210° and 10°, respectively (Dawson et al., 2008).

Relative sea-level changes due to ocean bottom pressure changes caused by thermal expansion

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Ocean thermal expansion does not alter the total global ocean mass but can nevertheless result in relative sea-level changes. The heat uptake by the ocean (in the case of a warming climate) varies locally both horizontally and in depth. In a simplified model the total water column in the deep ocean tends to expand more than in shallow areas (illustrated with arrow 1 in Figure 1). In order to maintain an equipotential surface, water has to flow from the deep ocean to the shallow areas. This redistribution of water (illustrated with arrows 2 in Figure 1) consequently results in a spatial change in ocean bottom pressure. These ocean bottom pressure changes result in relative sea-level changes.

Atmospheric CO_2 concentrations and projected global sea-level rise over the period from 1860 to 2200 used here are based on IPCC scenario simulations (see Figure 2 in Landerer et al., 2007). Landerer et al. (2007) calculated ocean bottom pressure changes caused by secular oceanic mass redistribution due to thermal expansion. They developed a numerical model for the mass transfer from deep open water to coastal (shallow) areas. A data set of ocean bottom pressure changes produced by this model has been provided by Felix Landerer. The variations are expressed as changes of mass load in meters of water and are given on an annual basis from 1860 to 2200 on a 1° x 1° grid. Three examples of 10-year averages are shown in Figure 2. The plots show an increase in intensity of the redistribution of mass particularly from 2000 onwards.

The plots in Figure 2 show the overall transfer of mass from the southern to the northern hemisphere. In particular, the Arctic Ocean shelves experience an above-average increase in mass load. It appears that there is a good correlation between ocean bottom pressure changes and ocean bathymetry. For the IPCC scenario simulations used here, positive loads of up to 0.4 m by the end of the 21st century and 0.8 m by the end of the 22nd century are projected mostly for the Arctic Sea, while the deeper oceans (especially in the southern hemisphere) experience negative loads of _0.2 m and _0.4 m by 2100 and 2200, respectively. These results represent the redistribution of mass assuming a rigid Earth. Hence, the so-called second order relative sea-level changes as a result of the viscoelastic response of the Earth to the redistribution are now calculated. Since only thermal expansion is considered here, no mass is added or taken away from the ocean and the total change in mass over the oceans is zero.

The bottom pressure changes, expressed as water-mass loads, have been implemented in a sea-level program (the calsea program; Johnston 1993a,b; Lambeck et al., 2003). The resulting relative sea-level changes for 10-year averages are shown in Figure 3. Changes in relative sea level from this source are negligible until the beginning of the 21st century. By the end of the 22nd century, relative sea-level rise reaches a maximum of approximately 60 mm in the Arctic. This value is expressed relative to the mean of the period 1860-1869, which is assumed to be an unperturbed period. As the spatial distribution of relative sea-level changes (Figure 3) correlates with the spatial distribution of ocean bottom pressure changes (Figure 2), a rise in second order relative sea level is predicted mostly in coastal areas, in particular in the Arctic Ocean, whereas second order relative sea level falls in deep ocean areas.

Assuming this climate scenario adequately represents future thermal expansion, relative sea-level changes due to the redistribution of water caused by secular ocean mass redistribution are amplified by about 10% due to these ocean bottom pressure changes.

While there is a variety of uncertainties in thermal expansion models (e.g. size of the surface warming, the effectiveness of heat uptake by the oceans for a given warming, and the expansion resulting from a given heat uptake; see Section 11.5 in Church et al., 2001), predicted future sea-level changes will have to be increased by 10% to account for the redistribution of ocean water following thermal expansion.

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Johnston, P. (1993a). Deformation of the earth by surface loads. PhD thesis, The Australian National University, Canberra.

Johnston, P. (1993b). The effect of spatially non-uniform water loads on prediction of sea-level change. Geophysical Journal International, 114, 615–634.

Lambeck, K., Purcell, A., Johnston, P., Nakada, M., and Yokoyama, Y. (2003). Water-load definition in the glacio-hydro-isostatic sea-level equation. Quaternary Science Reviews, 22, 309–318.

Landerer, F. W., Jungclaus, J. H., and Marotzke, J. (2007). Ocean bottom pressure changes lead to a decreasing length-of-day in a warming climate. Geophysical Research Letters, 34 (L06307).

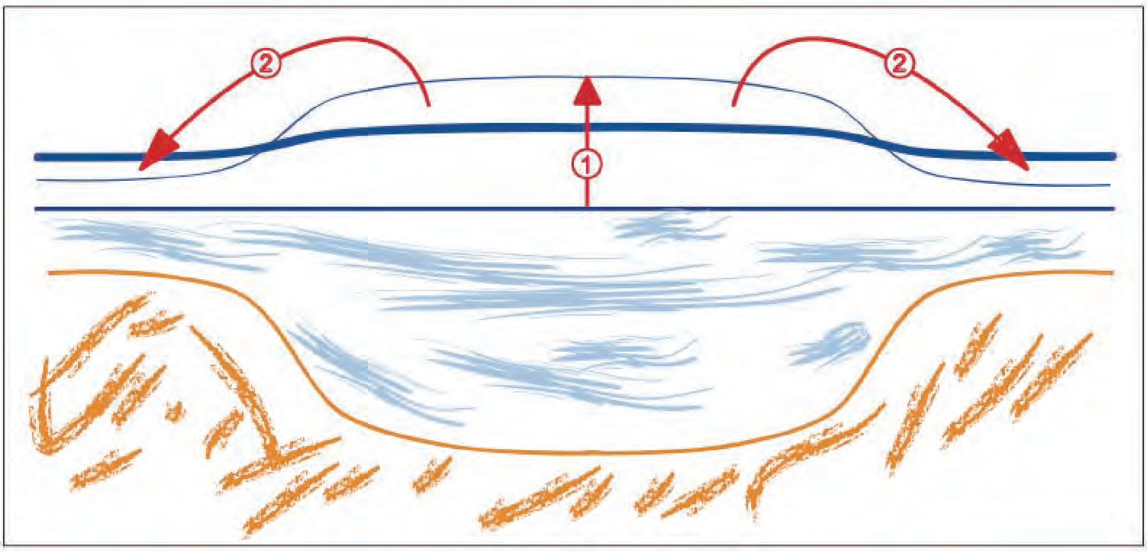


Figure 1.

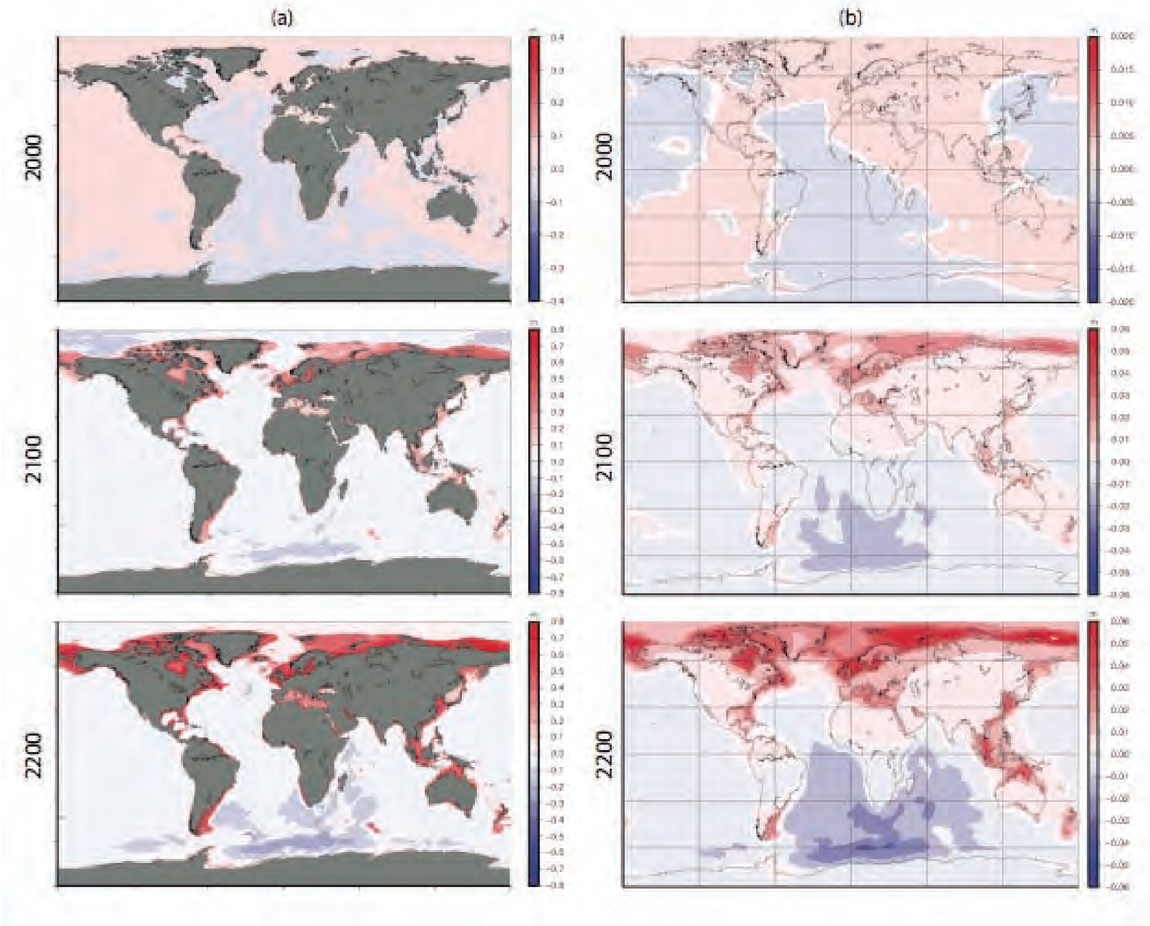


Figure 2.

The roles of bottom topography and internal gravity waves in horizontal convection

Ross W. Griffiths[1], Graham O. Hughes[1], Melissa A. Coman[1], Kial D. Stewart[1]

[1] *Research School of Earth Sciences, Australian National University, Canberra, ACT 0200, Australia*

Horizontal convection is the flow generated by heating and cooling along one horizontal boundary of a box. Studies of this form of convection have yielded much insight into the fundamental dynamics governing the ocean overturning circulation. In particular, equatorial surface waters are heated and high latitude surface waters are cooled, and analogies with horizontal convection allow us to investigate the role of surface buoyancy forcing in the overturning circulation. We have examined the progress in this field in a major review article published this year (Hughes and Griffiths, 2008).

In 2008 we have built on our previous studies of horizontal convection, and work has progressed on two main fronts. Firstly, we have studied the role of bottom topography in restricting flows between ocean basins, and thus in controlling the rate of overturning circulation. Secondly, we have discovered the spontaneous generation of internal gravity waves in the convective flow.

Laboratory experiments (figure 1) have shown that the introduction of bottom topography blocks the circulation, isolating waters in adjoining basins below the level of the sill. The circulation is most strongly affected when the depth of the sill is comparable with the depth to which the surface thermal boundary layer extends (i.e. the thermocline). In this regime, the range of densities in the flow increases markedly and the rate of overturning decreases. On this basis we expect the Denmark Straits and Faroe Bank Channel in the North Atlantic and the Weddell Sea ice shelf overflow in the Southern Ocean to influence the global overturning circulation.

Numerical simulations of horizontal convection have revealed the existence of coherent propagating waves (figure 2). Further investigation has shown that highly localized sinking plumes (as in figure 1) perturb the density stratification and excite a spectrum of internal gravity waves. We have been able to identify interaction of these wave modes as a source of strong variability in the circulation. Further work is required to assess the importance of this phenomenon in the ocean overturning circulation.

Hughes, G.O. and Griffiths, R.W. (2008) Horizontal convection. *Annu. Rev. Fluid Mech.* **40**, 185–208.

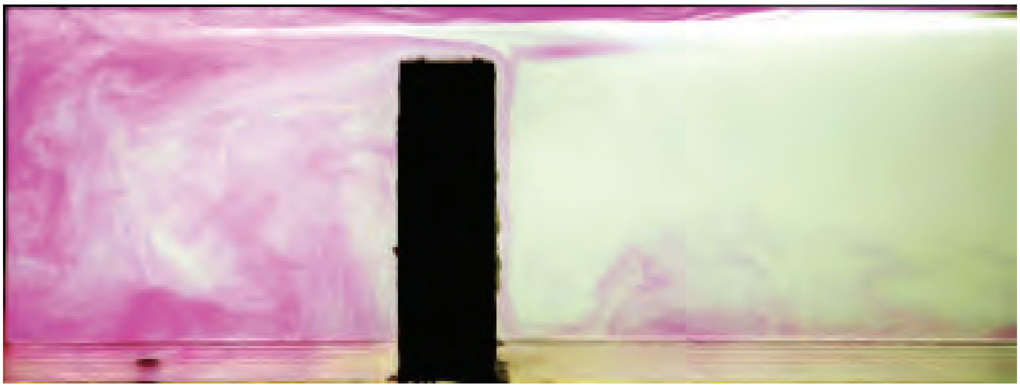
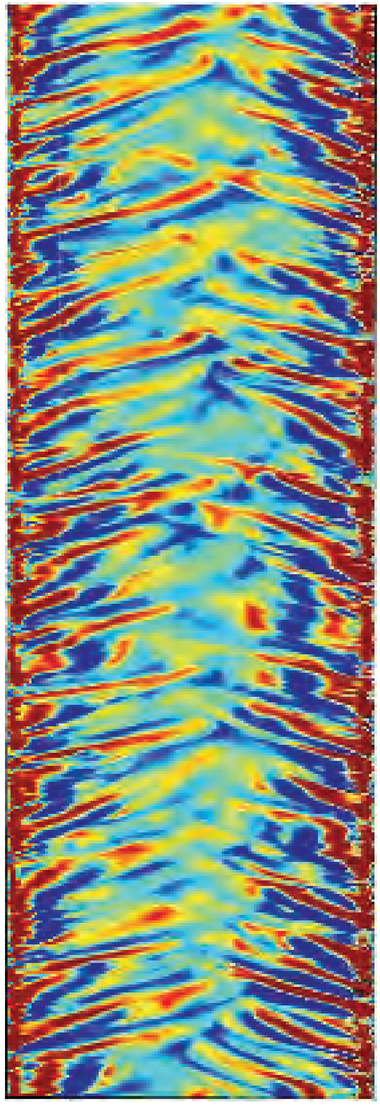


Figure 1. Dye visualization of a horizontal convection experiment with bottom topography (the field of view includes only the left-hand half of the box). The overturning circulation is forced by surface cooling at the left-hand end of the box ("polar latitudes") and surface heating over the right-hand end ("equatorial latitudes"; not visible). The dye reveals that relatively warm surface waters flow from right to left above the sill, where they subsequently become very cold, sink, and are trapped on the left of the topography at levels below the sill. This trapped water eventually fills the left-hand basin and can be seen leaking across the top of the sill (from right to left), whence it enters the main basin as a highly localized sinking plume.

Figure 2. Hovmöller plot of the vertical velocity along a horizontal section at mid-depth from a 2-D numerical simulation of horizontal convection. Time increases upwards; blue represents upwelling motion, green approximately no motion, and red downwelling motion. Regions of high latitude sinking are situated in this case at both the left and right hand ends of the horizontal section, and excite strong wave modes that propagate towards 'low latitudes' at the centre of the section. These waves and their interactions appear to be responsible for much of the variability in the circulation.



Multi arrival tomography

Juerg Hauser[1], Malcolm Sambridge[1] and Nicholas Rawlinson[1]

[1] *Research School of Earth Sciences, Australian National University, Canberra, ACT 0200, Australia*

In seismic imaging the focus has largely been on first arrivals, with a wide variety of schemes developed for their calculation. However, later arrivals often contribute to the length and shape of a recorded wave train, particularly in regions of complex geology. They are likely to contain additional information about seismic structure as their two point paths, differs from that of the first arrival. If they can be used in seismic tomography, improved images should result. Here we use the wavefront construction principle as the basis of a new scheme for computing travel times for first and later arrivals that arise from smooth variations in both velocity structure and interface geometry.

To investigate the possibility of using later arrivals to improve seismic imaging a numerical test is performed. We compare the results of first and multi arrival tomography, when recovering a two layered crustal scale structure characterised by two low velocity anomalies and a u-shaped valley in the interface. The inversion is performed simultaneously for interface and velocity structure. There are sources above and below the interface and two incoming plane waves are also simulated. Figures 1.a and 2.a show the ray path coverage of the structure, which we will try to recover using travel times. Clearly the later arrivals not only contain additional information about the two low velocity anomalies but also about the shape of the valley in the interface. Figure 1.b shows the difference between the inversion result and the true structure when only first arrivals are used in the inversion. The trade off between interface geometry and velocity anomaly is clearly not as well resolved compared to when both first and later arrivals are used (figure 2.b).

This example demonstrates that multi arrival tomography has the potential to lead to an improved recovery of structure. An important difference between first and later arrivals is that the existence of a later arrival is a function of the structure. This means that during the iterative inversion procedure, the number of ray paths and hence data is not constant. Using later arrival therefore makes the inverse problem much more non-linear, which means that care must be taken to avoid instabilities in an iterative non-linear approach.

Potential applications of multi arrival tomography include surface wave tomography, where observations of multipathing has been a long recognised phenomenon, with measurements and analysis using earthquake sources dating back many decades.

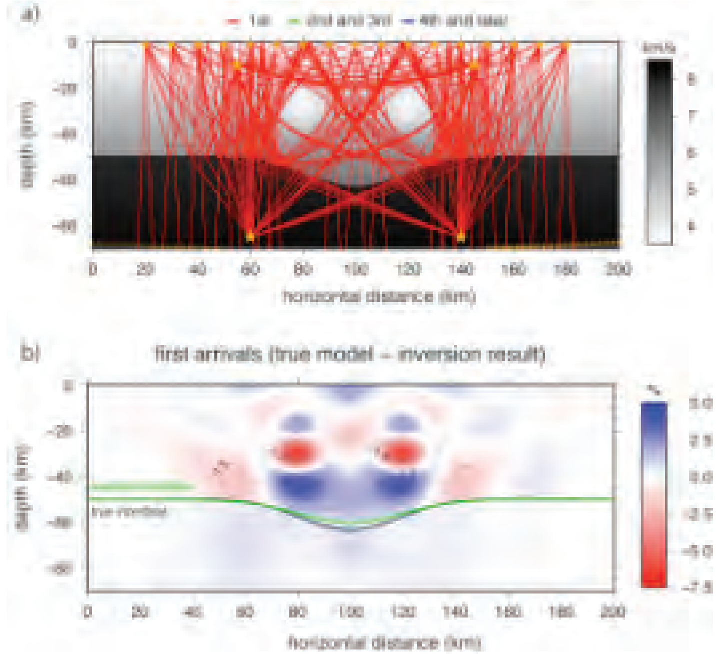


Figure 1. a) Layered velocity model and associated first arrival paths used in the inversion test. Point sources are denoted by stars and receivers by triangles. Note that paths also emanate from two impinging plane waves. b) Relative error in percent between the true model and the inversion result. Contour lines are plotted at 1.5% intervals.

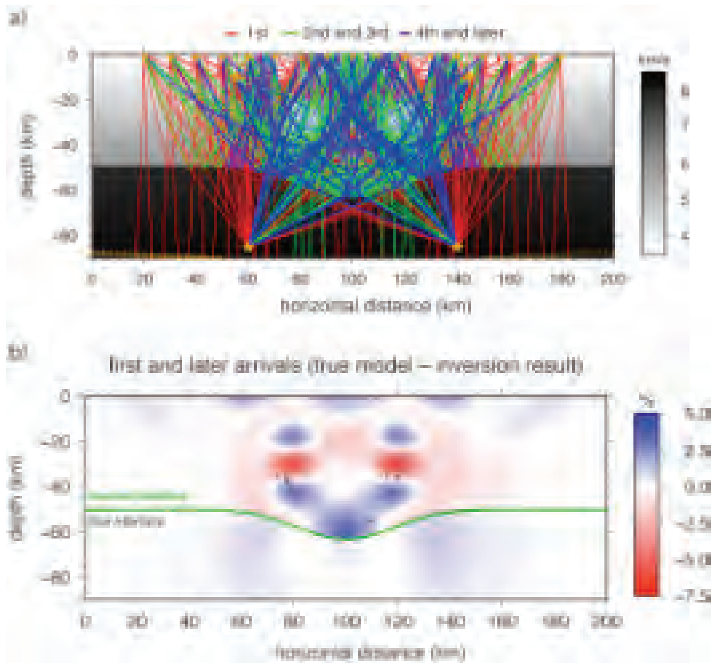


Figure 2. a) Layered velocity model and associated first and later arrival paths used in the inversion test. Point sources are denoted by stars and receivers by triangles. Note that paths also emanate from two impinging plane waves. b) Relative error in percent between the true model and the inversion result. Contour lines are plotted at 1.5% intervals.

The effects of mesoscale ocean-atmosphere coupling on the large-scale ocean circulation

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[2] Department of Oceanography, Florida State University, Tallahassee, USA
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[4] Cambridge University, UK
[5] University of Wisconsin, Milwaukee, USA

Recent satellite measurements of wind stress at the ocean-atmosphere interface have pointed to large variations in stress on very fine scales. These fine scales are set by ocean mesoscale dynamics, and the variations in stress occur due to coupled interaction between the ocean and atmosphere. Given that wind stress drives the ocean circulation, there is a realistic possibility for coupled feedback acting to alter ocean currents.

We model this ocean-atmosphere interaction using high-resolution ocean model, coupled to a dynamic atmospheric mixed layer. The goal is to answer the question: Do small-scale variations in stress alter the large-scale ocean circulation?

The model results show that, despite the small spatial scale of the forcing anomalies, mesoscale coupling reduces the strength of the large-scale ocean circulation by approximately 30-40%. This result is due to the highest transient wind stress curl (or Ekman pumping) anomalies (see Fig. 1) destabilising the flow in a dynamically sensitive region close to the western boundary current separation.

These results indicate the complexity involved in migrating ocean models to eddy-resolving scales. The next generation of ocean models need to resolve atmospheric boundary layer processes at the same resolution as the ocean model.

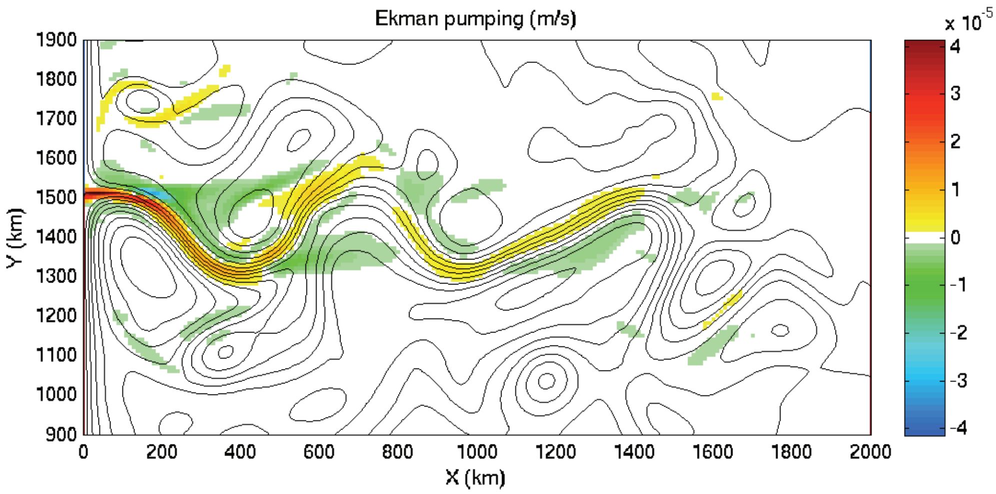

Figure 1. Snapshot of wind stress curl (or Ekman pumping) in colour, with contours of streamfunction superimposed. The streamfunction shows a western boundary current separating from the boundary, and forming a meandering zonal jet in the interior. This jet is accompanied by strong sea surface temperature gradients, which interact with the atmospheric boundary layer to produce large values of wind stress curl over the core of the jet. This extra forcing, somewhat paradoxically, acts to reduce the circulation by destabilizing the mean flow.

Energetics of the global ocean overturning circulation

Graham O. Hughes[1], Andy McC. Hogg[1], Ross W. Griffiths[1]

[1] *Research School of Earth Sciences, Australian National University, Canberra, ACT 0200, Australia*

The overturning circulation of the global oceans regulates Earth's climate, and oceanographers have been interested in which energy sources maintain that circulation. Energy input from surface winds and tides is important, but whether or not surface heating and cooling also contribute has been the subject of considerable debate. An understanding of the energetics is essential in addressing problems such as the response of the overturning circulation to forcing changes and in highlighting processes that need to be addressed in the development of general circulation models and climate models.

This year we have developed a theoretical framework that can be used to study the energy budget of the ocean overturning circulation. The concept of available potential energy, which is a measure of how far the density field is from equilibrium, underpins this framework. We have demonstrated that surface buoyancy forcing generates available potential energy, and is indeed an important energy source for the overturning circulation. In particular, only mixing and surface buoyancy forcing act to change the density of waters and, in a steady circulation, the energy transports associated with these two processes must balance. We have further clarified how the sources of kinetic energy associated with the winds and tides are simultaneously necessary to maintain the observed ocean overturning circulation.

We have in conjunction with our theoretical work undertaken a series of high-resolution numerical computations using a general circulation model of an ocean basin (figure 1). The results confirm our theoretical findings. Importantly, they also show that deductions regarding the energy budget of the ocean overturning circulation are strongly influenced by parameterizations of small-scale processes that are in common use in numerical models.

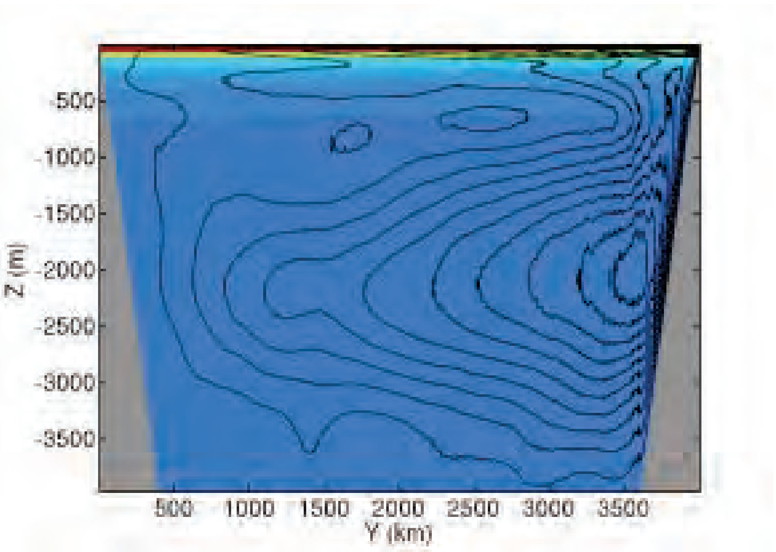

Figure 1. The time-averaged overturning circulation obtained in 2-D numerical simulations of a model ocean basin forced only by surface heating and cooling (varying smoothly from 200 W/m^2 at the left end to –200 W/m^2 at the right end, but with no net heat input to the basin). The simulation was non-hydrostatic, was conducted at high resolution (10–75 m vertical resolution and 0.75 –7.5 km horizontal resolution), and was run with a vertical diffusion coefficient of 10^{-4} m^2/s. The coldest waters are coloured blue and warmer waters towards the surface are shown as yellows and reds. The maximum overturning streamfunction is 28 x 10^3 kg/s per unit width.

Effect of thermal diffusion on the stability of strongly tilted mantle plume tails

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Mantle plumes are produced by heat conducted into the Earth's mantle from the underlying core. This heating forms a thermal boundary layer of hot, low viscosity fluid, which focuses into narrow plumes that rise through the mantle. At the Earth's surface, partial melting of the plumes produces flood basalts from plume heads and volcanic island chains from plume tails.

As plume tails rise through the mantle, they are deflected by large-scale convection driven by the subduction of cold lithospheric plates. Last year, we reported a series of laboratory experiments that investigated the effect of thermal diffusion on the gravitational stability of these plume tails when they have been strongly tilted. This year, we examined this instability using a series of numerical calculations (Figure 1).

At large viscosity ratios, we conclude that the instability is unaffected by thermal diffusion when the Rayleigh number *Ra* is greater than about 300. When *Ra* is less than 300, thermal diffusion significantly increases the time for instability, as the rising fluid region needs to grow substantially by entrainment before it becomes unstable. When *Ra* is less than about 140, and the rise height available is less than about 40 times the cylinder radius, the rising region of fluid is unable to grow sufficiently and instability is prevented. When our results are applied to the Earth, we predict that thermal diffusion will stabilize plume tails in both the upper and lower mantle (Kerr, Mériaux and Lister 2008). We also predict that some of the buoyancy flux in mantle plumes is lost during ascent to form downstream thermal wakes in any larger scale mantle flow.

Kerr RC, Mériaux C, Lister JR (2008) Effect of thermal diffusion on the stability of strongly tilted mantle plume tails. *Journal of Geophysical Research* **113**: B09401, doi:10.1029/2007JB005510

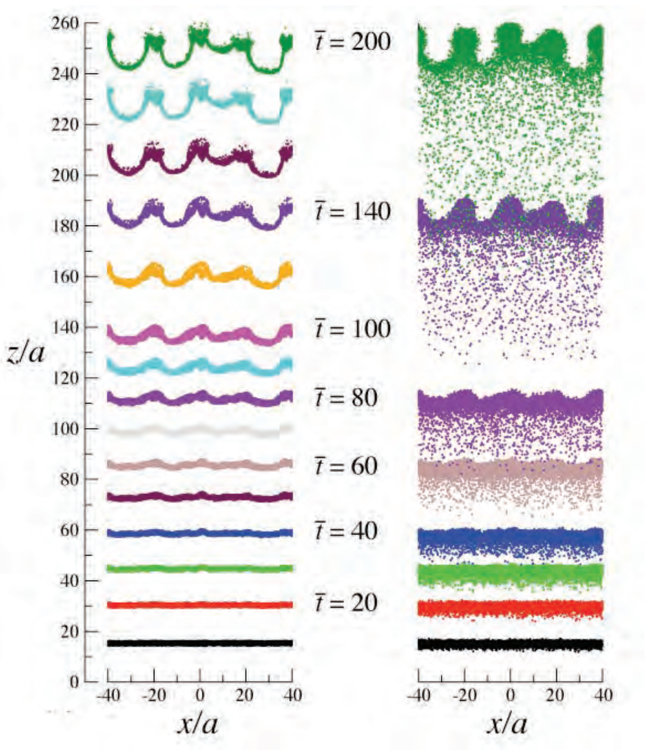

Figure 1. Numerical calculations showing the rise and eventual instability of a cylinder of buoyant fluid, as a function of dimensionless time. The cylinder has an initial radius *a*, and a Rayleigh number of 80. The side views show the distribution of tracers (left) and buoyancy (right).

Testing the Plume Hypothesis: Laboratory models of Subduction-plume interaction for the Cascades and Tonga-Lau Convergent Margins

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[2] *Research School of Earth Sciences, Australian National University, Canberra, ACT 0200, Australia*
[3] *Richard Carlson & David James (Carnegie Inst. Of Wash.), Tim Grove (MIT), William Hart (Miami Univ.), Anita Grunder & Robert Duncan (Oregon State Univ.), Matt Fouch (Ariz. State Univ.), Randy Keller (Univ. of Oklahoma), Steve Harder (Univ. of Texas), Maureen Long (Yale Univ.).*
[4] *Stan Hart, Mark Behn & John Collins (Woods Hole), Greg Hirth (Brown Univ.), Magali Billen (Univ. of California, Davis).*

Subduction of lithospheric plates back into the mantle at subduction zones (ocean trenches) provides the dominant driving force for plate tectonics and causes thermal and chemical exchange with the Earth's interior. We have developed a laboratory apparatus for modeling 3D aspects of flow in subduction zones in response to various modes by which plates move and subduct into the mantle. These include slab rollback, when the slab sinks with a backward retreating or horizontal component of motion, and periods where the angle of descent (slab dip) either increases or decreases with time. Previous work has documented the importance of these modes of plate motion on 3D shallow mantle return flow and both slab and mantle wedge temperatures (Kincaid and Griffiths, 2003; 2004).

Kincaid and Griffiths are involved with two NSF funded projects to look at aspects of plume vs. non-plume models for reconciling patterns in geophysical and geochemical data collected within subduction zones. One project (the High Lava Plains project) involves a combination of efforts (seismology, geology/geochemistry and geodynamics) to better understand the evolution of the Cascades subduction system, spatial–temporal patterns in melt production and continental growth in the northwestern USA. In addition to field geology, this effort involves an a spatially detailed broadband seismic experiment coupled with a recent large scale active source seismic experiment. In terms on modeling, Kincaid and Griffiths are exploring aspects of 3D mantle flow and both thermal and compositional evolution of the mantle, and spatial-temporal patterns melt production for a subduction zone with representative plate motions for the Cascades-Pacific northwest USA system.

Plume-subduction interaction experiments show that plumes can be strongly deformed by rollback subduction and can be efficiently drawn into the arc wedge corner over large horizontal distances (~1000 km). The combination of rollback subduction and backarc extension deform the plume head and tail in a way that produces an early, circular large volume melt feature and two subsequent linear melt production features which are offset in space and time (~15 Ma). Two tracks are formed with time-transgressive rhyolite melting (e.g. reheating of the plate) and basaltic melt production, which trend in opposite directions. One is similar to the High Lava Plains in central Oregon, and the other is similar to the Snake River Plain. The initial, circular magma production feature is offset from the linear features by 300-400 km in a trench-parallel direction. The style of back-arc spreading changes the offsets and orientations of these three basic features. The influence of plate steepening is to deform the plume material into a very narrow feature. The severe, rapid deformation of plume material works to limit rise rates, essentially trapping much of this material deep in the wedge. The combined effects of increased diffusion and small length scales, partial melting and severe distortion in 3D, will make these remnant plume features difficult to image with seismic techniques.

In 2008 a URI PhD student, Ms Kelsey Druken, is working to extend these models of Cascades subduction system, including the effect of a keel-like morphology (Figure 1a) for the base of the overriding plate. An important part of the project is to also test non-plume models. Three-dimensional flow-fields (Figure 1) are being analysed in combination with temperature data and a melt production model to calculate spatial patterns in vertical heat and melt flux through time for non-plume cases. In addition, finite strain is being observed within the flow through the use of whiskers. These act as a proxy for olivine alignment within the upper mantle and are being compared with seismic anisotropy data collected from the High Lava Plains.

Kincaid, C., and R. W. Griffiths (2003) Thermal evolution of the mantle during rollback subduction, *Nature*, 425, 58-62

Kincaid, C. and R. W. Griffiths (2004) Variability in mantle flow and temperatures within subduction zones. *Geochem. Geophys. Geosyst.*, 5, Q06002, doi:10.1029/2003GC000666

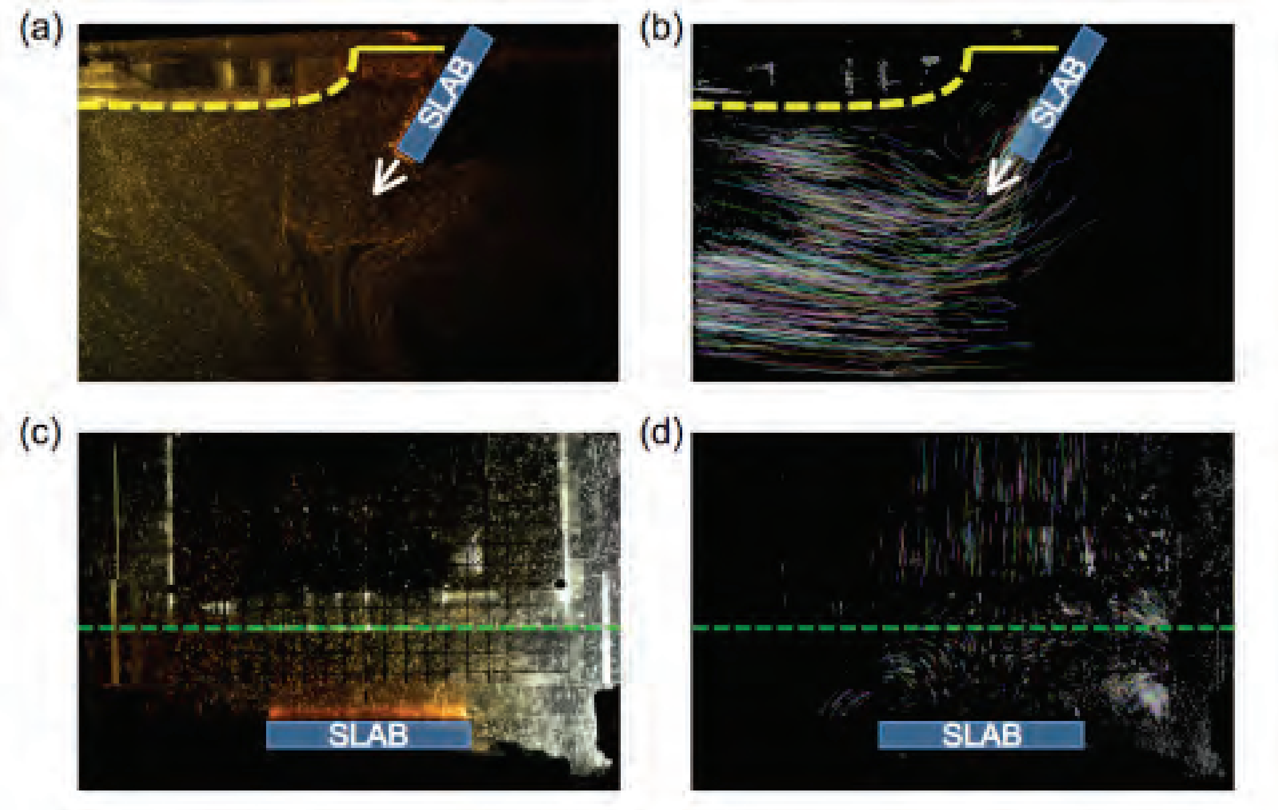

Figure 1: Top- and side-view images of the non-plume modelling of the Cascades using the 3D subduction system. that includes down-dip slab motion (5 cm/Ma), rollback slab motion (2.8 cm/Ma) and westward drift of the overriding plate (OP) at 1.4 cm/Ma. The combination of trench rollback and OP westward motion give a net extension rate about the spreading center (green dashed line) of 1.4 cm/Ma. Vertical and horizontal slices are imaged to produce 3D flow fields using particle tracking velocimetry (PTV) in FluidStream (developed by R. Nokes) (a) Side-view slice 4.5 cm (225 km scaled) along trench from plate centerline illustrating the subducting slab and the keel-like morphology of the over-riding plate (dashed yellow line) (b) Path-lines from PTV on the side-view slice using FluidStream. (c) Top-view slice at 2 cm (100 km scaled) depth where the back-arc spreading center (green dashed line) marks the start of the thickened morphology of the over-riding plate. (d) Path-lines for the top-view image using FluidStream PTV analysis.

Seismic Investigations of Lithospheric Transitions between the Northern and Southern Australian Cratons (BILBY)

Sara H. Pozgay[1] and Brian L.N. Kennett[1]

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We aim to determine the nature of the transition at lithospheric depths between the northern and southern Australian cratons. What are the controlling factors of the regions with anomalously slow velocities beneath the central Australian intercratonic suture zones? Do these intercratonic transitions propagate with depth and, if so, in what manner? To answer these questions, 25 broadband seismic stations were deployed in August-September 2008 and will remain operational for approximately one year.

Much of the Australian continent is an amalgamation of several smaller cratons and multiple orogenic events. The transitions between any two cratonic regions, however, do not necessarily reflect the same processes. Beneath the Capricorn Orogen (connecting the Yilgarn and Pilbara cratons), seismically fast wavespeeds (relative to a reference earth velocity model) and low attenuation are relatively continuous from 75 to >300 km depth. These large-scale observations suggest that a simple thermal origin is a likely explanation for the seismic signature of the orogen. However, much of central Australia is different; the central intercratonic belt regions exhibit low attenuation as for the case of the Capricorn Orogen, but slow wavespeeds persist at ~75 km depth. Only 25 km deeper, wavespeeds are fast and become relatively continuous at ~125 km depth. These observations suggest that the physical mechanism responsible for the observed seismic signature is more complex than simple thermal variations would predict.

What is the nature of this slow wavespeed region around 75 km depth beneath these intercratonic suture belts? Do the transitions between them extend through the whole lithosphere, as suggested by prior studies of the central Australian (Arunta Block) region? Several orogenic events should have made a lasting imprint through the whole lithosphere (e.g. the Alice Springs Orogeny 400-300 Ma), however these effects have yet to be imaged at the appropriate resolution to determine the nature of different lithospheric sections. Prior seismic deployments in the region were largely designed to image either crustal fault systems or deep lithosphere and upper mantle structures and, therefore, can provide only first-order constraints on the intercratonic suture belts.

We deploy an ambitious seismograph station configuration to image these lithospheric transitions between the northern and southern Australian cratonic regions and across parts of the intercratonic suture belts. The experiment configuration is designed specifically to connect the Gawler Craton in the south to components of the North Australian Craton - specifically, through the Musgrave Block and to the northern side of the Arunta Block, and to connect the Arunta Block with the Mt. Isa Block. A combination of rigorous analysis tools, such as velocity and attenuation tomography coupled with receiver functions, will help to provide a comprehensive understanding of the amalgamation of continental cratons and the associated intercratonic transitions. In addition, a significant amount of information will be added to the present understanding of intercratonic suture belts and further constraints on the Australian lithospheric structure and overall continental amalgamation will be realised.

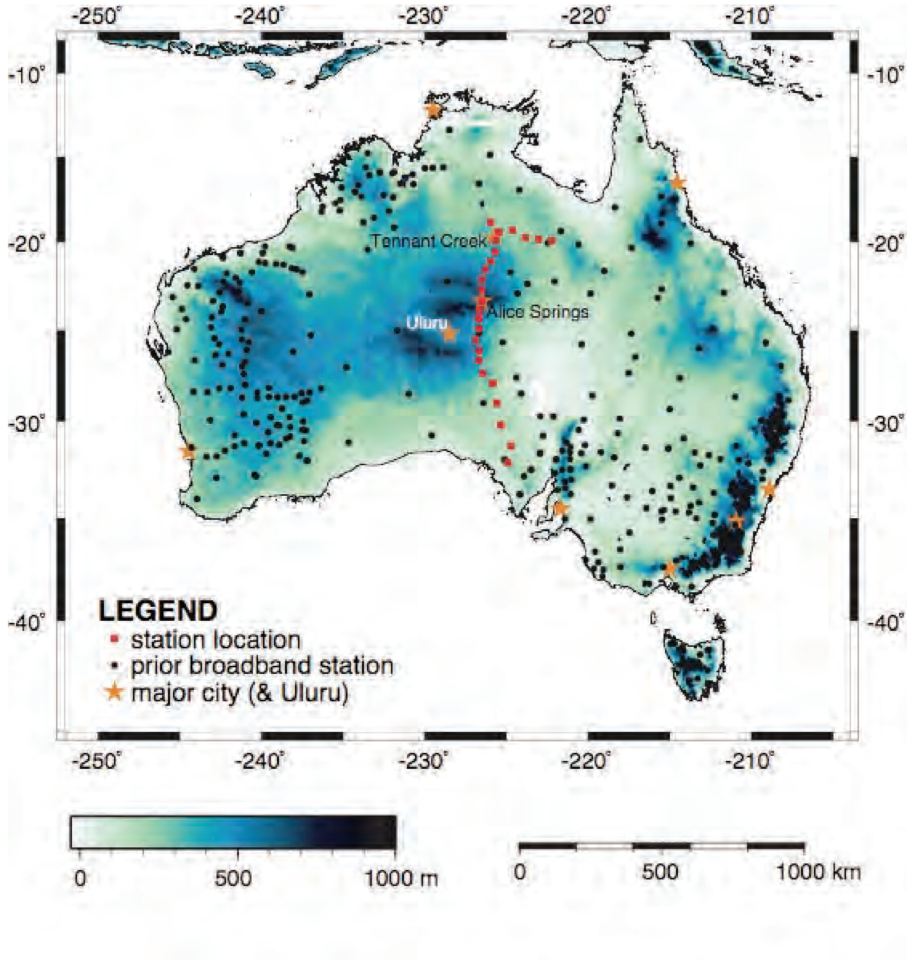

Figure 1. BILBY station map. Red squares indicated proposed station locations; black circles are prior broadband instrumentation; orange stars are major landmarks. Topography scale (in meters) shown at bottom.

Figure 2. Station near Alice Springs.

Exploring deep Australia with the WOMBAT array

Nick Rawlinson, Brian Kennett and Hrvoje Tkalcic

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In the last decade, a dense rolling array of short period seismometers has been used to achieve a cumulative coverage of over 400 sites throughout southeast Australia (see Figure 1). This experiment, known as WOMBAT-SE, has recorded large volumes of passive seismic data for use in teleseismic tomography, ambient noise tomography, receiver function analysis and array studies of deep mantle and core structure. Station spacings vary between approximately 15-20 km in Tasmania, and 30-50 km on mainland Australia. Deployment times of early experiments in western Victoria and southeast South Australia are approximately 4 months, but since EVA (Figure 1), they have been extended to 8-12 months. The majority of instruments used have been ANU solid state short period recorders connected to vertical component L4Cs (natural frequency of 1Hz), but since SETA (Figure 1), three-component Lennartz LE-3Dlite sensors (also with a natural frequency of 1Hz) have been deployed.

To date, a variety of studies have been carried out with the recorded data, including teleseismic tomography, joint inversion of passive and active source data, ambient noise tomography, and analyses of exotic core phases. In this report, early results from a combined inversion of teleseismic arrival time residuals will be featured. Figure 2 shows a tomographic image at 150 km depth produced by the inversion of EVA, LF98, MB99, SEAL and SEAL2 datasets. One of the clearest features in Figure 2 is the east to west change from slower to faster velocities from the Bendigo Zone to the Stawell Zone. It is tempting to interpret this as a change from Phanerozoic mantle lithosphere of oceanic origin to Proterozoic mantle lithosphere of continental origin. Expected changes in both composition and temperature between these two types of material make this a plausible argument. In addition, this approximate boundary has also been observed, albeit at lower resolution, using surface-wave tomography, which appears to clearly distinguish between cratonic western Australia and the younger orogens that characterise eastern Australia. However, it must remembered that recent overprinting effects, such as the hotspot-related Newer Volcanic Province in Victoria and magmatic processes related to the opening of the Bass and Otway basins and the Tasman Sea, may well have contributed significantly (via increased temperatures) to reduced wavespeeds observed in central and southern Victoria.

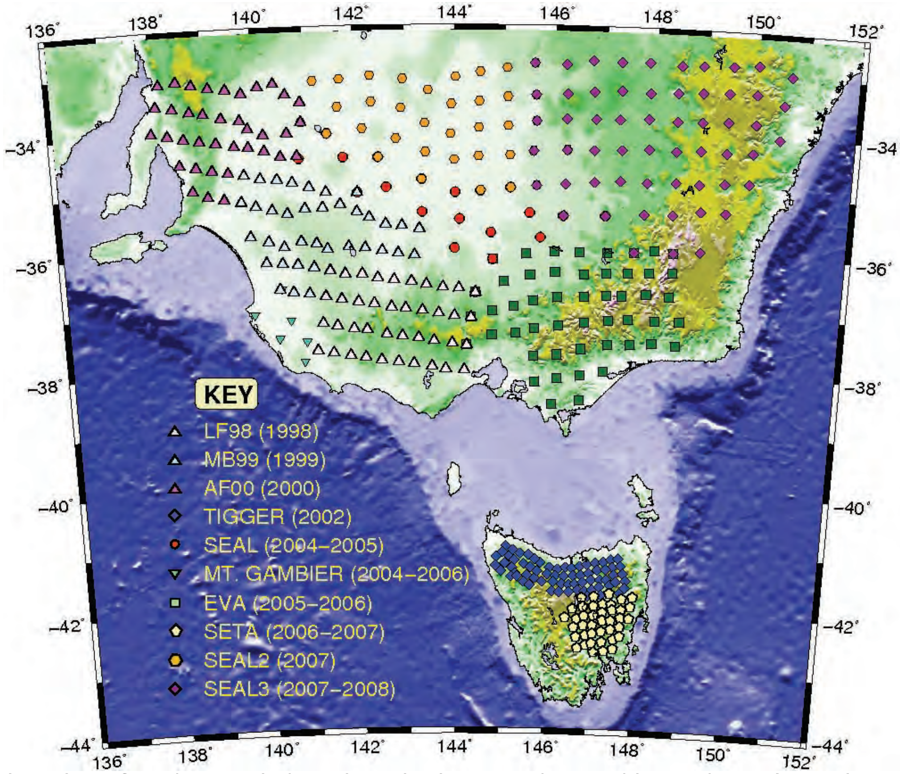

Figure 1. Location of all short period passive seismic arrays deployed in southeast Australia over the last decade

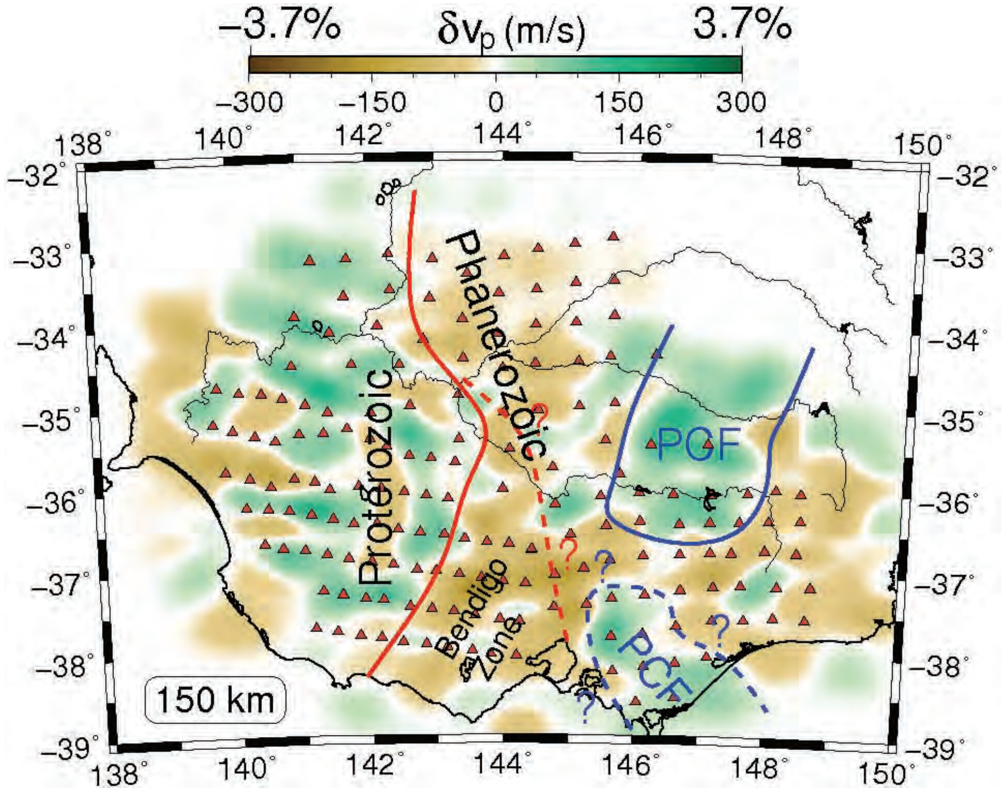

Figure 2: Preliminary image obtained from joint inversion of teleseismic arrival time residuals recorded at five arrays of the WOMBAT-SE project. PCF = Proterozoic Continental Fragment.

The dynamics of solidifying lava flows with a Bingham yield strength rheology

Jesse Robertson[1], Ross Kerr[1] and Ross Griffiths[1]

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Lava flows cover much of the Earth, the Moon, Mars, Venus, and several satellites of the outer planets. They vary greatly in their viscosities and eruption rates and form a wide range of flow types from long channel and tube flows to lava domes. Recent research in the GFD Laboratory has focused on surface crust formation, channel formation and flow morphology in Newtonian fluids subject to surface cooling (Griffiths et al. 2003; Kerr et al. 2006). This work predicts the behaviour of crystal-poor lava flows with a Newtonian rheology, such as some proximal basaltic flows on Kilauea Volcano, Hawaii and submarine lava flows near submarine spreading ridges. However, many lava flows contain sufficient crystals for the lava to have a viscoplastic rheology with a substantial yield strength, including those typical of distal Hawaiian channels and most Mt Etna flows. The yield strength can have a significant effect on the velocity distribution in a channel flow, and hence should have a major impact on the very complex interaction between convection and surface solidification seen in solidifying channel flows.

Experiments carried out this year have aimed to develop a quantitative understanding of solidification, cooling mechanisms, and tube formation in lava flows with a Bingham viscoplastic rheology. In these experiments, slurries of polyethylene glycol and kaolin flowed down a long sloping channel under water. We systematically varied flow rate, slope and channel width for flows with no cooling, flows with cooling but no solidification, and flows with cooling and solidification (Figure 1). This data set will allow us to determine the roles of yield strength, flow rate, cooling rate, slope and aspect ratio in governing surface crust distribution, the critical conditions for transition from open channel to lava tube flow, and the thermal efficiency of the flows.

Griffiths RW, Kerr RC, Cashman KV (2003) Patterns of solidification in channel flows with surface cooling. *Journal of Fluid Mechanics* **496**: 33-62

Kerr RC, Griffiths RW, Cashman, KV (2006) The formation of channelized lava flows on a slope. *Journal of Geophysical Research* **111**: B10206, doi:10.1029/2005JB004225

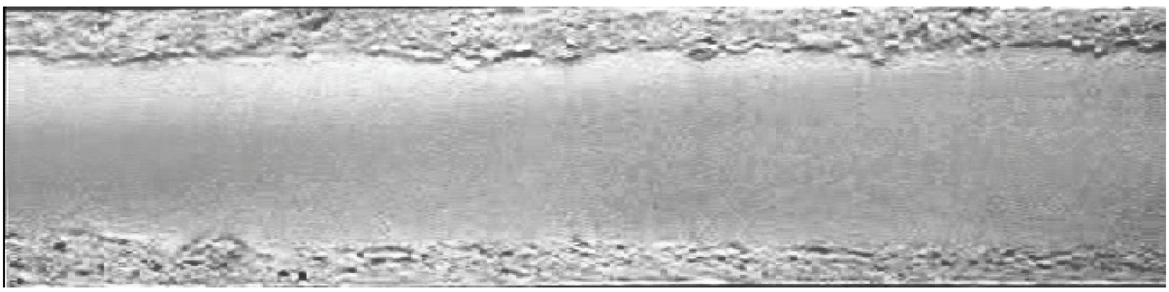

Figure 1. Overhead photograph of a slurry of polyethylene glycol and kaolin, flowing from right to left down a 8 cm wide sloping rectangular channel. The flow is overlain by cold water, and freezes to form a central raft of smooth solidified crust, separated from the walls by two shear layers.

Gawler Craton Array

Michelle Salmon[1], Brian Kennett[1]

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As part of a wider AUSCOPE project 35 short-period seismometers have been deployed across the Gawler Craton in South Australia. Station spacing is approximately 50 km and the area covered runs from Port Lincoln in the Eyre Peninsular to Leigh Creek just west of the Flinders Ranges (figure 1.). Stations will record continuous three component data for a period of 8 months. The primary aim of this array is to increase data coverage in this part of Australia for seismic imaging. There are only two permanent seismographs in the region covered by this array. Data from this array will eventually be publicly available providing the information required to build basic images of the earth structure in the region.

The instruments are capable of recording data from both local and distant earthquakes. This area of South Australia is seismically active and local earthquake data recorded on this array (figure 2.) will help improve our ability to locate and characterize these events. Distant earthquakes will be used to produce tomographic images of the crust and upper mantle in the region. Receiver functions constructed from the three component data can will also be used to locate seismic discontinuities such as the crust-mantle boundary.

The eastern edge of the Gawler craton is currently of particular interest for the supply of geothermal energy and there are many ongoing industry projects in the area. Geoscience Australia completed a deep seismic reflection transect across the top of the Eyre Peninsular just prior to the deployment of the Gawler array. This array will provide broad scale earth imaging required for more detailed studies.

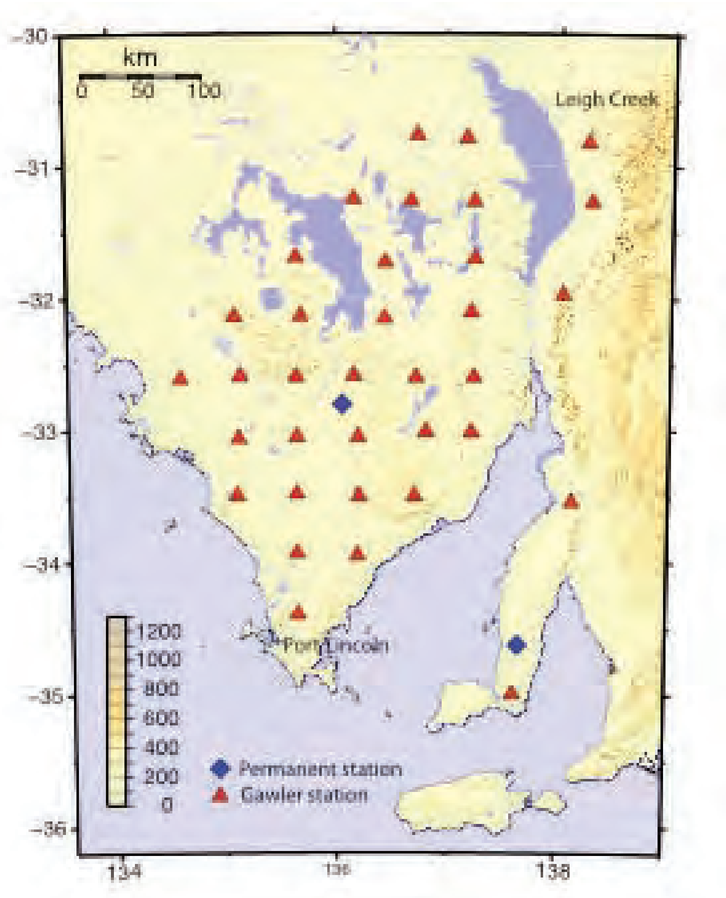

Figure 1.

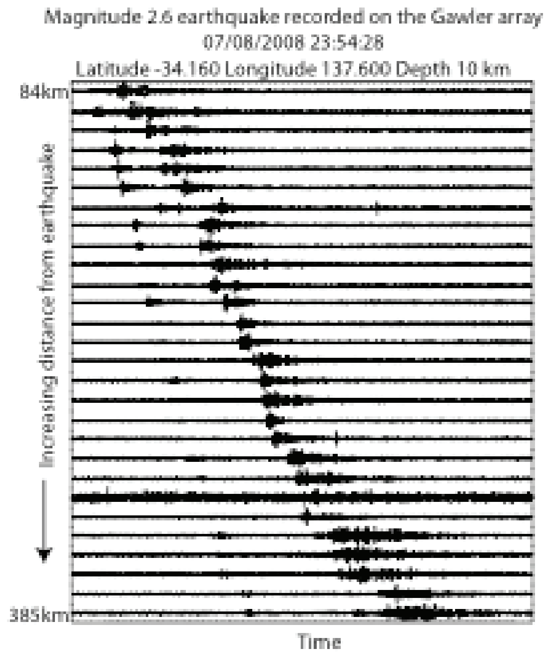
Magnitude 2.6 earthquake recorded on the Gawler array
07/08/2008 23:54:28
Latitude -34.160 Longitude 137.600 Depth 10 km
84km
Increasing distance from earthquake
385km
Time

Figure 2.

Dynamic objective functions in seismic tomography

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[2]*Geoscience Australia, Symonston ACT 2609, Australia*

A new technique designed for generating multiple solutions to seismic tomography problems using gradient based inversion has been developed. The basic principle is to exploit information gained from previous solutions to help drive the search for new models. This is achieved by adding a feedback or evolution term to the objective function that creates a local maximum at each point in parameter space occupied by the previously computed models (Figure 1). The advantage of this approach is that it only needs to produce a relatively small ensemble of solutions, since each model will substantially differ from all others to the extent permitted by the data. Common features present across the ensemble are therefore likely to be well constrained.

A synthetic test using surface wave traveltimes and a highly irregular distribution of sources and receivers shows that a range of different velocity models are produced by the new technique. These models tend to be similar in regions of good path coverage, but can differ substantially elsewhere. A simple measure of the variation across the solution ensemble, given by one standard deviation of the velocity at each point, accurately reflects the robustness of the average solution model. Comparison with a standard bootstrap inversion method unequivocally shows that the new approach is superior in the presence of inhomogeneous data coverage that gives rise to under or mixed-determined inverse problems. Estimates of posterior covariance from linear theory correlate more closely with the dynamic objective function results, but require accurate knowledge of *a priori* model uncertainty.

Application of the new method to traveltimes derived from long term cross-correlations of ambient noise contained in passive seismic data recorded in the Australian region demonstrates its effectiveness in practice, with results well corroborated by prior information (Figure 2). The dynamic objective function scheme has several drawbacks, including a somewhat arbitrary choice for the shape of the evolution term, and no guarantee of a thorough exploration of parameter space. On the other hand, it is tolerant of non-linearity in the inverse problem, is relatively straightforward to implement, and appears to work well in practice. For many applications, it may be a useful addition to the suite of synthetic resolution tests that are commonly used.

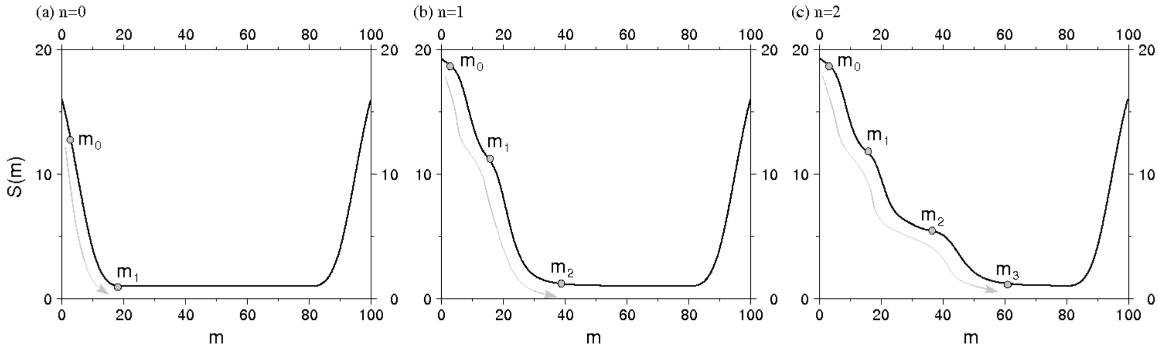

Figure 1: Schemactic diagram demonstrating the principle of the dynamic objective function method. When each new solution is located by the gradient based method, a "hump" is introduced in model space at that point to disuade future solutions from investigating this region.

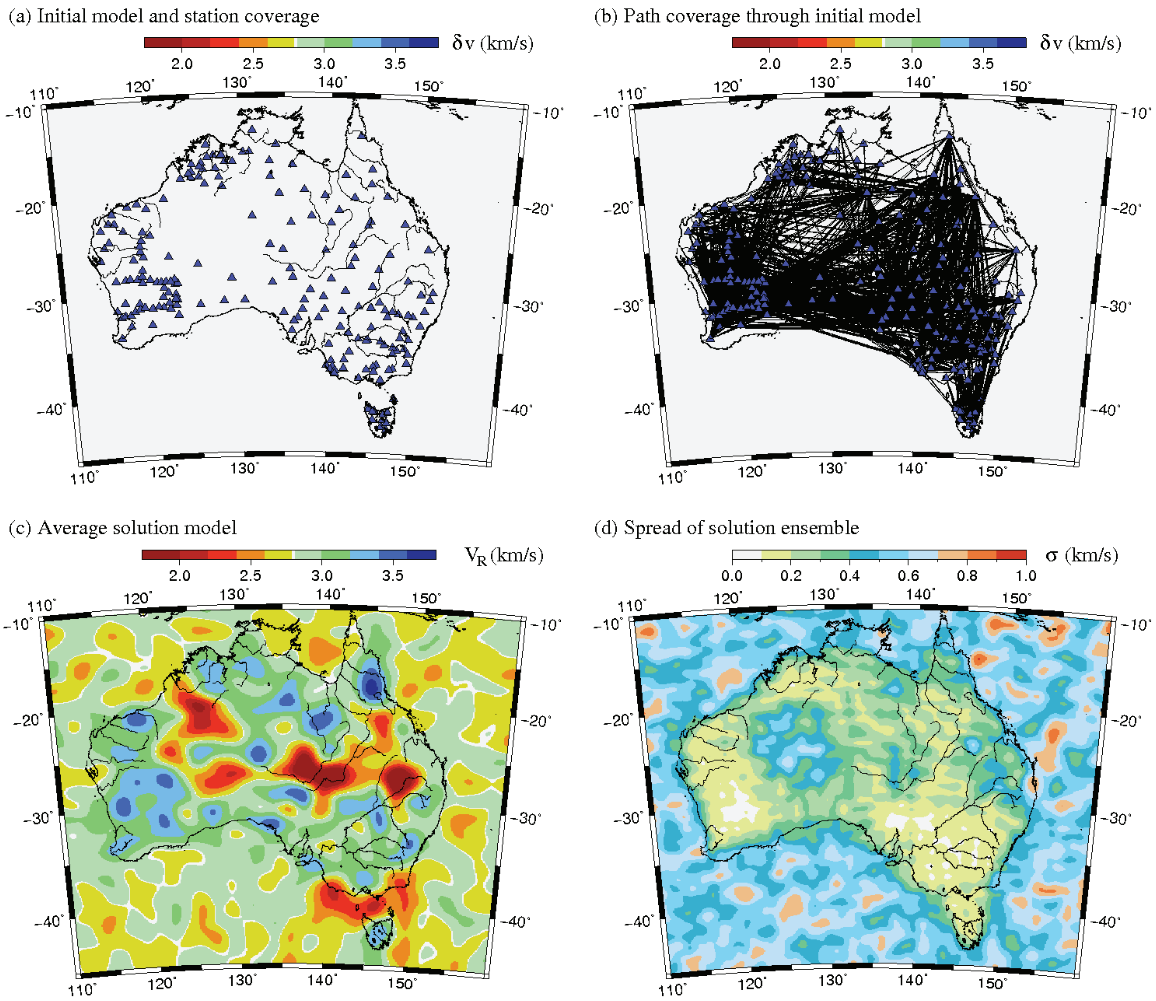

Figure 2: (a) Stations used in the cross-correlation of ambient noise data; (b) *path coverage through the initial model; (c) average solution model computed from an ensemble of 25. V_R denotes Rayleigh wave group velocity; (d) variation of the model ensemble as represented by one standard deviation of the distribution.*

On The Inner-Outer Core Density Contrast From New PKiKP/PcP Amplitude Ratios And Uncertainties Caused By Seismic Noise

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The inner core boundary of the earth is characterised by a discontinuous change in elastic properties between the liquid outer and solid inner core. In the ray theory approximation, a measure of the density contrast at the inner core boundary is given by the amplitude ratio of P waves reflected from the core-mantle boundary (PcP waves) and the inner core boundary (PKiKP waves), since that ratio conveniently appears in an explicit form in the transmission/reflection coefficient equations. The results for inner-outer core density contrast derived from direct amplitude picks of these waves in the time domain have varied significantly among different authors.

The transmission/reflection coefficients on the liquid-solid and solid-liquid boundaries derived from ground displacements enable a direct comparison between the amplitude measurements on displacement seismograms in the time domain and theoretical values. A new approach is proposed and applied to integrate effects of microseismic and signal-generated noise with the amplitude measurements, thus providing a direct maximal uncertainty measure. To suppress the effects of varying radiation pattern and distinctively different ray-paths at longer epicentral distances, this new method was applied to high-quality arrivals of PcP and PKiKP waves from a nuclear explosion observed at epicentral distances 10° to 20° from recording stations. The resulting uncertainties are high precluding precise estimates of the inner core boundary density contrast, but provide a robust estimate of an upper bound from body waves of about 1100 kg/m^3.

Median values of two amplitude ratios observed around 17° epicentral distance indicate a small density contrast of 200-300 kg/m^3 and suggest the existence of zones of suppressed density contrast between the inner and the outer core, a density contrast stronger than 5000 kg/m^3 at the core-mantle boundary, or a combination of both (Figure 1). Such a small estimate of the density contrast across the inner-core boundary from body waves could still produce the desired effect on the compressional velocity profile in the thermo-chemical boundary layer at the bottom of the outer core and return a modest heat flux from the inner core with a substantial inner core age, but only if accompanied by a small estimate of the density contrast of about 400 kg/m^3 from normal modes. If the inner-core boundary is characterized with such a mosaic of variable density contrast to which seismic body waves are sensitive, it is more likely that the density fluctuations are restrained to the top of the inner core. It has been argued that at least the top of the inner core is a dendritic mushy zone, in which interdendritic fluid pockets likely coexist to explain the observed nature of attenuation and attenuation in anisotropy of body waves. If PKiKP waves reflect from the inner core at the places where less dense features at the top of the inner core reduce the density contrast, than this could explain the observed lower values for stations at around 17° (Figure 1).

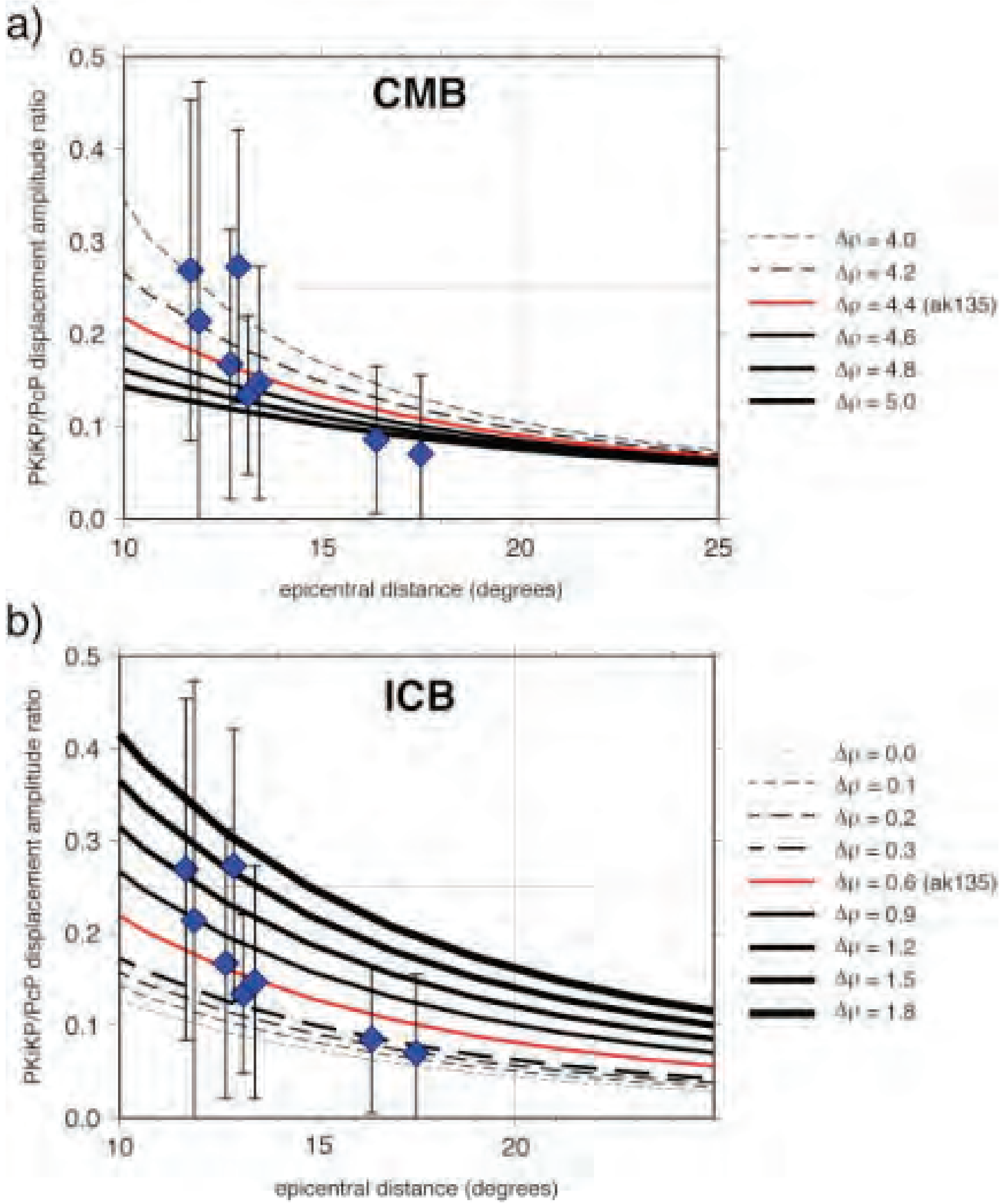

Figure 1. PKiKP/PcP amplitude measurements and their uncertainties (the median values are shown by diamonds, and the uncertainties are shown by error bars) plotted as a function of epicentral distance for: a varying density contrast at the inner core boundary (top) and the core mantle boundary (bottom). Theoretical values are indicated with lines of various thicknesses. Red line indicates the theoretical ratio from the ak135 model.

Drought in the Murray-Darling Basin

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[3]Groupe de Recherche en Géodesie Spatiale, CNRS, Toulouse, France.

The Murray-Darling Basin (MDB) is experiencing one of the most severe droughts in recorded history, driven by record high temperatures and several years of rainfall deficit. The multi-year drought has seen an almost complete drying of surface water resources, water that is required for agriculture and domestic use.

It has always been difficult to quantify total water storage in drainage basins because of the difficulty of measuring and monitoring water retained as soil moisture and in groundwater reservoirs. With the launch of the Gravity Recovery and Climate Experiment (GRACE) space gravity mission in 2002, it is now possible to estimate basin-scale total water storage. GRACE detects changes in the Earth's gravity field – more precisely, changes in potential between the centre of the Earth and the satellites. Making the assumption that the changes in potential are due entirely to changes in water volume, it then becomes possible to estimate the spatial and temporal variations in water integrated across large regions.

Figure 1 shows the time series of changes in total water storage of the MDB since the beginning of the GRACE mission (*Leblanc et al.,* 2008) compared to groundwater, soil moisture and surface water variations. A significant loss of ~260 GTonnes of water can be seen between 2005 and 2007 in the GRACE estimates and the overall loss of total water storage correlates with groundwater losses. The meteorological drought (ie rainfall quantities) abated in 2007 and early 2008 with a return to average or above-average rainfall in the northern part of the basin. The drought actually began some years earlier; hence it is not possible to quantify the total loss of water caused by the current drought. Nonetheless, the GRACE total water storage data indicates that a substantial water deficit remains. Rainfall levels have declined below average values since March 2008.

Leblanc, M., P. Tregoning, G. Ramillien, S. Tweed and A. Fakes, Basin scale, integrated observations of the 21st Century multi-year drought in southeast Australia, *Water Resourc.. Res. in revision.*

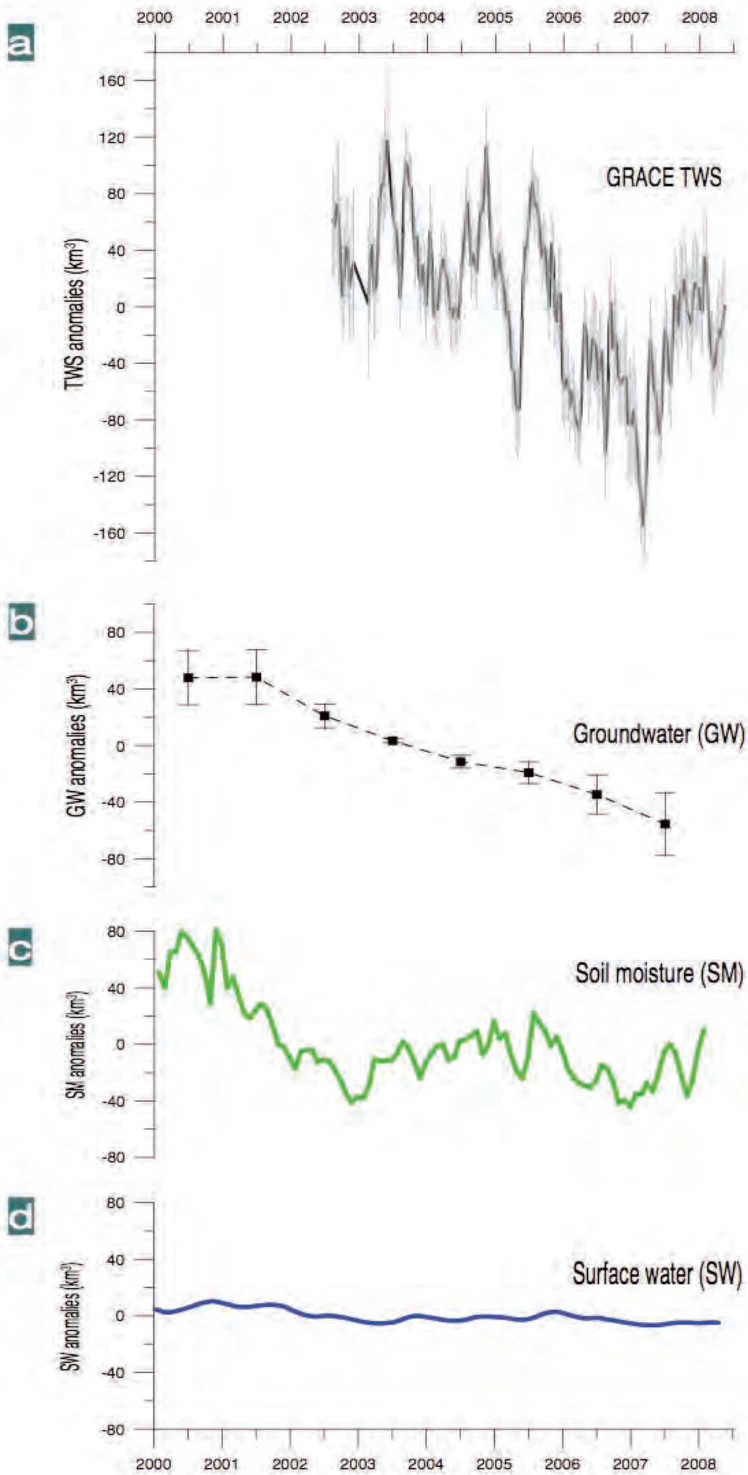

Figure 1. Change in water storage of the Murray-Darling Basin as estimated from a) GRACE space gravity observations b) groundwater borehole measurements c) GLDAS soil moisture model d) lake, river and reservoir level estimates (*Leblanc et al.*, 2008)

A global dataset of frequency-dependent body-wave travel times: towards a global finite-frequency tomography of the Earth's mantle.

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[1] *Institut de Physique du Globe de Strasbourg, Ecole et Observatoire des Sciences de la Terre, Centre National de la Recherche Scientifique and Université de Strasbourg, France*
[2] *Research School of Earth Sciences, Australian National University, Canberra, ACT 0200, Australia*

With the growth in the number of seismic stations, the increase in computational power and the development of new analysis tools that extract more information from seismograms, the resolution of global seismic tomographic models has improved significantly in the last 25 years. For example the lateral resolution of surface wave velocity and anisotropy models of the upper mantle has decreased from 5000 km (Woodhouse and Dziewonski (1984), Nataf et al., 1984) to about 1000 km in the most recent seismic models, allowing the anisotropic behaviours between continents to be distinguished (Debayle et al., 2005).

Finite-frequency theory (Dahlen et al. 2000) incorporates single scattering into the formulation, and has been developed for long period body-waves. It is known that long period body waves are sensitive to the wave speed over a broad 3D volume surrounding the geometric ray. The corresponding 3D kernels have become known as "banana-doughnut" (BD) kernels because of their shape (See Figure 1).

The actual benefit of a finite-frequency theory remains controversial (Sieminski et al., 2004, de Hoop and van der Hilst, 2005a; Dahlen and Nolet, 2005; de Hoop and van der Hilst, 2005b; Montelli et al., 2006a; van der Hilst and de Hoop, 2006; Boschi et al., 2006). These authors suggest that the effect of the improved theory could be smaller than that of practical considerations such as the level of damping, the weighting of different data sets and the choice of data fit, especially when considering the relatively small amount of finite-frequency data (~90 000 long period body waves) compared with the large number (~1 500 000) of travel time data analysed with ray theory (e.g. van der Hilst et al. 2005).

Other limitations come from the travel-time datasets. Until now, most finite-frequency studies have been made using long period travel-times measured for ray theory applications. These travel times are not well suited for an inversion using Dahlen et al. (2000) kernels which are designed for travel-times measured by cross-correlation of a broadband seismic phase with a synthetic. To take a full advantage of Dahlen (2000) finite frequency theory, it is necessary to keep control of the frequency content of the waveform associated with a given travel-time, so that it can be associated with a finite-frequency kernel carrying the same frequency information. Secondly, by measuring finite frequency travel-times over different frequency ranges, it is possible to extract more information from each seismic phase. According to Dahlen et al., (2000), the width of a given BD kernel increases with the dominant period of the corresponding body waveform. Therefore, by measuring the travel-time of a seismic phase at several frequencies, there is a potential for increasing the amount of independent information in the inverse problem, as at each frequency, the waveform "senses" a different weighted average of the structure, through a different Banana Doughnut kernel.

If the debate about the real benefit of finite-frequency is still active, we believe that significant progress can be achieved by building a new dataset of massive long period body phases travel-times measured over a broad frequency range. To date, there is no such global database of frequency-dependent body-wave travel-time measurements.

A first result from this project is an automated approach for measuring long period body wave travel times at multiple frequencies. The approach has been designed to built a dataset for global finite-frequency SH or SV-wave tomography, but can be easily extended to P-wave tomography. The travel times are computed by cross correlation and are fully compatible with the kernels provided by Dahlen, (2000). Currently, our approach allows us to measure in an automated way S, ScS, SS travel-times on SH components in different frequency-bands covering the period range 6-68 s. Frequency dependent crustal and attenuation corrections for WKBJ synthetics can also be incorporated.

The figures show the finite frequency kernels together with maps showing the coverage of the new data set. The automated procedure has been used to build a global dataset of finite frequency travel times, using 30 years of data from IRIS and GEOSCOPE networks. This will be the basis of future work on mantle imaging.

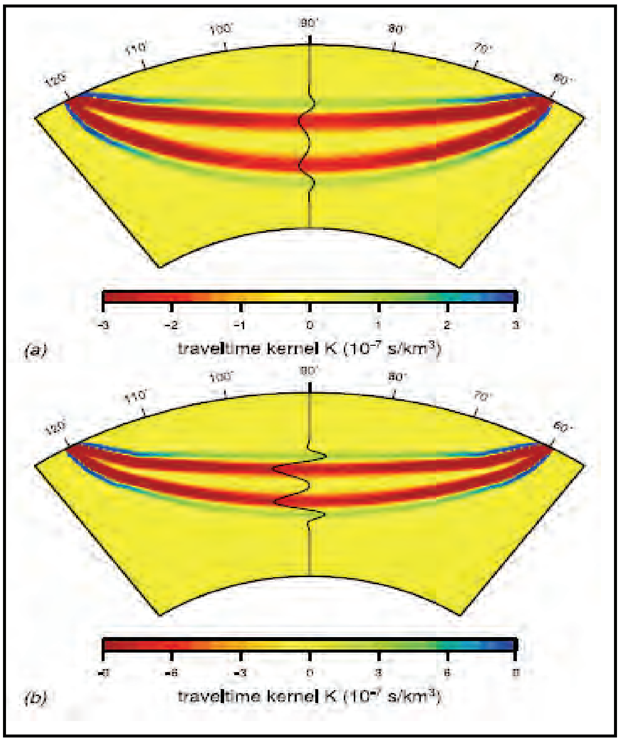

Figure 1. Fréchet Kernels at 20s period for a) P wave and b) S wave.

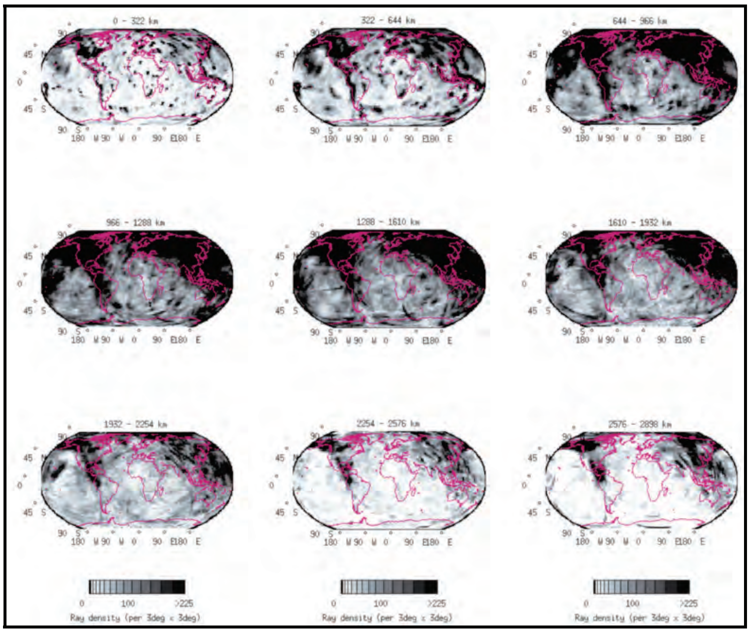

Figure 2. Ray density maps at different depth of the new dataset.

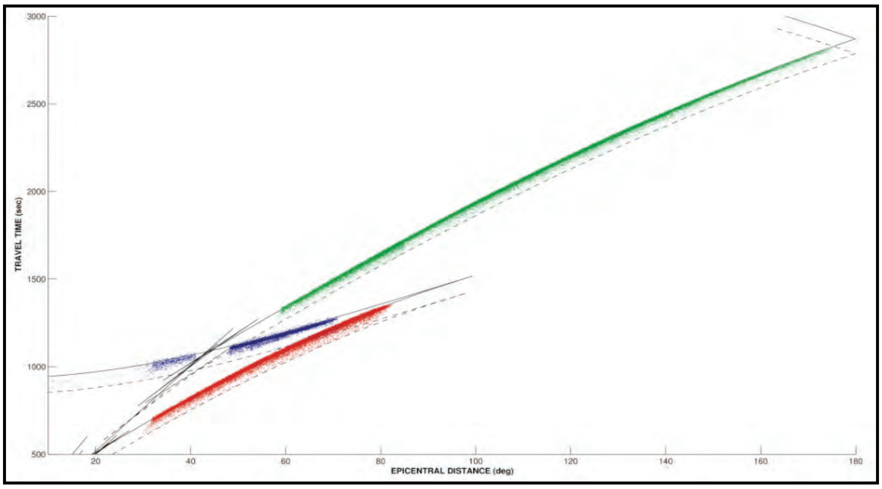

Figure 3. Arrival times of S, ScS and SS phases retained in the final dataset.

Australian trials of the French Transportable Laser Ranging System (FTLRS)

Jason Zhang[1] Chris Watson[2], Francis Pierron[3],
Richard Coleman[2,4,5], Paul Tregoning[1]

[1] Research School of Earth Sciences, Australian National University, Canberra, ACT
[2] University of Tasmania, Hobart, Tasmania
[3] Observatoire de la Côte d'Azur, Grasse, France
[4] Centre for Australian Weather and Climate Research (CAWCR), Hobart, Tasmania
[5]Antarctic Climate and Ecosystems Cooperative Research Centre, Hobart, Tasmania

The Bass Strait in-situ calibration site has been used in the calibration and validation of satellite altimeter data since the launch of TOPEX/Poseidon in 1992. The primary focus at the site has been the estimation of absolute bias in altimeter derived sea surface height (SSH) using a combination of oceanographic moorings, GPS buoy deployments, coastal tide gauge and land based GPS data. As the sole site of its kind in the Southern Hemisphere, the Bass Strait site provides important input into understanding various error sources in satellite altimetery.

With an objective of improving our understanding of any geographically correlated orbit errors present in altimeter orbits, the Bass Strait site was selected as part of a collaborative French/Australian project to trial the French Transportable Laser Ranging System (FTLRS). The FTLRS was operated in Tasmania over a five month period between 1 December 2007 to 17 April 2008 jointly by French and Australian staff. The FTLRS and temporary GPS were located within the city of Burnie beneath Jason-1 descending pass 088, several kilometers from the Burnie tide gauge/CGPS and inland CGPS sites.

During the Tasmanian FTLRS campaign, a total of 673overflights from 12 different satellites were observed and a total of 9200 normal points have been computed In this poster, we present initial results from our analysis of FTLRS data. Whilst building SLR capacity in Australia, we seek to highlight the influence of an additional tracking station in this area of the Southern Hemisphere. Our FTLRS based orbits will assist in quantifying regional or geographically correlated orbit errors present in satellite altimeter data, allowing any bias in altimetry derived SSH in this region to be estimated.

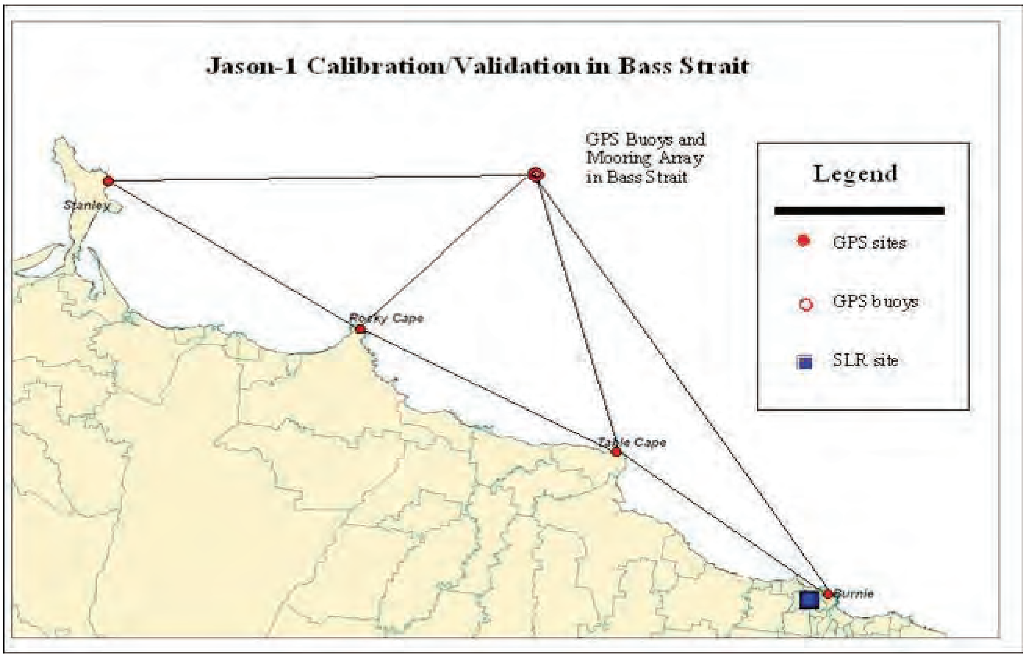

Figure 2. Sketch of the Bass Straite In-Situ Calibration Site

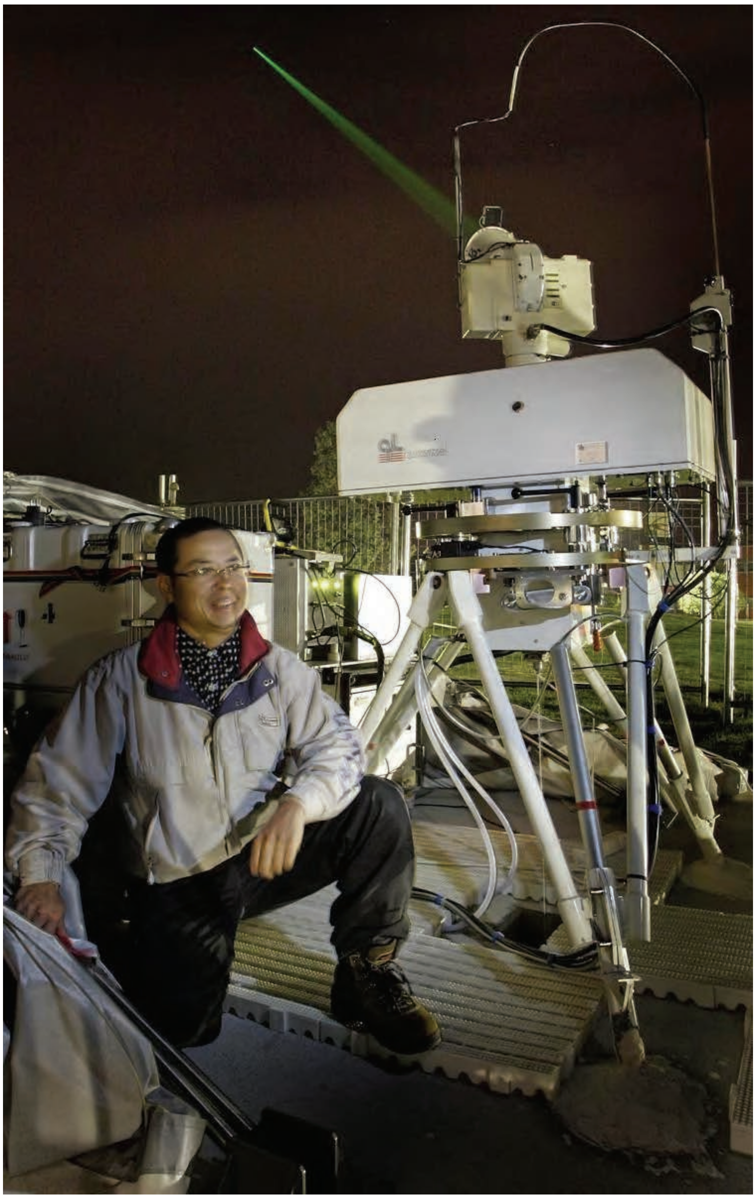

Figure 1. *FTLRS in night operation*

Integrated Ocean Drilling Program

Australia has joined the Integrated Ocean Drilling Program (www.iodp.org), which is the world's largest multinational geoscience program and includes almost all OECD countries. IODP carries out deep scientific coring around the world's oceans, and provides 'ground truthing' of global geoscientific theories that are often based largely on remote sensing techniques.

New technologies and concepts in geoscience are continuously being developed through IODP. IODP is a long-term program and membership will have important scientific outcomes for us. Australia was a highly successful member of IODP's precursor, the Ocean Drilling Program (ODP). The Research School of Earth Sciences hosts the Australian IODP Office (www.iodp.org.au) along with other National Facilities - AuScope and ANSIR.

Submarine plateaus off northeast Australia

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[1]*Geological Survey of Queensland, 80 Meiers Rd, Indooroopilly, QLD 4068*
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[3]*School of Earth Sciences, University of Tasmania, Hobart, TAS 7000;*
[4]*Canberra, ACT.*

Mellish Rise and adjacent deep-water plateaus of northeast Australia: new evidence for continental basement from Cenozoic micropalaeontology and sedimentary geology. *In*: Blevin, J.E., Bradshaw, B.E. and Uruski, C. (Eds), *Eastern Australasian Basins Symposium III*, Petroleum Exploration Society of Australia, Special Publication, 317-323.

Widespread rifting and seafloor spreading replaced the compressional regime off eastern Australia from around 120Ma, in the Early Cretaceous. The magnetic anomalies in the newly formed oceanic crust indicate that spreading commenced in the south and migrated progressively northwards carving off large ribbon-like microcontinents. Gaina et al (1998) postulated from geophysical data that the Mellish Rise and other seafloor highs off northeast Australia might be microcontinental fragments but no geological evidence was available.

Two scientific cruises using R.V. *Southern Surveyor* (GA270 and GA274) obtained core and dredge samples, and seismic and bathymetric data, from the Kenn Plateau and Mellish Rise, and the Louisiade Plateau. A diverse suite of sedimentary rocks includes shallow and deep-water carbonates, siliciclastics, volcanogenic facies, deep-water siliceous lithologies, and some seawater precipitates. The carbonates have provided age dates from foraminiferal and calcareous nannofossil assemblages, which range in age from Paleocene to present day, and prevailing climate and palaeo-water have also been determined.

Some carbonates and siliciclastics contain quartz and mica grains and metamorphic lithic fragments indicating a continental provenance. Dredge sites located along the recently acquired seismic profiles indicate that the continental-derived lithologies correspond to isostatically buoyant basement blocks that have a uniform chaotic seismic reflection. The elevation of the basement blocks relative to oceanic crust in the intervening deep basins, coupled with the petrological properties of the grains and lithics, suggest that continental basement underlies the seafloor highs. The best evidence comes from a Late Eocene sandy glauconitic calcarenite on the southern Mellish Rise, which incorporates angular quartz grains. The age implies that deposition occurred subsequent to drifting and hence reflects a local source rather than contamination by terrestrial material from the continental shelf.

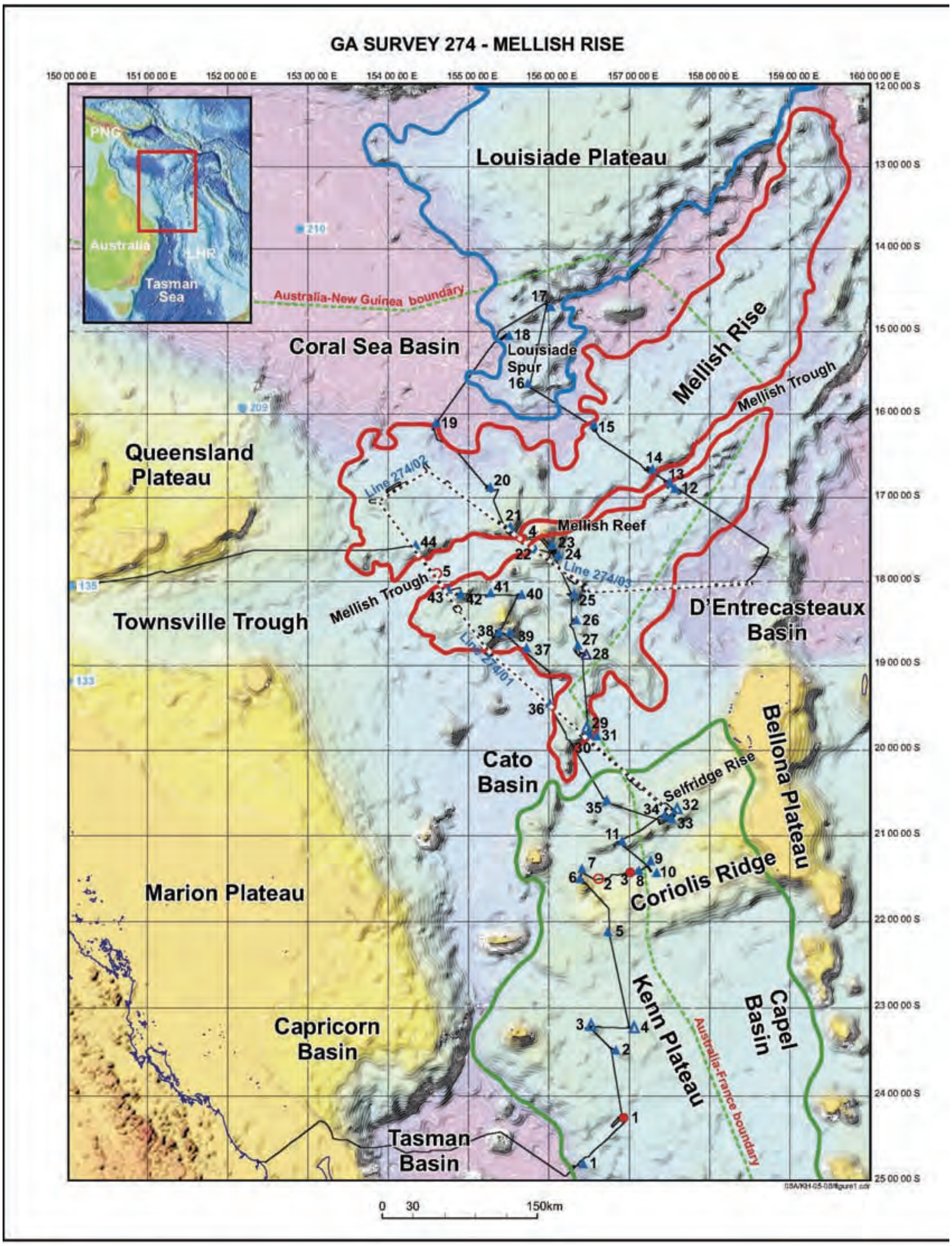

Figure 1. Bathymetric map of offshore northeast Australia showing the Kenn Plateau, Mellish Rise (north and south segments), and Louisiade Plateau with the ship's tracks, dredge and gravity core sites from GA274 cruise. Legend: dredge sites (blue triangles), gravity core sites (red circles), ship's track (solid black line), seismic lines (dashed black line), and ocean drilling sites (numbered blue circles).

PRISE

PRISE operates as a self-funded research group within the Research School of Earth Sciences, providing commercial and collaborative access to the Research School's specialised equipment and expertise in areas of geochronology, geochemistry and petrology. PRISE scientists also undertake their own research projects and supervise postgraduate students, both within the Research School and internationally.

All PRISE staff members are actively involved in wide-ranging collaborative research projects with academic colleagues throughout the world, as well as providing research and analytical skills to industry and Government agencies on a commercial basis. During 2008 PRISE hosted twenty-nine local and international visitors, most of whom undertook collaborative projects using the SHRIMP, Laser ablation- and solution ICPMS, electron microprobe and TIMS analytical facilities. PRISE staff also participated in a number of field-orientated studies in Australia, Africa, South America and Europe.

Some areas of current research include:

- Investigations of the origins of pyroxenite bodies in peridotite massifs of the Western Gneiss Region, Norway (PhD student A. Rosenthal)
- High pressure experimental investigations of kimberlite and carbonatite petrogenesis (PhD student K. Kiseeva)
- Impactor fluxes in the inner solar system from the ages and compositions of lunar glasses (PhD student S. Hui)
- Multi-isotopic and trace element zircon studies to constrain magmatic evolution of plate margins and continental reconstructions; combined U-Th-Pb, Lu-Hf, Ti geothermometry, trace and REE chemistry, and oxygen isotope studies.
- Development of in situ sulphur isotope analytical protocols for the SHRIMP
- Use of sulphur isotopes to aid in understanding the origin and conditions of formation of metal sulphides
- Chronology of the Archaean-Proterozoic transition and the rise of oxygen in the atmosphere
- Geological Connection between West Antarctica and Patagonia since the late Paleozoic: Tectonism, Paleogeography, Biogeography and Paleoclimate
- Placing realistic constraints on the timing of world-wide Neoproterozoic glacial events: a critical examination of the "Snowball Earth" hypothesis
- Bioarchaeology in early Cambodian populations and in situ oxygen and strontium analysis of human teeth
- Development of new mineralogical tools for diamond exploration
- Ages of granites and related mineralisation in NSW.
- Origin and evolution of plume magmas and Hawaiian volcanoes.
- Hydrochemistry of groundwater resources in the Sydney basin and Murrumbidgee Irrigation area of NSW.

Further developments in the *in situ* analysis of sulphur isotopes using SHRIMP II

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For several years the successful measurement of sulphur isotope ratios on the SHRIMP has been frustrated by the lack of suitable standards and the difficulty in producing reproducible, accurate and precise data through instrumental problems and idiosyncrasies. Establishing suitable standards is a difficult and time-consuming process, as internationally available material might be uniform on the bulk scales they were measured at, but might show some variation in composition at the 20 µm scale commonly measured on the SHRIMP. For analyses of sulphides, the early work by Eldridge et al. (1988, 1989) on SHRIMP I showed that matrix effects require the standards to be matched to the composition of the unknown sulphides. We have spent some considerable time in analysing available sulphide standards (e.g. those described by Crowe and Vaughan, 1996) and have managed to overcome many instrumental problems, enabling us to report consistent d^{34}S/^{32}S isotope measurements with external precisions of ~2‰ in standards in a variety of sulphides. Figure 1 shows results from two different composition pyrites (Balmat and Ruttan) run in a single session on SHRIMP II. These results are in excellent agreement with the reported values for these standards.

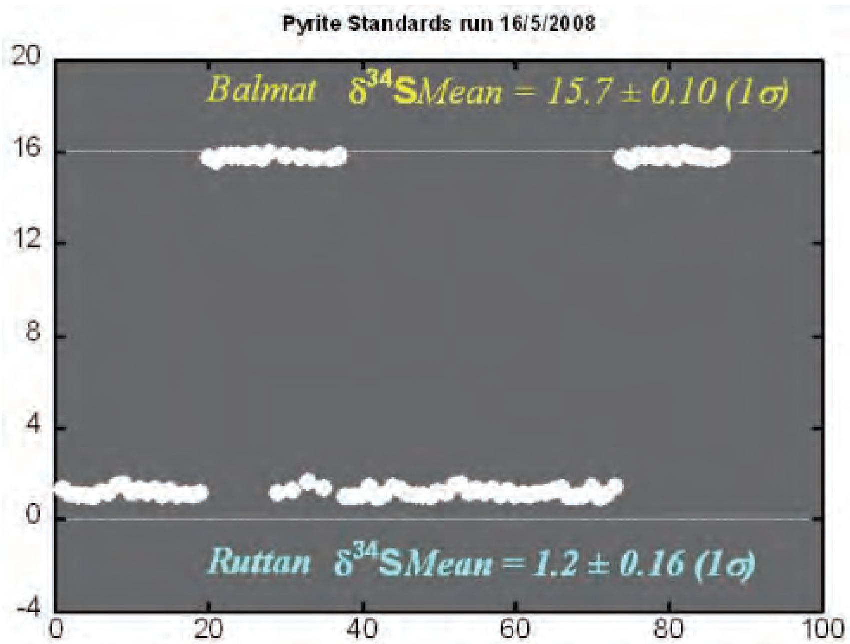

Figure 1. *Sulphur isotope compositions of two pyrite standards as measured on SHRIMP II during a single analytical session.*

Eldrige et al. (1988, 1989) were also able to show that isotope variations on the SHRIMP scale can be large and not necessarily comparable to bulk analyses in some ore deposits. Our investigations of a number of ore deposits from around the world have confirmed this finding. Detailed small-scale analyses within and across various types of pyrite grains from the Witwatersrand deposit show ranges up to 19‰ from core to rim. Many of these traverses show characteristic rhythmic saw-toothed changes in composition, suggesting a repeated process of formation in these particular concentric, structured grains. Figure 2 illustrates both the structure and isotope variation across a concentric Archaean pyrite grain from the Witwatersand sequence.

The successful development of this analytical capability on SHRIMP II will be extended to other more exotic applications, with an emphasis on establishing a routine for the added analysis of ^{33}S. This currently requires modifications to the mulitcollector configuration, but should be possible in the near future. This will extend our research capabilities, enabling us to assess and measure complex mass-dependent and mass-independent fractionation patterns relating to the early development of the Earth's atmosphere, as described by Farquhar and Wing, 2005.

Crowe, D.E. , Vaughn, R.G. (1996). Characterization and use of isotopically homogeneous standards of is situ laser microprobe analysis of $^{34}S/^{32}S$ ratios. Amercian Mineralogist, **81**: 187-193.

Eldridge, CS, Compston, W, Williams, IS, Both, RA, Walshe, JL, Ohmoto, H. (1988) Sulfur-isotope variability in sediment-hosted massive sulphide deposits as determined using the ion microprobe SHRIMP: 1. An example from the Rammelsberg orebody. Economic geology **83:** 443-449.

Eldridge, CS, Compston, W, Williams, IS, Walshe, JL, (1989) Sulfur isotope analyses on the SHRIMP ion microprobe. U.S. Geological Survey Bulletin **1890**: 163-174.

Farquhar, J, Wing, BA (2005) The terrestrial record of stable sulphur isotopes: a review of the implications for evolution of Earth's sulphur cycle. In: McDonald, I, Boyce, AJ, Butler, JB, Herrington, RJ, Poyla, DA (eds): Mineral Deposits and earth Evolution, Geological Society, London, Special Publication 248: 167-177.

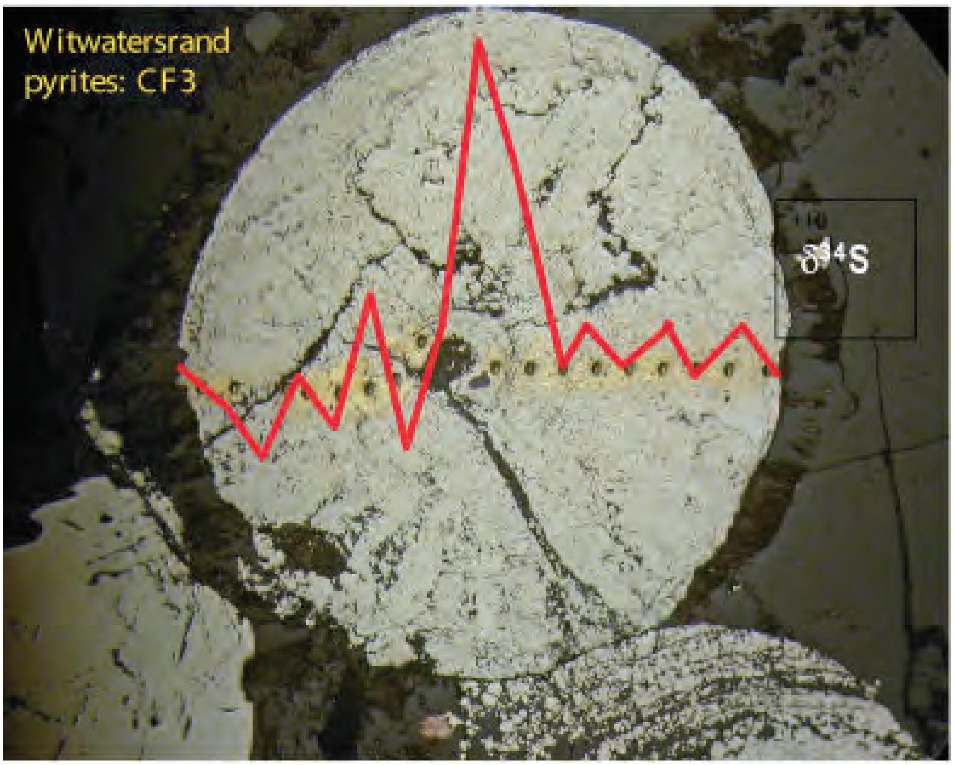

Figure 2. A concentrically-grown pyrite grain from the Witwatersrand gold deposit, South Africa, showing a series of SHRIMP analytical spots across the grain. The SHRIMP spots are approximately 20 mm in diameter. Sulphur isotope compositions were measured across the growth bands and show a large range in values from +10‰ in the centre to ~-7‰ in one of the bands near the margin.

Geochemistry and Analysis of Apollo 16 Lunar Impact Glasses

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Lunar impact spherules are micron to centimetre sized glass particles formed during impact events where shock induced melting of the lunar regolith and impactor produce melt splashes that can be deposited locally or be ejected far beyond the point of impact. These particles can be found within the lunar soil and in microbreccias and are a medium from which we can study lunar chemistry and impact history.

We have separated over 900 lunar spherules, most of them likely to be from impact origins, from the Apollo 16 fines, 66031. Using new mounting and analysis techniques we aim to obtain major and trace element compositions while preserving the maximum amount of sample for ^{39}Ar-^{40}Ar dating on singular particles. Preliminary tests were conducted using shards of crushed USGS standard TB-1G which represents extremes in irregularity. Using wavelength-dispersive electron microscopy techniques to obtain major element compositions of the TB-1G shards, we are able to achieve errors of less than 5% relative.

Following this success, petrographic descriptions and dimensions were obtained for 272 lunar glasses greater than 75μm in diameter along with major element compositions. There are broad positive correlations between MgO vs. FeO and negative correlations between Al_2O_3 and CaO vs. FeO. The majority of the impact spherules have chemistry consistent with derivation of the glasses from the local regolith.

Most impact spherules are irregular and splash-like in shape, often with a coat of adhering grains while highly spherical forms are rarer but have cleaner surfaces. We also find that irregular shapes tend to be more internally heterogeneous in major element composition than the highly spherical forms. This may indicate that highly spherical forms cooled before contacting the lunar surface suggesting a more distant origin. However, rare exotic compositions are more likely to be irregularly shaped which might be due to fragmentation of the glass.

Results of this study were presented at the 8th Australian Space Science Conference, Canberra, Australia, 29th September-1st October 2008.

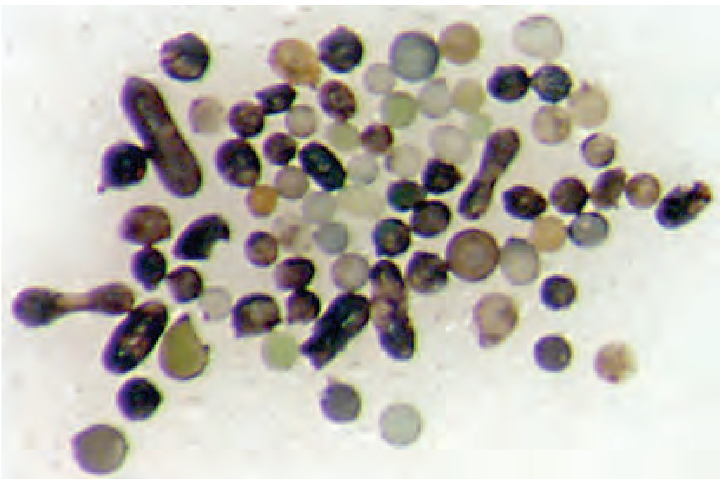

Figure 1.

The role of carbonated eclogite in kimberlite and carbonatite petrogenesis

Ekaterina S. Kiseeva[1], Gregory M. Yaxley[1] and Vadim S. Kamenetsky[2]

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[2]CODES and School of Earth Sciences, University of Tasmania, Hobart, TAS, Australia

The exotic and rare rock types – kimberlites and carbonatites are undoubtedly of mantle origin and are sometimes considered to be genetically related, but the compositions of their parental melts and melting conditions are still widely debated. A component in the source of kimberlitic and carbonatitic melts may be carbonate-bearing eclogite, reflecting heterogeneity in the mantle derived from recycling during subduction of oceanic crust.

The aim of this study is to use high pressure experimental petrology to investigate the behaviour of carbonate-bearing eclogite in upper-mantle conditions and to test its possible involvement in the mantle sources of kimberlite and related magmas. The first part of our investigation aims to locate the solidus positions and partial melt compositions as functions of bulk compositional parameters such as SiO_2 and CO_2 contents, Ca/Mg, Na_2O/CO_2, etc.

Altered oceanic crust typically contains a few % calcite, formed during hydrothermal alteration. The starting experimental composition (GA1) is an average "altered" MORB composition. Ten % $CaCO_3$ was added to GA1 in the experiments to facilitate detection of carbonate in the runs. The second mix, Volga, is GA1 minus 6.5% SiO_2, to which 10% $CaCO_3$ was also added (Volga+10%cc). Experiments were run at 3.5 to 5.5 GPa and 1000-1400°C in piston-cylinder presses at RSES. The run results were analyzed with a HITACHI 4300 SE/N FESEM and JEOL 6400 at the ANU Electron Microscopy Unit, using EDS detectors for quantitative analysis of mineral phases.

Experimental runs after quenching contained the three main phases: garnet, clinopyroxene and melt (Fig. 1, A, B), and sometimes various accessory phases such as K-feldspar, rutile, coesite and carbonate.

Several types of melt were observed in our experiments. A large fraction (>30%) of silicate melt is present in higher temperature runs (T1250 °C). In these cases silicate melt segregated to a pool at one end of the capsule (Fig. 1, A). The totals are about 88-92%, suggesting 8-12% CO_2 dissolved in the melt. At T = 1150 to 1250 °C and 3.5 GPa in GA1+10%cc and 1100 to 1200 °C in Volga+10%cc experiments tiny particles of incompatible-element rich material (ie K-rich and P-rich) are distributed throughout much of the graphite capsules (Fig. 1, C, D) which was often vesiculated or fragmented, indicating decarbonation of a silicate-carbonate melt during quenching. Capsule piercing of some of these runs into a gas chromatograph detected significant CO_2-fluid. With decreasing temperatures at high pressures (4.5 and 5 GPa) carbonate-silicate melts formed small pools of melt within the graphite spheres. Interestingly, at near-solidus conditions in all the investigated pressure intervals two immiscible carbonate and silicate melts are formed. Potassium usually fractionates into the silicate melt, while phosphorous prefers the carbonate.

In sub-solidus conditions in GA1 + 10%cc 1050 °C and 3.5 GPa experiment apatite (Ap), potassium feldspar (K-Fspar), rutile (Ru) and carbonate were observed. At higher pressures potassium feldspar as well as apatite is no more stable and K and P presumably fractionate into the fluid. GA1 + 10%cc solidus at 3.5 GPa is at about 1075 °C, Volga + 10%cc solidus is at least 50 °C lower at all the studied pressures.

Carbonate-rich melts formed from a low degree of eclogite melting will infiltrate neighbouring peridotite, resulting in metasomatism and refertilization. Our next aim is to investigate how these melts would interact with peridotite and compare the outcomes with melt compositions that may be parental to kimberlites.

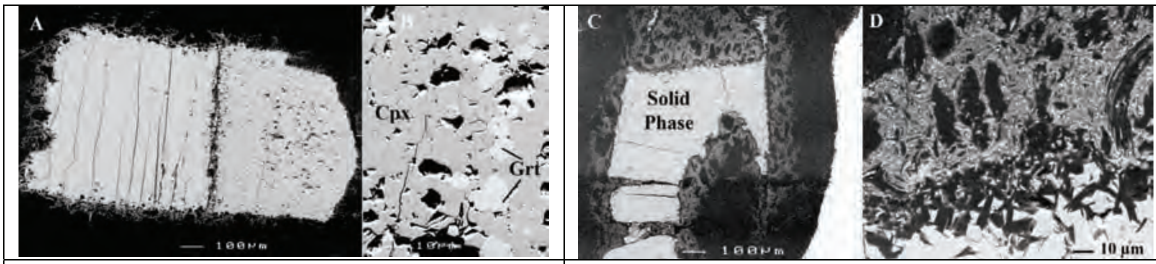

*Fig. 1. Backscattered electron image of GA+10%cc 1350°C 3.5 GPa (A, B) and 1200°C, 3.5 GPa (C, D) run material. **A**. Melt (left) and solid phase (right). **B**. Magnified view of part of the solid material in **A**, showing clinopyroxene (Cpx) and garnet (Grt) crystals. **C**. Solid phases represented by Grt and Cpx crystals. **D**. Magnified area of melt distributed within the capsule. Melt is in contact with residue.*

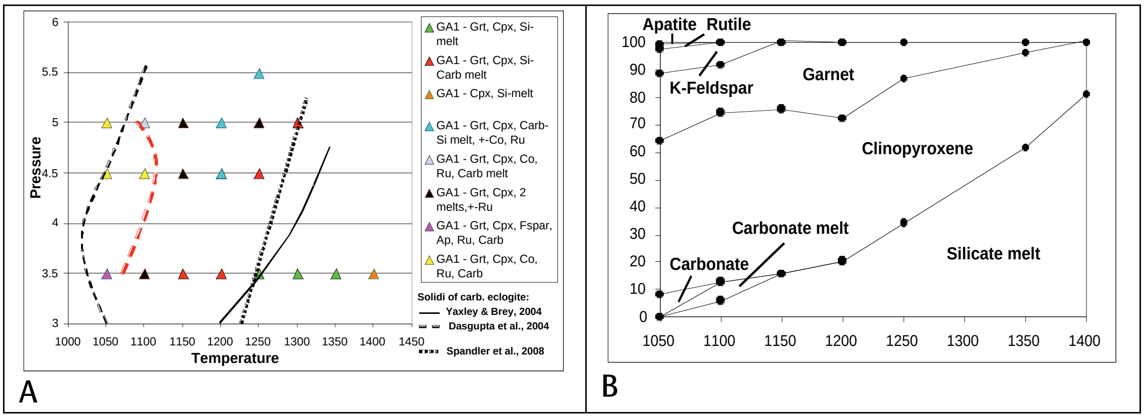

*Fig. 2. **A.** Results of experiments with GA1+10%cc. Approximate solidus is shown by the red dashed line. **B.** Phase proportions for GA1+10%cc at 3.5 GPa pressure. The sole liquidus phase is Cpx.*

The Lunar Cataclysm: Reality of Mythconception?

Marc Norman[1] and Robert Duncan[2]

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Understanding the early impact history of the terrestrial planets is a priority goal for solar system exploration. More specifically, ascertaining whether or not the Earth and Moon experienced a cataclysmic Late Heavy Bombardment of impacting planetesimals ~3.9 billion years ago remains an open question with significant implications for the dynamical history of the Solar System, environmental conditions on the early Earth, and the development of crustal structures on Mars.

The idea of a Late Heavy Bombardment is controversial. Lunar impact melt breccias have crystallisation ages that cluster between 3.8 and 4.0 Ga (Norman et al., 2006; Figure 1), corresponding to an episode of intense crustal metamorphism defined by U-Pb isotopic compositions of lunar anorthosites. The late cataclysm interpretation invokes a spike in the mass flux to the Earth and Moon at precisely the time when the Earth's oldest preserved continental crust was forming and life was emerging. Alternatively the age distribution of lunar impact melts may reflect a steadily declining flux of impactors, with the older record being erased by younger events.

Relating lunar surface deposits to specific basins is critical for assessing the reality (or otherwise) of the late cataclysm. An excellent example is the Descartes Formation, a regional unit of fragmental impact breccia that was sampled by the Apollo 16 mission in 1972. Taking advantage of recent improvements in mass spectrometry we measured high-precision ^{39}Ar-^{40}Ar ages and trace element composition of anorthositic clasts from two of the Descartes breccias. These measurements show that the breccias were deposited 3.866 $\pm$ 0.009 billion years, most likely as ejecta from the massive Imbrium basin, located some 1000 km to the NW of the Apollo 16 landing site (Fig. 2). The trace element compositions support this interpretation.

The significance of this discovery is that Imbrium is one of the youngest impact basins on the Moon. Previous interpretations linked the Descartes breccias to the older Nectaris basin, strongly supporting the idea of a late cataclysm. Our study pulls the pin on the cataclysm hypothesis by showing that age of Nectaris is effectively unconstrained by the sample data. Absolute ages of older basins will be necessary to define the pre-3.9 Ga impact history of the Earth and Moon.

Norman MD, Duncan RA, and Huard JJ (2006) Identifying impact events within the lunar cataclysm from 40Ar-39Ar ages and compositions of Apollo 16 impact melt rocks. *Geochimica et Cosmochimica Acta* **70**: 6032-6049.

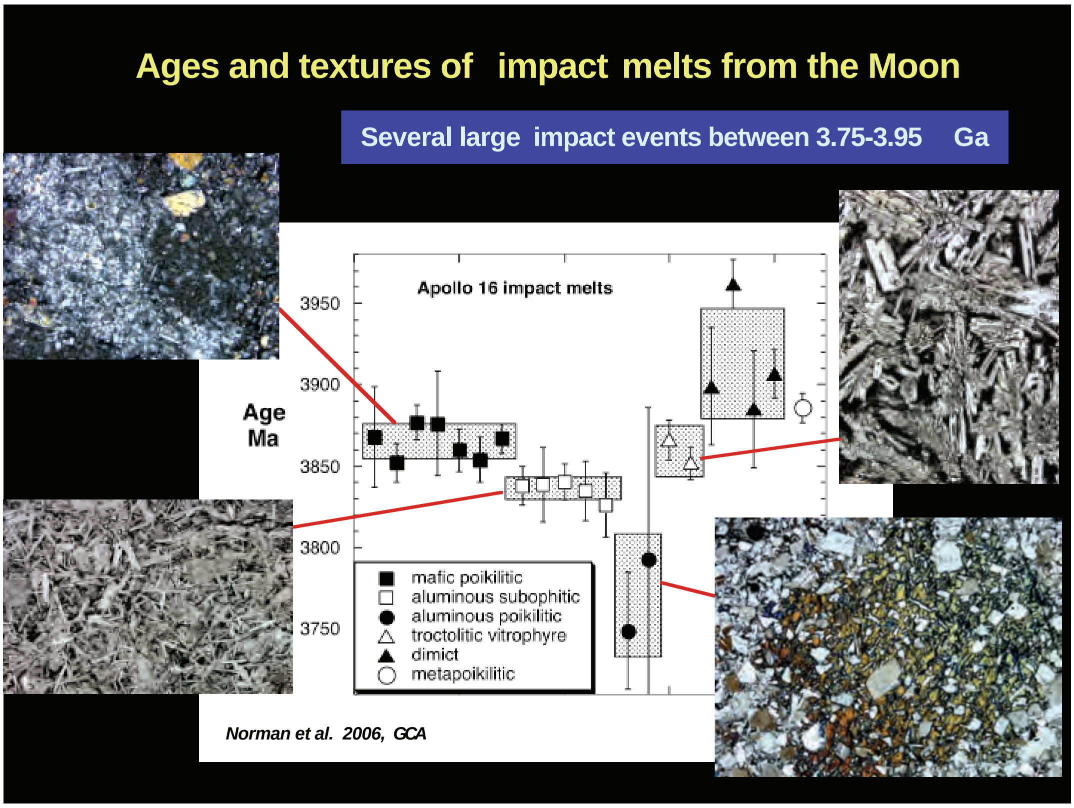

Figure 1.

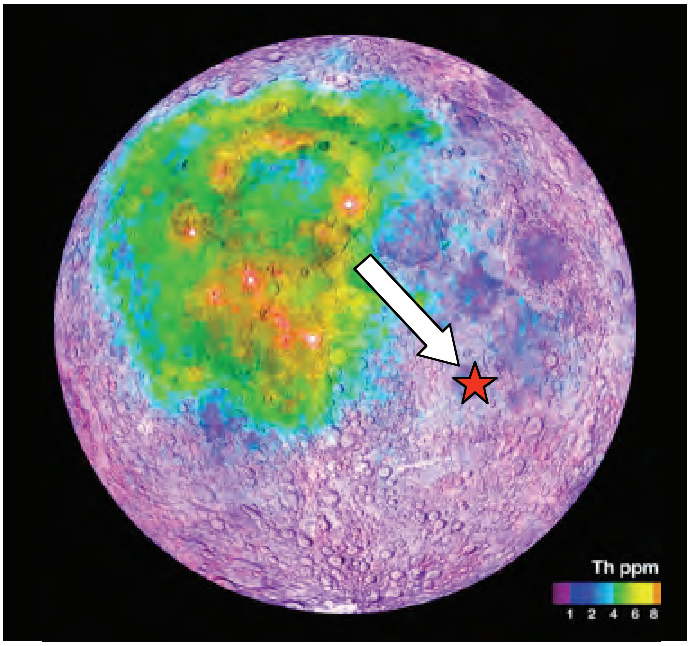

Figure 2.

Melting of residual eclogites with variable proportions of quartz/coesite

Anja Rosenthal[1], Gregory M. Yaxley[1], David H. Green[1], Jörg Hermann[1] and Carl S. Spandler[2]

[1] Research School of Earth Sciences, Australian National University, Canberra, ACT 0200, Australia
[2] School of Earth and Environmental Sciences, James Cook University, Townsville, Australia

Eclogite and pyroxenite layers and veins within the peridotitic mantle may be important in genesis of many magmas. Understanding high pressure melting of residual eclogites with varying amounts of quartz/coesite (qz/co) will improve understanding of the melting behaviour of heterogeneous mantle assemblages.

We are investigating the phase and melting behaviour of a residual eclogite composition, which crystallizes garnet (grt) + clinopyroxene (cpx) at 3.0 & 4.0 GPa with no qz/co (REC). The melting behaviour of REC reveals the anhydrous solidus of a coesite-free eclogite.

The subsolidus phases of REC are garnet (grt) and clinopyroxene (cpx) at 3.0 & 4.0 GPa. The solidus is at 1325±25°C at 3.0 GPa, and at 1475°C±25°C at 4.0 GPa. Melt compositions and proportions with cpx > grt are controlled by grt-cpx cotectics. At 3.0 GPa, cpx/grt ratios decrease with increasing % melting. At 4.0 GPa, cpx/grt ratios are lower at a given % melting than at 3.0 GPa.

We are also studying eutectic-like melting in coesite-bearing eclogites with varying proportions of qz/co. REC10 and REC20 are identical to REC, but have 10% and 20% higher SiO_2 contents, respectively.

Both REC10 & 20 crystallise sub-solidus as grt + cpx + qz/co at 3.0 GPa. The solidi of both are similar at 3.0 GPa, at 1275±25°C. Low-% melting (<20%) is eutectic-like until qz/co melts out. Like REC, grt-cpx cotectics control high degree melting for all compositions, with cpx abundance always exceeding grt. However, for REC, the proportion of cpx always exceeds those in REC10 & 20, but the % melt is always lower than for REC10 & 20 at given temperature.

Melts vary with increasing % melting from andesitic to basaltic for REC & REC10, but from dacitic to basaltic-andesitic for REC20. At <25% melting, melt in REC has lower Mg# at given % melting than melt in REC10 & 20. The contrary is observed at higher % melting.

Garnet and cpx in REC have higher Mg# at a given % melting than grt and cpx in REC10 & 20. Towards higher % melting (>25% melting), variations in cpx Mg# diminish.

These variations of residual grt and cpx Mg# and melt Mg# are principally because melts from REC (qz/co-free) are more mafic at a given % melting.

These outcomes reveal the strong dependence of Mg# of residual mineral phases & melt on the presence or absence of qz/co in melting of eclogites.

Rosenthal A, Yaxley GM, Green DH, Hermann J, Spandler CS (2008) Melting of residual eclogites with variable proportions of quartz/coesite. Geochimica et Cosmochimica Acta 72 (12): A806

Advancing diamond exploration – novel techniques for the interpretation of diamond indicator minerals

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[2]Department of Earth Science and Engineering, Imperial College, London, UK

We have developed new mineralogical tools applicable to the search for diamonds in Australia and overseas. This project was an ARC Linkage Project with industry partners BHP-Billiton, de Beers and Rio Tinto Exploration, through AMIRA International.

Techniques of high-pressure experimental petrology were used to develop mineral thermometers based on partitioning of Zn and Mn between upper mantle minerals. A new synchrotron-based technique for determining the redox state of the upper mantle is also being developed. These tools are being applied to fragments of garnet peridotite transported from the deep lithosphere to the surface by deeply-derived, occasionally diamondiferous kimberlite magmas. The resulting temperature and redox information will provide fundamental constraints on lithospheric diamond stability, and will be important in diamond exploration programs at a strategic level for targeting cratonic lithospheric domains more likely to contain high grades of diamonds, and at a more local level for targeting particular kimberlites for grade assessment by expensive bulk sampling techniques.

High-pressure experiments, focussing on Mn partitioning between garnet and olivine under upper mantle pressure-temperature conditions, have been completed. Algorithms for a Mn partitioning thermometers based on statistical fitting of experimental Mn-Mg and Fe-Mn exchange data between garnet and olivine have been determined. Experiments measuring Zn partitioning between Cr-spinel and olivine were also conducted and an olivine-spinel Zn-based thermometer was developed. These thermometers were applied to a comprehensive range of natural garnet $\pm$ spinel peridotite xenoliths samples from kimberlites erupted through the Kaapvaal and Slave Cratons. They performed extremely well in most cases, when compared with conventional thermometers (eg two-pyroxene thermometry etc).

The calibration of a synchrotron-based, X-ray Absorption Near Edge Structure Spectroscopy (XANES) method for determining Fe^{3+} contents of mantle garnets has proved unexpectedly challenging, despite a promising start (Figure 1), due to complexities relating to the compositional variations of natural garnets. We therefore adopted the alternative approach of obtaining the Fe^{3+} data by conventional Mössbauer Spectroscopy in collaboration with Prof Alan Woodland (Uni of Frankfurt) and by the newly developed electron microprobe based Flank Method in collaboration with Dr Heidi Höfer (Uni of Frankfurt). This will still allow determination of the oxygen-fugacity depth profiles through the lithospheric section represented by the garnet peridotite xenoliths supplied by the sponsor companies. These calculations are currently underway.

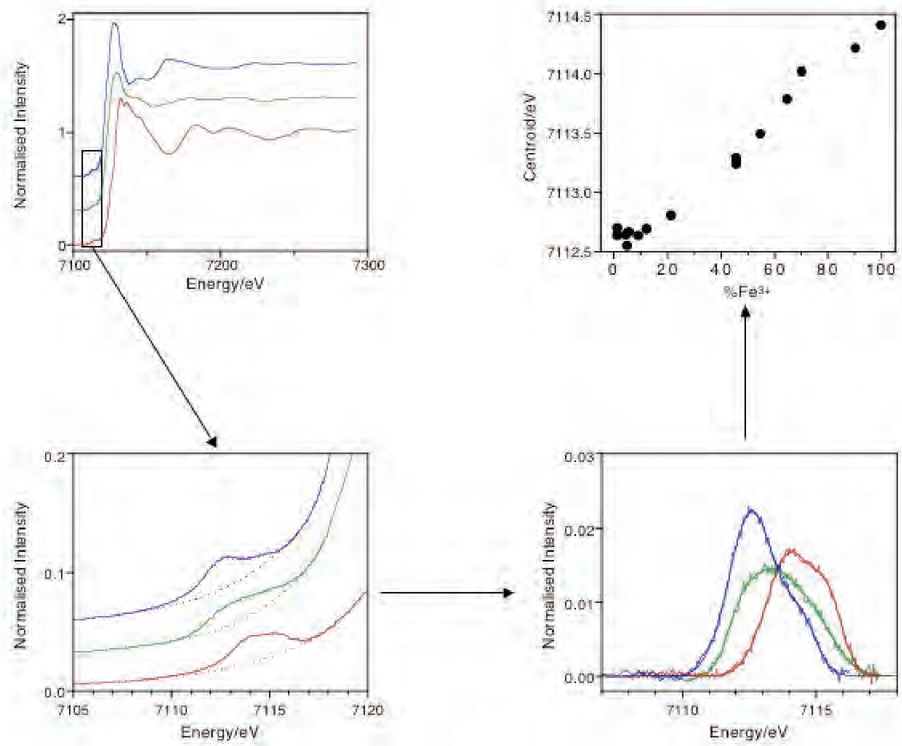

***Figure 1**: Top left panel: Representative raw XANES spectra for synthetic garnets with Fe^{3+}/Fe = 1.0, 0.46 and 0.01 (red, green, blue respectively – compositions known from stoichiometry of skiaigite - almandine - andradite series, kindly supplied by Prof. Alan Woodland, University of Frankfurt) showing Fe K-edge and near edge structure in inset. Data was collected on the Australian National Beamline Facility, KEK, Tsukuba, Japan; Bottom left panel: Expanded view of inset in A, showing pre-edge spectral features with backgrounds (dashed lines); Bottom right panel: Pre-edge peaks after background subtraction and best fit from fitting a number of Gaussian components; Top right panel: Pre-edge peak centroids as a function of Fe3+/Fe, showing linear correlation, the basis of the calibration.*

Visiting Fellows' Research in 2008

The Electronic Geophysical Year 2007-2008

Charles E. Barton[1] , Daniel N. Baker[2] and William K. Peterson[2]

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[2] Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, USA

A worldwide revolution is taking place in the way we store, access, and analyze data and information. For the geosciences, our ability to gather data about the Earth and its space environment is unprecedented. Data acquisition rates of a petabytes per day no longer cause surprise and real-time access to data is becoming widespread. We can obtain data and services via the internet and grid systems from anywhere in the world, we can store and serve data with true interoperability, we can deal with real-time data applications, assimilate data into models, build virtual observatories, and more.

The challenges of organizing, providing ready access to, and using data effectively expand as data volumes, data complexity, and interoperability requirements increase. Meeting these challenges demands investment of time and resources as well as new skills. The onset of these demands has been rapid and novel.

The Electronic Geophysical Year of 2007–2008 (eGY – see www.egy.org) has served to build an international foundation for capitalizing on the new opportunities, The objective is to raise awareness of, and promote informatics capabilities in Earth and space science research; to advance towards the goal of a geoscience information commons in the spirit of the International Geophysical Year fifty years ago; to accelerate the development and adoption of virtual observatories and similar cyber-based systems for dealing with the large, diverse data and information requirements of modern research, and to promote better data management policies and practices. The formal themes of eGY are data access, data discovery, data release, data preservation & rescue, reducing the Digital Divide, and education and outreach.

The central outcome of eGY, which ends in December 2008, has been a heightened awareness among scientists and their professional bodies such as ICSU, IUGG, IUGS, COSPAR, AGU, GSA, and EGU, of the role of infomatics in science.

Microbialtes of Hamelin Pool and Lake Clifton, Western Australia

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[2] *Department of Theoretical Physics, , Research School of Physical Sciences & Engineering and*

Mathematical Sciences Institute, Australian National University, Canberra, ACT 0200, Australia
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[4]*Department of Microbiology, University of Western Australia*

The Hamelin Pool stromatolites show great morphological variation and extend from the high intertidal zone to subtidal depths of about 2 metres. Analysis of variation in stromatolite height shows that the tallest structures occur in the shallow subtidal zone, and that stromatolite relief decreases toward both the upper intertidal zone and toward the deeper subtidal limit of occurrence. Stromatolites at similar depths all have similar relief. The shape of the stromatolites also varies consistently depending on the position relative to present sea-level. Flat forms dominate the high intertidal zone, cauliflower-shaped stromatolites are found in the lower intertidal zone, columnar-shapes dominate in shallow subtidal environments and the deepest examples are all small domes.

Several authors have related variation in stromatolite shape to the occurrence of different types of microbial communities at different elevations. Burne (1991-1992) suggested that stromatolite growth was initiated in subtidal environments, and the present distribution is the result of falling sea levels and modification by intertidal microbial communities.

We have now (a) precisely surveyed the distribution of stromatolites in Hamelin Pool, and (b) modelled stromatolite growth variation by stipulating depth limits for stromatolite growth; suggested stromatolite growth rates; likely rate and direction of sea-level change; and period of time of that conditions for stromatolite growth have existed. We conclude that the morphological variation of stromatolites in Hamelin Pool can be accounted for by a model in which principal growth occurs only between mean low sea level and a depth of 2 metres, growth rate is 5 mm/decade, conditions suitable for stromatolite growth commenced 1,500 years ago, and relative sea level has fallen by 2 metres in the past 4000 years.

In 2007 research on Lake Clifton, a RAMSAR wetland south of Perth was resumed. Despite the recognised significanceand importance of Lake Clifton and its protection as part of a National Park (Burne and Moore 1987, Moore and Burne 1994), there has been very serious environmental degradation over the past 15 years. There appear to have been three major causes of environmental degradation –

Nutrient levels in the Lake - The naturally low nutrient levels of Lake Clifton were essential for the health of the thrombolite-based ecosystem. Despite the importance of monitoring of nutrient levels and limiting nutrient input to the Lake being emphasised by the Scientific Advisors in the Management Plan for the Lake, no monitoring appears to have been undertaken and nutrient levels appear to have risen considerably, possibly as a consequence of sub-division of the Lake's eastern border.

Introduction of Black Bream into Lake Clifton - The introduction of Black Bream into Lake Clifton by a Mandurah resident has had a devastating impact on the water quality, biota and microbial communities of the LakeResearch is being undertaken on the nature of possible remedial action that might be implemented.

Freshwater aquifer depletion - It appears that the construction of the Dawesville Cut involved pumping of the groundwater aquifer and discharge of the fresh groundwaters into the sea. This channel was constructed as an ecologically questionable engineering solution aimed at dealing with the environmental degradation of the Peel Harvey Estuary. The coincidence between the excavation of the Dawesville Cut and elevated salinity of Lake Clifton lake water suggests that this groundwater pumping severely impacted the fresh groundwater aquifer running along the eastern boundary of Yalgorup Lakes. This may account for the salinisation of the aquifer, the reduction in carbonate and fresh water input into Lake Clifton, and the death of stands of Tuart Trees along the eastern Boundary of the Lake System. This may therefore be the result of not properly assessing the environmental impact of Groundwater pumping.Possible remedial action is under consideration.

Burne R.V. (1991-92): Lilliput's Castles: Stromatolites of Hamelin Pool. *Landscope* V.**7** No.2 Summer ed. p. 34-40

Burne, R.V., Moore, L.S. (1987) Zircons from Syros, - Microbialites: Organosedimentary deposits of benthic microbial communities. *Palaios*, **2**:241 – 254

Moore, L.S., Burne, R.V. (1994):-The modern thrombolites of Lake Clifton, Western Australia. in Phanerozoic Stromatolites II .(Bertrand Sarfati, J., & Monty C. L., Editors), Kluwer Academic, Pages 3 - 29.

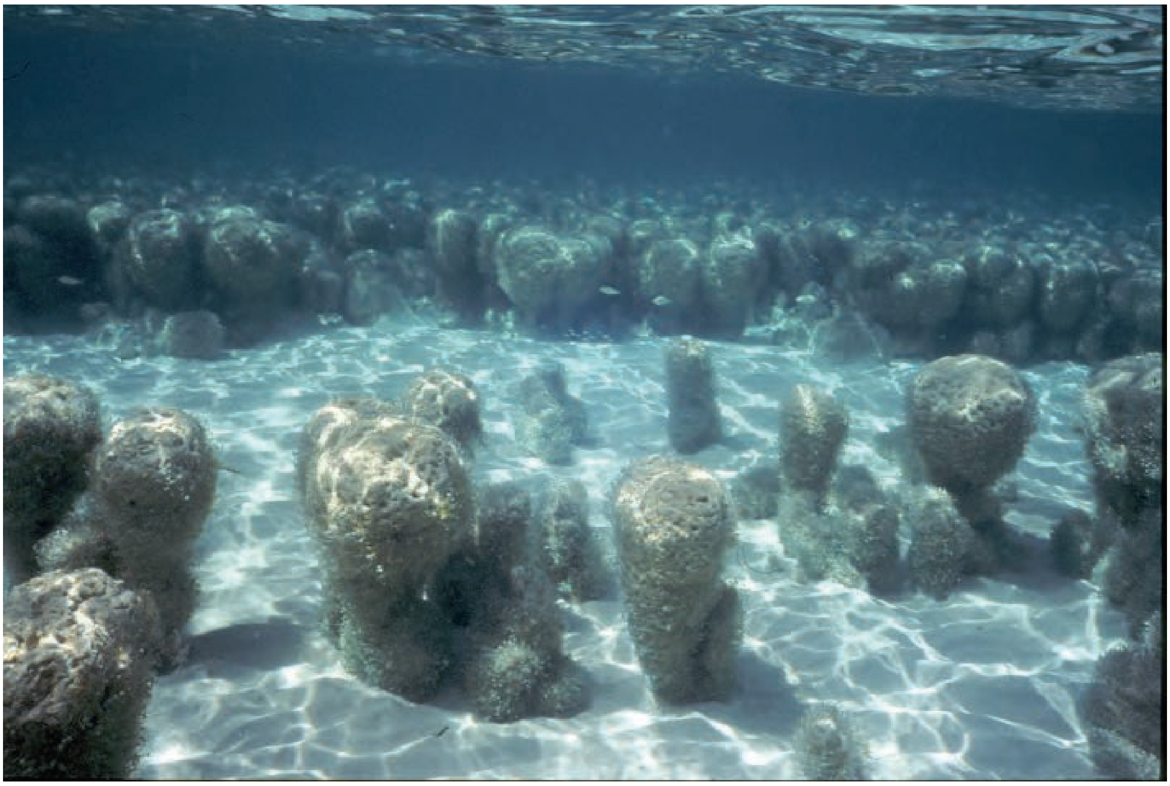

Figure 1. Subtidal Stromatolites, Hamelin Pool

The significance of the Gogo Fauna

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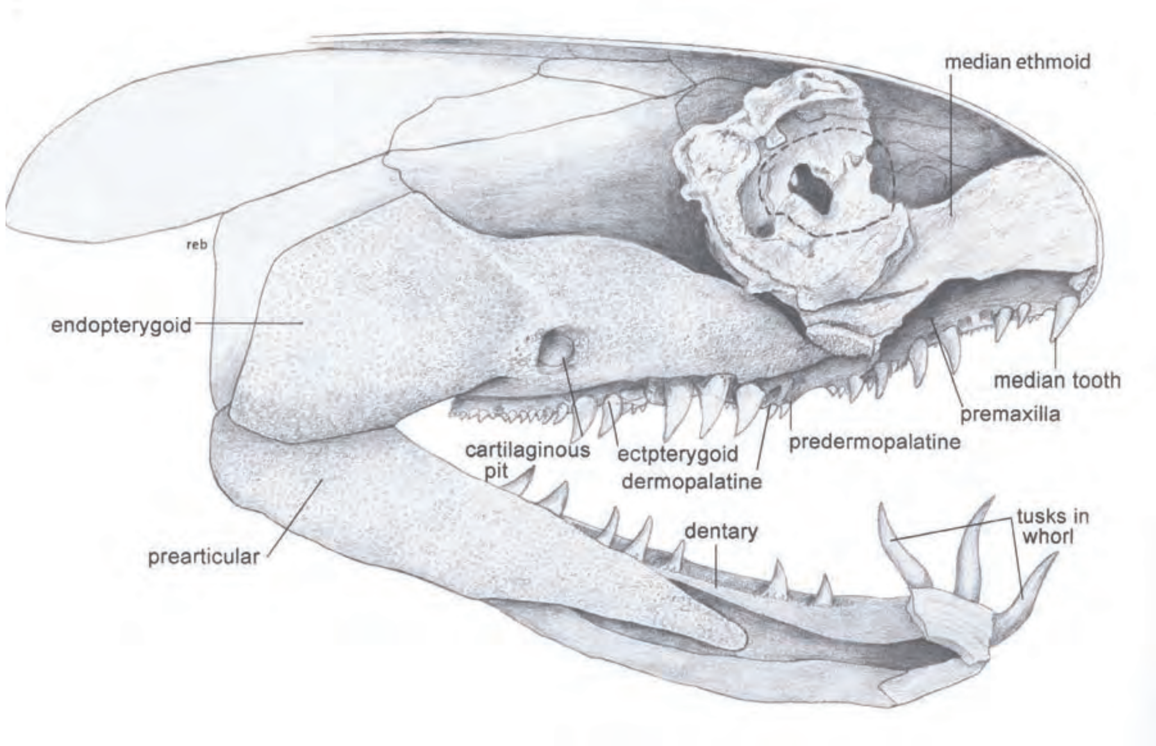
This fauna is of Early Devonian age. It as deposited as a fore-reef carbonate deposit in embayments in the reef system along the Canning Basin edge of the Kimberley Precambrian Massive. Because of the quiet conditions in these embayments, the enclosing sediments frequently covered the bottom dwelling fauna. Many of these organisms were vertebrates, and because some of them after burial wee not disturbed by preditors, they are preserved in almost three dimensions and their histological structure is preserved in the finest detail. For this reason a large number of organisms have been described. In most other areas the specimens are squashed flat, and the finer details are lost because of alteration. Gogo specimens can be freed from the limestone sediment by etching with acetic acid and such features as the neural system, the vascular systems and the growth patterns of the bones can be displayed. What is more, the techniques developed by Professor Tim Senden and A.J. Lemay in the School of Applied Mathematics , IAS, have enabled us to see details that were not revealed even by etching. This includes internal structures of the braincase and the genital systems.

As examples of the quality of the preservation we refer to four recent discoveries that have hit the headlines.

Andrews, S.M., long, J.A. Ahlberg, P. Barwick, R.E. & Campbell, K.S.W. 2006 . The structure of the sarcopterygian Onychodus jamdemarrai n.sp from Gogo, Western Australia : with a functional interpretation of the skeleton. Transactions of the Royal Society of Edinburgh; Earth Sciences : Vol 96: 197-307 Figs 1-75.

Campbell, K.S.W. & Barwick, R.E. 2006 Morphological innovation through gene regulation from Onychodontiform fish. International Journal of Developmental Biology, Vol 50: 371-375.

Long, J.A. Trinajstic , K., Young,G.C. & Senden T, 2008. Live birth in the Devonian Period. Nature : Vol 453: 650-652



Stoichiometry and kinetics of jarosite dissolution in acid sulfate soils

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[4] The Ohio State University, Columbus, Ohio, USA
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Jarosite, ideally $KFe^{3+}_3(SO_4)_2(OH)_6$, is stable under acid oxidising conditions and is an important mineral in acid sulfate soils. It accommodates a wide range of trace cations in solid solution, which can be remobilised if it dissolves. We have found jarosite dissolution to be strongly incongruent: large cations such as K^+ can be lost or exchanged even when the iron sulfate framework remains largely intact. Rare earth cations display extreme fractionation of LREE into jarosite and exclusion of HREE from it, with the result that dissolution of jarosite produces characteristic MREE enrichment in the associated water. Long-duration kinetic studies show that the dissolution stoichiometry in a closed system evolves in a complex fashion through time, from fast release of sulfate to slower release of Fe to constant in Fe as the system becomes buffered by saturation of Fe-oxyhydroxide phases.

Welch SA, Kirste D, Christy AG, Beavis SG, Beavis F (2007) Jarosite dissolution I - trace cation flux in acid sulfate soils. *Chem. Geol.* **245**: 183-197.

Welch SA, Kirste D, Christy AG, Beavis FR, Beavis SG (2008) Jarosite dissolution II - reaction kinetics, stoichiometry and acid flux. *Chem. Geol.* **254**: 73-84.

Welch SA, Kirste D, Christy AG, Beavis F, Beavis SG (2008) Jarosite reactivity and trace metal geochemistry in acid sulfate soils. Goldschmidt 2008 Geochemistry Conference, Vancouver, Canada, 13 -18 July, 2008. *Geochim. Cosmochim. Acta* **72**: A1013 Suppl. (Refereed conference abstract).

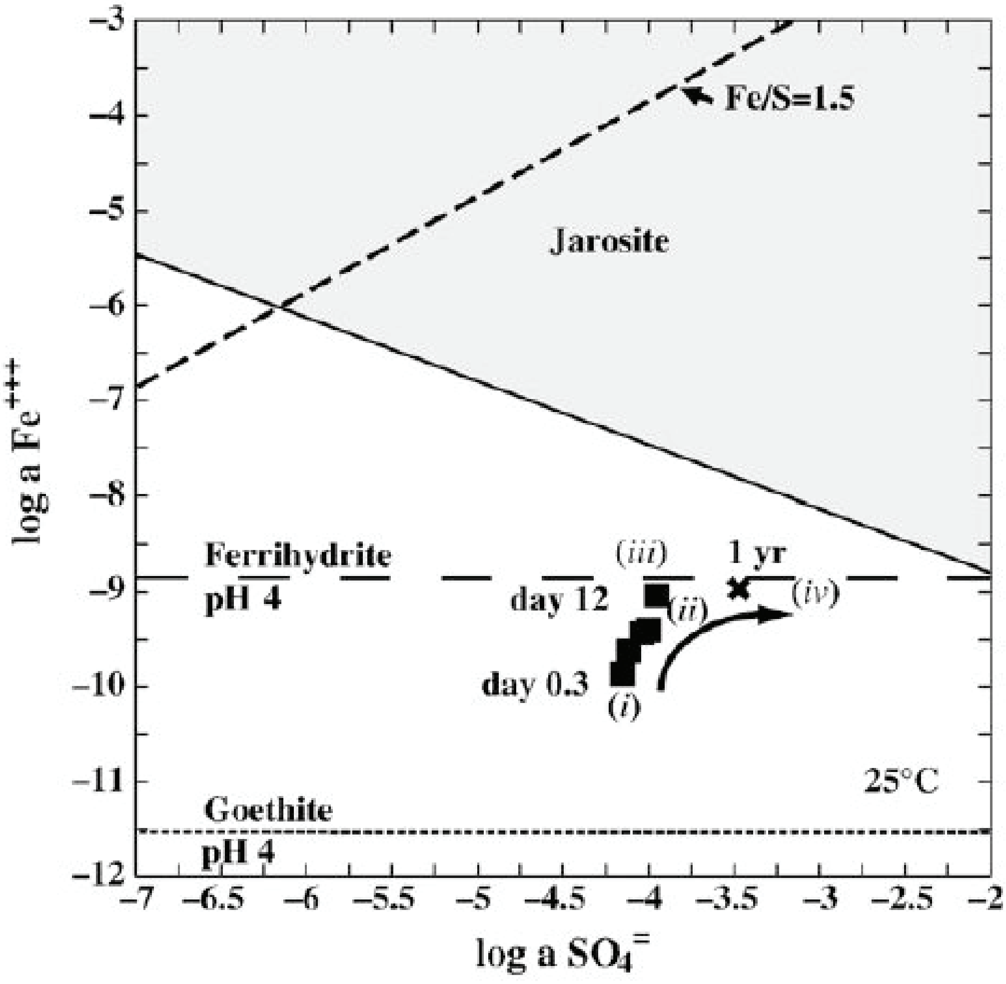

Figure 1. Time evolution of ferric iron and sulfate concentrations in water associated with dissolving jarosite. Stoichiometric dissolution indicated by Fe/S = 1.5 dashed line. Earliest measurements show substantial release of sulfate, followed by slower release of Fe (steep part of curve) until ferrihydrite becomes saturated (flat part of curve). Jarosite saturation ultimately achieved at far right of activity-activity diagram.

Enhanced detection capability at infrasound stations in the global CTBT verification network

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A 60-station global infrasound monitoring network is being constructed as part of the verification regime for the Comprehensive Nuclear-Test-Ban Treaty (CTBT). Nearly 70% of this network has been established and it is anticipated that the network will be completed in the next few years. The network, which is far larger and much more sensitive than any previous infrasound monitoring network, consists of state-of-the-art infrasonic array stations distributed as uniformly as possible over the face of the globe. Current studies indicate that the final global network will reliably detect signals from a 1-kiliton atmospheric nuclear explosion at two or more monitoring stations.

Research at the ANU during the past few years has focused on the development of techniques that can lower detection thresholds, improve location capability and enhance the overall reliability of the network. This has resulted in the development of an optimal infrasonic array design that eliminates problems with spatial aliasing of high frequency signals and problems with signal coherence between array elements. Substantial work has also been carried out on the development of a new and effective technique for reducing wind-generated background noise.

Wind-generated background noise is still the most significant problem at many stations in the global infrasound monitoring network. Wind-generated noise may seriously limit detection capability at stations located in high wind environments with little shelter from the ambient winds. A wind-noise-reducing pipe array is currently used at all infrasound stations in the CTBTO verification network. While these devices provide significant noise reduction, the level of background noise at some stations remains unacceptably high, especially during the daytime. It is generally recognized that further improvements in pipe array design will not resolve this problem. Work at the ANU on infrasound background noise reduction has therefore been concerned with a new approach to the wind-noise problem that appears to have the potential to effectively eliminate wind noise at most monitoring stations.

This technique is based on the use of a turbulence-reducing enclosure constructed from a series of screens positioned around the sensor inlet ports. A large variety of enclosures have been constructed and tested near one of the standard International Monitoring System (IMS) array elements at IS07, Warramunga. A larger than usual 20-m diameter enclosure (version 6) with three concentric porous walls was tested during the year in an attempt to improve the longer period performance of the device. Rather surprising, the performance of this large diameter device was found to be almost identical to a smaller 14-m diameter enclosure (version 5B) with two concentric walls. Both of these enclosures suppress wind-generated noise by up to four orders of magnitude at higher frequencies, even when the sensor is connected to only a single inlet port located at the center of the enclosure.

We conclude that version 5B shown in Figure 1 is the most effective practical design for a turbulence-reducing enclosure.

The performance of version 5B has also been compared directly with the performance of a standard IMS 96-port 18-m diameter pipe array at site H1 at IS07 Warramunga. This comparison shows that the degree of noise reduction provided by the turbulence reducing enclosure with only a single inlet port is more than two orders of magnitude better than the standard 96-port pipe array at higher frequencies. The performance of the pipe array is, however, slightly better at low frequencies.

This suggests that the performance of existing pipe arrays at IMS infrasound stations can be improved very substantially by enclosing the pipe array inside a turbulence-reducing enclosure similar to version 5B. It is recommended that all new IMS stations should be constructed with wind-noise-reducing pipe arrays located inside a turbulence-reducing enclosure.

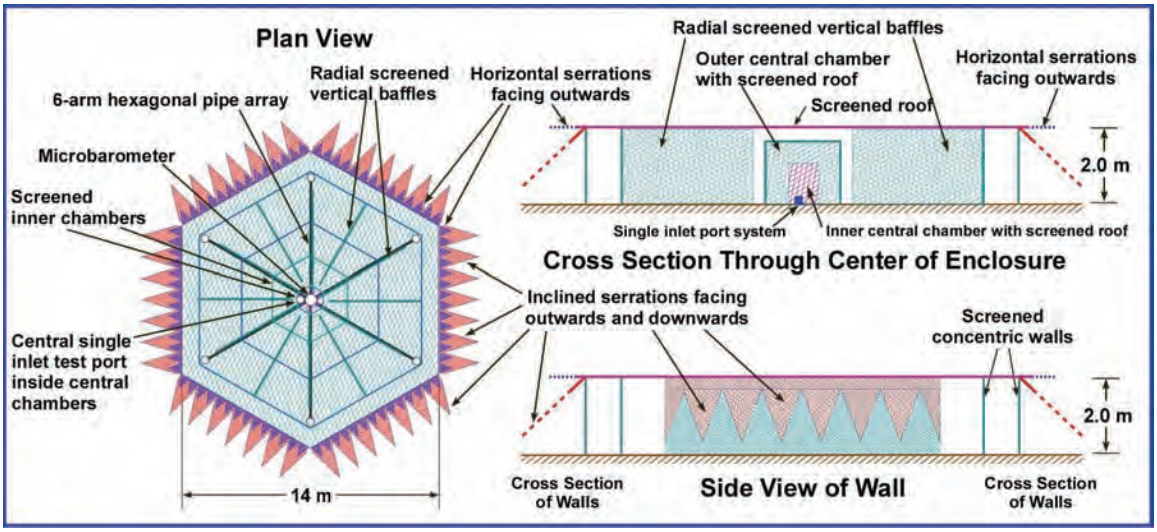

Figure 1. Version 5B of the infrasonic wind-noise-reducing enclosure.

Effects of Archaean to early Proterozoic asteroid impact clusters on crustal evolution

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(joint with, and logistically assisted by, the Pilbara project of the Geological Survey of Western Australia).

The role of asteroid and comet impacts as triggers of mantle-crust processes poses one of the fundamental questions in Earth science. Evidence has been documented for close association between impact ejecta/fallout units with major unconformities and lithostratigraphic boundaries in early Precambrian terrains, including abrupt changes in the nature of volcanic and sedimentary environments across stratigraphic impact boundaries, with implications for the composition of provenance. In the Barberton Greenstone Belt, eastern Kaapvaal Craton, South Africa, 3.26-3.24 Ga asteroid mega-impact units are juxtaposed with abrupt break between mafic-ultramafic volcanic crust and an overlying association of turbidites, banded iron formations, felsic tuff and conglomerates.

Contemporaneous stratigraphic relationships are identified in the Pilbara Craton, Western Australia. Evidence for enrichment of seawater in ferrous iron in the wake of major asteroid impacts reflects emergence of new source terrains, likely dominated by mafic compositions, attributed to impact triggered oceanic volcanic activity. Relationships between Impact and volcanic activity are supported by the onset of major mafic dyke systems associated with ~2.48 Ga and possibly the 2.56 Ga mega-impact events. Abrupt breaks at 3.26-3.24 Ga between ~12 km-thick mafic-ultramafic volcanic sequences of Archaean greenstone belts and overlying felsic volcanic-turbidite-banded iron formation assemblages in the Transvaal and the Pilbara cratons are accompanied by 4 asteroid ejecta units. Mass balance calculations based on Ni/Cr, PGE and $^{52/53}$Cr isotope data indicate mafic-ultramafic target crust and parent asteroid on a scale of 20 – 50 km diameter. Kinematic models of impact by such asteroids on thin geothermally active Archaean crust and lithosphere suggest consequent reorganization of mantle convection cell systems, accounting for contemporaneous peak igneous activity.

The onset of ferruginous sedimentation immediately following the impacts, indicated by occurrence of BIF above ejecta units, indicates increased supply rates of soluble ferrous iron to the oceans under the low Eh conditions of the Archaean hydrosphere, indirectly suggesting the erosion of mafic volcanics possibly triggered by the impacts. A new impact crater discovered by Dr A.H. Hickman and documented by the author is reported in the current issue to the Australian Journal of Earth Science (see Figure 1). The results of this study are reported in 16 papers in international and national scientific journals and in books during 2004 – 2008.

Figure. 1. The newly found Hickman Crater, Ophthalmia Range, Western Australia, reported in Glikson et al., Australian Journal of Earth Science, December, 2008.

Clarification of the Influence of Water on Mantle Wedge Melting

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Water is a significant component in primitive island arc magmas and its ubiquitous presence is attributed to release of water from dehydration reactions in subducted oceanic crust and lithosphere. Water released from the subducted slab is inferred to be transferred as aqueous vapour or water-rich melt into the overlying peridotite of the mantle wedge. Because of the inverted temperature gradient inferred for the mantle wedge immediately above the subducted slab, access of aqueous vapour or water-rich melt will initiate melting close to the water-saturated peridotite solidus. The location of a region of water-saturated mantle melting, if it exists, can be predicted if we know the P,T dependence of the water-saturated peridotite solidus and can model the temperature distribution in a particular subduction setting. We have confirmed the results of a number of experimental studies in the 1970's which defined the P,T conditions for the water-saturated solidus of lherzolite up to 3GPa..

We conducted 60 experiments from 1.5 GPa to 6 GPa using different water contents and several bulk compositions. Electron microprobe analyses of 4-7 phases in each experiment document systematic compositional changes in co-existing phases. In addition Fourier Transform Infra-Red (FTIR) spectroscopy was used to measure the water contents of nominally anhydrous minerals (commonly abbreviated NAMS) in 25 of the experiments. The solidus decreases rapidly from ~1100˚C at atmospheric pressure to 0.5 GPa, 1000˚C, and continues to decrease slightly to a minimum of 970˚C at 1.5 to 2 GPa. We demonstrate that for hydrous silicate melt, the fluid-saturated solidus of lherzolite model mantle composition with small (0.2-2%) water contents and very small carbon content, is ~1010˚C at 2.5 GPa, ~1210˚C at 4GPa. and at least 1375°C at 6GPa.. The melt composition at the water-saturated solidus at 2.5GPa is a very silica-undersaturated olivine nephelinite and is extremely silica-undersaturated at higher pressure.

We also used olivine single crystal discs and either olivine aggregates or carbon sphere aggregates as melt and fluid traps forming interstitial films or inclusions within olivine. For several experiments with high water contents, the capsule was pierced under high vacuum at room temperature and the vapour released was analysed by gas chromatography. We have conducted layered experiments for the purpose of measuring the water content of nominally anhydrous minerals under conditions where we were simultaneously observing melting, water-rich vapour, pargasite or phlogopite in fertile lherzolite. We obtained data using the layered capsules with 'sensor' layers of olivine, low-Al and high-Al orthopyroxene and clinopyroxene, at pressures of 1.5, 2.5, 4, and 6 GPa..

Allowing for the uncertainty in calibrations in the quantification of IR spectra, our results show that if water contents in fertile mantle lherzolite (i.e. HZ1 Lherzolite, MORB Pyrolite, MM3 lherzolite) are as low as 100-250 ppm H_2O, then pargasite is stable at 2.5 GPa and melting begins at the 'fluid-absent lherzolite+ H_2O dehydration solidus' which is close to 1100°C for these compositions. With increasing water content the proportion of pargasite at the solidus increases to ~10-15% (i.e. with 1500-2000 ppm H_2O in the lherzolite) but the water content of NAMS remains unchanged. At higher water contents a water-rich vapour is present and melting begins at the vapour-saturated solidus with pargasite stable at and slightly above the solidus. Our data on the water content in olivine in the sequence from the first appearance of a water-rich vapour (e.g. between 0.073% and 0.145% H_2O at 2.5Gpa, 1000°C) to 'leached' experiments with 14.5% H_2O show little change with increasing bulk water content, suggesting that water activity is effectively buffered by the pargasite-bearing assemblage.

At >3GPa, pargasite is unstable and with water contents of 100-250 ppm or more, melting begins at the vapour-saturated solidus which for a water-rich vapour and fertile lherzolite composition is at ~1225 °C at 4Gpa and ~1375°C at 6GPa. The data also show that if a melt is formed at the vapour-saturated solidus at >3GPa ('incipient melting regime') and migrates out of the vicinity, then the water content retained in the residual but still fertile lherzolite (in nominally anhydrous minerals) is 100-250ppm H_2O. Decompression melting of such residual lherzolite at temperatures in the 'major melting regime' i.e. slightly above the anhydrous solidus, will produce magmas at ~10% or ~20% melting containing 0.1-0.25% or 0.05-0.13% H_2O respectively, i.e. controlled by the residual water contents retained in NAMS. Such magmas would have incompatible element contents reflecting the history of their source including the loss of very small melt fraction(s) in the garnet lherzolite stability field. These characteristics match those of N-MORB or D-MORB, whereas E-MORB characteristics reflect source lherzolite to which a migrating incipient melt has been added.

The preservation of microbial lipids in saline and acid-saline environments

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We are currently working on a pair of separate, but related, lipid biomarker analyses on samples from Lake Tyrrell, VIC, Australia, in order to ascertain the timescales and extent of biomarker preservation within a hypersaline lacustrine system. In the context of the primary project, we have obtained a ~13m drill core (see Fig. 1) from the northern end of the lake during field work in July 2008; from this core we are extracting lipids to construct a temporal sequence. Prof S. George and his PhD student, Mr. P.S. Bray, both from Macquarie University, will perform compound specific radiocarbon dating on archaeol extracted from the core and optically stimulated luminescence dating (in collaboration with Dr Kathryn Fitzsimmons, RSES) on quartz lenses within the core to ascertain the timescales over which environmental change occurred. To determine the magnitude and nature of this change, we are examining suites of lipids from each sub-sampled depth to reconstruct the microbial community that was present in the lake at the time the compounds were deposited. The objectives of this work are to 1. Determine the potential for Australian salt lakes to be used as data sources for paleo-environmental reconstruction; 2. Refine estimates of past aridity for the Tyrrell Basin; and 3. Investigate the extent of community re-structuring by micro-organisms in response to salinity changes.

The secondary project examines biomarker preservation at pH 4 acidic seeps found at the southern end of Lake Tyrrell. Anoxic, iron-rich ground waters flowing from these seeps oxidize near the surface and result in ferricrete deposition. The ferricretes are composed of quartz-rich lake sediments cemented into meter-scale rocks by iron oxides (magnetite) and oxyhydroxides (goethite). These ferricretes are underlain by typical acid-saline depositional facies, very similar to that encountered at Meridiani Planum on Mars by the rover Opportunity. To determine whether molecular markers for life can coexist with oxidized mineral deposits, we extracted samples of ferricrete and underlying sediments to establish the presence and provenance of free and bound lipid biomarkers.

In order to assess the effects of oxic lithification on redox sensitive lipids, we monitored the concentration of phytanol and its oxidation product, phytanic acid, in ferricretes and surrounding sediment samples. Results indicate that the jarosite-rich (KFe_3+3$[(OH)_3SO_4]_2$) sediment directly underlying the concretion is a poor matrix for lipid preservation: only small concentrations of phytanol were evident, and phytanic acid was below detection limits. By contrast, both the goethite-rich layer of the concretion and the reduced sulfide-rich sediments surrounding it showed greater concentrations of each compound (20x and 250x, respectively). Interestingly, the ratio of phytanol to phytanic acid is approximately equal within the oxic concretion and the reduced sediment, indicating that abiotic oxidation is not likely to be a relevant diagenetic pathway for phytanol in this setting.

Differences in compound concentrations between samples demonstrate the differential preservation of lipids within the ferricrete and the underlying sediment. While the concentrations of lipids are ~10 times lower in ferricrete than in sediment, their presence indicates that biomarker molecules may survive the oxidizing conditions of ferricrete formation broadly analogous to those that existed on the Martian surface.

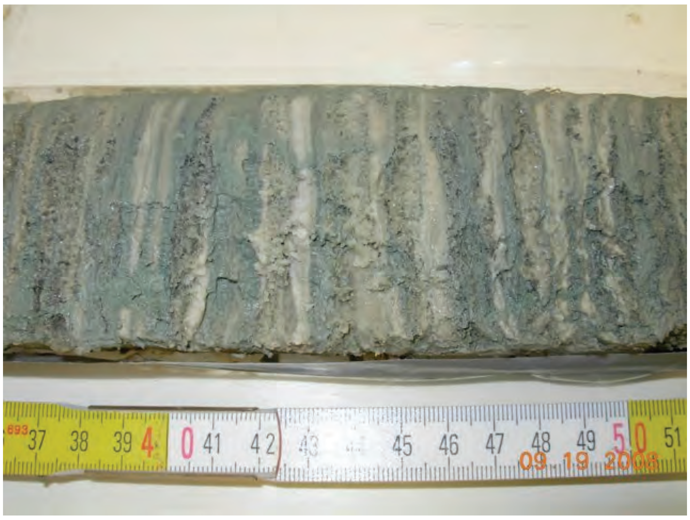

Figure 1. Section of drill core from Site 12 at Lake Tyrrell, ~5m depth

Oxygen isotope values from Permian high latitudes: clues for palaeolatitudinal sea-surface temperature gradients and Late Palaeozoic deglaciation.

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Institut für Geologie, Mineralogie Korte, C., Jones, P.J., Brand, U., Mertmann, D. & Veizer, J. (2008) Oxygen isotope values from Permian high latitudes: clues for palaeolatitudinal sea-surface temperature gradients and Late Palaeozoic deglaciation. *Palaeogeography, Palaeoclimatatology, Palaeoecology 269, 1-16.*

The Permian was a period of waning large-scale continental glaciations in the southern Hemisphere. The waning of these ice sheets during the Early Permian led to discharge of ^{18}O-depleted ice-melt water into the oceans. This, coupled with rising seawater temperatures, resulted in a concomitant decline of about 2.5 ‰ in the _^{18}O of seawater, as recorded by brachiopod shells from low-latitude (< 30°) habitats. The transition from ice- to greenhouse conditions is reflected also in the oxygen isotope data of unaltered brachiopods and bivalves from high latitudes. Moreover, the high-latitude specimens have consistently more positive _^{18}O, by about 2.5‰, than their coeval low-latitude counterparts, suggesting a Permian sea- surface temperature (SST) gradient of about 9 to 12°C between tropical-subtropical (<30°) and high southern (55 ±10°) latitude localities, apparently irrespective of whether in a greenhouse or an icehouse mode. This Permian SST gradient is comparable to the SST gradient of about 14°C. The _^{18}O seawater records suggest that the global warming that resulted in the waning of the Permo-Carboniferous ice sheets during the Sakmarian was followed by another cooling during the late Kungurian and by renewed warming during the Mid- and Late Permian.

Australia-Laurasia convergence, Alice Springs Orogeny and tectonic extrusion of the Thomson Orogen

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Most of the year has been spent on fine-tuning the concept by expressing it into figures and finalizing literature searches. The hypothesis has been presented at the Australian Earth Science Convention in Perth. Work is now geared towards publication. Current status of the concept summarizes as follows:

Palaeomagnetic results from the ignimbrite-rich Carboniferous succession of the Tamworth Belt, Southern New England Orogen (SNEO), show a northward excursion over more than 30° of latitude with an apex in middle-late Visean (Figure 1A). The excursion is identifiable also in limited palaeomagnetic data from the Australian craton and the Tasman Orogenic System (TOS) and may have started in the Early Devonian. By middle-late Visean, the promontory of the Australian craton in New Guinea, as part of Gondwanaland, reached 30°-40°N, well within the latitudinal range of the Central Asian Orogenic Belt (CAOB).

Devonian-Carboniferous convergence/collision of northeastern Gondwana (Australia) and southern Laurasia (CAOB) is thought the cause of contemporaneous, Variscan, tectonism in the CAOB and in Australia (Alice Springs Orogeny [ASO], Quilpie and Kanimblan Orogenies). Compressional deformation in Australia was largely confined behind the New Guinean promontory, between the Bintuni, Bonaparte and Ord Basins, Halls Creek Fault Zone and the Lasseter Shear Zone in the west and the Aure Trough, Queensland Basin and Bowen-Gunnedah-Sydney Fault Zone in the east.

Convergence-driven N-S compression, hot crust in the Larapintine Graben and a free oceanic boundary, constituted Variscan Australia-Asia conditions that were comparable to the Cenozoic India-Asia indentation/extrusion. Tectonic extrusion of ductile lower crust (and melt?) from the central Larapintine Graben caused eastward displacement of the Thomson Orogen and the Northern New England Orogen (NNEO) along the Diamantina River Lineament-Clarke River Fault Zone in the north and along the Darling River/Cobar-Inglewood Lineaments and Cato Fracture Zone in the south (Figure 1B). The buttress of the NNEO caused telescoping of an unpinned SNEO during Stephanian reversal of Gondwana's rotation.

Different tectonic grains (ASO, Quilpie, Kanimblan, kinkbanding) represent the integrated effects from convergence/collision on the brittle upper crust (direct N-S compression) and on the ductile, partially molten?, lower crust (hydraulic transmission, fanning out from N-S compression toward alignment with an E-W pressure gradient). A single N-S compressional event can thus lead to contemporaneous deformations with widely different tectonic grains, varying from N-S to E-W.

Seismic tomography shows continental-like velocities in the lower crust/upper mantle of the more internal TOS and E-W fanning of SV azimuthal anisotropy in support of the extrusion model. Large-scale negative magnetic anomalies in the Larapintine Graben and the TOS are likely to represent hematite-residing Kiaman reverse remanence in the lower and upper crust and may trace lower crustal flow throughout the TOS.

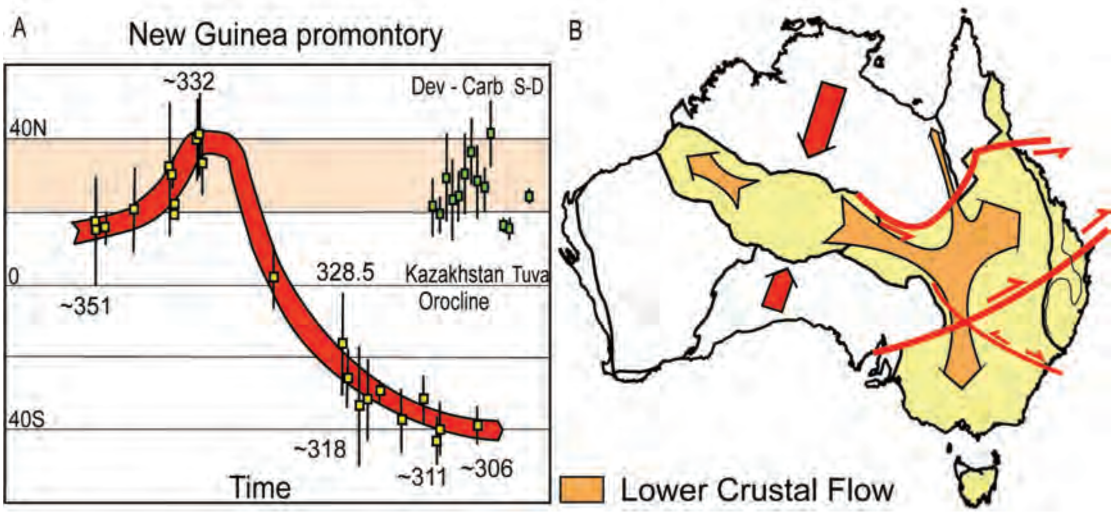

Figure 1 A) Red band shows Carboniferous palaeolatitudes for the New Guinean promontory of the Australian craton according to SNEO results (yellow squares, Klootwijk 2002, 2003, in prep.). Green squares show Devonian-Carboniferous palaeolatitudes for the Kazakhstan Orocline and Tuva terrane of the Central Asian Orogenic Belt. B) Red arrows indicate compression from Australia-Laurasia convergence during the Devonian-Carboniferous. Orange arrows indicate ductile flow of lower crust from the Larapintine Graben into mainly the Thomson and Lachlan Orogens. Major ENE-WSW fault zones guided up to 200 km upper crustal eastward displacement of the Thomson Orogen and the NNEO. The yellow compartments indicate at large the weaker, heated, crust of the Larapintine Graben and the weaker, originally oceanic, crust of the Tasman Orogenic System.

Chronological control of Plio-Pleistocene strata in the Omo-Turkana Basin, Ethiopia and Kenya

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The Omo-Turkana Basin of northern Kenya and southern Ethiopia developed in the northern Kenya Rift about 4.3 Ma ago in the Early Pliocene, with deposition occurring over an area as much as 400 km (N-S) by 70 km (E-W), centred on Lake Turkana. Nearly 800 m of sediments, mainly sands, silts and clays deposited in fluvial, deltaic and lacustrine environments, comprise the Omo Group. Numerous rhyolitic tuffs in the sequence not only have facilitated secure correlations between the formations of the Omo Group but also have provided material for precise $^{40}Ar/^{39}Ar$ age measurements on single crystals of alkali feldspar separated from pumice clasts within the tuffs.

Ages are now available on over 30 stratigraphic levels, all of which are consistent with their relative stratigraphic order (McDougall & Brown, 2006, 2008). The new ages, which have a precision of the order of 1% (standard deviation of the population), based on pooling of many single crystal ages, are all consistent with the stratigraphic order, providing confidence that they accurately record the timing of the volcanic eruptions, with deposition of the tuffs and pumices occurring shortly thereafter. Thus we now have a robust numerical time framework for the depositional history of the Omo-Turkana Basin.

The majority of the ages lie between 4.2 and 0.75 Ma and have been measured on samples from the three main formations mapped in this large area, with correlations made between sequences on the basis of the distinctive geochemistry of the individual tuffs. The sequence is famous for the very large number of hominin and other vertebrate fossils that have been recovered from it, providing an important record of evolution. It is through the geochronological measurements that we are able to date individual fossils, often to significantly better than 0.1 Ma, through stratigraphic correlations of their position relative to known tuffaceous beds.

This has provided an accurate time scale that is independent of assumptions as to the direction and rate of vertebrate evolution. In some cases we are able to correlate the depositional history in the region with paleoclimatic indicators in deep sea cores, related to Milankovitch cycles and the astronomical time scale. This has been successfully accomplished in relation to the younger Kibish Formation, where correlations have been made with sapropel deposition in the Mediterranean Sea some 3000 km to the northwest (McDougall et al., 2008). With increased precision of the ages, potentially possible using the new generation of multiple collector mass spectrometers for argon isotopic analysis, controls on deposition in the Omo-Turkana Basin related to paleoclimatic factors will become correlateable with the more detailed records in the deep sea cores.

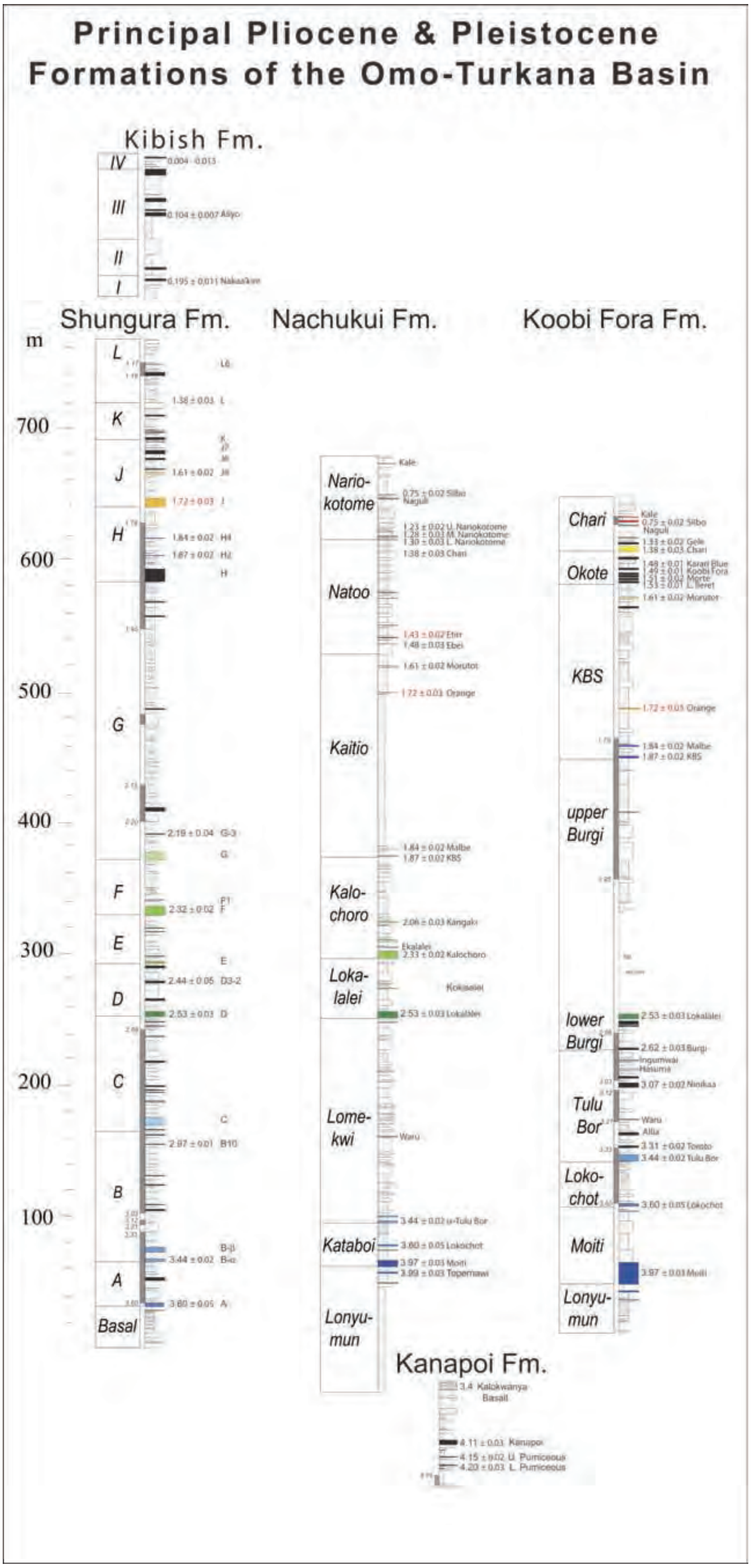

Figure 1: Principal Pliocene and Pleistocene formations of the Omo-Turkana Basin showing the $^{40}Ar/^{39}Ar$ ages determined on alkali feldspars from pumice clasts within the tuffs, and correlations between the formations based upon the distinctive chemistry of the tuffaceous beds.

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Early geological investigations of the Pleistocene Tamala Limestone, Western Australia

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Abstract: The first geological studies of the Quaternary deposits, which crop out extensively along the coast of Western Australia, were carried out by members of English and French expeditions of discovery, between 1791 and 1836. The exploring parties included scholars with a background in geology, zoology and botany, as well as knowledgeable surgeons and sea captains with a strong interest in the natural sciences. Their collective work established the continuity, over vast distances, of a sequence of sedimentary rocks composed of quartz grains and shell debris, which today form the major part of the Tamala Limestone sequence. Their observations of the internal features of these rocks led some among them to develop views on the nature and origin of the cementing substance that bonds sand grains and shell debris in sedimentary layers and in concretions. There was disagreement among successive parties of visitors on the nature and origin of rhizoliths and other petrified woody matter in calcareous rocks. The finding of well-preserved sea shells in rocks now above sea level provided convincing evidence to investigators that the ocean had, in recent times, retreated from the land. The discovery of species of mollusc, known to be extinct in Europe, raised questions about an assumed world-wide extent of sedimentary sequences.

Evolution of the Svecofennian orogenic province

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In several areas of the Svecofennian Province, a major discontinuity has been recognized between Svionian complexes, strongly deformed and metamorphosed at ~1.92 Ga, and overlying post-1.92 Ga Bothnian volcano-sedimentary sequences (Annual reports, 2005, 2006, Skiöld and Rutland, 2008). In Ostrobothnia, Finland (Williams et al., 2008), a similar discontinuity has now been identified within the mostly metasedimentary Western Pohjanmaa Belt and separates two distinct stratigraphic groups. The western Lappfors group, interpreted as a Svionian basement complex, has strong W-trending folding and aeromagnetic signatures that contrast with the unconformably overlying eastern Evijärvi group, interpreted as lower Bothnian, which has more open N-trending folding and magnetic patterns. Several lines of evidence date the unconformity at ~1.92 Ga. Detrital zircons from two samples of Lappfors group metasediment, and a sample of the basal Nivala gneisses in the Eastern Pohjanmaa Belt, have 1.92–1.91 Ga post-depositional low-Th/U metamorphic overgrowths.

The maximum deposition age of the Lappfors sedimentary protoliths, based on detrital zircon ages, is between ~1.97 and ~1.94 Ga. Three samples of Bothnian sediments lack pervasive ~1.91 Ga overgrowths, instead having a variety of detrital zircons as young as ~1.95–1.91 Ga, reflecting recycling of the underlying basement complex. The maximum deposition age of the lower Bothnian sedimentary protoliths is inferred to be ~1.91 Ga. The Niska granite, which intrudes the Evijärvi group and is deformed only by the younger tectonic episode affecting that sequence, has a zircon age of 1896 ± 6 Ma. That episode, which established the present relationships between basement and cover, is dated by ~1.88 Ga metamorphic zircon overgrowths in both the Svionian and Bothnian samples, and by 1878 ± 4 Ma metamorphic monazite from a metasediment from the Savo Belt, east of the Nivala district.

Part of the FIRE 3A reflection seismic profile (Kukkonen et al., 2006; Sorjonen-Ward, 2006) ran NW from the western part of the Central Finland Granitoid Complex (CFGC) across the boundary with the Evijärvi group and into the Lappfors group. Our preliminary interpretation of this section (Kousa et al., 2008) suggests that the Svionian Lappfors group is the surface expression of a middle crustal unit that displays a widespread system of E- to SE-dipping reflectors with listric-type geometry, identified by Kukkonen et al. (2006, pp.29-30). This crustal unit may therefore correspond to the accreted Svionian marginal basin, buried to the east beneath the younger, Bothnian, volcano-plutonic complex. As a corollary, the widespread vertical change in reflectivity between upper and middle crust, (op. cit. p.21), and which is present beneath the western CFGC, may be closely related to the change from the overlying Bothnian complexes to underlying Svionian metamorphic complexes.

We now interpret the observed stratigraphic and structural relationships in Ostrobothnia in terms of an extended orogenic evolution, viz.

(1) Deposition of the Lappfors group, with local maximum deposition ages between ~1.97 and ~1.94 Ga as part of an extensive Svionian marginal basin.
(2) Early Svecofennian (D_1) closure of the Svionan Basin at ~1.92 Ga involving possible subduction zones.

(3) An extensional episode during which the Svionian complex was eroded and the lower Bothnian Evijärvi group with its submarine mafic volcanism was deposited at ~1.91-1.90 Ga in a successor marginal basin.

(4) Transition from marine to terrestrial deposition at ~1.90-1.89 Ga as bimodal calc-alkaline volcanism developed, the upper Bothnian sequence was deposited, and early plutonism occurred.

(5) Continued plutonism and Middle Svecofennian (D_2) deformation at ~1.88 Ga, during which D_2 folds, faults and shear zones were superimposed on the earlier W-trending penetrative D_1 structures in the Lappfors group (Fig. 1). These D_2 structures are largely responsible for the present relationship between the Svionian basement and the Bothnian cover.

Kousa, J., Rutland, R.W.R., Sorjonen-Ward, P., Williams, I.S., 2008. Geological significance of the regional change in reflectivity between the upper and middle crust in the Svecofennian Province. SEISMIX 2008, Saariselka, Finland. *Abstracts*.

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Williams, I.S., Rutland, R.W.R., Kousa, J., 2008. A regional 1.92 Ga tectonothermal episode in Ostrobothnia, Finland: Implications for models of Svecofennian accretion. *Precambrian Research* **165**;15-36

Figure 1. Tight ~1.92 Ga pre-Bothnian folds in the Lappfors group overprinted by open minor folds, crenulations and veins (left to right) of the post-Bothnian ~1.88 Ga episode. Note the glacial striae from top left to bottom right.

Silurian brachiopod faunas, Yass Syncline – taxonomy and biostratigraphy

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A paper on the rhynchonellide species in the Yass fauna, previously undescribed, has been accepted for publication in the Proceedings of the Linnean Society of NSW, with an expected publication date of February 2009. Work is well advanced on revising, and adding to, the species of spiriferide brachiopods from the same succession. This will also involve revision of some species known from the slightly older succession in Canberra. The only remaining aspect of the study will be a compilation of all the biostratigraphic data, for presentation at the next Brachiopod Congress in Melbourne in February 2010.

Sections on Silurian stratigraphy and palaeontology were provided for the recent publication on the geology of the Canberra region compiled by D. Finlayson and published by the ACT Division of the Geological Society of Australia, and I was one of the few involved in reviewing and editing the whole volume. I was also involved in editing a generalized geological map of the ACT prepared by R.S. Abell and D. McCue also under the auspices of the Geological Society of Australia.

As a result of recent excavations in the heritage area on Woolshed Creek, Pialligo, large collections have been made which will be used to revise the species present, particularly the dominant one (*Atrypa duntroonensis*). It was this species which was recognized by Rev. W.B. Clarke as being, for the first time, an indicator of the presence in Australia of Silurian rocks. This study will follow completion of the Yass study, and will be the start of further work on the brachiopod faunas of the Canberra region.

I was consulted by the contractors and Heritage ACT on the possible impact of the work on the Woolshed Creek heritage site, and as a result of that early involvement the workers have been extremely cooperative and interested in preserving as much as possible – the original outcrops are untouched.

Electronics Group

Introduction

2008 has proven to be a productive year for the RSES Electronics Group. During this period we have implemented several long term projects, maintained operation of RSES electronic instrumentation and successfully provided in house training for staff members. The demand for electronics engineering has been substantial for the year allowing the Electronics Group to distribute resources into development projects utilising equipment and staff effectively during 2008. This year the Electronics Group has successfully relocated SHRIMP 2's instrumentation and also implemented several major electronic improvements during the procedure. The Electronics Group has continued developing electronic instrumentation for the SHRIMP SI project completing major system components ready for installation in 2009. The Electronics Group has made a commitment to staff development with one third of members attending tertiary courses in electronics engineering. The Group includes two trainee technical officers giving members the opportunity to participate in peer development.

Electronic Engineering Developments and Fabrications

During the first half of 2008 Group focus was mainly on developing equipment intended for the SHRIMP SI project, Table 1 displays resource allocations of the group for the year where Earth chemistry receives the majority of development time. The maintenance load this period has been reduced from previous year's accounts, however administrative purchasing overheads have burdened the groups productivity.

Table 1 RSES Electronics Group Resource Distribution 2008	
Electronic & Mechanical Engineering	
Earth Chemistry	42.40%
Earth Physics	2.59%
Earth Environment	7.90%
Earth Materials & Processes	2.16%
Maintenance	
Earth Chemistry	3.87%
Earth Physics	0.60%
Earth Environment	0.68%
Earth Materials & Processes	1.13%
Mechanical Workshop	0.35%
Administration	
Electronics Group	24.58%
Training & Development	9.43%

The SHRIMP 2 mass spectrometer was originally built and located in Jaeger 3, the machine was scheduled to be relocated to Jaeger 5 following the completion of the new Earth Chemistry SHRIMP Laboratory. The Electronics Group was directly involved in the coordination, removal and reconstruction of SHRIMP 2's electronic instrumentation. This period of downtime provided an opportunity to implement new electronics systems onto SHRIMP 2, including new analogue signal acquisition system, digital beam monitors, distributed vacuum management system and new power distribution. Technologies developed for these projects will also be utilised by the SHRIMP SI mass spectrometer in 2009.

The main electronic engineering projects for 2008 are listed below with acknowledgments to contributing staff members:

Earth Chemistry

- SHRIMP SI Sample Stage Mechanical Engineering — Corrigan
- IFLEX Electrometer — Schram
- SHRIMP SI FC4, Field Controller 4 — Latimore
- SHRIMP SI Beam Monitors — Cummins
- SHRIMP SI ION, Optical communications network HUB — Redman
- SHRIMP SI HV High Voltage system — Schram, Sasaki, Redman
- SHRIMP SI SIMHK Magnet House Keeper — Sasaki, Redman, Latimore
- SHRIMP SI Field Probes — Cummins
- SHRIMP SI SIADU Analogue signal Distribution Unit — Sasaki
- SHRIMP 2 S2ADU Analogue signal Distribution Unit — Sasaki
- SHRIMP 2 Inchworm Motor Controller 2 — Latimore
- Helix MC Line Solenoid valve Control unit — Champion
- SHRIMP 2 DVS Distributed Vacuum management System — Cassar, Latimore, Redman, Sasaki
- SHRIMP SI IPCS Ion Pulse Counting System — Sasaki, Latimore
- SHRIMP 2 Relocation to J5 — Electronics Group

Earth Materials & Processes

- Green Machine upgrade — Schram
- J1PC - Jaeger 1 Process Cooling — Cassar

Earth Physics

- Heating Mat Controller Upgrade — Redman
- Pump Remote Control — Sasaki
- Submersible pump modifications — Sasaki

Earth Environment

- Graphitization Furnace: 12 channel — Schram
- IICU - PCIS Integration & Interface control Unit — Cummins
- Laser Ablation Cell Development — Corrigan
- Liquid Nitrogen Cryogenic Heater motor stage controller — Latimore, Corrigan
- Cave Sensor development — Cummins

Staffing

The Electronics Group comprises of seven employees with one post employed on part time bases. The Electronics Group contains:

- Engineer and Manager (Latimore)
- Senior Technical Officer Mechanical (Corrigan)
- Technical Specialist (Schram) Part Time post
- Two Technical Officers (Cassar, Cummins)
- Two Trainee Technical Officers (Redman, Sasaki)
- Trainee Technical Officer 2008 Secondment (Champion)

In 2008 the Electronics Group hosted Greg Champion, a Trainee Technical officer employed by John Curtin School of Medical Research. Greg worked in RSES Electronics Group for a two month secondment involving practical and theoretical training provided by Electronics staff. The Group has continued to involve training as part of daily operations and is committed to developing staff member's technical skills and knowledge. This year David Cassar has commenced study into ANU's Bachelor of Engineering degree, his tertiary expertises will broaden the Electronics Group's knowledge base for future electronic engineering projects.

Planning

The 2009 Electronics Group budget indicates replacing aging analysis equipment including purchasing a new Nuclear Magnetic Resonance probe a precision Magnetic field measuring device. In 2009 the Group has planned to purchase a flat panel printer capable of producing quality instrument panel designs that may be utilised throughout the wider University electronics community. Considerable time is forecast for SHRIMP SI implementation with the majority of components nearing completion at the end of 2008. Resources will be allocated to achieve a mid year completion of electronic instrumentation for the project, also major projects will continue concurrently including, installation of the Jaeger 1 Process Cooling for Earth Materials and Laser Ablation cell for Earth Environment. The Electronics Group will endeavour to provide timely professional service to support RSES research.

Engineering Group

Andrew Wilson[1], David Thomson[1], Carl Were[1], Geoff Woodward[1], Brent Butler[1], Link Williams[2], Ben Tranter[2], Hayden Miller[3] and Nick Best[4]

[1] Research School of Earth Sciences, Australian National University, Canberra, ACT 0200, Australia
[2] College of Science Apprentice on six to nine month rotation
[3] Trainee Technical Officer 50/50 Earth Materials/Workshop from October
[4] On Secondment from JCSMR Workshop for the month of January 2008

The Engineering Workshop was heavily occupied this year with internal work from all areas of the school. In an effort to provide parity to all major areas of the school, progress on the SHRIMP SI was somewhat compromised, although a completion within the first six months of 2009 should be quite achievable. Due to the high demand for workshop time from within the school very little external work was carried out.

A higher than usual amount of training was necessary for apprentices Link Williams and Ben Tranter as well as for Hayden Miller joining us half time in the last few months of the year. The purchase of some new equipment also added to our training requirements.

Workshop staff logged a total of 8818 hours to the month of November. 69% of total hours were devoted to charged RSES internal work. External clients accounted for 2% of our time. 29% of our time was uncharged.

Internally the main commitments were:

SHRIMP SI- Internal mechanical components. (Geoff Woodward, David Thomson, Brent Butler, Link Williams, Ben Tranter and Andrew Wilson)

New hot pressing and rock deformation furnace assembly for Prof Ian Jackson (Brent Butler, Link Williams)

Coral coring kits for Prof Malcolm McCulloch and Dr Stewart Fallon. One kit for Dr Sander Scheffers of Southern Cross University. (Carl Were, Ben Tranter)

Ten new half inch bore pressure vessels for Prof Hugh O'Neill. (Carl Were, David Thomson)

General SHRIMP Maintenance (Ben Tranter, David Thomson and Link Williams)

SHRIMP RG ESA Modifications and deflection electrodes (Nick Best, Brent Butler and Andrew Wilson)

OSL Broadband Lens components (Andrew Wilson, Ben Tranter)

Gravitational instrument supports for Dr Herb McQueen (Ben Tranter, Link Williams, Brent Butler and Carl Were)

Extensive support was also provided for Dr Masahiko Honda's Noble Gas Laboratory including new standard tanks, furnace elements and heat shields, (Ben Tranter, David Thomson, Andrew Wilson, Carl Were and Brent Butler)

It is interesting to note that 24% of our charged time was spent on jobs which took less than 50 hours each to complete.

2557 hours of uncharged time was accounted for as follows:

39% Staff Training

27% Workshop Administration

16% Workshop Infrastructure. This includes the time taken for improvements and modifications to tooling, machines, workshop layout, workshop storage and assistance with workshop building maintenance.

13% Machine Maintenance

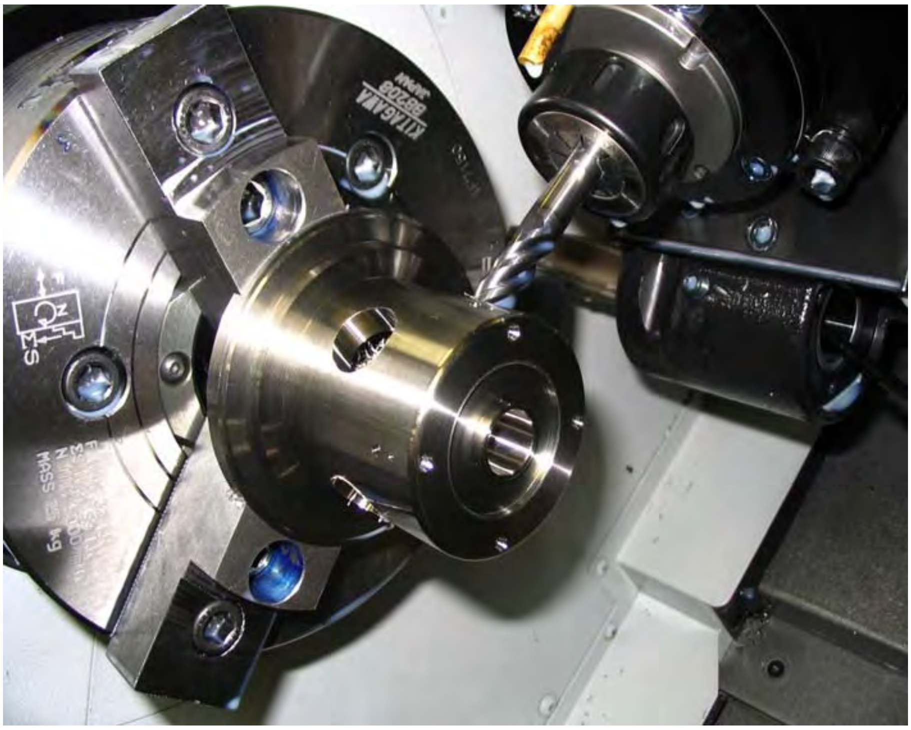
5% of uncharged hours were spent at meetings, seminars, conferences and exhibitions as well as on some uncharged jobs.

Other Developments

A new CNC Lathe and a second hand Elecro-Discharge Machine (EDM) were installed early in the year. The Lathe, a Mori-Seiki NL machine, was funded with the Vice Chancellors infrastructure fund which we received late 2006. The Lathe is unique to the ANU in that it has live tooling enabling complex off axis milling, as well as the usual turning operations and has already proved a valuable asset. The EDM machine, a Sodick Moldmaker 3, was purchased using workshop funds.

Brent Butler has again been involved in 'Worldskills' where the top apprentices are selected nationally to compete in the prestigious Worldskills international competition. Brent was selected as the Australian coach for the Manufacturing team Challenge event which is one of 40 categories to be held in Calgary later in 2009. Brent has been involved in this competition since being part of the team that won the international gold medal in Helsinki in 2005.

New Lathe showing side milling on SHRIMP SI component



Specially modified stainless steel vacuum fittings

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NATIONAL AND INTERNATIONAL LINKS 2008

COLLABORATION WITH AUSTRALIAN UNIVERSITIES, CSIRO & INDUSTRY

Earth Chemistry

Dr Y. AMELIN collaborated with Dr. R. Nicoll (Geoscience Australia) and Dr. I. Metcalfe (University of New England) on the timescale of Permian-Triassic transition in Australia.

Ms. J.N. Avila collaborated with Prof. E. Zinner, Dr. S. Amari and Mr. F. Gyngard, Laboratory for Space Sciences, Washington University, St. Louis, USA, on the study of light and heavy elements on presolar silicon carbide grains.

Ms. J.N. Avila collaborated with Dr. P. Heck, University of Wisconsin, Madison, USA, on the study of interstellar residence times of presolar silicon carbide grains.

Dr. V.C. BENNETT collaborated with Dr A. Brandon, NASA-Johnson Space Center, Dr. A.P. Nutman and Dr. Y. Wan (Chinese Academy of Geological Sciences) on determining the isotopic signatures of extinct nuclides in the oldest rocks from the Archean terranes of Greenland and China.

Dr J.J. BROCKS collaborated with Prof S. George and S. Bray (Macquarie University), The organic geochemistry, geochronology and microbial history of saline Lake Tyrrell in outback Victoria.

Dr J.J. BROCKS collaborated with Prof B. Rasmussen (Curtin University of Technology), The carbon isotopic composition of Precambrian organic matter and the syngeneity of ancient biomarkers.

Dr J.J. BROCKS collaborated with Prof A. Cooper (University of Adelaide), The preservation of lipids, proteins and DNA in the Devonian Gogo Fish.

Dr J.J. BROCKS collaborated with Dr J. Moreau, Dr. S. McLaren (Melbourne University), Dr D. Gleeson, Dr J. Cliff and Dr M. Kilburn (University of Western Australia), Seafloor clay mineral diagenesis and seismicity in the Nankai Trough Subduction Zone: a microbially-mediated process?

Dr J.J. BROCKS collaborated with Mr R. Schinteie (RSES, ANU) and Dr G. Halverson (University of Adelaide), The geochemical and biological evolution of the oceans in the Neoproterozoic.

Dr J.J. BROCKS collaborated with Prof P. De Deckker (RSES, ANU), Dr G. Allison and Mr C. Munday (BamBi, ANU)

Prof I.H. CAMPBELL and Dr C. ALLEN collaborated with Professor R. Cass and Dr R. Squire, (Monash University); Understanding the stratigraphic and structural architecture of late Archean basins and the context of their gold deposits.

Prof I.H. CAMPBELL and Dr C. ALLEN collaborated with Dr A. Harris (University of Tasmania); U-Pb dating of felsic intrusions from Cadia NSW.

Prof I.H. CAMPBELL and Dr C. ALLEN collaborated with Professor C. Wilson and Ms E. Henry (University of Melbourne); zircon age patterns from Early Paleozoic sandstones of western Victoria.

Dr. S.J. FALLON collaborated with Dr. R. Thresher (CSIRO, Climate from Deep Sea Corals); M. Cheetham (Southern Cross University, history of rainfall in N. Queensland); Dr. J. Lough (Australian Institute of Marine Science, climate records from tropical corals); Dr. E. Krull (CSIRO, history of Coorong Delta); Dr. L. Wallis (Flinders University, dating of Coorong settlement); Dr. L. Reed (Flinders University, Vegetation history of Naracoorte Cave region); Prof. A. Cooper (Adelaide University, Dating of fossils for ancient DNAanalysis.

Dr M. Forster collaborated with the members of TANG3O (Thermochronology and Noble Gas, Geochronology and Geochemistry Organization) in particular Dr P. Vasconcelos (University of Queensland), Assoc. Prof D. Phillips (University of Melbourne), and Dr F. Jourdan (Curtin University).

Dr M. Honda collaborated with Prof A. Chivas (The University of Wollongong) and A/Prof D. Phillips (The University of Melbourne), Continuation of collaboration on cosmogenic noble gas studies in young basalts; A/Prof D. Phillips (The University of Melbourne), Continuation of collaboration on noble gas studies in diamonds; Dr M. Kendrick (The University of Melbourne), Continuation of collaboration on noble gas studies in ore-forming minerals.

Prof T.R. IRELAND with Australian Scientific Instruments, Geoscience Australia, Prof P. Vasconcelos (University of Queensland), Prof A. Gleadow (University of Melbourne), Dr P. Carr & Dr C Fergusson (University of Wollongong), Dr G. Clarke (University of Sydney), Dr R. Large and Dr G. Davidson (University of Tasmania), Dr J Hellstrom (University of Melbourne), Dr A. Kennedy and Dr P. Kinny (Curtin University), and Dr B. McInnes (CSIRO), on the SHRIMP SI Project and TANG3O.

Dr D. RUBATTO collaborated with Dr D. Haley, Curtin University of Technology on the subduction of Corsican ophiolites.

Mr R. Schinteie's thesis co-advisors are Dr. E. Grosjean, (Geoscience Australia, Canberra), and Dr G. Halverson (University of Adelaide).

Dr I.S. WILLIAMS with Australian Scientific Instruments – SHRIMP development, and Prof B.W. Chappell (University of Wollongong) – granite geochemistry.

Earth Environment

Mr M. AUBERT collaborates with Prof Paul Taçon and Dr Sally May (Griffith University) on investigating rock art in Yunnan, China for Uranium-series dating.

Dr L. K. AYLLIFFE with Dr G. J. Prideaux (Flinders University), Dr J Hellstrom (University of Melbourne).

Prof. P. DE DECKKER and Dr S. Eggins collaborated with Prof. C. Murray-Wallace (University of Wollongong) and Dr J. Cann (University of Sth Australia) on dating paleo-Murray River channels and estuaries on the Lacepede Shelf.

Prof. P. DE DECKKER, Dr M. Norman, Dr K.E. Fitzsimmons and Dr S. Fallon completed a research paper on a >40,000 years old aeolian deposits from Blanche cave in Naracoorte, SA together with Mr N. Darrenougue from Bordeaux, Dr S. van der Kaars of the University of Gottingen, and Dr L. Reed from Flinders University.

Dr A. DUTTON with Dr C. Woodroffe (University of Wollongong) and Dr S. Smithers (James Cook University) on Holocene Sea Level in the Australian Region.

Dr A. DUTTON with Dr T. Esat (ANSTO) on submerged speleothems from the Mediterranean and last interglacial corals from Western Australia.

Dr S. EGGINS collaborated with Dr B. LANDENBERGER (University of Newcastle) on radiogenic isotope microanalysis and geochronology of granites from the New England Fold Belt.

Dr M.J. ELLWOOD collaborates with Dr. Edward Butler (CISRO), Dr. Andrew Bowie (ACE CRC) on Trace metals in Southern Ocean waters, and Prof. William Maher (University of Canberra) on Germanium and silicon isotope fractionation in sponges and diatoms.

Dr K.E. FITZSIMMONS collaborates with Dr T.T. Barrows (ANU) on high resolution geochronology and palaeoenvironmental reconstruction in the southeastern Australian highlands.

Dr K.E. FITZSIMMONS collaborates with Prof. J.M. Bowler (University of Melbourne), Prof. P. Veth (ANU) and Prof. M. Smith (National Museum of Australia), on human-environmental interactions at Mulan, northwestern Australia.

Dr K.E. FITZSIMMONS collaborates with Prof. P. De Deckker (ANU) on fine resolution geochronology of southeastern Australian cave records.

Dr K.E. FITZSIMMONS collaborates with Dr A. Keene and Mr M. Cheetham (Southern Cross University) on fluvial geomorphology in eastern Australia.

Dr K.E. FITZSIMMONS collaborates with Dr N. Porch (ANU) on palaeoenvironmental records in western Victoria.

Dr K.E. FITZSIMMONS collaborates with Prof. G. Hope (ANU) on archaeological deposits at Kosipe, Papua New Guinea.

Dr K.E. FITZSIMMONS collaborates with Mr D. Horne (UNSW@ADFA) on coastal dune development and sea level change in northern Australia.
Dr K.E. FITZSIMMONS collaborates with Assoc. Prof. R.T. Wells (Flinders University) on arid zone palaeoenvironmental reconstruction.

Dr M.K. GAGAN, Dr. L.K. AYLIFFE, Mr. D. QU, Ms R. BERDIN, and Ms J. MAZERAT with Dr. J. Lough (Australian Institute of Marine Science) and Dr G. Meyers (CSIRO Marine and Atmospheric Research), Co-investigators on ARC Discovery Grant DP0663227 (2006-2010): The Indian Ocean Dipole, Australasian drought, and the great-earthquake cycle: Long-term perspectives for improved prediction.

Dr M.K. GAGAN, Dr L.K. AYLIFFE and Ms S. Lewis with Dr J.-x. Zhao (University of Queensland) and Dr R. Drysdale (University of Newcastle), Co-investigators on ARC Discovery Grant DP0663274 (2006-2008): Monsoon extremes, environmental shifts, and catastrophic volcanic eruptions: Quantifying impacts on the early human history of southern Australasia.

Dr M.K. GAGAN with Dr H. McGregor, Dr D. Fink and Dr E. Hodge (Australian Nuclear Science and Technology Organisation), Comparison of radiocarbon and stable-isotope ratios in Holocene coral microatolls from the tropical Pacific Ocean.

Prof R. GRÜN, Dr. I. WILLIAMS and Prof. M SPRIGGS (Archaeology and Anthropology) collaborated with a large number of international scholars on the ARC grant Microanalysis of human fossils: new insights into age, diet and migration.

Prof R. GRÜN collaborated with Prof. Roberts and Dr. Z. Jacobs, University of Wollongong, and Prof. G. Duller, University of Aberystwyth, on the ARC grant Out of Africa and into Australia: robust chronologies for turning points in modern human evolution and dispersal.

Prof R. GRÜN worked with Dr. E. RHODES, Prof S Webb (Bond) and Drs N Stern (La Trobe) and A. Fairbairn (UQ), on the ARC Linkage grant Environmental Evolution of the Willandra Lakes World Heritage Area.

Prof R. GRÜN collaborates with Dr J. Field, Dept. of Archaeology, University of Sydney, on the dating of the archaeological and megafauna site of Cuddie Springs.

Prof R. GRÜN collaborates with Dr J. Dorth, Department of Archaeology, University of Sydney and Dr M Cupper, School of Earth Sciences, University of Melbourne, on the dating of the megafauna site of Lancefield.

Prof R. GRÜN collaborates with and Dr R. Wells, Flinders University, on dating a series of South Australian sites with faunal remains including Naracoorte Cave and the Rocky River Site on Kangaroo Island.

Miss T.E. KELLY collaborated with Dr N Stern & Miss J Tumney (Latrobe University) and with the 3TTG inc. (three traditional tribal groups), Mungo Project.

Prof M. McCULLOCH is an Associate Director of the ARC Centre of Excellence Coral Reef Studies. The new Centre, known as the ARC Centre of Excellence for Coral Reef Studies is a partnership of James Cook University (JCU), the Australian Institute of Marine Science (AIMS), The Australian National University (ANU), the Great Barrier Reef Marine Park Authority (GBRMPA) and The University of Queensland (UQ). The budget for the Centre of Excellence will be approximately A$40 million over the first 5 years with funding recently extended with additional funding to 2013. The centre is headquartered at James Cook University, in Townsville under the Directorship of Professor Terry Hughes and is now the centre for Australia's leading contribution to coral reef sciences, and acts to focus foster stronger collaborative links between the major partners and 24 other leading institutions in nine countries. Collectively, the Centre creates the world's largest concentration and highest cited group of coral reef scientists.

Prof. M. McCULLOCH is collaborating with Dr. J. Lough from the Australian Institute of Marine Sciences (AIMS) on a wide range of coral reef projects.

Prof. M. McCULLOCH is collaborating with Dr Steve Lewis and John Brody and Dr Stacy Jupiter together with Professor Ove Hoegh-Guldberg, (UQ) and Professor Robert Dunbar (Stanford University) are chief investigators on the ARC Linkage grant entitled "Long-term records of water quality and connectivity between Coral Reefs and Mangrove Ecosystems in the Great Barrier Reef ". Industry Partners include GBRMPA, Mackay City Council and The Queensland Department of Primary Industry.

Prof. M. McCULLOCH and Professor Mike Kingsford from James Cook University are continuing their collaboration on the study of the geochemistry of fish otoliths from the Great Barrier Reef.

Prof. M. McCULLOCH and Dr Brian Gulson from CSIRO and Macquarie University are continuing collaborating on a medical project on the possible human health hazards of zinc nano particles in sunburn protections.

Mr I. MOFFAT collaborated with Professor Rainer Grün, Research School of Earth Sciences, The Australian National University on a project investigating the applicability of Sr isotope tracing to human migration in the Levant.

Mr I. MOFFAT collaborated with Professor Rainer Grün, Tegan Kelly and Kathryn Fitzimmons from the Research School of Earth Sciences, The Australian National University and Dr Nikki Stern and Jacqui Tumney from the Department of Archaeology, La Trobe University on a project investigating the stratigraphic and palaeo-environmental evolution of the Lake Mungo Lunette

Mr I. MOFFAT collaborated with Dr Lynley Wallis, Department of Archaeology, Flinders University on a project excavating the Gledswood One Rockshelter in North West Queensland.

Ian MOFFAT collaborated with Mark Reily, Whistler Research on a project investigating the stratigraphy and ichnology of the Darling River, Western NSW.

Ian MOFFAT collaborated with Dr Lynley Wallis, Department of Archaeology, Flinders University on a project investigating the effectiveness of various geophysical techniques to locate historic graves in a variety of geological environments.

Dr. B. OPDYKE has ongoing collaboration with Dr. L. Collins at Curtin University and Dr. K. Burns at the Australian Institute of Marine Science.

Prof B.J. PILLANS with Prof R. Roberts (University of Wollongong) on luminescence dating of Aboriginal rock art.

Prof B.J. PILLANS with Prof M.A.J. Williams (University of Adelaide) and Prof R. Bourman (University of South Australia) on landscape evolution in southern South Australia.

Prof B.J. PILLANS with Dr B. Kohn (University of Melbourne) on apatite fission track thermochronology and landscape evolution in the Tanami Desert.

Prof B.J. PILLANS with Woodside Energy, regolith and rock art on the Burrup Peninsula, Western Australia.

Ms J. SUTTON with Alan Williams and Monika Schlacher-Hoenlinger for Tasmanina sponge material collect on Southern Surveyor voyage SS0207. Financial Support for this voyage was through the Australian Government Department of Environment, Water, Heritage and the Arts, the CSIRO Wealth from Oceans Flagship, and Australia's Marine National Facility vessel. Funding to facilitate the collection of the East Antarctic sponges was from the Australian Antarctic Division and two Australian Research Council grants DP0770820 and DP0771519.

Dr P TREBLE collaborates with Dr M. Fischer, ANSTO, Drs J. McDonald and R. Drysdale, University of Newcastle and Dr J. Hellstrom, University of Melbourne, on reconstructing rainfall records for southern Australia using speleothems.

Dr J. TROTTER collaborates with Prof. P. Cawood (Uni. of WA) on Sr isotope compositions of conodonts, Assoc. Prof. A George on oxygen isotope compositions of conodonts, Prof. B. Gulson (Macquarie University; CSIRO) on Zn isotope absorption in human blood, Dr R Thresher (CSIRO) on geochemistry of cold water corals.
Dr G. YOUNG with A/Prof. John Long (Museum Victoria), Drs I. Percival and L. Sherwin (NSW Geological Survey), Dr E. Papp (Papp Geophysical Survices), Dr C. Burrow and Dr S. Turner (Queensland Museum), Dr K. Trinajstic (University of WA), and Dr Yong-Yi Zhen (Australian Museum).

Earth Materials

Prof S.F. COX and Dr A. Halfpenny are collaborating with Assoc Prof D. Cooke, University of Tasmania, on aspects of the development of fracture-controlled flow systems in intrusion-related hydrothermal ore systems. This collaboration forms part of the activities of the ARC Centre for Excellence in Ore Deposits.

Mr R.J.M. FARLA collaborated with Assoc Prof U.H. Faul (Boston University), A. Barnhoorn (Utrecht University).

Dr J.D. FITZ GERALD with Dr J. Keeling (Primary Industries and Resources, South Australia) on crystallography and defect structures in asbestiform antigorite deposit from Rowland Flat.

Prof. W. Collins and Dr S. Richards (James Cook University), Dr P. Betts (Monash University), Professor A. Gleadow and Professor M. Sandiford (The University of Melbourne).

Dr A. HALFPENNY collaborated with Dr D.R. Cooke, CODES, University of Tasmania, Hobart.

Prof I. JACKSON collaborated with Dr R.P. Wang (RSPSE, ANU) and Dr Z.H. Stachurski (Dept. of Engineering, CECS, ANU).

Prof G. LISTER collaborated with Australian Scientific Instruments, Geoscience Australia, Dr P. Vasconcelos, Dr H. Mulhaus and Mr S. McTaggart (University of Queensland),

Dr D.C. "Bear" McPHAIL collaborated with Dr P. de Caritat (Geoscience Australia) on groundwater geochemistry for mineral exploration in Cobar, NSW, northwestern India and northern Chile;

Dr D.C. "Bear" McPHAIL collaborated with Prof J. Brugger (South Australian Museum and University of Ireland) on the aqueous chemistry of gold, tellurium and zinc;

Dr D.C. "Bear" McPHAIL collaborated with Dr B. Macdonald (Fenner School of Environment and Society) on origin and nature of salinity in the Hunter catchment, NSW;

Dr D.C. "Bear" McPHAIL collaborated with Assoc Prof K. McQueen (University of Canberra), Mr M. Wimberger and Mr R. Berthelsen (The Peak Gold Mines, Cobar), and Mr K. Scott (CSIRO Exploration and Mining) on groundwater geochemistry and exploration geochemistry in the Lachlan Fold Belt, NSW;

Dr D.C. "Bear" McPHAIL collaborated with Dr P. Polito (Anglo American, Perth) and Prof T. Crawford (University of Tasmania) on exploration geochemistry in northern Queensland

Dr D.C. "Bear" McPHAIL collaborated with Dr B. Bourne (Barrick, Perth/South Africa) on mineral exploration in Tanzania; and

Dr D.C. "Bear" McPHAIL collaborated with Dr W. McLean (Parsons Brinckerhoff, Sydney) and Dr M. Norman (RSES) on groundwater dynamics in the Lower Murrumbidgee catchment, NSW.

Mr N.D. TAILBY collaborated with Dr K. Evan (Curtin University) on Ti-in-zircon and RbBr synchrotron research at the Advanced Photon Source and Brookhaven National Laboratory.

Dr U. TROITZSCH with A. Willis from Research School of Chemistry, ANU, and with Dr K. Grice and Dr B. Nabbefeld from Curtin University of Technology, Perth.

Mr L. WHITE has been collaborating with Dr P. Lennox (UNSW) on understanding the character of shear zones in the Wyangala Batholith, Lachlan Fold Belt, NSW.

Earth Physics

Prof R.W. GRIFFITHS, Dr G.O. HUGHES and Ms M. O'BYRNE with Prof J. Middleton (University of New South Wales) on wake flows in coastal oceans, funded by a joint ARC Discovery grant.

Prof B.L.N. KENNETT is Director of ANSIR which continues as a National Research Facility, as a joint venture between The Australian National University and Geoscience Australia linking to the Earth Imaging component of AuScope.RSES supports the portable seismic instrument.
The ANSIR portable equipment is available via a competitive proposal scheme with support in 2008 for broadband instruments in Western and Southern Australia and short-period experiments in NSW and Tasmania

AuScope

Prof B.L.N. KENNETT acts as Program Manager and Senior Scientist for the Earth Imaging component of AuScope. In addition to equipment provision via ANSIR, the Earth Imaging program supports major Geotransects. Work this year was concentrated in South Australia with a deployment of passive sensors across the Gawler craton to complement refection profiling. A large reflection experiment ('GOMA') carried out in November 2008 starting in the Northern Territory and working southwards along the side of the Adelaide to Darwin railway with a combination of funding from Geoscience Australia, AuScope and Primary Industries South Australia.

Prof K. LAMBECK with Dr J. Church, Dr N. White and Dr J. Hunter, Briefing: A post-IPCC AR4 update on sea-level rise, for the Department of Climate Change.

Dr M.L. RODERICK collaborates with with Dr T. McVicar & Dr L. Rotstayn (CSIRO), Dr G. McKeon & Dr J Carter (Qld Department of Natural Resources, Mines and Water), Dr I. Hume (NSW Dept of Primary Industries).

Dr N. RAWLINSON collaborates with Dr. Anya Reading (University of Tasmania).

Dr H. TKALCIC continues collaboration with Geoscience Australia (Dr. A. Gorbatov), on the construction of synthetic seismograms for the implementation of earthquake source parameters inversion in Australia.

Dr H. TKALCIC collaborates with Dr A. Reading, University of Tasmania, on studying the lowermost mantle and core from core-sensitive seismic waves recorded at the GSN and SSCUA stations in Antarctica, installed by Dr Reading.

Dr P. TREGONING collaborated with Dr M. Leblanc (James Cook University) on a study of drought in the Murray-Darling Basin. He also collaborated with Dr C. Watson and Prof. R. Coleman on a satellite altimetry calibration experiment in Bass Strait. He collaborated with Dr C. Watson on a study of atmospheric pressure loading and propagation effects in the analysis of GPS data.

Integrated Ocean Drilling Program (IODP)

The Australian IODP Office (AIO) was established at RSES in 2008. The Australian Research Council, fourteen Universities and three Government Agencies provided funding for Australia to join the Integrated Ocean Drilling Program (IODP), a major international program, from the beginning of 2008 ($8,150,000 over five years). Dr Neville Exon was acting Head of Australian IODP activities in the early part of the year, and later Program Scientist with the Australian IODP Office under a professorial contract. The office also represents New Zealand in what is now a joint IODP consortium (ANZIC). Naturally, the office has collaborated with a great variety of individuals in Universities, Government agencies and foreign agencies. The program now has a Governing Council and a Science Committee, and we have representatives on a number of IODP panels. Australian and New Zealand scientists have been placed on a number of forthcoming IODP expeditions. A web page has been established as www.iodp.org.au.

PRISE

Dr R.A. ARMSTRONG collaborated with Dr I. Graham (University of NSW) on megacrystic zircons from Cenozoic intraplate basalts along the Indo-Pacific continental margins; Dr L. Shewan (University of Sydney) on studies of human mobility on Archaeological sites from Cambodia; Dr J. Dodson, (ANSTO) on the isotope fingerprinting of archaeological samples from China.

Mr C.M. FANNING with Dr S. Boger (University of Melbourne) on the timing and tectonic evolution of Madagascar; Professor G. Clarke (Sydney University) on the timing and tectonic evolution of Cordillera Darwin, Tierra del Fuego; Geological Survey of South Australia and Mr G. Teale (Teale and Associates) on SHRIMP projects.

Mr S. Hui collaborated with Dr. Fred Jourdan, Western Australia Argon Isotope Facility, Curtin University, Western Australia, on 39Ar-40Ar dating of Lunar Impact Spherules.

Dr M.D. NORMAN collaborated with Parsons-Brinkerhoff on the geochemistry of groundwaters in NSW; Dr Philip Blevin (Geological Survey of NSW) on ages of mineralization related to granites; Medivac-Diakyne on development of laser ablation technologies; Dr A. Nemchin and Prof. R.A. Pidgeon (Curtin University) on the origin and evolution of the Moon.

A. Rosenthal collaborated with Dr Terry Mernagh, Laser Raman Spectroscopy, Geoscience Australia, on studies of minor amounts of H2O in melts.

Dr G. YAXLEY collaborated with BHP-Billiton, de Beers and Rio Tinto Exploration through an ARC Linkage Project with AMIRA International, to develop new mineralogical tools for diamond exploration. He also collaborated with Dr V. Kamenetsky at CODES, University of Tasmania, in joint supervision of RSES PhD student Kate Kiseeva, on experimental investigations of the melting of carbonate eclogite in the upper mantle and with Drs Ian Graham (Sydney University) and Lin Sutherland (Australian Museum) on the genesis of gem quality zircons.

Visitors

Dr Ray Binns continues his collaboration with former colleagues in CSIRO Exploration and Mining, concerning seafloor mineral deposits. He also serves on the Science Advisory Board of Nautilus Minerals, Inc. of Vancouver and on the Strategies Review Committee of Tri Origin Minerals Limited operating in southern NSW.

Dr R. V. BURNE collaborates with Prof. Brian Lees (Department of Geography and Oceanography, UNSW-ADFA), Prof. Di Walker and Assoc. Prof. Gary Kendrick (Department of Plant Biology, UWA), Dr L. S. Moore (UWA) and Dr. Alan Kendrick (Marine Science Program, Department of Environment and Conservation, Western Australia)

Dr K. A. W. CROOK, assisted Dr E. A. Felton, (RSES, ANU) and Dr Wayne Stephenson, University of Melbourne with studies in geomorphology and sedimentology of rocky shorelines; and assisted Dr E. A. Felton in providing Dr D. Fink of the Australian Nuclear Science and Technology Organisation with samples for cosmogenic age dating of rocky coastal geomorphic features.

Dr W. COMPSTON with Australian Scientific Instruments, with Dr J. R. De Laeter (Curtin University of Technology), and with Dr R. J. F. Jenkins (South Australian Museum).

R.A.Eggleton with Rio Tinto Aluminium, CSIRO Entomology, University of Canberra, Primary Industries South Australia.

Dr E. A. Felton is working with Dr D. Fink of the Australian Nuclear Science and Technology Organisation and Dr K. A. W. Crook, ANU on cosmogenic age dating of rock coastal geomorphic features. She is collaborating with Dr Wayne Stephenson, University of Melbourne on studies of geomorphology and sedimentology of rocky shorelines.

C. Jones with Dr. S. George, Macquarie University, and Dr. J. Moreau, University of Melbourne as collaborators on field site of thesis project, with Dr. J. Volkman, CSIRO Hobart as informal advisor on sterol extraction/identification, and with Dr. K. Grice at Curtin University of Technology for bulk isotopic measurements on sediment samples.

Dr P.J. JONES collaborated with Ms S. Martin (Ph.D. candidate, Monash University) on recognition of spinocaudatans (Branchiopoda) in association with insect remains in the Early Jurassic Cattamarra Coal Measures of the Perth Basin, WA.

Dr C. KLOOTWIJK with Dr P. Milligan (Geoscience Australia) and Dr R. Korsch (Geoscience Australia).

Prof K. LAMBECK with Dr J. Church, Dr N. White and Dr J. Hunter, Briefing: A post-IPCC AR4 update on sea-level rise, for the Department of Climate Change.

Dr I.C Roach with The University of Adelaide (Dr S.M. Hill), CSIRO (Division of Exploration and Mining, Perth), Alkane Resources Ltd. on the Wyoming gold deposits, central western NSW and Rimfire Pacific Mining NL on the Fifield Pt-Au deposits, central western NSW.

KEITH SCOTT with CSIRO Exploration and Mining (Jon Huntington and Rob Hewson), Barry Murphy (University of Melbourne) and OZ Minerals (Angela Lorrigan and Rodney Anderson).

INTERNATIONAL COLLABORATION

Earth Chemistry

Dr Y. AMELIN collaborated with Dr. Qing-zhu Yin, University of California, Davis, and Prof. T. Irving, University of Washington, on chronology and origin of angrites.

Dr Y. AMELIN collaborated with Dr. C. Stirling, Otago University, on detecting small uranium isotopic variations in nature and evaluating their origin and significance

Dr Y. AMELIN collaborated with Dr. A. Krot, University of Hawaii, on the origin of chondrites and their parent asteroids

Dr Y. AMELIN collaborated with Prof. M. Wadhwa, Arizona State University, and Prof. Stein Jacobsen, Harvard University, on refining techniques of isotopic analysis.

Dr. V.C. BENNETT and Dr. M. Honda collaborated with Dr. M. VanKranendonk (Geological Survey of Western Australia), Rare earth element and noble gas geochemistry of Archean cherts from the Pilbara drill core, Western Australia.

Dr J.J. BROCKS collaborated with Prof P. De Deckker (RSES, ANU), Dr G. Allison and C. Munday (BamBi, ANU), Prof K.-U. Hinrichs, Dr E. Schefuss and Ms M. Bausch (Marum, University of Bremen), Molecular Signatures of Biological Soil Crusts and Salt Lakes of South Australia.

Dr J.J. BROCKS collaborated with Prof J. Banfield, Ms C. Jones (UC Berkeley), Dr K. Heidelberg (University of Southern California), Prof E. Allen (UC San Diego), Prof E. Roden (University of Wisconsin in Madison), the J. Craig Venter Institute and JCI, Lipidomics and metagenomics of saline Lake Tyrrell, Victoria.

Dr J.J. BROCKS collaborated with Prof A. Pearson (Harvard University) and Prof T. Bosak (Massachusetts Institute of Technology), Molecular fossils and physiological function of oligoprenyl-curcumenes.

Dr J.J. BROCKS collaborated with Prof N. Butterfield, Ms M. Pawlowska (University of Cambridge) and Mr R. Schinteie (RSES, ANU), The Paleontology and organic geochemistry of Mesoproterozoic successions from Russia.

Dr J.J. BROCKS collaborated with Dr P. Wynn (Lancaster University), Molecular fossils and elemental iodine in Stalagmites.

Dr J.J. BROCKS collaborated with Dr P. Schaeffer (University of Strasbourg, France), Carotenoids of the Palaeoproterozoic Barney Creek Formation.

Prof I.H. CAMPBELL, Y. WANG and Dr C. ALLEN collaborated with Prof P. Reiners (Yale University); Triple-dating detrital zircons from the Ganges River.

Prof I.H. CAMPBELL and Dr C. ALLEN collaborated with Prof P. Clift (University of Glasgow); Double-dating zircons from Southeast Asian Rivers.

Prof I.H. CAMPBELL and Dr C. ALLEN collaborated with Prof J. Gill (University of California at Santa Cruz); zircon age patterns from sandstones of Fiji, and their and oxygen and hafnium isotope composition

Prof I.H. CAMPBELL and Dr C. ALLEN collaborated with Prof B. Nash and Dr H. Cathey (University of Utah); age, and oxygen and hafnium isotope composition of zircon from ancient Yellowstone volcanic centres.

Prof I.H. CAMPBELL and Dr C. ALLEN collaborated with Dr S. Bryan (University of Queensland/Kingston University, London) and Mr A. Ramos (Kingston University); age and inheritance history of zircons from the Sierra Madre Occidental

Dr. S.J. Fallon collaborated with Dr. B. Roark (Texas A&M), Prof R. Dunbar (Stanford University) and Dr T. Guilderson (Lawrence Livermore National Laboratory) on climate records from North Pacific Deep Sea Corals; with Dr L. Skinner on ocean overturning from deep sea sediment cores; with Dr P. Montagna and Dr S. Silenzi (ICRAM, Italy) on Mediterranean sea level and radiocarbon reservoir ages; and with Dr O. Sherwood (Memorial University, on dating and climate from deep sea corals.

Dr M. Forster collaborated with Prof T. Ahmad, University of Delhi on the structure and metamorphism of the NW Himalaya; with Prof D. Papanikolous, Dr N. Scarpelis, Dr S. Lozios, Mr K. Soukis and Ms E. Moustaka (all from Athens University) on shear zone operation and exhumation of HP rocks on Evvia, Greece; with Dr M. Cottam and Prof Hall (Royal Holloway, University of London), on the exhumation of Mt Kinabalu, SE Asia.

Dr M. Honda with Dr J. Harris (The University of Glasgow, UK), Continuation of collaboration on noble gas studies in diamonds.

Prof T.R. IRELAND is collaborating with Prof E. Zinner and Prof B. Fegley (Washington University in St Louis), and Prof K. McKeegan (UCLA).

Dr D. RUBATTO collaborated with Prof M. Engi, Dr A. Berger and Dr E. Janots, University of Bern, Switzerland, on the behavior of LREE accessory minerals during prograde metamorphism and the timing of anatexis in the Central Alps.

Dr D. RUBATTO collaborated with Dr A. Azor of the University of Granada on the geochronology of mafic magmatism in the South Iberian Suture.

Dr D. RUBATTO collaborated with Prof R. Carosi, Univeristy of Pisa, Italy and Dr D. Visona, University of Padova, Italy on the chronology of high-temperature shear zones in the core of the Higher Himalayan Crystallines

Dr D. RUBATTO collaborated with Dr P. H. Leloup and Miss C. Sassier, Ecole Normale Superieure de Lyon, France, on the duration of deformation along the Ailao-Shan - Red River Shear Zone, China.

Dr D. RUBATTO collaborated with Prof S. Chakraborty, Ruhr Universität Bochum, Germany, Dr R. Anczkiewicz, Polish Academy of Sciences, Krakow, Poland, Prof S. Dasguspta, Indian Institute of Science Education & Research, Kolkata, India and Prof D. K. Mukhopadhyay, Indian Institute of Technology Roorkee, India on the chronology of metamorphism in the Sikkim region of the Himalayas.

Dr D. RUBATTO collaborated with Dr R. Anczkiewicz, Polish Academy of Sciences, Krakow, Poland, on the composition and age of highly differentiated melts from Vietnam and the timing of metamorphism in the Polish Sudetes.

Dr D. RUBATTO collaborated with Prof R. Compagnoni and Mr I. Gabudianu-Rudulescu, University of Torino, Italy, on the stability of allanite and monazite at high pressure and the age of high-pressure metamorphism in the Gran Paradiso Massif, Western Alps.

Dr D. RUBATTO collaborated with Prof R. Compagnoni, Dr B. Lombardo and Dr S. Ferrando, University of Torino, Italy, on the age and composition of zircon in high-pressure granulites from the Argentera Massif, Western Alps.

Dr D. RUBATTO collaborated with Dr M. Beltrando University of Turin, Italy and Dr G. Manatchal, University of Strassburg, France, on the chronology of major detachments within the Alpine orogeny.

Dr D. RUBATTO collaborated with Dr M. Beltrando and Mr A. Vitale-Brovarone University of Turin, Italy on the timing of subduction of the Corsican ophiolites.

Dr D. RUBATTO collaborated with Prof B. Cesare University of Padova, Italy on the volcanism in the Neogene Volcanic Province of SE Spain.

Mr R. Schinteie collaborated with M.M. Pawlowska, Department of Earth Sciences, Cambridge University, UK, on biomarkers of fossil-bearing Mesoproterozoic sedimentary rocks.

Ms D. VALENTE and Professor I. H. CAMPBELL collaborated with Phelps Dodge Ltd; the geochemistry, geochronology and evolution of the El Abra porphyry copper deposit in Northern Chile.

Dr I.S. WILLIAMS and Prof R.W.R. RUTLAND with Dr J. Kousa (Geological Survey of Finland). The evolution of the Svecofennian orogen.

Dr I.S. WILLIAMS with Dr J. Wiszniewska and Dr E. Krzeminska (Polish Geological Institute, Warsaw). The evolution of the basement beneath the East European Platform in Poland.

Dr I.S. WILLIAMS with Prof Oh Chang Whan and Dr Kim Sung Won (Chonbuk National University, South Korea). The timing of thermal events in South Korea and South China.

DR I.S. WILLIAMS with Prof Cho Moonsup, Dr Cheong Chang Sik, Dr Kim Jeongmin, Mr Yi Keewook and Mr Kim Yoonsup (Korea Basic Science Institute and Seoul National University, South Korea). The chronology of thermal events in South Korea.

DR I.S. WILLIAMS with Dr Sun Weidong and Dr Liu Yulong (Chinese Academy of Science, Guangzhou). The age of carbonatite magmas associated with the Bayan Obo rare earth element deposit, Inner Mongolia.

DR I.S. WILLIAMS with Prof A. Nieva (University of Coimbra, Portugal). Petrogenesis of Early Ordovician granodiorite and Variscan two-mica granites from central Portugal.

DR I.S. WILLIAMS with Dr A.R. Sola (Instituto Nacional de Engenharia Tecnologia e Inovação, Portugal). U-Pb zircon ages and oxygen isotopic compositions of late Variscan granitoids from the Nisa-Albuquerque batholith, SW Iberian Massif.

DR I.S. WILLIAMS with Dr P. Fiannacca (University of Catania, Sicily). Age, sources and metamorphic history of para- and augen gneisses from the Peloritani Mountains, Sicily.

DR I.S. WILLIAMS with Prof F. Bea (University of Granada, Spain). SHRIMP U-Pb geochronology.

Earth Environment

Mr M. AUBERT collaborates with Director Yang Decong and Mr. Ji Xueping (Yunnan Institute of Cultural Relics and Archaeology) and Mr. Li Gang (Diqing Tibethan Autonomous Prefecture Cultural Relics Administration Office, China) on investigating rock art in Yunnan, China for Uranium-series dating.

Dr L. K. AYLIFFE with Dr T.E. Cerling (University of Utah), Dr B. H. Passey (CALTECH).

Prof. P. DE DECKKER continues his large ARC Discovery-funded project on the geochemical and microbiological fingerprinting of surficial aeolian deposits from central Australia, together with Dr J. Brocks, Dr G. Alison from the anu Medical School, and colleagues form the University of Bremen [Drs K-U. Hinrichs, E. Schefuss and J-B. Stuut] and from the Max Plank Institute of Marine Microbiology [Drs D. de Beer and R. Abed], Dr S. van der Kaars of the University of Gottingen,and Prof. N.J. Tapper and Mr T. O'Loinsigh from Monash University. Onre large paper was published in G-cubed in 2008.

Prof. P. DE DECKKER's collaboration with Dr S. Schmidt from the University of Bordeaux on radio-tracers in deep-sea marine cores from offshore South Australia is near completion.

Prof. P. DE DECKKER competed a research paper with Dr Y. Yokoyama from the University of Tokyo on post-glacial sea level change from the Gulf of Carpentaria.

Prof. P. DE DECKKER continues collaboration with Dr M. Moros from the Baltic Sea Research Institute on a deep-sea core offshore the River Murray mouth. Currently work is completed on the Holocene sequence [paper submitted], and work on the older sequence has commenced.

Dr A. DUTTON collaborates with Dr E. Bard (CEREGE, France), Dr F. Antonioli (ENEA, Italy), on dating submerged speleothems from Argentarola Cave, Italy.

Dr A. DUTTON collaborates with Dr F. Antonioli (ENEA, Italy), Dr C. Monaco (University of Catania), and G. Scicchitano (University of Catania) on dating submerged speleothems from Sicily.

Dr A. DUTTON collaborates with Dr R.M. Leckie, Dr S. Burns, and S. Dameron (University of Massachusetts) on abrupt changes in ocean circulation during the early Eocene climatic optimum.

Dr A. DUTTON collaborates with Dr P. Pearson (Cardiff University, UK) , Dr T. Bralower (Penn State University, USA), and Dr B. Wade (Texas A&M University, USA) on diagenesis in Eocene tropical planktonic foraminfera.

Dr A. DUTTON collaborates with Dr C. Stirling (Otago University, New Zealand) on dating last interglacial corals from the Cape Range Peninsula, WA.

Dr S. EGGINS collaborates with Dr Baerbel Hönisch (LDEO, USA), and Dr Ann Russell and Prof. Howard Spero (UC Davis, USA) on culturing planktic foraminifera (DP0880010); with Prof. James Zachos (University of Santa Cruz, USA) on the chemistry of ancient foraminifers; with Prof. Jonathon Erez (Hebrew Univeristy, Jerusalem) on the chemistry of benthic foraminifers; and with Dr Dorrit Jacob (University of Mainz, Ger) on in situ analysis of Ca and Sr isotopes in carbonates.

Dr M.J. ELLWOOD collaborates with Dr. Michelle Kelly (NIWA, NZ) on Understanding the growth habits of deep sea sponges, with Dr. Philip Boyd (NIWA, NZ) and Dr. Cliff Law (NIWA, NZ) on Trace element cycling in the Tasman Sea, with Dr Derek Vance (University of Bristol, UK) on isotope fractionation in diatoms and copper isotopes in oceanic waters.

Dr K.E. FITZSIMMONS collaborates with Prof G.A.T. Duller (Aberystwyth University) and Dr H.M. Roberts (Aberystwyth University) on further developing thermally-transferred OSL dating techniques.

Dr K.E. FITZSIMMONS collaborates with Prof. G.H. Miller (University of Colorado, Boulder) on comparison of aridity proxies (with Dr J.W. Magee, ANU), and monsoon influence on the north Australian arid zone.

Dr M.K. GAGAN, Dr. L.K. AYLIFFE, Mr. D. QU, and Ms J. MAZERAT with Dr W. Hantoro and Dr D. Natawidjaja (Indonesian Institute of Sciences), Prof. Z. Liu (University of Wisconsin – Madison), and Prof. K. Sieh (Earth Observatory of Singapore), Partner investigators on ARC Discovery Grant DP0663227 (2006-2010): The Indian Ocean Dipole, Australasian drought, and the great-earthquake cycle: Long-term perspectives for improved prediction.

Dr M.K. GAGAN, Dr L.K. AYLIFFE and Ms S. LEWIS with Dr W. Hantoro (Indonesian Institute of Sciences) and Dr G. Schmidt (NASA Goddard Institute for Space Studies), Partner investigators on ARC Discovery Grant DP0663274 (2006-2008): Monsoon extremes, environmental shifts, and catastrophic volcanic eruptions: Quantifying impacts on the early human history of southern Australasia.

Dr M.K. GAGAN and Ms R. BERDIN with Dr F. Siringan (University of the Philippines), Dr H. Kawahata (Tohoku University) and Dr A. Suzuki (National Institute of Advanced Industrial Science and Technology), PhD dissertation on Late Quaternary climatic histories from raised coral terraces in the Philippines.

Dr M.K. GAGAN with Dr N. Abram (British Antarctic Survey), Holocene history of the Indian Ocean Dipole during the Holocene.

Prof. R. GRÜN collaborated with Prof. C. Falgueres, Dr. J.J. Bahain and other staff members of the the Département de Préhistoire du Musée National d'Historie Naturelle, Paris, on the further development of dating techniques, he co-supervises Mr M. Duval, who visited the ANU to carry out ESR and isotopic measurements for his PhD work and collaborates with Drs D. Grimaud-Hervé and M.H. Moncel on the application of new isotopic systems on Neanderthal remains.

Prof. R. GRÜN collaborates on similar application with Dr. B. Maureille, Laboratoire d'Anthropologie des populations du Passé, Université Bordeaux 1, on the site of Les Predelles, where his student Ms T Kelley carried out her Honours project.

Prof. R. GRÜN collaborates with many international scholars on the timing of modern human evolution. He has collected hominid samples from the anthropological sites Cave of Hearths, and Hutjiespunt, South Africa (Prof V.A. Tobias, Dr L. Berger, Dept of Anatomy, Medical School, University of the Witwatersrand, Prof J. Parkington, Dept of Archaeology, Cape Town University), Skhul, Qafzeh, Tabun, Kebara and Amud, Israel (Prof Y. Rak, Department of Anatomy, Haifa University, Prof C.B. Stringer, Natural History Museum, London), Banyoles, Spain (Prof J. Maroto, Area de Prehistoria, Universitat de Girona), Irhoud, Sale and Thomas Quarry, Marocco (Prof J.J. Hublin, Max Planck Institute for Evolutionary Anthropology, Leipzig).

Prof. R. GRÜN collaborates with Dr J. Brink, Bloemfontein, on the dating of a range of sites in South Africa, including the newly discovered human site of Cornelia.

Prof. R. GRÜN collaborates with Prof. S. Brandt (Univeristy of Florida), Prof. M. Rodrigo (University of Madrid), Prof. J. Richter (Universität zu Köln), Prof. G. Barker (Univeristy of Cambridge) for the dating work in Africa.

Prof R. GRÜN's collaboration continues with Dr A. Pike, Department of Archaeology, University of Bristol, on uranium uptake of bones and Prof T. de Torres, Escuela Tecnica Superior de Ingenieros de Minas de Madrid, on the calibration of amino acid racemisation in bones, cave bear evolution.

Ms S.C. LEWIS visited Dr A. LeGrande, Dr M. Kelley and Dr G. Schmidt at NASA Goddard Institute for Space Studies, New York, 21 July to 21 September.

Prof. M.T. McCULLOCH is collaborating with Prof Claudio Mazzoli (Dipartimento di Mineralogia e Petrologia, Università di Padova , Italy), and Dr. Paolo Montagna and Dr. Sergio Silenzi (Istituto Centrale di Ricerca Applicata al Mare – ICRAM, Rome , Italy) collaborating on shallow water coral reefs in the Mediterranean.

Prof. M.T. McCULLOCH is collaborating with Dr Marco Taviani, and Dr Alessandro Remia (ISMAR-CNR, Bologna, Italy) and Dr Paolo Montagna (Istituto Centrale di Ricerca Applicata al Mare – ICRAM, Rome, Italy), on Deep Sea Corals in the Mediterraean.

Prof. M.T. McCULLOCH is continuing collaborating with Professor Robert Dunbar and Dr (Department of Geological and Environmental Sciences, Stanford University, California, USA) Brendan Roarck (Texas A&M) on Deep Sea corals in the Pacific Ocean. Dr Roarck was awarded an American Australian Association Fellowship to undertake research with Professor McCulloch at RSES

Prof. M.T. McCULLOCH is collaborating with Dr J. Blichert-Toft and Prof F. Albarede (Laboratoire des Sciences de la Terre, Ecole Normale Superieure de Lyon, France), on Lu-Hf isotopes in ancient zircons.

Prof M.T. McCULLOCH is collaborating with Prof Thierry Correge (Departement de Geologie et Oceanographie, Universite de Bordeaux I, France) on U-series dating of modern corals from New Caledonia.

Prof M.T. McCULLOCH is collaborating with Dr N. Prouty, Dr M. Field & Dr C. Storlazzi, U.S. Geological Survey, and Dr M. D'Iorio, William Lettis & Associates (CA, USA) on linkages between land use and water quality changes on Molokai, Hawaii.

Prof. M.T. McCULLOCH is continuing collaboration with Dr S.D. JUPITER who is now at the Wildlife Conservation Society (WCS), South Pacific Country Program.

Prof M.T. McCULLOCH is collaborating with Dr Jens Zinke from the Vrije Universiteit Amsterdam on coral research and land-use changes in eastern Africa and the Indian ocean.

Mr I. MOFFAT collaborated with Professor Avraham Ronen, Department of Archaeology, University of Haifa on a project investigating the applicability of Sr isotope tracing to human migration in the Levant.

Mr I. MOFFAT collaborated with Associate Professor Steve Hasiotis, Department of Geology, The University of Kansas on a project concerning the stratigraphy and ichnology of the Darling River, Western NSW.

Dr. B. OPDYKE has ARC funded collaborative research funded with Prof. J. Zachos of the University of Santa Cruz

Prof B.J. PILLANS with Prof J. Ogg (Purdue University, USA) and Prof P. Gibbard (Cambridge University) on the status of the Quaternary in the International Geological Time Scale.

Prof B.J. PILLANS with Prof A. Netto (Federal University of Rio de Janeiro) on landscape evolution in Brazil.

Prof B.J. PILLANS co-editing a new book on Australian geomorphology with Prof P. Bishop (Glasgow University).

Ms J. SUTTON with NIWA, the New Zealand Foundation for Research Science and Technology.

Dr P. TREBLE collaborates with Prof I. Fairchild, University of Birmingham, on reconstructing rainfall records for southern Australia using speleothems.

Dr J. TROTTER collaborates with Prof. C. Barnes (University of Victoria, BC, Canada) and Prof. C. Lécuyer (CNRS & Université Claude Bernard Lyon 1, France) on oxygen isotope compositions of conodonts, with Prof. R Dunbar (Stanford University), Dr B. Roark (Texas A & M), and Dr P. Montagna (ICRAM, Italy) on the geochemistry of cold water corals, and Prof. C. Barnes on Sr isotopes of Tertiary forams.

Dr G. YOUNG's collaborations include Prof Zhu Min, Prof Chang Meemann and Dr Zhao Wen-Jin at the Institute of Vertebrate Palaeontology & Palaeoanthropology, Academia Sinica, Beijing, Profs D. Goujet, P. Janvier and H. Lelievre at the Museum nationale d'Histoire naturelle, Paris, Prof. P. Ahlberg at the University of Uppsala, Dr T. Ryan Gregory at the University of Guelph, Ontario, Prof. C. Marshall at Harvard University, Dr M. Coates at the University of Chicago, Dr J. Maisey at the American Museum of Natural History, and Prof. Ivan Schwab, University of California.

Earth Materials

Dr A.G. CHRISTY collaborates with Dr S.A. Welch (Ohio State University, USA) and Dr D. Kirste (Simon Fraser University, Canada) on incongruent jarosite dissolution/precipitation and rare earth element fractionation as a monitor of this process.

Dr A.G. CHRISTY collaborates with Prof S.M. Clark (Advanced Light Source, Berkeley, California, USA) on the high-pressure structural behaviour of mercury oxide studied in diamond anvil cell using synchrotron x-rays.

Prof S.F. COX continued a collaboration with Dr N. Mancktelow (ETH-Zurich), Dr A.-M. Boullier (Univertite Joseph Fourier, Grenoble), Dr Y. Rolland (Universite de Nice) a Dr G. Pennachioni (Universita di Padova) on fluid flow in Alpine shear zones.

Dr J.D. FITZ GERALD collaborates with Prof I. Parsons, Grant Institute, University of Edinburgh and Dr U. Golla-Schindler, University of Münster on feldspar exsolution. He also collaborates with Dr A.K. Engvik, Geological Survey of Norway, Prof A. Putnis, Institut fur Mineralogie, University of Münster and Prof H. Austrheim, Institute of Geosciences, University of Oslo on Albitisation of granitoids. Another collaboration, on defect structures in phlogopite, continues with Dr A. Camacho, University of Manitoba and Dr J.K. Lee, Queens University. Microstructures in natural, growth-banded and recrystallized zircons are the focus of a collaboration with Dr P. Vonlanthen, now at University of Lausanne.

Dr A. HALFPENNY collaborates with Prof D. Prior, Department of Earth and Ocean Sciences, University of Liverpool, UK, and Dr J. Wheeler, Department of Earth and Ocean Sciences, University of Liverpool, UK, on the recrystallisation and nucleation mechanisms in quartzites and marbles.

Dr A. HALFPENNY collaborates with Prof D. Prior, Department of Earth and Ocean Sciences, University of Liverpool, UK, on the controlling deformation mechanisms of gabbroic shear zones collected on IODP Expedition 304/305.

Dr J. HERMANN collaborates with Prof M. Scambelluri and Dr N. Malaspina (University of Genova, Italy), Prof T. Pettke and Dr C. Spandler (University of Berne, Switzerland), on constraints on subduction zone fluids from high-pressure ultramafic rocks.

Dr J. HERMANN collaborates with Dr Q. Qing (Chinese Academy of Science, Beijing, China) on the formation of high Mg-diorites and the differentiation of the continental crust.

Dr J. HERMANN collaborates with Prof M. Harrison (UCLA, USA) and Dr M. Heizler (Bureau of Geology and Mineral Resources, Socorro, USA) on the experimental determination of Ar diffusion in muscovite.

Dr J. HERMANN collaborates with Dr A. Korsakov (Novosibirsk, Russia) on coesite and diamond facies metamorphism in the Kokchetav Massif, Kazakhstan.

Dr J. HERMANN collaborates with Dr M. Marocchi (University of Bologna, Italy), on trace element variations in hydrous minerals in mantle wedge peridotites and implications for mantle metasomatism.

Dr J. HERMANN collaborates with Prof M. Engi and Dr A. Berger (University of Berne, Switzerland), on Barrovian metamorphism in the Central Alps.

Dr J. HERMANN collaborates with Prof B. Cesare (University of Padova, Italy), Prof I. Buick (Stellenbosch University, South Africa) and Dr A. Acosta Vigil (University ofGranada, Spain), on partial melting in crustal xenoliths of the South Spanish volcanic province.

Dr J. HERMANN collaborates Dr M.T. Gomez Pugnaire and Mr. J.A. Padron (University of Granada, Spain), on dehydration of antigorite in subducted serpentinites.

Dr J. HERMANN collaborates Prof R. Compagnoni and Dr M. Beltrando (University of Torino, Italy), on formation and evolution of blueschist and eclogite facies rocks in the Western Alps and Corsica.

Dr J. HERMANN collaborates with Dr M. Satish-Kumar (Shizuoka University, Japan), on monitoring volatile and trace element contents of fluids in high-grade marbles from Antarctica.

Prof I. JACKSON collaborated with Dr D.R. Schmitt (University of Alberta, Canada), Assoc Prof U.H. Faul (Boston University, Dr Y. Aizawa (Japan Manned Space Systems Corporation, Japan), Dr A. Barnhoorn (Utrecht University), Dr J. Kung (National Cheng-Kung University, Taiwan), Prof R.C. Liebermann (Stony Brook University), and Dr S.J.S. Morris (University of California, Berkeley) in the laboratory measurement and modelling of seismic properties.

Dr F.E. JENNER collaborates with Dr J.E. Mungall, University of Toronto, Department of Geology on the chemistry of High-Ca Boninites from the Northern Tonga Region of the SW Pacific.

Prof G. LISTER collaborated: a) with Professor T. Ahmad at Delhi Universiy, India in developing an AISRF project and in the Himalayan 08 geotransect; b) with Professor Jean-Pierre Burg at ETH Zurich in initiating a PhD prject for Mr C. Augenstein in the Swiss Alps; c) with Mr C. Soukis, Dr N. Skarpelis and Prof D. Papanikolaou at Athens University in developing a project on Evia, Greece.

Dr D.C. "Bear" McPHAIL collaborated with Prof K. Kyser (Queen's University, Canada) and Dr C. Oates (Anglo American, London), with DR. P. de Caritat (Geoscience Australia) on groundwater geochemistry for mineral exploration in northern Chile and northwestern India.

Mr C. PIRARD collaborates with Dr F. Hatert (Laboratoire de Minéralogie, University of Liège, Belgium) on the mineralogy and ore geology of Katanga Cu-Co-U deposits, D.R. Congo.

Mr C. PIRARD collaborates with Prof A.-M. Fransolet and Dr F. Hatert (Laboratoire de Minéralogie, University of Liège, Belgium) on metasomatism in phosphates-bearing pegmatitic systems.

Mr C. PIRARD collaborates with O.Namur, Dr B.Charlier and Prof J. Vander Auwera (U.R. Pétrologie & Géochimie endogènes, University of Liège, Belgium) on the differentiation of ferrobasaltic magmas in the Sept-Iles Layered Intrusion, Quebec, Canada.

Dr R. RAPP collaborates with Prof H. Martin and Dr D. Laporte, Laboratoire Magmas et Volcans, Universite de Blaise Pascal, Clermont-Ferrand, France, and Dr J.-F. Moyen, Department of Geology, University of Stellenbosch, South Africa, on crust-mantle interactions in the Archean and the origin of Archean granitoid magmatism.

Mr N.D. TAILBY collaborates with Dr A.M. Walker (University College London), Dr A.J. Berry (Imperial College London), Dr S.R. Sutton (University of Chicago), Dr I.S. Rodina and Dr A.V. Soldatov (Southern Federal University, Russia), on Ti site occupancy in zircon.

Mr L. WHITE (and the structure and tectonics team) collaborates with Prof T. Ahmad (Delhi University) on Himalayan geology.

Earth Physics

Prof R.W. GRIFFITHS with Prof. C. Kincaid, University of Rhode Island, USA, on the flow in mantle subduction zones and the interaction of mantle plumes with subduction.

Dr A.McC. HOGG and Prof R.W. GRIFFITHS with Prof. W.K. Dewar, Florida State University, USA, and Dr P. Berloff, Woods Hole Oceanographic Institution, USA and University of Cambridge, UK, on small-scale ocean mixing produced by mesoscale eddies.

Dr A.McC. HOGG with Dr. M.P. Meredith, British Antarctic Survey, UK, Dr. C. Wilson, Proudman Oceanographic Laboratory, UK, and Mr J.R. Blundell, National Oceanography Centre, UK, on eddy heat flux in the Southern Ocean.

Prof B.L.N. KENNETT is collaborating with Dr S Fishwick, University of Leicester, UK, and Mr A. Fichtner, University of Munich, Germany, on surface wave tomography.

Prof B.L.N. KENNETT has collaborated with Dr T. Furumura at the Earthquake Research Institute, University of Tokyo, Japan on a variety of issues in seismic wave propagation, particularly the propagation of seismic waves in complex subduction zones and long range propagation in the lithosphere.

Dr R.C. KERR with Prof J.R. Lister, University of Cambridge, UK, on the gravitational instability of strongly sheared mantle plumes.

Dr. S.H. POZGAY collaborated with Dr. Christian Haberland, Dr. Trond Ryberg, Dr. Klaus Bauer, and Karl Otto (GeoForschungsZentrum Potsdam [GFZ]), Bambang Suwargadi (GeoTek, LIPI, Indonesia), and Hendra (BMG, Medan, Sumatra) installing seismic stations in north Sumatra, Indonesia.

Dr N. RAWLINSON collaborates with: Prof. Greg Houseman, University of Leeds, on teleseismic tomography; Prof. Tim Stern from the Victoria University of Wellington on wide-angle tomography; and Prof. Mike Kendall, Bristol University, on ambient noise tomography.

Dr M.L. RODERICK collaborates with Dr A. Dai, National Centre for Atmospheric Research, Boulder, Colorado, and Dr B. Liepert, Lamont-Doherty Observatory, Columbia University, New York, on changes in the global hydrologic cycle, and with Dr S. Schymanski, Max Planck Institute for Biogeochemistry, Jena, Germany and Prof M. Sivapalan, University of Illinois at Urbana-Champaign, on the development of a new theoretical framework for ecohydrology, and with Prof J. Shuttleworth, University of Arizona, on land surface physics.

Prof. M. SAMBRIDGE with Prof. R. Snieder (Colorado School of Mines), Coda wave interferometry, Dr. E. Debayle (Univ. of Strasbourg) on mantle imaging with body waves, Prof. K. Gallagher (Univ. of Rennes) on Bayesian inference methods, Prof. J. Tromp (California Inst. Of Tech.) on Adjoint methods for seismic imaging.

Dr H. TKALCIC has collaborated with with Prof. Doug Dreger, University of California at Berkeley, Prof. Gillian Foulger, University of Durham and Dr. Bruce Julian, USGS, on anomalous seismic radiation earthquakes in the Bárdarbunga area of Iceland.

Dr H. TKALCIC continues to collaborate with Prof. V. Cormier from University of Connecticut on the deep Earth structure, with Dr Y. Chen and Dr. Roland Gritto, Multimax, Inc., USA, on studying lithospheric structure under China from teleseismic receiver functions, and on studying lithospheric structure and seismic sources under the Zagros Mountains; with Prof. M. Herak, Dr. S. Markusic and Ph.D. candidate J. Stipcevic, on studying lithospheric structure under Croatia and the Adriatic Sea from teleseismic receiver functions; with Ph.D. candidate A. Fitchtner, University of Munich, Germany, on studying the crust and upper mantle under Australia using waveform modelling, and on studying volcanic earthquakes on Iceland.

Dr. P. TREGONING collaborated with Dr G. Ramillien and Dr J.-M. Lemoine on the analysis and interpretation of GRACE space gravity data. He collaborated with Drs R. King, T.A. Herring and S. McClusky on the development of the GAMIT GPS software and with Dr M. Vergnolle, N. Cotte and A. Walpersdorf on the slow-slip events in the Gurrero subduction zone.

Dr. J. ZHANG participated in a joint French-Australian Project of collaboration of Jason-1 altimeter using the French Transportable Satellite Laser Ranging System (FTLRS) in Tasmania, from Dec, 2007 to April, 2008

Integrated Ocean Drilling Program (IODP)

Collaboration with a considerable number of scientists in the American, Japanese, European, New Zealand and Korean IODP Offices in the IODP context.

PRISE

Dr R.A. ARMSTRONG collaborates with Prof. A. da Silva Filho and Assoc. Prof. I. de Pinho Guimarães, Federal University of Pernambuco, Recife, Brazil, on the geochronology and crustal growth history of the Borborema province, Brazil; Prof. R. Hall and Dr M. Cottam, Royal Holloway, University of London, on the geochronology of the mount Kinabalu granite of North Borneo; Prof. N. Beukes, B. Nel and R. da Silva, University of Johannesburg, South Africa, on the detrital and igneous zircon record and chronology of the western margin of the Kaapvaal Craton; Prof. N. Beukes and B. Masinga, University of Johannesburg, South Africa, on the age of deposition and mineralization of the Transvaal Sequence iron ore deposits, southern Africa; Dr E. Roberts, Witwatersrand University, on provenance and age of detrital zircons from the Rukwa Rift Basin, Tanzania; Dr. A. Cocherie and Dr. P Rossi, BRGM, France, on dating of samples from northern Africa and Corsica; Dr G. de Kock, Council for Geoscience, South Africa, on the geochronology and metamorphism the Birimian sequences of

Ghana; Dr Paul Macey, Council for Geoscience, South Africa, on the geochronology of western Madagascar; L. Longridge on the age and metamorphic history of the Khan valley region of Namibia; Dr. J. Harnmeijer and Prof. R. Buick, Center for Astrobiology & Early Earth Evolution, University of Washington on the age of ancient sediments from Greenland; C. Sanchez-Garrido, University of Stellenbosch, on the geochronology of pebbles in the Moodies Group, Barberton Mountain Belt, South Africa; J. Taylor, University of Stellenbosch, on the geochronology of migmatites on the Ancient Gneiss Complex, Swaziland; Prof, S. Siegesmund, Göttingen University, Germany, on SHRIMP dating of samples from Argentina.

Mr C.M. FANNING continued collaborations with Prof P.K. Link, Idaho State University on the provenance and time of deposition of Neoproterozoic sequences in Utah and Idaho; Dr J. Goodge, University of Minnesota, Duluth on geochronology and provenance of sequences in the central Transantarctic Mountains; Prof F. Hervé, Universidad de Chile and Dr R.J. Pankhurst, British Geological Survey on the geochronological and tectonic evolution of the Patagonia, Tierra del Fuego and the Antarctic Peninsula; Prof C. Rapela, Universidad Nacional de La Plata, Argentina and Dr R.J. Pankhurst, British Geological Survey on the geochronological and tectonic evolution of the north Patagonian massif and adjacent cratons/terrains of Argentina; Dr C. Casquet and Dr C. Galindo, Universidad Complutense, Madrid on the geochronological and tectonic evolution of the Sierras Pampeanas, NW Argentina; Dr J.N. Aleinikoff, United States Geological Survey on SHRIMP II U-Pb analyses of zircon and xenotime; Dr Christine Siddoway, Colorado College and Mr Rory McFadden, University of Minnesota on the tectonic evolution of the Fosdick Mountains, Mary Byrd Land, Antarctica.

Mr S. Hui collaborated with Prof. Ralph P. Harvey, Case Western Reserve University, Cleveland, USA on analysis of cosmic spherules from the Lewis Cliff, Antarctica.
Dr M.D. NORMAN collaborates with Prof. M. Garcia, University of Hawai'i, Honolulu, Prof. M. Rhodes, University of Massachusetts, Amherst, Dr. Aaron Pietruszka, San Diego State University, San Diego, and Prof. Dominique Weis, University of British Columbia, Vancouver, on the composition of the mantle and construction of Hawaiian volcanoes; Prof. R. Duncan, Oregon State University, Corvallis, on the impact history of the Moon; and Prof. D. Keppie, Universidad Nacional Autónoma de México, on the tectonics of Central America.

A. Rosenthal collaborated with Drs M. Drury, A. Barnhoorn and H. van Roermund, University Utrecht, Netherlands, on deformation, structure and Norwegian regional petrology/geology (part of her Mervyn and Katalin Paterson Fellowship); Prof S. F. Foley, Mainz University, Germany, on the establishments of near-solidus melts of peridotite in the presence of CO2 and H2O at 40-60kbar, using piston-cylinder apparaturs and ongoing studies of the petrogenesis of Ugandan kamafugites; Profs H. E. Höfer, G. Brey and A.B. Woodland, University Frankfurt am Main, Germany, on using the electron microprobe 'flank method' (Höfer and Brey), and Mössbauer spectroscopy (Woodland) to study the establishment of the oxidation state of the Norwegian peridotite body and also on the development of standards for Fe3+/Fe in garnets; Dr I. Kovacs, Eötvös Lorand Geophysical Institute of Hungary, Budapest, Hungary, on ongoing studies of minor amounts of H2O in melts of residual eclogite.

Dr G. Yaxley collaborated with Prof Steven Foley, University of Mainz on an experimental project relating to high pressure melting of hydrous carbonate-bearing peridotite; Prof A. Woodland and Dr H Höfer, University of Frankfurt, and Dr A. Berry, Imperial College, on determination of Fe3+ contents of garnets in garnet peridotite xenoliths by Mössbauer Spectroscopy, the Flank Method and synchrotron-based XANES.

Visitors

Dr C.E. BARTON collaborates with Prof. D.N. Baker and Dr. W.K. Peterson, Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, USA on the Electronic Geophysical Year (eGY) pogram.

Dr C.E. BARTON collaborates with Prof. Les Cottrell (Stanford Linear Accelerator Group, USA) and Dr Sandro Radicella and Prof. K.R. Sreenivasan (International Centre for Theoretical Physics, Trieste, Italy) on the PingER Project to measure Internet performance for Africa.

Dr R. V. BURNE collaborates with Prof. Josef Paul (Göttingen University), Dr Gumpei Izuno (University of Tokyo), Dr Tadashi Maruyama (JAMSTEC), and Prof. Jaap Kaandorp (University of Amsterdam)

Dr D.R. Christie collaborates with Dr P. Campus, Comprehensive Nuclear-Test-Ban Treaty Organization, United Nations, Vienna, Austria on CTBT verification activities, infrasound monitoring of volcanoes and other applications of infrasound.

Dr K. A. W. Crook assisted Dr E. A. Felton (RSES, ANU) and Dr A. Switzer (University of Hong Kong) with geological aspects of cosmogenic age dating of rocky coastal geomorphic features.

Dr K. A. W. Crook has accepted an invitation to serve as External MSc Examiner for the Victoria University of Wellington, New Zealand, of a thesis on "Recent Sedimentation at Palmyra Atoll".

Dr W. COMPSTON and others collaborated with Charles Meyer (Johnson Spacecraft Center, Houston) on the interpretation of lunar zircon ages.

Dr E. A. Felton is working with Dr A. Switzer, University of Hong Kong, on cosmogenic age dating of rock coastal geomorphic features.

C. Jones is a visiting scholar from the University of California, Berkeley, where her primary advisor is Dr. J. Banfield of the Departments of Earth & Planetary Science; Earth Science, Policy & Management; and Material Sciences. Also collaborating on the Lake Tyrrell Project (1 part of which comprises C. Jones' thesis and research with Dr. J. Brocks, RSES) are Dr. K. Heidelberg, University of Southern California; Dr. E. Allen, University of California, San Diego/Scripps Oceanographic Institute; Dr. E. Roden, University of Wisconsin, Madison; Dr. G. Luther, University of Delaware; Dr. D. Emerson, the American Type Culture Collection; Dr. M. Yim, University of Pennsylvania; and the J. Craig Venter Institute, San Diego, CA.

Dr P.J. JONES collaborated with Dr C. Korte, Freie Universität, Berlin, on Permian latitudinal sea-surface temperature gradients based on a 18O isotope analysis of high latitude brachiopod and bivalve samples from the Permian of Australia.

Prof K. LAMBECK collaborates with Dr F. Antonioli, ENEA, Rome, and Dr M. Anzidei, Instituto Nazionale di Geofisica e Vulcanologia, Rome, on sea-level change in the Mediterranean Sea.

Prof K. LAMBECK collaborates with Dr C. Sparrenbom, Swedish Geotechnical Institute, Prof Svante Björck, GeoBiosphere Science Centre, Lund University, and Dr Ole Bennike, Department of Environment History and Climate Development, Geological Survey of Denmark and Greenland on ice sheet evolution and sea-level changes in southern Greenland.

Prof K. LAMBECK collaborates with Prof G. Bailey, Department of Archaeology, University of York, UK, and Prof C. Vita-Finzi, The Natural History Museum, London, on an EFCHED project relating to archaeology in the Red Sea Basin.

Prof K. LAMBECK, Member of Executive Committee, InterAcademy Panel on international issues.

Prof K. LAMBECK, Chair Review Committee, AERES (agence d'evaluation de la recherché et de l'enseignement supérieur) Review of the Institut de Physique du Globe de Paris, 10 - 14 March 2008, Paris.

Prof I. McDougall continued his long-standing collaboration with Professor F.H. Brown, University of Utah, Salt Lake City, on the stratigraphy and geochronology of the sequences in the Omo-Turkana Basin, Kenya and Ethiopia. As part of this project, fieldwork was undertaken in July 2008, in the Shungura Formation of southern Ethiopia.

Dr Robert S. Nicoll with Dr. Jim Ogg, Purdue University, on the development of the Timescale and its application in Australia.

EMERITUS PROFESSOR M S PATERSON has installed a new module in one of the Paterson HPT rock deformation machines in the Swiss Technical University (ETH), Zürich, for the measurement of seismic attenuation in compression at prospecting frequencies.

Prof R.W.R. RUTLAND collaborates with Dr J. Kousa and Dr P. Sorjonen-Ward, Geological Survey of Finland, and with Dr T. Skiöld and Dr M.J. Whitehouse, Swedish Museum of Natural History, Stockholm, on the tectonic evolution of the Svecofennian province and the adjacent Archaean craton in Fennoscandia.

Prof S. R. TAYLOR collaborates with Prof Scott M McLennan, SUNY, Stony Brook, USA, on the completion of a book entitled Planetary Crusts.

COOPERATION WITH GOVERNMENT AND INDUSTRY

Earth Chemistry

Dr J.J. BROCKS collaborated with Dr E. Grosjean and Dr G.E. Logan (Geoscience Australia), The use of polyethylene byproducts to determine the permeability of rock.

Dr J.J. BROCKS collaborated with Dr C. Boreham (Geoscience Australia), Applications of HPLC in organic geochemistry.

Dr. S.J. FALLON collaborated with Dr. A. McDougall (Dept. Natural Resources & Water, aging of Queensland Lungfish).

Dr I.S. WILLIAMS holds a 25% appointment as Chief Scientist at Australian Scientific Instruments Pty. Ltd., a subsidiary of ANU Enterprise, where he works on SHRIMP development, marketing, testing and operator training.

Dr I.S. WILLIAMS provided SHRIMP technical and scientific advice to the Geological Survey of Canada (Ottawa, Canada), Hiroshima University (Hiroshima, Japan), The NationalInstitute of Polar Research (Tokyo, Japan), The Chinese Academy of Geological Sciences (Beijing, China), the All Russian Geological Research Institute (St. Petersburg, Russia), the Korea Basic Science Institute (Daejeon, South Korea), the University of São Paulo (São Paulo, Brazil) and Geoscience Australia (Canberra).

Dr I.S. WILLIAMS provided scientific and technical training in secondary ion mass spectrometry to scientists from laboratories that have purchased SHRIMP ion microprobes: Prof. Cho Moonsup, Dr Kim Jeongmin, Mr Yi Keewook and Mr Kim Yoonsup (Korea Basic Science Institute and Seoul National University, South Korea), and Dr Wan Yusheng, Mr Zhang Yuhai, Mr Fan Runlong and Ms Dong Chunyan (Chinese Academy of Geological Sciences, Beijing) during their visits to Australian Scientific Instruments.

Dr I.S. WILLIAMS collaborated with Dr M. Hotchkis and Dr D. Child (Australian Nuclear Science and Technology Organisation, Sydney) in the development of SHRIMP IIe multicollector techniques for the isotopic analysis of U and Pu in micro-particles of nuclear materials.

Dr I.S. WILLIAMS and Ms Heejin Jeon are collaborating with Dr P. Blevin (Geological Survey of New South Wales) in a study of the Late Palaeozoic granites of southeastern Australia.

Earth Environment

Prof R. GRÜN collaborates with the Department of Environment and Conservation, NSW, and the Three Traditional Tribal Groups in the ARC Linkage grant Environmental Evolution of the Willandra Lakes World Heritage Area.

Miss T.E. KELLY cooperated with National Parks and Wildlife Service, Department of Conservation and Climate Change, Mungo Project.

Prof M.T. McCULLOCH and Dr S.D. JUPITER formerly from RSES and now WCS are collaborating with the Great Barrier Reef Marine Park Authority, the Mackay Whitsunday Natural Resource Management Group and the Mackay City Council, Long-term changes in Mackay Whitsunday water quality and connectivity between coral reefs and mangrove ecosystems.

Prof. M. McCULLOCH together with Jon Brody from JCU and Dr Fabricius from AIMS are collaborating with the Commonwealth Department of Environment and Heritage in The Marine and Tropical Sciences Research Facility (MTSRF) which is part of the Commonwealth Environmental Research Facilities Program (CERF), an initiative of the Australian Government to invest in world-class public good research over the next four years. Professor McCulloch is involved in a project Funds to support the conservation and sustainable use of the Great Barrier Reef and the connecting coastal regions.

Mr I. MOFFAT collaborated with Alice Beale, Anthropology Department, Western Australian Museum on a project investigating the effectiveness of various geophysical techniques to locate historic graves in a variety of geological environments.

Prof B.J. PILLANS with Mr J. Wilford (Geoscience Australia) on landscape evolution in the Harden-Young region, N.S.W.

Earth Materials

Dr M.-A. BONNARDOT with Mr H. Jelsma (DeBeers), Structure and tectonics of parts of Central Africa and bearing on kimberlite emplacement.

Dr A. HALFPENNY with Mr F. Tulleman and Mr D. Schonfeldt (Porgera Joint Venture, Barrick Gold), on the structural controls and evolution of the Porgera gold deposit, Papua New Guinea

Prof S.F. COX and Dr S. Micklethwaite collaborated with a consortium of minerals industry sponsors, via AMIRA International, in an ARC Linkage project "Exploration potential of stress transfer modeling in fault-related mineral deposits".

Prof S.F. COX is collaborating with Gold Fields Australia Limited in a PhD project "Deformational Controls on Dynamics of Fluid Flow, Hydrothermal Alteration and Ore Genesis, Argo Gold Deposit, WA". This project is jointly funded by Gold Fields Australia Limited and an ARC Linkage grant.

Prof S.F. COX and Dr Angela Halfpenny are collaborating with geoscientists at the Porgera gold deposit (PNG) on studying the development of fracture-controlled flow systems in this rich and very large, intrusion-related gold system. This collaboration forms part of the activities of the ARC Centre for Excellence in Ore Deposits.

Dr S. MICKLETHWAITE with Mr A. Goode (AMIRA International), Mr J. Essman and others (Newcrest, Nevada), Mr C. Weakly and others (Barrick, Nevada), and Mr I. Pegg and others (Gold Fields, West Australia), Exploration potential of stress transfer modeling in fault-related mineral deposits.

Mr L. WHITE has been collaborating with the Southern Frontiers team at Geoscience Australia (Petroleum and Marine Division) to understand the distribution and character of faults in Australia's southern margin basins.

Dr D.C. "Bear" McPHAIL collaborated with Dr P. de Caritat (GA), Dr C. Oates (Anglo American) and Mr K. Kyser (Queen's University, Canada) on interpreting groundwater geochemistry in mineralized areas of northern Chile and northwestern India. Dr P. de Caritat (GA), Manfred Wimberger (The Peak Gold Mines, Cobar) on the hydrogeochemistry of the gold fields in Cobar, NSW. Dr W. McLean (Parsons Brinckerhoff) and Dr M. Norman (RSES) on hydrogeochemistry of the Lower Murrumbidgee Catchment, NSW.

Earth Physics

Prof. B.L.N. KENNETT has continued to provide support to the Comprehensive Nuclear-Test-Ban Treaty (CTBT) Organisation in Vienna through the operation of the Warramunga Seismic and Infrasound Research Station near Tennant Creek in the Northern Territory. From mid-2008 Dr H. Tkalcic has taken on the prime operational responsibility for the facility. The seismic and infrasound arrays have been very ably supported by Scott Savage as station manager at Warramunga. Very high reliability has been achieved with data transmitted continuously to the International Data Centre in Vienna via satellite link.

Dr N. RAWLINSON collaborates with Dr. Marthijn de Kool (Geoscience Australia) on seismic wavefront propagation in complex 3-D media, and with Dr. Dave Robson (NSW Geological Survey) on teleseismic tomography in NSW.

Dr M. SALMON collaborated with Department of Primary Industries and Resources SA in the deployment of the Gawler Craton array.

Dr M. SALMON liaised with Geoscience Australia to provide AUSCOPE instruments for the 2008 Gawler Craton deep seismic reflection transect.

Prof. M. SAMBRIDGE spent January to June on outside studies leave at Geoscience Australia, where he gave lectures on inverse methods and collaborated with Dr. P. Cummins, Geoscience Australia on earthquake finite fault inversions.

Dr TREGONING has cooperated with Mr G. Johnston and N. Dando on the AuScope gravity programme.

PRISE

Dr R.A. ARMSTRONG with D. Braxton of Anglo American Exploration (Australia) Pty Ltd on SHRIMP U-Pb geochronology of a Pliocene intrusive complex in Indonesia; Dr Hielke Jelsma (De Beers) on the geochronology of Angola and the Democratic Republic of Congo.

Dr R.A. ARMSTRONG and Dr M.D. NORMAN with S. Matthews of Minera Meridian Limitada, Chile on sulphur isotope studies of sulphide-bearing veins from the Andes.
Dr R.A. ARMSTRONG and Dr G. YAXLEY with the Northern Territory Geological Survey on the geochronology, provenance and history of selected areas of the Northern Territory, using U-Pb, oxygen and Hf isotope studies.
Dr M.D. NORMAN with G. Douglas, CSIRO, on field trials to investigate surface-groundwater interactions.

Visitors

Dr R. V. BURNE cooperates with Sue Hancock and Rory Chapple (Parks and Visitor Services, Department of Environment and Conservation, Western Australia) on the management and conservation of the Shark Bay World Heritage Area, and with FRAGYLE, Western Australia, on the management and conservation of the RAMSAR listed Yalgorup Lakes National Park.

Dr D.R. Christie with Dr D.J. Brown (Geoscience Australia) on matters related to verification of the Comprehensive Nuclear-Test-Ban Treaty.

Dr K. A. W. Crook and Dr E. A. Felton (50%/50%) provided a JOINT PROFESSIONAL OPINION, entitled "Rising sea-level and its implications for the preservation of cultural heritage at Kingston, Norfolk Island", to the Government of Norfolk Island, the Norfolk Island Museum Trust, and the Curator of the Norfolk Island Museum.

Dr E. A. Felton and Dr K. A. W. Crook (50:50) provided a JOINT Professional Opinion titled: Rising Sea-level and its implications for the preservation of cultural heritage at Kingston, Norfolk Island to the Government of Norfolk Island, the Norfolk Island Museum Trust and the Curator of the Norfolk Island Museum.

Dr P.J. JONES collaborated with Dr P. Kruse, Northern Territory Geological Survey, on a taxonomic study of Middle Cambrian bradoriids (Arthropoda) from the Georgina Basin.

Prof K. LAMBECK, as President of the Australian Academy of Science, was a member of the Prime Minister's Science Engineering and Innovation Council.

Prof K. LAMBECK, as President of the Australian Academy of Science, was a jury member for the L'Oréal Australia 2008 For Women in Science Fellowships.

Prof K. LAMBECK was Science Advisor to the National Geospatial Reference System, Geoscience Australia.

Prof K. LAMBECK, Chair, National Elevation Data Framework Workshop, 18 March.

Prof K. LAMBECK, Expert Panel Member, DEEWR Higher Education Endowment Fund.

Prof K. LAMBECK, Chair, Prime Minister's Science Prizes Award Committee.

EMERITUS PROFESSOR M S PATERSON has continued as a consultant to Australian Scientific Instruments Pty Ltd in connection with the manufacture of Paterson HPT high-pressure high temperature deformation machines, the latest of which was installed in Guangzhou Institute of Geochemistry, Chinese Academy of Science.

KEITH SCOTT with Northparkes Mine (Kerrie Edwards and Renee Morphett) on dust in mine area.

Dr D.L. STRUSZ with Dr J.R. Laurie (Geoscience Australia) and Dr L. Sherwin (NSW Geological Survey) on Silurian faunas of Canberra and the surrounding region.

STAFF ACTIVITIES 2008

CONFERENCES AND OUTSIDE STUDIES

Earth Chemistry

Ms. J.N. AVILA attended EURISPET - European Intensive Seminars of Petrology - Isotopes applied to petrological problems, The Australian National University, Canberra, Australia, 31 January - 9 February.

Ms. J.N. AVILA attended Silicate Dust in Protostars: Astrophysical, Experimental and Meteoritic Links, University of Tokyo, Tokyo, Japan, 25-26 July.

Ms. J.N. AVILA attended the 71st Annual Meeting of the Meteoritical Society, Matsue, Japan, 28 July - 1 August and presented a paper entitled "Tungsten Isotopic Compositions in Presolar Silicon Carbide Grains".

Ms. J.N. AVILA attended Chronology of the Solar System, Hiroshima, Japan, 3 August and presented a paper entitled "Tungsten Isotopic Compositions in Presolar Silicon Carbide Grains: Implications for 182Hf-182W and 187Re-187Os chronometers".

Ms. J.N. AVILA attended the 8th Australian Space Science Conference, Canberra, Australia, 29 September - 1 October and presented a paper entitled "Isotopic Signatures of Heavy Elements in Presolar Silicon Carbide Grains from AGB stars".

Dr. V.C. BENNETT, Visiting scientist Lunar and Planetary Institute and NASA- Johnson Space Center, Houston, Texas from 15 May - 15 July, 2008.

Dr J.J. BROCKS attended 'Contamination-free biomarker analysis of shales using oxidative microwave digestion - 15th Australian Organic Geochemistry Conference, Adelaide, Australia, 9 - 12 August 2008.

Dr J.J. BROCKS, gave an invited lecture entitled, "Molecular fossils and the reconstruction of billion-years-old microbial ecosystems" at the 12th International Symposium on Microbial Ecology (ISME), Cairns, 17 - 23 August 2008.

Dr J.J. BROCKS, Keynote Lecture, 'Molecular fossils and the evolution of eukaryotes in the Precambrian', International Kalkowsky-Symposium, Göttingen, Germany, 5 - 11 October 2008.

Dr J.J. BROCKS, Invited Lecture, 'Toxic purple oceans and the reconstruction of a billion year old microbial ecosystems', ACT MS Symposium, Canberra, 25 November 2008.

Dr J.J. BROCKS, "Building the Biomarker Tree of Life - Molecular Fossils & Environmental Genomics", Tempo & Mode Series B presentation for the Centre of Macroevolution and Macroecology, The Australian National University, 14 May 2008.

Dr J.J. BROCKS, 'Integrating community proteogenomics and lipid biogeochemistry to unravel ancient evolutionary history' - 15th Australian Organic Geochemistry Conference, Adelaide, 9 - 12 August 2008.

Dr J.J. BROCKS with Ms C. Jones (UC Berkeley), Prof S. George and Mr S. Bray (Macquarie University), drilling expedition to Lake Tyrrell, Victoria, 20 - 26 July 2008.

Dr J.J. BROCKS with Ms C. Lee (RSES, ANU), Prof J. Banfield, Ms C. Jones (UC Berkeley), Prof E. Allen (UC San Diego), Prof E. Roden (U. Wisconsin, Madison) and Prof G. Luther (U. Delaware), Field Work at Lake Tyrrell, Victoria, to collect samples for biomarker analysis and environmental genomics, 9 - 13 August 2008

Dr J.J. BROCKS with Dr. S Hinsken (University of Basel), Field work in the Rebberg Quarry, Altkirch, France, to collect Oligocene hypersaline sediments, October 2008.

Ms T.A. Ewing attended the EURISPET Intensive Seminar - Isotopes applied to petrological problems, Canberra, 31 January - 9 February, presented a poster entitled "Hf isotope measurements and U-Pb dating of rutile - Challenges and preliminary results".

Dr. S.J. Fallon attended the 11th International Conference on Accelerator Mass Spectrometry in Rome, Italy, 14 - 19 September 2008, and presented 2 papers entitled "The Next Chapter in Radiocarbon Dating at the Australian National University: Status report on the single stage AMS" and "A simple radiocarbon dating method for determining the age and growth rate of deep-sea sponges".

Dr. S.J. Fallon attended the 4th International Deep Sea Coral Symposium in Wellington, NZ, 1 - 5 December 2008 and presented a paper entitled "Age Determination and Ecological and Compositional Correlates of Growth Rates in Deep-Water Bamboo Corals (Isididae)"

Dr M. Forster conducted field work in the Lesser Himalaya, NW India on 4-22 April, in the Core Complex region in Arizona, USA in April 30 till May 4, in Evvia Greece with academics from Athens University from 27-30 May (Dr Lazios, Dr Kranis and students) and 19-21 June (Dr N. Skarpelis, Prof D. Papanikilous); in Cyclades island Ios Greece 1-18 June, in ophiolitic zones in Northern Greece 13-21 September.

Dr M. Forster undertook collaborative research in Athens University 10-12 September.

Ms C. GREGORY attended EURISPET Intensive seminars - Isotopes applied to petrological problems, ANU, Canberra, February, and presented a poster entitled "Tracing the evolution of calc-alkaline magmas using micro-analysis of accessory minerals".

Mr J. HIESS attended the 18th Annual V.M. Goldschmidt Conference, Vancouver, Canada, 13-18 July, and presented an invited talk entitled "Archean TTG petrogenesis - The U/Pb-O-Hf isotopic perspective."

Ms J. Hope attended 'Contamination-free biomarker analysis of shales using oxidative microwave digestion - 15th Australian Organic Geochemistry Conference, Adelaide, Australia, 9 - 12 August 2008.

Mr. S.J. McKibbin attended a workshop on Silicate Dust in Protostars: Astrophysical, Experimental and Meteoritic Link, 25-26 July, University of Tokyo, Japan, and a presented poster entitled "Isotopic Compositions and Systematics of Early Solar System and Presolar Materials: an Evaluation of Matrix Effects and Mass Interferences".

Mr. S.J. McKibbin attended the 71st Annual Meeting of the Meteoritical Society, 28 July - 1 August, Matsue, Japan, and presented a talk entitled "A new ion-probe determination of 53Mn/55Mn in D'Orbigny and Sahara 99555 using matrix-matched standards".

Mr. S.J. McKibbin attended the 8th Australian Space Science Conference, 29 September - 1 October, Canberra, and presented a talk entitled "Evolution of the angrite parent body and concordancy of isotope chronometers in angrite meteorites".

Dr D. RUBATTO attended the 33rd International Geological Congress, Oslo, Norway, 6-14 August 2008, presented a keynote paper on "U-Pb dating of high-grade metamorphism".

Dr D. RUBATTO conducted fieldwork in Corsica, France on September 17-20 2008.

Dr D. RUBATTO presented invited talk at the University of Lausanne, Switzerland on September 29 2008, and the ETH in Zurich, Switzerland on October 3 2008 on "U-Pb dating of metamorphism in the Central Alps".

Dr D. RUBATTO conducted fieldwork in Sikkim, India on November 1-10 2008.

Mr R. Schinteie attended the 15th Australian Organic Geochemistry Conference: Oil, soil, water wine, 8 - 12 September, Adelaide, and presented "Ancient life at the extremes: geochemical evidence for Neoproterozoic and Cambrian halophiles?"

Mr R. Schinteie attended the 2008 Kioloa Student seminars, Kioloa Campus, ANU, 16 November, and presented a talk entitled "Molecular palaeontology of the Neoproterozoic-Cambian interval: lipid biomarkers and ancient microbial ecosystems".

Dr I.S. WILLIAMS attended the Archaeological Science Conference, Canberra, 4 - 6 February and presented a paper entitled "A new technique for micro-scale analysis of oxygen isotopes in biogenic materials".

Dr I.S. WILLIAMS visited the Polish Geological Institute, Warsaw, 5 - 11 July, preparing work on the geochronology of the basement rocks of Poland carried out in collaboration with Dr J. Wiszniewska and Dr E. Krzeminska for publication.

Dr I.S. WILLIAMS attended the 18th Annual V.M. Goldschmidt Conference, Vancouver, Canada, 13 - 18 July, represented Australian Scientific Instruments at their exhibition booth, including demonstrating SHRIMP remote analysis. He also presented a paper entitled "Applications of SHRIMP II to oxygen isotopic analysis of granite zircon and conodont apatite".

Dr I.S. WILLIAMS attended the Australian Earth Sciences Convention 2008, Perth, 20 - 24 July and presented a paper entitled "Advances in SHRIMP zircon U-Pb geochronology and oxygen isotopic analysis".

Earth Environment

Dr L. AYLIFFE visited Dr J. Hellstrom at The University of Melbourne in September to perform U-Th dating of micro-carbonate samples from Liang Luar, Flores, Indonesia.

Prof. P. DEDECKKER organised and ran, together with Prof. J. H. Cann from the University of South Australia, in December a field trip associated with the AQUA conference in South Australia in the Coorong area of South Australia.

Dr A. DUTTON, Australian Earth Science Convention, Perth, WA, 21-24 July presented a paper entitled “Sea level reconstructions from fossil coral reefs along the Cape Range coast, Western Australia.”

Dr A. DUTTON Frontiers of Science Symposium held by the Australian Academy of Science, 21-22 February, was invited to give a talk entitled "Discovering the Dynamics of Earth's Environment: Geochemical Perspectives from Ancient Climates."

Dr A. DUTTON conducted field work in Western Australia from 10-19 November.

Dr S. EGGINS conducted an extended field-based foraminifer culture program at the Wrigley Institute for Environmental Studies (USC) on Santa Catalina Island during July and August, and assisted Prof. M McCulloch with coral coring activities on the southern Great Barrier Reef during October.

Dr M.J.ELLWOOD's Conference participation included:

J. Sutton, M. Wille, S. Eggins, W. Maher, P.L., Croot, AND M.J. ELLWOOD (2008) Germanium/Silicon and silicon isotopes fractionation in sponges. November 2008. Chemistry of the Biosphere, New Zealand Institute of Chemistry, Dunedin New Zealand.

A. De Leon, S. Wille, S. Eggins, AND M.J. ELLWOOD, (2008) A novel seawater palaeo-ph proxy in biogenic silica. November 2008. Chemistry of the Biosphere, New Zealand Institute of Chemistry, Dunedin New Zealand.

S.J. Fallon, K. James, R. Norman, AND M. ELLWOOD, (2008) Determining Age and Growth Rate of Marine Sponges by Radiocarbon Dating of Carbon trapped in Silica Spicules September 2008. 11th International Conference on Accelerator Mass Spectrometry, Rome, Italy

M.B., Anderson, D. Vance, C. Archer, M. ELLWOOD, C. Allen, C.D. Hillenbrand and R.F. Anderson (2008) The Zn isotopic composition of diatom frustules: An archive of past trace metal depletion in HNLC zones? July, 18th Annual Goldschmidt Conference, Vancouver, Canada

C. Law, M. Wooward, P. Boyd, C. Stevens, P. Sutton, M. ELLWOOD, A. Marriner, J. Hall, and K. Safi(2008). New nitrogen sources in the subtropical South-west Pacific. 18 June. Geochemical Seminar Series, School of Environmental Sciences, University of East Anglia, UK

C. Law, M. Wooward, P. Boyd, C. Stevens, P. Sutton, M. ELLWOOD, A. Marrier, J. Hall, AND K. Safi (2008). New nitrogen sources in the subtropical South-west Pacific. 25 June. Plymouth Marine Laboratory, UK

M.J. ELLWOOD AND P.W. Boyde (2008). Trace metal cycling during winter in the Subantarctic Zone from 40-52S; 155-160E. 14th Ocean Sciences Meeting, a joint meeting of AGU, ASLO, TOS, and ERF. 3-7 March. Orlando, Florida, USA

W.A. Maher, M.J. Ellwood AND P.L. Croot (2008). Oceanic germanium/silicon fractionation: evidence from oceanic profiles and diatom cultures. 14th Ocean Sciences Meeting, a joint meeting of AGU, ASLO, TOS, and ERF. 3-7 March. Orlando Florida.

M.J. ELLWOOD, P. Wilson, K. Vopel, AND M. Green (2008). Zinc cycling in the Whau Estuary, Auckland New Zealand. NZ Trace Elements Group Conference. 13-15 February. Hamilton, NZ

Dr K.E. FITZSIMMONS undertook a study visit to Aberystwyth University, UK, in October to December 2008 to participate in collaborative research relating to luminescence dating techniques.

Dr K.E. FITZSIMMONS, 12th International Conference on Luminescence and Electron Spin Resonance Dating, Beijing, China, September 2008, presented a paper entitled "Reconstructing Australian palaeoenvironments from lake records: evidence from Lake George, southeastern Australia."

Dr K.E. FITZSIMMONS, Australasian Quaternary Conference, Victor Harbour, Australia, December 2008, presented a paper entitled "Late Quaternary landscape change at Lake George, New South Wales."

Dr K.E. FITZSIMMONS, K.E., Australian and New Zealand Geomorphology Group 2008 Conference, Queenstown, Australia, February 2008, presented a paper entitled "The late Quaternary palaeoenvironmental history of Lake George, New South Wales".

Dr K.E. FITZSIMMONS, K.E., ANU Archaeological Science Conference, Canberra, Australia, February 2008, presented a paper entitled "Dating the landscape: the timing of sediment deposition using optically stimulated luminescence".

Dr M.K. GAGAN, Goldschmidt 2008 Conference, Vancouver, Canada, 13-18 July, presented an invited keynote paper entitled "The Indian Ocean Dipole and great earthquake cycle: long-term perspectives for improved prediction".

Prof. R. GRÜN, as direct successor of Professors Martin Aitken and Ann Wintle, became the Chairman of the standing International Organising Committee for the International Conferences on Luminescence and Electron Spin Resonance Dating.

Prof. R. GRÜN was invited to present The challenge of dating old human fossils at the Colloque international: Les premières expansions humaines en Eurasie à partir de l'Afrique Facteurs limitant ou favorisant. Muséum National d'Histoire Naturelle, Paris 26-28 November 2008. He presented a talk entitled The relevance of parametric U-uptake models in ESR age calculations at the 12th International Conference on Luminescence and Electron Spin Resonance Dating. 18-22 September 2008, Beijing, China.

Miss T.E. KELLY, ANU Archaeological Science Conference, 4 - 6 February 2008, Canberra, ACT, AUS. Presented a paper titled "Sr Isotope Tracing at a Neanderthal Site in Southern France".

Miss T.E. KELLY, 6th Applications of Stable Isotopes to Ecological Studies Conference (IsoEcol VI), Honolulu, Hawaii, USA. 25-29 August. Presented a paper titled "Strontium Isotope Tracing at a Neanderthal Site in France".

Miss T.E. KELLY, Old Forests, New Management Conference, Hobart, Tas, AUS. 17-21 February, was co-author (3rd) on a poster titled "Beetle assemblages in streamside reserves are edge-affected compared to unlogged forest".

Ms S.C. LEWIS, Goldschmidt 2008, Vancouver, Canada, 13-18 July, presented a paper entitled "Speleothem reconstructions of palaeomonsoon dynamics from Flores, Indonesia over the last 24 kyr".

Ian MOFFAT made the following conference presentation Moffat, I., Wallis, L.A., Chang, N. and Beale, A., 2008, The Geophysical Detection of Historic Graves, The Australian National University Archaeological Science Conference, Canberra, Australia.

Prof. M.T. McCULLOCH, gave a plenary talk at the 11th International Coral reef Symposium: Reefs for the future. Miami, Florida in July 2008.

Prof. M.T. McCULLOCH, presented a paper at the 2008 Goldschmidt Conference, Vancouver on sea level changes.

Prof. M.T. McCULLOCH presented a talk entitled "Current state and future of the oceans and marine life in a high CO2 world." Presented at 'IMAGINING THE REAL LIFE ON A GREENHOUSE EARTH', a conference organised by Manning Clark House in honour of Dr Barry Jones.

Prof. M.T. McCULLOCH, presented a paper at the 4th International Deep Sea Coral Conference entitled 'Proliferation and Demise of Deep-Sea Corals in the Mediterranean during the Younger Dryas'.

Prof. M.T. McCULLOCH was a co-author on 8 other presentations given at the 4th International Deep Sea Coral Conference.

Mr I. MOFFAT presented the conference posters Moffat, I., Wallis, L.A., Chang, N., Beale, A., Hall, S., Holt, L., Schuman, D., Snowdowne, L. and Snowdowne, J., 2008, The Role of Geophysical Techniques in Community Archaeology: Examples from Historic Cemeteries, AIMA/ASHA/AAMH Conference, Adelaide, South Australia

Mr I. MOFFAT presented the conference posters Keys, B., Wallis, L.A. and Moffat, I., 2008, Archaeological dating and the role of sedimentary analysis in exploring human-environment relationships at Gledswood 1, Queensland, AINSE Quaternary Dating Workshop, Sydney, New South Wales.

Mr I. MOFFAT presented the conference posters Moffat, I., Grün, R., Kelly, T.E., Fitzsimmons, K. and McMillan, R., 2008, Preliminary Findings on the Depositional History of the Lake Mungo Lunette, AINSE Quaternary Dating Workshop, Sydney, New South Wales.

Dr B. OPDYKE attended The International Coral Reef Society Meeting in Fort Lauderdale July 2008

Dr B. OPDYKE attended The Geological Society of America Meeting in Huston Texas, October 2008

Prof B.J. PILLANS conducted fieldwork in the Pilbara region, Western Australia from 5-19 May and in Brazil from 6-17 October 2008.

Prof B.J. PILLANS presented two papers at the 13th Australian & New Zealand Geomorphology Group Conference in Queenstown, Tasmania, 10th-15th February. Oral presentation: "Long term landscape evolution of the Western Australian Shield". Poster Presentation: "Joe Jennings: Father of modern Australian geomorphology".

Prof B.J. PILLANS gave an invited paper entitled"Challenges in Late Cenozoic chronostratigraphy and definition of the Quaternary" at the 33rd International Geological Congressin Oslo, 6th-14th August.

Prof B.J. PILLANS gave a keynote talk entitled "Geochronology of regolith-landform evolution in Australia: a brief review" at the Australian Earth Science Convention in Perth, 20th-24th July.

Prof B.J. PILLANS gave a plenary talk entitled: "Quaternary adventures in Zealandia: from Wanganui to the West Island" at the Geosciences'08 Conference in Wellington, New Zealand, 23rd-26th November.

Ms J. SUTTON, M. Wille, M. Ellwood, W. Maher, M. Kelly, S. Eggins. 2008. Germanium/Silicon and Silicon Isotope Fractionation in Sponges: Implications for Paleo-Reconstruction of Oceanic Silicon. Chemistry and the Biosphere conference, Dunnedin, New Zealand.

Dr P. TREBLE, attended an ARCNESS funded workshop "An integrated data modeling approach to the Australasian Holocene" at the University of New South Wales from 12-13 November.

Dr P. TREBLE conducted field work in southwest Western Australia from 5-12 April; 14-30 September.

Dr J. TROTTER, Goldschmidt conference, Vancouver, Canada, July 2008. Poster presentation, Trotter et al., "In-situ conodont thermometry: did cooler oceans trigger the Great Ordovician Biodiversification Event (GOBE)?"

Dr J. TROTTER, International Deep Sea Coral conference, Wellington, New Zealand, December 2008. Joint author, Montagna et al., "Growth rate, trace elements, and stable isotopes in Corallium rubrum from shallow and bathyal settings in the Mediterranean Sea".

Dr J. TROTTER participated in field work in the Great Barrier Reef in October and December 2008.

Earth Materials

Dr M.-A. BONNARDOT went to the Australian Earth Sciences Convention in Perth, July 2008.

Dr A. G. CHRISTY, Dr M.D. Norman and Prof R.J. Arculus were co-authors on the paper "A new variety of eucrite: clues to early differentiation of igneous asteroids." presented by former Honours Student Ms. K. R. Bermingham at the 39th Lunar and Planetary Science Conference, League City, Texas, USA, 10-14 Mar, 2008.

Dr A. G. CHRISTY and Prof D.J. Ellis were co-authors on the paper "The petrology of eclogiteS From the Bantimala Complex, Southern Sulawesi" presented by M.Phil student Mr A. Maulana at the 37th Annual Convention, Indonesian Association of Geologists, Bandung, Indonesia, 26-30 Aug, 2008.

Prof S.F. COX presented an invited lecture and a volunteered lecture at the Fall meeting of the American Geophysical Union, San Francisco, in December, together with a presentation at the Hubble Quorum at the US Geological Survey immediately prior to AGU. He also gave an invited plenary keynote lecture at the AusIMM PACRIM 2008 meeting at the Gold Coast in November.

Mr R.J.M. FARLA, 32nd Annual Condensed Matter and Materials Meeting, Wagga Wagga, Australia, presented a paper on "Dislocation Annealing in Fine-Grained Synthetic Olivine."

Mr R.J.M. FARLA, 2008 Australian Earth Sciences Convention (AESC), Perth, Australia, presented a poster on "From Dislocation Recovery to Dislocation Damping in Upper Mantle Materials."

Mr R.J.M. FARLA, 1st The Asian Network for Deep Earth Mineralogy (TANDEM) Symposium, Matsuyama, Japan, presented an updated poster on "Prospects for Laboratory Studies of Dislocation Damping."

Dr F. E JENNER, with Dr P. Holden, Dr J.A. Mavrogenes, Prof H.St.C. O'Neill and Dr C.M. Allen: AGU 2008 Fall Meeting, presented a poster entitled "Geochemical Behavior of Selenium in Igneous Systems".

DR F.E. JENNER, with Dr J.A. Mavrogenes, Prof R.J. Arculus: AGU 2008 Fall Meeting, presented a poster entitled "Magnetite fractionation of "chalcophile" elements."

DR F.E. JENNER, with Dr L.I. Karrei, Dr J.E. Mungall, Prof R.J. Arculus, and Dr J.A. Mavrogenes AGU 2008 Fall Meeting, presented a poster entitled "High-Ca Boninites From the Northern Tonga Region: Involvement of Four Independent Components During Petrogenesis, and Retention of Monosulfide Solid Solution in the Source".

Dr J.D. FITZ GERALD attended the 20th Australian Conference on Microscopy & Microanalysis in Perth 10-15 February to present a paper "Paleaoclimatology, Microanalysis and Microscopy of the Foraminifera Orbulina universa" and two coauthored posters "Dislocation Annealing in Fine-Grained Synthetic Olivine" and "Structured Diffuse Scattering and Polar Nano Regions in BaTiO3-based Relaxor Ferrolelectrics".

Dr A. HALFPENNY, ARC Centre of Excellence in Ore Deposits, Sciences Planning Meeting, CODES, Hobart, Tasmania, Australia, 2-5 June, presented a talk entitled "Effects of stress states and fluid pressure on fluid dynamics and compositional evolution of intrusion-related hydrothermal systems."

Dr A. HALFPENNY conducted field work in the Porgera Gold Mine, Papua New Guinea from 11-28 April; 16 September – 5 October and 26 October – 8 November.

Dr J. HERMANN, Australian Earth Science Convention, Perth, Australia, 20-24 July, presented a paper "Experimental constraints on the slab component of arc magmas".

Dr J. HERMANN, Experimental Mineralogy, Petrology and Geochemistry, Innsbruck, Austria, 7-10 September, presented a keynote lecture "Cooking the subduction soup".

Dr J. HERMANN attended the AESC pre-conference fieldtrip to the Pilbara region (Australia) from 13.-20.7. 2008.

Dr J. HERMANN conducted fieldwork in Corsica (France) from 14-20 September and in Liguria (Italy) on 21 September.

Dr J. HERMANN presented a seminar at the University of Lausanne, Switzerland, on the 30th September 2008.

Prof I. JACKSON attended and presented papers at the 32st Condensed Matter and Materials Meeting (Wagga Wagga, NSW, February), the Misasa III Symposium (Okayama University, Misasa, Japan, March, invited), the Australian Earth Sciences Convention, Perth, July), the Rheology Grand Challenge Workshop (MIT, Boston, August, invited), the Gordon Research Conference on Rock Deformation (Tilton, New Hampshire, August) and participated in a scientific workshop at Ehime University, Matsuyama, Japan (March) and in collegial discussions with Prof R. C. Liebermann and colleagues at Stony Brook University, Stony Brook, New York (August).

Dr G.S. LISTER attended the Donald Harrington Symposium on the Geology of the Aegean. Jackson School Geosciences, Austin Texas. U.S.A. The accretionary model for orogenesis and its application to the evolution of the Aegean crust, and – invited lecture.

Dr G.S. LISTER attended Tectonic mode switches and the nature of orogenesis. Invited Lecture, Athens University, June 18th, 2008.

Dr G.S. LISTER, Tectonic mode switches and the nature of orogenesis. Ophiolites 2008, Kalambaka, Greece 13-20 September – invited lecture.

Dr G.S. LISTER, Argon enters the retentive zone. At the 5th TANG3O workshop meeting at University of Queensland.

Mr G. MALLMANN, 1st Global COE symposium: Formation of The Asian Network in Deep Earth Mineralogy (TANDEM), Matsuyama, Japan, 23-25 November, presented a paper entitled "Determining the redox states of basalts and picrites using V/Sc olivine-melt partitioning: Experimental calibration and application to natural systems".

Mr G. MALLMANN visited the Argonne Photon Source in Chicago, USA, 13-15 February 2008, to work on the oxidation state of vanadium in silicate glasses.

Prof H.St.C. O'NEILL attended the 18th Goldschmidt conference in Vancouver, Canada, where he presented papers on "Clarification of the influence of water on mantle wedge melting" and "Collisional erosion and the non-chondritic composition of the Earth". He conducted experiments using synchrotron X-rays at the Advanced Photon Source, Chicago, in February, the Diamond Light Source, U.K., in August and the Photon Factory, Japan, in October.

Mr C. PIRARD, Eurispet Canberra 2008, Canberra, Australia, 31 January – 9 February presented a poster entitled "Time and chemicals evidenceS For suprasubduction dykes in Massif du sud, New Caledonia".

Mr C. PIRARD, Eurispet Budapest 2008, Budapest, Hungary, 21-31 August 2008 presented a poster entitled "Records of metasomatic events in the obducted lithospheric mantle of New Caledonia".

Mr C. PIRARD, Experimental Mineralogy Petrology Geochemistry (EMPG XII), Innsbruck, Austria, 8-10 September 2008 presented a talk entitled "Experimental investigation of fluid transfer in sub-arc mantle conditions".

Dr R. RAPP, 9th International Kimberlite Conference, Frankfurt, Germany, 9-15th August, presented a paper entitled "Continent formation and chemical evolution of the cratonic lithosphere".

Earth Physics

Dr P. ARROUCAU, 2008 Western Pacific Geophysics Meeting, Cairns, Australia, 9 July-1 August, presented a paper entitled "High Resolution Ambient Noise Tomography in Southeast Australia".

Dr G.F. DAVIES, Australian Earth Science Convention, Perth, 20-24 July 2008, presented the invited paper "The early mantle: depletion, plates, resurfacing episodes and isotopes".

Prof. R. W. GRIFFITHS, the American Physical Society – Division of Fluid Dynamics, San Antonio, USA, presented a paper on "Responses to changed boundary conditions in horizontal convection".

Prof. R. W. GRIFFITHS, attended the International Congress of the Union of Theoretical and Applied Mathematics, Adelaide, 25-29 August 2008.

Prof. R. W. GRIFFITHS, presented a paper "Effects of topography on mixing in controlled exchange flows"; Sandström Symposium on Ocean Circulation workshop, Stockholm, 3 November 2008.

Dr A.McC. HOGG, Australian Meteorological and Oceanographic Society 15th Annual Conference, Geelong, 29 January – 1 February 2008.

Dr A.McC. HOGG presented a paper "Enhanced warming of the Southern Ocean". European Geophysical Union General Assembly, Vienna, 14-18 April 2008.

Dr A.McC. HOGG presented a solicited paper "The Turbulent Oscillator: A mechanism of low-frequency variability of the wind-driven ocean gyres", and a paper "Eddy Heat Flux in the Southern Ocean: Response to variable wind forcing". International Congress of the Union of Theoretical and Applied Mathematics, Adelaide, 25-29 August 2008.

Dr A.McC. HOGG presented a paper "The large-scale effect of mesoscale ocean-atmosphere coupling". Sandström Symposium on Ocean Circulation workshop, Stockholm, 3 November 2008.

Dr G.O. HUGHES, the International Congress of the Union of Theoretical and Applied Mathematics, Adelaide, 25-29 August 2008.

Dr G.O. HUGHES presented a paper "Adjustment processes in horizontal convection"; Sandström Symposium on Ocean Circulation workshop, Stockholm, 3 November 2008, presented a paper "Available potential energy and irreversible mixing in the meridional overturning circulation".

Prof. B.L.N. KENNETT made a short visit to Europe in February for a Ph.D. examination in Utrecht and collaborative work in Munich.

Prof. B.L.N. KENNETT attended the Goldschmidt Conference in Vancouver with a presentation on mantle mixing scales. He then attended the Australian Earth Sciences Convention on Perth where he delivered a keynote address on the structure of the Australian lithosphere.

Prof. B.L.N. KENNETT In September visited Ehime University in Japan and gave a set of lectures and two seminars, he then engaged in collaborative work at the Earthquake Research Institute, University of Tokyo where he also presented a seminar.

Prof. B.L.N. KENNETT in late October went with an ANU delegation to Peking University and the Chinese Academy of Sciences in Beijing presenting two seminars.

Prof. B.L.N. KENNETT attended the European Geosciences Union meeting in Vienna in April, where he received the Gutenberg Medal in Seismology.

Prof. B.L.N. KENNETT also attended the Fall Meeting of the American Geophysical Union.

Dr R.C. KERR, the International Congress of the Union of Theoretical and Applied Mathematics, Adelaide, 25-29 August 2008, presented a paper "The effect of diffusion on the stability of strongly tilted mantle plume tails".

Ms M.J. O'BYRNE, the International Congress of the Union of Theoretical and Applied Mathematics, Adelaide, 25-29 August 2008, presented a paper "Effects of upstream disturbances in a model of headland wakes".

Dr S.H. POZGAY, American Geophysical Union, December 2008, presented a paper entitled "Seismic Investigations of Lithospheric Transitions between the Northern and Southern Australian Cratons (BILBY)". American Geophysical Union, December 2008, presented a paper entitled "Detection of Multiply Reflected Core Phases at Broadband and Short Period Arrays in Australia".

Dr S.H. POZGAY conducted field work in north Sumatra, Indonesia in April-May 2008, Central Australia in Aug-Sept 2008 and Nov 2008 and in southern New South Wales in Oct 2008.

Dr. N. RAWLINSON spent three months at Bristol University in the United Kingdom, where he collaborated with members of the seismology group on ambient noise and teleseismic tomography. He gave talks at Bristol University and the University of Leeds during his stay.

Dr. N. RAWLINSON presented a paper "Exploring deep Australia using active and passive seismic arrays" at Seismix 2008, June 2008, Saariselka, Finland and presented a paper "WOMBAT: An evolving seismic array experiment in Australia" at Australian Earth Sciences Convention, July 2008, Perth, Australia.

Dr M.L. RODERICK, American Geophysical Union Western Pacific Geophysics Meeting, Cairns, 29 July-1 August.

Dr M.L. RODERICK co-authored a paper entitled "Parameterizing evaporative demand in the Palmer Drought Severity Index across Australia".

Dr M.L. RODERICK attended American Geophysical Union Chapman Conference on Water Vapour and Climate Change, Kona, Hawaii, 20-24 October, presented a paper entitled "Evaporative demand and water resources under a changing climate"

Dr M.L. RODERICK attended American Geophysical Union Fall Conference, San Francisco, USA, 15-19 December, presented a paper entitled "Stilling and terrestrial hydrologic cycle". American Geophysical Union Fall Conference, San Francisco, USA, 15-19 December, co-organized and convened a session entitled "Evaporation and Water Transport Dynamics in the Atmospheric Boundary Layer".

Dr M. SALMON Thrust belt Formation followed by Back-Arc Extension: Mantle Dynamics from central North Island , New Zealand, Eos Trans. AGU, 89(53), Fall Meet. Suppl., Abstract T13D-1986.

Prof. M. SAMBRIDGE, attended the CIG workshop on Mathematical and Computational Issues in the Solid Earth Geosciences, Santa Fe, New Mexico, USA, between 15-17th September 2008.

Prof. M. SAMBRIDGE visited and gave seminars at Univ. of Edinburgh, Univ. of Strasbourg, Univ. of Rennes, ETH Zurich, Colorado School of Mines.

Mr K. STEWART, the International Congress of the Union of Theoretical and Applied Mathematics, Adelaide, 25-29 August 2008.

Dr H. TKALCIC, co-chaired the session "The crustal and deep earth structures under Asia and Oceania" for the AOGS Annual Meeting 2008 in Busan, South Korea.

Dr H. TKALCIC also co-chaired the session "Ins and Outs of the Earth's core" at The American Geophysical Union Fall Meeting 2008 in San Francisco, USA, and participated in eight presentations.

Dr H. TKALCIC was sponsored by The University of Zagreb, Croatia to work at the Department of Geophysics in Zagreb for two weeks (May) on the lithospheric structure under Croatia and the Adriatic Sea.

Dr H. TKALCIC conducted field-work in Central Australia (BILBY seismic deployment installation) for two weeks in September.

Dr. P. TREGONING attended the Western Pacific Geophysics Meeting where he presented two papers: "Present-day crustal deformation in Papua New Guinea", "Drought detection in the Murray-Darling basin from space gravity and hydrologic observations" and a poster "Detecting Hydrological Loading Effect variations from GRACE/GPS over the Amazon basin".

Dr. J. ZHANG conducted GPS field work from 21 May to 1 July 2008 in PNG .

Dr. J. ZHANG presented a poster in the Ocean Surface Topograpy Science Team (OSTST) meeting held on 10-15 Nov. 2008 in Nice, France, in the name of "Bass Straite In-Situ Calibration Site: Trials of the French Transportable Satellite Laser Ranging System".

Integrated Ocean Drilling Program (IODP)

Dr Neville Exon organized and chaired a session at the Australian Earth Science Convention in Perth in July entitled "The Geology of Australia's Offshore Areas", and presented three papers there, two related to IODP.

PRISE

Dr R.A. ARMSTRONG, Archaeological Science Conference to launch the Masters in Archaeological Science degree, Canberra, 4-6 February, presented a talk with L. Shewan (University of Sydney) on "Assessment of human mobility in Cambodia".

Dr R.A. ARMSTRONG, 6th South American Symposium on Isotope Geology, Bariloche, Argentina, 13-17 April.

Dr R.A. ARMSTRONG, Australian Earth Science Convention 2008, Perth, 20-24 July, presented a talk on "In situ measurement of sulphur isotope ratios: New developments and results using the SHRIMP".

Mr C.M. FANNING, Scientific Committee on Antarctic Research / International Arctic Science Committee International Polar Year Open Science Conference, St Petersburg, Russia, 8-11 July, presented a paper entitled "Isotopic constraints on the provenance of Patagonian and Antarctica Peninsula turbidites; implications for plate reconstructions".

Mr C.M. FANNING, The 2008 SHRIMP Workshop, St Petersburg, Russia, 29 June – 4 July.

Mr C.M. FANNING, VI South American Symposium of Isotope Geology, San Carlos de Bariloche, Argentina, 13-17 April, presented an invited keynote talk entitled "An overview of current and new research dealing with micro-chronology (U-Pb ion microprobe) and micro-isotope geochemistry (Lu-Hf and Oxygen isotope studies)" and co-authored a number of other presentations.

Mr C.M. FANNING, Australian Earth Sciences Conference, Perth, 20-24 August, presented a paper entitled "Age constraints on the Sturtian Glaciation in Adelaide Geoscyncline, South Australia and the Pocatelo Formation of Idaho, USA indicate that there was no single Sturtian Snowball".

Mr C.M. FANNING, Selwyn Symposium 2008, Melbourne, 25 September, presented an invited paper entitled "Age constraints for the Sturtian Glaciation; data from the Adelaide Geoscyncline, South Australia and Pocatello Formation, Idaho, USA".

Mr C.M. FANNING conducted fieldwork in the Sierras Pampeanas, Argentina, 24 April to 2 May, in Mendoza Province, Argentina, 15-20 November and in Tierra del Fuego, Chile, 27 November – 8 December.

Mr S. Hui, 39th Lunar and Planetary Science Conference, Houston, Texas, 10-14 March co-authored a poster "Petrography and Chemistry of Cosmic Spherules from the Lewis Cliff, Antarctica" (presented by Dr M.D. Norman).

Mr S. Hui, Australian Earth Sciences Convention, Perth, Australia, 20-24 July, co-authored a poster entitled "Petrography and Chemistry of Cosmic Spherules from the Lewis Cliff, Antarctica" (presented by Dr M.D. Norman).

Mr S. Hui, 8th Australian Space Science Conference, Canberra, Australia, 29 September – 1 October, presented a talk entitled "Geochemistry and analysis of Apollo 16 lunar impact glasses: Preliminary Results".

Ms. E.S. Kiseeva, EurISPet (European Intensive Seminars of Petrology) in Canberra (Australia), 31 January – 9 February.

Ms. E.S. Kiseeva, 9th International Kimberlite Conference, Frankfurt, Germany, 10-15 August, presented a poster entitled "The role of carbonated eclogite in kimberlite and carbonatite petrogenesis".

Dr M.D. NORMAN, Goldschmidt Conference, Vancouver, Canada 13-18 July, presented a paper entitled "Age and origin of Apollo 16 feldspathic fragmental breccias".

Dr M.D. NORMAN, Australian Earth Science Convention, Perth, Australia, 21 – 25 July, presented two papers entitled "New perspectives on the lunar cataclysm from crater density populations" and "A new type of basaltic eucrite: clues to early differentiation of igneous asteroids".

Dr M.D. NORMAN, 39th Lunar and Planetary Science Conference, Houston, USA, 5-9 December, presented an invited paper entitled "The lunar cataclysm: status and prospects".

A. Rosenthal, Goldschmidt Conference 2008, Vancouver, Canada, 13-18 July, (as part of Mervyn and Katalin Paterson Fellowship), gave an oral presentation entitled "Melting of residual eclogites with variable proportions of quartz/coesite" and co-authored a second oral presentation entitled "Clarification of the influence of water on mantle wedge melting".

A. Rosenthal, 9th International Kimberlite Conference, Frankfurt am Main, Germany, 10-15 August, (as part of Mervyn and Katalin Paterson Fellowship), presented two posters entitled "New insights into the genesis of peridotite-pyroxenite layers: Western Gneiss Region, Norway" and "Origin of kamafugite magmas in the East African Rift of western Uganda" and co-authored an oral presentation entitled "Experimental melting of peridotites in the presence of CO2 and H2O at 40-60kbar".

A. Rosenthal, Marie Curie EURISPET Seminar on “Isotopes Applied to Petrological Problems”, Canberra, Australia, 31 January - 9 February, presented a talk and a poster.

A. Rosenthal, Marie Curie EURISPET Seminar on “Petrology of the lithosphere in extensional settings”, Budapest, Hungary, 21 - 31 August, presented a talk and a poster.

Dr G. Yaxley, 9th International Kimberlite Conference, Frankfurt, Germany, 10-15 August, presented a paper entitled “Ni in garnet thermometry - a new experimental calibration at 3.0 – 4.5 GPa of Ni-Mg exchange between garnet and olivine at upper mantle pressures”.

Visitors

Dr C.E. BARTON, Earth and Space Science Informatics Summit, Vila Celimontana, Rome, Italy, 13-15 March, chaired the Summit, presented a paper "Outcomes of the Electronic Geophysical Year, 2007-2008"

Dr C.E. BARTON, Japan Geoscience Union meeting, Chiba City, 25-30 May, presented a paper entitled: "International eGY Activities".

Dr C.E. BARTON, co-convened Union Session "Earth and Space Science Informatics Developments for the 21st Century" and co-authored paper about the Electronic Geophysical Year, Western Pacific Geophysics Meeting, Cairns, 29 July-1 August.

Dr C.E. BARTON, 21st CODATA International Conference and General Assembly, Kiev, Ukraine, 5-10 October, presented a paper entitled "eGY-Africa: reducing the digital divide for science in Africa".

Dr C.E. BARTON, International Symposium "Fifty Years after IGY - Modern Information Technologies and Earth Sciences", Tsukuba, Japan, 10-13 November, presented a paper entitled "Data practices, policy, and rewards in the information era demand a new paradigm".

Dr C.E. BARTON visited the Laboratory for Atmospheric and Space Physics, Univ. Colorado, Boulder, USA 1-9 March for collaborative work and to run the 2008 eGY General Meeting.

Dr R. BARWICK accompanied a large international field expedition to Gogo in the Kimberley of Western Australia.

Dr Ray Binns PACRIM-2008 Conference, Gold Coast, Queensland, presented a paper entitled "The PACMANUS seafloor sulfide field, eastern Manus Basin, Papua New Guinea". He co-authored a paper delivered at the 33rd International Geological Congress, Norway, 20008 with C.J. Yeats and J.M. Parr "The SuSu Knolls hydrothermal field, Eastern Manus Basin, Papua New Guinea: An actively forming submarine high sulfidation copper-gold system".

BURNE, R.V., and CHAPPLE, R. - 2008: Under the Boardwalk - Tourism's encounters with Stromatolites. Addressing the issues of Stromatolite protection and visitor management. IN Dowling, R and Newsome, D., editors) Discover the Earth Beneath Our Feet - Proceedings of the Inaugural Global Geotourism Conference, 17 - 20 August 2008, Fremantle, Western Australia. Pages 107 - 112.

BURNE, R.V. and PAUL, J. - 2008: Hamelin Pool Western Australia - A Modern Analogue for Kalkowsky's "Oolith und Stromatolith" Association. IN Reitner, J., Quéric, N.-V., and Reich, M. (editors) Geobiology of Stromatolites - Proceedings of the International Kalkowsky Symposium, 4 - 11 October 2008, Göttingen, Universitätsverlag Göttingen. Pages 56 - 58.

IZUNO, G., BURNE, R.V. and BATCHELOR, M.T.: 2008 - The Distribution and Morphological Variability of Hamelin Pool Stromatolites, Shark Bay, Western Australia - New Light on a Fifty-Year Old Riddle. IN Reitner, J., Quéric, N.-V., and Reich, M. (editors) Geobiology of Stromatolites - Proceedings of the International Kalkowsky Symposium, 4 - 11 October 2008, Göttingen, Universitätsverlag Göttingen. Pages 82 - 83.

Dr D.R. Christie attended the Infrasound Technology Workshop, Bermuda, 3-7 November and presented a paper entitled "Wind noise reduction at IMS Infrasound stations".

Dr K. A. W. CROOK has attended The Australian Quaternary Association's 4th Quaternary Dating Workshop at the Australian Nuclear Science and Technology Organisation's complex at Lucas Heights, (26-27 March).

Dr K. A. W. CROOK has attended The Manning Clark House conference "Imagining the Real: Life on a Greenhouse Earth" at ANU (11-12 June).

Dr K. A. W. CROOK has attended The "Infinite Horizons Symposium" at the The Academy of Science Shine Dome, Gordon Street, Canberra, on 20 June, as part of Prof. J. M. A Chappel's retirement events. [Dr Crook was geological co-supervisor of John Chappell's PhD research at ANU.]

Dr K. A. W. CROOK has attended The NSW Government's Marine Habitat Mapping Information Session at Batemans Bay and contributed to discussion on the relevance of Laser Airbourne Depth-Sounder data to marine habitat mapping (20 November).

Dr W. COMPSTON addressed the Fourth SHRIMP WORKSHOP in St. Petersburg, Russia, June 30-July 5 2008.

Dr E. A. Felton attended The Australian Quaternary Association's 4th Quaternary Dating Workshop at the Australian Nuclear Science and Technology Organisation at Lucas Heights, Sydney (26-27 March)

Dr E. A. Felton attended The Infinite Horizons Symposium at the Academy of Science Shine Dome, Canberra, on 20 June in honour of Prof. J. M. A. Chappell.

Dr E. A. Felton attended The NSW Government's Marine Habitat Mapping Information Session at Batemans Bay on 20 November, flagging the suitability of the Habitat Mapping program for EMS-RSES student projects.

C. Jones attended the 12th International Symposium on Microbial Ecology, in Cairns, Australia, August 17 - 23, presented a poster entitled "Lipid Preservation In Modern Iron Oxide Deposits & Implications For The Search For Life On Mars", co-authors (in order): Claudia Jones, Marco Blothe, Eric Roden, Jill Banfield, Jochen Brocks

C. Jones attended the 15th Australian Organic Geochemistry Conference, Adelaide, Australia, September 8-12, presented a poster entitled "The preservation of microbial lipids in modern acid-saline precipitated ferricretes: implications for the search for life on Mars", co-authors (in order): Claudia Jones, Jill Banfield, Jochen Brocks

Dr C. KLOOTWIJK, 18th Australian Earth Science Convention, Perth, 20-24 July, presented a paper entitled "Tectonic extrusion of the Thomson Orogen: Australia-Asia equivalent of India-Asia deformation".

Dr C. KLOOTWIJK conducted field work in the Eastern Lachlan Orogen, NSW, from 16-24 April, visited the palaeomagnetic laboratory of Utrecht University, the Netherlands, from 22-24 October and presented a paper entitled "tectonic extrusion of the Thomson Orogen: Australia-Asia equivalent of India-Asia deformation".

Prof K. LAMBECK, Seminar at INGV, Rome, Italy, 15 January, entitled "Ice sheets and sea level during the last glacial cycle: inversion of geological data for the past 150,000 years".

Prof K. LAMBECK, VECTOR Project Seminar at La Sapienza University, Rome, Italy, 18 January, entitled "Relative Sea Level change in Italy during the Holocene".

Prof K. LAMBECK, Seminar at Lund University, Lund, Sweden, 22 January, entitled "Sea level and ice sheets during the last glacial cycle: 150,000 years BP to present".

Prof K. LAMBECK, Archaeological Science Conference to launch the Masters in Archaeological Science Degree, ANU, 4-6 February, presented a paper entitled "Patterns of sea level change".

Prof K. LAMBECK, Infinite Horizons: A one day symposium to mark the retirement of John Chappell, Canberra, 20 June, presented a paper entitled "Global Sea Level".

Prof K. LAMBECK, Sea-level Workshop 'Empirical constraints on sea-level rise over the next century', Bern, Switzerland, 25-29 August, presented a paper entitled "Sea level change and ice volumes about the time of the Last Interglacial (MIS-6 to MIS-5)".

Prof K. LAMBECK, The Geological Society William Smith 2008 Meeting 'Observations and Causes of Sea-Level Changes on Millennial to Decadal Timescales', London, UK, 1-2 September, presented a keynote address entitled "Sea levels and ice sheets during the last glacial cycle: new results from glacial rebound modelling".

Prof K. LAMBECK, Karthaus 2008: Glaciers and Ice Sheets in the Climate System, Karthaus, Italy, 10-17 September, presented lectures entitled "Introduction to geodynamics", "Interaction between ice sheets and the solid earth", and "What can we learn from glacial rebound?".

Prof K. LAMBECK, Sea Level Symposium, Tokyo University, Japan, 3 October, presented a keynote address entitled "Sea level and ice volumes during the glacial cycle from MIS-6 to present".

Prof K. LAMBECK, 'Academy, Research Institution And National Innovation System' Symposium, Chinese Academy of Sciences, Beijing, China, 12-14 November, presented a paper entitled "Role of the Australian Academy of Science in development of a national innovation policy".

Prof K. LAMBECK, Academy Presidents' Forum, Taipei, Taiwan, 6-7 December, presented a paper entitled "National Science Academies As One Driver In Knowledge-Based Development".

Dr W. MAYER, 33rd International Geological Congress, Oslo, Norway, 6-14 August, presented a paper entitled "The geological work of the Baudin expedition in Australia in 1801-1803: Discoveries, Personalities and Legacy".

Dr W. Mayer, conducted research in the Archives de la Gironde, Bordeaux and at the National Museum of Natural History, in Paris, June/July.

Dr. Robert S. Nicoll presented papers at the Australian Earth Sciences Convention 2008 (Perth) on "The Cambro-Ordovician, the Centralian Superbasin (Part 2) and trans Gondwanan Seaways" and "The Permian Conodont biostratigraphy of Western Australia - an update"

Dr Robert S. Nicoll conducted field work in the Canning Basin of Western Australia from 19-28 July, 2008

EMERITUS PROFESSOR M S PATERSON took part in a workshop on ultra-high pressure deformation at Massachusetts Institute of Technology, Cambridge, Mass., and attended a Gordon Research Conference on rock deformation at Tilton, New Hampshire in August, 2008.

Dr I.C. Roach conducted field work at the Beverley-Four Mile U deposits, Lake Frome Embayment, South Australia, 16-22 March and at the Fifield Pt-Au placer deposits in central western NSW, 22-24 August.

Prof R.W.R. RUTLAND, 13th International Symposium on Deep Seismic Profiling of the Continents and their Margins, Saariselka, Finland, 8-13 June, presented a paper entitled "Geological significance of the regional change in reflectivity between Upper and Middle Crust in the Svecofennian Province."(co-authors Kousa, J., Sorjonenen-Ward, P., Williams, I.S.)

Prof R.W.R. RUTLAND, 33rd International Geological Conference, Oslo, Norway, 10-14 August.

Scott KM, Radford NW and Hough RM (2008). Rutile compositions in the Golden Mile, Kalgoorlie, Western Australia, and their implications for Exploration. Abstracts GAC-MAC-SEG-SGA conference Quebec 2008. pp.155-156.

Shiga Y, Greene R, Scott K and Stelcer E (2008). Aeolian dust: its potential role as a carrier of terrestrial salt in Australia. Abstracts 4th Australian New Zealand Aerosol Seminar, Lucas Heights, 16-18 July 2008. p.5.

Scott KM (2008). So you want to write a book, eh? Presentation at the launch of the book Regolith Science at Geoscience Australia, 7th November 2008.

Prof. S. R. TAYLOR was invited to attend the attended the Annual Lunar and Planetary Science Conference in Huston, USA, and the forty anniversary of the Lunar and Planetary Institute were he was the first Visiting Scientist in 1969.

EDITORIAL RESPONSIBILITIES

Earth Chemistry

Dr Y. AMELIN is Associate Editor, Geochimica et Cosmochimica Acta.

Dr Y. AMELIN is a member of the editorial board, Chemical Geology.

Dr J.J. BROCKS, Associate Editor, PALAIOS, a Journal of the Society of Sedimentary Geology.

Dr J.J. BROCKS, Editor, Chemical Geology.

Dr M. Forster routinely reviewed manuscripts for Journal of Geophysical Research (Solid Earth) and Lithos.

Dr. M. Honda, Associate Editor, Geochemical Journal.

Prof T.R. IRELAND is an Associate Editor of Geochimica et Cosmochimica Acta.

Dr D. RUBATTO, Associated Editor, Lithos.

Dr D. RUBATTO, Editorial Board, Chemical Geology

Dr D. RUBATTO, Editorial Review Board, Journal of Metamorphic Geology.

Earth Environment

Prof. P. DE DECKKER is on the editorial board of Journal of Paleolimnology, Palaeogeography-Palaeoclimatology-Palaeoecology, and Journal of Marine Micropaleontology

Dr S. EGGINS, Editorial Board, Quaternary Geochronology.

Dr K.E. Fitzsimmons, Editor, Quaternary Australasia.

Prof. R. GRÜN is the Editor-in-Chief of Quaternary Geochronology, associate editor of the Journal of Archaeological and Anthropological Sciences and member of the Editorial Boards of Quaternary Science Reviews and Radiation Measurements.

Mr I. MOFFAT, Associate Editor, Exploration Geophysics.

Dr B. OPDYKE, Editor, Geology

Prof. B.J. PILLANS, Editorial Board, Quaternary Science Reviews.

Dr G. YOUNG, Editorial Board, Alcheringa; Guest editor, Palaeoworld (IGCP 491 special issue).

Earth Materials

Dr A.G. CHRISTY, Editorial Board, Mineralogical Magazine.

Dr A.G. CHRISTY, Editorial Board, Central European Journal of Geosciences.

Prof S.F. COX continued as a member of the Editorial Advisory Boards of Journal of Structural Geology and Geofluids.

Dr J.D. FITZ GERALD, Editorial Board, Physics and Chemistry of Minerals.

Dr J. HERMANN, Associate Editor, LITHOS.

Prof I. JACKSON, Member Editorial Board, Physics of the Earth and Planetary Interiors, Earth and Planetary Science Letters.

Prof G. LISTER, Associate Editor, Journal of Geophysical Research, American Geophysical Union.

Prof H. St.C. O'NEILL, Editorial Board, Chemical Geology; Editorial Board, Elements; and Editorial Board, eEarth.

Dr D.C. "BEAR" McPHAIL, Guest Editor, Chemical Geology, for Geofluids IV, April 2009.

Dr U. TROITZSCH, Reviewer, Journal of the American Ceramic Society.

Earth Physics

Prof. R.W. GRIFFITHS, Associate Editor, Journal of Fluid Mechanics

Prof. R.W. GRIFFITHS, member of the Editorial Committee for the Annual Review of Fluid Mechanics.

Prof. B.L.N. KENNETT, Member of Advisory Editorial board for Physics of the Earth and Planetary Interiors and Earth and Planetary Science Letters.

Dr S.H. Pozgay, Associate Editor for special issue entitled "The Izu-Bonin-Mariana Subduction System: A Comprehensive Overview" in Geochemistry Geophysics Geosystems

Dr P. TREGONING is an Associate Editor of the Journal of Geophysical Research – Solid Earth.

Integrated Ocean Drilling Program (IODP)

NEVILLE EXON, Editorial Board, Australian Journal of Earth Sciences.

PRISE

Dr R.A. ARMSTRONG, Editorial Board, Journal of African Earth Sciences.

Dr M.D. NORMAN, Editorial Board, Australian Journal of Earth Sciences and Open Mineralogy Journal.

Dr G. Yaxley coordinated production of a special issue of the Journal of Petrology to honour the career of Prof David Green.

Visitors

Dr R. V. BURNE has acted as a reviewer of articles for GEOLOGY

Dr D.R. Christie, Editorial Board, InfraMatics

Dr K. A. W. CROOK, Editor Emeritus, SEDIMENTARY GEOLOGY.

Dr K. A. W. CROOK, Reviewer, for JOURNAL OF SEDIMENTARY RESEARCH, of two related papers on the Kamouraska Formation, Cambro-Ordovician, Quebec Appalachians.

Dr E. A. Felton serves on the Editorial Board, Marine Geology.

Dr E. A. Felton reviewed several papers on aspects of rocky shoreline geology and tsunami research for the journals Geomorphology, Sedimentary Geology and Geology.

KEITH SCOTT invited to joint the Editorial Board for 2012 International Geological Congress (Brisbane).

OUTREACH AND WORKSHOPS

Earth Chemistry

Dr Y. AMELIN translated from Russian into English the preface by Victor Safronov (one of the founders of modern planetary physics) on Minoru Ozima's book "The History of the Earth". The material will be published in Eos.

Dr V.C. BENNETT presented a lecture on "Introduction to Radiogenic Isotope Tracers" at the EURISPET School, Canberra, 1-10 February.

Dr J.J. BROCKS was interviewed by Nature and several journalists about his publication "Reassessing the first appearance of eukaryotes and cyanobacteria".

Dr. S.J. Fallon hosted two students from the CSIRO Student Research Scheme.

Dr M. Forster visited Assoc Prof David Phillips at the University of Melbourne, Argon Laboratory, 27 March.

Dr M. Forster visited Dr Fred Jourdan at the Western Australian Argon Isotope Facility, Curtin University, 23 July.

Dr M. Forster attended the TANG3O workshop and meeting at University Queensland on 27-28 November.

Ms C. GREGORY participated in "Rock your World" at Questacon, presented by the Research School of Earth Sciences, 7 June, Canberra.

Dr D. RUBATTO organised the EURISPET international postgraduate school, Canberra, 1-9 February 2008, an event within the EURISPET Marie Curie Conferences and Training Courses.

Dr D. RUBATTO organised an outreach day at Questacon under the theme "Rock your World" on June 7 2008.

Dr I.S. WILLIAMS hosted a visit to the SHRIMP laboratory by students attending the National Youth Science Forum, 3 and 17 January.

Dr I.S. WILLIAMS hosted a visit to the SHRIMP laboratory by students and teachers from Radford College, 7 April.

Dr I.S. WILLIAMS joined many other staff and students from RSES as an explainer at Earth Science Day at Questacon, 7 June.

Dr I.S. WILLIAMS was a member of the organising committee for EURISPET08, held at RSES, 1 - 8 February. He presented a lecture entitled "An introduction to U-Pb geochronology (from a SHRIMPers point of view)" and was one of the guides for the 2-day geological field trip.

Dr I.S. WILLIAMS attended the 2008 SHRIMP Workshop, St Petersburg, Russia, 29 June - 4 July. He presented a paper entitled " Measuring SHRIMP U-Pb ages of Palaeozoic zircons: Can we do better?".

Dr I.S. WILLIAMS attended the Workshop on Data Handling in LA U-Th-Pb Geochronology, Vancouver, Canada, 12 - 13 July.

Earth Environment

Prof. P. DE DECKKER was a keynote speaker at an EGU session in Vienna on "Aeolian dust", and also on "Deep-sea canyons to the evolution of the Lacepede Shelf" at the Australasian Quaternary Association at Victor Harbour, SA.

Dr A. DUTTON, Pages Workshop on Empirical constraints on sea-level rise over the next century, Bern, Switzerland, 25-29 August, presented an invited paper entitled, Sea level reconstructions from submerged speleothems of Argentarola Cave, Italy."

Dr A. DUTTON participated in the "Rock Your World" day at Questacon and gave two lectures on climate change to Questacon visitors.

Dr S. EGGINS participated in the "Ocean Acidification: Australian Impacts in the Global Context" workshop in Hobart, June 2008, hosted by the ACE CRC.

Dr M.J. ELLWOOD was interviewed on radio about the growth of sponges in the deep ocean. Approximately 3 minute interview with Leigh Hatcher, ABC Radio Canberra, broadcast at 4.30 pm 26 July.

Dr K.E. FITZSIMMONS was guest lecturer at Aberystwyth University, UK, and Scottish Universities Environmental Research Centre, UK.

Dr K.E. FITZSIMMONS is a regular contributor on the Fuzzy Logic Popular Science radio show, 2XX FM.

Dr M.K. GAGAN was interviewed in July by Eric Hand of Nature magazine (Coral isotopes show quake history, v. 454, p. 378, 2008) regarding the use of carbon isotopes in corals to reconstruct submarine earthquake recurrence intervals.

Dr M.K. GAGAN was interviewed in November for television, radio, newspaper, and web-site postings regarding a publication in Nature Geoscience (v. 1: 849-853, 2008) entitled Recent intensification of tropical climate variability in the Indian Ocean.

Miss T.E. KELLY had her research reported in ScienceWise, the ANU College of Science magazine, in an article titled "How Wombats are Getting Their Teeth into the Climate Change Debate: the climate history of Willandra Lakes" (also available online at http://sciencewise.anu.edu.au/articles/wombats)

Prof M.T. McCULLOCH gave a presentation on 'Response of coral reefs to rapidly increasing ocean acidification' at the workshop on 'Ocean Acidification: Australian Impacts in the Global Context' sponsored by the Department of Climate Change in Hobart Tasmania in June 2008.

Prof. M.T. McCULLOCH was interviewed on ABC radio Brisbane regarding Ocean acidification, September 2008.

Prof. M.T. McCULLOCH was interviewed by ABC radio Adelaide regarding his plenary presentation at the at the 11th International Coral reef Symposium in Florida.

Prof. M.T. McCULLOCH presented a talk entitled "Coral Reefs Acid Trip" at the ARC Centre of Excellence Coral Reef Studies Public Symposium, Canberra, Academy of Science, October.

Prof. M.T. McCULLOCH presented a talk entitled "Coral Reefs in a High CO2 World"at the Botanic Gardens, Canberra in November.

Prof. M.T. McCULLOCH gave a presentation entitled 'Coral reefs and Global Change: an Australian Perspective' to the Department of the Environment and Heritage in Canberra in November 2008.

Mr I. MOFFAT contributed to a newspaper article discussing research, Bone hunters search for Meadows' secrets, The Courier, 03/10/08

Mr I. MOFFAT contributed to a newsletter article discussing research, Inland Northwest Queensland Archaeological Excavation, Southern Gulf links, October 2008.

Mr I. MOFFAT presented to the Meadows Primary School, South Australia about the application of geophysical to locating historic graves 28/11/08

Mr I. MOFFAT was interviewed by Radio 99.3 FM:

A Modern Australian Explorer, Sydney, 05/10/08

The Use of Geophysics for Historical Graves, Sydney, 22/10/08.

Mr I. MOFFAT contributed to a newsletter article discussing research, History and Archaeology: Working as One, Looking East: Newsletter of the City of Norwood Payneham and St Peters, 2008.

Mr I. MOFFAT contributed to a magazine article discussing research, Aboriginals and academics bury bones of contention, New Scientist, 9/9/08.

Mr I. MOFFAT made a television appearance using geophysical techniques to locate clandestine burials, Missing Persons Unit, Channel Nine, 29/5/08

Mr I. MOFFAT contributed to a magazine article discussing research, How wombats are getting their teeth into the climate change debate: The climate history of the Willandra Lakes, Science Wise Magazine, Vol. 5, Num 2, March/April 2008.

Mr I. MOFFAT contributed to a newsletter article discussing research, The Search for Casurina's Lost Anchor, The Link: DEH Volunteer News, Issue 14, 11/01/08

Mr I. MOFFAT gave a lecture in the Department of Archaeology Public Lecture Series, Flinders University, 2008, MOFFAT, I., Wallis, L.A., Chang, N. and Beale, A., "Locating Historic Graves with Geophysical Techniques".

Mr I. MOFFAT was a co-presenter to the Forensic Science Society of South Australia, 2008, Wallis, L.A. and Moffat, I., "Understanding the interplay between archaeology, geophysics and forensics: Case studies including the Woolgar Aboriginal Massacre, the Maesbury Street Cemetery, Sellheim Cemetery and Ngarrindjeri burials".

Dr B. OPDYKE does regular interviews on community radio, focussed on Climate Change issues.

Dr B. OPDYKE gave regular Climate Change talk to Melrose HS Students, in 2008 Dr B. OPDYKE gave a Climate Change talk to Public School Science Teachers as well as helped with a special Science teachers field trip showing the Geology around Canberra.

Ms J SUTTON participated in the "Rock Your World" day at Questacon.

Dr P. TREBLE was interviewed for The West Australian newspaper for the article "Drying caves studied for climate change link" which appeared 14/7/2008, for ECOS magazine "Caves provide new clues to Australian climate" on 28/10/08. Dr Treble was also interviewed for Bush Telegraph "Stalagmites and rainfall" on ABC Radio National on 1/2/2008. Her research also featured in The Sydney Morning Herald "Stalagmites' nuclear touch a record of climate change" 23/1/08.

Dr J. TROTTER participated in the "Ocean Acidification: Australian Impacts in the Global Context" workshop in Hobart, June 2008, hosted by the ACE CRC.

Dr J. TROTTER was interviewed by international and local media about her recent publication in "Science", covering Ordovician palaeoseawater temperatures and links with major marine biodiversification events. Media coverage included ABC radio, Deutschlandfunk, National Geographic, The Australian, The Advertiser, Geonieuws (Dutch Geological Assoc.), ScienceNetwork WA, Forskning (Norwegian research and science portal), Science Education News, and Sea Technology.

Dr J. TROTTER participated in the ARC Major Grants Announcements Expo at Parliament House, October 2008, highlighting the success of Discovery Project Proposal DP0986505 "Ocean Acidification in a Rapidly Increasing CO2 World" submitted by Prof. M McCulloch, Dr J Trotter, and Prof. R Dunbar.

Dr G. YOUNG conducted daily geology walks for members of the public during the ANU Open Week at Kioloa Field Station in January, demonstrating the Permian geology and palaeontology at Merry Beach. He also gave an evening public lecture on 'Ancient fossil fish from Australia'. He was interviewed on ABC 666 on 29 May about the Nature paper reporting the oldest evidence of vertebrate live birth; this received wide media attention across the world. An article on the significance of fossil fish collections at ANU was published in The Canberra Times (July 13, 2008).

Earth Materials

Dr A.G. CHRISTY assisted Prof D.J. ELLIS and Dr S.G. BEAVIS in delivering presentations at ANU to approximately 70 High School StudentS From the NSW South Coast, July 2008.

Prof S.F. COX presented a 3 day structural geology training workshop for Barrick Gold Ltd geoscientists and undergraduates of the University of Papua New Guinea during a research field visit to the Porgera gold mine (PNG) in October.

Dr J. HERMANN presented a talk at the Earth Science Day at Questacon (7 June) on "How to make Diamonds".

Dr J. HERMANN coordinated two visits of students participating at the National Youth Science Forum at RSES.

Prof G. LISTER was interviewed on television about the Sichuan Earthquake, China.

Dr D.C. "BEAR" McPHAIL gave an interview with Serena Locke of Radio 666, Canberra (13 October, 2008) on groundwater in the Lower Murrumbidgee Catchment, the subject of a new ARC Linkage Grant starting in 2009.

Dr D.C. "BEAR" McPHAIL provided independent expert commentary on the environmental impacts of potential uranium mining and transport of copper and uranium ore near Alice Springs, NT for the Alice Springs News, November-December 2008.

Dr D.C. "BEAR" McPHAIL represented RSES and the ANU on the Minerals Tertiary Education Council (MTEC), which is education and training body of the Minerals Council of Australia (MCA).

Dr D.C. “BEAR” McPHAIL represented RSES and the ANU on the Central Coast and Western NSW branch committee of the Australian Institute of Minerals and Metallurgy (AusIMM).

Dr D.C. “BEAR” McPHAIL represented RSES and the ANU for the Anglo American Scholarship in Applied Geochemistry (3rd- and 4th-year undergraduate scholarship).

Dr D.C. “BEAR” McPHAIL hosted a visiting group of students from the University of the 3rd age for a tour of Earth and Marine Science displays and facilities (4 April, 2008).

Dr D.C. “BEAR” McPHAIL gave a lecture on acid mine drainage to a group of school students as part of the Australian School Innovation in Science, Technology and Mathematics (ASISTM) outreach program coordinated by David Ellis and Sara Beavis (28 July 2008).

Dr D. MICKLETHWAITE participated in the QUESTACON public outreach event.

Dr U. TROITZSCH coordinated ANU Open Day activities for the Earth and Marine Sciences Education Program.

Earth Physics

Prof. B.L.N. KENNETT gave a number of radio interviews on issues related to earthquakes and tsunamis.

Dr R.C. KERR and Mr J. ROBERTSON gave presentations on earth science to students at Aranda Primary School, Orana Primary School, and the Australian Science Festival.

Several members of the GFD Group introduced Year 11 students at the ANU Secondary College to the variety of research undertaken in the Geophysical Fluid Dynamics Laboratory.

Dr. N. RAWLINSON ran a four week course in seismology (EMSC8002) as part of the RSES Earth Physics Masters course.

Dr M.L. RODERICK presented an address entitled “The surface water balance: how is it panning out?” at the Annual General Meeting of the Geological Society of Australia (Canberra Branch), 15 April.

Dr M.L. RODERICK presented a public lecture titled “Climate Change and Water: Getting the Big Picture Right” at the National Science Festival, 21 August.

Dr M.L. RODERICK is the nominated “Scientist-in-Schools” representative at Radford College and ran a 1 day workshop on “Climate change and water” for the science teaching staff on 30 June.

Dr M. SALMON and Dr P. ARROUCAU were part of the organisation committee for the RSES Questacon earth science day. They helped plan and implement the seismology component. 7 June.

Dr H. TKALCIC gave two invited talks; at the University of Zagreb, Croatia and the University of Belgrade, Serbia, entitled: “Modern global seismology and things that Jules Verne didn’t know on his journey to the centre of the earth”.

Dr P. TREGONING was invited to give a presentation at the Australia-China Remote Sensing Symposium at the Australian Academy of Science in November 2008. He also attended the AuScope Workshop in October 2008

PRISE

Dr R.A. ARMSTRONG was invited to participate in a Field Workshop on the Limpopo Belt – International Field Laboratory, in the Limpopo Province, South Africa from 13 – 19 July.

Mr S. Hui was a demonstrator at the Questacon "Rock Your World" Day 7th June 2008.

Ms E.S. Kiseeva gave a talk at the A. P. Karpinsky Russian Geological Research Institute during her visit in Saint-Petersburg in July, 2008.

Dr M.D. NORMAN was interviewed by ABC regional radio stations about planetary science activities at the July 2008 Australian Earth Science Convention, Perth.

A. Rosenthal wrote a 'Student Profile' for CoS international postgraduate prospectus, published in the ANU College of Science prospectus 2009: "Anja". Science Graduate Prospectus, ANU, College of Science, p. 46. This is a printed publication aimed at recruiting international and interstate postgraduate students at ANU.

A. Rosenthal participated in an ANU Workshop in Science Communication.

Dr G. Yaxley was invited to participate as a lecturer in the EurISPet Workshop held in Budapest in August.

Dr G. Yaxley presented a seminar at GEMOC, Macquarie University in May, entitled "Melting of heterogeneous upper mantle – implications for magma genesis".

Visitors

Dr R. V. BURNE gave a presentation on the history and significance of microbialites in the Yalgorup Lakes to the Lake Preston Progress Association in August.

Dr E. A. Felton serves on the Executive Board of the Sapphire Coast Marine Discovery Centre, Eden NSW.

Prof K. LAMBECK, unveiled the plaque commemorating the 50th Anniversary of the active period of the "Old Magnetic Hut", Palaeomagnetism 1958 revisited, ANU, Geological Society of Australia, 22 October 2008.

Prof K. LAMBECK, as President of the Academy of Science, has provided a number of interviews on radio and print during 2008. This included an opinion piece "Innovate today, not tomorrow" presented on ABC Radio National show, Ockham's Razor, broadcast at 8:45 am 30 November 2008.

Prof K. LAMBECK as President of the Australian Academy of Science, participated in several Conferences and Symposia including the Enhancing the quality of the experience of postdocs and early career researchers Workshop, 14-15 February 2008, Australian Frontiers of Science, 21-22 February 2008, Sir Mark Oliphant Conference: "Vaccine and Immunotherapy Technologies", 9-11 April 2008, Science and Technology in Society Forum, Kyoto, Japan, 5-7 October 2008, High Flyers Think Tank on Preventative Health, Sydney, 6 November 2008, and the Australia-China Remote Sensing Symposium, 24-25 November 2008.

Dr D.L. STRUSZ and Dr D.M. FINLAYSON were interviewed by Craig Allen for the ABC TV Stateline program on the geology of the Canberra area, in conjunction with publication of a book on the subject.

Dr E.M.TRUSWELL, with Dr P. DE DECKKER, presented a talk on August 16th at a forum on Lake George during Science Week. A CD entitled "Lake George - Weereewa: the Ancient Story" has been made available to the public.

TEACHING ACTIVITIES

Earth Chemistry

Dr J.J. BROCKS taught 'Early evolution of life on Earth (and other planets?)' in Geol3022 Planetary Science.

Dr J.J. BROCKS taught the 'Carbon Cycle' as part of the 'Global Cycles' course EMSC3027.

Dr M. Forster taught the Honours course "Reading Rocks".

Prof T.R. IRELAND convened and taught the Planetary Geology course (EMSC 3022), and participated in a course on the Nuclear Cycle (PHYS 8205) and the Field Geology Course (EMSC 1007).

Dr D. RUBATTO coordinated and taught (60%) "Chemistry of Earth and Oceans", a 2nd year undergraduate course (GEOL2015).

Dr D. RUBATTO taught "U-Pb dating of high-grade metamorphism" at the EURISPET international postgraduate school, Canberra, 1-9 February 2008.

Dr I.S. WILLIAMS ran an intensive hands-on training course in SHRIMP analysis procedures for new SHRIMP users at Australian Scientific Instruments, 24 September - 17 October.

Earth Environment

Prof. P. DE DECKKER taught 2nd year Marine Palaeontology and Evolution of Life and shared the teaching of the 3rd year course Environmental and Regolith Geoscience, together with Prof. B. Pillans.

Prof. P. DE DECKKER taught one week in the 1st year course The Blue Planet.

Prof. P. DE DECKKER taught the 3rd year course on Carbonate Reef Field Studies in New Caledonia. Several staff form the IRD [Institut de Recherche pour Le Dévelopement] in Nouméa participated in the teaching activities and staff helped ferry students to the island which the students mapped as part of their work. The course commenced in 2007 and continued into 2008.

Dr A. DUTTON taught a 2-week section of the Surficial Processes course (EMSC 2014).

Dr A. DUTTON participated as a field instructor for one day of the field mapping course near Wee Jasper.

Dr A. DUTTON taught a component of Introduction to Earth Science in the Field (EMSC 1007) which included 6-days on site at the Kioloa campus.

Dr S. EGGINS taught a third year course Special Topics (EMSC 3050).

Dr S. EGGINS with Dr M. ELLWOOD (40:60) taught the third year course Marine Biogeochemistry (EMSC 3023).

Dr S. EGGINS taught a week long unit on marine chemistry and a related fieldwork component in the 1st year course Blue Planet (EMSC 1006).

Dr M.J. ELLWOOD coordinated and taught the third year course Marine Biogeochemistry (EMSC 3023).

Dr M.J. ELLWOOD taught the third year course Special Topics (EMSC 3050).

Dr M.J. ELLWOOD taught the second year course Chemistry of the Earth and Oceans (EMSC 2015).

Dr K.E. FITZSIMMONS gave a guest lecture and laboratory tour for the ANU Centre for Archaeological Research workshop for Honours and Masters students.

Dr M.K. GAGAN taught a section on stable isotope geochemistry for the Earth and Marine Science course Chemistry of the Earth and Oceans (EMSC2015, second semester)

Dr M.K. GAGAN served as external supervisor (2006-2008) for Ms E. St Pierre, ARC Postgraduate Research Scholar with Dr J.-x. Zhao and Assoc. Prof. S. Golding at the University of Queensland, and for Mr M. Griffiths, ARC Postgraduate Research Scholar with Dr R. Drysdale at the University of Newcastle.

Prof. R. GRÜN taught a 6 unit course Scientific dating techniques and isotope analysis for archaeology and palaeoanthropology (BIAN 3010/6510) at the Dept. of Archaeology and Anthropology, ANU.

Miss T.E. KELLY taught as a lab and field demonstrator in SRES1004, Australia's Environment.

Ian MOFFAT was the principal lecturer for the subject “Introduction to Archaeological Geophysics”, Department of Archaeology, Flinders University.

Ian MOFFAT was a sessional lecturer in “Indigenous Archaeology Field School”, “Archaeological Field Methods Field School” and “Archaeological Field Methods”, Department of Archaeology, Flinders University.

Dr B. OPDYKE has taught the following course units:

EMSC1006 The Blue Planet including Course Coordinator 2 hour Lectures (given), attended 15 Lectures, planned and ran a 2 day field trip, tutored 5 practicals (each repeated 4 times) and helped mark them, marked field reports, helped mark the exams, 6 one hour tutorials, 126 Students

EMSC2014 Surficial Processes including 30 lectures, 9 (2 hour) practicals, 2 day field trip.

EMSC2012 Introduction to Structural and Field Geology including 6 full days in the field.

EMSC3027 Global Cycles including Course Coordinator, attended all 39 lectures, 18 students.

EMSC3019 Coral Reefs including 7 Days in the field, 3 full days travel.

Prof. B. PILLANS gave 12 lectures and co-convened EMSC3026 “Environmental and regolith geoscience” (third year undergraduate course, second semester)

Dr G. YOUNG taught the vertebrate palaeontology part of the ‘Marine Palaeontology and Evolution’ course (EMSC 2019).

Dr G. YOUNG had one student (D. Evans) on a special topic project during first semester (GEOL 3050).

Earth Materials

Dr A.G. CHRISTY co-convened (with Prof D.J. Ellis), demonstrated all practicals and delivered some lectures in EMSC 2017 Mineralogy, first semester, 2008.

Dr A.G. CHRISTY demonstrated all practicals and delivered some lectures in EMSC 2020 Lithosphere, second semester, 2008.

Dr A.G. CHRISTY delivered lectures and practicals in the Master of Nuclear Science course PHYS 8205 The Nuclear Fuel Cycle, August 2008.

Dr A.G. CHRISTY taught for the first week of the field course EMSC 1007 Introduction to Earth Sciences in the Field, November 2008.

Prof S.F. COX taught EMSC2012 Introduction to Structural and Field Geology, EMSC3002 Structural Geology and Tectonics, and portions of EMSC1007 as part of the RSES Earth and Marine Science Education program.

Dr J. HERMANN was convener of the course “Magmatism and Metamorphism” (EMSC 3024) and taught 15 hours of lectures, 36 hours of practicum and one day of excursion.

Dr J. HERMANN taught one hour at the course “Chemistry of Earth and Oceans” (EMSC 2019).

Dr J. HERMANN taught one day at the course “Introduction to Earth Science in the field” (EMSC 1007).

Prof I. JACKSON coordinated and co-taught PHYS3070 Physics of the Earth (with Drs. H. TKALCIC and P. TREGONING) and PEAT8011 Introduction to Earth Materials (with Prof H.St.C O'NEILL and Dr J.D. FITZ GERALD).

Prof G. LISTER taught third year Geology Field Camp (GEOL 3001).

Dr D.C. 'BEAR' McPHAIL coordinated and delivered the 3rd-year course EMSC3025 Groundwater, co-coordinated and taught 6 weeks of the 2nd-year course CHEM2204 Environmental Chemistry, co-coordinated and delivered part of the MTEC Honours course Regolith Geoscience for Mineral Exploration.

Mr N.D. TABILY tutored in first year earth science and third year economic geology courses.

Dr U. TROITZSCH taught several lectures and practicals about X-ray Diffraction, X-ray Fluorescence, and Clay Mineralogy, as part of the undergraduate courses Mineralogy (EMSC2017) and Chemistry of the Earth and Oceans (EMSC2015).

Earth Physics

Dr P. ARROUCAU – Computer based practical course, Seismology (EMSC 8002).

Dr G.F. DAVIES taught the Physics of the Earth Honours and Masters course Plate Tectonics and Mantle Dynamics (EMSC8016).

Dr. G.F. DAVIES taught two weeks of Global Cycles and Paleoceanography (GEOL3027).

Dr A.McC. HOGG taught The Blue Planet (GEOL1006).

Dr A.McC. HOGG and Dr M. RODERICK taught Ocean and Atmosphere Modelling (EMSC3029).

Drs G.O. HUGHES, A.McC. HOGG and R.C. KERR, and Prof R.W. GRIFFITHS taught Physics of Fluid Flows (PHYS3034 and EMSC8004).

Prof. B.L.N. KENNETT – "Research Methods and Management", a component of the Masters Course in Physics of the Earth and a component of EMSc1007 "Earth Sciences in the Field".

Prof. B.L.N. KENNETT presented a set of lectures on "Imaging the Earth" as part of the Global Centre of Excellence in Deep Earth Studies at Ehime University, Japan – he was the first international lecturer in the new CoE.

Dr S.H. POZGAY taught laboratory practicals for Seismology (PEAT 8002). Dr S.H. POZGAY taught laboratory practicals for Physics of the Earth (PHYS 3070).

Dr. N. RAWLINSON ran a four week course in seismology (EMSC8002) as part of the RSES Earth Physics Masters course.

Dr M.L. RODERICK conducted lectures, for two weeks, on the hydrologic cycle as part of the third year course titled Global Cycles and Paleooceanography (EMSC3027).

Dr M.L. RODERICK conducted lectures, for two days, on surveying and mapping as part of the first year course titled Introduction to Earth Science in the Field (EMSC1007).

Dr M.L. RODERICK convenes the Bachelor of Global and Ocean Sciences (Hons) degree program.

Dr M. SALMON taught the earthquake magnitude lab class for Seismology masters course (EMSC8002).

Prof. M. SAMBRIDGE taught a graduate course geophysical inversion at California Institute of Technology, USA, during his sabbatical visit there.

Prof. M. SAMBRIDGE supervised the research project of Mr. Peter Crosthwaite as part of the Physics of the Earth Master's course.

Prof. M. SAMBRIDGE taught the pre-meeting short course on geophysical inversion at Colorado School of mines industry sponsors meeting in May 2008.

Prof. M. SAMBRIDGE gave a guest lecture in the 3rd year undergraduate course (PHYS3070) entitled 'Physics of the Earth'.

Dr H. TKALCIC taught an undergraduate course "Physics of the Earth" with Prof I. Jackson and Dr P. Tregoning (PHYS 3070), Faculty of Science (second semester).

Dr H. TKALCIC took a share in teaching a Masters course "Seismology" (PEAT 8002), Faculty of Science), with Dr. Rawlinson (first semester).

Dr P. TREGONING taught the Master's course EMSC8009 "Melting polar ice sheets, sea level rise and climate change" and also taught 1/3 of the course PHYS3070 "Physics of the Earth". He is the Masters Coordinator at RSES and was the sub-Coordinator of the Physics of the Earth Honours programme.

Visitors

Dr R. V. BURNE assisted Prof Richard Arculus voluntarily wth the teaching of Sedimentology to the 1st Year Field Geology Course (Geol 1007) at Kioloa. He was retained by the Fenner School as a Casual Academic to assist with the teaching of (GEOL 1006) "The Blue Planet", and also gave a lecture in the first year Geography Course at ADFA.

Dr R. V. BURNE is a PhD adviser to Richard Schinteie who is undertaking research supervised by Dr Jochen Brocks in RSES. He acted as an examiner of Nathan Pittman's Honours Thesis.

Dr K. A. W. CROOK provided Prof B. Pillans with laboratory teaching materials for the regolith component of EMSC3026, Environmental & Regolith Geoscience, together with teaching assistance during two field-trips.

Dr K. A. W. CROOK led the Eden on-land component of the two-day EMSC1006 (Blue Planet) Field-trip to the NSW Far South Coast (ca. 120 students; 6-7 Sept. 2008), Dr B. Opdyke (EMS-RSES) having had to limit his leadership to the marine-based component, because of an injury.

R.A. Eggleton: One week contribution to Geology 3026 and 2 lectures in Regolith Geoscience and Mineral Exploration Short Course.

R.A. Eggleton Some advice to Honours and Graduate Students

Dr E. A. Felton assisted in field teaching for the regolith component of EMSC3026, Environmental and Regolith Geoscience.

Dr E. A. Felton assisted with teaching during the 2-day field trip for EMSC 1006 (Blue Planet) at Eden, NSW (120 students) and made arrangements for the students' use of laboratories at Eden Marine High School.

Dr K.G. McQueen helped present the MTEC Regolith Geoscience for Mineral Exploration Honours shortcourse at the ANU from the 14-17th April 2008. He also taught part of the Environmental and Regolith Geoscience undergraduate course in second semester.

KEITH SCOTT taught the Gossan Geochemistry component of "Regolith Geoscience and Mineral Exploration" in the Earth Sciences Honours course (April 2008).

HONOURS AND MASTERS SUPERVISION

Earth Chemistry

Dr J.J. BROCKS supervised the Honours project of Ms A. Green, The Evolution of Sterol Biomarkers in the Proterozoic.

Dr J.J. BROCKS co-supervised the Honours project of Mr C. Munday, Characterising the Microflora of Aeolian Dust and its Sources in Australia.

Dr J.J. BROCKS co-supervised the honours project of Ms M. Bausch (Marum, University of Bremen), Molecular Signatures of Biological Soil Crusts and Salt Lakes of South Australia.

Dr M. Forster supervised two honours projects: Ms C. Firth on the character of the greenschist overprint on the HP rocks on Ios Greece, and of Ms Jia-Urnn Lee on the microstructural character of shear zones within the Lesser Himalaya, NW India.

Mr R. Schinteie assisted in the laboratory supervision of honors student Ms A. Green.

Earth Environment

Prof. P. DE DECKKER supervised Mr G. Nash on 'Aspects of the late Quaternary evolution of the Lacepede Shelf in South Australia"

Prof. P. DE DECKKER co-supervised the thesis of Mr C. Munday from the School of Biochemistry and Molecular Biology on the microflora of aerosols from the Lake Gnarpurt region of Victoria.

Dr A. DUTTON is supervising the honours project of Ms C. Thompson on "Diagenesis in Eocene tropical planktonic foraminifera".

Ian MOFFAT is co-supervising the honors project of Mr. B Keys on "Geoarchaeology and Geochronology of the Gledswood One Rockshelter, North-west Queensland", Department of Archaeology, Flinders University.

Dr B. OPDYKE has one current Honours student

Prof. P. DE DECKKER is co-supervising Ms L. Bean's thesis on the fossil fish from Talbragar, NSW .

Prof. R. GRÜN supervised the Masters project of Ms W. Lees on Sr isotope tracing of human migration in Vanuatu.

Dr B. OPDYKE has one current Masters student

Dr GAVIN YOUNG supervised M.Sc student James Hunt and M.Phil student Greg Bell.

Dr D.C. "BEAR" McPHAIL supervised the three Honours projects of Mr J. McDonald on the Reactive Transport of Copper in Iron-Rich Regolith: Experiments and Modelling, Mr S. Biddlecombe on the Alteration Zoning at the Tusker Gold Deposit, Tanzania, and Ms L. Soroka on the Groundwater Geochemistry for Mineral Exploration in the Cobar Goldfields, NSW. He also co-supervised with Dr I. Roach (GA) the Honours project of Rhiannon Mann on the regolith characteristics and landscape evolution of the Tomingley Area, NSW.

Earth Materials

Dr A.G. CHRISTY and Prof D.J. ELLIS are supervising Mr A. Maulana in his M.Phil project on high-pressure rocks in subduction complexes of southwest Sulawesi, Indonesia

Dr M.-A. BONNARDOT supervised half-time the honours project of Mr T. O'Kane on the tectonic reconstruction of Papua New Guinea and full-time the intern Ms D. Tanner on relationship between transform/transfer faults and anorogenic alkaline trends in Namibia and Angola.

Dr J. HERMANN supervised two Honours projects of Ms. K. Boston on "P-T-t history of the, Sesia-Lanzo Zone, Western Alps" and Ms S. McAlpine on "An Investigation of the Contact metamorphic Overprint on Eclogite Facies Rocks, Sesia-Lanzo Zone, Western Alps".

Prof I. JACKSON supervised the M. Sc. project of Mr R. Chopping on modeling the seismic signature of altered rocks in crustal shear zones.

Prof G. LISTER supervised the honours project of Mr A. Barker on a the large-scale tectonics of the Aegean Sea, Greece; b) Mr T. O'Kane on a the large-scale tectonics of PNG; and c) Ms I. Stenhouse on Geospeedometry using the garnet-ilmenite system

Dr D.C. "BEAR" McPHAIL supervised the three Honours projects of Mr J. McDonald on the Reactive Transport of Copper in Iron-Rich Regolith: Experiments and Modelling, Mr S. Biddlecombe on the Alteration Zoning at the Tusker Gold Deposit, Tanzania, and Ms L. Soroka on the Groundwater Geochemistry for Mineral Exploration in the Cobar Goldfields, NSW. He also co-supervised with Dr I. Roach (GA) the Honours project of Rhiannon Mann on the regolith characteristics and landscape evolution of the Tomingley Area, NSW.

Earth Physics

Dr A.McC. HOGG supervised the Honours project of Mr D. Hutchinson on "Wind Stress Parameterisation in the Southern Ocean".

Dr G.F. DAVIES supervised the Masters project of Mr Chow Song Wei on "Thermal evolution of the Earth with plate bending".

Dr H. TKALCIC supervised the Honours project of Myall Hingee, on a development of a real-time system for source parameter determination in the Australian region.

Dr H. TKALCIC supervised the final project (Engineering Degree) of Edward Leask, on studying the source of the 2007 Shark Bay, WA earthquake.

Dr H. TKALCIC supervised the GEOL 3050 special topic research project of Steven Petkovski, on studying the lithospheric structure under The Republic of Macedonia using teleseismic receiver functions.

Dr H. TKALCIC supervised the Ph.B. project of Daniel Leykam, on studying the Earth's core using seismic data from Antarctica.

Visitors

Dr E. A. Felton served as examiner of the Honours thesis of Nathan Pittman, titled "Geomorphology of Bondi Lake, South Coast, NSW."

Dr C. KLOOTWIJK contributed to the honours project of Rhianon Mann on regolith characteristics of the Tomingly area, NSW, by arranging literature coursework on aeromagnetic interpretation of buried topography.

Dr I.C. Roach supervised Ms Rhiannon Mann on the distribution of palaeochannels and landscape evolution of the Wyoming gold deposits, central western NSW.

OTHER MATTERS

Earth Chemistry

Dr V.C. BENNETT was on the Program Committee of the 2008 Goldschmidt Conference and was the theme organizer for the Early Earth sessions.

Dr V.C. BENNETT is on the Board of Directors of the Geochemical Society.

Dr V.C. BENNETT, member ANU Major Equipment Committee.

Dr V.C. BENNETT served as a member of the Petrology and Geochemistry Panel of the US National Science Foundation.

Dr J.J. BROCKS, Member of the ANU College Advisory Board.

Dr J.J. BROCKS was selected for the ANU Earl Career Development Program.

Dr J.J. BROCKS, Member of The ANU Early Career Think Tank.

Dr J.J. BROCKS, Selection Committee for the Stanley Miller Award (given to young scientists working in the field of the Origin of Life).

Professor I.H. CAMPBELL, Secretary General of the Commission for the Evolution of the Solid Earth, a sub-commission of the International Mineralogical Association; and is co-leader of the Commission for Large Igneous Provinces (LIP).

Dr M. Forster is a member for the TANG3O group, a national group involved in noble gas geochronology.

Dr M. Forster is a member for the OHS committee, RSES.

Dr M. Forster is a member of Organizing Committee for 2010 Australian Earth Science Conference to be held in Canberra.

Dr D. RUBATTO, Treasurer, Association for Research between Italy and Australasia.

Mr R. Schinteie assisted visiting student Ms M.M. Pawlowska (Cambridge University, UK) settle into the biogeochemistry laboratories (Jaeger 1) and showed her how to use equipment and teach principles of organic geochemistry.

Earth Environment

Mr M. AUBERT was awarded a grant from the Social Sciences and Humanities Research Council of Canada (SSHRC): Rock-Art Science Task Group.

Prof. P. DE DECKKER is a member of the Australian IODP Council.

Dr A. DUTTON served as a member of the MARGO committee to promote Marine Geoscience in Australia.

Dr A. DUTTON is the treasurer for the Sedimentary Division of the Geological Society of Australia.

Dr A. Dutton is a member of the ANU Climate Initiative.

Dr M.K. GAGAN served as a member of the ANZIC Science Steering Committee for the Australian Integrated Ocean Drilling Program (IODP).

Dr M.K. GAGAN is a member of the Australasian INTIMATE Project (INTegration of Ice, MArine and TErrestrial records of the Last Glacial Maximum and Termination), which is a core program of the INQUA Palaeoclimate Commission.

Dr M.K. GAGAN is a corresponding member of the INQUA Palaeoclimate Commission (PALCOMM).

Miss T.E. KELLY, Committee Member, ANU Postgraduate Representative Council (PRC).

Miss T.E. KELLY, Representative for Research School of Earth Sciences, Postgraduate and Research Student Association.

Miss T.E. KELLY, Representative for PARSA, University Research Committee.

Miss T.E. KELLY, Representative for PARSA, College of Science HDR Committee.

Miss T.E. KELLY, Committee Member and Newsletter Editor, Canberra Archaeological Society.

Prof. M.T. McCULLOCH, is a counsel member of the Australian Coral Reef Society, and attended the meetings in 2008.

Prof. M.T. McCULLOCH, participated Centre of Excellence, Scientific Management Meeting, Miami Florida July 2008.

Prof. M.T. McCULLOCH, organised a coral reef session entitled Lessons from the Past at the 11th International Coral reef Symposium, Florida USA.

Prof. M.T. McCULLOCH, attended the Marine and Tropical Sciences Research Facility Workshop in Townsville, Queensland.

Dr B. OPDYKE is the Chair of the Australian Sedimentologists Specialists Group (subdivision of the Geological Society of Australia)

Dr B. OPDYKE served on the Geological Society of Australia's Executive council until July 2008.

Prof B.J. PILLANS, President, Stratigraphy & Chronology Commission, International Union for Quaternary Research.

Prof B.J. PILLANS, Vice President, Geological Society of Australia

Prof B.J. PILLANS, President, Australian & New Zealand Geomorphology Group

Prof B.J. PILLANS, Chair, Working Group on Lower/Middle Pleistocene Boundary, International Commission on Stratigraphy

Prof B.J. PILLANS, President, ACT Branch, Geological Society of Australia

Dr P. TREBLE began employment at the Australian Nuclear Science & Technology Organisation in July 2008. She remains a Visiting Fellow at RSES, ANU until July 2009.

Dr GAVIN YOUNG is a Titular Member of the International Union of Geosciences Subcommission on Devonian Stratigraphy, and co-leader (with Prof ZHU MIN, Beijing) of IGCP Project 491 ('Middle Palaeozoic Vertebrate Biogeography, Palaeogeography and Climate')

Earth Materials

Dr A.G. CHRISTY is Australian National Representative on the Commission for New Minerals and Mineral Classification of the International Mineralogical Association.

Dr A.G. CHRISTY is a member of the Pyrochlore Group Nomenclature subcommittee of the Commission for New Minerals and Mineral Classification.

Dr A.G. CHRISTY is co-ordinator for the Ph.B. program in the Earth Sciences disciplinary area, exclusive of Geophysics.

Prof I. JACKSON served as Executive Committee member and Vice-President, International Association for Seismology and Physics of the Earth's Interior, and as co-convenor of Symposium L1 Structure and dynamics of the lithosphere: observations, modelling and laboratory constraints, IASPEI General Assembly Capetown, South Africa 10-16 January 2009.

Prof H.St.C. O'NEILL serves on the Program Advisory Committee of the Bragg Institute, for the new OPAL Reactor at Lucas Heights, NSW.

Dr D.C. "BEAR" McPHAIL served on the Executive of the Cooperative Research Centre for Landscape Environments and Mineral Exploration, followed by serving as an alternate Board member representing ANU.

Earth Physics

Dr P. ARROUCAU collaborated with Telopea Park School (Barton, ACT) to develop "Sismos a l'Ecole", a project aimed at setting up a seismic station in a school as a springboard for educational and scientific activities dealing with earthquakes and natural hazard.

Prof. B.L.N. KENNETT, Chair, Geological Society of Australia Specialist Group in Solid Earth Geophysics to July 2008.

Prof B.L.N. KENNETT, Member National Committee for Earth Sciences and Chair of Working Party on National Geotransects.

Dr H. TKALCIC was responsible for the managing of the seismic and infrasonic facility in Warramunga, NT.

Dr H. TKALCIC, with Dr. C Tarlowski, Mr. A. Arcidiaco and Mr. J. Li organised an effort for the major seismic data reformatting, reorganisation and building the acquisition tools to access the RSES archive of seismic data.

Dr H. TKALCIC hosted a three month long visit by Professor Vernon Cormier from the United States, sponsored by the VC's Office.

Dr P. TREGONING was the Geodesy representative on the Program Committee of the Western Pacific Geophysics Meeting held in Cairns in August 2008.

PRISE

Dr R.A. ARMSTRONG acted as the external supervisor and advisor for 2 PhD and 2 MSc students from South Africa and assisted RSES PhD students with analytical procedures, laboratory practice and interpretation of data for their theses and publication.

Dr M.D. NORMAN, Steering Committee, Australian Space Science Decadal Plan and Chair, Planetary Science Working Group.

Dr M.D. NORMAN, National Executive Committee, Geological Society of Australia.

Dr M.D. NORMAN, Program Committee, Australian Earth Science Convention, Perth.

A. Rosenthal acted as RSES Student Facilitator and initiated the RSES mentoring network for new PhD students.

A. Rosenthal coordinated organization of the inaugural RSES Student Conference (April 30th, 2008), aimed at facilitating exchange of recent scientific research results and experiences, including an oral presentation.

A. Rosenthal coordinated organization of the presentations in honour of Professor David H. Green's '18th birthday' (February 29th, 2008), including an oral presentation.

A. Rosenthal gave an invited talk at Utrecht University, The Netherlands within a Solid Rock Seminar Series.

Visitors

Dr C.E. BARTON served as a member of the National Committee for Earth Sciences, Australian Academy of Science.

Dr C.E. BARTON served as a member of the National Committee for Space Science, Australian Academy of Science.

Dr C.E. BARTON served as a member of the Australian ad-hoc "CODATA" Committee for Scientific Data and Information.

Dr C.E. BARTON served as a member of the Working Committee, UN GAID - eSDDC program (UN Global Alliance for Enhancing Access to and Application of Scientific Data in Developing Countries)

Dr C.E. BARTON, International Chair, Electronic Geophysical Year, 2007-2008 (eGY).

Dr C.E. BARTON, Vice-chair, IUGG Union Commission for Data and Information.

Dr C.E. BARTON, Past-President, International Association of Geomagnetism and Aeronomy.

Dr C.E. BARTON, Chair, Organising Committee for the Geoinformatics Summit, Vila Celimontana, Rome.

Dr C.E. BARTON, Member, Organising Committee for IUGG 2011, Melbourne

Dr K. A. W. CROOK, a member of the ANU Emeritus Faculty [Lecturer/Snr Lecturer/ Reader, ANU Dept of Geology, May 1961 - June 1992; Departmental Visitor (from Uni. Hawaii) 2003/4; Visiting Fellow EMS from July 2004], has initiated (together with Emeritus Prof. John Molony, Nik Forminas and Peter Fuller) a review of the historical and other evidence for the hypothesis that extensive mapping of the eastern coastline of Australia was carried out by Europeans more than 200 years before James Cook's 1770 survey.

C. Jones assisted in the collection of two (2) drill cores from Lake Tyrrell, VIC, Australia in July 2008. Also present on the field trip were Dr. J. Brocks (RSES), Mr. P.S. Bray (PhD student, Macquarie University), Mr. Damien Kelleher (master driller) and Mr. Nigel Craddy (drilling assistant, RSES).

Prof K. LAMBECK, President, Australian Academy of Science.

Prof K. LAMBECK, President Elect, Federation of Asian Scientific Academies and Societies.

Professor I. McDougall was invited to attend a workshop held in Addis Ababa, Ethiopia, concerned with Scientific Drilling for Human Origins: Exploring the Application of Drill Core Records to Understanding Hominin Evolution, sponsored by the International Continental Scientific Program and the US National Science Foundation.

Dr K.G. McQueen presented an invited lecture to the Mineralogical Society of New South Wales on the 1st February 2008 entitled "The history of the Mount Boppy Gold Mine and some geological comments". He addressed the ACT Division of the Geological Society of Australia at their September meeting on "A redefinition of laterite - after a visit to the type locality in Kerala and other rambles in India".

Dr K.G. McQueen also gave an invited presentation entitled "A guide for exploring through the regolith" at the Exploration in the House seminar held at Parliament House in Sydney on the 2nd of July. On the 1st August he was invited to address the AusIMM Exploration Forum held in Orange on "Highlights for regolith research for mineral exploration in the Cobar region".

Dr Robert S. Nicoll is a corresponding member of the Ordovician, Permian and Triassic Subcommissions of the International Commission on Stratigraphy. Dr P. TREGONING, Vice President and Science Program Chair, IAG/IAPSO/IABO Joint Assembly 2005 Local Organising Committee.

KEITH SCOTT serves as a member of the International Mineralogical Association Committee on Nomenclature of the Alunite supergroup.

Dr D.L. STRUSZ is a Corresponding Member of the International Subcommission on Silurian Stratigraphy.

Dr E. M. TRUSWELL served on the Council of the National Youth Science Forum, representing the Australian Academy of Science. She also serves on the national committee for the International Geological Cooperation Program (UNESCO).