Research School Of Earth Sciences
Annual Report 2012

The 364m long ice core was drilled on the summit of James Ross Island by a team of 7 scientists and engineers.
Photo credit: Nerilie Abram.

Australian National University

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Director's Review of 2012: a Year of Change

After two-and-a-half years of distinguished service to the School as Director, Professor Andrew Roberts was appointed Dean of the ANU's College of Physical and Mathematical Sciences with effect from late August. Following an internal search, I was appointed Director, RSES from mid-October. On behalf of the School, I wish to thank Andrew Roberts for his considerable legacy including strong morale reflecting his consultative and supportive style of management, and his leadership in the important process of ongoing renewal involving the appointment of several mid-career researchers (Drs. Andrew Berry, Penny King, Simon McClusky and Jimin Yu) and the recruitment of ARC Laureate Fellow Professor Eelco Rohling due to join the School in March 2013. We also thank the long-serving School Manager Mike Avent who retired at the end of 2012, but not before receiving appropriate recognition through the Vice Chancellor's award for innovation in service delivery. Special thanks are also due to Dr. Vickie Bennett for so ably serving the School as Interim Director between August and October.

My appointment as Director is the culmination of a long association with earth sciences at ANU. With a newly-minted Physics honours degree from the University of Queensland, I arrived in Canberra in 1972 to start a PhD supervised by Bob Liebermann and Ted Ringwood in the then Department of Geophysics and Geochemistry of the Research School of Physical Sciences. During the first two years of my PhD project, I also enjoyed the opportunity to study geology for the first time – taking introductory geology, and mineralogy and petrology classes in the then Geology Department well-taught by David Brown, Ken Campbell, Bruce Chappell and Tony Eggleton, amongst others. So, I am a proud alumnus of both strands of the ANU earth science tradition which came together in 2008 to form the modern Research School of Earth Sciences (RSES). After a Postdoc at the California Institute of Technology, I returned to RSES as a Research Fellow and have enjoyed the privilege of pursuing a rewarding research career here in rock physics ever since.

Completion of the School's new building in late 2011 allowed co-location on the Jaeger site of all staff and PhD and Honours students, along with much of the undergraduate teaching activity – a significant step towards full realization of the merger of 2008. Some environmental geoscience laboratories remain for now in Building 47, pending their ultimate relocation to refurbished space adjacent to the Jaeger site in the heritage-listed building that previously housed part of the John Curtin School of Medical Research.

2012 was a particularly successful year for RSES as indicated by research funding outcomes and external recognition. The School enjoyed a 35% success rate in Discovery Project funding from the Australian Research Council (ARC) as well as success in the Laureate Fellowship (Rohling), Future Fellowship (Berry, Hogg), Linkage and LEIF programs with new research funding totalling more than $7 million. Emeritus Professor Kurt Lambeck was awarded the 2012 Balzan Prize for solid-earth sciences with emphasis on inter-disciplinary research 'for his exceptional contribution to the understanding of the relationship between post-glacial rebound and sea level changes. His findings have radically modified climate science'. Professor Hugh O'Neill was elected to Fellowship of the Royal Society for 'fundamental contributions to the study of mineral equilibria and their application to understanding planetary processes'.

Three staff members were recognised in 2012 by the Australian Academy of Science: Professor Patrick De Deckker was elected to Fellowship for 'pioneering studies of the Quaternary history of the oceans bordering Australia, using microfossils and their chemical composition to reconstruct past changes'. The Mawson Medal and Lecture for outstanding contributions to earth sciences was awarded to Professor Gordon Lister for his studies of 'tectonic processes that lead to the building and destruction of mountain belts'. Dr. Andy Hogg was awarded the 2012 early-career Frederick White Prize for physical, terrestrial and planetary sciences work which contributes to the understanding of natural phenomena for his work in 'using models of ocean circulation to understand the role of oceans in climate'.

In October, at a function well-attended by staff, students and friends of the School, we formally launched the Allan White Endowment and the Chappell-White memorial bench in the grounds of the Jaeger complex. The endowment honours the legacy of the late Professor Allan White, a distinguished member during the 1960s of the then Department of Geology. The endowment funds the Allan White scholarship to be awarded annually on merit as a Ph D top-up scholarship. The scholarship is intended to foster the study of hard rocks in the tradition of Allan White - in a way that integrates field observations, with petrology and petrography, and with chemical and experimental data. The inaugural Allan White scholarship was presented to Helen Cocker by Allan White's widow Heather White and Connie Treloar, the sister of the late Bruce Chappell.

The Jaeger-Hales lecture for 2012 entitled 'The last deglaciation as a key example of long-term global warming' was delivered in July to an appreciative audience by Professor Edouard Bard of the Collège de France and Université Aix-Marseille. During the same week, Professors Bard and Rohling and Dr Tregoning addressed a well-attended Sea-Level Rise Forum 'Climate change and its impact on the oceans'.

The challenge of maintaining and enhancing our reputation for national and international leadership in research and research-intensive training requires an understanding and continuing exploitation of the factors responsible for our competitive advantage. Foremost amongst these are the distinctive capacity to draw upon the enabling sciences to address the big questions in earth sciences, the recruitment and retention of skilled technical and workshop staff, provision of a special environment for the training of graduate students, and research-led undergraduate training.
Our successes with research funding, external recognition and satisfied graduates reflect the hard work and commitment by all – faculty members and research students, specialized technical and workshop staff, and those responsible for IT and administrative support. To all, my thanks for the hard work and commitment during 2012.

In 2013, we will celebrate the 40th anniversary of the founding of the Research School of Earth Sciences, and look forward to sharing that occasion with the many alumni and friends of the School.

Professor Ian Jackson
Director, RSES

Honours & Awards

Mr. A. CHOPRA was awarded the 2012 Robert Hill Memorial Prize for displaying excellence in research, good communication skills, proven publications record, and the ability to communicate research to a broad audience.
Mr. A. CHOPRA was awarded the Best Talk Prize at the 2012 Mt. Stromlo Student Christmas Seminars.
Mr. A. CHOPRA was awarded the "Best Postgraduate Oral Presentation" at the 2012 Australian Space Science Conference.
Mr A. CHOPRA was awarded 1st Prize and Audience Favourite Prize at the 2012 “3 Minute Thesis Competition” at ANU.
Mr A. CHOPRA was awarded a $2500 grant from the Astronomical Society of Australia and RSES, ANU to present at the 2012 Astrobiology Science Conference in Atlanta, USA.
Ms A. F. KOMUGABE received the Vice Chancellor’s Travel Grant to attend the 5th International Symposium on Deep-Sea Corals, 2 - 7 April, Amsterdam, Netherlands.
Dr C.H. LINEWEAVER received the 2012 David Allen Prize from the Astronomical Society of Australia "in recognition of his outstanding contribution to fostering public interest in astronomy" ($5000, awarded every three years) awarded July 5th, 2012 at the Sydney, Astronomical Society of Australia Meeting, http://asa.astronomy.org.au/DAP/.
Dr C.H. LINEWEAVER and PhD student Eriita Jones were nominated for the ANU Media Award for "highest international impact for a media release" Dec 5, 2012.
Mrs K. STRZEPEK received a Travel award (€750) to attend the International Symposium on Deep-Sea Coral in Amsterdam, April 2012. Kelly Strzepek won the Peter Holloway Oceanography Award for Best Oral Presentation at the Australian Marine Sciences Association Conference, July 2012 and the Best Student Presentation at the 17th Australian Organic Geochemistry Conference, December 2012. Kelly was also nominated for an ANU media award for best use of new media and technology, for her contributions to the blog ‘OnCirculation.
Prof Patrick De Deckker was made a Fellow of the Australian Academy of Science in May 2012.
Prof B.J. PILLANS was awarded an ARC Linkage Grant (LP120200626 “Landscape evolution, environmental change and human occupation history at Lake George – a rare natural archive”).
MS HELEN COCKER received the Allan White Scholarship.
DR PENNY KING was awarded a VC Teaching Enhancement Grant, ANU– King, P.L., Eggins, S., Fulton, C., Lindesay, J. and Fraser, C. for Promoting deep learning in the cross-college introductory Earth Systems class using new online and research-led approaches: Creating a springboard for a future Office of Learning and Teaching grant application – $10,000, plus $20,000 matching funds; Co-Investigator on a grant for *The Alpha-Particle X-ray Spectrometer on the Mars Science Laboratory mission* through the University of Guelph (from the Canadian Space Agency; Principle Investigator on a grant

for *The Alpha-Particle X-ray Spectrometer on the Mars Science Laboratory mission* through the University of New Mexico (from NASA Jet Propulsion Laboratory).
DR OLIVER NEBEL received a fellowship from the Group-of-Eight Universities Australia and the Chinese Government, embedded in the research exchange program for young researchers between both countries (YSEP fellow). He was also granted the Vice Chancellor's travel grant for young researchers.
PROFESSOR HUGH O'NEILL was awarded a Fellow of the Royal Society (FRS 2012).
DR GREG YAXLEY was awarded a 3-month extension of his Alexander von Humboldt Fellowship at the University of Frankfurt from August to October.
Dr N BALFOUR received the Vice Chancellors Staff Excellence Award for Public Policy and Outreach as part of the Australian Seismometers in Schools team.
Dr N BALFOUR is nominated for ANU Media Awards for best emerging talent and best use of new media and technology.
Dr A.McC. HOGG received the Frederick White Prize from the Australian Academy of Science for his contributions to the understanding of natural phenomena.
Prof B.L.N. KENNETT gave a Keynote Lecture at the International Geological Congress in Brisbane in August, and the Selwyn lecture at the Selwyn Symposium of the Victorian Division of the Geological Society of Australia in October.
Dr M. SALMON was awarded a Vice-Chancellors award for Public Policy and Outreach.

ACADEMIC STAFF

Director and Professor

A.P. Roberts, BSc Massey, BSc (Hons) PhD DS Victoria University (Wellington) (to 17 August 2012)

I.N.S. Jackson, BSc Qld, PhD ANU (from 15 October 2012)

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. DeDeckker BA 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, Diplo Geol, Dr.rer.nat.habil Köln, DSc ANU, FAAH

T.R. Ireland, BSc Otago, PhD ANU
I.N.S. Jackson, BSc Qld, PhD ANU
G.S. Lister, BSc Qld, BSc (Hons) James Cook, PhD ANU
H.St.C. O'Neill, BA Oxford, PhD Manchester, FAA
B.J. Pillans, BSc PhD ANU, HonFRSNZ
M.S. Sambridge, BSc Loughborough, PhD ANU, FRAS

Senior Fellows

V.C. Bennett, BSc PhD UCLA
S. Eggins, BSc UNSW, PhD Tasmania
C.M. Fanning, BSc Adelaide
M.K. Gagan, BA UCSantaBarbara, PhD James Cook
J. Hermann, Dip PhD ETH Zürich
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 Virginia Tech
D.C. McPhail, *BSc. (Hons) MSc British Columbia, PhD Princeton*
M. Norman, BSc Tennessee Technological University, MSc Tennessee, PhD Rice
M.L. Roderick, BAppSc QUT, PGDipGIS Qld, PhD Curtin
D. Rubatto, BSc MSc Turin, PhD ETH Zürich
P. Tregoning, BSurv PhD UNSW
I.S. Williams, BSc PhD ANU

Fellows

N. Abram, BSC Advanced (Hons) Sydney, PhD ANU
C. Alibert, MS Paris VII, First thesis ENS Paris, State thesis CRPG, Nancy
Y. Amelin, MSc PhD Leningrad State University
R. Armstrong, BSc MSc Natal, PhD Witwatersrand
J.J. Brocks, Dip Freiburg, PhD Sydney
M. Ellwood, BSc (Hons) PhD Otago
S. Fallon, BA MS San Diego, PhD ANU
D. Heslop, BSc Durham, PhD Liverpool, Dr habil Bremen
A.M. Hogg, BSc ANU, PhD UWA
G. Hughes, BE ME Auckland, PhD Cambridge
P King, BSc (Hons) ANU, PhD, Arizona State (from 1/1/2012)
S. McClusky, BSurv PhD NSW
B.N. Opdyke, *AB Columbia, MS PhD Michigan*
N. Rawlinson, BSc PhD Monash
H. Tkalcic, Dip Engineering in Physics, Zagreb, PhD California Berkley
G. Yaxley, BSc PhD Tasmania (ARC Future Fellow)
J. Yu, BSc, MSc, Nanjing University, PhD Cambridge (from 20/8/2012)

Research Fellows

A. Abrazhevich, Dip Geology & Geophysics St Petersburg, MPhil Hong Kong, PhD Michigan
M. Davies, MSc Washington, PhD Oregon State

J. Montillet, BSc MSc Ecole Centrale d' Electronique, MSc. Aalborg, PhD Nottingham
M. Forster, BSc MSc PhD Monash
G. Iaffaldano, BSc Rome, PhD Munich
O. Nebel, Diplom Geology Dr. rer. nat. Munster
U. Proske, (from 13/2/2012)
A. Purcell, BSc (Hons) PhD ANU

Postdoctoral Fellows:

N. Balfour, BSc (Hons) MSc Victoria University (Wellington), PhD Uni Victoria (British Columbia)
N. Darbeheshti, BSc MSc K.N. Toosi University of Technology, PhD Curtin
T. Iizuka, BSc, MSc, PhD, Tokyo Institute of Technology (to 31/03/2012)
L. Martin, BSc (Hons) MSc Paris XI, PhD Henri Poincare University (to 26/06/2012)
S. Rawlinson, BA Boston AM PhD Washington
M. Salmon, BSc (Hons) PhD, Victoria University (Wellington)
U. Saenz, Umana BEng Universidad de los Andes, PhD Illinois
E. Saygin, BEng Istanbul Technical University, PhD ANU
M. Ward, BSc (Hons) Florida, CAS Cambridge, PhD Florida State
L. White, BSc (Hons) UNSW (to 10/03/2012)

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*
G.F. Davies, MSc Monash, PhD CalTech
D.H. Green, BSc MSc DSc, DLitt (Hon) Tasmania, PhD Cambridge, FAA, FRS*
K. Lambeck, BSurv NSW, DPhil DSc Oxford, FAA, FRS*
I. McDougall, BSc Tasmania, 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 Sydney, PhD Cambridge, FIP, FAIP, FAA, FRS*
G.C. Young, BSc (Hons) ANU, PhD London

* Emeritus Professor

Research Officers

S. Alford, BSc (Hons) UC Davis, MSc Michigan (to 26/03/2012)
S. Hart, BSc (Hons) Melbourne (to 27/01/2012)
P. Holden, BSc Lancaster, PhD St. Andrews
G. Luton, BSurv UNSW
H.W.S. McQueen, BSc Qld, MSc York, PhD ANU
R. Rapp, BA State University of New York, PhD Rensselar Polytechnic
J. Shelley, BSc, MSc, University of Canterbury (NZ)
S. Sosdian, BSc Monmouth, PhD Rutgers
M. Ward, BSc (Hons) Florida, CAS Cambridge, PhD Florida State
R. Wood, BSc (Hons) Durham, MSc, DPhil Oxford

Research Assistants

A. Arcidiaco, BAppSc GradDip SAInst
B.J. Armstrong, BSc UNISA

POST-GRADUATE STUDENTS

PhD Candidates

A. Arad, BSc (Hons) ANU
C. Augenstein, BSc MSc ETH-Zurich
R. Benavente Bravo, B. Physics, Universidad de Concepción, Chile
K. Boston, BSc (Hons) ANU
L. Brentegani, BSc (Biological) Bologna, MSc Ancona
J. Brownlow, BSc (App Geology) UNSW
B. Bruisten, B. Georesources Management & M. Applied Geosciences, RWTH Aachen University, Germany
C. Chapman, BSc (Adv), BE (Hons) Syd, Grad Dipl BMTC
A. Chopra, BSc Univ. WA, BSc (Hons) ANU
P. Castillo Gonzalez, BSc MSc Univ Chile
R. Chopping, BSc (Hons) Tas, MSc ANU
N. Darrenougue, BSc MSc Univ. Bordeaux
A. David, BSc(REM) Hons ANU
A. De Leon, BSc (Hons) Univ. Melbourne
J.P. D'Olivo Cordero, MSc UABC Mexico
J. Doull, BSc (Hons) ANU
B. Frasl, BSc MSc Univ. Leoben
L. Gauthiez-Putallaz, BSc MSc Lausanne Uni
E. Gowan, BSc (Geophysics) (Hons) Univ. Manitoba, MSc Vict Univ., Canada
N. Gueneli, Dipl Biochem Kiel, Dipl Geol Kiel
T. Haber, BSc University of Leipzig, MSc University of Leipzig
B. Hanger, BEng (Chem) (Hons), BSc Monash, Hons ANU
J. Hoffmann, BA BSc (Hons) Monash Univ.
K. Holland, BGOS (Hons) ANU
K. Horner, BSc (Hons) Univ. British Columbia, MSc Vrije Universteit Netherlands
Md. J. Hossen, BSc MSc Univ. Dhaka, MSc Florida State Univ.
M. Huyskens, BSc MSc Westfallische Wilhelms-Universität Münster
E. Ingham, BSc (Hons) Victoria Univ. Wellington
A. Jarrett, BSc (Hons) ANU
E. Johnson, BSc (Hons) Newcastle Univ
M. Jollands, BSc, MGeol (Hons, Int) University of Leeds
B. Kallenberg, BSc MSc Freie Univ., Berlin
J. Kang, BSc MSc Korea Univ.
T. Kelly, BSc Univ. Tasmania, BSc (Hons) ANU
A. Kimbrough, BSc Arizona Univ.
P. Koefoed, BSc University of Auckland, PGDip University of Auckland, MSc University of Auckland
A. Komugabe, BBiotech/BBus UTS, Hons ANU

O. Koudashev, BSc Hons ANU
C. Krause, BSc (Hons) Macquarie Univ.
J. Lee, BSc (Hons) ANU
Yang Li, BSc Sun Yat-sen University (Guangzhou, China), MSc ANU
J. Mazerat, BSc MSc Bordeaux Univ.
S. McAlpine, BSc (Hons) ANU
A. McCoy-West, BSc MSc (Hons) BCA Victoria Univ. Wellington
I. McCulloch, BSc UNSW, GradDip ANU
S. Meyerink, MSci, Univ. Southampton, UK
N. Mikkelson, BSc (Hons) ANU, BArts ANU
P. Millsteed, Dip 1 Cert in Gemmology ACT Institute of Technology, BSc Univ. Canberra
I. Moffat, BA BSc (Hons) Univ. Queensland
M. Moore, BSc (Geol) (Geomatics) Melbourne Univ.
A. Morrison, BSc (Hons) ANU, GradDipEd, Univ. Canberra
M. Morse, BSc (Hons) Melb Uni, Grad Dip (Computer Studies) Murdoch Univ., MSc (Inf Tech) Univ. NSW
M. Mustac, BSc (Geophysics) MSc (Physics-Geophysics) Univ Zagreb
G. Nash, BA/BSc (Hons) ANU
T. O'Kane, BSc (Hons) ANU
C. O'Neill BSc (Hons) BEcon ANU
R. Owens, BSc (Hons) ANU
S. Pachhai, BSc MSc Uni Tribhuvan, Nepal, Dipl. ICTP, Italy
A. Papuc, BSc (Hons) ANU
S. Pilia, B Exploration & App Geophysics, Cagliari, MSc (Expl & Geoph) Univ. Pisa
S. Rajabi, B. Geology Univ. Tehran, Iran, M. Geology Research Center for Earth Sciences, Geological Survey of Iran, Iran
L. Richardson, BSc (Hons) ANU, MSc Queens Univ. Canada
J. Roberts, BSc (Hons) ANU
I. Rosso, BSc MSc, Univ. Turin, Italy
S. Sagar, BGeomEng (Hons) Univ. Melbourne, BSc Univ. Canberra
M. Samanta BSc Univ. Burdwan, India
M. Sapah BSc (Hons) Univ. Ghana
N. Scroxton, MSc Oxford Univ., UK
K. Snow, BMath BSc Hons Wollongong
P. Sossi, BSc (Hons) Univ. Adelaide; Dip. Lang. (Italian) Univ. Adelaide
I. Stenhouse, BSc (Hons) ANU
P. Stenhouse, BSc (Hons) Univ. Otago, NZ
K. Strzepek (nee James), BSc (Adv) (Hons) ANU
D. Tanner, BSc Hons ANU
C. Thompson, BSc (REM) Hons (Geology) ANU
J. Thorne, BSc (Hons) ANU
S. Tynan, BA BSc (Hons) ANU
P. Vasilyev, BSc MSc Moscow State Uni
B. Wang, BSc (Hons) UTS
T. Whan, BSc (Hons) ANU
M. Willmes, BSc MSc Univ. Münster
J. Wykes, BSc (Hons) MPhil ANU
Y. Xue, BSc China Univ., MSc Peking Univ.

M. Young, BA Physics Hendrix College
S. Yuguru, B. Env Sci (HIIA Honours Monash Univ., MSc Univ. Papua New Guinea
U. Zannat, BSc Geology & M.S Petroleum Geolog, Dhaka Univ., Bangladesh
I. Zhukova, B. Geology & M. Geology Univ. Novosibirsk, Russia

MPhil Candidates

R. Burne, B.Sc (Wales), D.Phil. (Oxon)
I. Gunawan, BSc Inst Tech Bandung, Indonesia
A. Higgins, BSc (Hons) ANU
J. McDonald, BSc ANU
M. Nash, B.Comm UC, BSc ANU
A. Omang, BSc Inst Tech Bandung, Indonesia
A. Rudyanto BSc Universitas Nasional (Jakarta-Indonesia), dipl. Tsu International Institute of Seismology and Earthquake Engginering (Tsukuba-Japan), MDM National Graduate Institute for Policy Studies (Tokyo-Japan).
M. Samanta BSc Univ. Burdwan, India (Trf to PhD)

Honours Students

* Mid Year start 2010/2011
# Mid Year start 2011/2012

Geology Honours

David Caust
Nathan Coleman *
Clare Connolly
Bronwyn Dixon
Sam Eggins
Dean Erasmus
Anna Haiblen
Amy Tiffany Halcon *
Christopher Harris-Pascal
Luke Hogan *
Rebecca Kaye
Sarah Lawrie
Eleanor Peterson
Rohana Rogan-Darvill*
Christopher Rouen*
Gerhard Schoning#
Dylan Singh
Hanling Yeow#

Honours Physics of the Earth

Penelope Deacon

Masters Students

Master of Natural Hazards (7512)

Rani Barus
Fausto Basantes Moreno
Cornelia Cornejo Redroban
Kathryn Hayward
Shaleen Hinduja
Kellie Massouras
Monica Osuchowski
My Pham
Ana Ramirez
Catriona Ross

Masters Physics of the Earth (7903)

Jingming Duan
Marco Maldoni

PhD THESES SUBMITTED

Feavis, Fern - Using Multi-Element Comparisons to Discriminate Between Natural and Anthropogenic Post-Depositional Additions in Estuarine Sediments

Clement, Alice - The Anatomy, Evolution and Interrelationships of Devonian Dipnoans, with Insights from the Extant Australian Lungfish, Neoceratodus forsteri

Crawford, Matthew - Dynamic Coupling Between Deformation Processes, Fluid-Rock Interaction, and Gold Deposition in the Argo Gold Deposit, St Ives, Western Australia

Jeon, Heejin - U-Pb, Lu-Hf and O Isotopes in Zircon from Late Palaeozoic Granites Across Orogens, Southeastern Australia

Jones, Jesse - Experimental Constraints on the Thermodynamic Modelling of Siderophile Element Distribution during Core-Segregation and Basalt Petrogenesis

Kiseeva, Ekaterina - Experimental Study of Carbonated Mid Ocean Ridge Basalt at 3.5-21 Gpa - Implications for the Earth's Deep Carbon Cycle

Li, Huijuan - Apatite as an Indicator of Fluid Salinity in Subduction Zone Settings: Implications for the Deep Earth Chlorine Cycle

McKibbin, Seann - Mn-Cr Chronology and Trace Element Systematics of Olivine from Angrite and Pallasite Meteorites

Park, Jung Woo - Platinum-Group Elements Geochemistry in Felsic Rocks

Pirard, Cassian - Transfer of Melts in the Sub-Arc Mantle: Insights from High-Pressure Experiments and from the New Caledonia Ophiolite.

Robertson, Jesse - Rheological Controls on the Dynamics of Channeled Lava Flows

Schinteie, Richard - Ancient Life at the Extremes: Molecular Fossils and Paleoenvironmental Contexts of Neoproterozoic and Cambrian Hypersaline Settings

Sinclair, Natalie - Upper Jurassic (Oxfordian) Dinoflagellate Cyst Taxonomy, Palynostratigraphy and Biosequence, Stratigraphy of the Jansz-IO Gas Field, North West Shelf, Australia

Stepanov, Aleksandr - Monazite Control on Th, U and REE Redistribution During Partial Melting: Experiment and Application to the Deeply Subducted Crust

Stewart, Kial - The Effects of Sills and Mixing on the Meridional Overturning Circulation

White, Lloyd - The India-Asia Pile Up

Students awards

A.L. Hales Honours Year Scholarship: Sam Eggins
ARC Centre of Excellence for Climate System Science Honours Scholarship: Anna Haiblen & Rebecca Kay
RSES Science Honours Scholarship: Bronwyn Dixon
Action Trust Honours Scholarship: Christopher Harris-Pascal
Mervyn and Katalin Paterson Travel Fellowship: Christopher Chapman (visited LEGOS in Taulouse, France)
D.A. Brown Travel Scholarship: Claire Thompson (attended the Biennial Ocean Science Meeting in USA).
Robert Hill Memorial Prize: Aditya Chopra
A.E. Ringwood Scholarship: Michael Jollands
John Conrad Jaeger Scholarship: Kate Snow
Allan White Scholarship: Helen Cocker

Summer Research Scholarships (2012-2013)

Anton Gulley - under the supervision of Ross Griffiths and Gayen Bishakhdatta
Bethany Ellis - under the supervision of Nerilie Abram

Student Internships

Rachel Woods - under the supervision of Penny King
Anushka Sandanam - under the supervision of Steve Eggins

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

Student Administrator HDR

Maree Coldrick

Student Administrator Coursework

Joy McDermid

Information Technology Manager

Paul Davidson, BSc, MSc, Auckland, PhD, ANU (from 19/3/2012)
Hashantha Mendis, BInfTec (Multimedia) Deakin (acting to 16/3/2012)

Client Services and Web Manager

Hashantha Mendis, BInfTec (Multimedia) Deakin (from 31/3/2012)

Information Technology Officer

Duncan Bolt, BSc Sydney
Brian Harrold, BSc ANU

Receptionist

Shannon Avalos

Area Administrators
Earth Chemistry – Josephine Margo
Earth Environment – Robyn Petch
Earth Materials – Mary Hapel
Earth Physics – Sheryl Kluver, Assoc Diploma in Graphic Communications, Australian Army

IODP Administrator
Catherine Beasley

Technical Officers

Charlotte Allen, AB Princeton, MSc Oregon, PhD Virginia Tech
Anthony Beasley, AssocDip CIT
Brent Butler, Cert III Mechanical Engineering Sydney Institute
Joseph Cali, BAppSc QIT
David Cassar, Adv Dip, CIT
David Clark, Cert III Metal Fabrication Adv Dip Eng CIT
Derek Corrigan
Joan Cowley, BSc ANU
Daniel Cummins, Adv Dip Eng, CIT
John Foster, BSc Sydney, MSc PhD ANU
Lobo Fraser, MInfoTec Uni Canberra (from 1/3/2012)
Bin Fu, BSc Chungchun, MSc Nanjing, PhD Vrije
Ben Jenkins, BSc UTS, PhD ANU
Leslie Kinsley, BSc GradDipSc ANU
Harri Kokkonen, Certificate in Lapidary ACT TAFE, BAppSc Canberra College of Advanced Education
Andrew Latimore, BEng University of Canberra
Qi Li
Linda McMorrow, AssocDip Sc NTU
Graham Mortimer, BSc PhD Adelaide
Hayden Miller, Ad Dip in Mech Eng CIT
Shane Paxton
Anthony Percival
Tristan Redman Ass Dip (Elect Eng) CIT
Hideo Sasaki, Ass Dip CIT
Norman Schram, Dip EIE SAIT
Dean Scott, Ass Dip Mech Eng, CIT
Heather Scott-Gagan, BSc Sydney
David Thomson
Ben Tranter, Cert II Auto Radiator Services John Batman Institute TAFE, Auto Climate Control/Air conditioning Casey Institute of TAFE
Ulrike Troitzsch, Diplom Technische Universität Darmstadt, PhD ANU
Carlyle Were
Andrew Wilson
Geoffrey Woodward
Xiaodong Zhang, PhD LaTrobe

Research Activities 2012

Earth Chemistry

Introduction

As is illustrated in the research highlights and activities sections, research by members of the Earth Chemistry group spans the geologic timescale from the beginning of the solar system through to the present day, and in scope from planetary systems to individual molecules. Active areas of research within the Earth Chemistry area include planetary and early Earth studies, metamorphic and igneous geochemistry, geochemistry of life processes, and development and improvement of analytical methods and instrumentation to determine the chronology of processes at all time scales.

2012 was a year of strong research productivity with a continuing flow of publications in national and international journals. Earth Chemistry faculty and students were also prominent at national and international conferences, including organization, convening sessions and conference presentations at the Goldschmidt Conference, held in Montreal in June, the Lunar and Planetary Science Conference at Houston in March, American Geophysical Union meeting in December in San Francisco and the 2012 International Geologic Congress, Brisbane in August.

Awards this year included the presentation to Charley Lineweaver of the 2012 David Allen Prize, given only once every 3 years, from the Astronomical Society of Australia "in recognition of his outstanding contribution to fostering public interest in astronomy". Kelly Strzepek won the Peter Holloway Award for best student presentation at the joint Australian Marine Sciences Association and New Zealand Marine Sciences Society Conference in Hobart in June and the best student presentation award at the Australian Organic Geochemistry Conference in Sydney. The 2012 Robert Hill memorial prize was given to Aditya Chopra. The Prize is awarded to an RSES student who has displayed outstanding research, communication and scientific outreach in the Earth Sciences. Alex McCoy-West was awarded the 2012 D.A. Brown travel scholarship, which he will use to attend the 2013 Goldschmidt Conference in Florence.

Congratulations to Aleksandr Stepanov (PhD supervisor Daniela Rubatto) and Heejin Jeon (PhD supervisor Ian Williams) on successful completion of their PhD programs.

In 2012 we welcomed the arrival of 7 new PhD students to the area. New staff member Sonja Zink took up her position in April as the technical officer responsible for the geochemistry clean laboratory and thermal ionization mass spectrometry laboratory. We congratulate Xiaodong Zhang, (Noble Gas Laboratory Manager) and Shane Paxton (Mineral Separation Facility Manager) on their reclassifications in the last promotion round. Hontong Gao

was appointed as the new mineral separation technician. We look forward to his arrival in January.

2012 was a year of consolidation and much-needed renewal of some facilities. Many Earth Chemistry staff and students were able to leave the basement bowels and expand into office space in the “Old Library” wing following the completion of building J8. On a sad note, the deconstruction of SHRIMP I was completed in 2012. It has been a landmark instrument for RSES and is responsible for many pioneering scientific studies. Many of the main components of the SHRIMP I will live on in display in the SHRIMP laboratory (Bldg. J5). The newest generation large ion-probe, the SHRIMP SI continues to progress. Analysis of conductive materials demonstrates that SHRIMP SI is capable of extremely high precision and accuracy for stable isotope measurements. The old SHRIMP 1 laboratory space underwent timely refurbishments, becoming the new state-of-the-art accelerator mass spectrometery-14C sample preparation laboratory (academic supervisor Stewart Fallon). This new laboratory also houses the MEC funded stable isotope ratio mass spectrometer for automated sample preparation. There was also major refurbishment of the old argon instrument laboratory prior to the installation of the new ARC-funded Argus mass spectrometer (academic supervisor Marnie Forster). We end the year on a positive note with the scheduled arrival in January 2013 of the long-awaited ARC funded Helix MC, a new generation mass spectrometer for noble gas isotopic measurements (academic supervisor Masahiko Honda).

Dr. Vickie Bennett
Associate Director, Earth Chemistry

Precise and direct determination of the half-life of ^{41}Ca

G. Jörg[2], Y. Amelin[1], K. Kossert[3] and C. L. v. Gostomski[2]

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Radionuclides with half-lives between 10^5 and 10^8 years, such as ^{26}Al, ^{53}Mn and ^{41}Ca, which were synthesized shortly before the formation of the Sun and our Solar System, are now extinct, but their stable decay products (^{26}Mg, ^{53}Cr, ^{41}K) are still present in the most ancient rocks and minerals. Variations in abundance of these decay products are used to measure the time of the disk accretion and the stellar environment of the Solar System's formation. The time resolution of these "extinct" nuclide chronometers depends on the half-life of the parent radionuclide: the shorter the half-life, the finer the bits of time that can be resolved.

Among the radionuclides commonly used as "extinct nuclide" chronometers, ^{41}Ca has the shortest half-life of about 10^5 years. As the analytical techniques of ^{41}Ca-^{41}K dating improve, the uncertainty of the half-life is increasingly becoming a limiting factor in chronological interpretations. The half-life of ^{41}Ca was measured many times (Table 1), but still is not reliably known: the values range from 7.7 to 19.0 × 10^4 years, and all values suffer from large uncertainties.

We determined the ^{41}Ca half-life with the set of techniques intended to achieve the best possible precision and accuracy. Radiochemically pure ^{41}Ca was extracted, without addition of inactive Ca carrier, from borosilicate glass from the absorber rods of a decommissioned pressurized water reactor. The concentration of separated calcium and the ^{41}Ca/^{40}Ca ratio were measured by thermal ionization mass spectrometry with a ^{42}Ca-^{48}Ca double spike, exponential normalization, and an independently determined absolute isotopic composition of Ca. The activity was measured by a liquid scintillation counting technique exploiting the triple-to-double coincidence ratio method.

The results of two independently processed and analysed samples of ^{41}Ca yielded statistically indistinguishable values. Their average value of $(9.937\pm0.146)*10^4$ y is proposed as the new half-life value. The new half-life value overlaps the uncertainty interval of the previously accepted value of $(10.2\pm0.7)*10^4$ y, therefore it does not call for an immediate re-interpretation of the existing ^{41}Ca-^{41}K data. Furthermore, the ^{41}Ca-^{41}K method is still in the early stage of development and application, and the existing data are not particularly precise. With future refinements of the ^{41}Ca-^{41}K techniques, the significance of a more precisely and accurately known ^{41}Ca half-life will increase.

Full report:

Jörg, G., Amelin, Y., Kossert, K., v. Gostomski, C.L. 2012. Precise and direct determination of the half-life of ^{41}Ca. Geochimica et Cosmochimica Acta, 88, 51–65.

The progress of half-life determinations of ^{41}Ca.

Reference	Half-life in 10^4 y	Relative standard uncertainty in %	Method
Sailor and Floyd (1951)	---	---	First experiments with X-ray
Brown et al. (1953)	11.0(30)	27.3	n.-irr. of ^{40}Ca-enriched Ca ($n_{41_{Ca}}$); X-ray ($A_{41_{Ca}}$)
Drouin and Yaffe (1962)	7.7(11)	14.3	n.-irr. of Ca ($n_{41_{Ca}}$); X-ray ($A_{41_{Ca}}$)
Wahlin (1966)	12.0	---	
Emery et al. (1972)	13.0(20)	15.4	
Mabuchi et al. (1974)	10.3(4)	3.9[g]	n.-irr. of ^{40}Ca-enriched Ca ($n_{41_{Ca}}$); X-ray ($A_{41_{Ca}}$)
Browne and Firestone (1986)	10.3(4)	3.9	Decay data evaluation
Paul et al. (1991)	10.1(10)	9.9	„standard MS techniques“ ($n_{41_{Ca}}$); X-ray ($A_{41_{Ca}}$)
Klein et al. (1991)	10.3(7)	6.8	Ratio $^{41}Ca/^{36}Cl$ in Antarctic meteorites
Klein et al. (1991)	19.0(60)	32	Updated values for neutron capture cross section of ^{40}Ca and fluorescence yield of X-rays
Klein et al. (1991)	16.0(25)	16	
Klein et al. (1991)	11.4(5)	4.4[g]	
Cameron and Singh (2001)	10.2(7)	6.9	Decay data evaluation
This work	**9.937(146)**	**1.47**	**TIMS and LSC**

Figure 1. The progress of half-life determinations of ^{41}Ca

Tracking Water Mass Movements Through Time

Aimée Komugabe[1], Stewart Fallon[1], Ron Thresher[2] and Steve Eggins[1]

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Current understanding of present-day natural climate variability can be improved by obtaining a good baseline through investigating past variability during the Holocene (11,500 cal yr B.P. to the present). In particular, changes in marine reservoir radiocarbon ages through the Holocene can provide information on regional ocean circulation. In the southwest Pacific, little is known about the variability of reservoir ages during this period. This limits efforts to reconstruct southern hemisphere ocean and atmospheric circulation over this period and to balance historical global carbon budgets.

Our study aims to determine mid- to late-Holocene water mass movements for the southwest Pacific. Marine reservoir ages have been derived using combined uranium series (MC ICPMS) and radiocarbon (AMS) measurements on deep-sea corals from the Tasman Sea. Preliminary results indicate a decrease in reservoir ages in the Norfolk Ridge (east Tasman), from the mid 19th Century to present day. This suggests an increase in surface ocean ventilation of water masses and/or a greater influx of well-equilibrated water of sub-tropical origin into this region. These results are consistent with observational and modelling studies for the last century, which show significant changes in regional circulation and suggest these changes started as early as the 17th century.

Reconstructing climate using the organic skeletons of deep-sea coral:

Kelly M. Strzepek[1], Stewart J. Fallon[1], Ron E. Thresheer[2] and Andrew t. Revill[2]

[1] Research School of Earth Sciences, Australian National University, Canberra, ACT 0200, Australia
[2] CSIRO Marine and Atmospheric Research

Figure 1. Protein node from Bamboo Coral showing banding structure, ~8mm diameter.

The eastern seaboard of Australia is a chronically under sampled region with little known about the effect of recent climate change on key oceanographic processes, such as nutrient distribution and corresponding ecosystem structure. Deep-sea coral archives can address this paucity of information as they continuously integrate surface particulates into the organic fraction of their skeletons, following the old adage 'you are what you eat'. This protein has a banding structure similar to tree rings (see inset) permitting a reconstruction of discrete moments in time from the chemical composition of the skeleton. The enrichment of nitrogen isotopes from bulk samples is the traditional approach used to reconstruct food web dynamics, however this interpretation is confounded when looking at archives, as you need knowledge of the temporal evolution of the baseline before you can calculate enrichment through time. To overcome this difficulty we are using nitrogen isotopes from individual amino acids to obtain an internal index of both baseline and enrichment over the passed 100 years. The information gleaned from samples along the Lord Howe Rise suggest a long-term trend of increasing input from nitrogen fixation, punctuated by changes in food-web dynamics that correspond to the climatic influences of the Pacific Decadal Oscillation. This relatively new technique shows tantalizing potential to reveal natural variability in the Western South Pacific against a backdrop of longer term global warming.

Cosmogenic noble gas dating of young basaltic lavas from southern Mendoza, Argentina

Venera R. Espanon[2], Masahiko Honda [1] and Allan R. Chivas[2]

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Southern Mendoza, Argentina is characterized by abundant Pleistocene to Holocene volcanism associated with back-arc magmatism, influenced by the subducting Nazca plate. Age determinations in this volcanic area have been improved during the last 5 years. However, there are some volcanic structures especially in the Payunia Volcanic Field (PVF), suggesting fairly recent eruptions which have not been chronologically determined. Recent publications from Llancanelo Volcanic Field (LLVF) and PVF have determined volcanic activity mainly using K-Ar and 40Ar/39Ar, as well as cosmogenic 3He. While these methods are well established, K-Ar and 40Ar/39Ar are difficult to produce reliable ages in Holocene basaltic flows. To better constrain the younger volcanic activity in LLVF and especially in PVF, surface exposure dating using cosmogenic 3He and 21Ne was used in five volcanic structures. By applying cosmogenic 3He and 21Ne ages ranging from late Pleistocene (PY-9) to mid Holocene (PY-4) were obtained for basalts from the area of Los Volcanes from PVF. The younger age acquired is significant as it supports previous evidence for mid Holocene volcanic activity in PVF and the first noble gas cosmogenic surface exposure age obtained from a basaltic bomb. A third age from the late Pleistocence was obtained for a basaltic tumulus from the Llancanelo Volcanic Field (LLVF). This study illustrates the importance of using two nuclides for cosmogenic exposure ages for recent volcanic eruptions. The present study indicates that PVF was active 5 ka and possibly even >5 ka as has been already suggested.

In-situ oxygen isotope analysis of monazite to monitor crustal fluids.

Daniela Rubatto and Celine Crepisson

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

Aqueous fluids play a critical role during metamorphic processes in the Earth's crust because they have first order influence on element transport, reaction kinetics and heat transfer. Monazite is a robust accessory mineral that is commonly present in crustal rocks from low to high-grade conditions. Experimental and field studies have shown that monazite readily recrystallizes in the presence of fluids developing specific zoning patterns. This mineral has therefore the potential to record and preserve different fluid signatures during the host rock evolution, but its potential remains largely unexplored.

In order to take advantage of monazite internal complexity, we performed in-situ oxygen analysis of monazite using the SHRIMP ion microprobe and a newly characterised standard. Reproducibility of delta18O ion microprobe analyses for homogeneous monazite is comparable to what routinely obtained for zircons (0.4-0.6 per mil, 2 sigma). The variable composition of natural monazite has the potential to produce matrix effects during ion microprobe measurements compromising accuracy. Measurements of monazite grains from a syenite display a scatter in delta18O that correlates primarily with Th content. The matrix effect is estimated in a shift of circa one delta18O every 10 wt% Th and has to be corrected when analysing natural monazite with composition significantly different from the standard. We analysed monazite from high-grade metasediments (Himalaya and Central Australia) in order to evaluate the robustness of oxygen signature in monazite, and quantify monazite-zircon oxygen fractionation.

In search of lost continents: An ancient cratonic nucleus identified in the southwest Pacific lithosphere

A. J. McCoy-West[1], V. C. Bennett[1], I. S. Puchtel[2] and R. J. Walker[2]

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[2] Department of Geology, University of Maryland, College Park, Maryland 20742, USA

Figure 1. A mantle xenolith (green; ~8 cm long) within almost aphyric alkali basalt (black). This sample is from the Fortification Peak locality.

The formation, preservation and destruction of the lithospheric mantle and its role in craton growth and stabilisation are crucial, but largely unknown components of the crust formation process. Typically studies of the lithospheric mantle and its relationship to continental development have focused on the oldest preserved continental sections. In a paper available online in *Geology* (February, 2013 issue; "Extreme persistence of the cratonic lithosphere in the southwest Pacific: Paleoproterozoic Os isotopic signatures in Zealandia") PhD student McCoy-West and co-authors take a different approach by determining the age structure of the mantle components of New Zealand, a young composite continental block that formed by stepwise accretion during the Phanerozoic. New Zealand is part of Zealandia, a largely submerged, continental fragment in the southwest Pacific, generally considered to be derived from East Gondwana, but whose origins, age, structure, and relationships with other continental masses are poorly known. In various localities throughout New Zealand, pieces of the lithospheric mantle in the form of xenoliths entrained in basaltic magmas (Fig. 1) provide a rare opportunity to directly study the composition and age structure of the underlying upper mantle.

By determining the rhenium and osmium isotopic compositions of mantle xenoliths collected from 12 localities throughout New Zealand (Fig. 2), McCoy-West et al., were able to provide new constraints on continent formation in the southwest Pacific. In a surprising result the Re-Os data yield ages between 0 and 2.3 Ga (billion years) with six samples from a single region, the newly defined Waitaha domain, South Island, having a narrow range of ages from 1.6–1.9 Ga (Fig. 3). The discovery of a large, coherent, chunk of early Proterozoic mantle (~1.9 Ga) underlying New Zealand's South Island is a highly unexpected find as the basement crustal rocks in this region are only 200 Ma. This >1.7 billion year difference is the largest temporal decoupling between the mantle lithosphere and overlying crust yet observed. Additionally, these ages are substantially older (>500 Ma) than Os model ages preserved in other regions of mantle lithosphere from the eastern margin of Gondwana (e.g., southeastern Australia and Marie Byrd Land, Antarctica).

This raises the questions of where this ancient mantle lithosphere formed and where is the associated Paleoproterozoic continental crust? Consideration of possible plate tectonic reconstructions suggests that this piece of Paleoproterozoic mantle lithosphere may be exotic to Gondwana, forming perhaps in the period of major continental growth at 1.8-2.0 Ga as part of what is now western North America. After rifting from its parent continent, this large tract of mantle lithospheric likely resided at the margins of several supercontinents during the past ~2 Ga. The presence of old cratonic mantle lithosphere under the young New Zealand crust suggests that lithospheric mantle may be necessary for the stablization of new continental crust. Additionally, the discovery of extensive ancient lithosphere within Zealandia provides new information on its origins and assembly history, with tectonic implications for the present-day development of the Australia-Pacific plate boundary cutting through New Zealand.

This interesting research is available online here:
http://geology.gsapubs.org/content/early/2012/12/13/G33626.1.abstract

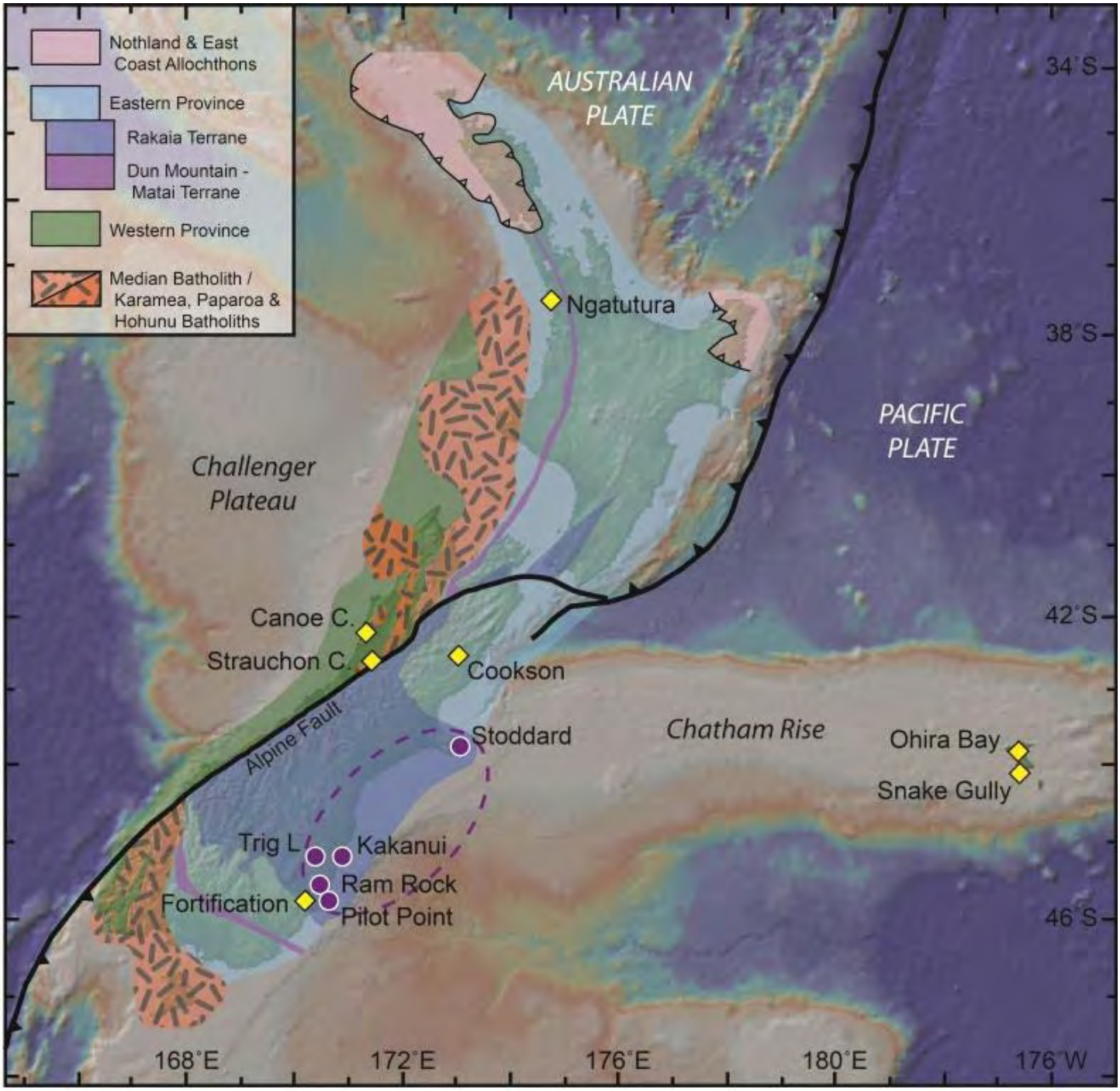
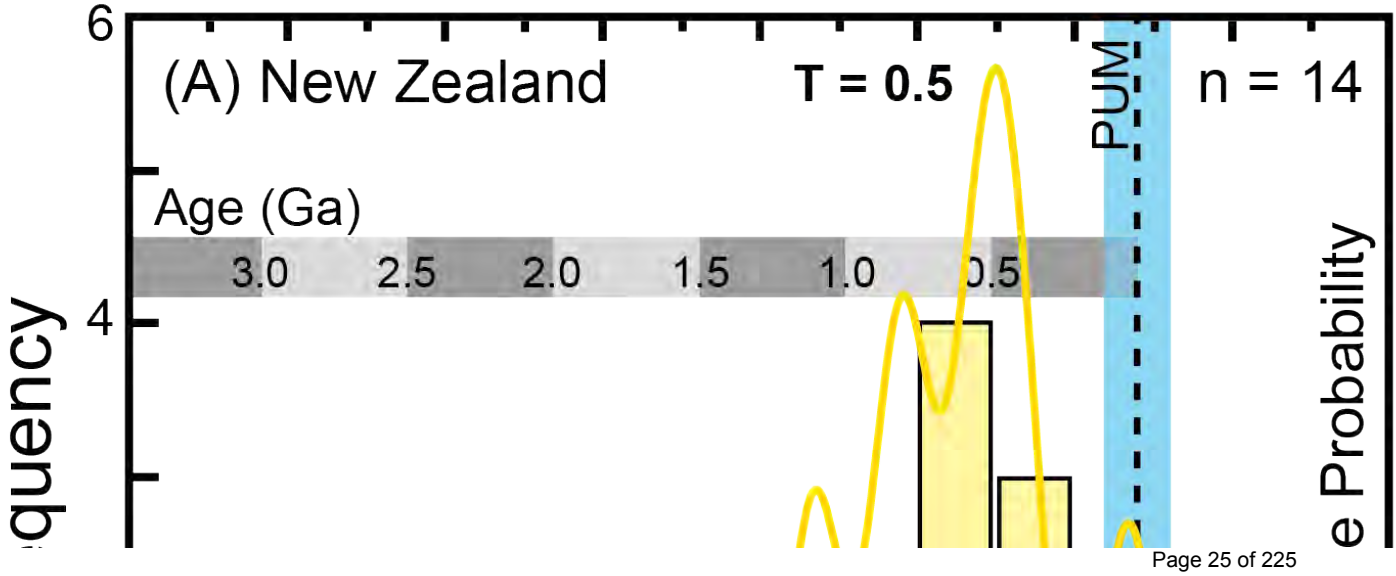
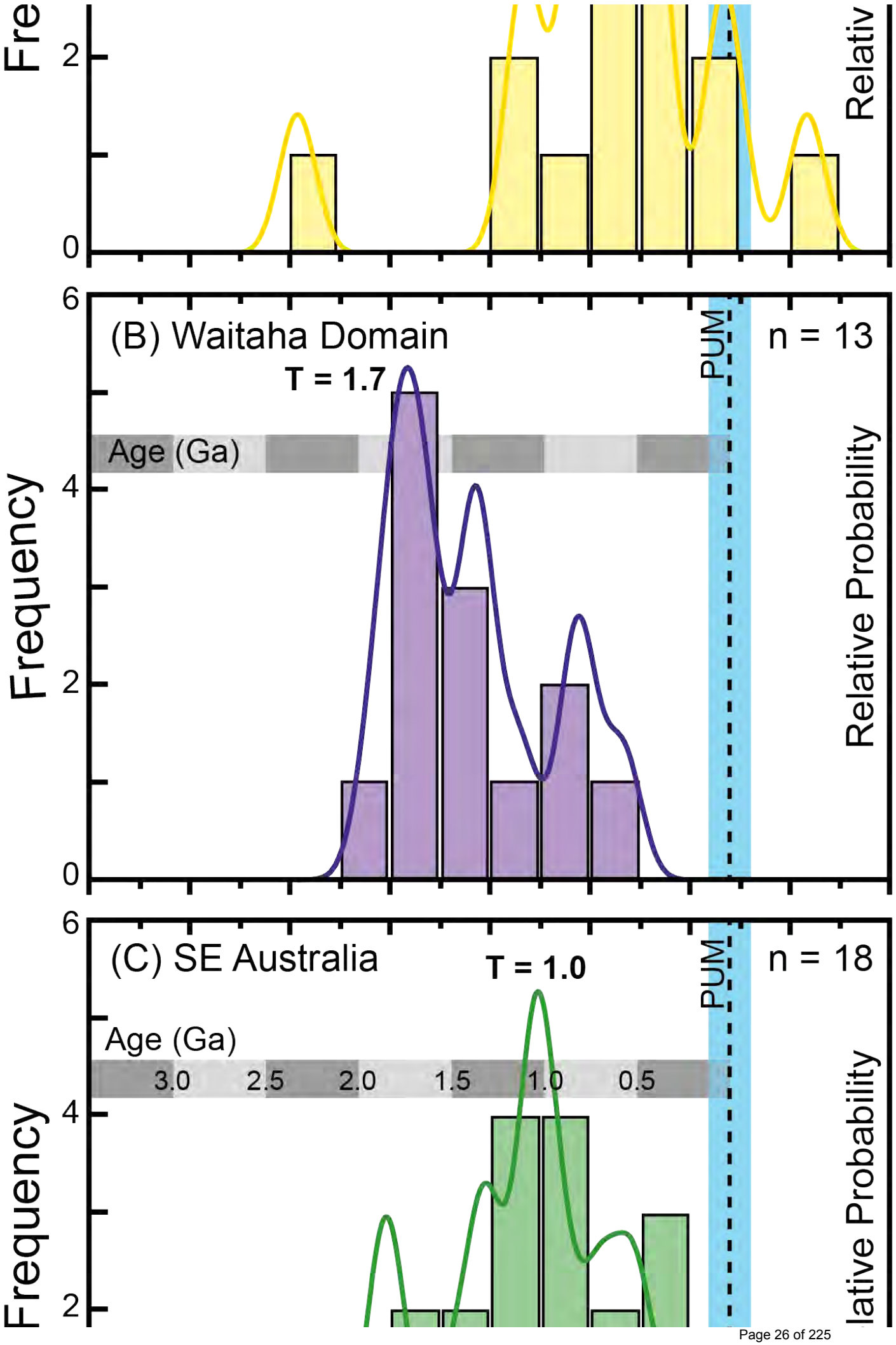


Figure 2. Simplified geological map of New Zealand's crustal basement showing the major lithostratigraphic divisions. Mantle xenolith localities are divided into two groups 1) the southern Waitaha domain (circles); 2) all other localities (diamonds). The dashed ellipse represents the minimum extent of the newly recognized Paleoproterozoic, Waitaha domain. Geology modified from Mortimer (2004). Reproduced from article *in press* in Geology.

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(B) Waitaha Domain
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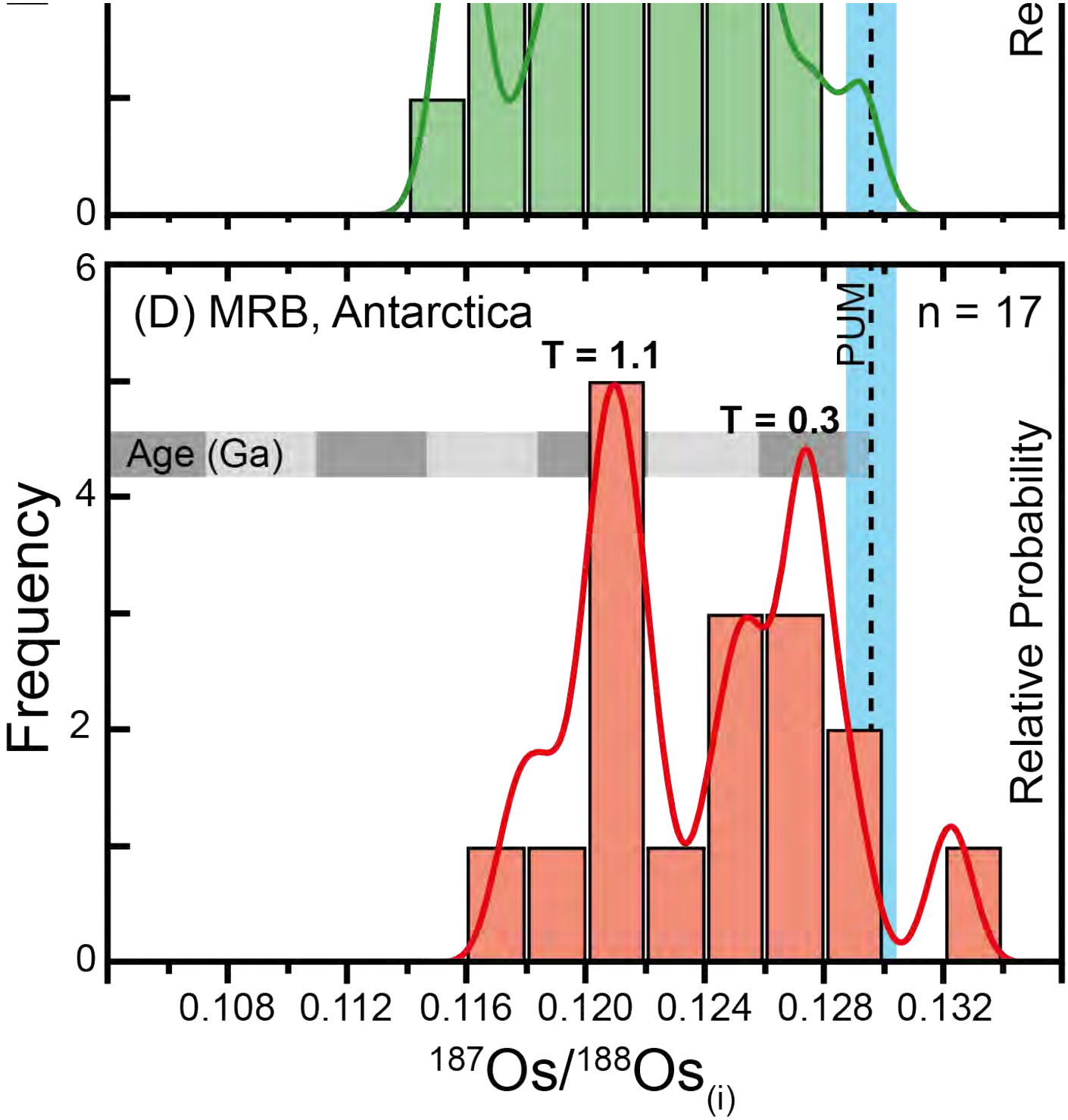

Figure 3. Histograms of initial $^{187}Os/^{188}Os$ comparing mantle xenoliths from New Zealand (A; this study); Waitaha domain (B; this study); southeastern Australia (C; Handler et al., 1997); and Marie Byrd Land (MBL), Antarctica (D; Handler et al., 2003). Dotted line represents composition of the modern primitive upper mantle (PUM) $^{187}Os/^{188}Os$ = 0.1296 ± 8 (Meisel et al., 2001). Gray bar shows Re depletion ages corresponding to the $^{187}Os/^{188}Os$ isotopic compositions. Lines overlying histograms represent relative probability density plots of T_{RD2} model ages; bold numbers are major age peaks. Samples from Waitaha domain are significantly older than any other sampled Gondwanan mantle region. Reproduced from article *in press* in Geology.

Stratigraphic Geochronology in the Omo-Turkana Basin, East Africa

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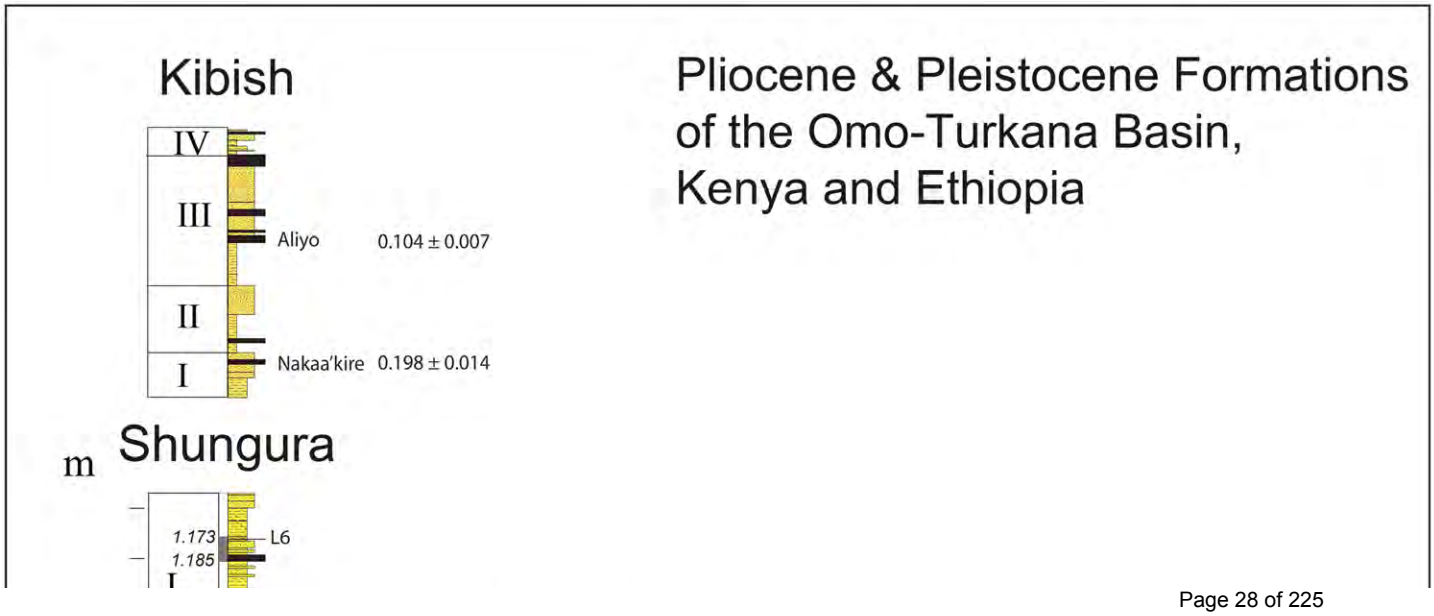
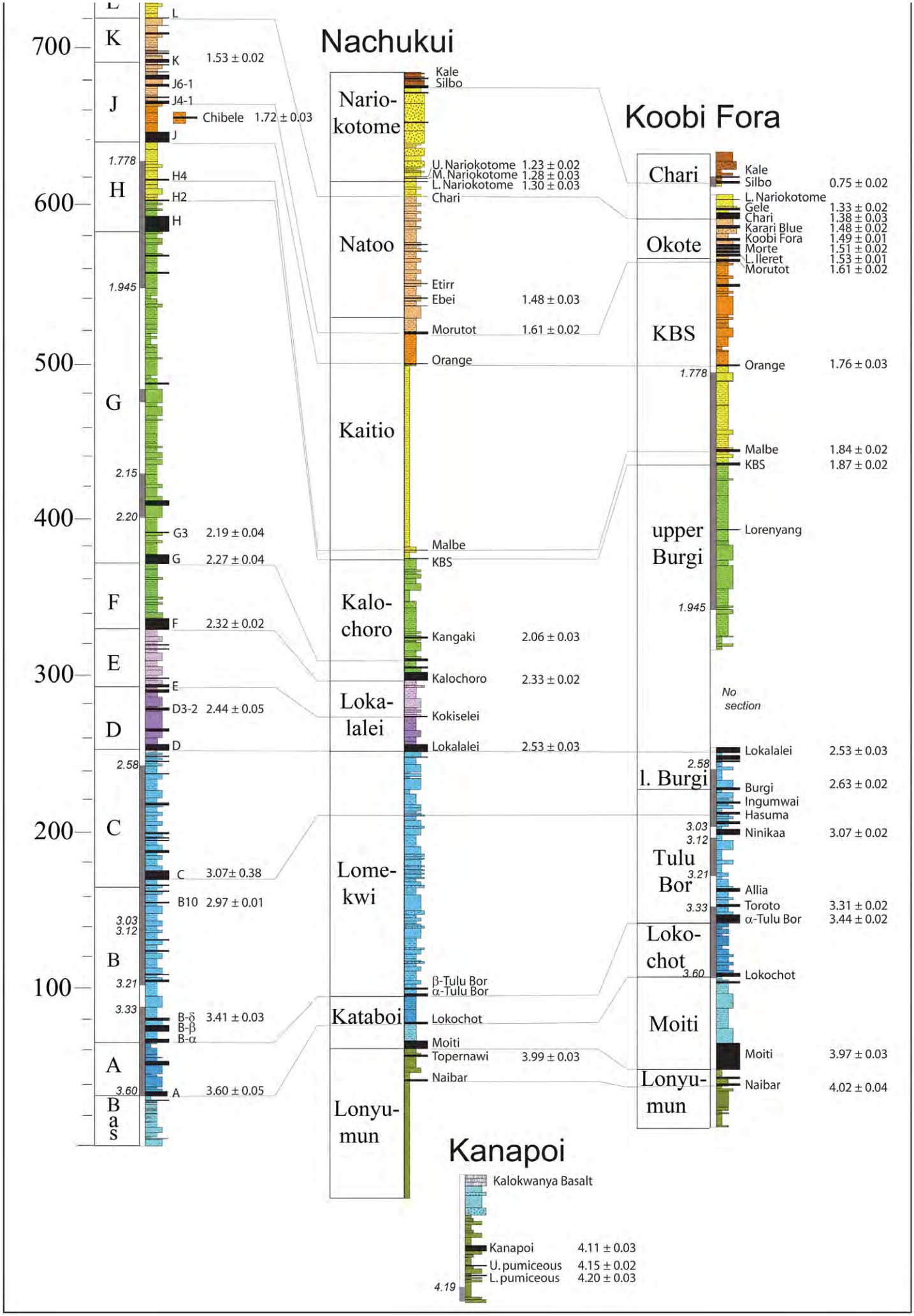
Recent dating of a further five rhyolitic tuffaceous beds in the University of Queensland on the Omo Group in the Omo-Turkana Basin in northern Kenya and southern Ethiopia by single crystal $^{40}Ar/^{39}Ar$ dating techniques on anorthoclase from pumice clasts has shown consistency between the new work and that done previously at ANU. The Omo Group constitutes up to 800 m of subaerially exposed sediments surrounding Lake Turkana within the East African Rift system in northern Kenya and southern Ethiopia (Figure 1). Rhyolitic explosive eruptions produced tuffs and pumice clasts that are considered to have been deposited shortly after eruption. Among other comparisons, new ages on two pumice clasts from the Burgi Tuff in the Koobi Fora Formation gave values of 2.64 ± 0.04 Ma (n = 16), where the error is the standard deviation of the population. This, together with previous measurements on single crystals of anorthoclase from six pumice clasts from the same unit at different localities measured previously at ANU, giving a mean age of 2.62 ± 0.03 Ma (n = 77), yield an overall mean of 2.63 ± 0.02 Ma, attesting to the consistency between the two laboratories. In the most recent work a number of significant gaps in the numerical time scale for the deposition of the Omo Group have been filled. Ages include 4.02 ± 0.02 Ma for the Naibar Tuff, low in the Koobi Fora Formation, 3.41 ± 0.03 Ma for Tuff B-delta in the Shungura Formation, shown to be the youngest tuff of the Tulu Bor Tuff complex, 2.27 ± 0.04 Ma for Tuff G in the Shungura Formation, 1.76 ± 0.03 Ma for the Orange Tuff, stratigraphically below the Morutot Tuff and above the Malbe and KBS tuffs in the Koobi Fora Formation, and 1.53 ± 0.02 Ma on anorthoclase from pumice clasts in Tuff K of the Shungura Formation. Previous studies indicated that deposition in the basin began at least 4.24 Ma ago and apart from absence of sediments between 0.7 and 0.2 Ma ago, there has been more or less continuous deposition since ~4.2 Ma. A major driving force for the detailed geochronology has been the recovery of numerous vertebrate fossils, including hominins. With current and new age control on more than 35 stratigraphic levels, remarkably consistent with the stratigraphic order, provided fossils can be placed relative to the known sequence of rhyolitic tuffs, then ages can be assigned to generally better than 0.1 Ma, without the need for further dating. Although our last assessment of the ages of hominin fossils was made in 1989, only a minority of adjustments greater than 0.1 Ma are required, including the age assigned to the hominid skull KNM ER 3733, regarded as one of the earliest known fossils assigned to *Homo erectus*, now thought to be 1.65 ± 0.05 Ma old. Numerical time scales of this kind are extremely useful as they allow ages to be placed on vertebrate fossils independently of assumptions as to their evolutionary origins, as well as calculation of rates of geological processes such as that of deposition, and correlations with the climatic cycles.

McDougall, I., Brown, F.H., Vasconcelos, P.M., Cohen, B. E., Thiede, D.S. and Buchanan, M.J. (2012). New single crystal 40Ar/39Ar ages improve timescale for deposition of the Omo Group, Omo-Turkana Basin, East Africa. Journal of the Geological Society, London. 169, 213-226.

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Koobi Fora
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J6-1
J4-1
Chibele 1.72 ± 0.03
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1.945
2.15
2.20
G3 2.19 ± 0.04
G 2.27 ± 0.04
F 2.32 ± 0.02
E
D3-2 2.44 ± 0.05
D
2.58
C 3.07± 0.38
B10 2.97 ± 0.01
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B-δ 3.41 ± 0.03
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Nario-kotome
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U. Nariokotome 1.23 ± 0.02
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Ebei 1.48 ± 0.03
Morutot 1.61 ± 0.02
Orange
Malbe
KBS
Kangaki 2.06 ± 0.03
Kalochoro 2.33 ± 0.02
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Lokalalei 2.53 ± 0.03
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Topernawi 3.99 ± 0.03
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Karari Blue 1.48 ± 0.02
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Orange 1.76 ± 0.03
Malbe 1.84 ± 0.02
KBS 1.87 ± 0.02
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Burgi 2.63 ± 0.02
Ingumwai
Hasuma
Ninikaa 3.07 ± 0.02
Allia
Toroto 3.31 ± 0.02
α-Tulu Bor 3.44 ± 0.02
Lokochot
Moiti 3.97 ± 0.03
Naibar 4.02 ± 0.04
Kalokwanya Basalt
Kanapoi 4.11 ± 0.03
U. pumiceous 4.15 ± 0.02
L. pumiceous 4.20 ± 0.03
4.19

Figure 1. Figure 1. Composite stratigraphic sections of the main formations of the Omo Group in the Omo-Turkana Basin, together with the results of $^{40}Ar/^{39}Ar$ dating of mainly single crystal anorthoclase from pumice clasts within tuffs, where the quoted error is the standard deviation of the population. The main tuffaceous beds are shown, often named, and correlations between the stratigraphic columns are indicated by linking lines. To the left of the stratigraphic columns for the Koobi Fora and Shungura formations are the measured magnetic polarities, where grey shading represents normal polarity and unshaded indicates reversed polarity. Ages assigned to the polarity boundaries are from Gradstein, Ogg and Smith (2004; A Geologic Time Scale 2004, Cambridge University Press, Cambridge, U.K.). For the dating, the Fish Canyon Tuff sanidine fluence monitor was assigned a reference age of 28.1 Ma.

Extra-terrestrial life probably like life on Earth

Charles H. Lineweaver and Aditya Chopra

Planetary Science Institute, a joint initiative of Research School of Earth Sciences and Research School of Astronomy and Astrophysics, Australian National University, Canberra, ACT 0200, Australia

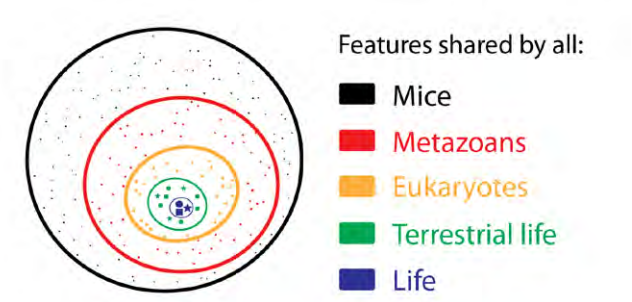

Figure 1. Of all the features in mice, only a small subset are shared by all metazoans (animals). An even smaller subset of features is shared by all eukaryotes and likewise by all life on Earth. Lineweaver and Chopra have identified some of the features (depicted here in blue) that are most likely to be shared by all life in universe.

When it comes to studying life 'out there', a lot can be learnt from life 'down here'.

In a effort to identify features of possible extraterrestrial life, astrobiologists Dr Charles Lineweaver and PhD Student Aditya Chopra at the Planetary Science Institute, have put together a list of features that are common to all life forms on Earth and hence are the most likely features of terrestrial life that could be shared by life elsewhere in the universe.

In a time when we are starting to find habitable planets beyond our Solar System and on the verge of visting sites within our solar system such as Mars and Jupiter's moon Europa to look for life, Dr Lineweaver says "it is necessary for us to consider what signs of life we should be looking for in these places... and what better place to guide our search than what we find at home."

Some of the most fundamental features of life on Earth are that all known life forms use liquid water as the solvent and carbon as the scaffold for biochemistry. All life forms also have a similar stoichiometry of the major bioelements such as nitrogen, phosphorus and sulphur. Lineweaver and Chopra's research suggests that despite the differences and peculiarities of all the different life forms on Earth, be it a tiny cyanobacterium or a shrew mouse, they are remarkably similar in their elemental composition. The authors suggest that the main reason for this similarity is that the composition of life reflects to a large extent the composition of the environment. Since water is the most abundance solvent and carbon is the most abundant element that can form complex biomolecules, not just on Earth but also across the universe, it is more likely that any extra-terrestrial life will also be based on carbon and water, rather than being based on silicon or ammonia-based biochemistry.

Other features that the authors have identified are common to life on Earth and hence likely to be universal include the LEGO principle, homochirality, harnessing free energy from thermodynamic disequilibria and the Darwinian evolution of inheritable molecules. By examining the earliest divergences of life on Earth, the authors also predict that the earliest life forms on other worlds would be hyperthermophilic or heat-loving.

Lineweaver and Chopra argue against expecting other frequently espoused candidate features of extra-terrestrial life such as multicellularity, sexual reproduction, and human-like intelligence because they are based on subjective notions of universal fitness.

To be published in Lineweaver, C. H., & Chopra, A. (2012). What can Life on Earth Tell Us about Life in the Universe? In J. Seckbach (Ed.), Genesis - In The Beginning: Precursors of Life, Chemical Models and Early Biological Evolution (p. 804). Springer. ISBN 978-94-007-2940-7.

Publications are avaliable for download on the author's website:

Charles Lineweaver's website
http://www.mso.anu.edu.au/~charley/publications.html

Aditya Chopra's website
http://www.mso.anu.edu.au/~aditya/

What makes our Earth habitable? Are there other habitable Earths in the Universe?

Charles H. Lineweaver and Aditya Chopra

Planetary Science Institute, a joint initiative of Research School of Earth Sciences and Research School of Astronomy and Astrophysics, Australian National University, Canberra, ACT 0200, Australia

As we get closer to finding planets beyond our solar system that are similar to Earth, we wonder if these extra-solar planets are habitable. Astrobiologists Dr Charles Lineweaver and PhD student Aditya Chopra at the Planetary Science Institute have examined what features of our own planet enabled the origin and evolution of life, and if these features are common elsewhere in the universe.

Figure 1. The green line around the planet represents the thin bioshell on Earth which is inhabitated by life. It ranges from ~10 km beneath the surface to ~ 10 km above the surface.

With the advent of instruments such as the space-based Kepler Telescope, we are on the verge of finding planets that are about the same size and mass as the Earth and in the 'habitable zone' of a star where it is possible for liquid water to be present on the surface. Would such a planet be sufficient to host life? Lineweaver says, "While liquid water is an important requirement for life, it is not the only constraint. On Earth, there are places where there is liquid water but without life." Lineweaver points out that if we are to seriously study habitability we need to consider the "astrophysical, geochemical, geophysical and biological limits on planet habitability."

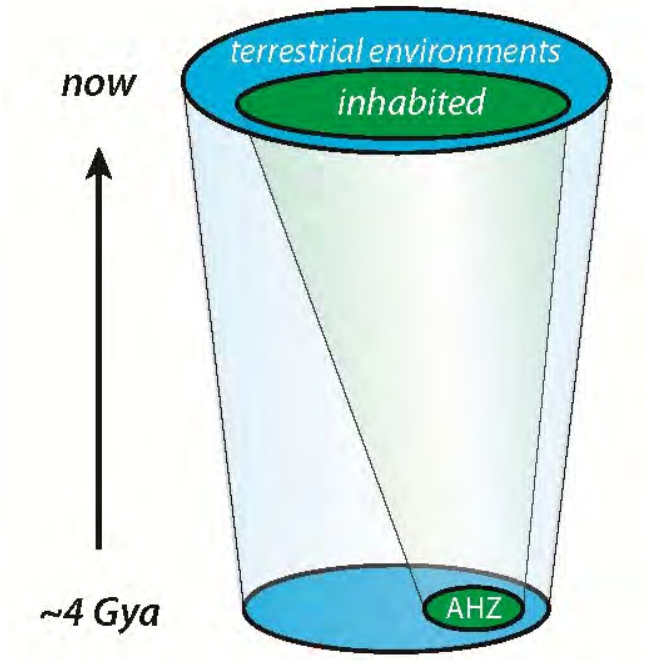

Figure 2. Abiogenesis Habitable Zone (AHZ). The conditions needed for the origin of life (before life could adapt) are narrower than the broader conditions to which life has adapted.

In order to quantify the habitability of Earth, the authors describe the profile of the 'bioshell' - the small part of our planet, which is inhabited by life. "People are familiar with the term biosphere. Here we have introduced the term bioshell to highlight the relative thinness of the sphere within which we live.", says co-author Chopra. "The thinness is even more apparent when one considers that until a billion years ago almost all of the biomass was within marine sediments and only since plants spread on land has half of the biomass been distributed above the sea-floor."

The notion of habitability is not restricted to the present day. "The habitability of planets can change over time.", Lineweaver says. Life and its environment co-evolve. Our planet transitioned from an uninhabited planet to an inhabited planet with life forms that continually modify the environment, for example by oxygenation of the atmosphere. The authors propose the dynamic concept of an 'Abiogenesis Habitable Zone' (AHZ, where life can get started) which then could transition into a 'Habitable Zone' and suspect there might be planets which might be habitable but because they were not within the AHZ at any time, they remained uninhabited.

Reviewing discoveries of exoplanets, Lineweaver and Chopra find that nearly all of stars have planets around them and that a large fraction of them will be habitable. The expectation that the universe is filled with habitable planets is based on the finding that the presence of liquid water and the temperature range (between -20°C and 120°C) are the two most important parameters controlling habitability - features that should not be unique to Earth.

In this invited paper for the 2012 Annual Reviews of Earth and Planetary Sciences, the authors have considered habitability from the view point of what energy sources power the simplest life forms to identifying the habitable and inhabited regions on Earth. Not limited by scale, they also discuss habitable zones around stars and within galaxies.

Describing the research, Lineweaver says that over the years he has seen a many factoids dispersed in the literature about life on Earth and exoplanets. In writing this review, "we have tried to take a comprehensive view of habitability."

To be published in Lineweaver C.H. and Chopra A. (2012) The Habitability of Our Earth and Other Earths: Astrophysical, Geochemical, Geophysical, and Biological Limits on Planet Habitability, Annual Review of Earth and Planetary Sciences, Vol. 40.

Publications are available for download on the author's website:

Charles Lineweaver's website
http://www.mso.anu.edu.au/~charley/publications.html

Aditya Chopra's website
http://www.mso.anu.edu.au/~aditya/

Research Activities 2012

Earth Environment

Introduction

In 2012, we welcomed three new staff members to the Earth Environment Area. Dr Jimin Yu joined us from the Lamont Doherty Observatory. He started working with Dr S. Eggins and Dr M. Ellwood to investigate new isotopic proxies to understand the links between climate change and ocean chemistry.

Dr Robert Strzepek joined us to work with Dr M. Ellwood on nutrient isotope fractionation in the Southern Ocean.

We were also very pleased to attract Prof Eelco Rohling, from University of Southampton, to our Area. He was awarded a prestigious Laureate Fellowship in 2012, which he will take up in early 2013. The Laureate Fellowship, and supporting funds from the Vice Chancellor, will allow Prof Rohling to set up new stable isotope laboratories and establish a large research group that will focus on sea-level change. I expect that the integration of our existing research in marine sciences with that of Prof Rohling will result in a world-leading research programme for ocean and climate change.

Four new PhD students joined Earth Environment in 2012: Ms Alena Kimbrough, to work under the supervision of Dr M. Gagan, Mr Anthony David, to work with Dr B. Opdyke, Ms Moneesha Samanta, with Dr M. Ellwood, and Mr Robert Burne, with Dr S. Eggins.

Two of our PhD students submitted their theses in 2012: Mr Kyle Horner, supervised by Dr D.C. McPhail, on new environmental tracer methods for quantifying solute sources in semi-arid alluvial aquifers, and Mr Nicolas Darrenougue, supervised by Prof P. De Deckker, on rhodoliths as environmental archives in the tropics.

ARC grants awarded for funding beginning in 2012 allow us to explore new, exciting avenues of environmental research. The grant success showcases the analytical capabilities of Earth Environment and the diverse applications and research interests that are pursued by Earth Environment staff members.

Dr David Heslop was funded to study sediments from the oceans around Australia to understand how the Earth's magnetic field was recorded. He will use this information to construct a new generation of computer models that will provide insights into the physics of the recording process. The research is underpinned by Prof A. Roberts's ARC grant to set up a world-class rock magnetic facility to support Australian palaeomagnetic and environmental research. Prof Bradley Pillans was successful with an ARC Linkage Grant for

exploring landscape evolution, environmental change and human occupation history at Lake George.

The outstanding quality of our students was perhaps best demonstrated by Ms Kelsie Long (Honours student) who was awarded the best student presentation prize at the Australian Archaeological Association meeting, and by Ms Rebecca Kaye (Honours) who was awarded the best student presentation at the ACT branch of the Australian Atmospheric and Oceanographic Society.

The high research profile of Earth Environment continues to be documented by the numerous publications in world leading journals such as Nature, Nature Geosciences, Proceedings of the National Academy of Sciences, Earth and Planetary Science Letters, Quaternary Science Reviews, and Palaeogeography, Palaeoclimatology, Palaeoecology. In 2012 Dr Marc Norman was appointed as Executive Editor for the world's leading geochemistry journal, Geochimica et Cosmochimica Acta.

One of the outstanding highlights of 2012 was the election of Prof Patrick De Deckker to the Academy of Science in May.

Earth Environment staff has been prominently involved in the RSES teaching activities in Earth and Marine sciences, as well as other undergraduate programs. The large number of students based in our Area documents their success.

None of our 2012 research activities were possible without our experienced and dedicated technical staff, Mr Joe Cali, Mrs Joan Cowley, Mr Les Kinsley, Mrs Linda McMorrow, Dr Graham Mortimer, Mrs Heather Scott-Gagan, and Mrs Judith Shelley. A number of casual staff have also assisted our research efforts. I am particularly grateful to our Area Administrator, Mrs Robyn Petch who continues to go the extra mile in managing our administration.

Professor Rainer Grün
Associate Director, Earth Environment

The IRHUM database - bioavailable strontium isotope ratios of France for geochemical fingerprinting

Malte Willmes[1], Ceridwen Boel[2], Ian Moffat [1], Rainer Grün [1], Richard Armstrong [1], Stephen Eggins[1], Les Kinsley[1], Linda McMorrow[1], Patrice Courtaud [4], Antoine Chancerel[3] and Bruno Maureille [4]

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Strontium isotope ratios ($^{87}Sr/^{86}Sr$) are a powerful geochemical tracer and are used in a wide range of fields including Archaeology, Forensic sciences, Palaeontology, Ecology, Soil and Food sciences. These applications are based on the principal that the strontium isotope ratios of a certain material will reflect the sources of strontium, which were available during its formation.

The IRHUM (isotopic reconstruction of human migration) database provides a reference of bioavailable strontium isotope ratios for France. It requires the Google Earth API to run and can be found at **-> www.rses.anu.edu.au/research-areas/archaeogeochemistry**.

The aim of the database is to allow easy access to our data and to provide spatial context for each sample. The current dataset contains 400 sample locations covering the major geologic units of the Paris and Aquitaine Basin, the Massif Central, and the Pyrenees. At each site rock, soil, and plant samples have been collected. The samples were analysed at the Environmental Geochemistry and Geochronology Laboratory at RSES using a Neptune Multicollector Inductively Coupled Plasma Mass Spectrometer (MC-ICP-MS). New results will be added to the database continuously with the aim of creating a reference map covering all major geologic units of France within the next 2 years.

Strontium isotopes as tool to investigate ancient human migrations

Humans and animals incorporate strontium from their diet into their bones and teeth. Tooth enamel contains strontium isotope signatures acquired during childhood and is most resistant to weathering and overprinting. The strontium isotope signature in bones on the other hand will reflect the average isotopic composition over the last ~10 years of the organism's life, due to the continuous biological remodelling of the bones. Thus, measuring the isotope ratios of human skeletal remains and comparing them to a strontium isotope reference map of the environment enables us to reconstruct human mobility across geologically different terrains.

Figure 1. Typical sample location in the Pyrenees Mountains. The plant, soil and rock samples were collected in close proximity to each other.

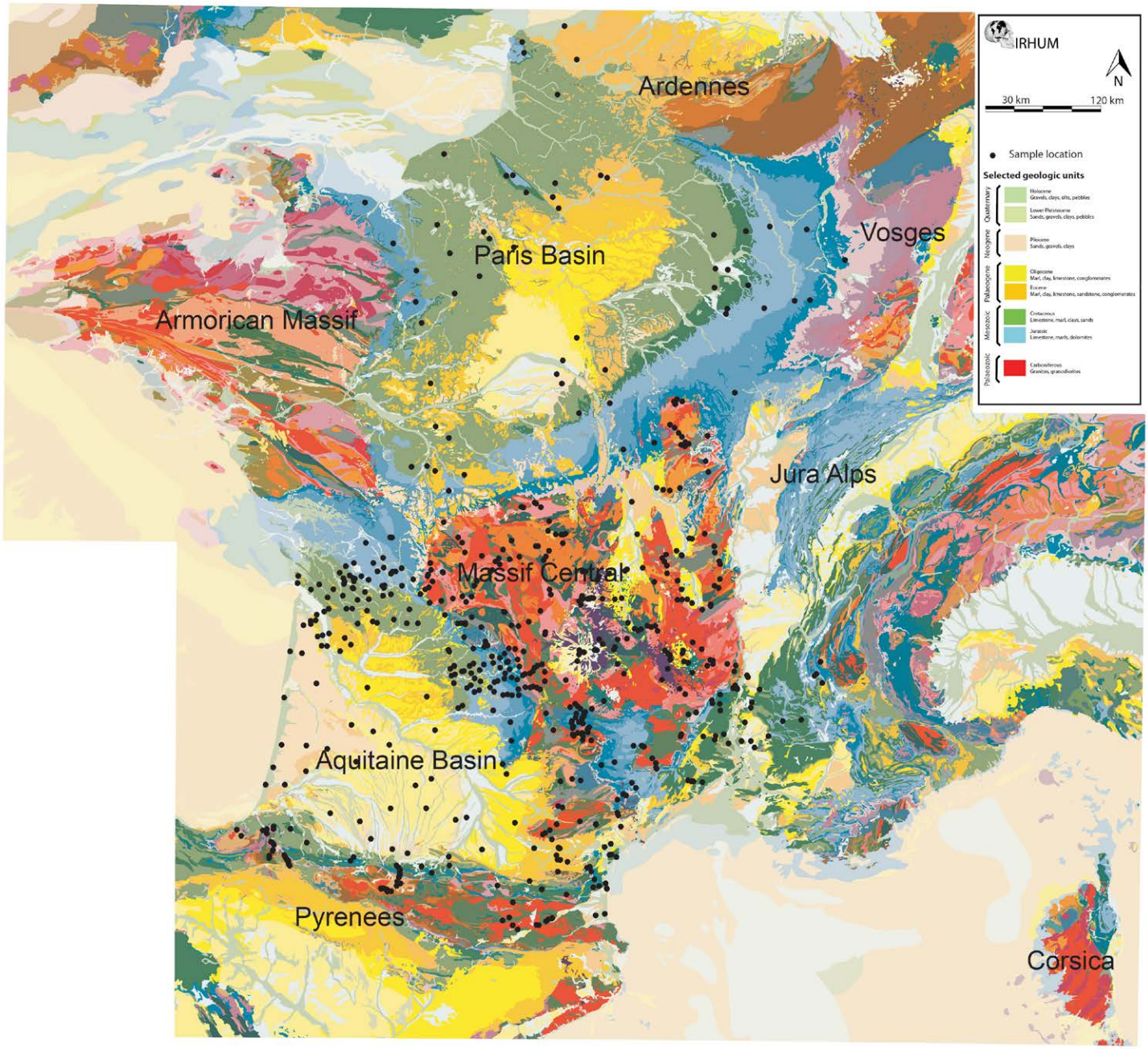

Figure 2. Geologic map of France with black spots marking the sample locations.

A 90,000-year record of vegetation change on Flores: A tale of survival and extinction for the Hobbit

Nick Scroxton[1], Mike Gagan[1], Linda Ayliffe[1], Ian Williams[1], Wahyoe Hantoro[2], John Hellstrom[3], Hai Cheng[4,5], Larry Edwards[5], Jian-xin Zhao[6], Heather Scott-Gagan[1], Joan Cowley[1], Hamdi Rifai[7] and Bambang Suwardgadi[2]

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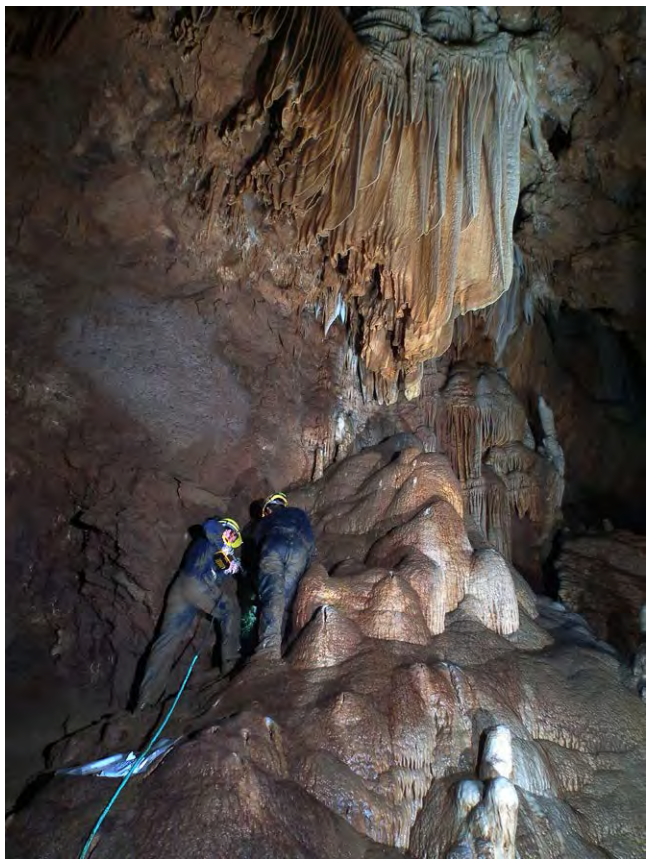

Figure 1. Figure 1: Nick Scroxton and Hamdi Rifai drilling a flowstone in Liang Luar Cave, Flores during 2011. Photo by Garry Smith

What killed off *Homo floresiensis*, aka "the Hobbit", some 17,000 years ago? Possibilities include a volcanic catastrophe, climate and environmental change, or even human activity. So far we have little information on the history of the island of Flores, Indonesia, the home of *H. floresiensis*. High-resolution palaeoclimate records such as those gained from speleothems may hold clues to the answer.

Oxygen isotopes ($\delta^{18}O$) have become an important palaeoclimate tool in the tropics, acting as palaeo-rain gauges (e.g. *Wang et al. 2001, Griffiths et al. 2009*). These have revealed changes in climate, at multiple time-scales, across the tropics. However the records do not reveal the impacts of climate changes have on the environment. Carbon isotopes ($\delta^{13}C$) in speleothems serve as a proxy for vegetation type and activity above the cave site, and may well be the proxy that fills this gap, revealing the ecological consequences to climate change.

Our speleothem $\delta^{13}C$ record for western Flores consists of a 50-year resolution, time-averaged analysis of thirteen speleothems (stalagmites and flowstones) from Liang Luar cave, a site perfectly located to record changes in the southern extent of the East Asian/Indo-Australian monsoon system. Six of the speleothem time-series are new and unpublished, including all of the record before 30 kyr BP (thousand years before present).

For most of the record, the $\delta^{13}C$ correlates well with its companion $\delta^{18}O$ record. This indicates that vegetation largely tracks the changing rainfall over Flores (see Gagan et al. 2012 RSES Research Highlight). $\delta^{13}C$-excursions from the $\delta^{18}O$ record indicate times when vegetation deviates from the climatic forcing. This could be due to volcanic eruptions, changes in the source water $\delta^{18}O$ composition unrelated to variations in rainfall amount, or due to human impacts, such as the clearance of forest above the cave to make way for agriculture.

The most striking excursion occurs at ~69 kyr BP when an 8‰ shift increases the $\delta^{13}C$ values to near 0‰. This could represent a substantial reduction of vegetation cover and subsequent recording of bedrock values, or it may indicate a shift to vegetation that uses the C4 photosynthetic pathway. E.g. grasses and a drier savannah type environment, as compared to the tropical woodland of today. The 7,000 year length of the excursion could indicate vegetation collapse followed by recolonisation by C4 vegetation.

Correlation of the $\delta^{13}C$ signal with anomalously high sulphur concentrations in the stalagmite suggests a volcanic eruption may have been the cause of this large and lengthy excursion (see. Scroxton et al.

2011 RSES Research Highlight).

The speleothem $d^{13}C$ record has profound implications for the survival and extinction of *Homo floresiensis*. The $d^{13}C$ record indicates that *H. floresiensis* was remarkably adaptable, given that it somehow survived a major environmental shift during a prominent occupation phase of Liang Bua between 74 and 61 kyr BP (*Westaway et al. 2009*). In contrast, the $d^{13}C$ record shows that environmental conditions were relatively stable during the Hobbit extinction interval on Flores around 17-10 kyr BP (*Roberts et al. 2009*). Our findings bring to the fore the possibility of a human role in the surprisingly recent demise of *H. floresiensis*.

This research is supported by Australian Research Council Discovery grants DP0663274 to M.G., J.-x.,Z., and W.H. and DP1095673 to M.G., J.H., W.H., L.E. and H.C.

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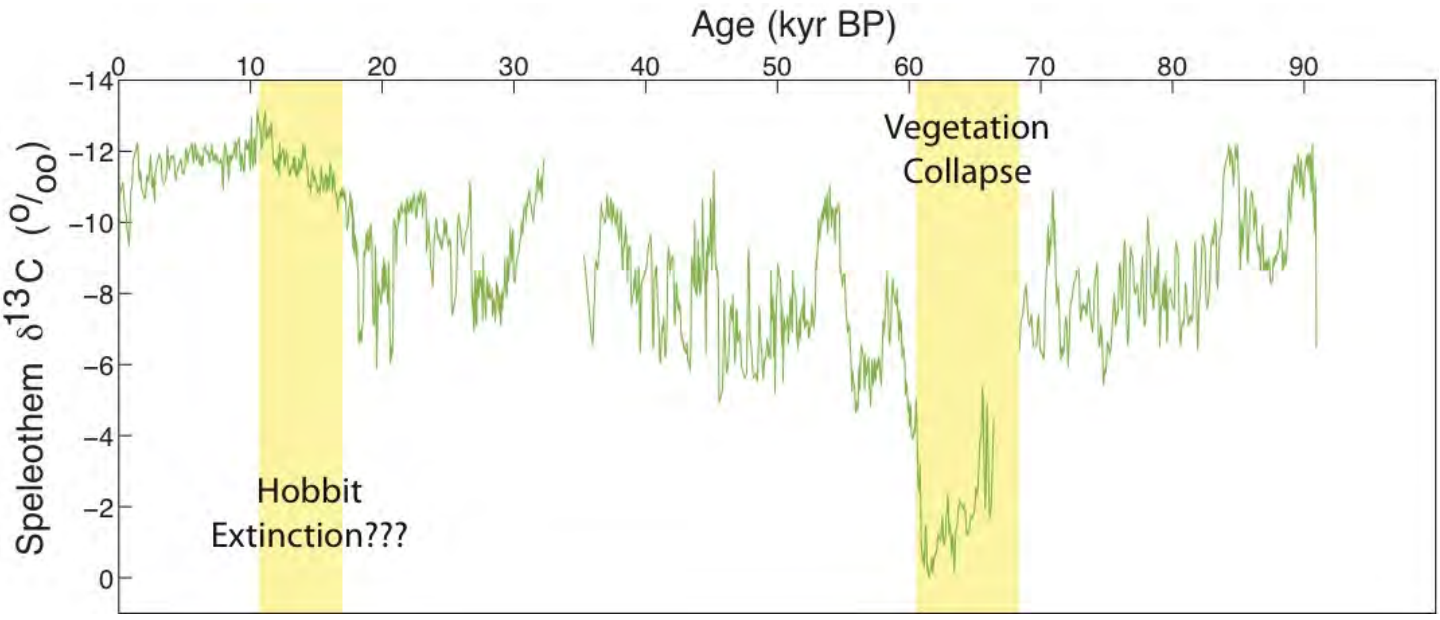

Figure 2. Figure 2: The Flores speleothem composite carbon isotope record. Highlighted areas indicate the vegetation collapse beginning at ~69kyr BP and the Hobbit extinction interval. The Hobbit extinction interval is taken as being between 17.1 and 10.2kyr BP, determined from dates of volcanic units bracketing the *Homo floresiensis* remains in Liang Bua (Roberts et al. 2009).

The significance of recent Antarctic Peninsula warming documented by a Holocene ice core record

Nerilie Abram[1] and Robert Mulvaney[2]

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Analysis of the first ice core record from the Antarctic Peninsula spanning the whole of the Holocene interval has shed new light on the significance of recent rapid warming on the Antarctic Peninsula.

Over the last 50 years, the rate of warming on the Antarctic Peninsula has been the fastest of anywhere in the Southern Hemisphere, and this rapid warming has been implicated in the collapse of ice shelves and accelerated glacier mass loss across the region. New ice core research has now been able to put these short observational records of Antarctic Peninsula climate change into a geological perspective.

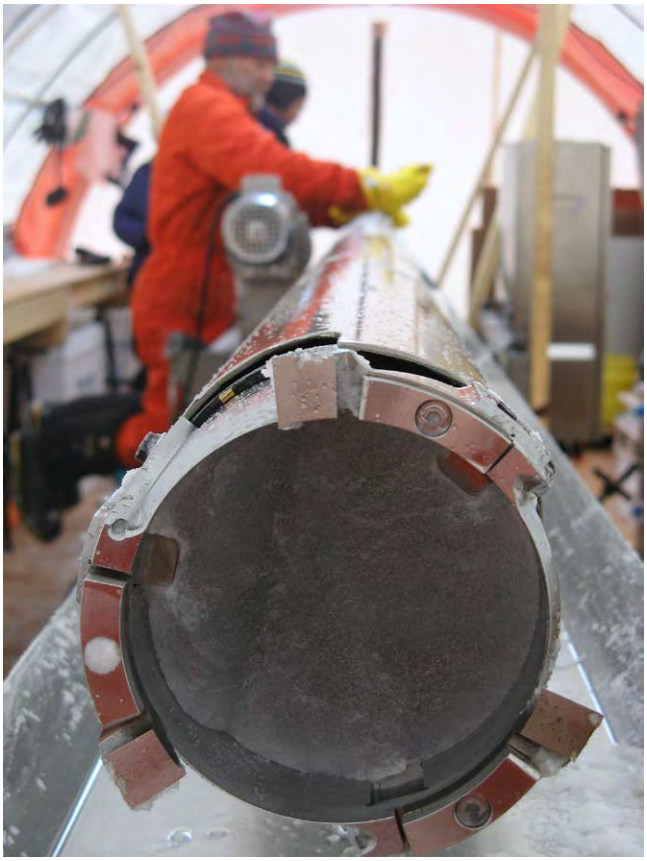

Figure 1. The 364m long ice core was drilled on the summit of James Ross Island by a team of 7 scientists and engineers. Photo credit: Nerilie Abram.

Using water isotopes in the ice core, it was found that warming of the Antarctic Peninsula began around 600 years ago (Mulvaney et al., 2012; Abram et al., submitted). Although the mean temperatures experienced on the Antarctic Peninsula over recent decades are not unprecedented, the rapid rate of warming over the last century is highly unusual and is in the upper 0.3% of all century-scale trends over the last 2000 years.

Comparison of the Holocene temperature reconstruction with records of ice shelf presence along the northeastern Antarctic Peninsula, shows that there has been a strong connection between past atmospheric temperature and ice-shelf stability. If warming of the Antarctic Peninsula continues then it is likely that ice-shelf vulnerability will encroach farther southward to affect ice shelves that have been stable throughout the Holocene.

Acknowledgements

Nerilie Abram is supported by a Queen Elizabeth II fellowship awarded by the Australian Research Council under Discovery Grant DP110101161

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Figure 2. The logistics for the ice core drilling campaign, which involved transporting more than 8 tonnes of equipment to and from the site, were provided by the British Antarctic Survey and the British Royal Navy ship HMS Endurance. Photo credit: Robert Mulvaney.

Mg/Ca as a temperature record in the shell of Sydney Rock Oysters.

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Oyster shells are made up of calcium carbonate, which forms layers as the oyster grows. Other elements, such as Mg, can also be incorporated into the shell in trace amounts. In many other biogenic carbonates (calcium carbonate that is produced by an animal to make their shell or skeleton) Mg incorporation is dependent upon temperature, so analysis of the Mg/Ca in these carbonates provides a temperature record for when that animal grew.

We wanted to check if this Mg/Ca-temperature relationship holds true for oysters. We grew Sydney Rock oysters (*Saccostrea glomerata*) on the south coast of New South Wales and southeast Queensland for one year, measuring water temperature continuously. We then measured the Mg/Ca of the oyster shells and found that the Mg/Ca of the incremental oyster shell layers does indeed track the temperature of the water over time.

Figure 1. Sydney Rock oyster (*Saccostrea glomerata*)

We also analysed shells that were around 1600 years old from an Aboriginal midden site in southeast Queensland. The Mg/Ca from these shells indicates average annual temperatures when these shells grew were around 3ºC cooler than modern temperatures.

Advances in the Understanding of Pre-Salt Carbonate Reservoirs of Offshore Brazil and Angola from Studies of Australian Lakes.

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Figure 1. Section through carbonate crust from Lake Preston showing tufa and/or microbialitic leiolite structures

Since the introduction of the term "Microbialite" to biogeology 25 years ago (Burne & Moore 1987) there have been great advances in understanding of the mineralization, morphogenesis, ecological setting and facies distribution of both ancient and modern microbialites. The discovery of extensive hydrocarbon accumulations in carbonate reservoirs described as "Microbialites" in palaeo-lacustrine environments in pre-salt proto-Atlantic sag and rift basins offshore of Brazil (Henry 2009, Beasley et al. 2010, Correa 2012), and Angola (Wasson et al 2012) have given fresh impetus to this research (e.g. Wright 2012). These highly prospective Cretaceous basins formed during separation of Africa and South America in the Neocomiam, Barremian and early Aptian (Reston 2009). Research at ANU is currently reassessing the significance of the "Microbialite" concept in the light of recent studies of material from the important Atlantic pre-salt reservoirs. Early interpretations for the depositional environments of these reservoirs drew parallels with the famous modern occurrence of microbialites in the hypersaline marine basin of Hamelin Pool (Figure 2), in Shark Bay, Western Australia (Corrêa 2012, Jahnert & Collins 2012). However Dorobeck et al (2012) concluded that in some pre-salt reservoirs microbes may not have been essential for mediating carbonate precipitation and they were rather formed from primary aragonite and dolomite precipitated both on the floor of the pre-salt lakes, as well as *within* previously deposited sediment by displacive crystal growth,. The extensive experience of petroleum exploration world-wide has led to the establishment of knowledge bases that draw on the amassed information from sedimentological analogues to model likely distributions and characteristics of reservoir lithologies in a prospective basin (e.g. Dewever 2012, Griffiths et al. 2012). Wright (2012) has pointed out that Facies models for lacustrine carbonates do not currently incorporate the diversity of microbialite carbonate development or the influence of volcanic related processes found in rift settings. We are currently examining microbialites, ooids, spherulites and tufa deposits from a number of Australian lakes to attempt to provide more comprehensive models for petroleum-bearing sequences that contain these important carbonate lithologies. In Hamelin Pool hypersaline conditions have led to and association of oolitic and bioclastic carbonate sands, subtidal stromatolites and thrombolites, microbial organic ooze, and coquina beach ridges (Burne 1992, Burne & Johnson 2012). Post-mortem mineralization of organic substrates and bio-micritisation of carbonate grains are especially significant in Hamelin Pool microbialites, and also seem to have been important in the Buntsandstein association of stromatolites and oolites described by Kalkowsky (1908). However, Descriptions of Brazilian pre-salt reservoir lithologies (Terra et al, 2009-2010) reveal many parallels with both non-marine lacustrine microbialites and travertines forming in Australian lakes but show that Hamelin Pool does not provide appropriate analogues for most pre-salt reservoirs. In Lake Clifton the establishment of hyposaline conditions after the isolation of a marine embayment led to the evolution of thrombolites and lacustrine carbonate silts and sands In Lake Preston extensive carbonate pavements and are being studied to examine the relationship between tufa and leiolites (Figure 1). The interesting occurrences of microbial carbonates in the alkaline lakes associated with craters of extinct volcanoes in South Australia and western Victoria represent a rather different environment that has some close parallels with the palaeogeographic setting of some of the pre-salt reservoirs. These studies will help to address the key question of the relative roles of biogenic versus abiogenic mineralization in microbialites and tufa deposits.

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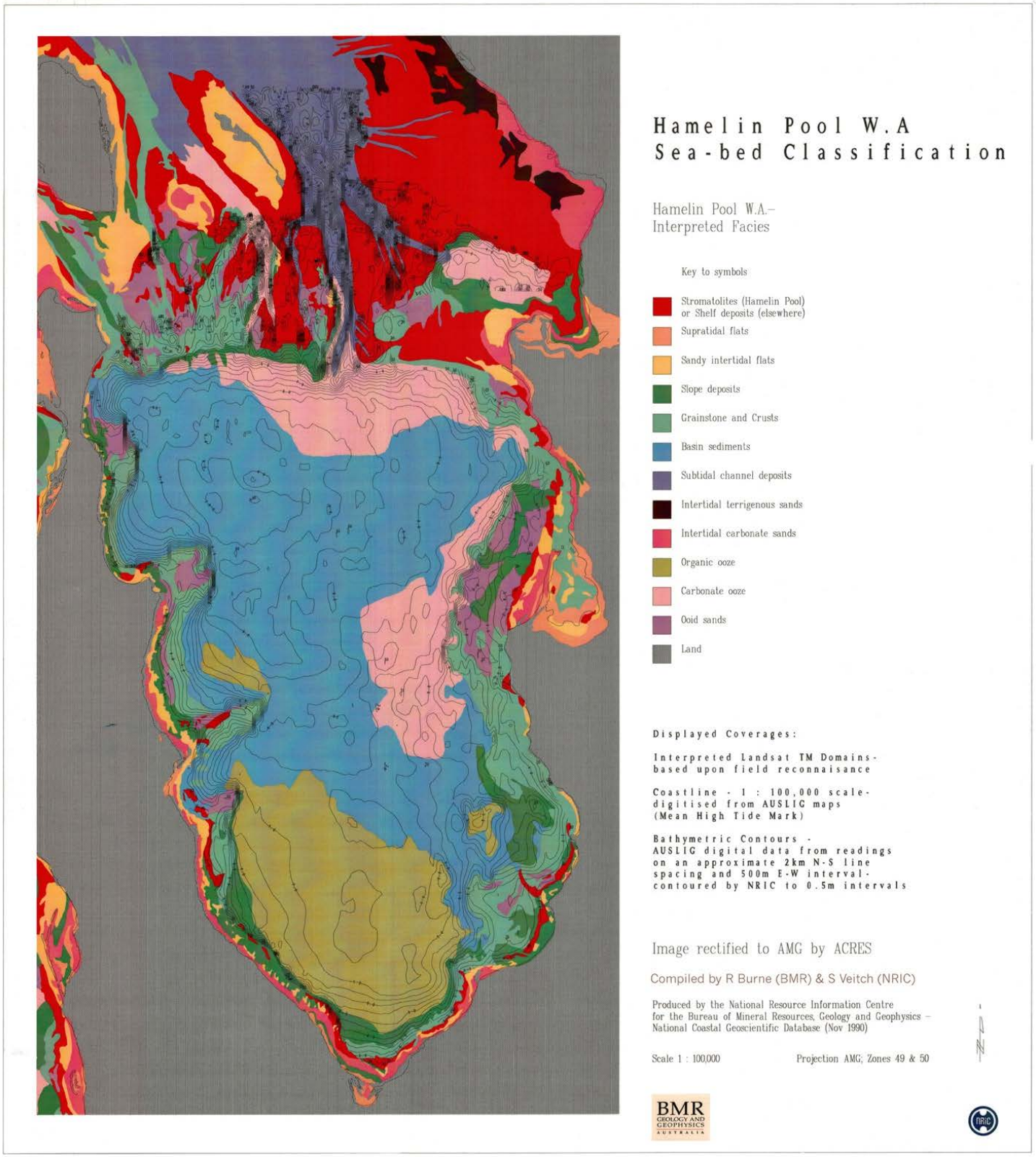

Figure 2. Bathymetry & Sea-Bed Classification of Hamelin Pool, Shark Bay. Previously unpublished coverage by Burne and Veitch.

Changes in the Australian-Indonesian Summer Monsoon throughout Glacial Terminations III and II

Alena Kimbrough[1], Michael K. Gagan[1], Wahyoe S. Hantoro[2], Hai Cheng[3,4], John C. Hellstrom[5], R. Lawrence Edwards[4], Gavin B. Dunbar[6] and Hamdi Rifai[7]

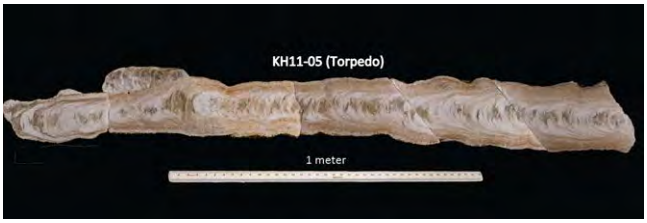

Figure 1. A 1.93 m long stalagmite collected from Sulawesi, Indonesia in 2011. Preliminary U/Th dates suggest this formation extends back to 272,000 years B.P.

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Speleothems are calcium carbonate cave deposits. These formations are capable of providing information of Earth's past climate and environment within their geochemical signals. In the tropics, variations in the oxygen isotope ratios ($\delta^{18}O$) within these formations are interpreted to reflect changes in rainfall amount. This work will present the first speleothem $\delta^{18}O$ record from southwest Sulawesi, Indonesia that extends back to 272,000 years B.P. These tropical terrestrial records provide insight to the mechanisms controlling variability of the Australian-Indonesian Summer Monsoon (AISM) throughout the third and second most recent glacial terminations. Currently, there is insufficient data from the Southern Hemisphere tropics to fully understand the behavior of tropical monsoon systems and Intertropical Convergence Zone (ITCZ) migration over long timescales. Key records document the Northern Hemisphere Asian Monsoon (AM) over this time frame (Kelly et al., 2006; Wang et al., 2008; Cheng et al., 2009) and a new record for northern Borneo has documented interglacial hydroclimate over the last ~500,000 years B.P. (Meckler et al., 2012). These records, together with the new record for Sulawesi, serve to unravel ocean and atmosphere dynamics influencing tropical monsoon intensity and ITCZ migration during times when Earth's climate was warming rapidly.

Initial analysis of $\delta^{18}O$ in the Sulawesi stalagmites suggests a prominent north-south antiphasing of the AISM and AM systems following glacial termination III (227,000-206,000 years B.P.). Where overlap occurs, the Sulawesi record is mostly in-phase with the Borneo record throughout termination III. These results support previous proposals that the AISM and ITCZ positioning are influenced by climate change in the North Atlantic region. At least three speleothems will be analyzed from Sulawesi. We aim for all three records to have periods of overlap and, combined, span glacial terminations III and II. Additional goals for this project include investigating the role of the tropics in driving ice age terminations and the degree to which eustatic sea-level-rise and flooding of the Sunda Shelf influences AISM rainfall intensity throughout glacial-interglacial cycles.

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Chinese, Borneo, and Sulawesi Speleothem d18O Records: Spanning the last 600,000 years

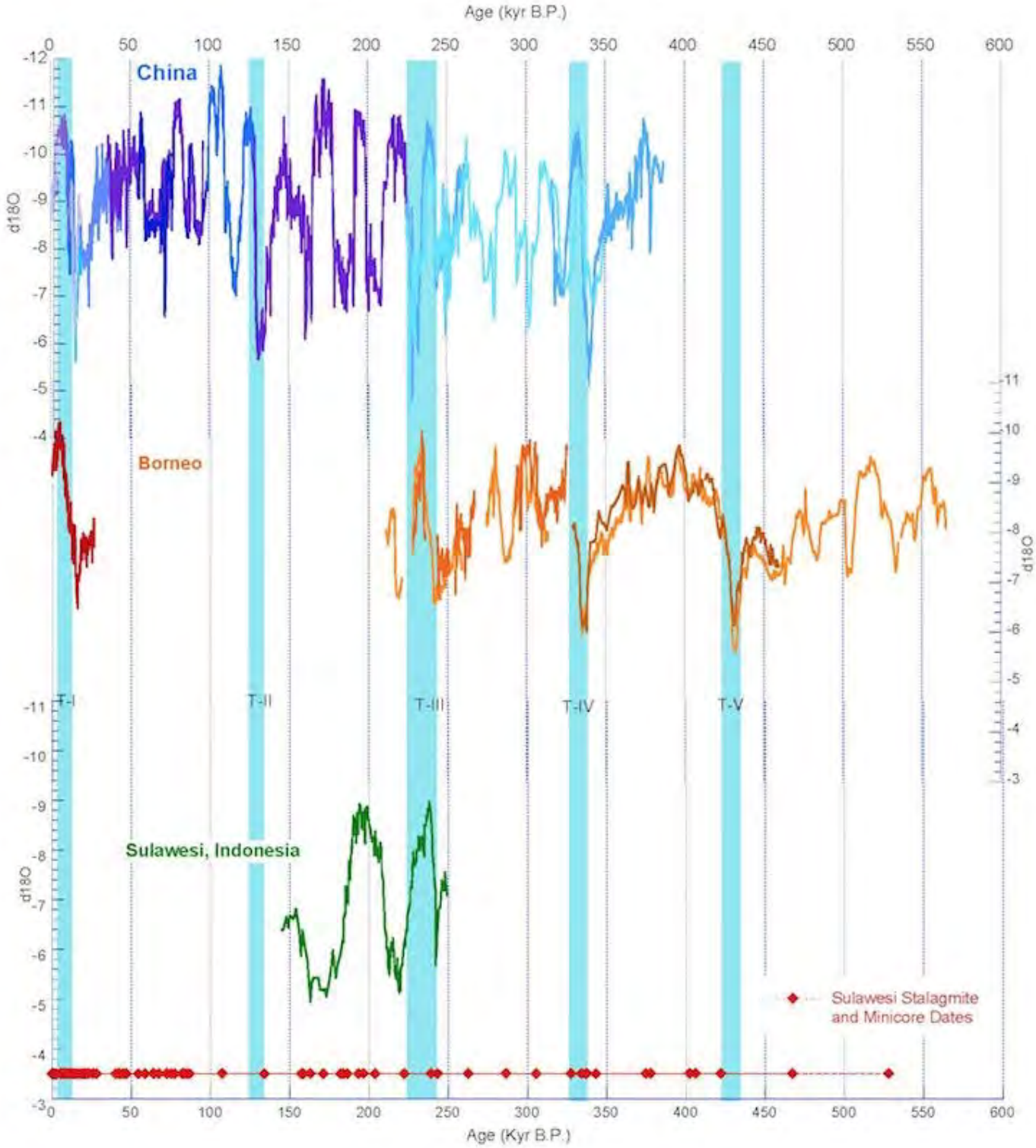

Figure 2. Preliminary Oxygen Isotope (δ18O) data for a Sulawesi stalagmite KH11-03 (green) compared with the Borneo (orange/red) (Partin et al., 2007; Meckler et al., 2012) and China (blue/purple) (Kelly et al., 2006; Wang et al., 2008; Cheng et al., 2009) composite stalagmite δ18O records. Blue shaded bars indicate glacial terminations, T-I through T-V. The red dots signify ages of mini-core and stalagmite material collected from Sulawesi.

Predicting palaeoprecipitation from the magnetic properties of soils

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Quantitative predictions of past climates are key to the reconstruction of palaeoenvironments and are essential for climate model validation. Iron oxide nanoparticles form as a by-product of the pedogenic processes that occur during soil formation. These particles reflect the environmental conditions under which soil formation took place and can be quantified using standard rock magnetic measurements. Numerous quantitative predictions of past climates have been based on soil magnetic mineral assemblages. For example, detailed time series of Quaternary mean annual precipitation and palaeoprecipitation gradients across wide geographic regions have been predicted from the rock magnetic properties of Chinese loess and palaeosols (Maher and Thompson, 1995). However, little attention has been given to estimating the uncertainties associated with such empirical rock magnetic climofunctions and the predictions they make (Figure 1).

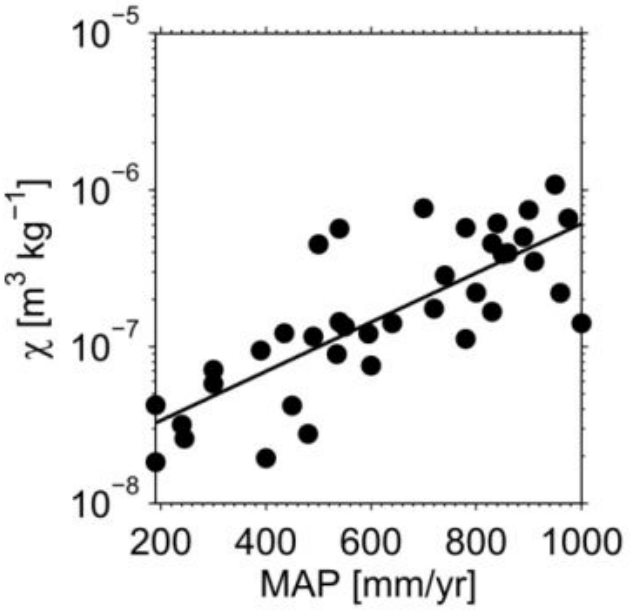

Figure 1. The regression-based climofunction of Balsam *et al.* (2011) relates modern mean annual precipitation (MAP) to the magnetic susceptibility (χ) of African soils. When this relationship is inverted and used as a climofunction, what are the errors on predictions of MAP based on χ?

We have performed a retrospective error analysis on an ensemble of published climofunctions that were previously employed to predict past rainfall levels from a variety of soils on different continents. Based on our analysis we can now assign uncertainties to a number of the palaeoprecipitation predictions published in the literature. We find that existing climofunctions have associated uncertainties that are so large their resulting predictions are effectively invalid. Thus, current palaeoprecipitation reconstructions must be treated with extreme caution.

Our findings suggest that future climofunctions should incorporate more geological considerations. By taking into account both empirical and theoretical models of soil development, smaller uncertainties can be achieved by the construction of physically-constrained climofunctions.

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Influence of the Indo Pacific Warm Pool on the interhemispheric climatic asymmetry during the last glacial

A record of the Leeuwin Current offshore South Australia spanning the last 40,000 years

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The history of oceanic changes offshore southern Australia sheds new light on the functioning of global climate changes. For quite some time, scientists have recognised that, over the last 45,000 years or so, there has been a climate antiphase, whereas when the northern hemisphere is warm, the southern is cold and *vice versa*. This has been referred to as the **bipolar seesaw.** The common consensus, for many decades, has been that the north Atlantic region has been the main driver of climate change of global implication.

We studied a deep-sea core located offshore Kangaroo Island (Fig. 1). The core site lies below the pathway of the Leeuwin Current, a warm current that originates in the tropics [often referred to as the Warm Pool] and offshore northwestern Western Australia. The Warm Pool is often called the 'heat engine of the world' because there is a large exchange of heat and moisture between the oceans and the atmosphere. Tropical microscopic planktonic foraminifers [= calcareous microfossils living in the upper water column] are transported by the Leeuwin Current as far as southern Australia when the current is strong, such as is the case this year, being a strong La Niña event.

We found that in the past, at millennial scales, when the Leeuwin Current was strong offshore southern Australia [recognized by the remains of the tropical microfossils such as *Globigerinoides ruber* found in the core – see Fig. 2], the northern hemisphere experienced very cold phases, exemplified by large releases of icebergs in the northern Atlantic Ocean. Implications are those findings are that offshoots of the Warm Pool and the Leeuwin Current warm waters would have also traveled as far as the east coast of Africa, circumnavigated the Cape of South Africa and consequently entered the Atlantic Ocean, at a time when the westerly wind belt had weakened. In parallel, the oceanic Subtropical Front that could prevent the Leeuwin Current from turning around Cape Leeuwin at the southern tip of Western Australia was positioned further south. Such a shift would also have occurred offshore the Cape Peninsula of South Africa. This warm water would have interfered with oceanic circulation in the Atlantic and may have caused disruptions that engendered cold conditions in the north.

The new research findings highlight that the region north of Australia is linked with broad climatic changes that non only affected oceanic circulation offshore western and southern Australia, but extended as far as the northern Atlantic Ocean, with global implications.

Findings were published in *Nature Geoscience* 5, 266-269 [2012].

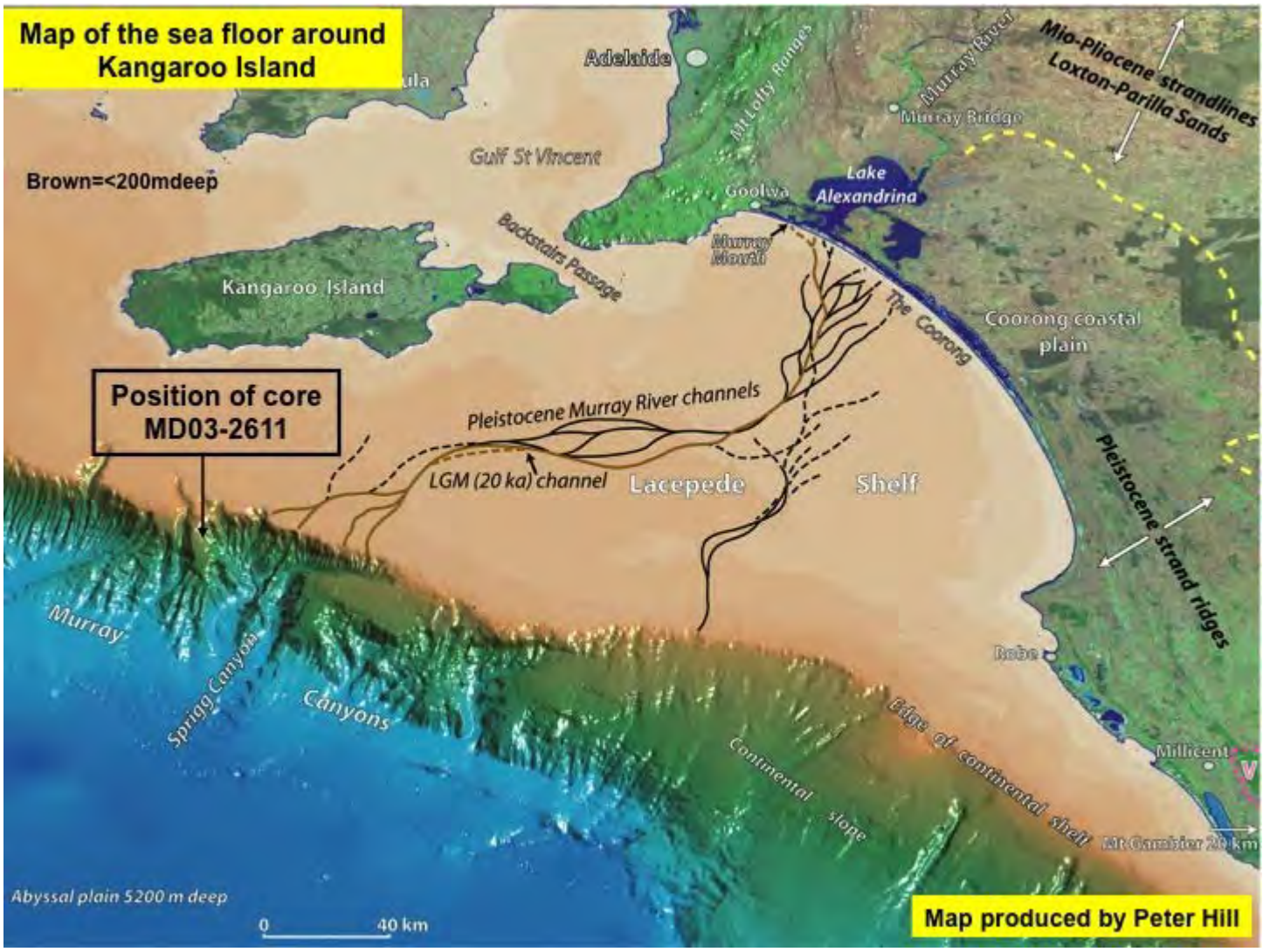

Figure 1. Location of the core mentioned here that is located offshore Kangaroo Island, adjacent to the Murray Canyons.

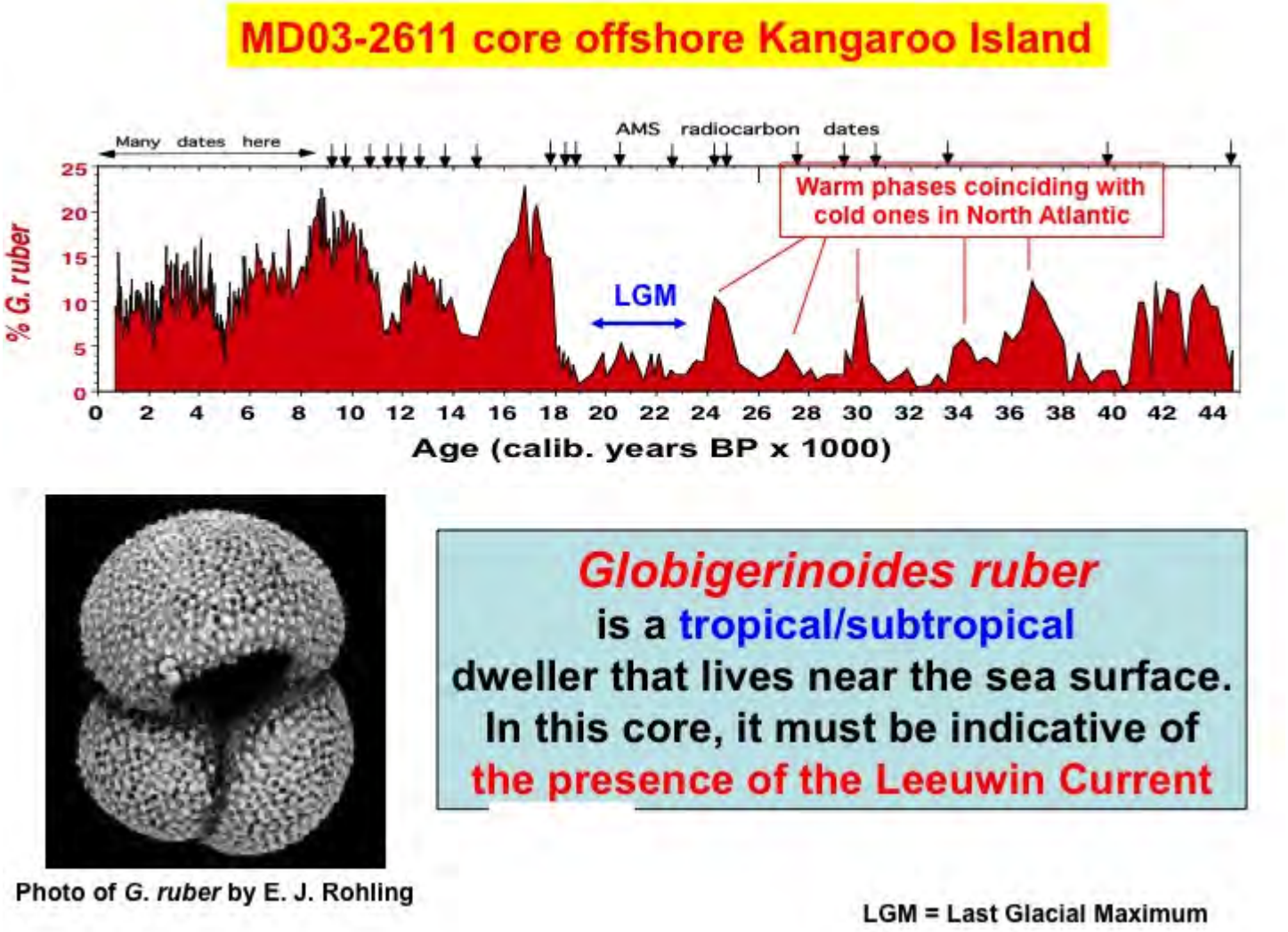

Figure 2. The 45ka record of core MD03-2611 showing the percentages of the near-surface dweller foraminifer *Globigerinoides ruber* which are indicative of the presence of the Leeuwin Current [warm subtropical water] above the core site. We found that in the past, at millennial scales, when the Leeuwin Current was strong offshore southern Australia [recognized by the presence of *G. ruber* in the core], the northern hemisphere experienced very cold phases, exemplified by large releases of icebergs in the northern Atlantic Ocean. The position of the radiocarbon dates in the core obtained from planktic foraminifers is presented at the top.

History in the making: A 90,000-year record of the Australasian monsoon

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Figure 1. The 2006 expedition team in Liang Luar cave, west Flores, Indonesia. Photo credit: Garry Smith.

Stalagmite oxygen-isotope ($^{18}O/^{16}O$) records from China and Borneo have revealed changes in Asian monsoon rainfall over glacial-interglacial cycles (e.g. Wang et al. 2008, Cheng et al. 2010, Meckler et al. 2012), yet little is known about orbital- and millennial-scale climate change in the 'southern half' of the Australasian monsoon domain. To fill this gap, we aim to build stalagmite $^{18}O/^{16}O$ records for the seasonal monsoon rainfall belt of south-central Indonesia. We have completed four expeditions to Liang Luar cave on the island of Flores (Figure 1) and are currently analysing $^{18}O/^{16}O$ and carbon-isotope ratios ($^{13}C/^{12}C$) in stalagmites with U-series ages extending to ~90,000 yBP.

The new Flores $^{18}O/^{16}O$ records for ~90,000 to 35,000 yBP (analysed in 2012) serve to complete the first high-resolution, absolute-dated Late Pleistocene history of rainfall variability across the entire Australasian monsoon system. There is clear (but non-linear) antiphasing of the Flores and China (Hulu/Sanbao caves) stalagmite $^{18}O/^{16}O$ records on precession time-scales over the last ~90,000 years (Figure 2). A strong synchronous climate shift marks the onset of Marine Isotope Stage 3 ~60,000 yBP (drier Flores, wetter China) and heralds the driest 30,000-year interval on Flores. A distinct monsoon rainfall maximum on Flores ~21,000 yBP suggests the intertropical convergence zone (ITCZ) moved southward during the Last Glacial Maximum in response to the southern hemisphere summer insolation maximum at that time (Ayliffe et al., submitted).

Interestingly, the largest $^{13}C/^{12}C$ anomaly for the last ~90,000 years on Flores begins at ~70,000 yBP in the absence of any clear climate forcing (record not shown). The ~4,000-year-long $^{13}C/^{12}C$ signal is under investigation, but probably reflects catastrophic vegetation collapse in the aftermath of a massive volcanic eruption (See Scroxton et al. 2012 RSES Research Highlight).

Targeted U-series dating of the new Flores stalagmite $^{18}O/^{16}O$ record is in progress, but it already shows that Australasian monsoon rainfall and climate change in the North Atlantic region are inextricably linked on millennial timescales (e.g. Griffiths et al. 2009, Lewis et al. 2011). For example, cooling in the North Atlantic region during Heinrich Event 1 (~16,000 yBP) and the Younger Dryas (~12,000 yBP) correlates with a southward shift of the Australasian ITCZ and increased rainfall in Flores. There are still small gaps in the Flores record around Heinrich events 2 and 3, but a similar antiphased monsoon response is evident around Heinrich events 4, 5 and 6 (~38,000 yBP, ~48,000 yBP, ~61,000 yBP), and during other less distinctive intervals.

Our findings indicate that millennial-scale changes in ITCZ positioning in tropical Australasia, through

their influence on large-scale oceanic-atmospheric circulation, could have played a key role in the rise of atmospheric CO_2 and global warming that ultimately led to the demise of the last ice age, as summarised by Denton et al. (2010) and others.

This research is supported by Australian Research Council *Discovery* grants DP0663274 to M.G., J.-x.,Z., R.D. and W.H. and DP1095673 to M.G., R.D., J.H., W.H., L.E. and H.C.

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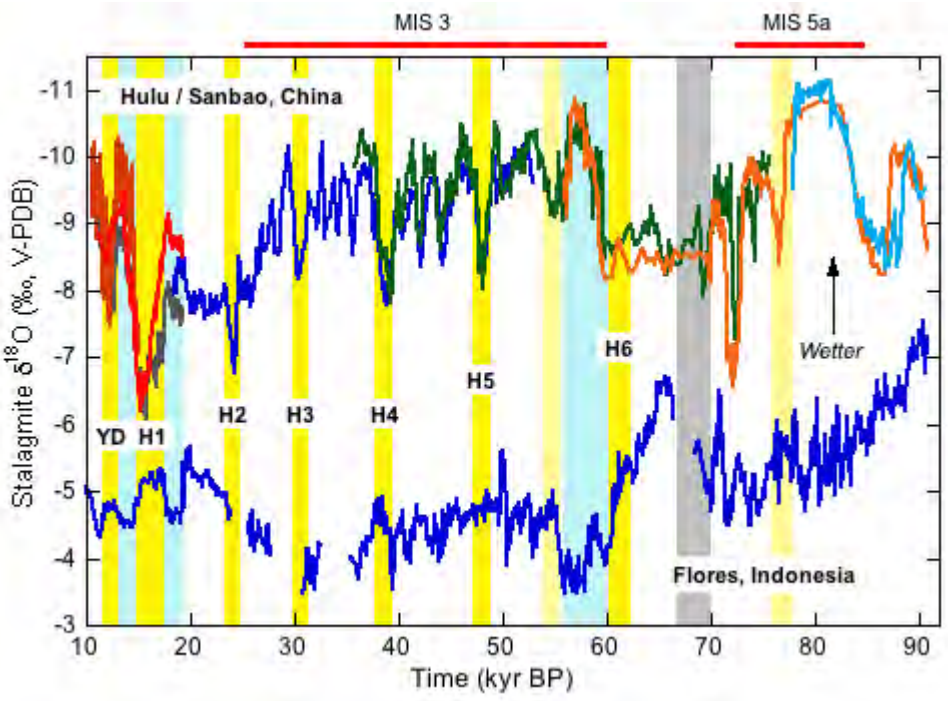

Figure 2. Comparison of stalagmite $\delta^{18}O$ records for Liang Luar, Flores (blue) and Hulu / Sanbao, China from ~90,000 to 10,000 kyr BP (kyr BP, thousand years before the present). The Liang Luar $\delta^{18}O$ record is a composite of time-series produced by Lewis et al. (2010), Ayliffe et al. (submitted) and new data generated in 2012 for the ~90 to 35 kyr BP interval. The U-series chronology is preliminary and will be refined with targeted dates. Yellow bars show times of North Atlantic cold intervals (Younger Dryas and Heinrich Events 1 to 6), drier conditions in China, and wetter conditions in Flores. Blue bars indicate the opposite. The grey bar marks a ~4,000-year-long vegetation collapse in Flores related to a large volcanic eruption (See Scroxton et al. 2012 RSES Research Highlight).

Changes in the Intertropical Convergence Zone over the last 40,000 years: A continuous stalagmite δ18O record for Sulawesi, Indonesia

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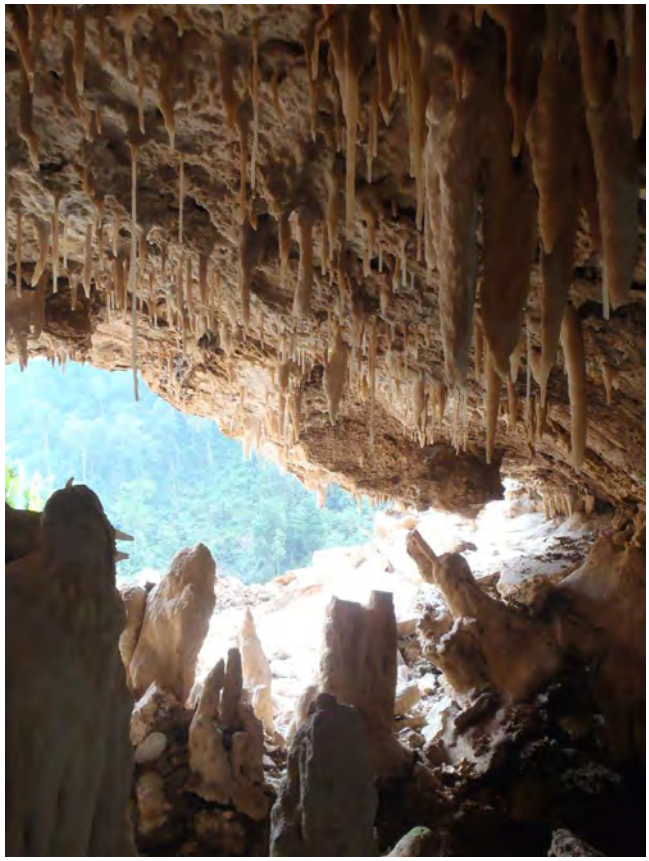

Figure 1. Stalagmite cave from southwest Sulawesi, Indonesia

A number of prominent records of the Asian Monsoon (AM) intensity over the last glacial/interglacial cycle have been published for the Northern Hemisphere, however there remains a large gap in our understanding of the southern counterpart of the AM, referred to here as the Indo-Australian Monsoon. Importantly, one of the key drivers of monsoon intensity, insolation, is out of phase between the hemispheres. The relative importance of insolation compared to other environmental parameters known to influence monsoon intensity (sea level, sea surface temperature, relative humidity) that are largely in phase between the hemispheres on glacial/inter-glacial timescales remains unresolved.

We have developed a continuous palaeomonsoon record based on $\delta^{18}O$ analysis of a stalagmite from southwest Sulawesi, Indonesia, spanning 40,000 years ago to the present. This site is positioned to document changes in austral summer monsoon rainfall and track north-south migrations of the mean location of the intertropical convergence zone (ITCZ) since the last glacial.

Comparison of the new palaeomonsoon record from south-central Indonesia with AM records allows us to develop, for the first time, a "palaeomonsoon index" that maps the spatial and temporal changes in the intensity of the AM over the last 40,000 years. The pattern of north-south ITCZ migration across the Australasian monsoon domain clearly correlates with summer insolation curves for the northern and southern mid-latitudes, providing corroboration for the importance of insolation in driving the ITCZ and the Australasian monsoon system. The palaeomonsoon index forms the basis for our interpretation of the Sulawesi $\delta^{18}O$ record within the context of the wider Asian- Indo-Australian monsoon system, and for examining the potential role that ITCZ positioning played in the start of the last deglaciation.

This research is supported by Australian Research Council *Discovery* grant DP1095673 to M.G., J.H., W.H., L.E. and H.C.

The rise and fall of great earthquakes in Sumatra

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Figure 1. Massive *Porites* corals on Nias mark co-seismic uplift of 2.5 m during the *28 March 2005 M_W 8.7 Nias-Simeulue* earthquake.

The ongoing sequence of earthquake disasters along the Sumatran subduction zone has shocked the world since it began with the giant Sumatra-Andaman earthquake on 26 December 2004. The Sumatra subduction megathrust has produced five catastrophic earthquakes exceeding moment magnitude (M_W) 8.5 since 1797, yet the nature of any recurrent interseismic precursors that herald these events remains obscure. Development of palaeoseismic records for subduction zone earthquakes is challenging because the seismic sources are underwater and the great-earthquake cycle spans hundreds of years (Sieh *et al.*, 2008), thus unusually stable and long-lived natural recorders are required.

Here we show that carbon isotope ratios ($\delta^{13}C$) in massive *Porites* corals positioned above the Sumatra megathrust are sensitive to vertical crustal motions during earthquakes (Fig. 1). It has been known for some time that water column light intensity, coral symbiont photosynthesis, and coral skeletal $\delta^{13}C$ are inextricably linked. In the first instance, we built on this concept by documenting the response of skeletal $\delta^{13}C$ to co-seismic uplift for a *Porites* coral from Sipora Island that was raised 0.7 m during the M_W 8.7-8.9 earthquake in February 1797 (Zachariasen *et al.*, 1999). The abrupt 1.6‰ increase in skeletal $\delta^{13}C$ marks uplift of the coral into shallower, brighter water (Fig. 2).

The 28 March 2005 M_W 8.7 Nias-Simeulue earthquake provided a rare opportunity to see if $\delta^{13}C$ *in Porites corals is* sensitive to both co-seismic uplift and subsidence*. Vertical crustal deformation around the island of Nias ranged from +2.9 m above the rupture to -1.1 m landward from the trench (Briggs et al., 2006).* In May 2009 we collected underwater drill-cores from *Porites* corals along the coast of Nias that continued to grow under altered light exposure after the earthquake.

Results for sites that rose 1.8 m and subsided 0.4 m are shown in Fig. 2. All six coral records from the +1.8 m reef show a significant increase in $\delta^{13}C$ after the earthquake, with an initial $\delta^{13}C$ shift of 0.7‰. The coral $\delta^{13}C$ response to 0.4 m subsidence is smaller, but three of five corals drilled show a clear 0.3‰ decrease in $\delta^{13}C$. In both cases, coral $\delta^{13}C$ variability during the 10 years leading-in to the quake is significantly smaller than the shift in $\delta^{13}C$ due to co-seismic changes in ambient light intensity. Together, the records show that $\delta^{13}C$ in the skeletons of massive *Porites* is sensitive to vertical crustal motion.

Given this encouraging result, we are analysing $\delta^{13}C$ in long vertical cores extracted from fossil *Porites* corals to see if skeletal $\delta^{13}C$ also responds to crustal deformation brought about by decades to centuries of interseismic strain accumulation. If this aspect of the work is successful, we will then be positioned to reconstruct co-seismic, post-seismic, and interseismic crustal strain above the Sumatra megathrust over the last ~6,000 years, thus allowing us to document the tectonic patterns of many great-earthquake cycles in the past.

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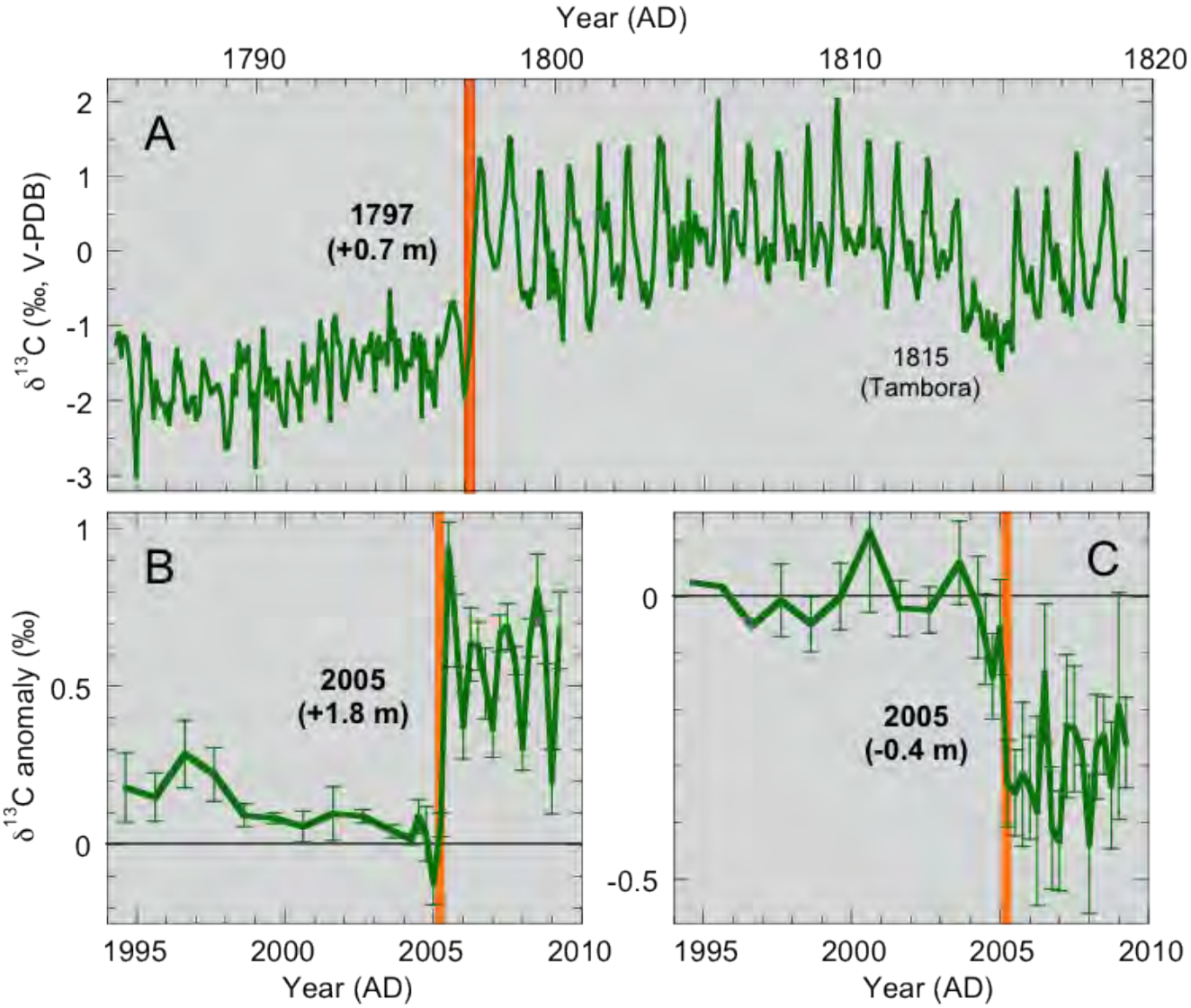

Figure 2. The coral $\delta^{13}C$ response to co-seismic uplift and subsidence. (**A**) Profile of skeletal $\delta^{13}C$ in a *Porites* microatoll from Sipora Island, Mentawai Island group. The record shows a sharp increase in $\delta^{13}C$ marking co-seismic uplift of 0.7 m during the M_W 8.7-8.9 earthquake in February 1797 (orange bar), and a reduction in $\delta^{13}C$ near the time of the 1815 AD eruption of Mt. Tambora. (**B**, **C**) Composite skeletal $\delta^{13}C$ profiles for massive *Porites* corals that recorded co-seismic uplift (1.8 m, *n* = 6 corals) and subsidence (0.4 m, *n* = 3 corals) along the coast of Nias during the March 2005 earthquake (orange bars). The records are normalised to the average $\delta^{13}C$ value for the 6 months preceding the quake (black lines). Error bars show ± the standard error of the mean values. Note that the scale differs between panels.

Tektites, minitektites and microtektites from the Kalgoorlie region, Western Australia

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Figure 1. Figure 1: Minitektites and microtektites from Lake Kuchel, ~200 km east of Kalgoorlie (smallest spheres are ~1 mm in diameter).

About 790,000 years ago, an asteroid or comet impacted in southeast Asia, melting crustal rocks (and regolith) and producing glassy impact debris, known as tektites or australites, which are found over more than 10% of the Earth's surface, including much of Australia and surrounding oceans. The tektites formed as molten "splash" material cooled during high-velocity movement through the air and range in size from spheres less than 1 mm (microtektites, found mainly in deep sea cores) to irregular blocks weighing up to more than 20 kg (Muong Nong tektites in SE Asia).

Tektites have been found in abundance at numerous sites across Australia, particularly southern Australia where it is estimated that finds must number in the tens of thousands. In the Kalgoorlie region tektites are typically found in surface exposures where recent erosion has removed finer material and left larger material as a lag. They are also found as bedload lags in small streams and gullies, and in shoreline deposits of saline lakes (Cleverley 1994). In most cases, therefore, the tektites are not *in situ*, but have been redeposited from their original fall position.

At one site east of Kalgoorlie, microtektites (<1 mm) and minitektites (1-5 mm) occur in sandy beach sediments on the eastern side of a small saline lake known informally as Lake Kuchel (McColl & Hitchcock in press). The tektites (Fig 1) only occur on the east side of the lake and appear to have a localized source in sediments that are being eroded by wave action and surface wash from adjacent, older exposures. This is the first known on-land site in Australia to yield microtektites and one of only three reported on-land sites from the Australasian tektite strewn field, the other two being in Antarctica (Folco *et al*. 2008) and China (Zhou & Shackleton 1999). Our stratigraphic investigations of tektites at Lake Kuchel are focusing on their source and reasons for their preservation at this site.

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Research Activities 2012

Earth Materials and Processes

Introduction

The Earth Materials and Processes area comprises research groups in Rock Physics, Experimental Petrology, and Structure & Tectonics. A large part of our research centres around laboratory based measurements at high temperatures and pressures under carefully controlled conditions that simulate those occurring in nature; such experiments are characterized by a rich array of analytical equipment, which are also put to use studying natural samples. These activities are complimented by extensive field-based observations, often in collaboration with scientists from other institutions, nationally and internationally. Through such investigations we aim to develop understanding of the structure and chemical composition of the Earth and planetary interiors in general, and the processes by which the Earth and other rocky planets evolve. Our interests start at the very beginning of solar system history with how the Earth and other rocky planets accrete, and then cover 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 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.
- Speciation 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.
- Coupling between fluid flow and fault mechanics in the continental crust. Field-based studies of a normal fault system in Oman, along with complementary stable isotope and other geochemical studies of associated calcite vein systems, are being used to explore how fault-

controlled fluid flow is localized among components of regionally extensive fault networks. Laboratory studies of the seismic properties of the cracked and fluid-saturated rocks of the upper crust.

- Building "The Map That Changes The Earth" to provide a spatio-temporal context that will allow a greater understanding of planetary tectonics from the point of view of plate-scale physical processes. To provide critical data for the tectonic reconstructions "listening posts" are being established that provide samples that can be analysed and dated using $^{40}Ar/^{39}Ar$ and U-Pb geochronology.

Professor Hugh O'Neill
Associate Director, Earth Materials & Processes

Poroelastic Relaxation in Thermally Cracked Aggregates of Sintered Glass Beads

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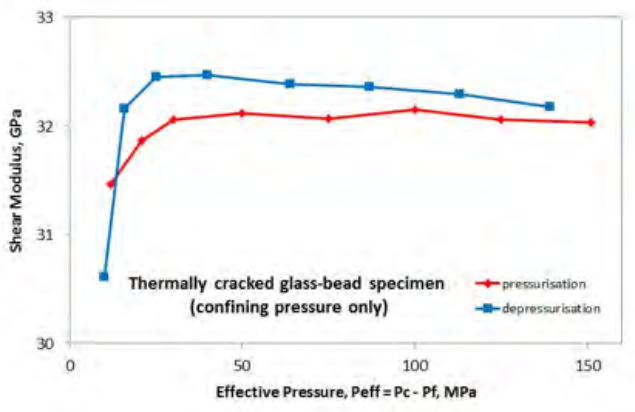

Figure 1. The variation of shear modulus (rigidity) with oscillation period and effective pressure (confining pressure minus pore pressure). (Figure to be simplified.)

Building on preparatory work reported in previous research highlights, a composite specimen of ~3% porosity was prepared as a stack of three sintered glass cylinders each of 50 mm length and 15 mm diameter. This specimen was tested in both torsional and flexural oscillation, prior to and following thermal cracking by quenching from 500°C into water. Under conditions of argon saturation, the shear modulus (rigidity) measured on the cracked specimen is independent of oscillation period within the range 1-100 s and increases systematically with increasing effective pressure below 50 MPa (Fig. 1) – consistent with the pressure-induced closure of narrow-aperture cracks. A major upgrade of procedures for computer control & data acquisition newly allows remote switching between torsional and flexural modes of oscillation, and the prospect of improved signal/noise ratios. Work in progress on the same cracked medium, saturated with water, is exploring the possibility of significantly higher elastic moduli when stress-induced local fluid flow is suppressed by higher fluid viscosity. Such experiments with fluids ranging wide in viscosity have the potential to provide important new constraints on dispersion (frequency dependence of elastic wave speeds) with diverse applications in crustal geophysics.

The high-temperature transition from elastic to anelastic behaviour in upper-mantle olivine

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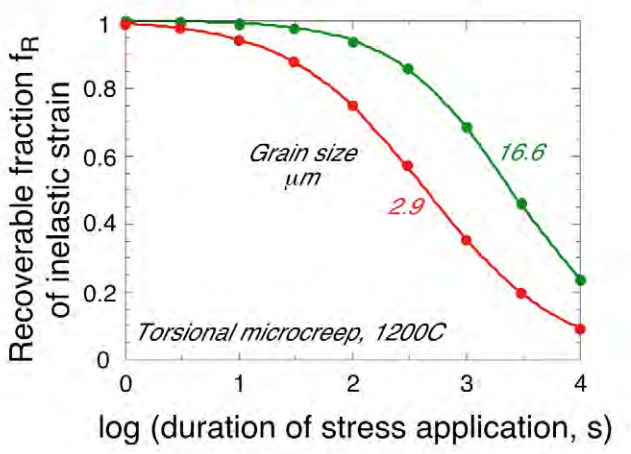

Figure 1. The variation of the recoverable fraction of non-elastic strain with the duration of stress application and grain size for essentially melt-free polycrystalline olivine.

According to the classic theory of grain-boundary sliding, elastic behaviour breaks down at sufficiently high temperatures and appropriate timescales of shear stress application – by sliding on boundaries of relatively low viscosity, accommodated, in the first instance by elastic distortion of the neighbouring grains. The distribution of normal stress across the slipped boundary is responsible for such elastic deformation, and provides the restoring force for recoverable (anelastic) behaviour. Only at higher temperatures and longer time scales, is it possible for appreciable diffusion to erode this distribution of boundary normal stress and progressively allow the additional permanent strains of diffusionally accommodated sliding. Separate characteristic timescales for elastically and diffusionally accommodated sliding, with distinctive dependencies on temperature and grain size, are difficult to reconcile with control of the full spectrum of viscoelastic behaviour by a single master variable, as has been widely advocated. However, in experimental studies of pure polycrystalline materials, the strain-energy dissipation peak predicted for elastically accommodated sliding has proved to be very elusive. In a recent attempt to reconcile the results of forced-oscillation experiments with the predictions of the theory of grain-boundary sliding, we have tentatively attributed a dissipation plateau at moderate temperatures for fine-grained polycrystalline olivine to elastically accommodated sliding. More recently, we have assessed two further lines of evidence concerning the nature of the transition between elastic and viscoelastic behaviour in polycrystalline olivine: (i) a re-assessment of torsional microcreep data that constrains the (grain-size sensitive) recoverable fraction of the non-elastic strain (Fig. 1); and (ii) closer scrutiny of the mildly non-elastic behaviour observed at moderate temperatures through forced-oscillation tests conducted in copper jackets. In this way the complicating effect on the mechanical behaviour of the austenite-ferrite phase transition in the usual steel jacket is avoided. These new experimental observations, along with the predictions of theory, suggest that elastically accommodated grain-boundary sliding plays an important role in the high-temperature breakdown of elastic behaviour.

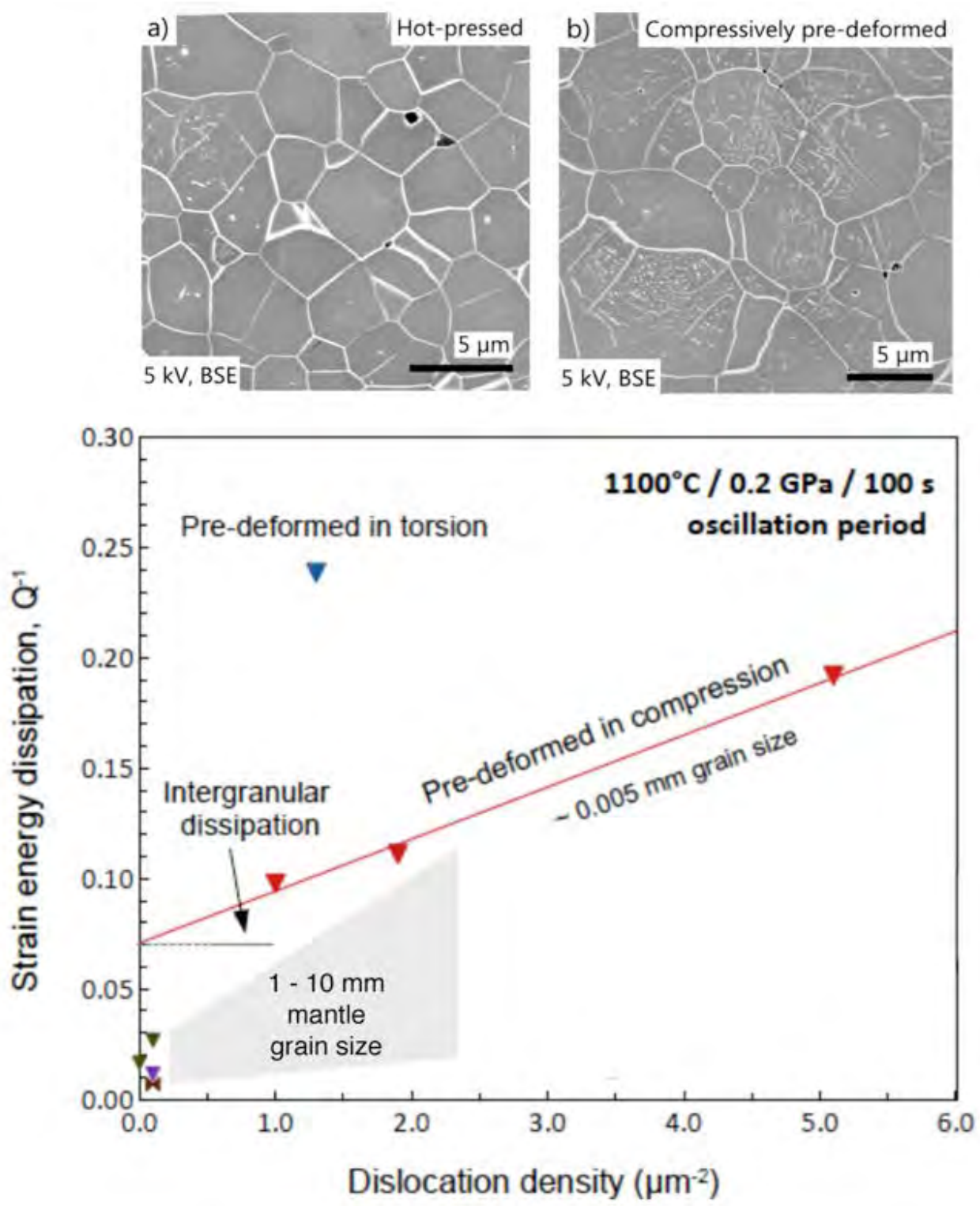

Figure 2. Back-scattered electron images of oxidised grain boundaries and dislocations in hot-pressed and compressively pre-deformed specimens. Torsional forced oscillation testing of such materials reveals a clear positive correlation (red line) between strain-energy dissipation and dislocation density, and substantially higher levels of dissipation for a single torsionally pre-deformed specimen (blue symbol), with implications for seismic wave attenuation in the Earth's upper mantle (see text).

Permeability and Fluid Pathways in Fault-Controlled Hydrothermal Ore Systems – A Seismogenic Framework

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Where fault ruptures breach overpressured fluid reservoirs, earthquake rupture sequences and associated seismogenic permeability enhancement generate pathways for fluid redistribution in tight rocks in the upper half of the continental crust. Seismogenic permeability enhancement plays a key role in controlling the architecture of fluid migration associated with the formation of many types of fault-related ore systems, including mesothermal gold systems, some iron-oxide Cu-Au systems and some intrusion related hydrothermal systems.

With the increasingly widespread deployment of modern seismometer networks, complemented by increasingly precise relocation of earthquake hypocenters, unprecedented insights are being gained about the architecture of seismogenic permeability enhancement and nature of fluid flow associated with earthquake rupture sequences. Two end-member behaviours are significant for the operation of fault-related hydrothermal flow systems: (1) largely stress-driven mainshock – aftershock sequences, and (2) largely fluid-driven earthquake swarm sequences.

In mainshock-aftershock sequences, rupture propagation is controlled mainly by rapid elastic strain release, with large ruptures typically propagating at speeds in excess of $2000ms^{-1}$. Mainshocks are usually followed by a cascade of aftershocks (Figure 1) that is triggered largely by changed stress states caused by the mainshock rupture. Potential for major fluid redistribution in the crust occurs when mainshock – aftershock sequences breach overpressured fluid reservoirs.

Although fluid reservoirs may drain via mainshock ruptures, aftershock sequences generate rupture networks that can provide transiently higher hydraulic connectivity to a deeper and larger crustal volume than mainshock ruptures, and hence provide better hydraulic connectivity to fluid reservoirs. The importance of aftershock networks for localizing fluid migration is supported by the common occurrence of fault-related ore deposits being hosted by low displacement faults within regional-scale fault networks. Major aftershock activity tends to localize near areas of high slip gradient on mainshock ruptures and reveals much detail of the structure and geometry of fault networks activated during aftershock sequences (Figure 1). Particularly intense clusters of aftershock activity can be spatially associated with fault bends, step-overs, splays and rupture terminations on high displacement mainshock ruptures (Figure 2). Whether or not such seismicity clusters act as fluid pathways depends on connectivity to overpressured fluid reservoirs at depth. A key outcome for mineral exploration is that potentially fluid-conductive aftershock networks can localize fluid flow many kilometers away from the large displacement driving faults.

When seismicity is driven primarily by fluid pressure changes associated with migration of overpressured fluids, the style of seismicity contrasts with that of typical mainshock – aftershock sequences. Examples of fluid-induced seismicity are provided by fluid injection experiments into low permeability rocks, as well as by swarm seismicity in areas of natural hydrothermal activity. Fluid-induced swarm seismicity involves sequences of hundreds to tens of thousands of small moment magnitude events over periods of days to weeks, with intervening low seismicity intervals of years to decades. Swarms lack a clear larger mainshock near the beginning of the sequence. Although individual swarm sequences are usually localized along one or several small fault zones (Figure 3), successive swarm sequences can migrate around a volumetrically larger fault network. During individual swarm sequences, a seismicity front usually propagates along faults over periods of days to weeks, driven by propagation of a fluid pressure pulse away from a site of fluid injection into the fault. Net slip on individual faults accumulates via hundreds to thousands of swarm sequences.

By analogy with contemporary fluid-induced rupture sequences, the formation of ore deposits in overpressured, high fluid flux faults is interpreted to involve repeated sequences of swarm (micro)seismicity. Migration of a fluid pressure pulse through a fault network during each swarm sequence is short-lived relative to intervening periods of flow quiescence between swarms. Episodic bursts of fluid flow and associated fluid-driven seismogenic permeability enhancement can occur separate from typical mainshock-aftershock sequences and be driven by episodic leakage from fluid reservoirs. Alternatively, if overpressured fluid reservoirs are breached by cascades of elastically-triggered shear failures within mainshock-aftershock sequences, bursts of fluid-induced swarm seismicity may then be triggered and influence subsequent fluid redistribution within aftershock networks.

Within swarm sequences, fluid flow is governed by transitory permeability enhancement during cascades

of small ruptures. Migration of rupture fronts and associated fluid pressure fronts can occur at rates up to 100s metres/day. But flow in response to individual rupture events in swarms is likely to be transiently much faster and associated with sudden fluid pressure changes. These processes favour episodic pulses of ore formation at potentially severe chemical disequilibrium conditions. Swarm recurrence rates and moment release rates in contemporary fluid-driven rupture sequences indicate that individual fault-hosted ore deposits can form on timescales as little as 10^4 – 10^5 years.

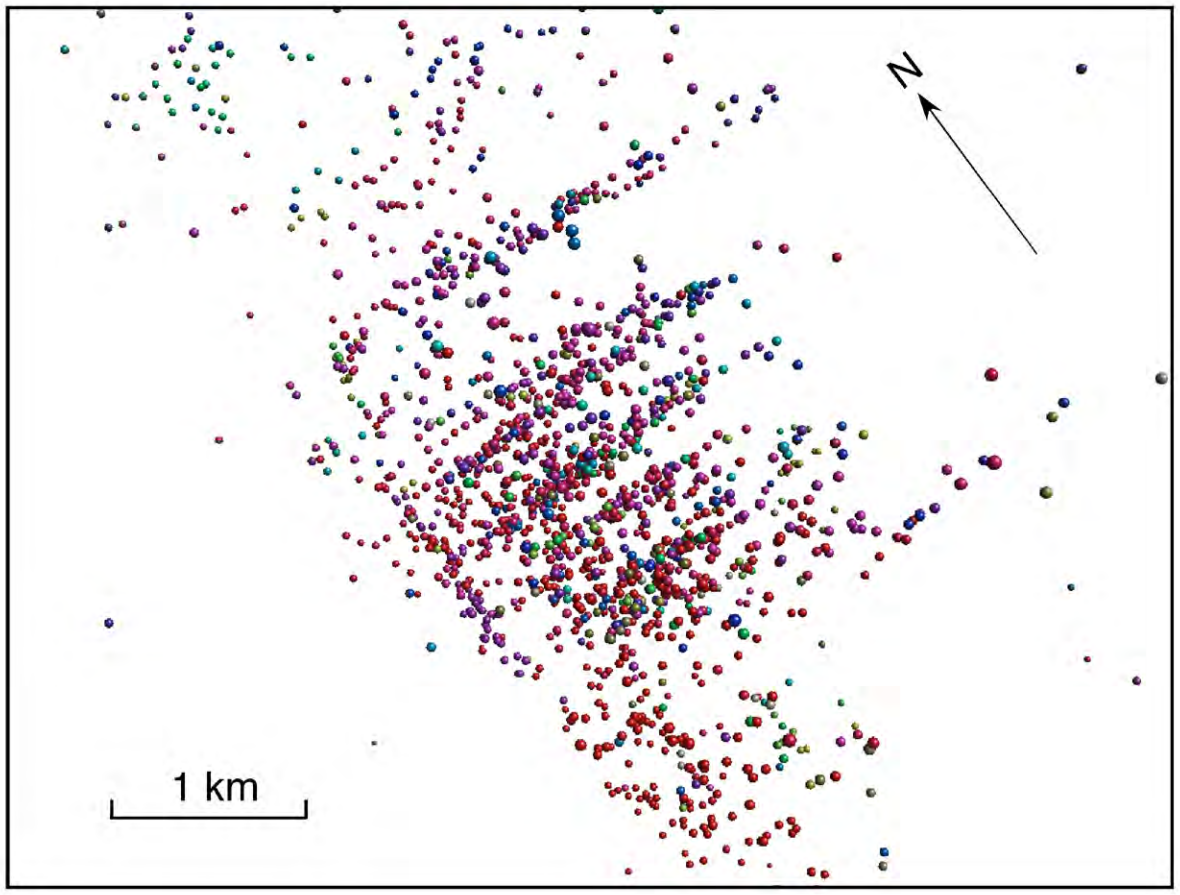

Figure 1. Detail of fine-scale fault structure illuminated by aftershock hypocentres associated with the M_W 5.4 Mount Lewis earthquake (March, 1986), northern California. Map view of aftershock distribution immediately north of the mainshock rupture zone highlights an array of small, steeply-dipping, E-W trending faults and less common, steeply-dipping N-S faults. Individual faults were repeatedly reactivated during the aftershock sequence. Hypocentre data courtesy of F Waldhauser and the Northern California Earthquake Data Center.

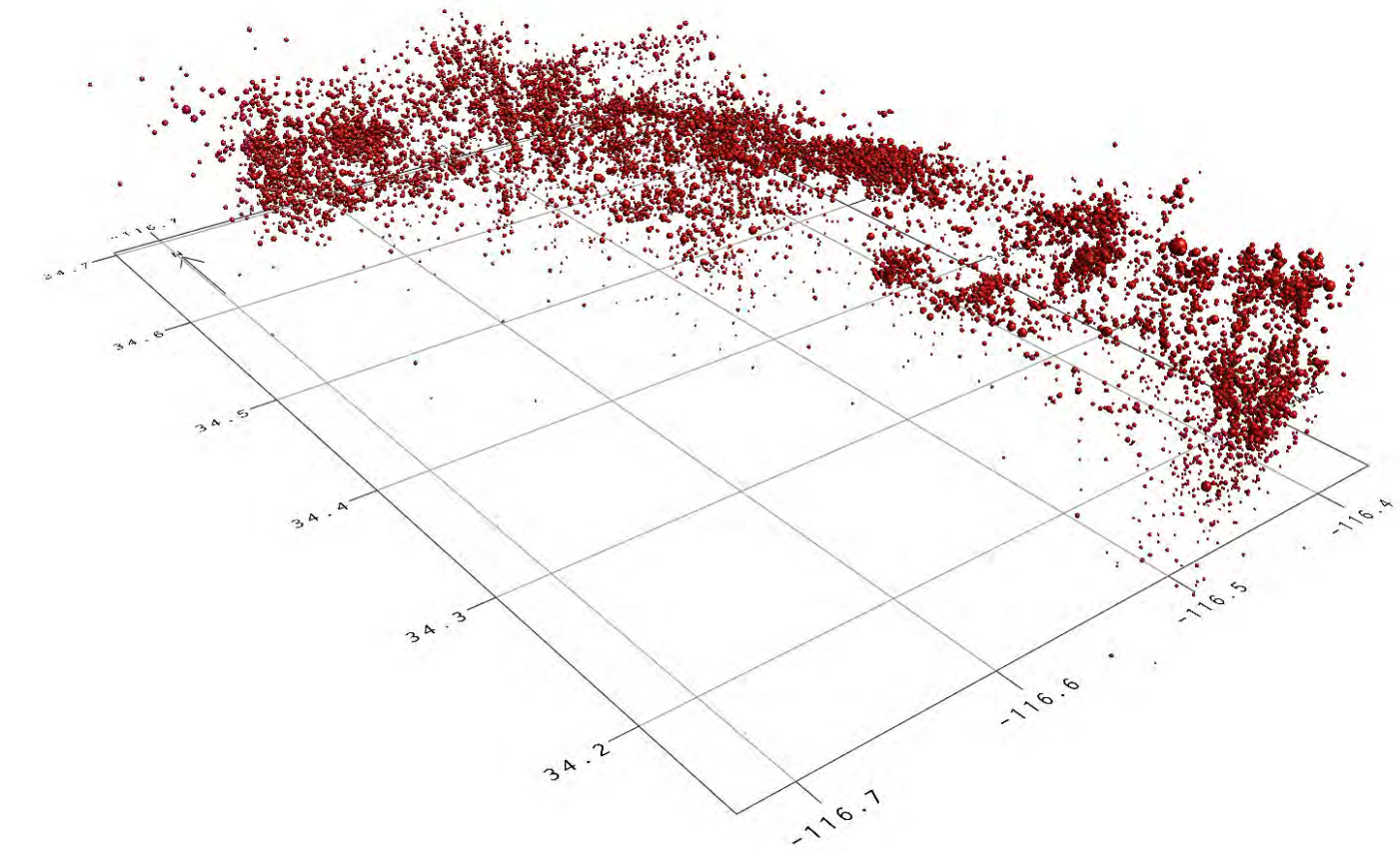

Figure 2. 3D perspective view of distribution approximately 22000 aftershocks following the June, 1992 Landers earthquake, California. The dataset covers the period 28 June 1992 to 30 June 2001. Hypocentre data from Zanzerkia (2003).

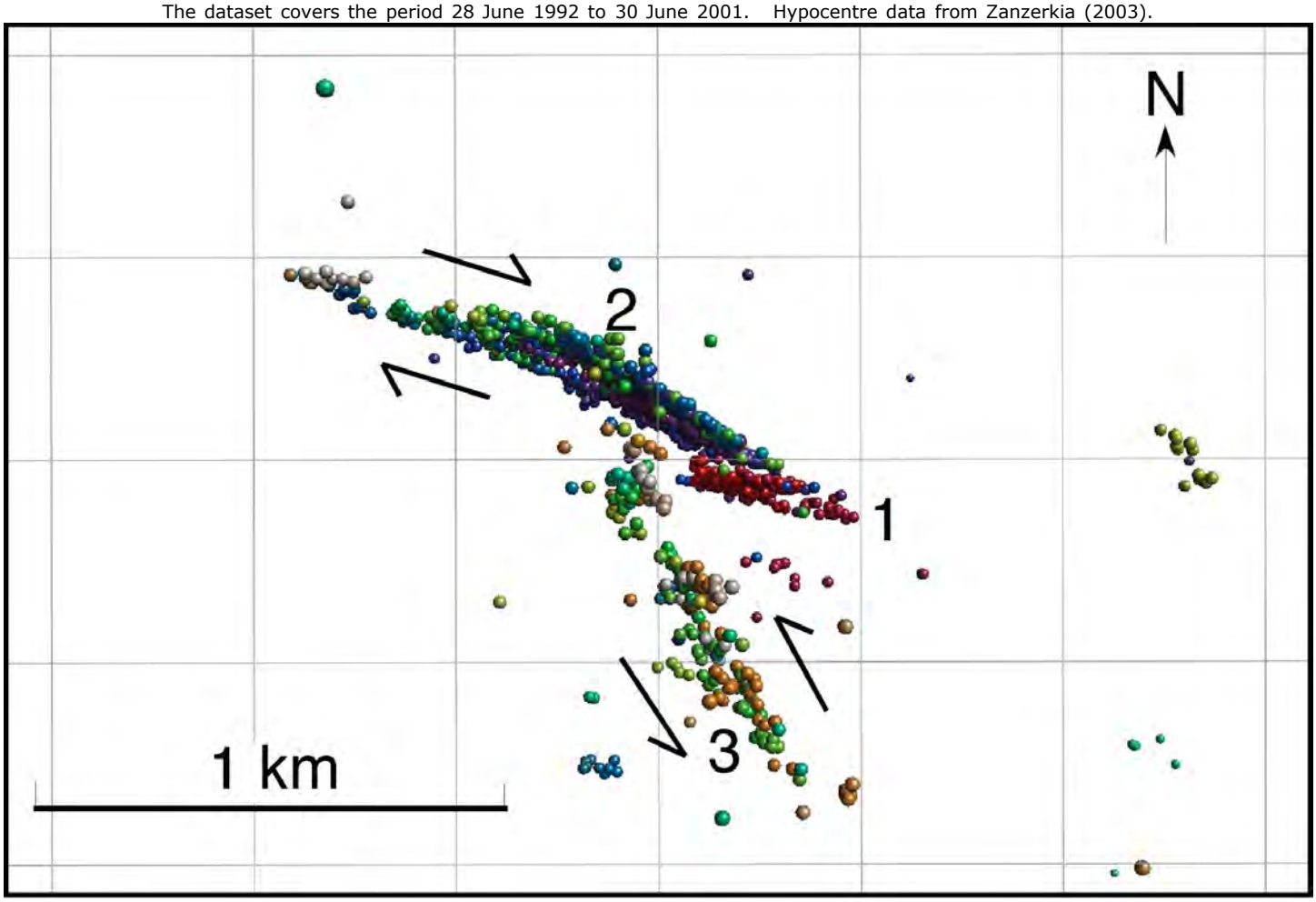

Figure 3. High precision hypocenter locations for a swarm sequence in a magmatic-related system at Hakone caldera, Japan, in 2009. This swarm sequence activated three faults over a period of 8 days and involved more than 1100 events in the magnitude range -0.5 to 3.2. The earliest seismicity occurred on fault 1 (mainly red coloured hypocentres), then migrated to fault 2 (mainly green to blue

hypocentres), and finally stepped across to fault 3 (mainly green to yellow hypocentres). Hypocentre locations courtesy of Y. Yukutake.

The seismic properties of cracked and fluid-saturated crustal rocks (2012 update)

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Figure 1. The glassbead specimen after thermal cracking with 15 mm diameter and 50 mm length.

The follow-up work of this project conducted in 2012 involves using the soda-lime glassbead specimens as the synthetic analogues to the Earth's crustal rocks after the previously systematic measurements on the polycrystalline alumina and Cape Sorrell quartzite. Glass beads with diameters between 300 and 350 microns were selected and sintered near the temperature of glass transition (~700 °C). Subsequent thermal cracking was achieved by heating the sintered sample to 500 °C first and then quenching it into the liquid water at room temperature to allow cracks developing with low aspect ratio at ~0.0007.

The average porosity of glassbead specimens A3-5 (three separate specimens with the cylindrical shape and the geometry of 15 mm diameter and 50 mm length for each) determined by optical method is 1~2%. By perturbing the reservoir at either end of the specimen assembly by ~ 5 MPa, the permeability then was extracted from the pore-fluid pressure evolution time series.

The poroelastic and viscoelastic behaviours of glassbead specimens were studied by performing forced-oscillation experiments on the Jackson-Paterson Attenuation Apparatus with separately controlled confining and pore-fluid pressure systems for both torsional and flexural motions. The apparatus data acquisition system underwent a 6-month upgrade to provide higher resolution results with a higher bit AD convertor, and more user friendly environment by operating within the newly installed Labview system. The shear modulus was determined from the results of torsional mode forced oscillation, and the Young's modulus could be obtained by the finite difference modelling based on the information provided by the newly developed flexural mode forced oscillation capability. Both the confining and the effective pressure (the difference between the confining pressure and the pore fluid pressure) dependencies of elasticity were systematically studied with varying confining and pore-fluid pressures. The observed crack closure effect at ~ 50 MPa is consistent with the theoretical estimate Peff=Eα. By changing the pore fluid from argon to water (with ~100 times higher viscosity), we are hoping to observe the transition associated with the local (squirt) and the global (specimen-wide) fluid flow.

The high-temperature transition from elastic to anelastic behaviour in upper-mantle olivine

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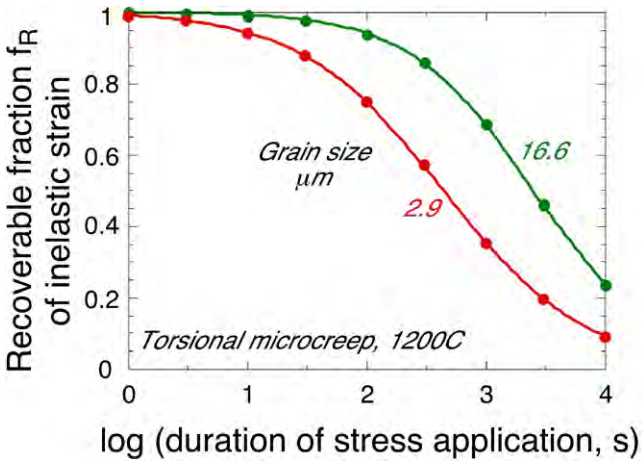

Figure 1. The variation of the recoverable fraction of non-elastic strain with the duration of stress application and grain size for essentially melt-free polycrystalline olivine.

According to the classic theory of grain-boundary sliding, elastic behaviour breaks down at sufficiently high temperatures and appropriate timescales of shear stress application – by sliding on boundaries of relatively low viscosity, accommodated, in the first instance by elastic distortion of the neighbouring grains. The distribution of normal stress across the slipped boundary is responsible for such elastic deformation, and provides the restoring force for recoverable (anelastic) behaviour. Only at higher temperatures and longer time scales, is it possible for appreciable diffusion to erode this distribution of boundary normal stress and progressively allow the additional permanent strains of diffusionally accommodated sliding. Separate characteristic timescales for elastically and diffusionally accommodated sliding, with distinctive dependencies on temperature and grain size, are difficult to reconcile with control of the full spectrum of viscoelastic behaviour by a single master variable, as has been widely advocated. However, in experimental studies of pure polycrystalline materials, the strain-energy dissipation peak predicted for elastically accommodated sliding has proved to be very elusive. In a recent attempt to reconcile the results of forced-oscillation experiments with the predictions of the theory of grain-boundary sliding, we have tentatively attributed a dissipation plateau at moderate temperatures for fine-grained polycrystalline olivine to elastically accommodated sliding. More recently, we have assessed two further lines of evidence concerning the nature of the transition between elastic and viscoelastic behaviour in polycrystalline olivine: (i) a re-assessment of torsional microcreep data that constrains the (grain-size sensitive) recoverable fraction of the non-elastic strain (Fig. 1); and (ii) closer scrutiny of the mildly non-elastic behaviour observed at moderate temperatures through forced-oscillation tests conducted in copper jackets. In this way the complicating effect on the mechanical behaviour of the austenite-ferrite phase transition in the usual steel jacket is avoided. These new experimental observations, along with the predictions of theory, suggest that elastically accommodated grain-boundary sliding plays an important role in the high-temperature breakdown of elastic behaviour.

Fractionation of Nb and Ta by biotite and phengite: Implications for the “missing Nb paradox”

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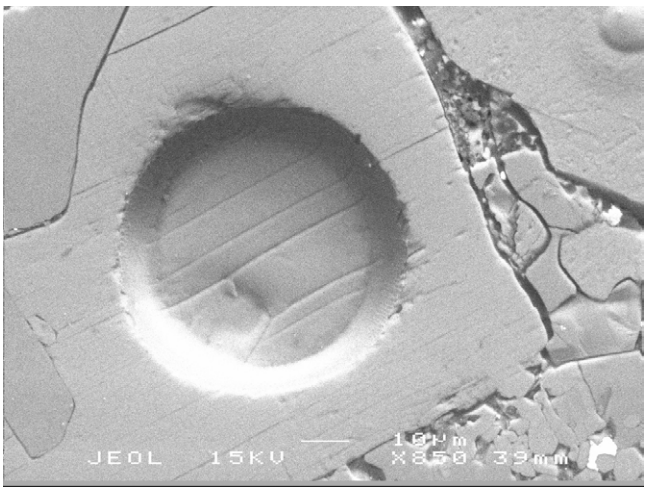

Figure 1. Ti-rich phengite in the experimental run. The pit was created by Laser Ablation and the material was ionized and analyzed with a mass spectrometer in order to determine trace elements.

Nb and Ta are regarded as geochemical twins. Therefore it is surprising that significant fractionation of Nb and Ta is observed at a global scale. The Nb/Ta of the depleted mantle is 11-16, which is considerably lower than the 18-20 of the bulk Earth as estimated from chondrite meteorites (Jochum et al., 2000; Münker et al., 2003). The continental crust has also a subchondritic Nb/Ta of 8-14 and hence there is an apparent deficit of Nb in the bulk Earth. This problem has been named the "missing Nb paradox" and a reservoir is needed that is characterized by high Nb and high Nb/Ta (Rudnick et al. 2000). Ti-rich minerals such as rutile, ilmenite and titanite have a strong affinity for Nb and Ta and thus were thought to control the redistribution of Nb and Ta during crustal differentiation. Nb and Ta are compatible in rutile, ilmenite and titanite and these minerals preferentially incorporate Ta over Nb during partial melting (Schmidt et al., 2004; Prowatke and Klemme, 2005; Xiong et al., 2011). Therefore, residual rocks containing rutile, ilemenite and titanite are characterized by high Nb contents but low Nb/Ta and thus are unable to explain the missing Nb paradox.

We have measured Nb and Ta partitioning between biotite, phengite and melt in high pressure and high temperature experiments using Laser Ablation ICP-MS (Figs. 1, 2). The results show that Nb is compatible in biotite and that biotite and phengite preferentially incorporate Nb over Ta. Biotite and phengite incorporate wt.% levels of TiO_2 and they can act as major host of Ti, Nb and Ta in K-rich rocks (Luvizotto and Zack, 2009). Therefore, during incipient partial melting of amphibolite-facies, biotite-rich crustal rocks, restites with high Nb and Nb/Ta are formed, which could represent one of the missing Nb-rich reservoirs. It has to be evaluated with further studies whether such mid- to lower-crustal rocks are sufficiently abundant to solve the missing Nb paradox.

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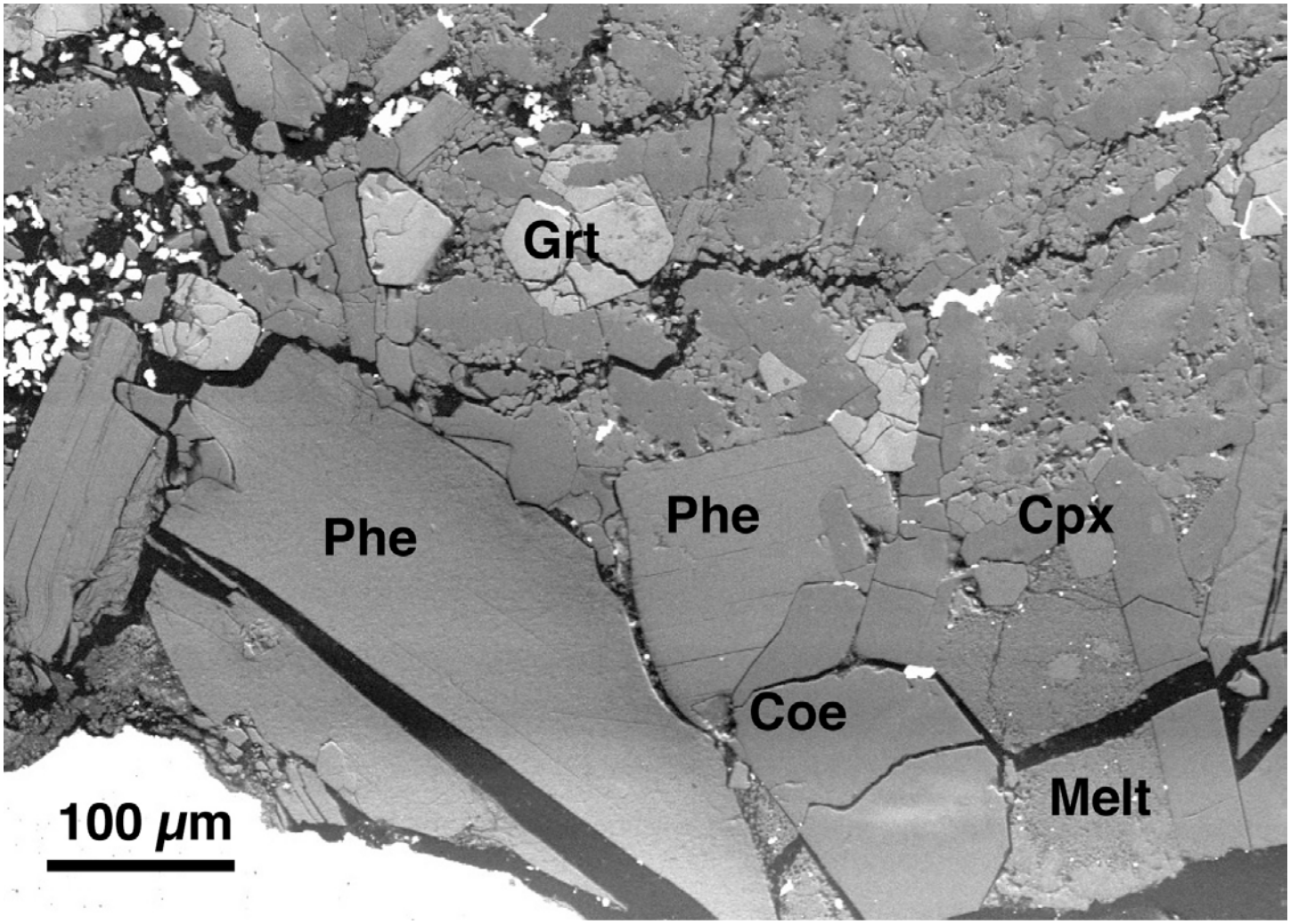

Figure 2. Experimental run products of a pelite starting material at 4.5 GPa and 900°C containing garnet (grt), phengite (phe), clinopyroxene, coesite (coe) and melt.

Diamonds in Antarctica? Discovery of Antarctic kimberlites extends vast Gondwanan Cretaceous kimberlite province

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Kimberlites are a volumetrically minor component of the Earth's volcanic record, but are of great importance as the major commercial source of diamonds and as the deepest samples of the Earth's mantle. They were predominantly emplaced into ancient, stable regions of continental crust, known as cratons, from Å2000 Ma to Å10 ka ago but are also known from continental rifts and mobile belts. Kimberlites have been reported from all major cratons on all continents except for Antarctica. We report here the first *bona fide* Antarctic kimberlite occurrence, from the northern Prince Charles Mountains, emplaced as a result of reactivation of the Lambert Graben during rifting of India from Australia-Antarctica. The samples exhibit the textural, mineralogical and geochemical features typical of Group I kimberlites from more classical localities. The ages of the nPCM kimberlites, based on radiometric dating (120 Ma), overlap with many kimberlites and related rocks from other localities on the Gondwanan continents. This discovery extends a 135-115 Ma Gondwanan kimberlite province, for the first time, into Antarctica. The kimberlites' emplacement reflects tectono-magmatic processes associated with Cretaceous rifting between the India and Antarctica-Australia.

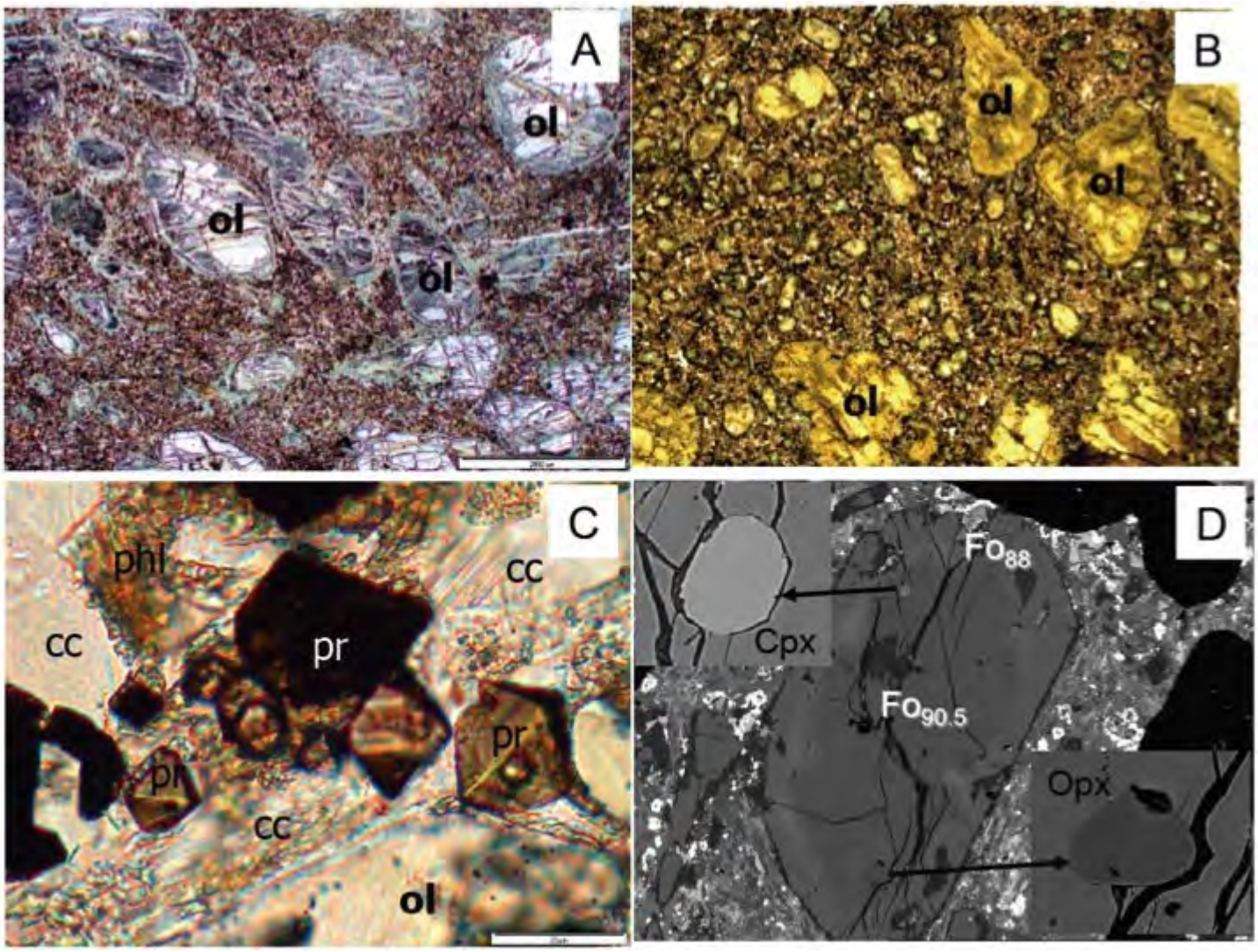

Figure 1. A-C – plain light photomicrographs of the Antarctic kimberlites showing porphyritic texture, and two generations of olivine

(fragmented and euhedral), olivine alignment, and olivine rimmed by oxide crystals (Ti-magnetite, Cr-spinel and perovskite). Olivine (ol) crystals are set in a fine- to coarse-grained groundmass, consisting of phlogopite (phl), calcite (cc), perovskite (pr), apatite and magnetite. D – backscattered electron image of zoned olivine crystal with euhedral inclusions of high-Ca (Cpx) and low-Ca (Opx) pyroxenes in the resorbed core (sample 77082).

Titanium diffusion in forsterite

Mike Jollands, Hugh O'Neill and Joerg Hermann

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Diffusion is a process which we all intrinsicaly understand, even if not by that name. The commonly cited example of diffusion is a smelly one; if someone sprays perfume at one end of a room within a minute everyone will smell it. Technically, this is partly convection as well, but the analogy generally holds up.

In solid crystals, diffusion also occurs, although it is much slower and less intuitive. In the same way that diffusive movement of perfume in air occurs by random motion of molecules in the air, atoms within a crystal are able to randomly move around by jumping from one point to another. I investigate the movement of titanium within forsterite (Mg_2SiO_4), which is a type of olivine, a mineral common in many igneous and mantle rocks.

We find that diffusion within this system is more complex than previously thought. Generally, as temperature increases, so too does diffusivity, because atomic vibrations increase which also increase the likelihood of an atom jumping from one spot to another within a crystal. However, we also investigate the effect of other variables, such as the oxygen fugacity of the experiment (the oxidation state of the atmosphere) and find that changing these can also alter diffusivity.

Back-arc mantle convection - What goes around comes around

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Convergent plate margins are the active interface where the Earth's crust and underlying mantle interact. Mass transfer from and to the mantle can cause explosive volcanism, create island chains along these 'subduction zones' or form metal deposits of ore quality. A complex and dynamic regime of mantle flow is ever constantly supplying this region: the so-called mantle wedge; an area between diving and overriding plates. The sourcing of island arcs by flux-melting in the mantle wedge is nowadays well established, yet the subsequent fate of residual mantle sections after melt extraction and overprint by fluids juiced from the downgoing slab remains virtually unknown.

We have now demonstrated that sea floor basalts sourced at a divergent plate margin in the Lau oceanic back-arc basin are sourced from material that once resided at the arc front. The isotope and trace element signatures bear witness of prior melting and overprinting events that took place underneath the arc front. The distance to the trench require a deep mantle recycling process over hundreds of kilometers until the material returns in a constant flow back towards the surface. A combination of Hf-Nd-Fe isotopes and key trace elements carry the memory of the melting event at the arc front all the way down into the mantle and back up to the surface over hundreds of kilometers…the circle of rocks!

Partitioning of Rare Earth Elements between Garnet and Clinopyroxene in Peridotite

Brendan J. Hanger and Greg M. Yaxley

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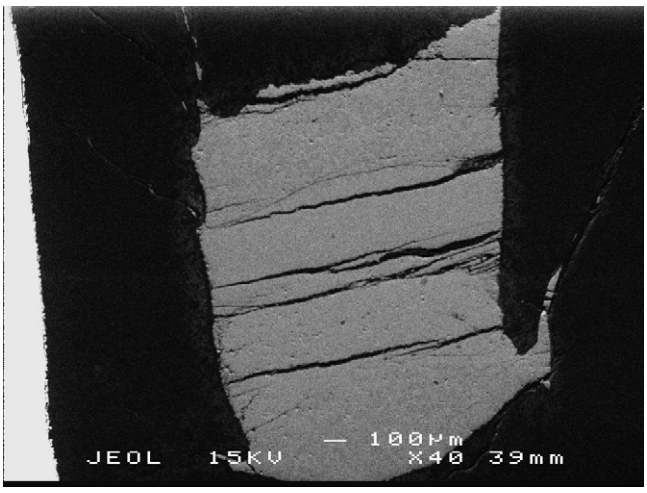

Figure 1. Backscattered electron image showing the layered structure of peridotite, garnet and clinopyroxene in one of our experiments. Obtained using the JEOL6400 SEM at the Centre for Advanced Microscopy.

Peridotite is the major component present in the Earth's upper mantle and is comprised of four main minerals at depths of greater than about 100km: olivine, orthopyroxene, clinopyroxene and garnet. The mantle is sampled by volcanic eruptions, such as kimberlites, which sometimes accidentally entrained fragments of mantle peridotite called xenoliths, bringing them rapidly to the surface where they are accessible. Kimberlites also transported most of the Earth's diamond stocks and as such the study of these peridotite xenoliths is important in helping us understand the processes involved in the creation and transport of diamonds.

In order to understand how fluids and magmas have affected peridotites we generally investigate the concentration of the rare earth elements in each mineral, with particular attention paid to the ratio of the concentration in the mineral compared to a melt phase, this is known as the partition coefficient. Partition coefficients are determined using high pressure experiments where conditions such as temperature, pressure and composition are varied in a systematic manner. However in the past most studies have focussed purely on the partitioning between one mineral and the melt phase, neglecting the interactions of the other minerals. In this study we aim to investigate the interactions between garnet and clinopyroxene in peridotites, as they both host significant concentrations of the rare earth elements and thus record the signature of ancient metasomatism.

We are performing a series of high pressure experiments using piston cylinder apparatus which we will use to determine distribution coefficients between garnet and clinopyroxene over a range of relevant temperatures and Ca in garnet compositions. It is hoped that this will help us understand more about the effects of metasomatism on rare earth elements, including how clinopyroxene can affect REE patterns in garnet. This will also build on our understanding of the systematics involve in the evolution of radiogenic isotopes such as Sm-Nd or Lu-Hf.

Slumping slab sheets, outer rise earthquakes and the origin of double seismic zones

Subducting slabs are structured - just any other rock body on the Earth.

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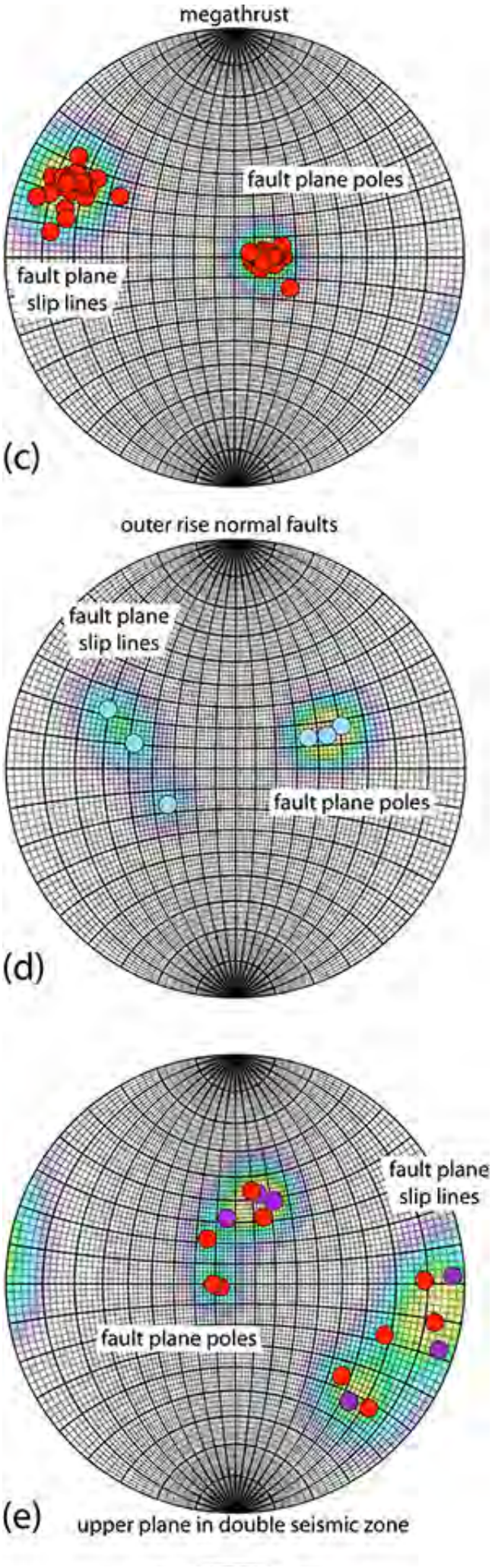
Outer-rise normal-fault earthquakes are a typical feature in the aftermath of large megathrust events. They may result from flexure of the lithospheric slab as it begins to subduct, and many outer-rise normal faults may commence life in this way. But the slab flexure model offers no explanation as to the reason why large normal-fault earthquakes begin to take place, sometimes within minutes of a megathrust earthquake. Nor do such models explain why such faults continue to rupture in the decades that follow a catastrophic failure event. Slab flexure also does not explain why the normal ruptures that cause the largest of outer-rise earthquakes appear to dip consistently landward, in the same direction as the subducting slab, or the cascades of landward-dipping normal faults that can occasionally be observed on the trench side of the outer rise. This geometry and relative timing suggest that the mechanics of outer-rise earthquakes must be driven by deeper level processes.

We suggest that the geometry and timing of outer-rise normal-fault earthquakes can be linked to slumping slab-sheets in subduction zones. These slumping slab-sheets may form as ~20 km thick slices at the top of the subducting slab at depth, demarcated by double seismic zones, with weak dehydrating serpentine at their base. We suggest that they are held in place at surficial levels by locked megathrusts. Once the megathrust fails it no longer has the strength to maintain the counter-traction that holds the slab-sheet in place. In consequence outer-rise earthquakes begin to occur soon after the adjacent megathrust ruptures. These should continue until the megathrust once again locks. If we are correct then large landward-dipping outer-rise normal faults may be headwall faults connected (aseismically?) to these slumping slab-sheets.



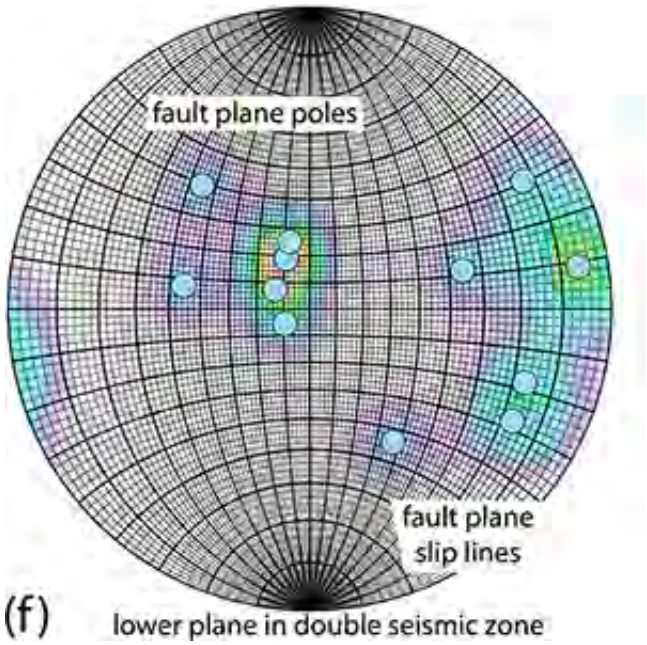


Figure 1. Stereoplots for; (c) the megathrust; (c) the outer-rise normal faults; (c) the upper-plate of the doubdle seismic zone; and (d) for the lower plane of the double seismic zone. Data from the Lamont-Doherty Global CMT project.

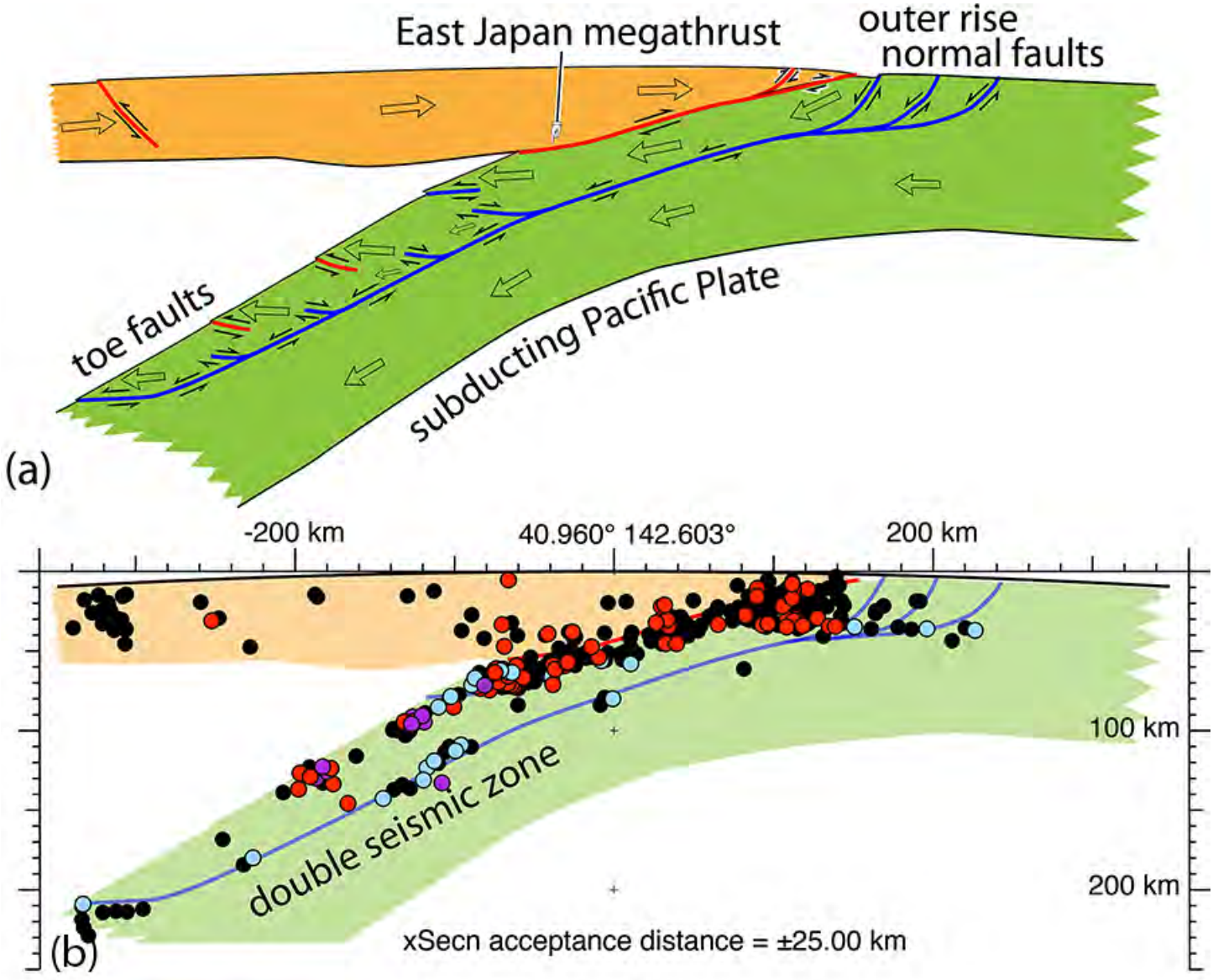


Figure 2. In (a) an interpretation of the geometry of the slab-sheet slump, with the outer-rise faults being the headwall faults of a giant slab sheet slump. The lowermost plane of the double seismic zone marks the base of the slump, with ductile faulting and brittle faulting on sub-horizontal fractures between. In (b) fault hypocentres in black have no fault palne solutions as yet determined, whereas blue

circles are normal faults, red circles are reverse faults, and purple circles are strike-slip faults.

Development of the Southern New England oroclines: a paleomagnetic model

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How and what formed the spectacular oroclines of the Southern New England Orogen (SNEO) remains a contentious issue. The oroclinal nature of the Texas and Coffs Harbour megafolds in the north of the SNEO is well established and is also likely for the Manning structure in the south. Opinions vary widely regarding time, mode and cause of oroclinal bending. Proposed timings vary from Late Carboniferous to Late Permian-Early Triassic. Recent models focus on the earlier part of the Gondwanide Orogeny (320-230 Ma) and on contemporaneous formation of the northern and southern oroclines in spite of their opposite vergences (Klootwijk 2009; Cawood et al., 2011). Emphasis differs however, on timing of the main phase of oroclinal bending — the Late Permian Hunter-Bowen Phase of the Gondwanide Orogeny (Cawood and Leitch 2006; Cawood et al., 2011), or the latest Carboniferous-earliest Permian Tablelands Phase (Klootwijk 2009). Proposed modes of deformation vary from thin-skinned to thick-skinned lithospheric engagement, and modes of displacement with respect to the Lachlan-Thomson Orogen vary from southward movement of the whole New England Orogen (SNEO and NNEO), to southward movement of the NNEO with a pinned SNEO, to northward movement of the SNEO with a pinned NNEO. Recent models focus on northward displacement and telescoping of the SNEO with a pinned NNEO, extending from crustal to uppermost lithospheric mantle levels. The established view remains fixated on a Paleopacific driver, but an alternative pole path for Australia/Gondwana (Klootwijk 2010) indicates Tethyan orogenesis as a more likely driver.

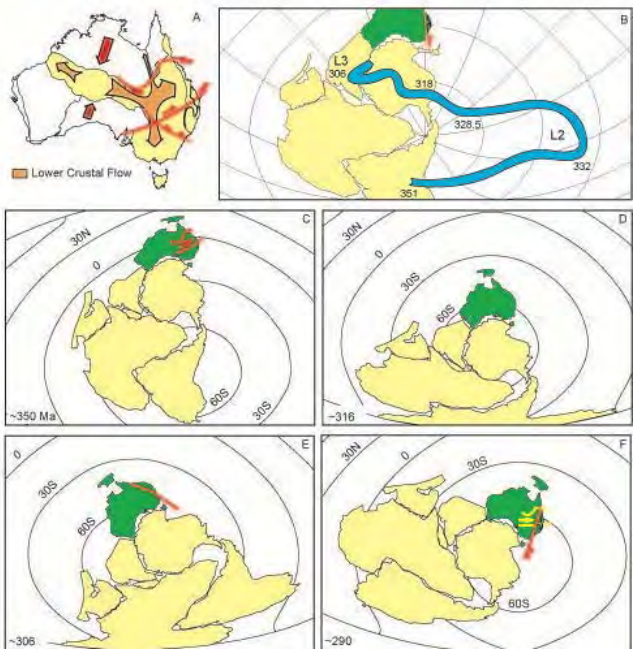

Figure 1. A) Alice Springs Orogeny (ASO)-related tectonic extrusion model (http://rses.anu.edu.au/research/annrep/ar2008/visitors/index.php?p=klootwijk, http://rses.anu.edu.au/highlights/view.php?article=47). B) Carboniferous pole path for the Southern New England Orogen (SNEO), corrected for northward telescoping over ~500km, considered representative for Australia and Gondwana (http://rses.anu.edu.au/highlights/view.php?article=157). C-F) Gondwana positioned according to selected paleomagnetic data from the SNEO pole path (B: Klootwijk 2009, 2010). (C) Waverley Formation; Australia moving northward, toward collision with the Central Asian Orogenic Belt, ASO-related tectonic extrusion in progress. (D) Base of Currabubula Formation: Australia has moved to south polar latitudes. (E) Top of Currabubula Formation: development of the Eastern Australian Rift System as part of a larger shear along Gondwana's Protopacific margin. (F) Boggabri Volcanics: SNEO telescoped against the eastward extruded buttress of the Northern New England Orogen with formation of the SNEO oroclines.

So what is the paleomagnetic model about? It concerns implications from ongoing detailing of a Carboniferous pole path for the SNEO (Figure 1B: Klootwijk 2009, 2010), considered representative for Australia/Gondwana and featuring two major loops reflecting major changes in global plate movements. The older loop (L2, middle-late Visean apex) details an extensive northwards excursion. It offers the novel, heretic, view of Devonian-Early Carboniferous closure of the eastern Rheic/Paleoasian Ocean, with Australia/eastern Gondwana colliding with the Central Asian Orogenic Belt (CAOB) and then from late Visean onward retreating southward whilst opening the Paleotethys. Collision causes Variscan deformation of the CAOB, the Alice Springs Orogeny and also eastward tectonic extrusion leading to about 200 km eastward displacement of the NNEO with respect to the SNEO (Figure 1A, C). The younger loop (L3, latest Carboniferous apex, ~ 305 Ma) details the start of a substantial clockwise rotation of Gondwana, at about the same time as the start of large-scale dextral shear of Gondwana versus Laurasia within Pangea. Development of the Eastern Australian Rift System — part of a major shear zone inboard of the Gondwanan Paleopacific margin (Figure 1E) and precursor to the Sydney-Gunnedah-Bowen basin system — separates a SNEO ribbon continent. Major clockwise rotation of Gondwana (Figures 1E, F) telescopes the SNEO ribbon continent against the, previously eastward extended, buttress of the NNEO, forming the Texas-Coffs Harbour and Manning Oroclines (Figure 1F). Preliminary paleomagnetic constraints from SNEO rocks (primary magnetizations from Alum Rocks volcanics [~293 Ma, Texas block] and Alum Mountain Volcanics [~274 Ma; Myall blocks), and coinciding (in-situ) reverse polarity, Kiaman, overprint magnetizations from sediments in the Texas and Coffs Harbour blocks and Tamworth Belt ignimbrites (Rouchel block) constrain major rotation to prior to the younger Hunter-Bowen Phase of the Gondwanide Orogeny and mainly associated with the older Tablelands Phase. Although this paleomagnetic model and the Cawood et al. (2011) model attribute the main phase of oroclinal bending to different phases of the

Gondwanide Orogeny, they share northward telescoping of a SNEO ribbon and a pinned NNEO.

The paleomagnetic model implies contemporaneous, latest Carboniferous-earliest Permian, formation of the SNEO oroclines and of the Cantabrian-Asturian Arc (CAA) that forms the core of the Ibero-Armorican Arc of European Variscan massifs. Analyses of paleomagnetic (Weil et al., 2010) and geological data (Gutiérrez-Alonso et al., 2011) constrain CAA oroclinal bending to ~310-295 Ma. It thus appears that the SNEO and the CAA oroclines can be interpreted as contemporaneous, antipodal, expressions of mega-drag folding along fault-bounded margins of a rotating Gondwana.

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Research Activities 2011

Earth Physics

Introduction

The Research School of Earth Sciences includes substantial activities in geophysics. The main research themes are Geodynamics, Geodesy, Geophysical Fluid Dynamics, Mathematical Geophysics and Seismology. These span 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.

Several members of Earth Physics have the recipients of major prizes in 2012. Dr. Andrew Hogg was awarded the 2012 Frederick White Prize for physical, terrestrial and planetary sciences; in August Dr. Michael Roderick was awarded the Dalton medal of the European Union of Geosciences for his ground breaking contributions in the areas of ecohydrology and remote sensing science; and in November Professor Kurt Lambeck was awarded the Balzan prize for his exceptional contributions to the understanding of the relationship between post-glacial rebound and sea level changes contributions. ANU staff excellence awards were received by Drs. Natalie Balfour and Michelle Salmon in Public Policy and Outreach for their contributions to the Australian Seismometer in Schools project, and Mr. Tony Beasely for excellence over 25 years of service.

Earth Physics staff were successful in applications for multiple ARC Discovery, during the year and Dr. Andrew Hogg was awarded an ARC Future Fellowship. Academic staff joining Earth Physics in 2012 were Dr. Sebastien Allgeyer in Seismology, Drs. Achraf Koulali and Lydie Lescarmontier in Geodesy and Drs. Andreas Klocker and Bishakhdutta Gayen in Geophysical Fluid Dynamics.

Ph.D. student T. Bodin, graduated and moved to a Miller research Fellowship at Univ. of Berkely, USA. Co-supervised Ph.D. student J. Stipcevic graduated and is now a postdoctoral fellow on an ARC Endeavour Scholarship. Ph.D. student Surya Pachhai is the recipient of the Paterson Scholarship.

During 2012, the **Seismology** group at RSES was heavily involved in both the acquisition of new portable seismic instrumentation and field campaigns to collect passive seismic data in various parts of Australia. Through AuScope AGOS, the seismology group is responsible for the construction of 250 new generation seismic recorders and the purchase of 20 deep sea Ocean Bottom Seismometers (OBS) for use by the Australian research community. In late 2012, the first 50 of the new generation recorders was completed and deployed in northeast New South Wales and southeast Queensland as part of the SQEAL1 array. SQEAL (South Queensland Eastern Australian Linkage) represents the next phase of the transportable seismic array experiment

known as WOMBAT, which is run by the RSES seismology group and has grown to become the largest transportable array experiment in the southern hemisphere. Since 1998, a total of 15 separate array movements involving over 650 station locations has taken place, resulting in cumulative coverage of Tasmania, Victoria, New South Wales, southern Queensland and southern South Australia. Data from this experiment has helped transform our understanding of the deep structure and tectonic evolution of Phanerozoic Australia. Other fieldwork that has bee undertaken includes maintenance of the EAL3 array, which lies just south of SQEAL1, and maintenance of the BASS array between Tasmania and Victoria. The goal of BASS - a joint venture between RSES and the University of Tasmania - is to image the sedimentary and crustal structure beneath Bass Strait using ambient noise methods. An array of 24 broadband seismic stations was deployed on southern Victoria, northern Tasmania and several of the Bass Strait islands in late 2011, and will continue to operate until May 2013. In addition to ambient noise, teleseismic receiver functions and shear wave splitting techniques will be applied to improve our understanding of the tectonic relationship between Tasmania and mainland Australia.

In **global seismological studies of the deep interior** research has been ongoing in the area of structure and dynamics of the Earth's inner core, the lowermost mantle and the lithosphere. With the recent expansion of global seismic data and the developments of new inversion techniques, the progress has been made in imaging and interpreting short scale structures in the inner core and the lowermost mantle. A project on the rotational dynamics of the inner core with respect to the mantle has been finalized, and a new project has been initiated in which array seismology is utilized to investigate a hemispheric dichotomy in inner core structure and to understand the nature of growth of the inner core (in collaboration with JAMSTEC, Japan and National Seoul University, Korea). International collaboration also includes a project on the multidisciplinary approach between seismology and mineral physics to understand inner core complex anisotropic structure (with University of Madrid). Partition modeling has also been applied to global dataset of seismic body waves sensitive to the lowermost mantle, and a new tomographic model of the lowermost mantle has been developed. Source physics and normal mode problems are being approached through partition modeling and these are now subjects of ongoing studies with PhD students.

In **Geophysical Fluid Dynamics** 2012 was the second year of operation of the ARC Centre of Excellence in Climate System Science, with one of its 5 university nodes in the Earth Physics area of RSES, focusing on ocean modelling. Research highlights included results from a suite of 'eddy permitting' to 'eddy resolving' simulations of the Southern Ocean. These showed that although the eddy field may strongly oppose any wind-induced increase in the transport in the Antarctic Circumpolar Current, the eddy compensation of the Southern Ocean overturning circulation is relatively weak, and therefore upwelling in the Southern Ocean may increase substantially under the enhanced westerly wind stress projected for the future. In other work, direct numerical simulation of a simple convection model was used to unravel the complex problem of kinetic and potential energy

conversions when differential heating and cooling are applied to the ocean surface. Related solutions were also found from an ocean general circulation model applied to a simplified global ocean and analysed in terms of the energy conversions. It was concluded that surface wind stress and buoyancy forcing are likely to be of comparable importance in driving the overall global circulation and that there is an interesting coupling between the two forcing mechanisms. State-of-the-art numerical ocean model configurations were developed to resolve very small scales in the ocean, and these will be used to understand the role of these small scale processes in transporting tracers, such as heat and carbon dioxide, in the global ocean. A study of the interactions of turbulent mixing and convection using laboratory experiments, relevant to the deep overturning of the oceans, showed that convective overturning rates depend on the rates of mixing, as previously predicted, but also indicate that only the mixing rates in the upper ocean are of importance, in contrast to previous theories of deep circulation driven by abyssal mixing.

In **Mathematical Geophysics** research has been ongoing in the area of nonlinear inverse problems and development of new ensemble based approaches for seismic imaging and more general inference problems. In 2012 the focus has been on computational statistical approach to various data inference problems. The AuScope inversion laboratory saw much activity during the year with development of new codes for Bayesian regression and Partition modelling. This is a venture whereby scientific computer software is developed for the geoscience community implementing advance algorithms for nonlinear inversion applied to various data types. Several new projects were initiated during the year including studies on the inference of tectonic plate motion changes, reconstruction of the Australian Moho variability from multiple seismic datasets, and a collaboration with Earth environment staff on Uranium series dating in bones. Previous results on transdimensional inference algorithms were extended in collaboration with colleagues from Univ. of Rennes, France and Univ. of Berkeley, USA.

In **lithosphere dynamics** attention has been focused on tackling problems related to the strength of large-scale plate margins in a simple inverse fashion. Most of the strength of plate interfaces resides in the brittle regime, but estimates of the friction coefficient of tectonic margins are largely missing, and the few estimates available are incompatible with results from laboratory experiments. It has been found that the coefficient of friction of large-scale plate margins is more than one order of magnitude smaller than indicated by laboratory experiments. Further, its lateral variations are primarily controlled by the sediment intake of plate margins, which acts as a physical lubricant of the plate interface. These inferences have important implications for understanding the balance of lithosphere torques, as well as the stress-drop associated with seismic events.

Geodynamics research activity has focused in 2012 on the use of satellite observations to study changes on Earth. This has included studies of the redistribution of water resources on Earth, developing more accurate methods for deriving height changes from satellite altimetry, studies of sea level variations around the Australian coastline and deformation of the Australian

continent and Indonesia caused by earthquakes at the plate's boundaries. The studies use a suite of different satellite missions including space gravity (GRACE), satellite altimetry (Cryosat II, Jason, Envisat), Interferometric Synthetic Aperture Radar and GPS. Estimates of changes in the Earth's gravity field can now be made using in-house software to analyse the raw GRACE mission observations and a new website (grace.anu.edu.au) was developed to enable users to derive estimates of deformation and changes in water quantities using the GRACE satellites, providing the first such capability in Australia.

Professor Malcolm Sambridge
Associate Director, Earth Physics

Plate motions: Simpler than they look

Giampiero Iaffaldano[1], Thomas Bodin[2] and Malcolm Sambridge[1]

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Understanding lithospheric plate motions is of paramount importance to geodynamicists. Much effort is going into kinematic reconstructions featuring progressively finer temporal resolution. However, the challenge of precisely identifying ocean-floor magnetic lineations, and uncertainties in geomagnetic reversal timescales result in substantial finite-rotations noise. Unless some type of temporal smoothing is applied, the scenario arising at the native temporal resolution is puzzling, as plate motions vary erratically and significantly over short periods (< 1 M Myr). This undermines our ability to make geodynamic inferences, as the rates at which forces need to be built upon plates to explain these kinematics far exceed the most optimistic estimates. Here we show that the largest kinematic changes reconstructed across the Atlantic, Indian and South Pacific ridges arise from data noise. We overcome this limitation using a trans-dimensional hierarchical Bayesian framework. We find that plate-motion changes occur on timescales no shorter than a few million years, yielding simpler kinematic patterns and more plausible dynamics (Fig. 1).

Associated publication

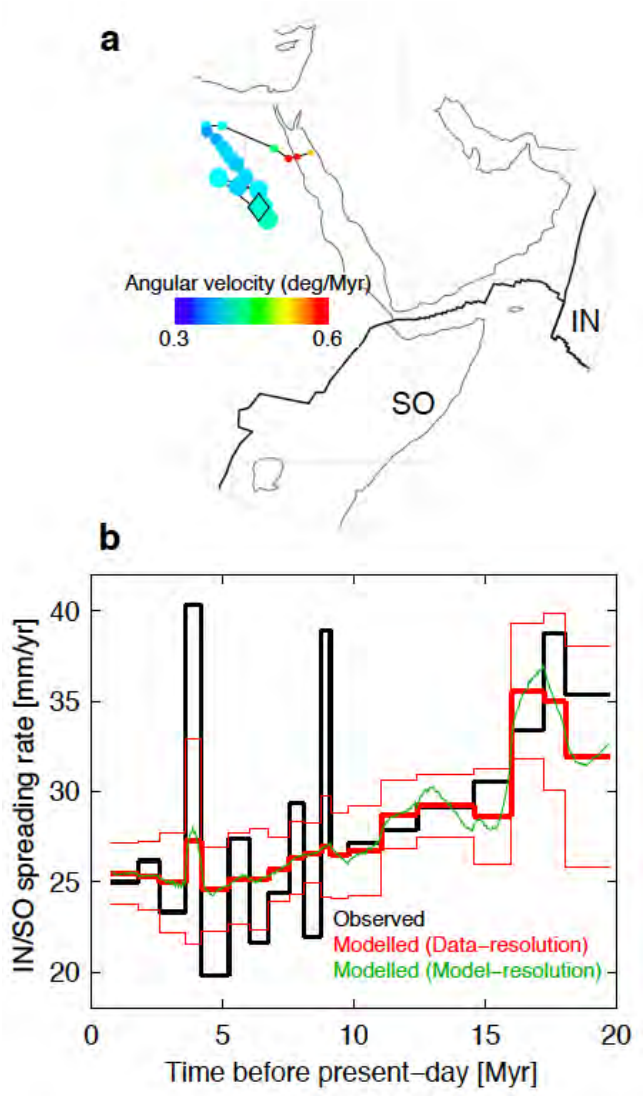

Figure 1. Modelled plate kinematics. (a) Euler poles (dots) for the relative motion of the Indian plate (IN) with respect to fixed Somalia plate (SO) since ~20 M Ma, reconstructed from modelled finite-rotations discretized according to the temporal resolution of observations. Euler poles are colour-coded according to their angular velocity. Note the same colour bar of Fig. 1a. Symbol size increases from the oldest to the youngest (shown as diamond) Euler pole. IN and SO plate margins are in black. Coastlines are in grey. (b) IN/SO spreading rate at (62E, 5N) from observed (in black) and modelled (in green) Euler vectors. In thick red are modelled spreading rates discretized at the temporal resolution of observations. Uncertainty ranges from the model ensemble are in thin red.

http://people.rses.anu.edu.au/iaffaldano_g/CONTENT/ibs_nc_2012.pdf

A new Probe of the Inner Core Boundary

Frequency Dependent Amplitude Ratio of PKiKP/PcP Waves Observed at the Hi-net Array in Japan

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[2] *Japan Agency for Marine-Earth Science and Technology*

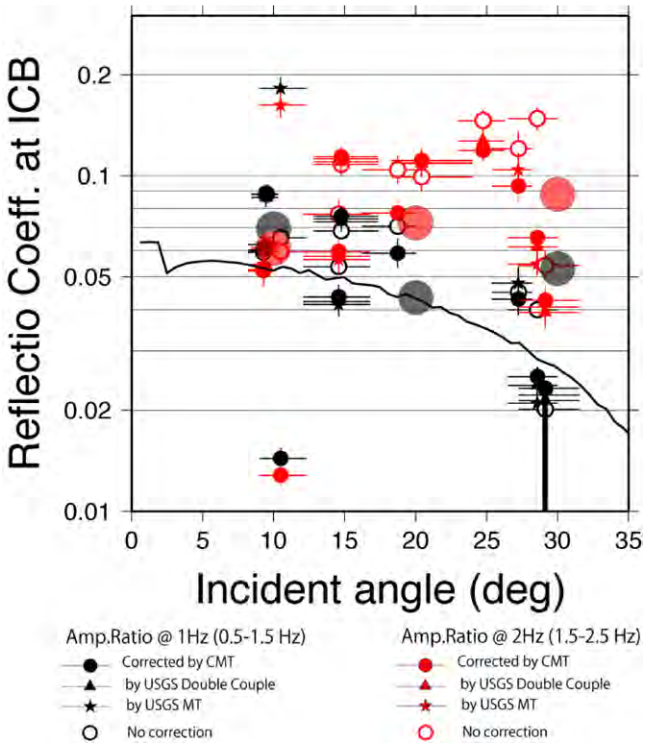

Figure 1. Amplitude ratios of the inner core- and outer core-reflecting PKiKP and PcP waves for nine events observed at Hi-net array plotted as a function of incident angle at the inner core boundary. Different symbols for each event indicate data corrected for earthquake source radiation pattern (from different methods). Black symbols represent data measured at 1 Hz, and red symbols represent data measured at 2 Hz. Black line is a theoretical prediction from ak135 model. Big circles are PKiKP/PcP ratios calculated from numerical simulations of a short scale topography at the inner core boundary.

The inner core boundary (ICB) is a vital region for understanding the Earth's core dynamics, e.g., the growth mechanism of the inner core and the source of geodynamo. The inner core has recently been described to be in a convective translation mode, such that the quasi-eastern hemisphere is a melting hemisphere (Alboussière et al., 2010). The amplitude ratio of the inner and outer core reflected seismic waves, PKiKP/PcP, has been used to infer the density jump at the ICB as well as the shear velocity at the top of the inner core. Previous studies, which have usually analysed amplitudes of PKiKP waves with predominant frequency of 1 Hz, were hampered by a large scatter of these data, which precluded uniquely constraining relevant parameters of the ICB structures. Poupinet and Kennett (2004) reported the existence of high frequency PKiKP (up to 5 Hz) with steep incident angles at the ICB observed across arrays and temporal broadband networks on the Australian continent suggesting a complex ICB. These high frequency PKiKP waves might hold the keys to understanding the growth mechanism and dynamics of the Earth's inner core. Here we observe and collect an unprecedented volume of high frequency PKiKP and PcP waves recorded by a dense network in Japan — Hi-net, and examine their frequency characteristics. This has relevance for understanding the Earth's core dynamics in the quasi-eastern hemisphere.

We detected clear PcP and PKiKP phases on high-pass filtered seismograms of 9 events with magnitude greater than 5.8 around Japan, of which hypocenters are located at Volcano Is., Mariana Is., Andreanof Is., Kuril Is., Sea of Okhotsk, Philippine, Banda Sea, Sumatra Is. The location of these events and the Hi-net array covers epicentral distance range from 15 to 45°. The spectra of PcP and PKiKP waves show several peaks around 1 and 2 Hz, resulting in the variations in the spectral ratio of PKiKP/PcP. Further analysis including the effects of source radiation, attenuation in the mantle and variations with epicentral distance reveals that the peak spectral ratios present around 1 Hz gradually decrease from ~0.2 at 15° to ~0.04 at 45°, which is similar to or a bit larger than PKiKP/PcP amplitude ratio predicted by the refection of a plane wave from the ICB. On the other hand, the spectral ratio around 2 Hz shows a smaller amplitude decay from ~0.2 at 15° to ~0.1 at 45°. Furthermore, spectral ratios of PcP/P observed at distances greater than 40° show that there is no significant reduction of PcP amplitudes around 2 Hz compared to those around 1 Hz, suggesting that the frequency dependent amplitude ratio of PKiKP/PcP originates from the amplitude anomalies of PKiKP.

To explain the observed frequency dependent amplitude ratios, we simulate the seismic wavefield of PKiKP waves with a frequency content of up to 5 Hz using finite difference method simplified to a 2D case. This allows us to explore a range of plausible 2D structures in the vicinity of the ICB, including ICB topography. Our numerical modelling results favour the existence of topography with wavelengths between 1 and 2 km long and a thin liquid layer sitting on the top of ICB, which is an important seismological observation in the context of recently developed geodynamical models of the inner core.

Alboussière *et al.* (2010), *Nature*, **446**, 744-747.

Poupinet & Kennett (2004), *Phys. Earth Planet. Int.*, **146**, 497-511.

A segmentation based transdimensional inversion approach to derive shallow water properties from remote sensing data

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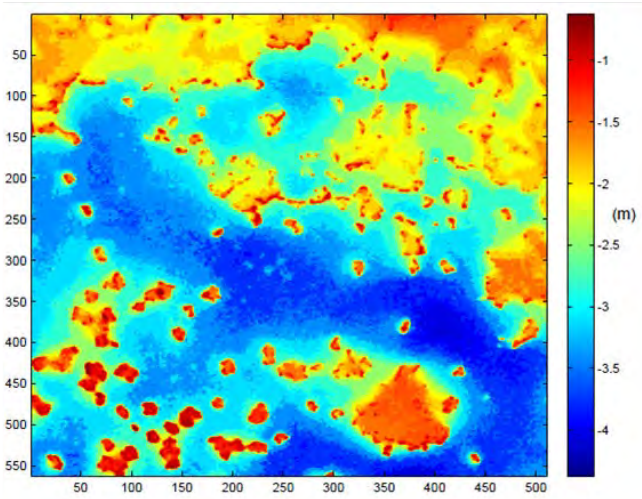

Figure 1. Original bathymetry data used for the synthetic data case study

The majority of remote sensing inversion methods are based on optimisation or look-up table approaches, aimed at providing a single best fit solution at each pixel. These are generally not suited to account for the uncertainty in both the data and possible ill-posed nature of the problem, or to quantify the uncertainty of the estimated parameters. Bayesian style inversion methods are probabilistic in nature, and designed to examine and reflect sources of uncertainty in the data, inversion model and solution. Their use in the inversion of remote sensing data has to date been limited by the high data volume and spatial heterogeneity inherent to remote sensing data, and the subsequent computational limitations in producing per-pixel inversion results.

We have developed a novel trans-dimensional reverse jump Markov Chain Monte Carlo (RJ-MCMC) approach applied to the shallow water inversion problem. To overcome the limiting issues of raster data dimensionality and spatial heterogeneity this approach incorporates object-based image segmentation to inform the Bayesian process.

As a case study, the developed RJ-MCMC algorithm has been applied to a synthetic high resolution hyper-spectral data-set representative of a shallow coral reef environment. Only bathymetry was varied in the semi-analytical model used in this study to create the synthetic data-set and to drive the sampling of the RJ-MCMC inversion algorithm. By keeping constant the substrate and water column properties, we isolate and examine the ability of the algorithm to sample and resolve spatial heterogeneity.

The results show that when guided by a segmentation of the synthetic data-set, bathymetry is retrieved more accurately and with lower uncertainties, spatial heterogeneity is more comprehensibly represented, and computational time is decreased. This illustrates the potential of the algorithm as a feasible Bayesian inversion method for remote sensing data. Further development of the algorithm will include the incorporation of substrate and water quality variability in the inversion and the use of existing ancillary data in a real-world scenario.

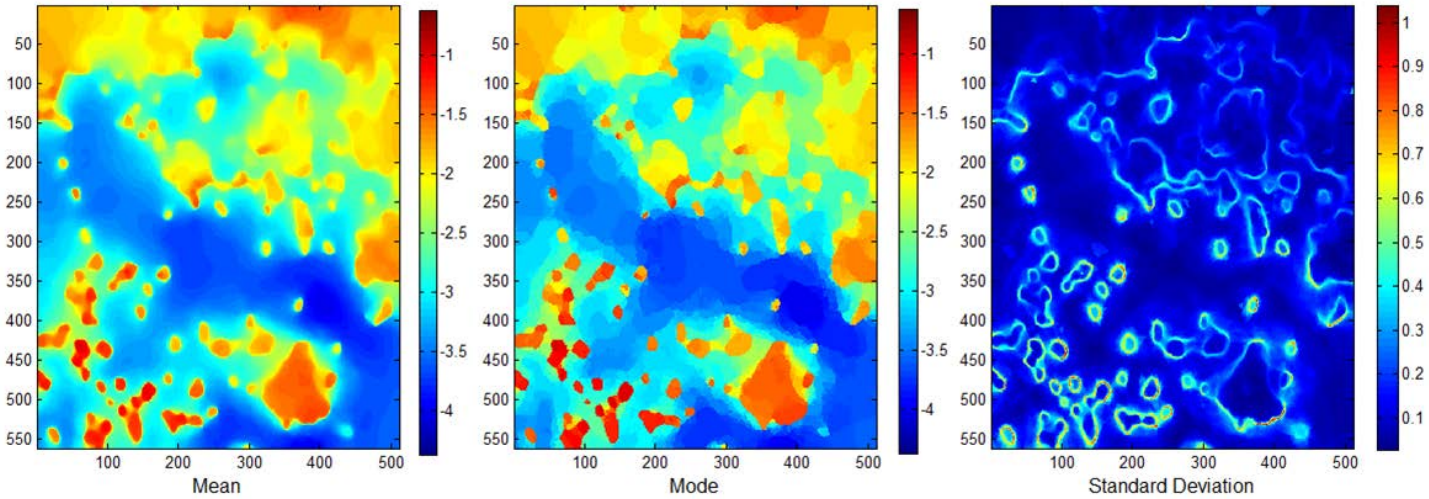

Figure 2. Estimated bathymetry models derived using the segmentation driven RJ-MCMC algorithm

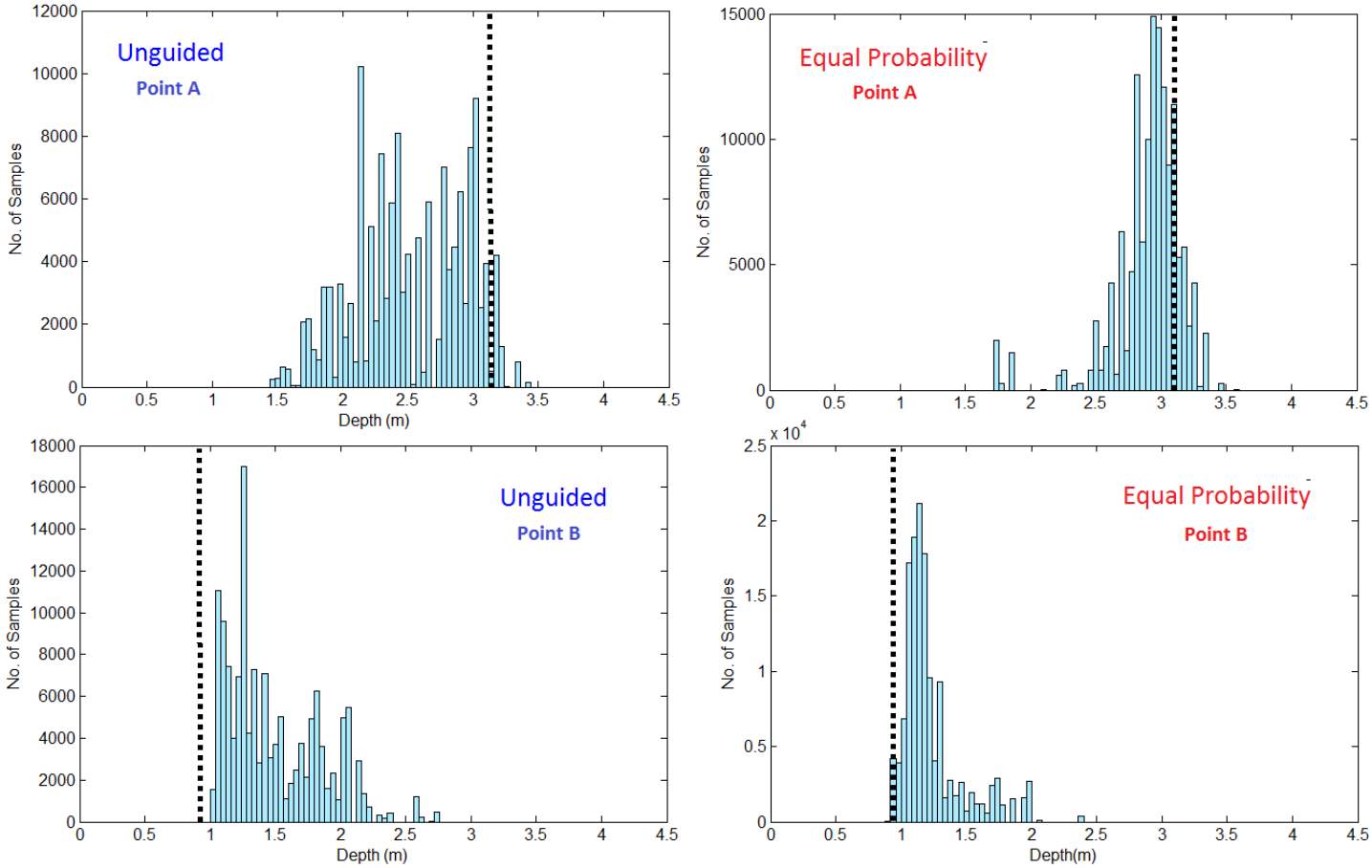

Figure 3. Comparison between the random (unguided) and segmentation driven (equal probability) algorithms - estimated depth marginal posterior distributions at two test points

AuSREM - Australian Seismological Reference Model

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The Australian Seismological Reference Model has just been completed. This model provides a grid based, fully interpolable seismological model of the Australian continent with a 0.5-degree resolution down to 300 km. The model is split into a crustal component and a mantle component. The crustal component provides a model of P-wave speed, S-wave speed and density at 5 km depth intervals and includes a model of the depth to Moho based on data from refraction, reflection, tomography and receiver functions. The mantle component provides a model of P-wave speed, S-wave speed, density and attenuation at 25 km depth intervals. The primary source of data for the mantle component is surface wave tomography.

Part of this project has included making these models publically available. This is an important step since good seismological models of the Earth's crust and upper mantle are critical for many tasks, such as the calculation of earthquake source parameters, regional hazard modelling and imaging of lithospheric dynamic processes. With the completion of this model we have made it publically available for download from the AuSREM website http://rses.anu.edu.au/seismology/AuSREM/. The model is currently being used in Australia for geothermal research, basin analysis, and earthquake location analysis. The models are also being used internationally for gravity and magnetic modelling. Work on tools to make this model even more accessible is ongoing.

AuSREM website
http://rses.anu.edu.au/seismology/AuSREM

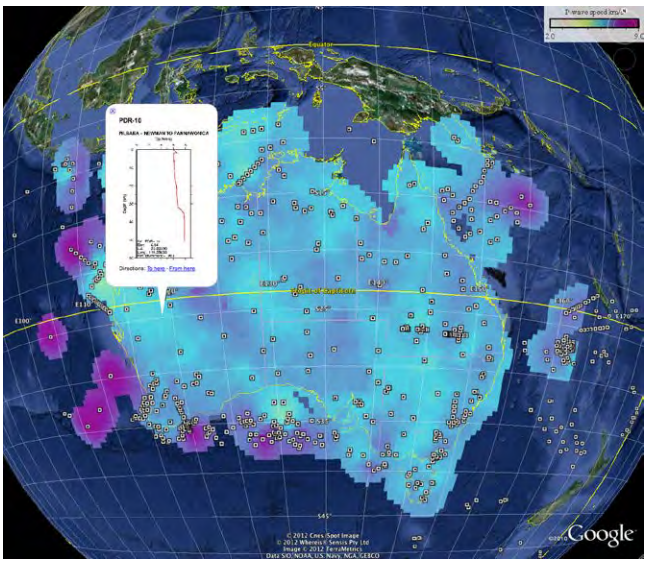

Figure 1. Crustal P-wave speed at 15 km depth. Squares show the locations of 1D velocity profiles used in the crustal model. An examle of these 1D models is shown in the insert bubble.

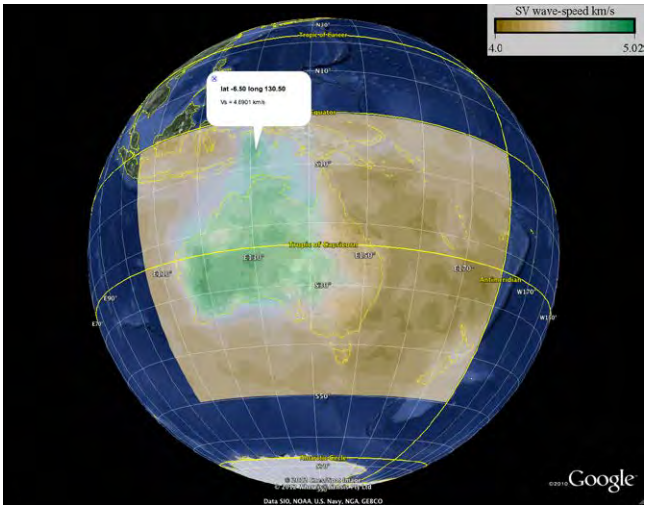

Figure 2. Mantle SV wave-speed at 150 km depth.

Improving source parameters by developing a regional velocity model for seismic hazard assessment in Indonesia

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When developing reliable seismic hazard assessments for Indonesia we require accurate moment tensor solutions. Not only are these source parameters relied on for describing the style of faulting and earthquake recurrence in a particular region, they are also critical in developing the Ground Motion Prediction Equations that determine the level of hazard for a given level of earthquake activity. In the past, reliable earthquake source parameters for Indonesia have been problematic due to the sparseness of local observations. However, the dramatic improvement in network coverage following the 2004 Sumatra earthquake should result in a commensurate improvement in the accuracy of earthquake source parameters.

This study aims at improving source parameter estimates for regional moment tensors in Indonesia so that they can be used for seismic hazard assessment. To assist with this we compiled a database that includes waveforms and associated metadata from both broadband and accelerometer instruments, and hypocenter locations, magnitudes and source mechanisms from multiple agencies and networks. From this we identified that depth estimates from moment tensor solutions are one of the least consistent source parameters. For example, solutions from a magnitude 6.5 earthquake on the Sumatra Fault in October 2009, has depth estimates of between 10-30 km. The complex crustal structure of the region is one possible cause for these inconsistences.

The Green's Functions used in the moment tensor inversions are computed using a variety of velocity models to investigate the sensitivity of the solutions to the models at different periods. Surface wave analysis was also performed in attempt to validate the models and identify any missing features.

Our preliminary results suggest the complex crustal and upper mantle structure beneath Indonesia may be simplified for moment tensor inversions of large events (M > 6) where long period surface waves are used (50-150 s). However, to determine regional moment tensors for smaller events (4.5 < M < 5.5) we require shorter periods (10-50 s) and a better understanding of the regional crustal model. Future work will aim to improve the regional velocity model so that we can use shorter periods and extend the moment tensor catalogue to smaller events (M < 5.5). We will also continue trying to improve the depth estimates from moment tensor solutions in Indonesia.

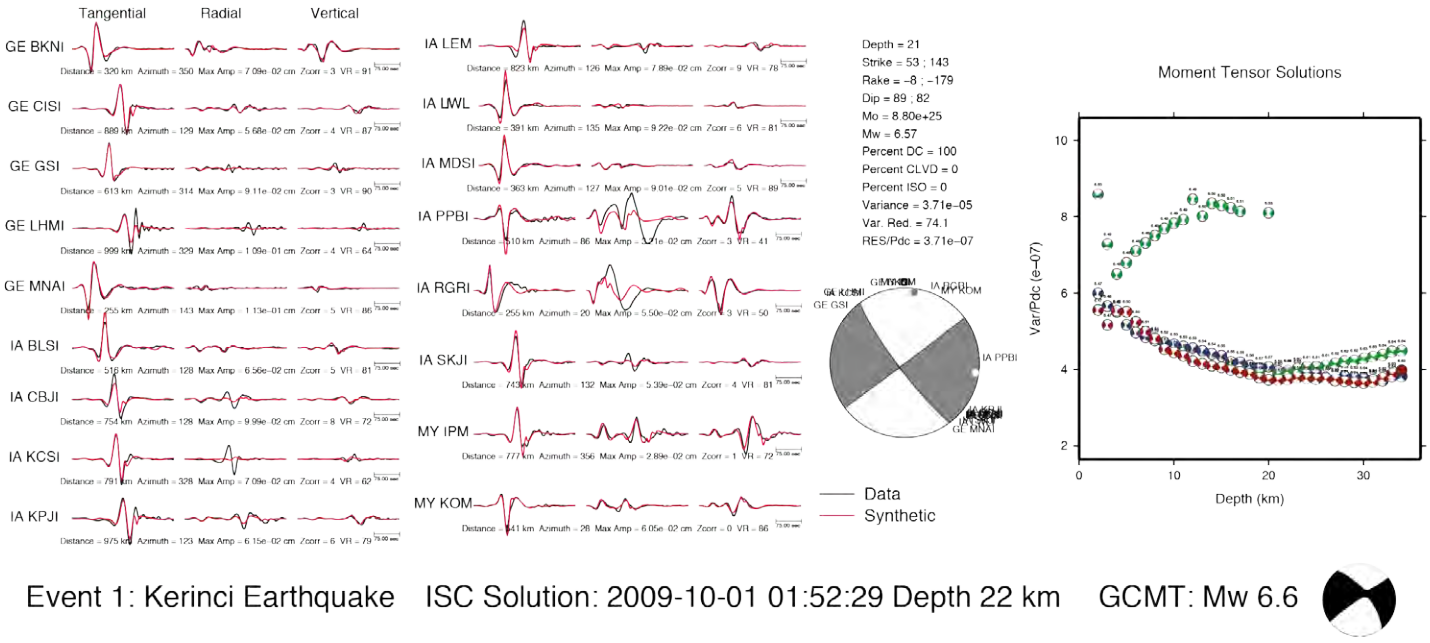

Figure 1. Moment tensor inversion results from the 2009 Kerinci Earthquake, Indonesia. The solution shown is chosen based on the preferred depth estimate from the ISC catalogue (22 km). To determine whether the depth can be determined from the moment tensor solution we have included the variation in the solution with depth and against the Variance/%double-couple (since they are expected to be highly douple-couple the smaller the value the better the solution). Also included is the GCMT solution for comparison. Note the wide

range of depths over which there are acceptable solutions.

Multi-scale seismic imaging with unknown data noise

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A meaningful interpretation of seismic measurements requires a rigorous quantification of the uncertainty. In an inverse problem, the data noise determines how accurately observations should be fit, and ultimately the level of detail contained in the recovered model. A common problem in seismic tomography is the difficulty in quantifying data uncertainties, and thus the required level of data fit. Dealing with multiple data sets that are characterized by different noise variances and that span the Earth at different scales is a major challenge.

Practitioners are usually required to arbitrarily weigh the contribution of each data type into the final solution. Furthermore, the spatial representation of the Earth model is usually uniform across the region of interest, while the data, and therefore its information content, is unevenly distributed. A new way to address these issues is adoption of a Hierarchical Bayesian inversion. The new algorithm represents an extension of the transdimensional tomography to account for uncertainties in data noise. This approach has the advantage of treating the level of noise in each data set, as well as the number of model parameters, as unknowns in the inversion. It provides a parsimonious solution that fully represents the degree of knowledge one has about seismic structure (i.e. constraints, resolution and trade-offs). Rather than being forced to make decisions on parametrization, level of data fit and weights between data types in advance, as is often the case in an optimization framework, these choices are relaxed and instead constrained by the data themselves.

The new methodology has been applied to ambient seismic noise data sets that span the Australian continent at different scales. We are able to simultaneously invert for a multiscale tomographic image of Rayleigh wave group velocity for the Australian continent. The procedure turns out to be particularly useful when dealing with multiple data types with different unknown levels of noise. The algorithm is able to naturally adjust the fit to the different data sets and provide a velocity map with a spatial resolution adapted to the spatially variable information present in the data.

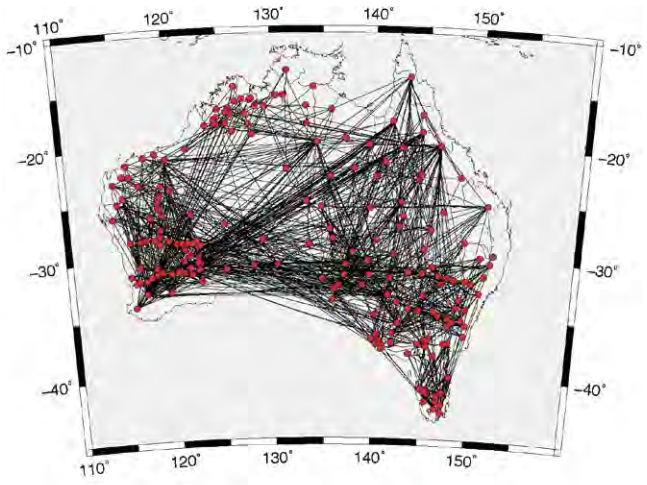

Figure 1. Data set 1 used in the multi-scale inversion. Australia wide ambient noise measurements at 5 s.

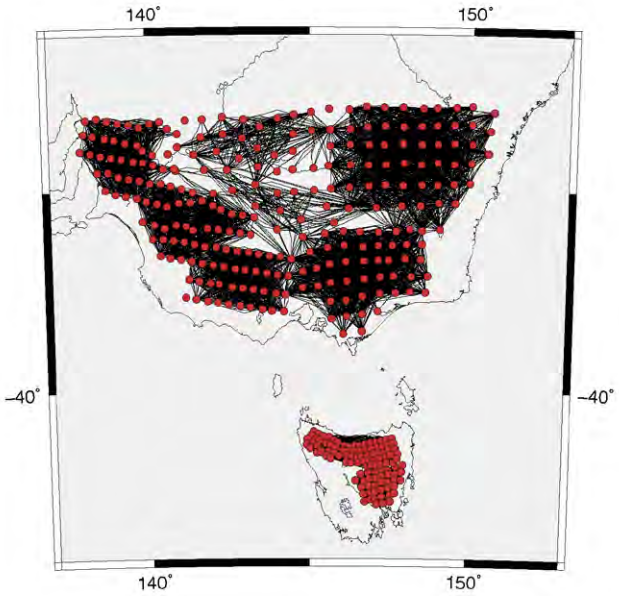

Figure 2. Data sets 2 and 3 used in the multi-scale inversion. Ambient noise measurements from the WOMBAT array in South Eastern Australia and Tasmania.

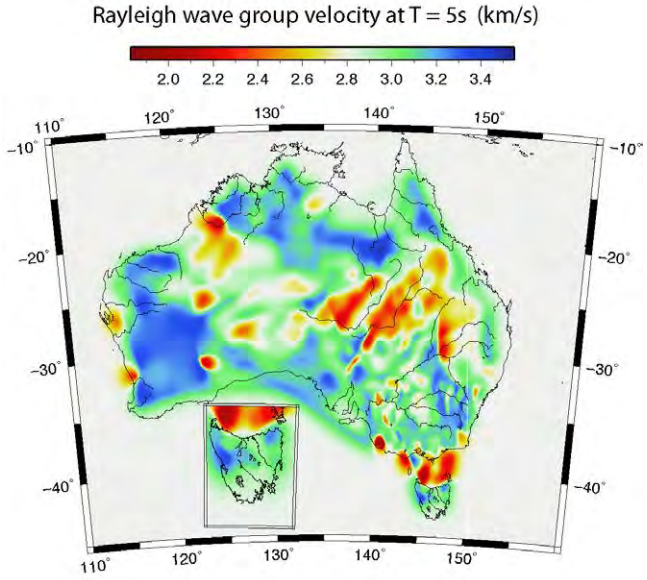

Figure 3. A multi-scale Surface wave Vs velocity distribution obtained with the transdimensional inversion scheme. The underlying data set consist of three distinct ambient noise

datasets with different spatial scale and unknown relative noise levels (See Figures 1 and 2). The inversion process is able to adapt the model to the detail in the data while determining the relative importance of each data set in construction of the final image.

W Phase Inversion For Finite Fault Slip

Roberto F. Benavente Bravo and Phil R. Cummins

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The W phase is a long-period seismic wave arriving together with the P wave, whose high group velocity makes it particularly useful for rapid determination of source mechanism. To date inversions of W phase waveforms have used the point source approximation. In this study we consider the utility of the W phase for extracting information about the finite character of faulting in major earthquakes. We have applied W phase inversion to seismic waveforms recorded following the 2010 Chilean earthquake (Mw=8.8). We consider inversion of broadband waveforms recorded by 19 stations in the distance range 5-90 degrees. Instead of inverting for the faulting mechanism as has been done in previous work using the W phase, we assume a faulting geometry of the Chilean megathrust: strike=18, dip=18, and let the rake vary. Our main results are in agreement with the features described in other solutions for this event. We believe this is an important step towards a rapid tsunami source characterization.

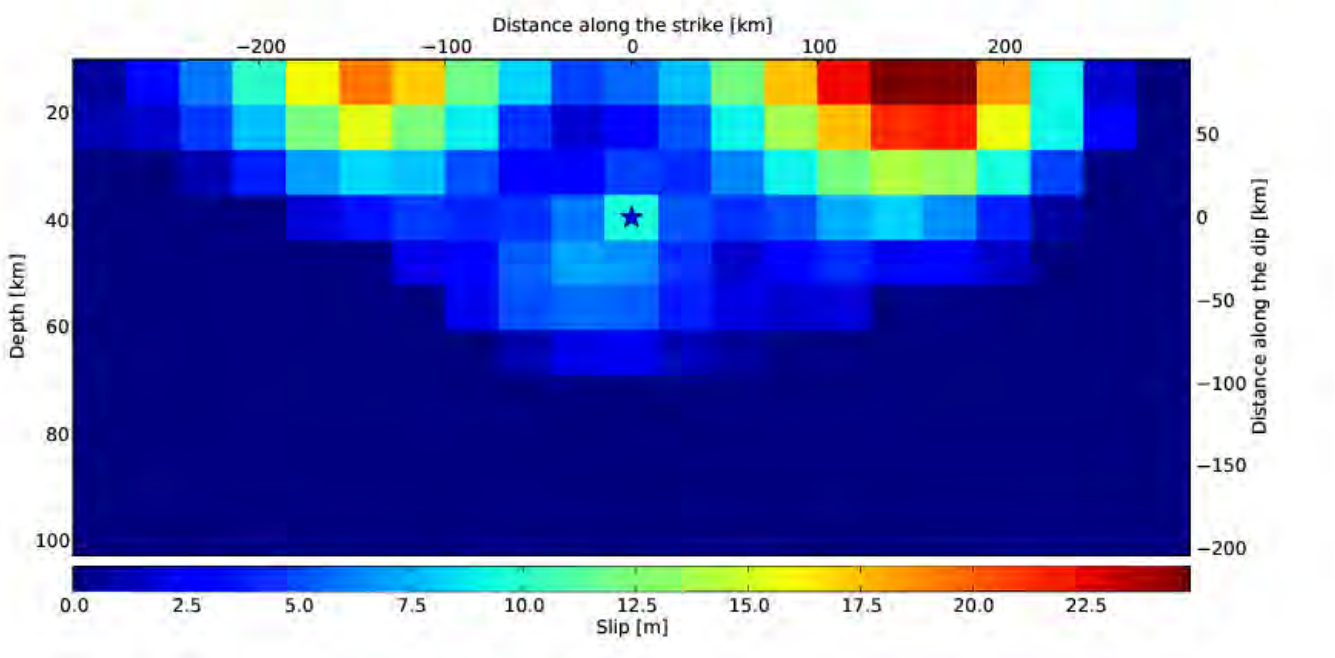

Figure 1. Slip distribution for the chilean earthquake. As in other solutions for this earthquake we found a bilateral rupture with a major moment release offshore.

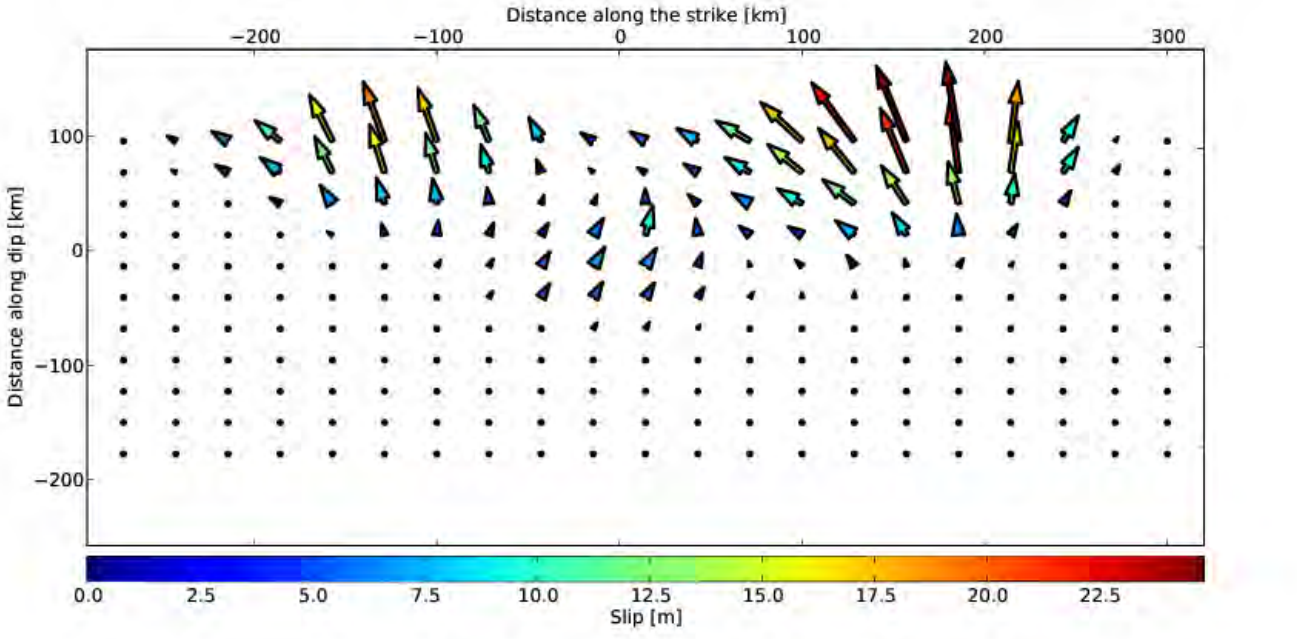

Figure 2. Rake distribution for the chilean earthquake. In the zone of major slip we found a value ~100º.

Illuminating the upper mantle beneath the Newer Volcanics province, southeast Australia, using seismic body wave tomography

Nicholas Rawlinson

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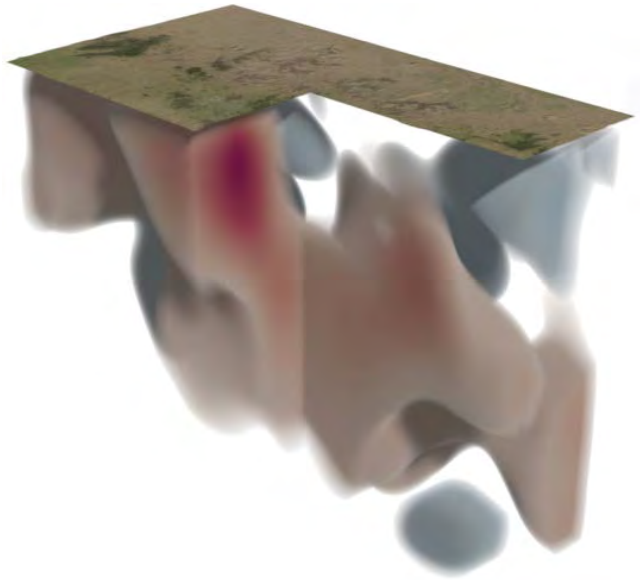

Figure 1. View of the low velocity anomaly associated with the Newer Volcanics province

The Newer Volcanics province (NVP), located in the state of Victoria, southeast Australia, represents the youngest evidence of basaltic intraplate volcanism in the Australian continent, with the most recent eruptions dated less than 5ka. Although one of many Cenozoic eruption centers that populate the eastern edge of the Australian mainland, the NVP is unique in that it is not obviously part of a hot-spot chain. For example, the distribution of NVP eruption centres is elongated in the east-west direction, perpendicular to plate motion. Moreover, it appears that the NVP is the latest phase of an eruption cycle that has operated intermittently since the early Eocene when fast northern motion of the Australian continent commenced. Coupled with modest surface topographic response (~100 m) and a relatively low eruption volume (~20,000 km^3) researchers have begun to suspect that the source of the NVP does not fit the mold of a traditional mantle plume model, but instead may be a phenomenon localized to the upper mantle. One possibility is that strong undulations in lithospheric thickness, as observed in surface and body wave tomography, together with a northward movement of the Australian plate relative to the subjacent mantle, may result in edge-driven convection, in which cells of warm, hydrous mantle are periodically advected upwards and release melt, which then migrates up to the surface.

In this study, we use teleseismic P-wave data recorded by the WOMBAT transportable array project in eastern Australia– the largest experiment of its type in the southern hemisphere - to image 3-D velocity perturbations beneath the NVP. Relative arrival times of global P-phases are inverted to constrain P-wavespeed anomalies in the uppermost mantle. Constraints from regional surface wave tomography are also incorporated into the results in order to account for the long-wavelength structures that are filtered out by the use of relative arrival time residuals.

The final P-wave velocity model shows a clear zone of low velocity underlying the NVP (maximum perturbation of -4% relative to AK135). It clearly extends to a depth of just over 200 km, before terminating, with no evidence of reduced velocities down to approximately 300 km, the maximum depth resolution of the seismic data. Furthermore, nearer the surface (~100km depth), there appears to be three distinct regions of low velocity that are distributed E-W between central Victoria and Mt. Gambier near the South Australian border. The lack of evidence for a deep seated anomaly is consistent with the hypothesis that the source of the NVP is confined to the upper mantle, although an important caveat is that plumes are expected to be narrow as they rise through the mantle before broadening out as they encounter the base of the lithosphere; as such, it s possible that the limited spatial resolution of the data (approximately 50 km) is unable to detect narrow vertical structures at depth. However, combined with the observations discussed earlier, our results strengthen the argument for a localized upper mantle anomaly.

Structural controls on localised intraplate deformation and seismicity in southern Australia: insights from local earthquake tomography of the Flinders Ranges

Simone Pilia[1], Nicholas Rawlinson[1], Nicholas Direen [2,3], Phil Cummins[1] and Natalie Balfour[1]

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[2] School of Earth Sciences, University of Tasmania, Hobart, Tasmania 7001, Australia
[3] FrOG Tech Pty. Ltd., PO Box 145, Blackmans Bay, Tasmania 7052, Australia

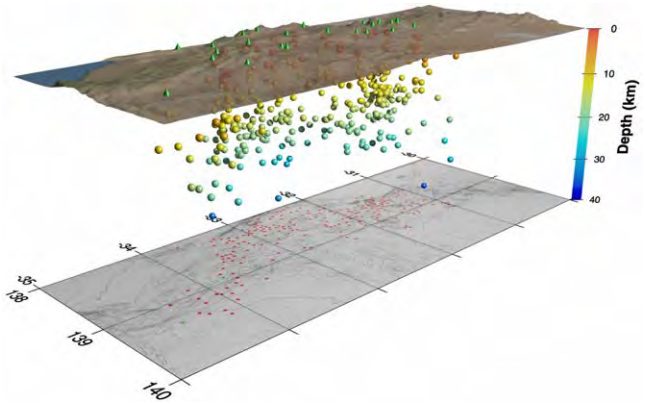

Figure 1. 3D model of relocated hypocenters. Green cones denote receivers and the contour map at the base of the figure highlights topography (grid in degrees).

In this study, data from an array of 24 seismometers is used to image the crust beneath the Flinders Ranges, southeast Australia, with the goal of improving our understanding of crustal structure, rheology, and the mechanism responsible for the localised intraplate deformation that characterises this region. A subset of P- and S-wave traveltimes is inverted to jointly recover earthquake hypocenters, P-wave velocity structure and vp/vs anomalies. The P-wave velocity model reveals a striking spatial correlation between major negative wavespeed perturbations and concentrations of seismicity. In particular, a cluster of seismicity is observed within a distinct low velocity region between the Archean-Mesoproterozoic Gawler Craton and the Palaeo-Mesoproterozoic Curnamona Province, from 7 to 20 km depth. We postulate that this may be associated with a pre-existing structural weakness in the crust which arises primarily from rifting between the Curnamona Province and the Gawler Craton. Another area characterised by a high level of seismicity overlies a major sequence of N-S trending Ross-Delamerian thrust faults - representing deformation associated with the initial phase of orogenesis responsible for the formation of Phanerozoic eastern Australia - which correspond to a band of low vp and particularly vp/vs. The lack of evidence for elevated heat flows in both of these seismogenic regions suggests that thermally induced weakness is unlikely to play a dominant role. Instead, the dynamic behaviour of this intraplate region appears to be caused by a serendipitously oriented regional stress field, provided by far field forces that originate from the boundary between the Pacific and Australian plates, which acts upon pre-existing structural weaknesses in the lithosphere that abut a mechanically strong Archean craton.

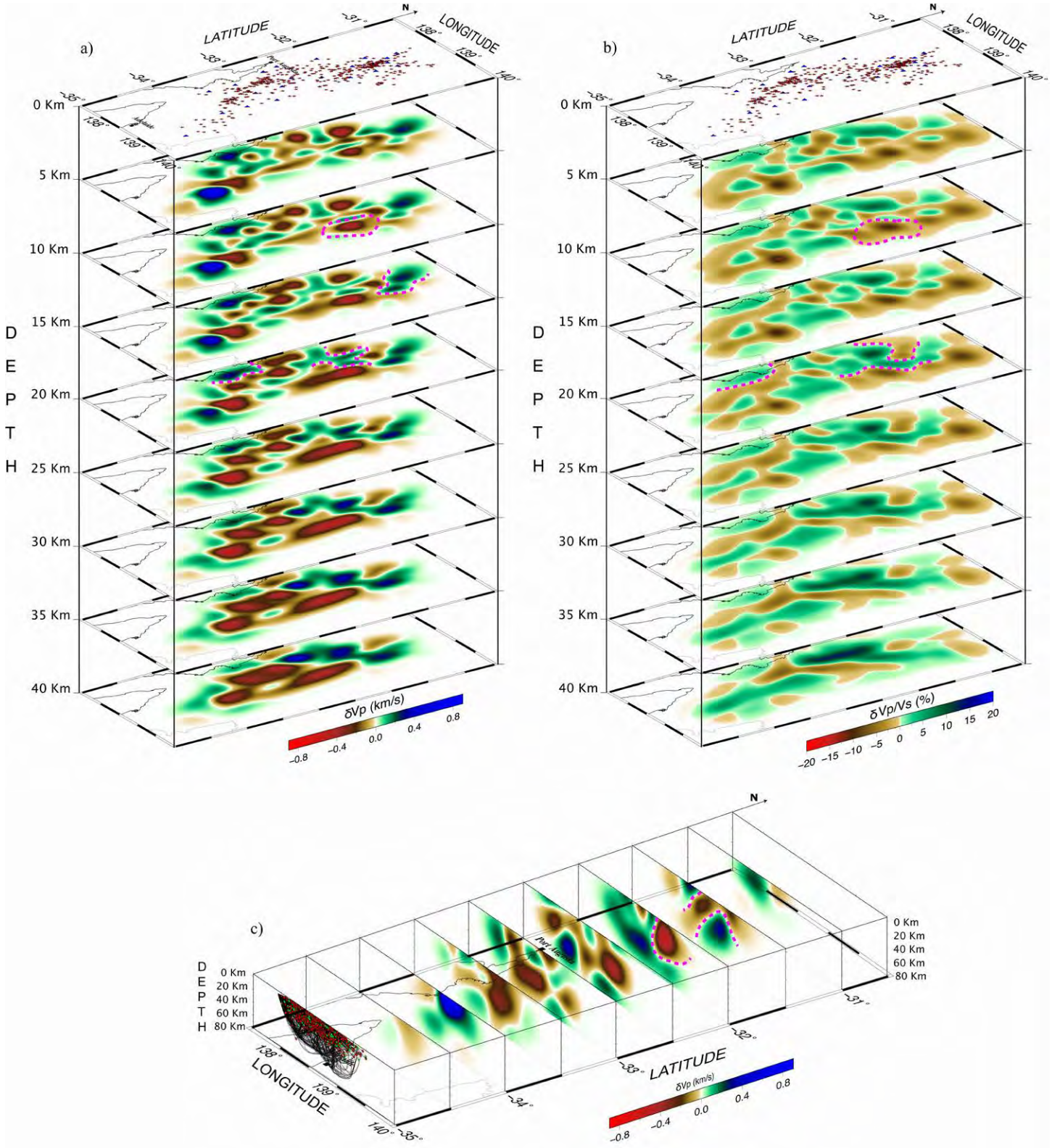

Figure 2. Horizontal and vertical slices through the final tomographic solution models. Depth vp (a) and vp/vs (b) slices and E-W vp cross-sections (c). Magenta dotted lines point out the main features

Structure of Mt. Isa and Surroundings from SeismicAmbient Noise Tomography

Structure of Mt. Isa

Erdinc Saygin[1], Herb McQueen[1], Laurie J. Hutton [2], Brian L.N. Kennett[1] and Gordon Lister[1]

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[2] Geological Survey of Queensland, Brisbane, QLD 4002, Australia

The crustal structure of Mt.Isa and surrounding blocks are delineated by using seismic ambient noise group and phase velocity tomography. The depth extent of the blocks were imaged along the spatial extent of the anomalies. Proterozoic Mt. Isa block is imaged with high seismic velocities comparable to cratonic blocks in Western Australia. The surrounding basins in the region have relatively low velocities, where seismic velocity anomalies show correlation with the regional Bouger gravity map, and high heat flow the region. Some of the isolated low velocity anomalies indicate previously unknown heat anomalies in the region.

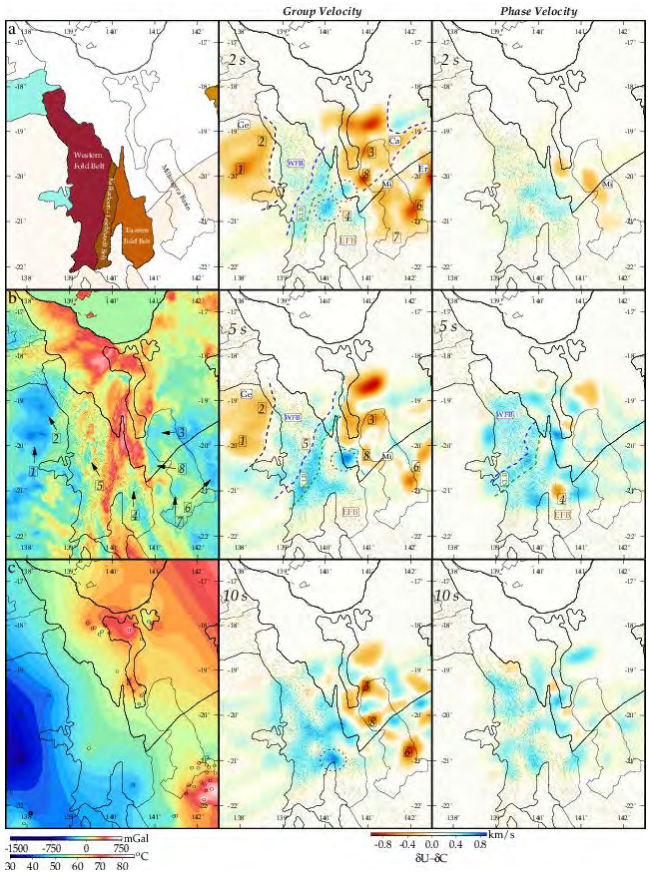

Figure 1. Comparison of group and phase velocity images with tectonic blocks (a), Bouger Gravity (b), and temperature distribution: OZTemp (Gerner and Holgate 2010) (c). Circles denote the actual location of measurements. Low seismic velocity regions which matches gravity lows are marked with numerals. Dashed lines show the inferred boundaries of blocks of Mt. Isa, and sedimentary blocks.

The Crustal Structure of Indonesia from Seismic Noise Tomography

The Crustal Structure of Indonesia

Erdinc Saygin[1], Phil R. Cummins[1], Suhardjono[2] and Kiwamu Nishida[3]

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[2] *Badan Meteorologi, Klimatologi, dan Geofisika, Jakarta, Indonesia*
[3] *Earthquake Research Institute, The University of Tokyo, Tokyo, Japan*

We apply group velocity seismic noise tomography to image crustal structure of Indonesia and surrounding regions by using over 500 stations. Green's functions retrieval from seismic noise and frequency-time analysis are applied for estimating group velocity dispersion. We inverted the traveltimes with a nonlinear hierarchical 2D tomography. Many geological features with low wavespeeds were imaged across Indonesia. The low velocity anomalies shown in Figure 1 (highligted with blue) correspond to the thick basins, and volcanic domains. Some of fragmented oceanic crust is also imaged with high velocities.

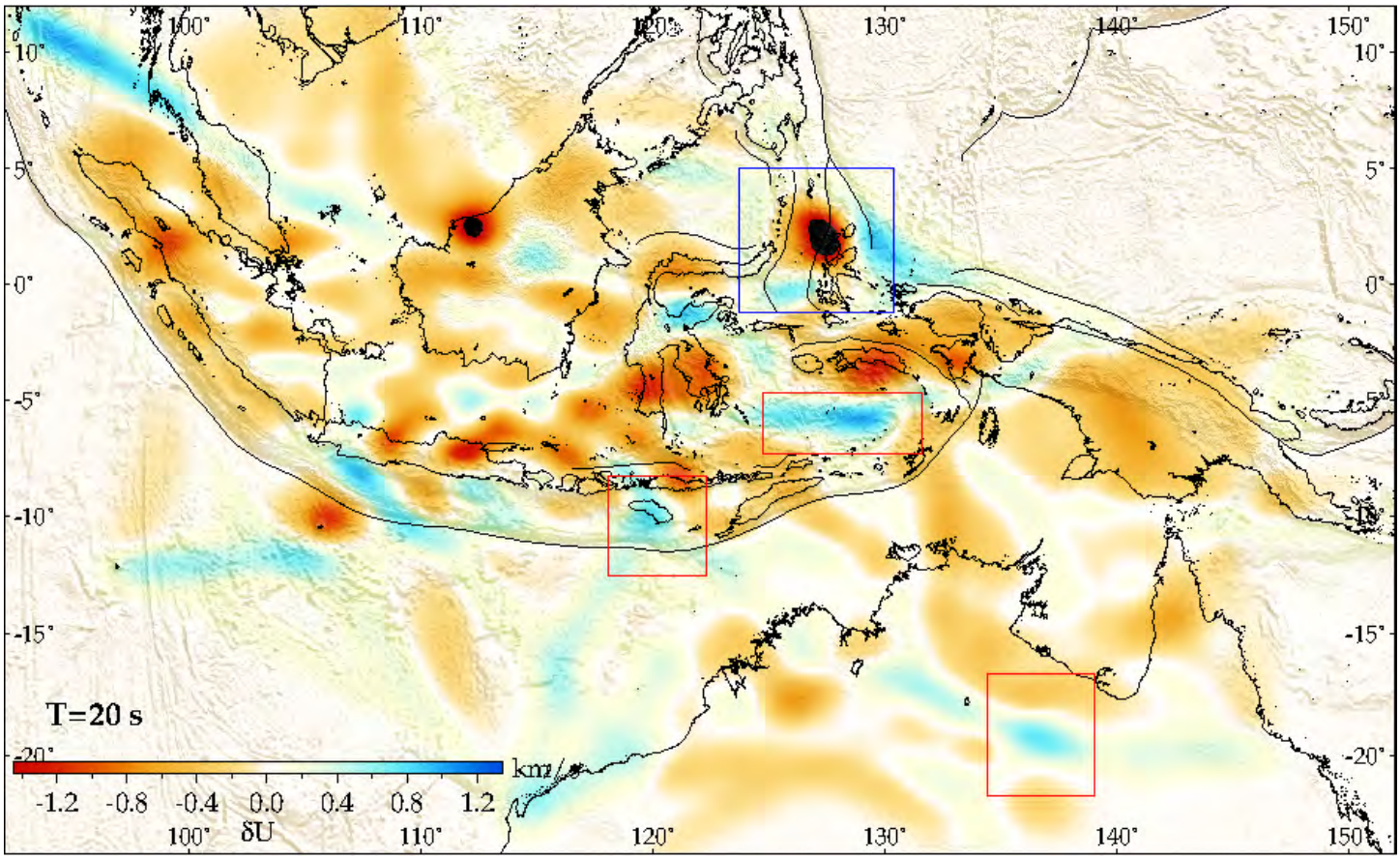

Figure 1. Seismic tomographic velocity image at 20 seconds. Regions with colored boxes show zones with very high velocity perturbations.

Earthquake Source Properties and Site Amplification for the Indonesian Strong-Motion Network

Indra Gunawan[1,2], Prof. Phil R. Cummins[1,3] and Dr. Hadi Ghasemi[3]

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[3] *Geoscience Australia, Canberra, Australia*

Spectral analysis for both intraslab and crustal earthquakes are needed to yield more detail about earthquake properties and site amplification. Basically, an earthquake recorded by a seismograph or accelerograph contains three main components namely, the source, path and site effects. The source effect is determined by earthquake parameters such as seismic moment, corner frequency, source radius and stress drop. The path effect is described by the Q factor and other seismic attenuation effects. Lastly, the site effect plays an important role in assessing amplification of ground motion and is a critical aspect in developing a reliable seismic hazard assessment.

We are analyzing available the Indonesian strong-motion and broadband data to constrain these source, path and site effects. We use spectral analysis of seismic body wave (P-wave) and attempt to fit with a theoretical "Brune-type" source model to constraint earthquake properties. We will also analyse the potential of using residual between observed spectra and Brune-type model in assessing preliminary site amplification information with its consistency. However, this approach is preliminary and We will develop a more robust approach to simultaneous estimation of source parameters and site amplification.

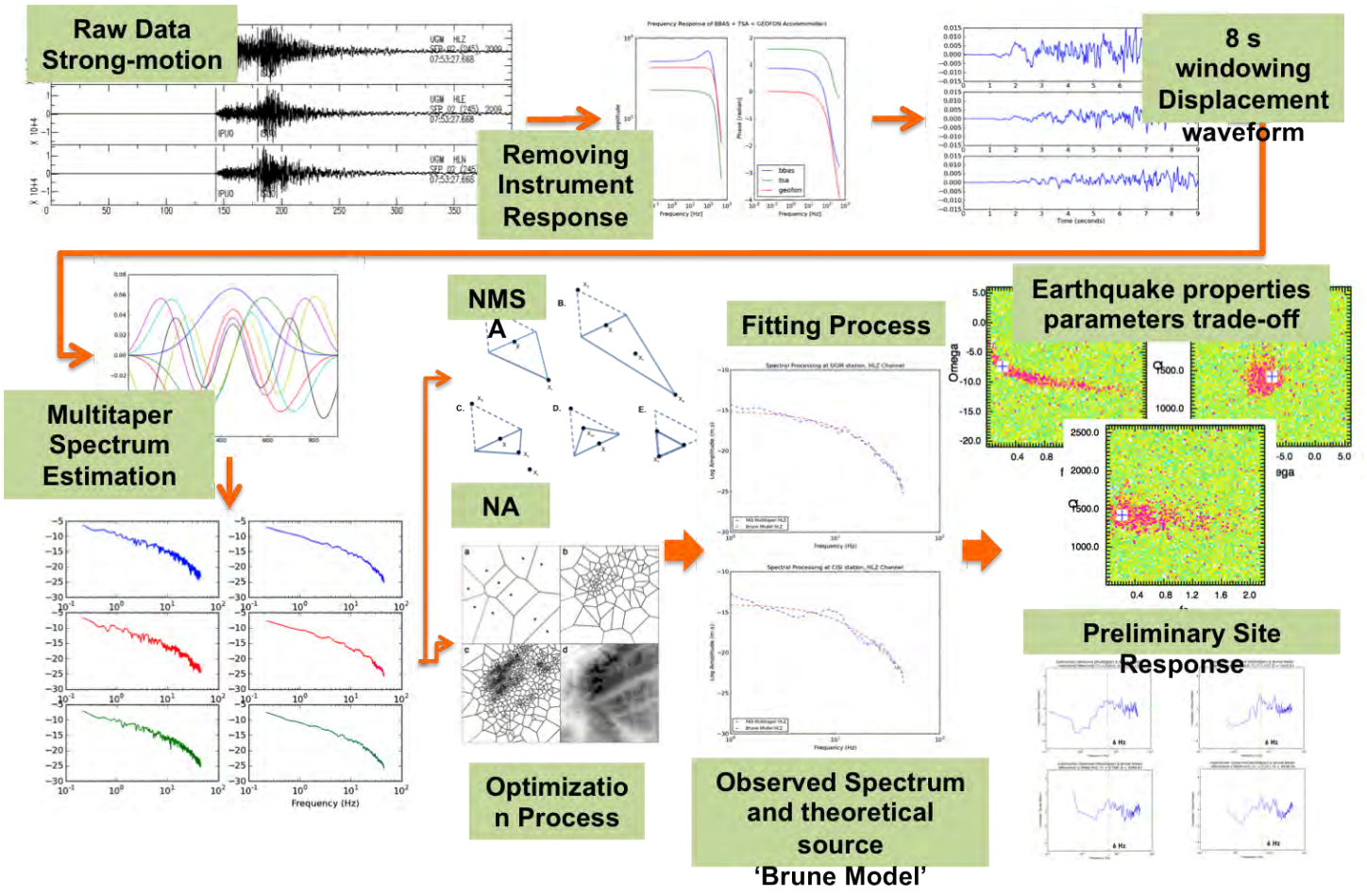

Figure 1.

Assessing Sensitivity of Probabilistic Seismic Hazard Analysis to Fault Parameters: Java and Sumatra Case Study

Amalfi Omang[1,2], Phil Cummins[1,3], Nick Horspool[3] and Sri Hidayati[2]

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Slip rate data and fault geometry as part of the fault parameters are two important inputs in determining seismic hazard, because they are used to estimate earthquake recurrence intervals and maximum magnitude which strongly influence the hazard level in an area. However, the uncertainty of slip-rates and geometry of the fault are rarely considered in any probabilistic seismic hazard analysis (PSHA), which is surprising given the estimates of slip-rates can vary significantly from different data sources (e.g. geological vs. Geodetic).

We use the PSHA method to assess the sensitivity of seismic hazard to fault parameters along the Sumatran Fault System (SFS) in Sumatra, Indonesia. We consider the epistemic uncertainty of fault slip rate by employing logic trees to include alternative slip rate models. The weighting of the logic tree is determined by the probability density function of the slip rate estimates using the approach of Zechar and Frankel (2009). We consider how the PSHA result accounting for slip rate uncertainty differs from that for a specific slip rate by examining hazard values as a function of return period and distance from the fault. We also consider the geometry of the fault, especially the top and the bottom of the rupture area within a fault, to study the effect from different maximum magnitudes.

Based on the results of this study, in some cases the uncertainty in fault slip-rates, fault geometry and maximum magnitude have a significant effect on hazard level and area impacted by earthquakes and should be considered in PSHA studies.

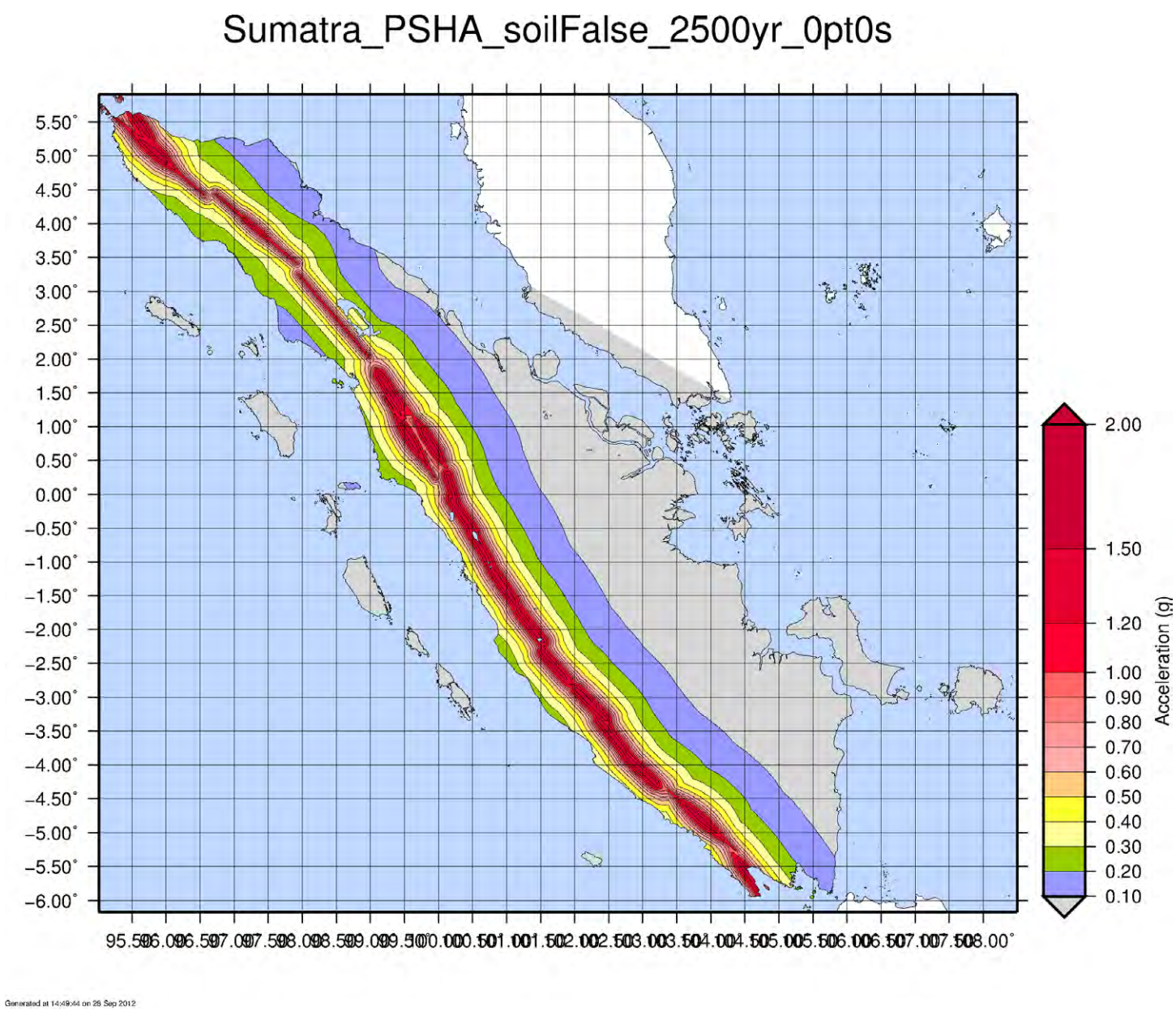

Figure 1. Sumatra peak ground acceleration map at 2500 year return period

DEVELOPMENT OF STRONG MOTION DATABASE FOR SUMATRA-JAVA REGION

Ariska Rudyanto[1,3], Phil Cummins[1,2], Hadi Ghasemi[2], Indra Gunawan[1,3] and Suhardjono[3]

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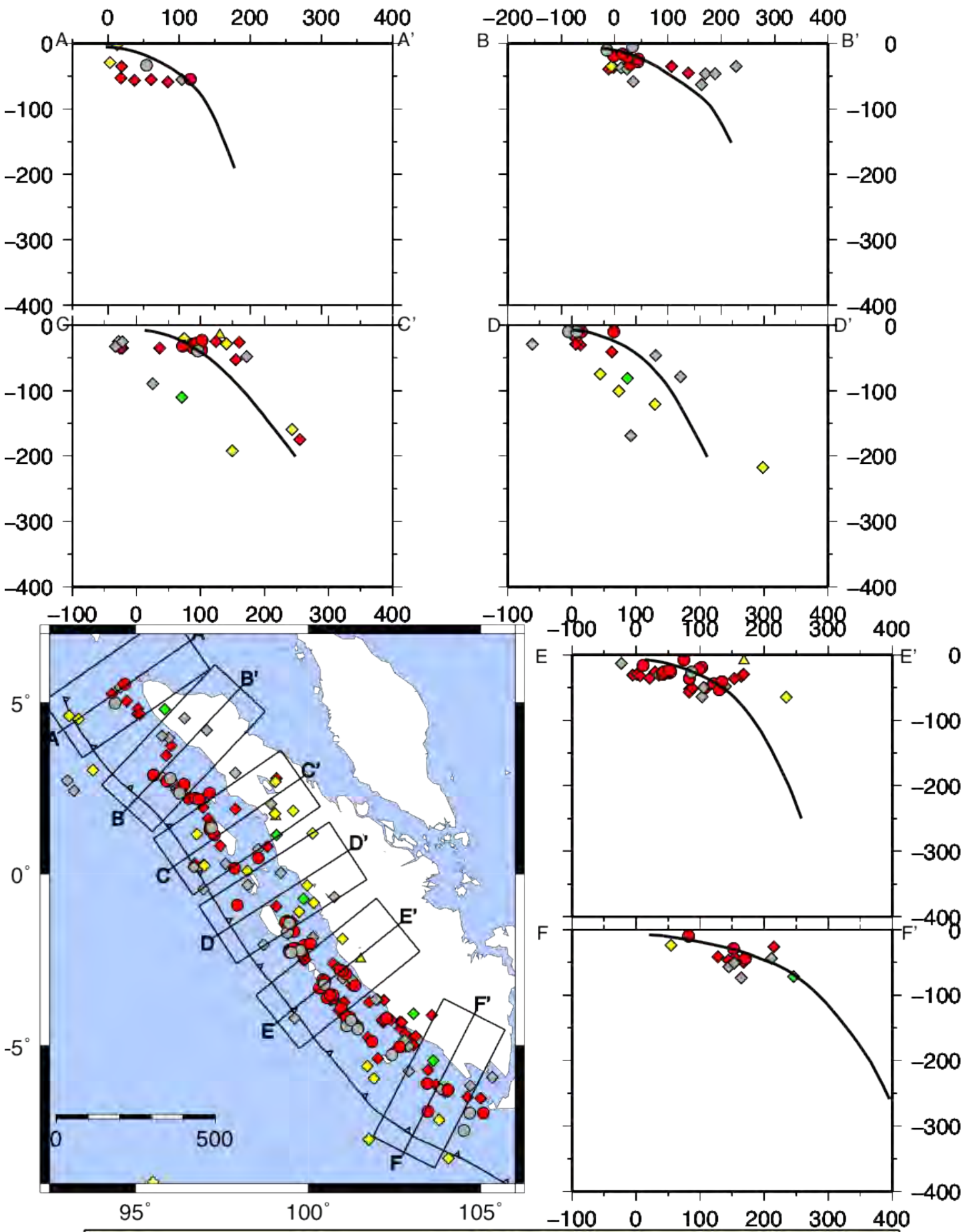
Since the Indonesian islands of Sumatra and Java lie adjacent to an active subduction zone and include some of the world's most densely populated areas, the reduction of potential earthquake fatalities through improved building codes and seismic hazard assessments is a high priority. One of the most critical parts of an earthquake hazard assessment is a quantitative description of the level of ground motion generated by an earthquake, as known as Ground Motion Prediction Equations (GMPEs). Until now, very limited information on ground motion is available, resulting in high uncertainty in PSHA results. With the recent development of modern seismographic network in Indonesia, it should be possible to develop much better information on ground motion that will result in more reliable earthquake hazard assessments. Also, better constraints on earthquake ground motion should result in improved reliability of rapid earthquake impact assessments.

We have developed a strong ground motion database for of Sumatra and Java regions. This catalog includes: best-available earthquake catalogue parameters; a compilation of site response information using various techniques; and ground motion parameters commonly used in seismology and engineering application, such as peak ground acceleration and response spectra. We will show how the database can be used for investigating which published Ground Motion Prediction Equation (GMPE) are appropriate to use for Indonesian earthquake hazard assessment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−300
−400
5°
0°
-5°
95°
100°
105°
500
LEGEND
Crustal
Interface
Intraslab
thrust
normal
strike slip
unknown

Figure 1. Distribution of earthquakes that have strong motion record at Sumatra area

Multi-scale Velocity Heterogeneity in the Lowermost Mantle

Mallory Young[1], Hrvoje Tkalcic[1], Thomas Bodin[2] and Malcolm Sambridge[1]

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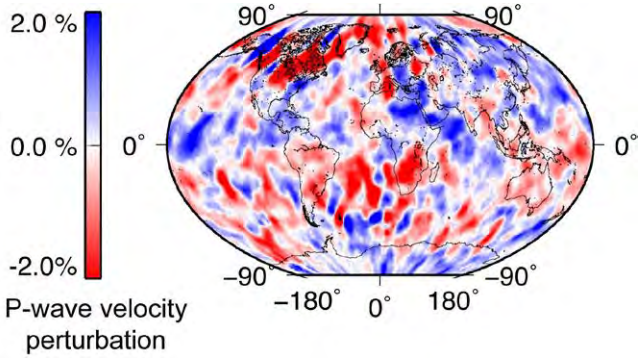

Figure 1. P-wave velocity variations (relative to the global reference model ak135 (Kennett et al. 1995)) in the lowermost mantle as revealed by this study.

Determining the scale-length, magnitude, and distribution of chemical and thermal heterogeneities in the lowermost mantle is crucial to understanding whole mantle dynamics, and yet it remains a much debated and ongoing challenge in geophysics. In response, we have developed a new approach to global tomography where the problem is addressed within a Bayesian framework and explicit regularization of model parameters is not required. We obtain high resolution images of the lowermost mantle P-wave velocity structure using a hand-picked data set of PKPab-df, PKPbc-df, PcP-P, and P4KP-PcP differential traveltimes. By using differential travel times, the biases associated with event mislocation and lateral heterogeneity in the lithosphere are minimized. Results so far reveal velocity heterogeneities on a variety of scales, thus providing an important link between the very short-scale imaging achieved through scattering experiments and the long wave-length maps resulting from more traditional tomographic approaches. Moreover, the power of heterogeneity in the lowermost mantle appears to be significantly larger than previous global-scale estimates. The pattern and characteristic scale-length and amplitude of heterogeneity revealed by this study will help refine allowable models of thermo-chemical convection in the lowermost mantle.

Extending the Global Database of Geomagnetic Excursions

Elizabeth Ingham and Prof. Andrew Roberts

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Geomagnetic excursions are short duration deviations of the Earth's magnetic field into an intermediate polarity state, usually defined as a deviation of the Virtual Geomagnetic Poles recorded at a site by more than 45° from the geographic pole. As one of the least well recorded or understood geomagnetic phenomena, there is an ideal opportunity to enhance our understanding of the Earth's magnetic field and it's behaviour by extending the database of recorded excursions. By targeting rapidly deposited sediment records of excursions, particularly from the Southern Hemisphere, we can explore unanswered questions such as whether excursional behaviour is a global feature of the geomagnetic field, and test hypotheses for how excursions are generated within the Earth's fluid outer core.

In this project we are targeting high resolution records of Brunhes Chron geomagnetic excursions, both in marine sediment cores and volcanic rocks. In 2011 two months were spent working at the Instituto Nazionale di Geofisica e Volcanologia in Rome. Here the magnetic properties of two Marion Dufresne marine sediment cores from the Murray Canyons were measured, along with one core from the Adriatic Sea. However, although u-channel measurements of sediment cores offer the opportunity for continuous direction and intensity sequences, there are numerous factors that can influence the reliability and quality of such paleomagnetic results. Processes such as post depositional remanent magnetization (PDRM), bioturbation, and diagenesis of the sediments can lead to otherwise ideal sediment deposits having weak or misleading magnetizations. As a result the three cores measured in Rome, although covering time spans expected to cover the Laschamp Excursion (41-42kya), were found to hold no useful magnetic records; the two Murray Canyon cores having very weak paleointensities, whilst the Adriatic Sea core held no sign of anomalous paleomagnetic directions.

Present and future work is therefore focussed on targeting sequences of sediment with high rates of deposition that are likely to provide high resolution records of geomagnetic excursion field behaviour. These include sites sampled offshore Australia and New Zealand by the International Ocean Drilling Program (IODP) and Marion Dufresne research vessel, along with the possibility of lake sediment sequences from within Australia. Samples from such sites will be measured and analysed in the ANU Paleomagnetism Laboratory, due for completion in early 2012.

More power to the global ocean circulation

Juan Saenz, Andy Hogg, Graham Hughes and Ross Griffiths

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

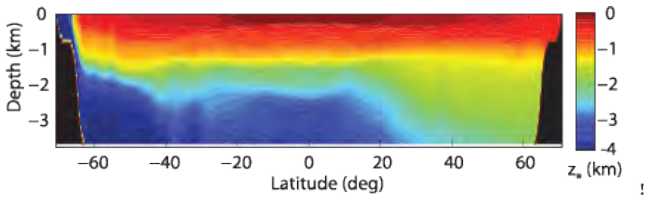

Figure 1. A plot of the depth z_* to which water parcels would fall (in a model circulation solution), if the water was allowed to adjust adiabatically to a state of no motion - its equilibrium depth. A north-south vertical section is shown. This height of fall is used to compute the available potential energy in the circulation, energy that can be converted to kinetic energy of large-scale flow and turbulence. The warmest water at the surface will stay at the surface, whereas dense water is formed at the surface near Antarctica and its equilibrium depth is at the bottom of this 4 km deep ocean. The surface cooling therefor presents a large source of potential energy for the circulation.

Is the circulation of the oceans forced primarily by surface wind stress, or surface buoyancy (heat and freshwater fluxes), or both? The question has been controversial. The answer matters because the forcing of the oceans on a global scale is a fundamental factor in the earth's climate system. As a practical application, understanding of the driving forces and energy balances will lead to a re-examination of the formulation of some aspects of ocean general circulation models.

We have applied our recent theoretical analysis of the conversion pathways for mechanical energy in the oceans, to solutions obtained from a general circulation model (MITgcm). The model system encompasses a simplified Atlantic Ocean basin and a circumpolar Southern Ocean channel, forced by surface wind and heat flux patterns representative of those in the oceans. The sensitivity of the circulation to wind and to surface heat fluxes was tested by solving for variations to each independently. A range of wind stresses was used and the strength of cooling in the poles and heating in mid latitudes was varied in several ways. The results show that the work done on the oceans by winds, to drive large-scale motion, is comparable to the generation of available potential energy by the surface heat fluxes. We found that the model circulation is as sensitive to changes in the heat fluxes as to changes in winds. We also found that changes in heat fluxes affect how wind does work on the circulation and vice versa, forming a positive feedback. This work will lead to better understanding of energy conversions in the oceans and will help to identify weaknesses in dynamical parameterizations used in current ocean models.

Saenz, J.A., Hogg, A.McC., Hughes, G.O. and Griffiths, R.W. Feedbacks between the mechanical power input to the ocean from winds and surface buoyancy forcing in an ocean model. *Geophys. Res. Lett*., to appear.

The ocean overturning circulation is like a bouncing super-ball

Ross Griffiths, Bishakhdatta Gayen, Graham Hughes and Juan Saenz

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

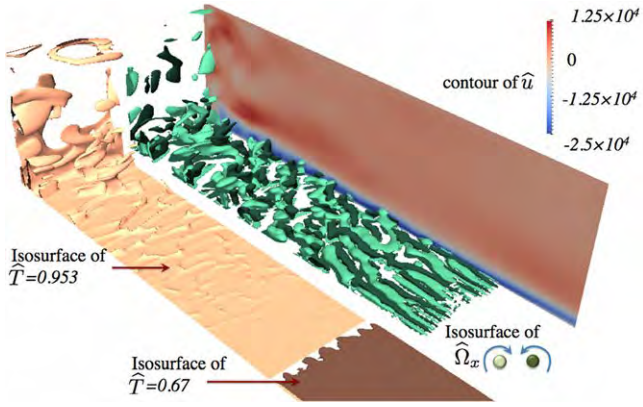

Figure 1. A solution for circulation driven by heating at the base of a simple rectangular basin – heating at left, cooling at right. Here the forcing is at the base rather than at the surface as in the oceans – the result will be the same. The solution shows the development of turbulent convection in the "mixed layer" on the left, and the ascent of buoyant, heated water as a plume at the endwall. The figure shows a surface of constant temperature (front), surfaces of constant vorticity (in the horizontal streamwise direction; centre), and horizontal velocity (rear plane).

The deep overturning circulation of the oceans, how it works and how it changes, remains somewhat mysterious and controversial. Some researchers have assumed that cooling at polar latitudes creates dense water that sinks and drives the overturning. Others have thought that the cooling (and matching heating in the tropics) is unimportant because it occurs only at the ocean surface. These researchers have pointed instead to an input of energy to small-scale turbulence and mixing from tidal motions and winds as an essential driver. Indeed, theory shows that when a body of water is heated and cooled at the surface, only a small amount of energy dissipation is possible, and this has been taken to support the idea that surface buoyancy fluxes cannot drive the circulation. Paradoxically, our experiments in recent years have demonstrated that surface heating and cooling can drive a strong overturning circulation. An explanation of how these results are consistent has been elusive.

We have used computed solutions for a relatively simple situation (a small rectangular ocean basin, heated and cooled at the surface, using a technique called Direct Numerical Simulation, which avoids the parameterizations used in ocean models) to determine all of the terms in the budget of kinetic and available potential energy. The results dramatically illustrate how an overturning circulation works. It is analogous to an efficient bouncing ball that vigorously bounces up and down and looses little energy on each bounce: in the oceans the sinking of cold, dense water near Antarctica and in the far North Atlantic represents a release of available potential energy generated by the surface cooling (as in the falling phase of the bouncing ball), and the upward return of the water toward to surface elsewhere involves the reverse energy conversion (as in the upward phase of a bounce). These conversion rates are orders of magnitude larger than the rate of dissipation of energy. In the long term, if the ocean is in a stationary state, the small dissipation is matched by the long-term of release of available potential energy to motion (equivalent to giving the bouncing ball a very small input of energy on each bounce to make up for the small energy loss to air drag and inelastic deformation). Hence the overturning is remarkably efficient in transporting mass and heat, and a small dissipation rate is reconciled with the strong circulation observed.

Gayen, B. Griffiths, R.W., Hughes, G.O. and Saenz, J.A. Energetics of horizontal convection. *J. Fluid Mech*., JFM Rapids (to appear January 2013).

Modelling Antarctic Bottom Water (AABW) Overflow in Global Climate Models

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[2] *Centre for Australian Weather and Climate Research, CSIRO, Hobart, Australia*

Antarctic Bottom Water (AABW), the dominant abyssal water of the global ocean and an important distributor of energy, carbon and nutrients, provides a significant contributor to the global ocean energy and sea level budget. To more fully understand the AABW's contribution to the global budgets, suitable representation of AABW formation and transport is required in global climate models (GCMs), processes currently poorly realized through the overflow parameterizations implemented in GCMs. Motivated by this poor representation, a sensitivity analysis of three different overflow parameterizations (a downslope transport scheme, a sigma bottom boundary layer scheme and an imbedded Lagrangian point particle method) is conducted using the Modular Ocean Model (MOM). Coupling MOM to the GFDL Sea Ice Simulator (SIS), the parameterizations are applied to a realistic-topography sector model of the Atlantic Ocean. Analyzing the sensitivity and performance of each parameterization provides an indication of the most suitable model for use in representing overflows in the Southern Ocean. Further, understanding of each parameterization's performance is important for an accurate representation of the AABW and the deep ocean in GCMs, hence allowing a more reliable indication of bottom waters contribution to the global energy and sea level budgets.

The vertical transport of tracers due to meso and sub-mesoscales: impacts in the Kerguelen region

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[2] *Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, TAS 7001 Australia*
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[4] *CSIRO Marine and Atmospheric Research, Hobart, TAS 7000 Australia*

The upper ocean can be considered a vehicle for the exchange of gases between the atmosphere and the deep ocean. In the surface layer, phytoplankton convert the carbon dioxide into organic compounds using nutrients and light irradiance via the photosynthetic process. Physical and bio-geochemical mechanisms transport nutrients between the surface, where they are depleted, and the depths, where they are remineralised. Recently, it has been shown that the vertical transport due to small horizontal scale structures of O(1-10) km called sub-mesoscales can enhance the availability of nutrients in the upper layers and, hence, trigger a phytoplankton bloom. This mechanism is profoundly linked to frontal instabilities that are caused by interactions between mesoscale eddies (O(100) km). Understanding these dynamics will allow a better estimate of the carbon export in the ocean.

Our interest is focused on the Southern Ocean, in particular on the area of the Kerguelen-Heard islands (Fig. 1) where a large phytoplankton bloom develops every year, highly contributing in the carbon uptake. The Southern Ocean is considered a HNLC area: despite the high abundance of major nutrients as nitrogen or silicon, it presents a low phytoplankton amount. It has been hypothesized that iron is the limiting factor. Several experiments have been done, but it is still not entirely understood how this nutrient is transported to the surface.

We are investigating the sensitivity of tracers dynamics and transport to the change of horizontal resolution (1/20° and 1/80°), quantifying the different contributions of meso and sub-mesoscale structures (Fig. 2 and Fig. 3). Furthermore, we are running numerical experiments using realistic bathymetry: this provides a significant case study of topographic effects on the vertical transport and allows to investigate sources and transport of iron.

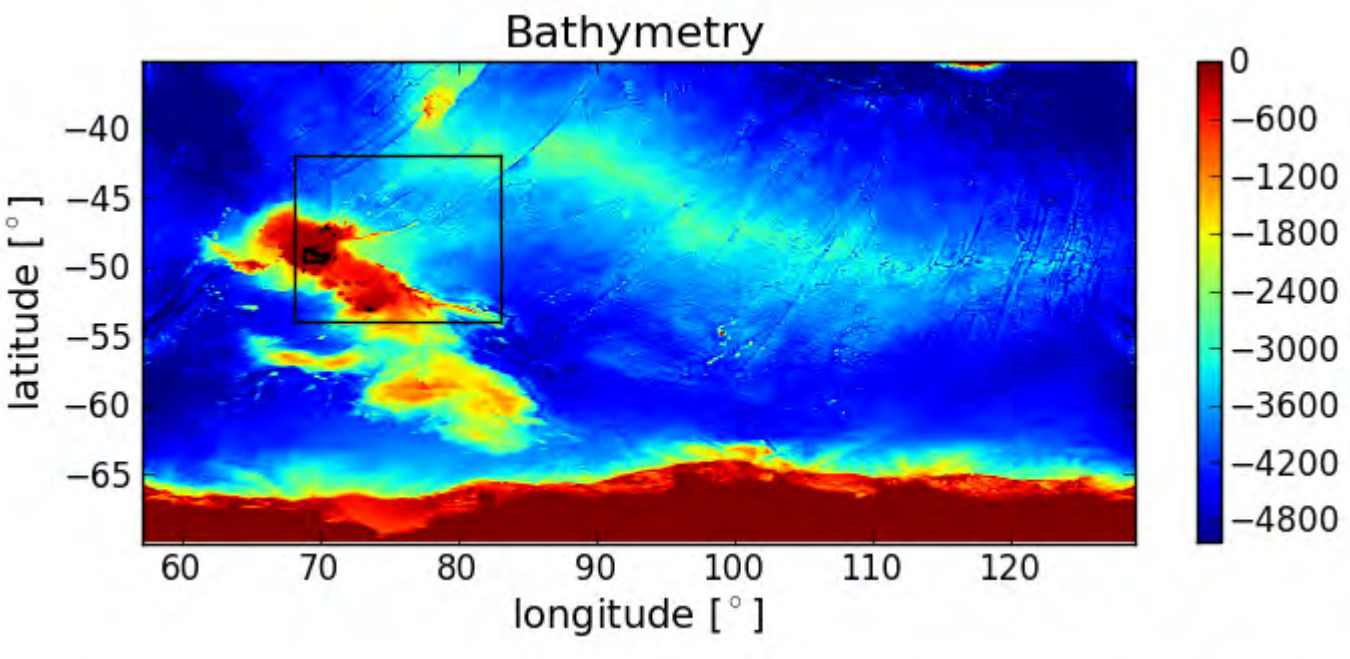

Figure 1. Model domain (the box shows the area for the 1/80° resolution model)

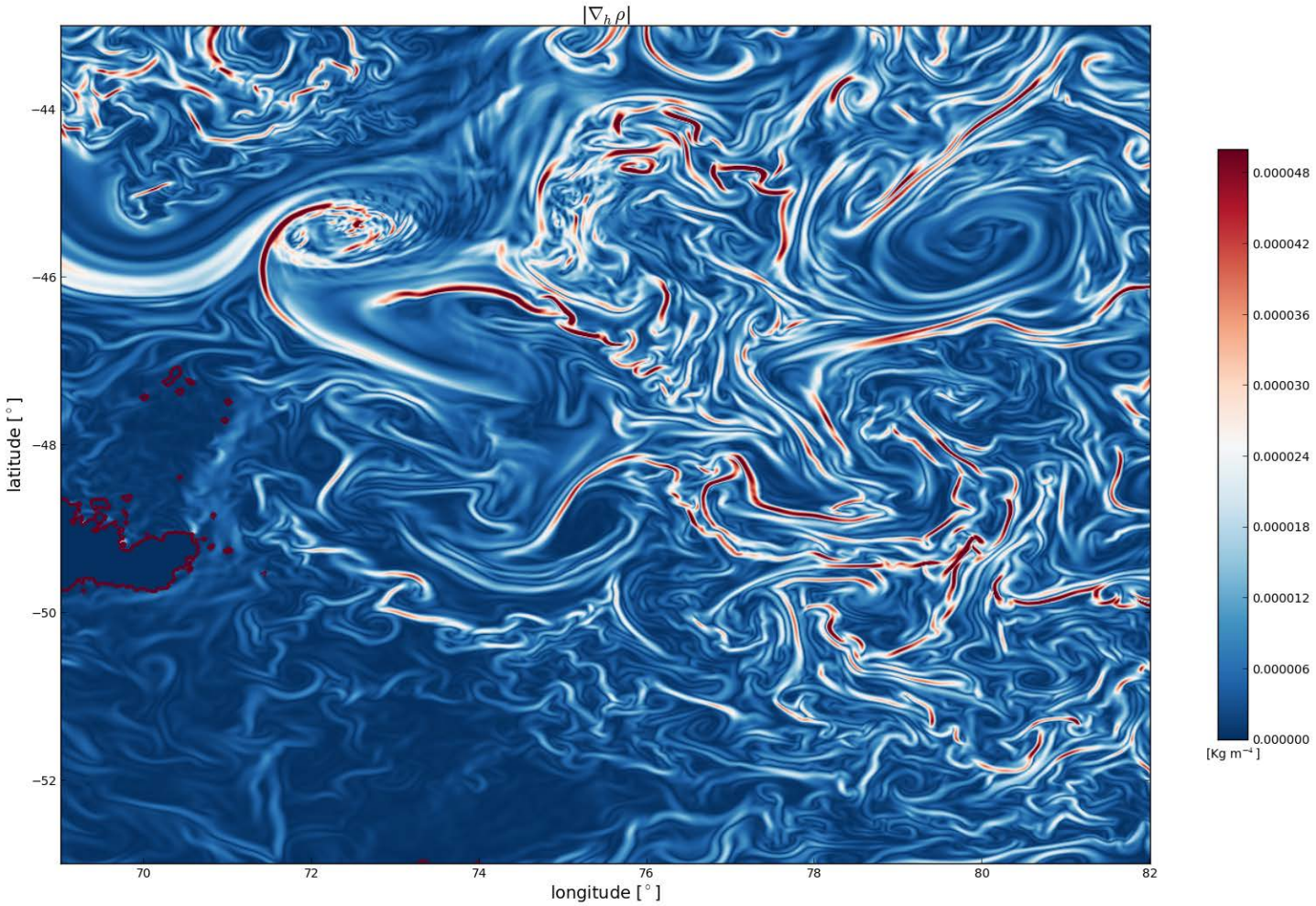

Figure 2. Filaments at the surface for the 1/80° resolution model: richness of dynamical structures in the North-East and East sides of the Kerguelen Plateau

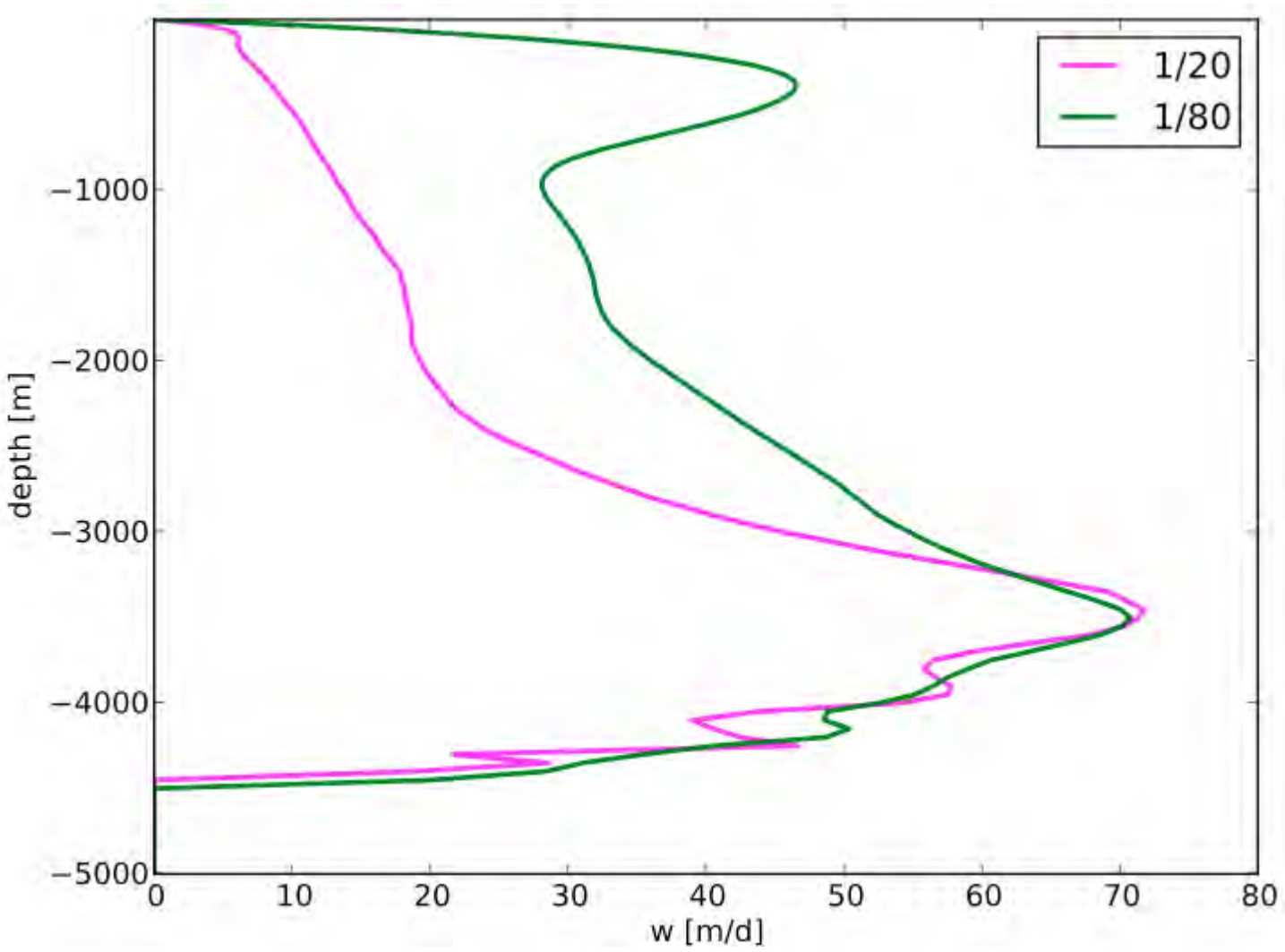

Figure 3. Root mean square of vertical velocity: the highest resolution run shows the greatest magnitude at the surface, signature of the activity of finer structures captured by the high resolution

The Energetics of a Collapsing Meridional Overturning Circulation

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[2] *Institute for Marine and Atmospheric Research, Department of Physics and Astronomy, Utrecht University, The Netherlands*

A well-studied example of natural climate variability is the impact of large freshwater input to the polar oceans, simulating glacial melt release or an amplification of the hydrological cycle. Such forcing can reduce, or entirely eliminate, the formation of deep water in the polar latitudes and thereby weaken the Atlantic Meridional Overturning Circulation (MOC). Such a scenario would cause rapid, irreversible global cooling.

Here we use a series of idealized, eddy-permitting numerical simulations to analyze the energetic constraints on the Atlantic Ocean's response to anomalous freshwater forcing. In this model, the changes in the MOC are not correlated with the global input of mechanical energy: both kinetic energy and available potential energy (APE) increase with northern freshwater forcing, while the MOC decreases. However, a regional analysis of APE density supports the notion that local maxima in APE density control the response of the MOC to freshwater forcing perturbations.

These results illustrate that energetic considerations can be used to predict the irreversibility of MOC shutdown. A coupling between APE input and changes in local density anomalies accounts for the difference in time scales between the recovery and collapse of the MOC. Freshwater input acts to decrease the surface density and rapidly decrease overturning; this inhibits the ability of freshwater anomalies to escape from the high latitudes, so that the re-initiation of high latitude sinking requires substantial density input (primarily surface cooling) before convection can begin again.

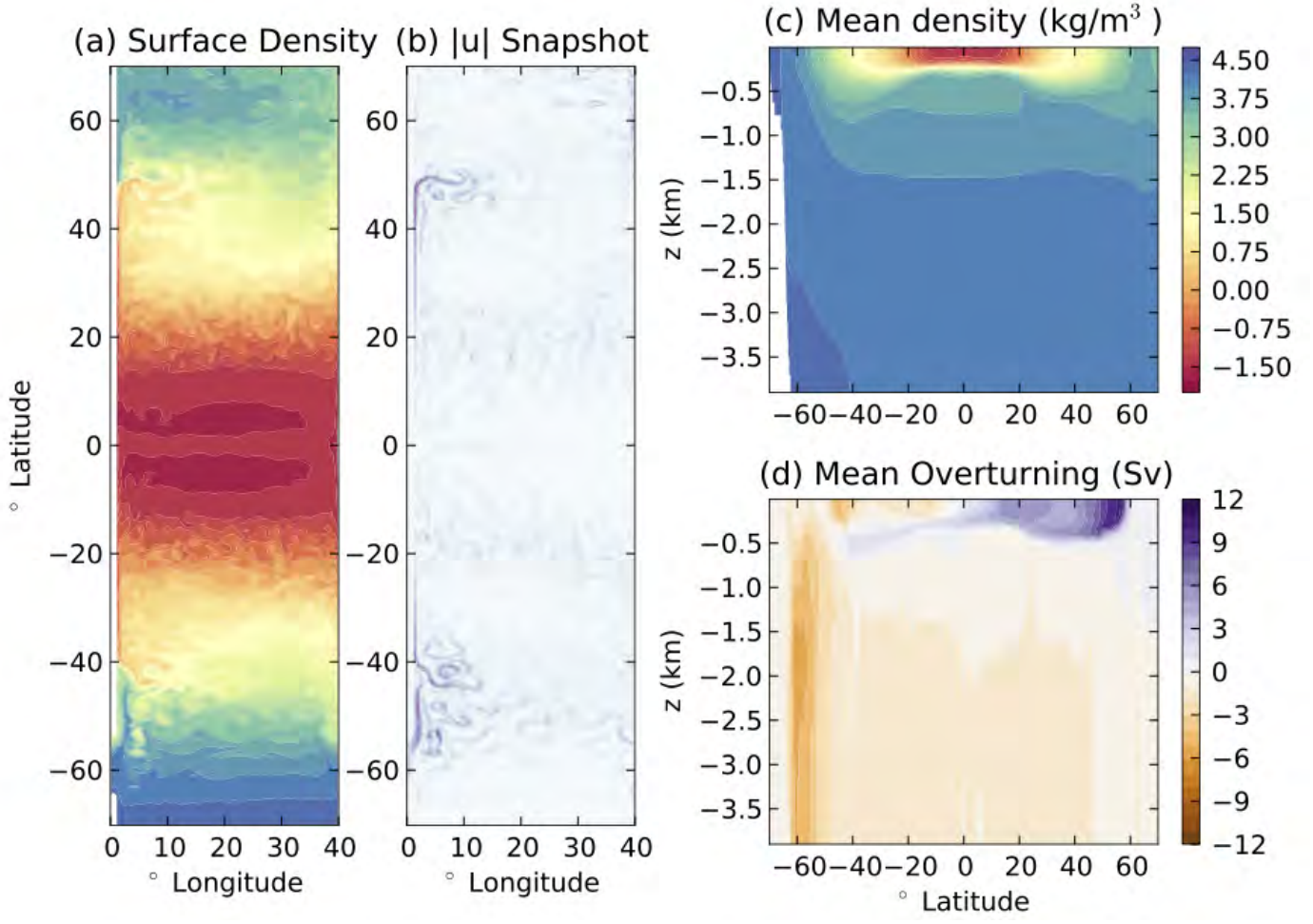

Figure 1. Equilibrium state of the reference case. (a) Snapshot of sea surface density (plotted as the anomaly from the reference density, ρ_0, and using the same color scale as panel (c); (b) Snapshot of the absolute magnitude of the horizontal velocity (color scale

ranging from 0 to 2.4 m/s); (c) Zonal and time averaged density field, and (d) Zonal and time averaged overturning circulation, evaluated on density surfaces and remapped into physical space.

Solidification dynamics in channelled viscoplastic lava flows

Jesse Robertson and Ross Kerr

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A clear understanding of the interaction of lava rheology and flow dynamics forms a crucial basis for the interpretation of lava flow morphology (Figure 1), the design of predictive models for lava flow emplacement and the development of mitigation strategies to minimize flow hazards to people or property (Figure 2). Although a fully molten lava has a purely Newtonian rheology, progressive crystallization of lava driven by cooling and degassing can generate a touching network of crystals. This network can bear a stress in addition to the viscous response of the melt fraction of the lava, and the lava will only flow when the shear stress induced by the weight of the fluid exceeds this yield strength (Robertson & Kerr 2012a).

In a major study (Robertson & Kerr 2012b), we have used analogue experiments to analyze the influence of a viscoplastic rheology on the dynamics of lava flows. The experiments used slurries of polyethylene glycol and kaolin, which flowed with a constant flux down an inclined channel under water. We present three sets of complementary experiments: isothermal, cooling, and solidifying flows which quantified the effects of the viscoplastic rheology on shear, internal convection and surface crust formation. The isothermal and cooling experiments showed the formation of unyielded central plug regions which were not broken up by the convective overturning. In the solidifying experiments flows fell into one of three regimes: a tube regime, in which crust covered the entire flow surface; a shear-dominant regime, with a mobile raft of crust in the channel centre and open shear zones near the walls; and a plug-dominant regime where the width of the central crust was determined by the width of the central plug region. We parameterized the crust coverage in terms of two dimensionless parameters: the ratio w_p of central plug region width to channel width and a parameter q which characterizes the relative importance of the strain and solidification rates. Finally we examined typical lava flows on Mt Etna and the 1984 Mauna Loa lava flow. We show that our parameterization agrees with lava flow crust widths observed in the field and find that even small yield strengths have a major effect on crust coverage.

Robertson JR, Kerr RC (2012a) Isothermal dynamics of channeled viscoplastic lava flows and new methods for estimating lava rheology. *Journal of Geophysical Research*, 117, B01202, doi:10.1029/2011JB008550.

Robertson JR, Kerr RC (2012b) Solidification dynamics in channeled viscoplastic lava flows. *Journal of Geophysical Research*, 117, B07206, doi:10.1029/2012JB009163.

Figure 1. A well-developed lava channel fed from a rift eruption of Pu`u `O`o on 23 September 2011. The channel is approximately 4 metres wide, 2 metres deep, and is moving at speed of about 3 metres per second. The erupting rift can be seen in the background, in front of the cone of Pu`u `O`o. View is to the southwest. Photo: Tim Orr, Hawaiian Volcanological Observatory.

Figure 2. A lava flow on the east flank of Mt Etna at around 2800 m above sea level, looking east over the Valle del Bove towards the town of Giarre. More than a million people live within range of lava flows in the Catania region. Image taken on 5th October, 2008. Photo credit: Thomas Reichart.

Extracting white noise statistics in GPS coordinate time series

jean-Philippe Montillet[1], Paul Tregoning[1], Simon McClusky[1] and Kegen Yu[2]

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The noise in GPS coordinate time series is known to follow a power-law noise model with different components (white noise, flicker noise, random-walk). This work proposes an algorithm to estimate the white noise statistics, through the decomposition of the GPS coordinate time series into a sequence of sub-time series using the Empirical Mode Decomposition algorithm. The proposed algorithm estimates the Hurst parameter for each sub time series, then selects the sub time series related to the white noise based on the Hurst parameter criterion. Both simulated GPS coordinate time series and real data are employed to test this new method, results are compared to the standard (CATS software) Maximum Likelihood (ML) estimator approach. The results demonstrate that this proposed algorithm has very low computational complexity and can be more than one hundred times faster than the CATS ML method, at the cost of a moderate increase of the uncertainty (5%) of the white noise amplitude. Reliable white noise statistics are useful for a range of applications including improving the filtering of GPS time series, checking the validity of estimated coseismic offsets and estimating unbiased uncertainties of site velocities. The low complexity and computational efficiency of the algorithm can greatly speed up the processing of geodetic time series.

conference Harvard citation and link
adsabs.harvard.edu/abs/2012EGUGA..14.4768M

SNAP lab website
www.gmat.unsw.edu.au/snap/publications/montillet_etal2012a.pdf

ANU website
rses.anu.edu.au/geodynamics/gps/papers/pubs_seq.html

The ANU GRACE visualisation web portal

Darbeheshti, N., L. Zhou, P. Tregoning and S.C. McClusky

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The launch of the Gravity Recovery and Climate Experiment (GRACE) space gravity mission opened new horizons to the scientific community for environmental monitoring. Through the provision of estimates of temporal changes in the Earth's gravity field, the products generated from the GRACE mission have enabled studies of mass balance changes in polar regions, deformation caused by very large earthquakes, glacial isostatic adjustment and quantification of water exchanges through various hydrological processes. International analysis centres provide estimates of the Earth's temporally varying gravity field in the form of spherical harmonic coecients which are then used to quantify the geophysical processes that have caused the changes in the Earth's gravity field. We have designed an online, publicly available web application that performs the computations to convert the spherical harmonic representations (of the French Groupe de Recherche en G´eodesie Spatiale) of the gravity field into estimates of crustal deformation and/or water loads, and provides users with the ability to visualise the estimates. Derived products are also available to download as numerical values for further analysis. This paper describes the scientific basis and technical approaches used by the web portal (grace.anu.edu.au/evasph.php).

PDF link
http://rses.anu.edu.au/geodynamics/tregoning/GFO_website_rev1.pdf

Research Activities 2011

PRISE

Introduction

The PRISE group operates as an externally funded unit within the Research School of Earth Sciences, providing analytical and research expertise to clients and collaborators in the areas of geochronology, geochemistry and archaeology. While the current emphasis is necessarily on commercial projects, PRISE staff have also continued their involvement in research projects supported by successful grant applications, both domestic and international. As in previous years, projects have been primarily SHRIMP-based and focussed mainly in South America, Africa and Southeast Asia.

Multi-dimensional zircon studies have combined SHRIMP analysis of U-Th-Pb, oxygen isotopes, Ti geothermometry, trace and REE geochemistry with Lu-Hf analysis by Neptune MC LA ICPMS. This approach has proved to be particularly valuable and widely applicable. Mark Fanning has been working on the age and composition of the East Antarctic Shield and determining the age of the oldest granitic rocks in northern Patagonia. Richard Armstrong has been involved in development of protocols and standards for sulphur isotope analyses on the SHRIMP and Bin Fu has continued his research into oxygen isotopes in zircon and the timing of mineralisation in the Victorian goldfields.

In addition, Mark Fanning and Richard Armstrong supervised activities of both RSES and international postgraduate students. In August we were pleased to welcome to our group Ms Paula Castillo, who has begun her PhD studies under the supervision of Mark Fanning.

During the year, PRISE hostedtwenty-one local and international visitors, working co-operatively on a wide range of geological, geochemical and archaeological projects.

Through the provision of research and analytical skills to industry and Government agencies on a commercial basis, as well as enhanced cost recovery on collaborative projects, the PRISE group has managed to generate income of just over $1M during 2012. This has been achieved in a financial environment not conducive to export earnings and has required a huge commitment in both time and effort that has been sustained throughout a very challenging year. A total of $299,979 has been transferred to Areas within the School for instrument use and a further $235,725 paid into School funds in the form of invoice overheads.

Technical support from the Mineral Separation laboratory staff has been pivotal to our success and PRISE staff wish to extend their thanks and appreciation for the exceptional service provided by Shane Paxton in

particular. Thanks are also due for assistance provided by technical staff responsible for instrument maintenance.

This year saw a rearrangement of responsibilities within the PRISE group and the appointment of a new Board of Management. We are grateful to our colleagues on the Board for their support and advice.

Associate Professor Mark Fanning
Manager, PRISE

Research Activities 2011

IODP

The Integrated Ocean Drilling Program (IODP) is the world's largest geoscience research program, with access to drilling facilities worth $US1 billion, and annual running costs of about $US210 million. It is at the frontier of scientific challenges and opportunities, because ocean drilling is the best method of directly sampling the two-thirds of our world that is covered by the world's oceans. IODP aims to solve global scientific problems by taking continuous core of rocks and sediments at a great variety of sites in the world's oceans, from as deep as several kilometres below the sea bed. Its broad aim is to explore how the Earth has worked in the past and how it is working now. It uses a variety of platforms, and provides 'ground truthing' of scientific theories that are based largely on remote sensing techniques.

IODP's key research areas are

- Deep biosphere and ocean floor.
- Environmental changes, processes and effects.
- Solid earth cycles and geodynamics.

Australia and New Zealand are partners (www.iodp.org.au; http://drill.gns.cri.nz) in the ANZIC consortium within IODP, which involves both geoscientists and microbiologists. We are making important contributions to IODP's scientific endeavours, and a number of major coring expeditions in our region and elsewhere have improved and will improve our understanding of global scientific questions. IODP is a scientific crucible for bringing our scientists in contact with research teams from around the world, and post-cruise research activities often extend far beyond IODP activities.

Membership of IODP helps us maintain our leadership in Southern Hemisphere marine research. For geographic, climatic, oceanographic and plate tectonic reasons, our region is vital to addressing various global science problems. Accordingly, the Australasian region has seen a great deal of ocean drilling since 1968, when the first program was established.

Australian scientists gain in various ways from IODP: by being on international IODP panels, through shipboard and post-cruise participation in cutting edge science, by building partnerships with overseas scientists, by being research proponents and co-chief scientists who can steer programs and scientific emphasis, and by early access to key samples and data. Post-doctoral and doctoral students have an opportunity of training in areas of geoscience and microbiology that could not be obtained in any other way.

The Australian IODP budget, administered at RSES, is $2.2 million, of which $US1.4 million goes to the US National Science Foundation as a membership

fee. The Australian IODP Office (AIO) is headed by ANZIC Program Scientist, Professor Neville Exon and Professor Richard Arculus is the lead Chief Investigator. Ms Catherine Beasley is the Program Administrator.

Dr Neville Exon
Program Scientist, Australian IODP Office

Research Activities 2012

Visiting Fellows

Research Support

Electronics Group

Research School of Earth Sciences Electronics Group Annual Report 2011

Andrew Latimore, Tristan Redman, Norm Schram, Derek Corrigan, Daniel Cummins, David Cassar, Hideo Sasaki
Research School of Earth Sciences, Australian National University, Canberra, ACT 0200, Australia

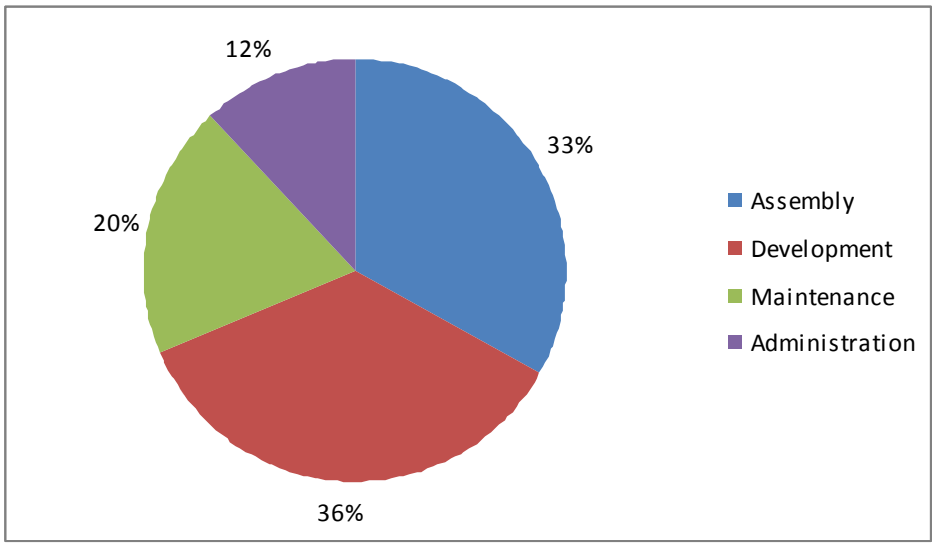
Introduction

The Electronics Group provides technical support to all Earth Sciences' academic research. The Group holds the responsibility for maintaining and servicing electronic systems within RSES and offers a development facility able to engineer innovative electronic solutions. The Electronics Group endeavours to ensure the Research School of Earth Sciences remains a state of the art institution.

During 2012 the Electronics Group successfully completed a major assembly project, finishing construction and testing of the first one hundred ANU Short Period Seismic Recorders. The recorders were designed by the Electronics Group during 2010/11 and are now in full production, the project will extend into 2013 to manufacture a total of 260 units. The Group worked efficiently to produce the units within the scheduled time period and Group members David Cassar and Tristan Redman were involved in deployment of the first 50 units. Production of the recorders was made possible by the new automated pick and place electronic component assembly machine that the Electronics Group purchased for the project, this facility will decrease design to completed product times providing the Research School of Earth Science with faster electronic engineering services.

In parallel to the Seismic Recorder project the Group continued to develop and implement other major tasks some of which are in their second year of refinement including, Earth Material's Attenuation Apparatus new acquisition system, Earth Physics' ICPMS Laser Cell shroud design, Earth Chemistry's MAT 261 electronics systems upgrade, Accelerating Mass Spectrometer automated sample preparation system implementation, and new microprocessor design for control of SHRIMP electronics systems.

The Electronics Group has kept up with the heavy electronics maintenance load of the school using 20% of labour resources to fault find and repair equipment.



Labour Distributions 2012
Electronic Engineering Highlights

SHRIMP Developments (Latimore, Cummins, Corrigan, Cassar, Schram, Redman, Sasaki)

This year the Electronics Group has installed new Magnetic Field Controllers version 4 “FC4” onto SHRIMP RG and SHRIMP 2. The new electronics required considerable time to construct and tune. Each mass spectrometer’s magnet requires individual Fuzzy Logic control parameter which involves careful analysis of system performance. The Field Controller 4 project was first introduced onto SHRIMP SI and has achieved unprecedented magnetic stability, following this success Earth Chemistry requested two additional controllers to be installed onto the existing SHRIMP facilities to improve machine resolution. By the year’s end the Ion Probe Group were running all Earth Sciences SHRIMP Machines with new Magnetic Field Controllers.

Attenuation Apparatus system upgrade (Latimore, Redman)

During 2012 The Electronics Group implemented major changes to the operation of Earth Materials’ Attenuation Apparatus. The modifications included removing aging synchronous rectifiers, preamplifiers and analogue filtering and providing new digitising system using modern National Instrument acquisition electronics and upgrading the host computer. The modifications have provided the operator with analysis resolution capability of 18-bits at sampling rate of ten thousand samples per second. The new National

Instruments Labview software interface has improved functional flexibility by allowing automated analysis and improved electronic noise levels.

Thermo Scientific ARGUS VI mass spectrometer installation (Cassar, Latimore, Sasaki)

The Electronics Group has designed and constructed auxiliary control equipment for the ARGUS VI mass spectrometer. The Group developed a pneumatic valve controller that remotely operates all high vacuum valves incorporated in the ARGUS VI's source line allowing the user to automatically manipulate the system via the host computer. The Group has designed and constructed power electronics for the mass spectrometer's source line including a twin furnace controller and contributed to the design and construction of power distribution infrastructure.

Finnigan MAT 261 Mass Spectrometer Upgrade (Schram)

This year the new electronic systems for the Finnigan MAT 261 mass spectrometer were completed and implemented. The heritage mass spectrometer is now equipped with automated computer control allowing the operator access to all system parameters and incorporates mass analysis software for acquiring data and tuning the mass spectrometer. The Electronics Group has developed systems to integrate with existing electronics to ensure future serviceability and minimise rebuilding working systems. The developments include; 8 channel digital 32-bit counters for beam current measurements, stepper motor controllers automating the high voltage source electrostatic deflection plates and sample carousel selection.

IPCMS Laser Aperture Control Automation (Corrigan)

This year the Electronics Group has continued work on improvements to the Inductively Coupled Plasma Mass Spectrometer's Laser ablation system. During 2012 the Electronics Group completed and installed a new aperture selection unit and gas flow control system. The Group has conducted further development into several auxiliary systems for the laser including a vacuum shroud to encase the laser, motorisation of the cell device and variable width aperture mechanism utilising stepper motor technology.

AMS Graphitization Furnace Automation (Sasaki, Cassar)

During 2012 the Electronics Group completed the construction of the 20 channel Automatic Graphitization Furnace system. The project has been successfully installed and is operational. The system will autonomously control 20 graphitization channels and operate 20 liquid nitrogen molecular traps simultaneously. The interface is touch screen controlled running Labview firmware will automatically measure the required volume and graphitize the sample. The Group has designed the liquid nitrogen control mechanics which includes vacuum insulated vessels for the molecular traps

and level sensing. The project aims to minimise liquid nitrogen loss and improve sample preparation productivity.

Fabrication projects (Cassar, Cummins, Sasaki, Redman, Latimore, Schram, Corrigan)

The Electronics Group has work productively this period on several fabrication projects.

- 4 x Field Controller version 4.
- 9 x STE MICRO version 2.1.
- 100 x ANU Short Period Seismic Recorder.
- Getter pump controller.
- Vertical Furnace Controller 4 channel.
- 6 x Tesla Tamer.
- Seismometers in schools

Research Support

Engineering Group

Research School of Earth Sciences Engineering Workshop Annual Report 2012
Andrew Wilson, David Thomson, Geoff Woodward, Carl Were, Brent Butler, Hayden Miller (1/2 time share with Rock Physics), Ben Tranter (1/6 to 1/2 time share with GFD)
Research School of Earth Sciences, Australian National University, Canberra ACT 0200, Australia

Introduction
Important scientific outcomes in Earth Sciences often require the boundaries of mechanical possibility to be approached. With experience and commitment from its staff and with their ability to apply knowledge extremely well, the boundaries of what is possible have not only been approached on a regular basis but have been moved significantly. In many cases, research today is no longer limited by mechanical boundaries at all.

A combined total of one hundred and thirty eight years of machining knowledge and experience are shared among the current workshop staff listed above. Ninety five of these years have been spent within the workshop at RSES dedicated purely to research in the Earth Sciences.

RSES Engineering Workshop Highlights

Some of the major projects undertaken in 2012 are listed below:

Prep Line for Argus6 Mass Spectrometer, Dr Marnie Forster (Brent Butler, David Thomson, Carl Were, Andrew Wilson, Ben Tranter)

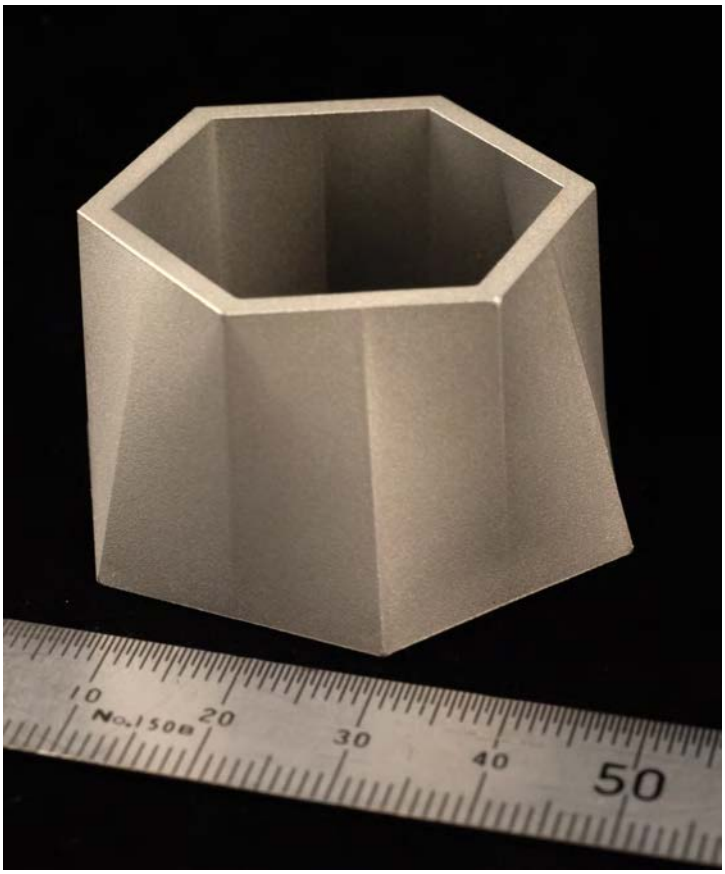
Seismic Recorders, Dr Nick Rawlinson (David Thomson, Brent Butler, Carl Were, Geoff Woodward)

SHRIMP Maintenance (David Thomson, Geoff Woodward, Brent Butler)

Field Work Equipment for Dr Bear McPhail (David Thomson)

Replacement Parts and Modifications to HTP Apparatus, Rock Physics Lab (Brent Butler, Geoff Woodward)

AMS Graphitization Line, Dr Stewart Fallon (Carl Were, Hayden Miller)



Wire EDM- top and bottom profile

Table1 **RSES Engineering Workshop Resource Distribution**		
Labour Totals	**Hours**	%
Uncharged Jobs	1158	15.2
Research Support	6076	79.5
External Work	404	5.3
Total	**7638**	
Uncharged Work		
Staff Training	263	3.4
Administration	578	7.6
Workshop Infrastructure	126	1.6
Machine Maintenance	142	2.0
Other	49	0.6
Total	**1158**	
Research Support Distribution		
Earth Chemistry	2795	44.2
Earth Environment	951	15.0
Earth Materials	819	13.0
Earth Physics	1485	23.5
Other ANU Clients	273	4.3
Total	**6323**	

2012 Publications by Author

(Listed alphabetically within research areas)

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Amelin Y., Ireland T.R., 2012 Dating the oldest rocks and minerals in the Solar System. Elements magazine, accepted for publication November 2012

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NATIONAL AND INTERNATIONAL LINKS 2011

COLLABORATION WITH AUSTRALIAN UNIVERSITIES, CSIRO & INDUSTRY

Earth Chemistry

Dr Y. AMELIN with Dr I. Metcalfe, University of New England, and Dr. R. Nicoll, Geoscience Australia, on the timescale of Permian-Triassic transition in Australia.

Dr Y. AMELIN with Prof R. Cas, Monash University, on geochronology and the origin of ores in the Archaean Yilgarn block, Western Australia.

Dr V.C. BENNETT with Dr A.P. Nutman, University of Wollongong on geochemical and isotopic investigations of greater than 3.7 billion year old rocks from southwest Greenland to reveal early Earth chemical processes and environments.

Dr V.C. BENNETT and Dr M. Honda with Dr M.J. van Kranendonk, University of New South Wales; Determining early atmosphere compositions through noble gas investigations of the Archean Pilbara sediments.

Dr J.J. BROCKS with Prof B. Rasmussen (Curtin University of Technology), The thermal maturity of Archean organic matter.

Dr J.J. BROCKS with Prof P. De Deckker (RSES, ANU), The reconstruction of sea surface temperatures over the past 300 years on Australia's east coast.

Dr J.J. BROCKS with Prof K. Grice and a cluster of researchers from Melbourne University, Curtin University and the University of Western Australia and international universities, 'Organic Geochemistry of Mineral Systems' CSIRO Flagship Cluster.

Dr J.J. BROCKS with Prof M. Kennedy (U. Adelaide), Organic Matter in the McArthur Basin.

Dr S.J. FALLON with Dr R. Thresher (CSIRO, Climate from Deep Sea Corals); Dr J. Lough and Dr K. Fabricius (Australian Institute of Marine Science, climate records from tropical corals); Dr E. Krull, Dr J. Sanderman (CSIRO, history of Coorong Delta); Dr L. Reed (Flinders University, Vegetation history of Naracoorte Cave region).

Dr M. FORSTER collaborates with Dr M. Roberts at Marengo Mining involving the supervision of a PhD student, Oleg Koudashev, involving argon geochronology dating and tectonic events at Yandera.

Dr M. FORSTER collaborates with Dr P. Lennox at the University of New South Wales involving argon geochronology of tectonic events on eastern Australia.

Dr M. FORSTER collaborates with Dr G. Batt at the University of Western Australia involving argon geochronology of tectonic events of China.

Mr T. HABER and Dr. M. Norman with Dr F. Jourdan (Curtin University, Perth) on using argon chronology to determine formation ages of lunar impact glasses.

Dr M. HONDA with A/Prof D. Phillips (The University of Melbourne) and Prof A. Chivas (The University of Wollongong), Continuation of collaboration on cosmogenic noble gas studies in young basalts; A/Prof D. Phillips (The University of Melbourne), Profs S. O'Reilly and B. Griffins (Macquarie University), Continuation of collaboration on noble gas studies in diamonds; Dr M. Kendrick (The University of Melbourne), Continuation of collaboration on combined studies on noble gas and halogen geochemistry on mantle-derived samples.

Dr C.H. LINEWEAVER collaborates with Dr Tamara Davis, University of Queensland on misconceptions about the big bang, energy conservation in cosmology and the relationship between entropy and gravity.

Ms A. F. KOMUGABE with Dr. R. E. Thresher (CSIRO MAR, Hobart), PhD Advisor.

Emeritus Professor Ian McDOUGALL is an Honorary Professor in the School of Earth Sciences, University of Queensland, where he has been collaborating with Professor P. Vasconcelos, Dr B. Cohen and Dr D. Thiede on further isotopic dating by the 40Ar/39Ar technique of samples from the Omo Group of the Omo-Turkana Basin in East Africa, especially in relation to evolution of the basin and the time scale for hominin evolution, as many important fossils have been found within the sedimentary sequences. This work has now been published.

Dr D. RUBATTO collaborates with Dr C. Spandler and Mr J. Hammerli from James Cook University, Townsville on oxygen composition of phosphates in metamorphic terranes .

Dr D. RUBATTO collaborates with Dr L. Martin, University of Western Australia, on the measurement of oxygen isotopic composition of garnet using SHRIMP.

Dr I.S. WILLIAMS with Australian Scientific Instruments Pty. Ltd. (Canberra) – SHRIMP development and marketing.

Dr I.S. WILLIAMS with Dr J.A. Trotter (University of Western Australia, Perth) and Prof. I. Metcalfe (University of New England, Armidale) – Palaeoclimatology using marine bioapatite oxygen isotopes. Dr Trotter visited

RSES for three weeks in June-July and two weeks in August to work with Dr Williams on this project.

Dr I.S. WILLIAMS with Prof J. Hergt, Dr J. Woodhead and Mr K. Iles (University of Melbourne) – The age and isotopic composition of zircon from the Middledale gabbroic diorite. Mr Iles visited RSES for three days in September to work with Dr Williams on this project.

Earth Environment

Mr R. BURNE collaborates with Dr. A. Kendrick (Department of Environment and Conservation, Western Australia), Dr J. Hamilton, (Lithicon), and Prof. V. Paul Wright (BG).
Prof Patrick De Deckker is collaborating with: Dr D. Wilkins (Antarctic Division) on the Holocene history and dating of crater lakes, Dr J. Reeves (RMIT) on ostracod taxonomy and ecology, with Prof C. Murray Wallace (University of Wollongong) on the palaeoenvironmental reconstruction of the Lacepede Shelf offshore South Australia, with Professor N. Tapper (Monash University) on airborne dust.

Dr M.J. ELLWOOD collaborates with Dr. E. Butler (CISRO), Dr. A. Bowie (ACE CRC), Dr. C. Hassler (University of Technology Sydney) on trace metals in Tasman Sea waters, and Prof W. Maher (University of Canberra) on mercury cycling in organisms.

Dr M.K. GAGAN collaborates with Dr R. Drysdale and Dr J. Hellstrom (University of Melbourne) on ARC *Discovery* grant DP1095673 (2010-2012): Multi-proxy fingerprinting, absolute dating, and large-scale modelling of Quaternary climate-volcano-environment impacts in southern Australasia, and with Dr H. McGregor and Prof C. Woodroffe (University of Wollongong) and Dr S. Phipps (University of New South Wales) on coral reconstructions of El Niño-Southern Oscillation variability in the central equatorial Pacific, and with Prof. J.-X. Zhao (University of Queensland) on U-series dating of Indonesian speleothems.

Prof GRÜN collaborates with Dr R. Armstrong (RSES, ANU), Prof M. Spriggs (Archaeology and Anthropology, ANU), Dr C. Falgueres (Département de Préhistoire du Muséum National d'Histoire Naturelle, Paris, France) and Dr. B. Maureille (Laboratoire d'Anthropologie des populations du Passé, Université Bordeaux 1, France) on the ARC grant DP110101415: Understanding the migrations of prehistoric populations through direct dating and isotopic tracking of their mobility patterns. Prof GRÜN also collaborates with Dr N. Stern (La Trobe University) on the environmental reconstruction of the Lake Mungo Lunette. Prof GRÜN collaborates with Dr G. van den Berg and Prof M. Morwood (University of Wollongong) on the dating of a range of Indonesian Sites, and with Dr Z. Jacobs (University of Wollongong) on the dating of Italian middle Palaeolithic sites.

Dr David Heslop collaborates with Dr P. Hesse (Macquarie University) on the analysis of Australian dust in marine sediments.

Ms Claire KRAUSE collaborates with Dr S. Phipps (CCRC, University of NSW) on Palaeoclimate Modelling, with Dr J. Hellstrom (University of Melbourne) on Uranium Thorium Dating of Speleothems, with Dr J. Reeves (University of Ballarat) on Aus-INTIMATE Publications, and with the working group of the Australian Quaternary Association, Aus-INTIMATE on two forthcoming publications.

Dr D.C. “Bear” McPHAIL collaborates with Dr J. Moreau (University of Melbourne), Dr F. Reith and Prof J. Brugger (Adelaide University), and Dr A. Dosseto (University of Wollongong) on the fractionation of uranium isotopes in the regolith.

Dr D.C. “Bear” McPHAIL collaborates with Dr W. McLean and Ms E. Webb (Parsons Brinckerhoff, Sydney) on groundwater dynamics in the Lower Murrumbidgee catchment, NSW.

Mr S. MEYERINK collaborates with Prof W. Maher (University of Canberra) and works on SIT extraction and identification with D. Jolley (University of Wollongong).

Mr R.J. OWENS collaborates with Mr J. Caves (Stanford University), on Reconstructing Cenozoic Seawater Chemistry.

Prof B.J. PILLANS with Prof M. Morwood, Dr G.D. van den Berg (University of Wollongong) on the Quaternary stratigraphy of Soa Basin, Flores and Walanae Basin, Sulawesi, Indonesia, and with Dr K. Mulvaney (Rio Tinto Iron Ore) on Aboriginal rock art, Burrup Peninsula, Western Australia.

Ms Jenna Roberts collaborated with and received assistance from CSIRO Centre for Environmental Contaminant Research (bioanalytical and chemical analytical facilities), School of Civil and Environmental Engineering, UNSW, and Actew Corporation, ACT.

Mr. N. SCROXTON collaborated on U/Th dating with Dr J. Hellstrom (University of Melbourne).

Dr Jimin YU collaborated with Dr L. Menviel (University of New South Wales).

Earth Materials & Processes

PROFESSOR RICHARD ARCULUS collaborated with Professor Simon Turner (Macquarie University); Professor Leonid Danyushevsky (University of Tasmania) and Professor Jon Woodhead (University of Melbourne)

PROFESSOR STEPHEN COX collaborates with Prof D Cooke (University of Tasmania) on aspects of the development of fracture-controlled flow regimes

in intrusion-related hydrothermal ore systems. This collaboration forms part of the activities in the ARC Centre for Excellence in Ore Deposits.

MR BRENDAN HANGER collaborates with Prof. V. Kamenetsky, Dr S. Feig and Dr K. Goemann (University of Tasmania) on the EPMA analysis of peridotite xenoliths from the Kimberley pipe, South Africa and Assoc Prof M. Kilburn and Dr R. Liu on the NanoSIMS analysis of zoned garnet from Wesselton, South Africa.

PROFESSOR JOERG HERMANN collaborates with Dr. C. Spandler (James Cook University, Townsville), on element recycling in subduction zones; Dr M. Turner (Macquarie University, Sydney) on water incorporation into clinopyroxene; Dr. M. Kendrick (Melbourne University) on subduction recycling of nobel gases and Prof. P. Vasconcelo and Dr. G. Rosenbaum (University of Queensland) on teaching undergraduate field geology.

PROFESSOR IAN JACKSON collaborated with Z. Stachurski (Dept. of Engineering, CECS, ANU).

PROFESSOR HUGH O'NEILL is collaborating with Dr Carl Spandler of the School of Earth and Environmental Sciences, James Cook University, Townsville, on diffusion of trace elements in olivine and other minerals at high temperature.

DR JOSE-ALBERTO PADRON-NAVARTA collaborates with Dr. M. Kendrick (Melbourne University) on subduction recycling of noble gases.

DR GREG YAXLEY collaborated with Prof Dima Kamenetsky, Dr Geoff Nichols (formerly Macquarie University), Dr Roland Maas (University of Melbourne), Dr Elena Belousova (Macquarie University), Dr Anja Rosenthal (University of Bayreuth) and Dr Marc Norman (RSES) on a study of the first reported occurrence of kimberlite in Antarctica. He also collaborated with Prof Keith Scott (CSIRO) on the use of sedimentary carbonates at Century Mine as an exploration tool. As well as a collaboration with Dr Andrew Berry (RSES) and Mr Brendan Hanger (RSES) on the application of Fe K-edge XANES to determination of Fe3+ in garnets from garnet peridotite xenoliths from the Kaapvaal, Slave and Siberian Cratons.

Earth Physics

Dr N BALFOUR collaborates with Craig O'Neill (Macquarie University), Tim Rawling (University of Melbourne) and Anya Reading (University of Tasmania) on Seismometers in Schools.

Mr C.C. CHAPMAN and Dr A.McC. HOGG with Dr. S.R. Rintoul (CSIRO Marine and Atmospheric Research) on variability in the Southern Ocean.

Dr S. DOWNES with Dr. P. Petrelli (University of Tasmania/ National Computational Infrastructure) on CMIP5 model output contributing to the IPCC Fifth Assessment Report.

Dr A.McC. HOGG and Dr M.L. Ward with Prof M.H. England and Dr P.A. Spence (University of New South Wales) on the development of a high-resolution ocean model.

Dr G.O. HUGHES with Prof. K. Lovegrove and Dr J. Pye (Engineering, ANU) on convective flows in solar thermal systems.

Dr Giampiero IAFFALDANO collaborates with Dr Cristian HEINE and Prof Dietmar MUELLER from the School of Geosciences at the University of Sydney.

AuScope

Prof B.L.N. KENNETT and Dr M. SALMON have worked on the construction of the Australian Seismological Reference Model (AuSREM) that has been part funded by AuScope. The Model was completed during the year and three papers have been accepted for publication. The model itself is available from the website http://rses.anu.edu.au/seismology/AuSREM.

Dr S. MCCLUSKY has collaborated with; Dr. C. Watson and Dr R. Burgette (University of Tasmania), Dr A. Van Dijk, Dr J.L. Pena Arancibia, and Dr R. Crosbie (CSIRO).

Dr. J.-P. MONTILLET is working with Dr. K. YU from the satellite and positioning laboratory (SNAP) at the University of New South of Wales on different studies.

Dr N. RAWLINSON with Dr. Anya Reading (University of Tasmania), Dr. Yingjie Yang (Macquarie University), Dr. Juan Carlos Affonso (Macquarie University), Dr. Nick Direen (FrOGtech), Dr. David Robson (Geological Survey of NSW), Dr. Dick Glen (Geological Survey of NSW), Dr. Mark Duffett (Mineral Resources Tasmania), Dr. Peter O'Shea (Geoscience Victoria), Prof. M. Sandiford (University of Melbourne), Prof. David Lumley (University of Western Australia), Prof. Mike Dentith (University of Western Australia), Dr. Jeffrey Shragge (University of Western Australia), Dr. Wouter Schellart (Monash University)

Ms I. ROSSO and Dr A.McC. HOGG with Assoc. Prof. P.G. Strutton (Institute for Marine and Antarctic Studies, UTAS), Dr. A.E. Kiss (School of Physical, Environmental and Mathematical Sciences, UNSW at ADFA) and Dr. R.J. Matear (CSIRO Marine and Atmospheric Research) on transport of nutrients in the ocean.

Dr M. SALMON National Information and Communications Technology Australia (NICTA) – Geothermal Machine Learning project

Dr M. SALMON Geoscience Australia – AuSREM project

Prof. M. SAMBRIDGE with Dr. V. Brando (CSIRO) on joint supervision of Ph.D. student project on transdimensional inversion approaches to remote sensing of geospatial data.

Prof. M. SAMBRIDGE, Dr. N. BALFOUR and Dr. M. SALMON with Dr. C. O'Neill (Macquarie Univ.) on the Australian Seismometers in Schools program, part of the AuScope Australian Geophysical Observing System (AGOS) Educational strand.

Prof. M. SAMBRIDGE with Dr. L. Gross (Univ. of Queensland) on development of inversion software, part of the AuScope Australian Geophysical Observing System (AGOS) Inversion laboratory strand.

Prof. M. SAMBRIDGE with Dr. R. Joannes-Boyau (Southern Cross University) on assessing the role of climate change on tropical cyclone variability.

Ms K. SNOW, Dr A.McC. Hogg, Dr S.M. Downes with Dr B.M. Sloyan (CSIRO Marine and Atmospheric Research) on Southern Ocean overflow parameterisations.

Dr H TKALČIĆ collaborates with Dr A. Reading (University of Tasmania) on a range of various research projects in seismology.

Dr P. TREGONING collaborated with Dr C. Watson and Dr R. Burgette (University of Tasmania) on global deformation caused by great earthquakes and with Dr G. McGrath on continent-scale drought in Australia.

Australian National Seismic Imaging Resource (ANSIR) Research Facility in Earth Sounding

Prof B.L.N. KENNETT is Director of ANSIR which continues as a National Research Facility, a joint venture between The Australian National University, Geoscience Australia and the University of Adelaide, linking to the Earth Imaging component of AuScope. RSES supports the portable seismic instruments.

The ANSIR portable equipment is available via a competitive proposal scheme, with support in 2011 for broadband instruments in North Island, New Zealand and around Bass Strait, and short-period experiments in NSW and Tasmania

Integrated Ocean Drilling Program (IODP)

The Australian IODP Office (AIO) at RSES is also the contact point for ANZIC – the Australian and New Zealand IODP Consortium. The Australian Research Council, fourteen Universities, three Government agencies, and a marine geoscience peak body (MARGO) provide funding for Australia's

membership of IODP. Naturally, the office has collaborated with a great number of individuals in Universities, Government agencies and foreign agencies.

ANU Professors Andrew Roberts, Richard Arculus and Neville Exon are on the Governing Council of ANZIC, but Professor Roberts is soon to be replaced by Professor Ian Jackson (ne Director of RSES). Professors Neville Exon and Michael Gagan are on the ANZIC Science Committee. Professor Richard Arculus is a member of the key IODP Planning Evaluation Committee

PRISE

Dr R.A. ARMSTRONG with Dr L. Shewan (University of Sydney) on studies of human mobility on Archaeological sites from Cambodia.

Dr R.A. ARMSTRONG with A. Giuliani (University of Melbourne) on the age and isotopic characteristics of possible metasomatic mantle zircons.

Dr R.A. ARMSTRONG with Dr M. Roberts (Marengo Mining Ltd) on the geochronology of the Yandera region, Papua New Guinea.

Dr R.A. ARMSTRONG with Dr M. Doyle (AngloGold-Ashanti) on geochronology of the Tropicana deposit, Western Australia.

A/Prof C.M. FANNING with Dr Pavlina Hasalova (Monash University) on the age of zircon and monazite from Himalayan and Australian rocks.

Dr B. Fu with A/Prof D. Phillips (The University of Melbourne) on determining the timing and origin of gold mineralisation in central Victoria.

Visiting Fellows

Dr K. A. W. CROOK is working with Dr D. Fink of the Australian Nuclear Science and Technology Organisation, Dr E. A. Felton, Earth and Marine Sciences, RSES, ANU & on cosmogenic age dating of rocky coastal geomorphic features.

Dr K. A. W. CROOK is working with Dr John Molony and others from ANU's Emeritus Faculty, on a research project re-evaluating evidence for Portuguese mapping of eastern Australia 250 years prior to Captain James Cook's voyages.

Emeritus Professor Richard A. Eggleton. Unsolicited and unpaid advice to Australian Bauxite Ltd.

Emeritus Professor Richard A. Eggleton. Collaborative research into the bauxites of the southern Highlands with Emeritus Prof G Taylor, UC.

Dr E. A. FELTON is working with Dr D. Fink of the Australian Nuclear Science and Technology Organisation and Dr K. A. W. Crook, Earth and Marine Sciences, RSES, ANU on cosmogenic age dating of rock coastal geomorphic features.

Dr E. A. Felton is working with Dr John Molony and others from ANU's Emeritus Faculty, on a research project re-evaluating evidence for Portuguese mapping of eastern Australia 250 years prior to Captain James Cook's voyages.

Dr C. Klootwijk collaborates with Dr E. Tohver (University of Western Australia) on magnetostratigraphy of upper Permian rocks from the Sydney and Gunnedah Basins and with Prof G. Rosenbaum (University of Queensland) on evolution of the Southern New England Orogen.

Dr D.L. STRUSZ with Dr I.G. Percival (Geological Survey of New South Wales) on a description and biostratigraphic analysis of the Silurian brachiopod fauna of the Delegate River Mudstone, southern New South Wales.

INTERNATIONAL COLLABORATION

Earth Chemistry

Dr Y. AMELIN with Dr R. Tucker, US Geological Survey, USA, on studying geological evolution and mineralisation in Madagascar, Afghanistan, and north-eastern US (New England).

Dr Y. AMELIN with Dr C. Stirling, Otago University, NZ, on detecting small uranium isotopic variations in nature and evaluating their origin and significance.

Dr Y. AMELIN with Dr A. Krot, University of Hawaii, USA, on the origin of chondrites and their parent asteroids.

Dr Y. AMELIN with Prof S. Jacobsen, Harvard University, USA, on chronology of the Solar System's oldest solids.

Dr Y. AMELIN with Dr K. Kossert, Physikalisch-Technische Bundesanstalt, Germany, on determination of half-lives of short-lived isotopes.

Dr Y. AMELIN with Dr Q. Yin, University of California Davis, USA, on the origin of chondrites and their parent asteroids.

Dr Y. AMELIN with Dr M. Schonbachler, University of Manchester, UK, in the extinct radionuclide systematics of the early Solar System.

Dr Y. AMELIN with Dr T. Iizuka, University of Tokyo, Japan, in the extinct radionuclide systematics and chronology of the early Solar System.

Dr Y. AMELIN with Dr T. Irving, University on Washington, USA, on chronology and origin of differentiated meteorites.

Dr V.C. BENNETT with Dr M. Handler (Victoria University of Wellington) on the development of analytical techniques for measurement of Pt stable isotopic compositions applied to understanding terrestrial core formation.

Dr V.C. BENNETT with Dr Q. Yin (University of California, Davis) and Dr V. Debaille (University Libre de Bruxelles) on determining high precision Nd isotopic compositions of meteorites.

Dr V.C. BENNETT with Dr N. Dauphas (University of Chicago) on integrated heavy stable isotope studies of Earth's oldest carbonates to reconstruct early atmosphere development and evolution.

Dr V.C. BENNETT and PhD student Alex McCoy-West with Dr R. Walker and Dr I. Puchtel (University of Maryland) on determining the age structure of the southern ocean basin through rhenium-osmium isotope analyses of mantle peridotites.

Dr J.J. BROCKS with Prof J. Banfield (UC Berkeley), Dr Karla Heidelberg (University of Southern California), Lipidomics and metagenomics of saline Lake Tyrrell, Victoria.

Dr J.J. BROCKS with Prof N. Butterfield, M. Pawlowska (University of Cambridge) and Dr R. Schinteie (Caltech), The Paleontology and organic geochemistry of Mesoproterozoic successions from Russia, and Molecular Taphonomic Models of the Proterozoic.

Dr J.J. BROCKS with J. Logemann and Prof J. Rullkötter (University of Oldenburg), Intact polar lipids of halophilic bacteria and archaea.

Dr J.J. BROCKS with J. Colangelo-Lillis and Prof J. Sachs (University of Washington, Seattle), Compounds specific hydrogen isotopes of a Proterozoic hypersaline basin.

Dr J.J. BROCKS with B. J. Bruisten (ANU), Dr R. Schinteie (Caltech), J. Colangelo-Lillis (U. Wash.), Dr L. Reuning and Prof R. Littke (RWTH Aachen University), Hydrothermal destruction of hydrocarbons in the Neoproterozoic Bitter Springs Formation, Amadeus Basin, central Australia.

Dr J.J. BROCKS with the Agouron Pilbara Drilling Project including Prof R. Summons and K. French (MIT), Dr C. Hallmann (MPI Bremen), Prof S. George (Macquarie U.), Prof G. Davidson Love (UC Riverside), Prof M. Van Kranendonk (UNSW), Prof R. Buick (U. Washington, Seattle), Prof J. Abelson (Agouron) and many others.

Dr S.J. FALLON collaborates with Dr B. Roark (Texas A&M), P Dr T. Guilderson (Lawrence Livermore National Laboratory) on climate records from North Pacific Deep Sea Corals; Dr L. Skinner on ocean overturning from deep

sea sediment cores; Drs P. Montagna, on Mediterrean sea level and radiocarbon reservoir ages.

Dr M. FORSTER collaborates with Prof R. Hall and Dr L. White, Royal Holloway University of London, SE Asia Research Group (SEARG) on the tectonics and dating of geological events on Sulawesi, Indonesia.

Dr M. FORSTER collaborates with Dr M. Cottam and Dr S. Suggate, Royal Holloway University of London, SE Asia Research Group (SEARG) on the tectonics and dating of geological events on northern Borneo, Malaysia, and the island of Palawan, Philippines.

Dr M. FORSTER collaborates with Prof E. Suparka, Institute Technical of Bandung (ITB), on the tectonics and dating of geological events on the south east arm of Sulawesi and central Java, Indonesia.

Dr M. FORSTER collaborates with Prof T. Ahmad, Kashmir University, on the tectonics and dating of geological events on in the NW Himalaya.

Dr M. FORSTER collaborates with National Institution of Oceanography (NIO), Goa, India, on the timing of mid-ocean spreading.

Dr M. HONDA collaborates with Dr J. Harris (The University of Glasgow, UK) and Dr D. Araújo (Universidade de Brasília) on noble gas studies in diamonds.

Dr C.H. LINEWEAVER collaborates with Prof P.C.W. Davies, Director of Beyond: Center for Fundamental Concepts in Science, Arizona State University on efforts to find alternative or “shadow” life on Earth and on taking an astrobiological approach to understanding cancer.

Dr C.H. LINEWEAVER collaborates with Prof C. McKay NASA Ames on efforts to find alternative or “shadow” life on Earth.

Dr C.H. LINEWEAVER collaborates with Prof D. Schwartzman, Geology and Geochemistry, Howard University, on the thermal history of the Earth and life on billion year timescales.
Dr C.H. LINEWEAVER is developing collaborations with Prof Norm Sleep, Stanford University, Prof Phil Nicholson, Cornell University, Prof Lawrence Krauss, Director of the Origins Initiative, Arizona State University and Dr Carlo Maley, Center for Evolution and Cancer, University of California, San Francisco.

Mr A. J. McCOY-WEST collaboration is ongoing with Prof R.J. Walker and Dr I.S. Puchtel, University of Maryland, USA on the age structure and development of the lithospheric mantle in New Zealand.

Mr A. J. McCOY-WEST and Prof T. Ireland are working with Dr N. Mortimer, GNS Science, Dunedin, New Zealand on the determining the age of gabbroic plutons of the Longwoods Range in Southland, New Zealand.

Emeritus Professor Ian McDOUGALL has been working closely with Professor F.H. Brown of the University of Utah, Salt Lake City, Utah, USA, in relation to the Omo-Turkana Basin in East Africa. Professor Brown and his collaborators have been responsible for much of the stratigraphy and stratigraphic assignments of fossils in the basin.

Dr D. RUBATTO collaborates with Prof P. Philippot and Miss C. Francois from Institut de Physique du Globe de Paris, France on the metamorphic evolution of Archean terranes in Pilbara and Barbeton.

Dr D. RUBATTO collaborates with Prof L. Baumgartner, Dr B. Putlitz, University of Lausanne, Switzerland on calibration of standards for oxygen isotopic analysis and oxygen in garnet.

Dr D. RUBATTO collaborates with Prof I. Buick, Stellenbosch University, South Africa on the development of standards for SIMS isotopic analysis.

Dr D RUBATTO collaborates with Dr D. Harlov, Deutsches Geo Forschungs Zentrum, Potsdam, Germany on the effect of recrystallization on monazite oxygen composition.

Dr D. RUBATTO collaborates with Prof D. Whitney and Prof C. Tessier, University of Minnesota, USA on the geochemical and geochronological evolution of the blueschist belt in Turkey.

Dr D. RUBATTO collaborates with Prof M. Engi, Mr D. Regis and Miss P. Manzotti University of Bern, Switzerland, on the chronology of Alpine metamorphism.

Dr D. RUBATTO collaborates with Dr M. Beltrando University of Turin, Italy on the chronology of paleo-margins assembled within the Alpine orogeny.

Dr D. RUBATTO collaborates with Prof S. Chakraborty, Ruhr Universität Bochum, Germany, Dr R. Anczkiewicz, Polish Academy of Sciences, Krakow, Poland, Prof S. Dasguspta, University of Allahabad, India and Prof D. K. Mukhopadhyay, Indian Institute of Technology Roorkee, India on the chronology of metamorphism in the Sikkim region of the Himalayas.

Mrs K. STRZEPEK with Dr D. Roberts (University of Tasmania), Dr A. Revill (CSIRO Marine and Atmospheric Research), Dr R. Leeming (CSIRO Marine and Atmospheric Research), Dr R. Thresher (CSIRO Marine and Atmospheric Research).

Dr I.S. WILLIAMS and Prof R.W.R. RUTLAND with Dr A. Solli (Geological Survey of Norway). The evolution of the Caledonian nappes of Norway. Prof. Rutland visited Norway for 10 days in July to collect samples for this project.

Dr I.S. WILLIAMS with Dr E. Krzeminska and Dr J. Wiszniewska (Polish Geological Institute, Warsaw). The evolution of the basement beneath the East European Platform in Poland.

Dr I.S. WILLIAMS with Dr E. Krzeminska and Dr I. Wysocka (Polish Geological Institute, Warsaw). Drs Krzeminska and Wysocka visited ASI, RSES and GA for a week in October for initial training in sample preparation for, and the operation of, the SHRIMP IIe ion microprobe.

Dr I.S. WILLIAMS with Prof F. Bea and Dr P. Montero (University of Granada, Spain). Dr Williams visited the University of Granada for two weeks in January-February to provide advanced training in the operation of their new SHRIMP IIe/mc ion microprobe.

Dr I.S. WILLIAMS with Dr P. Fiannacca, Dr R. Cirrincione and Prof A. Pezzino (University of Catania, Sicily). The chronology of thermal events in the Serre Massif, Calabria. Dr Fiannacca visited RSES for four weeks in November to work with Dr Williams on this project.

Dr I.S. WILLIAMS with Prof D. Liu, Dr Z. Ji and Dr G. Wu (Chinese Academy of Geological Sciences, Beijing). Tracing Permo-Triassic palaeoclimate in Tibet using marine bioapatite O isotopes. Dr Williams worked visited Beijing in April, partly to work on this project.

Dr I.S. WILLIAMS with Dr M. Rigo and Dr N. Preto (University of Padova, Italy). Late Triassic palaeoclimate in Sicily.

Dr I.S. WILLIAMS with Dr M. Chichorro (Universidade Nova de Lisboa), Dr R. Sola (Laboratorio Nacional de Energia e Geologia) and Dr F. Pereira (Universidade de Lisboa). Neoproterozoic to lower Paleozoic geodynamic evolution of northern Gondwana (SW Iberia).

Dr I.S. WILLIAMS with Dr M. Kusiak (Polish Academy of Science, Warsaw). Chronology of the composite Karkonosze pluton, Sudetes. Dr Kusiak visited RSES for a week in September to work with Dr Williams on this project.

Dr I.S. WILLIAMS with with Drs T. Kon and H. Shimoda (Japanese National Institute of Advanced Industrial Science and Technology). Training in the operation of the SHRIMP II ion microprobe.

Earth Environment

Dr A. Abrajevitch collaborates with Prof K. Kodama (Center for Advanced Marine Core Research, Kochi University, Japan) on the environmental rock magnetic study of ODP core 747a.

Dr N. ABRAM collaborates with Dr R. Mulvaney and Prof E. Wolff (British Antarctic Survey, Cambridge, UK) on polar ice core palaoeclimate reconstructions, and with Prof W. Hantoro (Indonesian Institute of Sciences, Indonesia), and Dr H. Rifai (Padang University, Indonesia) on tropical palaeoclimate studies using coral and cave samples.

Mr R. BURNE collaborates with Prof J. Paul (Göttingen University) and Dr T. Peryt (Geological Institute, Poland).

Mr N. DARRENOUGUE collaborates with Dr C. Payri (Institute for Research and Development (IRD), Noumea, New Caledonia).

Prof Patrick De Deckker collaborates: Dr S. Schmidt (University of Bordeaux I, France) on dating marine sediments using a variety of radionuclides, with Prof S. Schouten and his student Ms R. Lopez (NIOZ, Holland) on lipid biomarkers in deep-sea marine cores, Dr J.-B. Stuut (NIOZ, Holland) on airborne dust and deep-sea sediments and their composition, with Dr A. Wegner (AWI, Germany) and Dr P. Gabrielli (Ohio State University, USA) on the composition of dust in ice cores from Antarctica, with Dr R. Abed (University of Oman) on the microbiology of Australian airborne dust, with Dr M. Moros and Dr K. Perner (The Baltic Sea Research Institute) on the faunal composition and isotopic composition of deep-sea core offshore South Australia, with Dr A. Rathburn and his PhD student Ms A. Burkett (Indiana State University, USA) on deep-sea foraminifera from the Australian region, with Dr R. Speier (University of Leuven, Belgium) on the chemical composition of marine ostracods, and Prof K. Martens (Museum of Natural Sciences, Belgium) on the ontogeny of extraordinarily ornamented ostracods belonging to the Australian genus *Bennelongia*.

Dr M.J. ELLWOOD collaborates with Dr P. Boyd (NIWA, NZ) and Dr C. Law (NIWA, NZ) on trace element cycling in the Tasman Sea and Pacific Oceans, and with Dr D. Vance (University of Bristol, UK) on copper isotope fractionation in oceanic waters.

Dr M.K. GAGAN collaborates with Prof W. Hantoro (Indonesian Institute of Sciences, Indonesia), Prof L. Edwards and Dr H Cheng (University of Minnesota, USA), and Dr G. Schmidt (NASA Goddard Institute for Space Studies, USA) on ARC Discovery grant DP1095673 (2010-2012): Multi-proxy fingerprinting, absolute dating, and large-scale modelling of Quaternary climate-volcano-environment impacts in southern Australasia, and with Prof W. Hantoro and Dr D. Natawidjaja (Indonesian Institute of Sciences, Indonesia), Prof. C.-C. Shen (National Taiwan University), Prof K. Sieh (Earth Observatory of Singapore), Prof L. Edwards and Dr H. Cheng (University of Minnesota, USA), and Dr G. Schmidt (NASA Goddard Institute for Space Studies, USA) on ARC Discovery grant DP110101161 (2011-2015): Climate and natural hazards in Australasia: A comprehensive impact analysis of prehistoric droughts, great earthquakes, and the Toba super-eruption, and with Co-Chief Investigators Dr J. Webster (University of Sydney) and Associate Prof Y. Yokoyama (University of Tokyo, Japan) and the Expedition Scientists of Integrated Ocean Drilling Program (IODP) Expedition 325: Great Barrier Reef Environmental Changes.

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, France, and Dr M. Duval (Centro Nacional de Investigación sobre la Evolución Humana, Burgos, Spain) on the further development of dating techniques. He 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 applications with

Prof B. Maureille (Laboratoire d'Anthropologie des populations du Passé, Université Bordeaux 1, France) on the sites of Les Predelles, La-Chapelle-aux-Saints, La Piage, Les Fieux, and Rescoundudou where Mr. I. Moffat is carrying out aspects of his PhD studies. He collaborated with Dr P. Coutaud (Université Bordeaux 1, France) on Sr analysis of human remains at the site of Tumulus des Sabres, Dr V. Mourre (Université de Toulouse-Le Mirail, France) on Grotte Nosetier, where Mr M. Willmes carries out part of his PhD research, and Dr S. Pratt (UPR 2147, CNRS, France) on the dating of the Grotte de la Chèvre. Prof R. GRÜN is also part of Dr P. Villa's NSF grant on the dating of Middle Palaeolithic sites in Italy.

Prof R. GRÜN collaborates with many international scholars on the timing of modern human evolution. He has collected hominid samples from Skhul, Qafzeh, Tabun, Kebara and Amud, Israel in collaboration with Prof Y. Rak (Haifa University, Israel), Broken Hill, Omo 1, Wadjak, Iwo Eleru samples in collaboration with Prof C.B. Stringer (Natural History Museum, London UK). He collaborates with Dr J. Brink (Bloemfontein), Dr C.B. Bousman (Texas State University, USA) and Prof M. Bateman (University of Sheffield, UK) on the dating of a range of sites in South Africa, including the newly discovered human site of Cornelia. For the dating work in Africa, he collaborates with Prof G. Barker (University of Cambridge, UK), Dr M. Lahr (University of Cambridge, UK), Prof S. McBrearty (University of Connecticut, USA) and Prof M. Musso (Università di Roma "La Sapienza", Italy).

Prof R. GRÜN collaborates with the Institute of Geology, China Earthquake Administration, Beijing, on the dating of elevated river terraces for the reconstruction of elevation rates in the Himalayas as well as using paramagnetic centres in quartz for the calculation of cooling rates in the Pamir. He collaborates with Prof Z.-P. Lai (State Key Laboratory for Cryosphere Sciences, Cold and Arid Regions Environmental and Engineering Research Institute, Lanzhou, China) to work on environmental change in the Qaidam Basin. Collaboration also continues with Dr A. Pike (University of Southampton, UK) on uranium uptake of bones, and with Prof T. de Torres (Escuela Tecnica Superior de Ingenieros de Minas de Madrid, Spain) on the calibration of amino acid racemisation in bones, and cave bear evolution.

Dr David Heslop collaborates with Dr A. Govin and Dr J. Collins (MARUM, University of Bremen, Germany) on the elemental composition of Atlantic surface sediments.

Ms Alena Kimbrough, collaborates with Mr. Hai Cheng (University of Minnesota, USA) to process Uranium/Thorium dates.

Dr D.C. “Bear” McPHAIL collaborates with Prof K. Kyser (Queen’s University, Canada) and Dr. C. Stirling (Otago University, NZ) on uranium isotope fractionation in the regolith.

Mr S. MEYERINK collaborated with Dr P. Curnow (University of Bristol, UK) on SIT extraction.

Dr. B.N. Opdyke began a major international collaborative project with the International Ocean Drilling Program (IODP) by sailing on EXP342 to the North Atlantic early in the year.

Prof B.J. PILLANS with Prof J. Ogg (Purdue University, USA), Prof. F. Gradstein (University of Oslo, Norway) and Prof P. Gibbard (Cambridge University, UK) on a new book, “The Geological Time Scale 2012”, Elsevier. Prof

PILLANS also collaborates with Dr B. Alloway (Victoria University of Wellington, NZ) on the Quaternary stratigraphy of Soa Basin, Flores, Indonesia, and with Dr T. Barrows (Exeter University) on Southern Hemisphere Late Pleistocene glacial chronologies.

Ms Jenna ROBERTS collaborated and received assistance from Dr P. Behnisch, (Biodetection Systems, Amsterdam).

Mr. N. SCROXTON collaborated on U/Th dating from with Hai Cheng (Xi’an Jiatong University/University of Minnesota).

Ms. S. TYNAN collaborates with Dr A. Dutton, Department of Geological Sciences, University of Florida, on the reconstruction environmental information from the geochemical signatures of bivalve shells.

Dr Jimin YU collaborated with Dr A.W. Piotrowski (University of Cambridge, UK) on neodymium isotopes as a tracer for ocean circulation, and Drs. B. Anderson and W.S. Broecker (LDEO of Columbia University, USA), Dr R. Ryerson (Lawrence Livermore National Laboratory, USA) and Dr Z.D. Jin (Chinese Academy of Sciences, China) on deep ocean carbonate chemistry.

Earth Materials & Processes

PROFESSOR RICHARD ARCULUS collaborated with Professor Jon Blundy (University of Bristol) Professor Jon Davidson (University of Durham) Dr John Lupton, Dr Ed Baker, Dr Joe Resing (NOAA) Dr Erik Hauri, Dr Frances Jenner (Carnegie Insitution of Washington).

DR ANDREW BERRY Collaborated with Anglo American, Jamie Wilkinson (Imperial College London), and the Richard Herrington (Natural History Museum London) on the project "Geology of the Sakatti Cu-Ni-PGE deposit, Lapland, Finland" (PhD student: Will Brownscombe); Dominik Weiss, Ramon Vilar Compte, and Daryl Williams (Imperial College London) on the NERC funded project "AS-sure: new technology for delivering safe drinking water" (PhD student: Flo Bullough); Paul Schofield (Natural History Museum London) and Fred Mosselmans (Diamond Light Source) on the project "Using synchrotron radiation to investigate the geochemistry of magmas" (PhD student: Helen Halse); Jamie Wilkinson (Imperial College London) on the project "Molybdenum transport and deposition in porphyry ore systems" (PhD student: Ed Spencer); Sharon Ashbrook (University of St Andrews) and Stephen Wimperis on using nuclear magnetic resonance spectroscopy to

study the incorporation of water in nominally anhydrous mantle minerals; Paul Schofield (Natural History Museum London) and Andrew Walker (University of Bristol) on the crystal chemistry of hibonite.

PROFESSOR STEPHEN COX collaborated with PhD students M Arndt and S Virgo, and with Professor Janos Urai (all at RWTH - University of Aachen, Germany) on using C/O isotope studies to explore aspects of fluid flow associated with the formation of calcite vein arrays in Oman; with PhD student J Klaver and Professor J Urai (RWTH - University of Aachen) in using Broad Ion Bean polishing techniques, in conjunction with scanning electron microscopy, to quantify the evolution of pore structures during compaction of quartz aggregates at high temperature hydrothermal conditions. The study is exploring evolution of fluid transport properties in simulated fault rock during interseismic healing; co-supervising, with Prof C Hilgers (RWTH – University of Aachen) the research activities of MSc student F Schwartz on the geometry, kinematics and structural evolution of major shear zones associated with Au mineralization at Kambalda (WA).

PROFESSOR JOERG 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. Q. Liu (China University of Geociences, Wuhan, China) on the melting of subducted crust during exhumation; Prof. Y.F. Zheng (University of Science and Technology, Hefei, China) on fluids in subducted continental crust; Dr. A. Korsakov (Novosibirsk, Russia) on coesite and diamond facies metamorphism in the Kokchetav Massif, Kazakhstan; Prof. L. Baumgartner and Prof. O. Müntener (University of Lausanne, Switzerland), on the formation and subduction of altered oceanic crust in the Alps; Prof. M. Engi (University of Berne, Switzerland) on Barrovian metamorphism in the Central Alps; Prof. B. Cesare (University of Padova, Italy), Prof. I. Buick (Stellenbosch University, South Africa) and Dr. A. Acosta Vigil (University of Granada, Spain), on partial melting in crustal xenoliths of the South Spanish volcanic province and Dr. M. Beltrando (University of Torino, Italy), on formation and evolution of blueschist and eclogite facies rocks in the Western Alps.

PROFESSOR IAN JACKSON collaborated with D.R. Schmitt and H. Schijns (University of Alberta, Canada), U.H. Faul (Boston University, D.L. Kohlstedt and M. Zimmermann (University of Minnesota, Minneapolis), A. Barnhoorn (Technical University, Delft), R.J.M. Farla and S. Karato, Yale University, J. Kung (National Cheng-Kung University, Taiwan), R.C. Liebermann (Stony Brook University), Y. Kono (Carnegie Institution of Washington), and S.J.S. Morris (University of California, Berkeley) in the laboratory measurement and modelling of seismic properties.

DR PENNY KING collaborated with R.L. Hervig (Arizona State University); S. Wirick
(Brookhaven National Laboratory); P. Vernazza (Laboratoire d'Astrophysique de Marseille, France); M.D.Dyar (Mt Holyoke College); D.W. Beaty(NASA Jet Propulsion Laboratory; S.R. Sutton and A. Lanzirotti (University of Chicago/Advanced Photon Source); J.L. Campbell and R. Gellert (University

of Guelph, Canada); Ms. G. Perrett and Mr. N.I. Boyd (University of New Brunswick, Canada) J.G. Spray and L.M. Thompson, and Ms. B.E. Elliott (University of New Mexico, USA) C.B. Agee, Dr. T. Fischer, Dr. H. Newsom, Dr. Z.D. Sharp, Mr. M. Spilde, Mr. J. Berger, Mr. M. de Moor (University of Pittsburg, USA) M.S. Ramsey and R.J. Lee (University of Western Ontario, Canada); G. Southam, Dr. T.K. Sham, Mr. M. Izawa and Ms. L. Loiselle

DR OLIVER NEBEL visited the Universities of Hamburg, Germany; Tübingen, Germany; Hefei, China; and Guangzhou, China to establish and continue scientific collaboration.

PROFESSOR HUGH O'NEILL is collaborating with Dr Guilherme Mallmann of the Institute of Geosciences, (University of São Paulo, Brazil) on using XANES spectroscopy to quantify oxidation states in silicate melts. He continues to work with Dr. Frances Jenner of the Department of Terrestrial Magnetism, (Carnegie Institution of Washington), on the trace-element geochemistry of mid-ocean ridge basaltic glasses. He also collaborates with Dr Christine Putnis, Dr Andrew Putnis Ms Helen King and Mr Stephen Klemme (University of Munster).

DR JOSE-ALBERTO PADRON-NAVARTA collaborated with Dr. V. LOPEZ-SANCHEZ VIZCAINO (University of Jaen, Spain), and Dr. M.T. GOMEZ-PUGNAIRE (University of Granada, Spain) and Dr. C. MARCHESI (CSIC, Spain) on the high-pressure metamorphism of serpentinite and water recycling in subduction zones. He also collaborated with Dr. C.J. GARRIDO (CSIC, Spain) and Dr. K. HIDAS on the deformation of the subcontinental lithosphere from Ronda peridotite in South Spain.

DR GREG YAXLEY collaborated with Prof Gerhard Brey (University of Frankfurt) on a study of refractory spinel peridotites from the Kaapvaal Craton of southern Africa. He also collaborated with Prof Alan Woodland (University of Frankfurt) on investigations of redox conditions in the cratonic mantle. Collaborated with Prof Marc Hirschmann (University of Minnesota) and Dr Andreas Enggist (RSES) on a project concerning the earth's deep carbon cycle, funded by the Deep Carbon Observatory of the Carnegie Institute at Washington. Collaborated with Dr Anja Rosenthal (Bayreuth University) on a high-pressure experimental investigation of the stability of phlogopite in peridotite with excess hydrous fluid. Collaborated with Dr Kate Kiseeva (Oxford University) and Prof Kostya Litasov (Tohoku University) on high pressure experimental investigations of the deep subduction of carbonate-bearing MORBs.

Earth Physics

Mr. C.C. CHAPMAN with Dr. Rosemary Morrow, Laboratoire d'Études en Géophysique et Océangraphie Spatial, a joint division of CNRS, CNES and Université de Toulouse III, France, on the interaction of Southern Ocean currents with topography in the Southern Ocean.

Prof P.R. CUMMINS collaborates with Mr. Herve Damlamian of the Applied Geoscience and technology division (SOPAC) of the Secretariat of the Pacific Community (SPC) on tsunami inundation modeling to support evacuation planning in Nuku'alofa, Tonga.

Prof P.R. CUMMINS collaborates with Dr. Irwan Meilano of Bandung Insititute of Technology, Indonesia, Dr. Sri Hidayati of the Indonesian Geological Agency, and Mr. Suhardjono of the Indonesian Agency for Meteorology, Climatology and Geophysics on research related to active tectonics and earthquake hazard in Indonesia.

Prof P.R. CUMMINS collaborates with Prof. Doug Wiens of Washington University and Dr. David Heeszel of Scripps Institute of Oceanography on a study of the 2006 Tonga Earthquake.

Dr S. DOWNES with Dr. E.Y. Kwon (University of California, USA), Prof. J. Sarmiento (Princeton University, USA), Dr Riccardo Farneti (International Centre for Theoretical Physics, Italy) and Dr C. Deutsch (University of California, USA) on the seasonal cycle of subduction of upper Southern Ocean waters.

Dr. S. DOWNES with Dr. R.M. Key (Princeton University, USA), Prof. A. Orsi (Texas A & M University, USA), Prof. K.G. Speer (Florida State University, USA) and Prof. J.H. Swift (Scripps Oceanographic Institute) on tracing hydrothermal plumes and deep ocean circulation in the Southwest Pacific basin.

Dr S. DOWNES with Dr. E.Y. Kwon (University of California, USA), Prof. J. Sarmiento (Princeton University, USA), Dr. D. Menemenlis (NASA Jet Propulsion Laboratory, USA) and Dr. H. Zhang (University of California Los Angeles, USA) on the inter-annual variability of modelled subduction of upper Southern Ocean waters.

Prof R.W. GRIFFITHS with Prof C. Kincaid, Graduate School of Oceanography, University of Rhode Island, USA and Dr K. Druken, Department of Terrestrial Magnetism, Carnegie institution, Washington, USA, on the interaction of mantle subduction zones with mantle plumes and the history of volcanism in the Pacific Northwest of USA.

Prof R.W. GRIFFITHS with Dr S. Kalevi, University of Jyväskylä, Finland, on lake convection and circulation under spring ice cover.

Dr A.McC. HOGG with Dr M. Meredith, British Antarctic Survey, UK, Dr A.C. Naveira Garabato, National Oceanography Centre, UK and Dr R. Farneti, International Centre for Theoretical Physics, Trieste, Italy on the Southern Ocean overturning circulation.

Dr A.McC. HOGG and Dr M.L. Ward with Dr Stephen Griffies, Geophysical Fluid Dynamics Laboratory, USA, on the development of a high resolution ocean model.

Dr Giampiero IAFFALDANO collaborates with Dr Rhodri DAVIES at Imperial College London.

Prof KENNETT has collaborated with Dr S Fishwick, University of Leicester, UK, Dr A. Fichtner, University of Utrecht, the Netherlands, and Dr K. Yoshizawa, University of Hokkaido on the construction of the mantle component of the AuSREM seismological model.

Prof KENNETT has continued to collaborate with Dr T. Furumura at the Earthquake Research Institute, University of Tokyo, Japan and Dr K. Chen at the National Taiwan Normal University on a variety of issues in seismic wave propagation, particularly guided waves in subduction zones.

Prof KENNETT acted as Chair of an External Review Panel for the Data Services Division of IRIS (Incorporated Research Institutions in Seismology) the main international centre for earthquake seismology. The review was conducted in Seattle, WA in early November, Dr S. MCCLUSKY collaborates with; Prof. T.A. Herring, Dr R. Reilinger and Dr R.W. King, EAPS, MIT, Cambridge, MA, USA, on development of GAMIT/GLOBK GPS analysis software and Mediterranean/Mid East geodynamics studies.

Dr S. MCCLUSKY collaborates with; Dr P.Vernant, Géosciences Montpellier, Université Montpellier 2, Montpellier, France, on Western Mediterranean geodynamics.

Dr S. MCCLUSKY collaborates with; Dr S. Ergintav, TUBITAK, Marmara Research Center, Gebze, Turkey, on earthquake hazards in Turkey.

Dr S. MCCLUSKY collaborates with; Dr I. Meilano, GREAT, ITB, Bandung, Indonesia, on crustal deformation studies and earthquake hazards in Indonesia.

Dr. J.P. MONTILLET is collaborating with the Geospatial center at the University of Nottingham (U.K.). He is also supervising Mr. Lukasz Bonenberg (since 2010).

Dr. N. RAWLINSON collaborates with Dr. Stewart Fishwick (University of Leicester), Prof. Greg Houseman (University of Leeds) & Prof. Youxue Wang (Guilin University of Technology).

Dr M. SALMON collaborated with Prof T. Stern, Institute of Geophysics, Victoria University of Wellington on the New Zealand Moho depth.

Dr M. SALMON collaborated with Prof T. Stern, Institute of Geophysics, Victoria University of Wellington, Prof G. Houseman and L. Evans, School of the Environment, University of Leeds on convective edge-instability in continental interiors.

Dr M. SALMON collaborated with Dr T. Bodin, Earth and Planetary Science, University of California Berkley on using probabilistic surface reconstruction to map the Moho.

Prof M. SAMBRIDGE collaborates with Dr. T. Bodin, University of Berkeley, and Prof. K. Gallagher Univ. of Rennes, France) on Bayesian methods of data inference.

Dr E. SAYGIN with Dr A. Fichtner (ETH), Dr L. Vanacore (Unv. of Leeds), Prof. T. Taymaz (Istanbul Tech. Unv.) on seismic structure of Turkey, with Mr. Suhardjono (Badan Meteorologi, Klimatologi, dan Geofisika), Prof. S. Widiyantoro (ITB), Dr K. Nishida (ERI-Tokyo) on crustal structure of Indonesia and surrounding regions.

Dr. H TKALČIĆ collaborates with Dr S Tanaka, JAMSTEC, Japan, on structure of the inner core and core-mantle boundary, with Prof. J Rhee, Soul University on the Earth's core, with Prof. M. Mattesini from the Universidad Compultense de Madrid on the Earth's core, with Prof. R. Garcia from the University of Toulouse on the Earth's core, with Prof. M Herak and postdoctoral fellow J. Stipcevic, University of Zagreb, on lithospheric structure of Croatia and the Adriatic Sea, with Dr A Fichtner, Utrecht University on earthquake sources, with Dr Jan Dettmer from the University of Victoria on the application of Bayesian methods, and with Dr Y Chen, 3D Array Technologies, United States, on lithospheric structure of China.

Dr P. TREGONING collaborated with Dr K. Fleming, GeoForschungsZentrum on sea level change around the Australian coastline

M.K. YOUNG collaborates with T. Bodin, Berkeley Seismological Lab, University of Berkeley, USA, on seismic tomography using a transdimensional Bayesian approach.

M.K. YOUNG collaborates with S. Tanaka, Japan Agency for Marine-Earth Science and Technology, Japan, on imaging the lowermost mantle using differential body wave travel times.

Integrated Ocean Drilling Program (IODP)

Collaboration occurs with many scientists in America, Japan, Europe, New Zealand, India and Korea in the IODP context. We send Australian scientists to join IODP drilling expeditions each year. We also provide scientists for various IODP panels and reviews, and AIO is in daily contact with partner scientists and organizations around the world.

The relationship with New Zealand is very close and they are represented on the ANZIC Governing Council and Science Committee. Their scientists are part of the ANZIC quota for drilling expeditions and IODP panels.

PRISE

Dr R.A. ARMSTRONG with Prof. A. da Silva Filho and Assoc. Prof. I. de Pinho Guimaraes (Federal University of Pernambuco, Brazil) on the geochronology and crustal growth history of the Borborema province, Brazil.

Dr R.A. ARMSTRONG with Prof M. Pimentel and Mr Luis de Lana (Federal University of Rio Grande do Sul, Brazil) on establishing geochronological and provenance constraints on the Bambui Group, Brazil.

Dr R.A. ARMSTRONG with Prof F. Chemale (University of Brasilia, Brazil) on provenance of detrital zircons from various sedimentary basins in South America.

Dr R.A. ARMSTRONG with Dr C. Marsicano and Dr E.G. Ottone (University of Buenos Aires) on the age of tuffs associated with new dinosaur discoveries in Argentina.

Dr R.A. ARMSTRONG with C. Lana (Federal University of Ouro Preto, Brazil) on the geochronology of the Quadrilatero Ferrifero, South America.

Dr R.A. ARMSTRONG with Dr S. Master and Ms S. Glynn (University of the Witwatersrand) on the geochronology of the Magondi Belt, Zimbabwe and various African extraterrestrial impact sites.

Dr R.A. ARMSTRONG with Prof M. Macambira (Federal University of Para, Brazil) on geochronology of the Amazonian craton, Brazil.

Dr R.A. ARMSTRONG with Prof C. E. Suh (University of BUEA, Cameroon) on geochronology of the Congo craton and margins.

Dr R.A. ARMSTRONG with Dr G. de Kock (Council for Geoscience, South Africa) on the geochronology of the Damaran Belt, Namibia.

Dr R.A. ARMSTRONG with Dr P.Poprawa (Polish Geological Institute) on geochronology and provenance of zircons from Poland.

Dr R.A. ARMSTRONG with Professor S. McCourt (University of KwaZulu-Natal) on the geochronology and O and Hf isotope characterisation of volcanic rocks of the Tugela Valley, South Africa and on the geochronology of the Limpopo Belt, Botswana and surrounding cratons.

A/Prof C.M. FANNING with Prof P. K. Link and Mr J. Keeley (Idaho State University) and Dr C. Dehler (Utah State University) on the provenance and time of deposition of Neoproterozoic sequences in Utah and Idaho.

A/Prof C.M. FANNING with Dr J. Goodge (University of Minnesota, Duluth) on the geochronology and provenance of sequences in the central Transantarctic Mountains, Antarctica.

A/Prof C.M. FANNING with Prof F. Hervé (Universidad de Chile), Dr M. Calderón (Geological Survey of Chile, SERNAGEOMIN) and Dr R.J. Pankhurst (British Geological Survey) on the geochronological and tectonic evolution of the central Chile basement rocks.

A/Prof C.M. FANNING with Dr C. Rapela (Uni La Plata) and Dr C. Casquet and Dr C. Galindo (Universidad Complutense de Madrid) on the geochronological and tectonic evolution of the Sierras Pampeanas, NW Argentina.

A/Prof C.M. FANNING with Dr C. Siddoway (Colorado College), Prof M. Brown and Mr C.Yakymchuk (University of Maryland) on the tectonic evolution of the Fosdick Mountains, Mary Byrd Land, Antarctica.

A/Prof C.M. FANNING with Dr F. Espinoza (Geological Survey of Chile, SERNAGEOMIN) on the age and isotopic characteristics of Cretaceous to Tertiary volcanism in northern Chile.

A/Prof C.M. Fanning and Dr D. Elliot (Ohio State University) on the geochronology and isotopic characteristics of Permo-Triassic detritus in the Transantarctic Mountains.

A/Prof C.M. Fanning with Dr J. Aleinikoff (U.S. Geological Survey) on the age of igneous and metamorphic rocks in the New England area, USA.

Dr B. Fu with Prof M. Bröcker (Universität Münster, Germany) on O-Hf isotopic studies of zircons in pre-Cretaceous igneous rocks from the Cyclades, Greece.

Dr B. Fu with Prof Z. Xu (Nanjing University) on determining the timing and origin of molybdenum mineralisation and associated magmatism in eastern China.

Visiting Fellows

Dr K. A. W. CROOK collaborates with A/Prof. A. SWITZER, Nanyang Technological University, Singapore, on cosmogenic age dating of rocky coastal geomorphic features.

Dr E. A. FELTON collaborates with A/Prof. A. Switzer, Nanyang Technological University, Singapore, on cosmogenic age dating of rock coastal geomorphic features.

Dr C. Klootwijk collaborates with Dr H. Théveniaut, Bureau de Recherches Géologiques et Minières, France, on paleomagnetism of the Upper Permian Newcastle Coal Measures, Sydney Basin.

Dr Truswell continues to collaborate with a number of researchers in the US on sedimentary sequences on the Antarctic margin (Dr E.Domack, Hamilton College New York) and on Cenozoic vegetation history of Antarctica (DrSophy Warny, Louisiana State University).

COOPERATION WITH GOVERNMENT AND INDUSTRY

Earth Chemistry

Dr J.J. BROCKS with N. Güneli and scientists from an international oil company, Assessment of new Proterozoic oil source rocks.

Dr S.J. FALLON collaborates with Dr A. McDougall (Dept. Natural Resources & Water, aging of Queensland Lungfish).

Dr M. FORSTER collaborates with Dr G. Fraser at Geoscience Australia involving argon geochronology of tectonic events within Australia.

Dr M. FORSTER collaborates with Mr K. Mendis at ANSTO Opal reactor so as to undertake trial irradiation of geological samples for argon geochronology.

Dr M. FORSTER has cooperation with Petrobras for argon geochronology analysis.

Mrs K. STRZEPEK with Dr W. Howard (Chief Scientists Office) assisting in sample collection onboard the *Aurora Australis*.

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. As part of his work with ASI, Dr Williams provided SHRIMP technical and scientific advice to the Geological Survey of Canada (Ottawa, Canada), Hiroshima University (Hiroshima, Japan), The National Institute of Polar Research (Tachikawa, Japan), The Chinese Academy of Geological Sciences (Beijing, China), the All Russian Geological Research Institute (St. Petersburg, Russia), the Korea Basic Science Institute (Ochang, South Korea), the University of São Paulo (São Paulo, Brazil), the University of Granada (Granada, Spain) and Geoscience Australia (Canberra).

Dr Williams also provided scientific and technical training in secondary ion mass spectrometry to scientists from laboratories that have purchased, or are considering purchasing, SHRIMP ion microprobes. In January-February he spent two weeks in Spain providing advanced training in SHRIMP operation to staff of the University of Granada, Spain, in July he spent three days in Beijing for SHRIMP marketing, and for three weeks in November-December he worked on the preparation of a SHRIMP IIe for delivery to the Japanese National Institute of Advanced Industrial Science and Technology, including

training Institute scientist in SHRIMP operation.

Dr I.S. WILLIAMS is collaborating with Dr R.S. Nicoll (Geoscience Australia, Canberra) on palaeoclimatology using marine bioapatite oxygen isotopes.

Dr I.S. WILLIAMS is collaborating with Dr K. Sircombe (Geoscience Australia) and the Australian Federal Police exploring potential forensic applications of the SHRIMP II.

Earth Environment

Mr R. BURNE is providing advice to the Department of Environment and Conservation, Western Australia on the management and conservation of the Shark Bay World Heritage Area and the Yalgorup Lakes National, and to the U.K. Nature Conservancy on the origin and development of the North Cornish coastline.

Prof Patrick De Deckker is collaborating with Dr D. Cohen (ANSTO) on the composition of Australian aerosols.

Dr M.K. GAGAN collaborates with Dr M. Fischer and Dr D. Fink (ANSTO) on coral reconstructions of El Niño-Southern Oscillation variability in the central equatorial Pacific.

Dr D.C. “Bear” McPHAIL collaborates with Mr P. Kumar (NSW Office of Water) on groundwater in the Lower Murrumbidgee catchment, NSW.

Dr D.C. “Bear” McPHAIL with Dr W. McLean (Parsons Brinckerhoff, Sydney) and Dr K. Meredith (ANSTO) on dating groundwater using 14C.

Dr D.C. “Bear” McPHAIL collaborates with staff at Canberra Sand and Gravel and Mr H. Osborne (land owner Lake George area) on landscape evolution and groundwater in Lake George.

Dr D.C. “Bear” McPHAIL collaborates with J. Coram, R. Brodie, L. Gow and other staff at Geoscience Australia about groundwater studies in Lake George and the Menindee Lakes, NSW.

Dr D.C. “Bear” McPHAIL collaborates with D. Frater (BHP-Mitsubishi Alliance) about educational programs.

Dr D.C. “Bear” McPHAIL collaborates with the Minerals Tertiary Education Council on the Honours Geoscience program of the Minerals Council of Australia.

Dr D.C. “Bear” McPHAIL collaborates with the Australian Institute of Mining and Metallurgy (AusIMM) for the Lachlan Branch and its professional and student members.

Prof B.J. PILLANS with Dr P. Morris (Geological Survey of Western Australia)

on the geochronology of regolith/landform evolution in the Kalgoorlie region, WA.

Earth Materials & Processes

PROFESSOR RICHARD ARCULUS collaborated with Nautilus Minerals and Blue Water Metals

DR ANDREW BERRY Collaborated with Anthony Harris at Newcrest Mining Limited on using synchrotron radiation to understand the distribution and speciation of gold in ores; Collaborated with Martin de Jonge at the Australian Synchrotron on using X-ray fluorescence tomography to produce 3-D images of geomaterials. were awarded 3 days beamtime on the XFM beamline at Australian Synchrotron, Melbourne, in July with Dr Greg Yaxley.

MS HELEN COCKER collaborated with Clyde Leys at the Grasberg porphyry Cu-Au deposit, Indonesia (PT Freeport Indonesia);Andreas Molina Hidalgo and Jeff Gerwe from S.C.M. El Abra at the El Abra porphyry Cu deposit, Chile (CODELCO/Freeport-McMoran Copper & Gold Inc.).

PROFESSOR STEPHEN COX collaborated with Far Southeast Gold Resources Inc (a division of Gold Fields Ltd) in a petrographic study of mineral assemblages and significance of vein textures in the Far Southeast Cu-Au porphyry deposit in Northern Luzon (Philippines).

PROFESSOR IAN JACKSON served on the Program Advisory Committee of the Bragg Institute of the Australian Nuclear Science and Technology Organisation.

DR PENNY KING collaborated with T. Mernagh from Geoscience.

DR GREG YAXLEY and Dr Andrew Berry were awarded 3 days beamtime on the XFM beamline at Australian Synchrotron, Melbourne, in July.

Earth Physics

Dr. N. RAWLINSON cooperates with Mineral Resources Tasmania GeoScience Victoria and Frogtech on a current ARC Linkage proposal. Dr. N. Rawlinson also cooperates with the NSW Geological Survey on passive seismic deployments in NSW.

Dr M. SALMON AuSREM has made the AuSREM model available to Geoscience Australia.

Dr E. SAYGIN with Dr A. Gorbatov (Geoscience Australia) on retrieving body waves from autocorrelation of seismic noise, with Dr L. Hutton (Geological Survey of Queensland) on imaging seismic structure of Mt. Isa.

Dr H TKALČIĆ cooperates with Dr A Gorbatov from Geoscience Australia on

the determination of seismic sources in Australia and surroundings in real time using Geoscience Australia stations.

PRISE

Dr R.A. ARMSTRONG with Dr Hielke Jelsma (De Beers) on the geochronology of Angola, the DRC and Indian cratons.

Dr R.A. ARMSTRONG with Dr P. Blevin (NSW Department of Industry and Investment) on the geochronology and origin of granites from NSW.

Dr R.A. ARMSTRONG with Dr D. Broughton of Ivanhoe Nickel and Platinum Ltd., on the U-Pb geochronology of mafic rocks and sediments associated with the Neoproterozoic glacial sequences of Zambia and the DRC.

Dr R.A. ARMSTRONG with Dr M. Wingate of the Western Australian Geological Survey on the Sm-Nd compositions of rocks from Western Australia.

Dr R.A. ARMSTRONG with Dr David Jelley of Diatreme Resources Limited on the geochronology of granites from Queensland.

Dr R.A. ARMSTRONG with Dr Andrew Cross and Dr Keith Sircombe of Geoscience Australia on the geochronology and oxygen and Hf isotope studies of sediments and granites from a number of areas in Australia.

Dr R.A. ARMSTRONG with Dr Graham Lilley of Rio Tinto Desenvolvimentos Minerais Ltda, Brazil, and postgraduate students from the University of Brasilia on the geochronology of samples from the Amargosa project.

Dr B. Fu with Dr T.P. Mernagh (Geoscience Australia) on fluid inclusion studies of the Maldon gold deposit, central Victoria.

Visiting Fellows

Dr K. A. W. CROOK is a Fellow of the Australian Institute of Geoscientists. He is a BA(ANU) in Political Science, and is a Life Member of the Australian Labor Party. He provides professional advice to Ministers of the Commonwealth & NSW Governments on topics within his competence.

Dr K. A. W. CROOK is a collaborator with First Investigator Prof Bradley Pillans, RSES and others, in an ARC Linkage Project “Enigmatic Lake George - Changing environments, sustainable sand”, which received ARC Funding in June 2012.

Dr E. A. FELTON is a collaborator with First Investigator Prof Bradley Pillans, RSES and others, in an ARC Linkage Project “Enigmatic Lake George - Changing environments, sustainable sand”, which received ARC funding in

June 2012.
Dr E. A. FELTON and Mr Bruce Leaver of Sapphire Coast Tourism are collaborating on writing accounts of landscape geoheritage of SE Australia for Sapphire Coast Tourism's Heritage Tourism Strategy project, funded by a Commonwealth Government TQUAL grant.

Dr C. Klootwijk collaborates with Dr P. Milligan, Geoscience Australia, on magnetic interpretation of the Australian uppermost lithosphere.

DR Truswell continues ongoing co-operation with GA's Antarctic research team (Drs C.Carlson, A.Post, J.Smith, P.T.Harris) who have provided map data on sedimentary basins of the East Antarctic margin.

Dr Truswell provided editorial comment, text and illustrations for a revised edition of *Uluru and Kata Tjuta: a geological guide* (published August 2012).

Dr Truswell was asked to evaluate and provide text for the work with design contractors on

The National Arboretum, being developed by the ACT Government, with assistance from private industry, is due to be formally opened in 2013. As part of this, the Visitors Centre will include a series of glass panels as part of its tunnel-like entrance. These will display the evolution of plants through time in a series of etchings, With Dr David Cantrill, Director of the Melbourne Botanic Gardens.

Staff Activities 2012

CONFERENCES AND OUTSIDE STUDIES

Earth Chemistry

Dr Y. AMELIN, 43nd Lunar and planetary Science Conference, The Woodlands, TX, USA, March 19-23, 2012. Three poster presentations. Followed by 5 day stay at Q-Z. Yin's lab at the University of California Davis, Hf isotope analysis of meteorites.

Dr Y. AMELIN, 22nd V.M. Goldschmidt Conference, Montreal, Canada, 24-29 June 2012. Participated as a session organiser, and co-authored two presentations, but did not attend the meeting.

Dr Y. AMELIN, 75th Annual Meeting of the Meteoritical Society, Cairns, Australia, August 2012. Participated in the preparation as a member of the program committee, chaired two sessions, gave an oral presentation.

Dr Y. AMELIN, TANG3O Workshop, November 2012, Canberra. Gave an oral presentation.

Dr V.C. BENNETT, Goldschmidt Conference, Montreal, 24-29 June presented a talk in the symposium, T**he first billion years: assessing the geologic record** entitled, "Expanding early Earth frontiers: A new Eoarchean-Hadean(?) terrane in Southwestern Greenland".

Dr V.C. BENNETT conducted ARC funded fieldwork in the early Archean (>3.6 Ga) terranes of southwest Greenland in July and August.

Ms K. BOSTON, 34th International Geological Congress, Brisbane, Australia, 5-10 August 2012, presented a paper entitled "Geochronology of accessory allanite and monazite in the Barrovian metamorphic sequence of the Central Alps, Switzerland".

Dr J.J. BROCKS – Keynote Speaker – 12 to 13 March 2012 – - 'Archean Biomarkers: do it right or don't do it at all', Agouron Archean Biomarker Workshop, Riverside, CA.

Dr J.J. BROCKS – Oral Presentation – 27 April 2012 – 'Molecular fossils and the late rise of oxygenic photosynthesis', EGU General Assembly 2012, Vienna, Austria.

Dr J.J. BROCKS – Oral Presentation – 24 to 29 June 2012 – 'The unusual nature of the Proterozoic biomarker record and the Mat-Seal hypothesis', 22th Annual V. M. Goldschmidt Conference, Montreal, Canada.

Dr J.J. BROCKS – Oral Presentation – 8 Nov 2012 – ‘Molecular fossils, iron speciation and mineralization”, Organic Geochemistry of Mineral Systems CSIRO Flagship Cluster Workshop, Melbourne, Australia.

Dr J.J. BROCKS – Oral Presentation – 2 to 5 December 2012 – ‘The unusual nature of the Proterozoic biomarker record and the Mat-Seal hypothesis’, 17th Australian Organic Geochemistry Conference, Sydney, Australia.

Mr A. CHOPRA, Stromlo Student Christmas Seminars in Canberra, Australia, 23 November, presented a talk entitled “What are my friends made of?”. Co-author: Dr C.H. Lineweaver

Mr A. CHOPRA, presented an invited talk in the Trends in Environmental Research Series at the University of Technology Sydney entitled "An elemental view of life and the habitability of the Earth" on 24 October 2012. Co-author: Dr C.H. Lineweaver.

Mr A. CHOPRA, Australian Space Sciences Conference in Canberra, Australia, 25 September, presented a talk entitled “Creating the elemental composition of reference life.” Co-author: Dr C.H. Lineweaver

Mr A. CHOPRA, Research School of Earth Sciences Student Conference in Canberra, Australia, 20 September, presented a talk entitled “What am I made of?” Co-author: Dr C.H. Lineweaver

Mr A. CHOPRA, 34th International Geological Congress, Brisbane, Australia, 9 August, presented a talk entitled “Can elemental abundances be used to identify the most likely site for the origin of life?” Co-author: Dr C.H. Lineweaver

Mr A. CHOPRA, 2012 Astrobiology Science Conference, Atlanta, USA, 19 April, presented a talk entitled “A more universal definition of life suggests that we have already detected extraterrestrial life.“ Author: Dr C.H. Lineweaver

Mr A. CHOPRA, 2012 Astrobiology Science Conference, Atlanta, USA, 19 April, presented a talk entitled “The Habitability Limits of Our Earth and Other Earths.” Co-author: Dr C.H. Lineweaver

Mr A. CHOPRA, 2012 Astrobiology Science Conference, Atlanta, USA, 15 April, presented a talk entitled “Elemental Composition of Life.” Co-author: Dr C. H. Lineweaver

Mr A. CHOPRA, 2012 Astrobiology Science Conference, Atlanta, USA, 15 April, presented a poster entitled “Can Elemental Abundances be Used to Identify the Most Likely Site for the Origin of Life?” Co-author: Dr C.H. Lineweaver

Dr S.J. FALLON, attended the 5th International Symposium on Deep-Sea Corals 2010 in Amsterdam, The Netherlands and presented two papers: “Environmental Proxy Development in the deep-sea corals Corallium sp. and

theIsididae family corals from the southeast of Tasmania" and "Depth-Age Distribution of Solenosmilia corals from South/Southeast Tasmania".

Dr S.J. FALLON, attended the 21st International Radiocarbon Conference in Paris, France and presented two papers: "Bomb Radiocarbon at the Source: Coral D14C from Enewetak Atoll during the 1950s" and "There's carbon in the iron dear Liza, dear Liza".

Dr M. FORSTER attended the Structural Geology and Tectonics Special Group conference (SGTSG) at Waratah Bay, Victoria, from the 29 January to 4 February and presented a paper entitled "Dating movement using 40Ar/39Ar geochronology".

Dr M. FORSTER attended the International Geological Conference (IGC) in Brisbane from 5-11 August and presented a paper titled" "Argon geospeedometry used to constrain how long shear zones operate and the duration of heating cycles in metamorphic tectonites".

Dr M. FORSTER was one of the main organizers for the Australian Indian Scientific Fund (AISRF) workshop in Manali, NW India from 17-31 October: *'Workshop on Himalayan Mantled Gneiss Domes'*. And was invited to give a paper entitled "The importance of dating".

Dr M. FORSTER was invited to lecture and undertake collaboration at the National Institute of Oceanography in Goa, India from 22 September to 2 October presenting a lecture entitled "The scope and versatility of Ar/Ar geochronology*".*

Dr M. FORSTER attended the TANG3O (Thermochronology and Noble Gas, Geochronology and Geochemistry Organisation) from 19-20 November and gave an overview of "Argon Geochronology at ANU" as well as presenting a paper entitled "Diffusion of 39Ar in phengite/muscovite intergrowths*".*

Dr M. FORSTER was invited to ITB in Bandung in Indonesia for collaboration on the 14th September.

Dr M. FORSTER conducted fieldwork on the island of New Caledonia from the 17-24 March.

Dr M. FORSTER conducted fieldwork and supervision of RHUL, SEARG PhD candidates (eight in total) on the island of Elba in Italy from 12-21 June.

Dr M. FORSTER conducted fieldwork and supervision of ITB PhD candidate on the south-east arm of Sulawesi Central from the 29 August to the 9th September; and on Java from 10-13 September.

Mr T. HABER attended the 75th Annual Meeting of the Meteoritical Society, Cairns, Australia, 12-17 August.

Mr T. HABER attended the Meteoritical Society Central Australia Impact Crater Field Trip, Central Australia, Australia, 20-24 August.

Mr T. HABER gave a talk entitled “Asteroid fingerprints on the moons surface - what highly siderophile elements can tell us.” at the RSES Student Conference, 20 September.

Mr T. HABER conducted measurements for 40Ar/39Ar dating of lunar samples at Curtin University, Perth, Australia, 30 September – 28 October.

Dr M. HONDA, attended the IGC in Brisbane and presented a paper entitled ‘Noble gases and carbon in Argyle diamonds, Western Australia: Evidence for recycled volatiles’. He also attended TANG3O (**T**hermochronology **a**nd **N**oble **G**as **G**eochemistry and **G**eochronology **O**rganization) workshop held in Canberra, and presented a talk on “Overview on noble gas research activities at ANU”.

Ms M. HUYSKENS attended the International Geological Congress in Brisbane an presented a poster with the title: Placement of the Guadalupian – Lopingian (Capitanian –Wuchiapingian) Boundary in the Permian of eastern Australia.

Mr P. KOEFOED attended the 75th Annual Meeting of the Meteoritical Society, Cairns, Australia, 12-17 August.

Mr P. KOEFOED attended the Meteoritical Society Central Australia Impact Crater Field Trip, Central Australia, Australia, 20-24 August.

Ms A. F. KOMUGABE Fallon, S. J., Eggins, S., Thresher, R. E. & Mortimer, G. E. (2012), *‘Chronicles from the Deep? Holocene Reservoir Ages from Black Corals in South Eastern Australia’,* Australian Marine Sciences Association (AMSA) – New Zealand Marine Sciences Society (NZMSS) Conference, 1 - 5 July, Hobart, Tasmania

Ms A. F. KOMUGABE, A. F., Fallon, S. J., Eggins, S., Thresher, R. E. & Mortimer, G. E. (2012), *‘Holocene Reservoir Ages in South Eastern Australia’,* 5th International Symposium on Deep-Sea Corals, 2 - 7 April, Amsterdam, Netherlands.

Mr A. J. McCOY-WEST, 34th International Geological Congress, Brisbane, Australia, 5-10 August, presented a paper entitled “Tracing the origins of southern Zealandia using Os isotopes in mantle xenoliths”.

Mr A. J. McCOY-WEST, New Zealand Geosciences, Hamilton, New Zealand, 25-28 November, presented a paper entitled “A large chunk of Proterozoic mantle underlying the South Island”.

McCoy-West, A.J., Cocker, H., Koefoed, P., & Gowan, E.J. (2012). Exploring the Cambrian to Holocene geology of a fragment of Gondwana, South Island,

New Zealand. Research School of Earth Sciences, Australian National University. Canberra, Australia. 84 pp.

Mr A. J. McCOY-WEST successfully planned and lead the 12 day, 31 October-11 November long RSES PhD student fieldtrip for 17 students to New Zealand's South Island.

Emeritus Professor Ian McDOUGALL attended the 34th International Geological Congress in Brisbane in August and presented two keynote addresses, one a retrospective talk dealing with migration of volcanism in the Hawaiian Islands and K/Ar dating of Hawaiian lavas and the development of the geomagnetic polarity time scale and the other a summary of the geochronological study on the Omo-Turkana Basin in East Africa where we now have more than 40 well-dated levels throughout the hominin-bearing sedimentary sequence covering the last 4.25 Ma.

Emeritus Professor Ian McDOUGALL was an active participant in the Tang3o meeting in Canberra in November and presented a paper on the 40K decay constant.

Dr D. RUBATTO presented a talk at the AGU General Assembly, Vienna 22-27 April.

Dr D. RUBATTO presented a keynote talk the 34th International Geological Congress, Brisbane, 5-10 August

Dr D. RUBATTO conducted field-work in Turkey with Prof Donna Whitney and Prof Christian Tessier, University of Minnesota, USA, 1-10 June .

Miss M. S. SAPAH, Research visit to the Institute of Geophysics and Planetology at the University of Hawai'i at Manoa, USA, 12-26 May, for the characterization of a new meteorite, NWA 4502.

Miss M. S. SAPAH, 75th Annual Meeting of the Meteoritical Society, Cairns, Queensland, Australia, 12–25 August, presented a paper entitled "Cooling rates of plutonic Angrites from Pyroxene-Phosphate U-Pb chronology."

Mrs K. STRZEPEK, 5th International Symposium on Deep-Sea Coral in Amsterdam, Netherlands, April 1st-7th, presented an oral presentation,'What lies beneath? Compound Specific Isotope Analyses reveals shifting oceanic regimes' and a poster titled 'Preservation effects on Bamboo Coral geochemistry'.

Mrs K. STRZEPEK, Australian Marine Science Association, Hobart, Australia, July 1st-5th, presented an oral presentation titled 'Compound specific nitrogen isotopes in deep-sea corals from the Lord Howe Rise'.

Mrs K. STRZEPEK, 17th Australian Organic Geochemistry Conference, Sydney, Australia, December 2nd-4th, presented an oral presentation titled

‘Nutrient dynamics in a changing climate: δ15N amino acids from deep-sea corals’.

Dr I.S. WILLIAMS was an invited guest speaker at the 75th birthday celebrations in Beijing in April for Prof Liu Dunyi, Chinese Academy of Geological Sciences. He gave a talk entitled “Granite petrogenesis in the Bega Batholith, SE Australia: some insights from zircon U-Pb, O and Hf isotopes”.

Dr I.S. WILLIAMS attended the 6th International SHRIMP Workshop held outside Brisbane in August, where he gave a lecture entitled "Concerning conodonts”.

Earth Environment

Dr N.J. ABRAM, first workshop of the PAGES Sea Ice Proxy (SIP) working group, Montreal, 7-9 March, presented an invited talk entitled “MSA in ice cores: promise, problems and recommended strategies”.

Dr N.J. ABRAM, invited participant at Modes of Variability in the Climate System: Past-Present-Future conference, Obergurgul, 27 May - 1 June, presented a talk entitled “Tropical climate variability in the Indian Ocean during the last millennium”.

Dr N. ABRAM, Dr M.K. GAGAN, Ms C.E. KRAUSE and colleagues from the Indonesian Institute of Sciences and Padang University conducted fieldwork with in West Java and West Sumatra, Indonesia, 3 June - 8 July.

Mr R. BURNE, 29th IAS Meeting of Sedimentology in Schladming, Austria, 10-13 September, presented a paper entitled “Advances in the understanding of microbialites and their facies associations: Significance for Cretaceous sub-salt hydrocarbon plays in Brazil and Angola”.

Mr N. DARRENOUGUE, RSES Seminar, 24 May, presented his PhD results “Rhodoliths as environmental archives in the tropics”.

Prof Patrick De Deckker presented two talks at the European Geophysical Union conference held in Vienna, Austria and also gave a talk on ostracod geochemistry at the French Association of Ostracod Research in Geneva, Switzerland.

Dr. S.M. EGGINS, Field Workshop on Living Foraminifer, Okinawa and Yokosuka, Japan, 15-22 July.

Dr. S.M. EGGINS conducted fieldwork with Honours and PhD students in Eden and the south coast region of NSW, 15 November – 21 December.

Dr M.J. ELLWOOD organised the Symposium titled “From pico to peta: the role of trace elements in global marine cycles” at the Australian Marine

Sciences Association and New Zealand Marine Sciences Society Joint Conference (AMSA-NZMSS 2012) entitled “Marine Extremes – And everything in between”, Hobart, 1-5 July.

Dr M.J. ELLWOOD, Australian Marine Sciences Association and New Zealand Marine Sciences Society Joint Conference (AMSA-NZMSS 2012), Hobart 1-5 July, presented a paper entitled “Dissolved and particulate metal cycling during the annual subtropical spring bloom, east of New Zealand“.

Dr M.J. ELLWOOD, 2012 Ocean Sciences Meeting, 20-24 February, Salt Lake City, USA, presented a paper entitled “Dissolved and particulate metal cycling during the annual subtropical spring bloom, east of New Zealand“, and invited speaker at the “International Symposium on Paleoceanography in the Southern Ocean and NW Pacific: Perspective from Earth Drilling Sciences”, Kochi, Japan, 19-21 November 2012.

Dr M.J. ELLWOOD and Dr R. STRZEPEK, fieldwork on the research vessel RV Tangaora from September to October.

Dr M.K. GAGAN, 12th International Coral Reef Symposium, Cairns, 9-13 July, presented a paper entitled “Earthquake supercycle terminations in Sumatra over the last 5,500 years”, and the American Geophysical Union Fall Meeting, San Francisco, USA, 3-7 December, presented an invited paper entitled “Orbital- and millennial-scale changes in the Australasian monsoon through the Late Pleistocene”.

Prof R. Grün, 13th International Conference on Luminescence and Electron Spin Resonance Dating, 10-14 July, Torun, Poland, presentation entitled “Ionization efficiencies alanine dosimeters and tooth enamel exposed to gamma and X-ray irradiators”. He was also the Chair of the Scientific Committee for this conference and is the Editor of the proceedings to be published in Quaternary Geochronology.

Prof R. Grün, INQUA Congress, Bern, 21-27 July, where he was co-author on a number of presentations.

Prof R. Grün, Australian Archaeological Association Conference 2012, Wollongong, Australia, 9–13 December.

Prof R. Grün, fieldwork in Bordeaux and other regions of France, 1-18 May, with PhD candidate Mr M. WIllmes.

Prof R. Grün and Dr S.M. EGGINS, fieldwork in Lanzhao province, China, 9-20 September.

Prof R. Grün, invited to attend the Manali Workshop, Manali, India, 17-24 October.

Dr David Heslop, General Assembly of the European Geosciences Union, Vienna, Austria, 22–27 April, presented an invited paper entitled “Unmixing Magnetic Hysteresis Loops”.

Dr David Heslop visited the National Oceanography Centre, Southampton to perform palaeomagnetic measurements, 30 April – 4 May.

Ms Claire KRAUSE, AMOS 2012 Conference held at the UNSW 31 January – 3 February, presented a paper, “The Indo-Australian Monsoon of the Last 25 ka: A Continuous Stalagmite Record from Sulawesi, Indonesia.”

Dr D.C. “Bear” McPHAIL led ANU Honours students to present at the AusIMM Student Challenge in Moss Vale, NSW, 27 September.

Mr S. MEYERINK, AMSA 2012, 2–6 July, Hobart, and presented the poster “Switching on the lights in diatom cell walls: using PDMPO to investigate silicon uptake in diatoms”. He also attended R and D Topics 2012, 11–15 December and presented the talk “Switching on the lights in diatom cell walls: using PDMPO to investigate silicon uptake in diatoms”.

Dr B.N. Opdyke, International Geological Congress in Brisbane and Convened ‘Reefs and Carbonates – secular changes including climate’ and presented ‘Dynamic Dolomite as the Driver for Mg/Ca change in the Cenozoic Ocean’.

Mr R.J. OWENS, 34th International Geological Congress, Brisbane, 5-10 August, and presented a paper entitled “Comparing δ13C of *G. ruber* and *G. sacculifer* sheds light on the carbonate ion concentration of the surface ocean”.

Prof B.J. Pillans attended the 15th Biennial conference of the Australian & New Zealand Geomorphology Group (ANZGG) in Bundanoon, New South Wales, from 2nd December to 7th December 2012 and presented a paper: How old is Lake George?

Prof B.J. PILLANS conducted fieldwork in Indonesia in May 2012 with Prof M. Morwood and Dr G.D. van den Berg (University of Wollongong) and Dr B. Alloway (Victoria University of Wellington) on the Quaternary stratigraphy of Soa Basin, Flores.

Prof B.J. PILLANS conducted fieldwork in Indonesia in October 2012 with Prof M. Morwood, Prof R.G. Roberts and Dr G.D. van den Berg (University of Wollongong) on the Quaternary stratigraphy of Walanae Basin, Sulawesi.

Prof B.J. PILLANS attended the 35th International Geological Congress in Brisbane, from 5th to 10th August 2012 and presented an oral paper: “Burial and exhumation - the key to survival of pre-Cenozoic regolith and landforms in Australia and Africa?”

Ms Moneesha SAMANTA, AMSA 2012 meeting, Hobart, 2–6 July, presented the poster “Zinc isotope determination of marine samples’’.

Mr N. SCROXTON, Australian Meteorological and Oceanographical Society (AMOS) 18th National Conference, Sydney, 31 January – 3 February, presented talk entitled “Millennial-Scale Oscillations of the Inter-Tropical Convergence Zone over the last 50kyr as seen from the Flores speleothem paleo-monsoon record”.

Mr N. SCROXTON, 22nd V.M. Goldschmidt Conference, Montreal, Canada, 25–30 June, presented talk entitled “Vegetation collapse on Flores 69,000 years ago: A consequence of the Toba super-eruption, or a volcanic disaster closer to home?”

Ms S. TYNAN, 34th International Geological Congress, Brisbane, 5-10 August, and presented a paper entitled “Environmental information recorded in the trace element geochemistry of shell of the Sydney Rock Oyster (*Saccostrea glomerata*).”

Mr M. Willmes, European Geosciences Union General Assembly 2012, Vienna, Austria, 22 – 27 April, and presented a paper entitled “Isotopic reconstruction of ancient human migrations: A comprehensive Sr isotope reference database for France and the first case study at Tumulus de Sables, south-western France”.

Mr M. Willmes, 34th International Geological Congress, Brisbane, Australia, 5 – 10 August, presented a paper entitled “The bioavailable Sr isotope reference database of France – a tool for archaeology and forensic sciences”.

Mr M. Willmes, Australian Archaeological Association Conference 2012, Wollongong, Australia, 9 – 13 December, presented a paper entitled “Isotopic Reconstruction of Ancient Human Migration (IRHUM): A Bioavailable Sr Isotope Reference Database for France and Case Study at the Bell Beaker Site Tumulus de Sables, South-Western France”.

Mr M. Willmes conducted fieldwork for his PhD studies in Bordeaux and other regions of France, 1 May – 8 June.

Mr M. Willmes, RSES PhD students’ fieldwork in New Zealand, 31 October – 11 November.

Dr Jimin YU, invited keynote speaker at Goldschmidt, 24-29 June 2012, Montreal, Canada, with talk entitled “Responses of deep-sea carbonate system to carbon reorganization and sea level changes”.

Earth Materials & Processes

PROFESSOR RICHARD ARCULUS presented papers at “Caribbean Volcanism and Crustal Structure”, Bristol, UK, 9th to 10th July 2012 (keynote address.)

Gordon Research Conference “Geochemistry of Ore Deposits”, Andover, New Hampshire, USA, 15th to 20th July 2012, (session chairman).

34th International Geological Congress, 5th to 10th August, Brisbane, (keynote address).

PROFESSOR STEPHEN COX completed a period of nearly 6 months of outside studies at RWTH – University of Aachen at the end of January.

presented an invited keynote lecture at the AIG Conference “Structural Geology and Resources”, held in Kalgoorlie, 25 – 28 September.

presented a lecture at the 34th International Geological Congress in Brisbane in August.

MR BRENDAN HANGER attend the, 22nd Goldschmidt Conference, Montreal, Canada, June 24-29, presented a paper entitled “Redox Conditions and Metasomatic Activity beneath the Wesselton kimberlite, South Africa.”

PROFESSOR JOERG HERMANN presented a paper at “2nd Geofluids conference, Misasa” Japan, 18-21 March.

The Annual “European Geoscience Union General Assembly”, Vienna, Austria, 22-27 April, presented a poster.

The “34th International Geological Congress”, Brisbane, 5-10 August, (keynote address)

Presented invited seminars at the Kyoto University, Japan; Universities of Torino (Italy) and Wuhan, Hefei and Xi-An (China).

PROFESSOR IAN JACKSON participate and presented papers at each of the following meetings: the annual “Australasian Condensed Matter and Materials Meeting”, Wagga Wagga, NSW (February); the conference of the “Australian

Society of Exploration Geophysicists” Brisbane (February); the annual meeting of the “European Geophysical Union: (April); and the Fall Annual Meeting of the “American Geophysical Union” (December). He also visited and lectured at the

Ludwig Maxmillians University (Munich), ETH (Zürich), the Ecole Normale Supérieure (Paris), University of Lille and the Technical University of Delft.

DR OLIVER NEBEL attended the International Geological Congress in Brisbane, and gave a keynote lecture and a scientific presentation.

DR JOSE ALBERTO PADRON-NAVARTA, attended the 34th International Geological Congress, Brisbane, 5-10 August, presented an invited talk “Bimodal fluid flow pattern during the high-pressure dehydration of serpentinite”. He also attended the annual European Geoscience Union General Assembly, Vienna, Austria, 22-27 April, presented a poster “The fate of metaclinopyroxenite during serpentinite subduction” and was co-author on 4 other contributions.

PROFESSOR HUGH O’NEILL undertook Outside Studies Program from June until August at the University of Munster, Germany. Whilst in Europe he presented a paper on “The global pattern of trace-element distributions in Ocean Floor Basalts” at University of Bristol, University of Munster, University of Hanover, Koln University, Bayerisches Geoinstitut, Bayreuth, University of Gottingen. He also presented a paper on "Diffusion of Yttrium in olivine" at the EMC Conference in Frankfurt in September.

DR GREG YAXLEY presented talks at the European Geoscience Union in Vienna in April and at the European Mineralogical Conference in Frankfurt in September. He also undertook the Outside Studies Program at the Department of Earth Sciences, Oxford University in July and at the Institute for Geoscience, Frankfurt University from August until October. During his OSP he presented seminars at the Universities of Frankfurt and Münster (Germany) and CNRS in Nancy, France.

Earth Physics

Dr N BALFOUR attended the IGC Conference, Brisbane – August 2012, and presented two papers (oral and poster)

Dr N BALFOUR attended the HAGI/PIT Meeting, Palembang, Indonesia – September 2012, gave two oral presenations

Dr N BALFOUR attended the AGU Fall Meeting – December 2012, presented two papers (oral and poster)

Dr N BALFOUR attended Science Meets Parliament

Dr N BALFOUR attended The Australian Science Communicators Conference

Mr R. BENAVENTE, AGU Fall Meeting 2012, San Francisco, California, USA, 3 - 7 December, presented a poster entitled "W phase inversion for finite fault slip"".

Mr. C.C. CHAPMAN, the Australian Meteorological and Oceanographic Society Annual Conference, Sydney, January, presented a paper entitled

“Rapid Variability of Oceanic Jets Driven by Eddy-Topography Interaction”; the American Geophysical Union’s Ocean Sciences Conference, Salt Lake City, Utah, February, presented a poster entitled “Topographic Control of Surface Jet Variability”; Attended the Summer School on the Fluid Dynamics of Sustainability and the Environment, Cambridge University, September, presented a paper entitled “Rossby Waves and Rossby Solitons”.

Prof P.R. CUMMINS, 2012 Fall Meeting of the American Geophysical Union, presented a paper on “International Collaboration on Strengthening Earthquake Hazard Assessment in Indonesia”.

Prof P.R. CUMMINS, 2012 Conference on Computational Physics, presented a paper on “New Bayesian Approaches to Geophysical Data Inference”.

Prof P.R. CUMMINS, 34th International Geological Congress, presented a paper on “Towards Robust Earthquake Hazard Assessment in Indonesia”.

Prof P.R. CUMMINS, gave a special presentation on “The Threat to Tongatapu of Tsunamis Generated at the Tonga Trench” at the Pacific Tsunami Warning Center.

Neda DARBEHESHTI, Paul TREGONING and Simon McCLUSKY, European Geosciences Union General Assembly 2012, Vienna, Austrai, 22-27 April, presented a paper entitled “Extracting high spatial resolution local gravity field from GRACE data” The geophysical signals that can be detected and extracted from GRACE observations are currently limited by the spatial resolution dictated by the maximum degree of the spherical harmonic model of the gravity field. This results in estimates of local mass balance of glaciers or hydrological catchments being inaccurate. In this paper, we used Forward Masscon Model where mass rates are uniformly distributed over each area, and then least squares approach was used to estimate discrete mass changes of small regions that sum to the integrated signal as seen by GRACE.

Dr S. DOWNES: the Australian Meteorological and Oceanographic Society Annual Conference, Sydney, January, presented a paper entitled “Tracing Dense Circumpolar Water in the South Pacific using Potential Vorticity and He-3”; the American Geophysical Union’s Ocean Sciences Conference, Salt Lake City, Utah, February, presented a paper entitled “The role of large-scale phenomena in varying the subduction of mode waters in the Pacific", and co-chaired the session "The Southern Ocean and its role in the climate system"; the Tenth Informal ACCESS Model Evaluation Workshop, Melbourne, July presented a paper entitled "Eddy saturation and compensation in CMIP5 models"; the annual workshop of the ARC Centre of Excellence for Climate System Science, Hobart, September, presented a talk entitled “Saturation and compensation: Southern Ocean circulation in CMIP5 models"; the IODP Southwest Pacific Workshop, Sydney, October, presented a paper entitled "Potential temperature changes in the deep South Pacific ocean due to the circulation of geothermal heat”.

Prof R.W. GRIFFITHS, Australian Meteorological and Oceanographic Society Annual Conference, Sydney, January, presented a paper entitled “The effects of turbulent mixing in the meridional overturning circulation”; American Geophysical Union Ocean Sciences Conference, Salt Lake City, Utah, February, presented a paper entitled “Estimating the relative magnitudes of ocean energy input from surface buoyancy and wind forcing”; participated in first annual workshop of the ARC Centre of Excellence for Climate System Science, Hobart, September; American Physical Society – Division of Fluid Mechanics annual meeting, San Diego, USA, November, presented two papers on “Energetics of horizontal convection from DNS” and “Mechanical mixing in horizontal convection”; Australasian Fluid Mechanics Conference, Launceston, December, presented a paper on “Horizontal convection with mechanical stirring”.

Dr B. GAYEN, Australasian Fluid Mechanics Conference, Launceston, December, presented a paper on “Energetics of horizontal convection from DNS”.

Dr A.McC. HOGG, the Australian Meteorological and Oceanographic Society Annual Conference, Sydney, January, presented a paper entitled “A New Conceptual Model for the Antarctic Circumpolar Current (and the Global Ocean Overturning)”; the American Geophysical Union’s Ocean Sciences Conference, Salt Lake City, Utah, February, presented a paper entitled “A New Conceptual Model for the Antarctic Circumpolar Current (and the Global Ocean Overturning)”; the Southern Ocean overturning: stability and impacts on carbon drawdown workshop, Southampton, May, presented an invited talk entitled “What do idealised ocean models tell us about the Southern Ocean Overturning?”; Fujitsu Supercomputer Users Meeting, Salt Lake City, Utah, November, presented an invited talk entitled “High Resolution Ocean-Climate Modelling”.

Dr G. HUGHES, American Geophysical Union Ocean Sciences Conference, Salt Lake City, February, presented a paper entitled “Mixing efficiencies of ocean processes” and 2nd New Zealand Physical Oceanography Workshop, Wellington, June, presented a paper entitled “Stratified mixing processes and the energetics of the global ocean circulation”.

Dr Giampiero IAFFALDANO, American Geophysical Union Fall Meeting 2012, San Francisco, USA, 3-7 December, presented three papers entitled “The strength of large-scale plate boundaries: Constraints from the dynamics of the Philippine Sea plate since ~5 Ma”, “Plate motions: Simpler than they look” and “Slow-downs and speed-ups of India-Eurasia convergence since ~20 Ma: Data-noise, uncertainties and dynamic implications”.

Dr Giampiero IAFFALDANO, 34th IGC conference, Brisbane, AUSTRALIA, 5-10 August, presented a papers entitled “The strength of large-scale plate boundaries: Constraints from the dynamics of the Philippine Sea plate since ~5 Ma”.

Prof B.L.N. KENNETT attended the International Geological Congress in Brisbane in August where he gave a Keynote Lecture on structure beneath Australia introducing the new AuSREM model. In October he gave the Selwyn lecture
on Subduction Zones at the Selwyn Symposium of the Victorian Division of the Geological Society of Australia.

Dr S. MCCLUSKY, 2012 EGU General Assembly Meeting, Vienna, Austria, 22-27 April, 2012, presented a paper entitled, GRACE observations of 2010/2011 eastern Australian floods: Producing precise GRACE gravity fields in the absence of satellite accelerometer observations, S. McClusky, P.Tregoning, and H. McQueen. Dr S. MCCLUSKY, 2012 EGU General Assembly Meeting, Vienna, Austria, 22-27 April, 2012, was coauthor of a paper entitled, Mitigation of Site Specific Errors, M. Moore and S.McClusky.

Dr S. MCCLUSKY, 2012 EGU General Assembly Meeting, Vienna, Austria, 22-27 April, 2012, was coauthor of a paper entitled, Improving Coseismic Offset Estimation Using Statistical Tests, J.-P. Montillet, P. Tregoning, A.Purcell, and S. McClusky

Dr S. MCCLUSKY, 2012 EGU General Assembly Meeting, Vienna, Austria, 22-27 April, 2012, was coauthor of a poster entitled, Extracting white noise statistics in GPS coordinate time series, J.-P. Montillet, P. Tregoning, S McClusky, and K. Yu.

Dr S. MCCLUSKY, 2012 EGU General Assembly Meeting, Vienna, Austria, 22-27 April, 2012, coauthor of a poster entitled, Extracting high spatial resolution local gravity field from GRACE data, N Darbeheshti, P Tregoning, and
S. McClusky.

Dr S. MCCLUSKY, 2012 AGU Fall Meeting, San Francisco, Calif., 3-7 Dec, 2012, was coauthor of a paper entitled, GPS Velocity Field Across the Caucasus, R.W. King M. Floyd, S. McClusky, G Habubia, Gi Sokhadze, F. Kadirov, A.Karakhanyan, V. Milyukov.

Dr S. MCCLUSKY, 2012 AGU Fall Meeting, San Francisco, Calif., 3-7 Dec, 2012, was coauthor of a paper entitled, Modelling of Site Specific Effects and the Impact upon Local Tie Residuals, M. Moore, and S. McClusky

Dr S. MCCLUSKY, 2012 AGU Fall Meeting, San Francisco, Calif., 3-7 Dec, 2012, was coauthor of a poster entitled, Active NE-SW Compressional Strain Within the Arabian Plate, M Floyd, A. ArRajehi, R.W. King, S. McClusky, R. Reilinger, M. Douad, J. Sholan, F. Bou-Rabee.

Ms A.K. MORRISON, the Australian Meteorological and Oceanographic Society Annual Conference, Sydney, January, presented a paper entitled “Interplay between the zonal transport and meridional overturning in the Southern Ocean”; the American Geophysical Union’s Ocean Sciences Conference, Salt Lake City, Utah, February, presented a paper entitled

“Interplay between the zonal transport and meridional overturning in the Southern Ocean”; annual workshop of the ARC Centre of Excellence for Climate System Science, Hobart, September, presented a talk entitled “Interplay between Southern Ocean overturning and ACC transport”; Physical Oceanography Dissertation Symposium, Lihue, Hawaii, October, presented an invited talk entitled “The role of Southern Ocean overturning in past and future climate change”.

Dr N. RAWLINSON attended the EGU General Assembly in Vienna and presented a paper titled “Seismic anisotropy and heterogeneity in the crust beneath southeast Australia from ambient noise tomography”

Dr. J.P. MONTILLET went to EGU 2012 to present two studies in collaboration with Dr. Paul TREGONING, Dr. Simon McCLUSKY and Dr. Anthony PURCELL:

“**Extracting white noise statistics in GPS coordinate time series**”

“**Improving Coseismic Offset Estimation Using Statistical Tests**”

Dr N. RAWLINSON attended the IGC in Brisbane and presented a paper titled “Ambient noise tomography in southeast Australia from the WOMBAT transportable seismic array”

Dr N. RAWLINSON attended the AGU Fall Meeting in San Francisco and presented a paper titled "Illuminating the upper mantle beneath the Newer Volcanics province, southeast Australia, using seismic body wave tomography”

Ms I. ROSSO, the Australian Meteorological and Oceanographic Society Annual Conference, Sydney, January, presented a paper entitled “The Vertical Transport of Tracers in the Ocean: a Pump Driven by Sub-mesoscale Structures”; European Geophysical Union conference, Vienna, Austria, April, presented a paper entitled “The Vertical Transport in the Ocean: a Pump Driven by Meso- and Sub-mesoscale Structures”.

Dr J.A. SAENZ, European Geophysical Union conference, Vienna, Austria, April, presented a paper entitled “The relative magnitudes of energy input to the oceans from surface buoyancy and wind forcing”; participated in first annual workshop of the ARC Centre of Excellence for Climate System Science, Hobart, September; American Geophysical Union Fall Meeting, San Francisco, December, presented a paper “There is a net conversion of available potential energy to kinetic energy in the oceans”.

Dr M. SALMON European Geophysical Union, Vienna, Austria, 23-27th April presented paper entitled “AuSREM – Australian Seismological Reference Earth Model” and contributed to paper entitled “Seismic anisotropy and heterogeneity in the crust beneath southeast Australia from Ambient noise tomography”.

Dr M. SALMON International Geological Congress, Brisbane, 6-10th August presented paper entitled “AuSREM – Australian Seismological Reference Earth Model”

Prof. M. SAMBRIDGE, attended and gave a presentation at the Royal Society of London meeting `Signal processing and inference for the physical sciences’ in March, and also at the 29th IUGG Conference on Mathematical Geophysics, in Edinburgh, in June.

Mr S. SAGAR, Ocean Optics XXI Conference, Glasgow, UK, 7-12 October, presented a paper entitled “A Segmentation Based Bayesian Inversion Algorithm for Shallow Water Bathymetry Retrieval”.

Dr E. SAYGIN attended 34th IGC in Brisbane, August 2012 and presented 1 poster.

Dr E. SAYGIN attended AOGS-AGU meeting in Singapore, August 2012 and presented 2 posters.

Dr E. SAYGIN attended HAGI meeting in Palembang, Indonesia, September 2012 and presented 1 poster and gave a talk.

Dr E. SAYGIN attended AGU Fall Meeting 2012 in San Francisco, USA, December 2012 and presented 1 poster, gave a talk.USA, 5-9 December, presented a paper entitled “The thermal structure of the Kumaun Lesser Himalaya, north west India”.

Ms K. Snow, attended the Australian Meteorological and Oceanographic Society Annual Conference, Sydney, January; attended first annual workshop of the ARC Centre of Excellence for Climate System Science, Hobart, September.

Dr H TKALČIĆ gave an invited talk entitled “Seismological observation of shuffling rotational dynamics of the Earth’s inner core” at the East-west asymmetry of inner core and rotational dynamics conference in Wuhan, China, July, 2012.

Dr H TKALČIĆ coauthored 10 presentations (2 invited) and gave a talk entitled “What really lies beneath: defying conventional geophysical inversion and new observations from the crust to the core” in the special session on tomography at the AGU Fall Meetingin San Francisco, December 2012.

Dr P. TREGONING, GRACE Follow-On workshop, Heron Island, 3-6 September.

Dr P. TREGONING was a co-author on two oral presentations at the European Geophysical Union General Assembly, 22-27 April, titled “Improving Coseismic Offset Estimation Using Statistical Tests”, “GRACE observations of 2010/2011 eastern Australian floods: Producing precise GRACE gravity fields in the absence of satellite accelerometer observations”.

Dr P. TREGONING was a co-author on 4 poster presentations at the European Geophysical Union General Assembly, 22-27 April, titled “Antarctic mass balance changes from GRACE”, “Extracting white noise statistics in GPS coordinate time series”, “The effect of different forms of interpolation on estimates of Antarctic ice height change”, and “Extracting high spatial resolution local gravity field from GRACE data”.

Dr P. TREGONING was a co-author on two oral presentations at the American Geophysical Union Fall Meeting, 3-7 December, titled “Non-linear motions of Australian geodetic stations induced by non-tidal ocean loading and the passage of tropical cyclones” and “CryoSat-2 validation in East Antarctica: ASIRAS, ALS and in situ data analysis over Law Dome and Totten Glacier” and co-author on an invited oral presentation at the American Geophysical Union Fall Meeting, 3-7 December, titled “Distribution of contemporary crustal deformation and mechanisms for extension in the Woodlark Rift: insights from GPS”.

M.K. YOUNG, at the American Geophysical Union Conference, San Francisco, USA, 3-7 December, presented a paper entitled “New P-wave Velocity Images of the Lowermost Mantle from a Bayesian Inversion of PKP, PcP, and P4KP Differential Travel Times”.

Integrated Ocean Drilling Program (IODP)

Professor Exon was one of the two conveners of the *Marine Geoscience and Paleoceanography* Theme at the **International Geological Congress** in Brisbane in August, which covered a number of Symposia. He was one of the Conveners of two Symposia in that Theme – *Integrated Ocean Drilling Program* and *Offshore Minerals in Oceania* – giving a keynote address at the former symposium.

PRISE

Dr R.A. ARMSTRONG undertook field work in the Siep Riep area, Cambodia, 7-15 September as part of his ARC-funded research.

A/Prof C.M. FANNING conducted fieldwork in northern Chile from 27 November – 5 December.

Visiting Fellows

Dr K. A. W. CROOK attended the Sapphire Coast Marine Discovery Centre’s Marine Science Forum ‘Sea Connections’ at Eden on 24-25 March, 2012.

Dr E. A. Felton attended the Sapphire Coast Marine Discovery Centre’s Marine Science Forum ‘Sea Connections’ at Eden on 24-25 March, 2012.

Dr C. Klootwijk, 34th International Geological Congres, Brisbane, 5-10 August, presented a poster entitled “Middle-Late Paleozoic Australia-Asia convergence and Alice Springs Orogeny-related tectonic extrusion”, P3M-234: 2397.

Dr Truswell submitted a paper entitled *Thulia: a tale of the Antarctic: the earliest Antarctic poem and its musical setting.* Submitted to proceedings of the conference ‘Antarctica; Music, Sounds and Cultural Connections’ ANU School of Music, 25th 26th June, ANU e-press Submitted February 2012.

Dr Truswell presented a paper *Dredging up Mawson; implications for the geology of coastal East Antarctica* at the Mawson Conference, University of Tasmania, Nov.30 – Dec. 1 2011. Submitted to conference proceedings and is in press with Papers and Proceedings Royal Society of Tasmania.

EDITORIAL RESPONSIBILITIES

Earth Chemistry

Dr Y. AMELIN, Associate Editor, Geochimica et Cosmochimica Acta.
Dr Y. AMELIN, Member of the editorial board, Chemical Geology.
Dr J.J. BROCKS, Associate Editor, Geochimica et Cosmochimica Acta.
Dr J.J. BROCKS, Associate Editor, PALAIOS, a Journal of the Society of Sedimentary Geology.
Dr J.J. BROCKS, Editor Board, Geobiology.
Dr. M. HONDA, Associate Editor, Geochemical Journal.
Dr C.H. LINEWEAVER, Member of the Editorial Board, Astrobiology, Editor-in-Chief Sherry Cady, Mary Ann Liebert, Inc.
Dr D. RUBATTO, Associate Editor, Lithos.
Dr D. RUBATTO, Editorial Board, Chemical Geology
Dr D. RUBATTO, Editorial Review Board, Journal of Metamorphic Geology.

Earth Environment

Dr N.J. ABRAM is Editor of Climate of the Past.
Prof Patrick De Deckker is on the editorial board of Palaeoclimatology, Palaeoeceology, Palaeogeography, as well as Marine Micropaleontology, and Journal of Paleolimnology.
Dr M.J. ELLWOOD is an Associate Editor for Marine and Freshwater Research.
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.
Dr Marc NORMAN is the Executive Editor for Geochimica et Cosmochimica

Acta.
Prof B.J. PILLANS is on the Editorial Board of Quaternary Science Reviews.Dr Jimin YU was a reviewer of Earth and Planetary Science Letters, Geochimica et Cosmochimica Acta, Geochemistry, Geophysics, Geosystems (G3), Chemical Geology, and Geology.

Earth Materials & Processes

PROFESSOR STEPHEN COX continued as a member of the Editorial Advisory Boards of *Journal of Structural Geology* and *Geofluids*.
PROFESSOR JOERG HERMANN Editor*, Journal of Petrology*; Associate Editor, LITHOS.
PROFESSOR IAN JACKSON Member Editorial Board, *Physics of the Earth and Planetary Interiors, Earth and Planetary Science Letters.*
DR PENNY KING is Associate Editor for *Geochimica et Cosmochimica Acta* and contributing editor for the column *A Life in Science* in *Elements.*
PROFESSOR HUGH O'NEILL is on the Editorial Board*, Chemical Geology.*

Earth Physics

Dr N BALFOUR, Peer reviewed papers for Geophysical Journal International and Bulletin of the Seismological Society of America.
Prof P.R. CUMMINS, served on the Editorial Board of the book: *Shaping a Nation: A Geology of Australia,* Commonwealth of Australia (Geoscience Australia) and ANU E Press.
Dr S. DOWNES, Guest Chief Editor for Deep Sea Research II Special Issue: "Southern Ocean dynamics and biogeochemistry in a changing climate"
Dr. Giampiero IAFFALDANO, Associate Editor, Annals of Geophysics
Prof R.W. GRIFFITHS, Associate Editor, Journal of Fluid Mechanics, Cambridge University Press.
Prof B.L.N. KENNETT, Member of the Advisory Editorial boards for Physics of the Earth and Planetary Interiors and Earth and Planetary Science Letters.
Dr. J.P. MONTILLET reviews some manuscripts for the journal Acta Geodetica et Geophysica Hungarica
Dr. J.P. MONTILLET reviews a manuscript for the journal IET signal processing
Dr. J.P. MONTILLET reviews some manuscripts for the IEEE conferences: ISCIT – gold coast – 2012 and softCom –Croatia -2012.
Dr N. RAWLINSON, member of Editorial Board, Tectonophysics
Dr M. SALMON reviewed papers for Tectonophysics
Prof. M. SAMBRIDGE, Associate Editor of Geophysics, Special issue on uncertainty.
Dr. P. TREGONING, Associate Editor, Journal of Geophysical Research.

PRISE

Dr R.A. ARMSTRONG, Editorial Board, Journal of African Earth Sciences.
Dr B. Fu, journal reviews for Journal of Asian Earth Sciences, Lithos, Ore Geology Reviews, Earth and Planetary Science Letters.

IODP

Professor Neville Exon is involved in writing and editing various IODP documents, including the ANZIC Annual Report and reports relating to the Southwest Pacific IODP Workshop held in Sydney in 2012.
Catherine Beasley has taken the lead in designing the new ANZIC web site together with web designer *Voodoo Creative*. The new site will go live in December 2012.

Visiting Fellows

Dr K. A. W. CROOK is a Foundation Member of the Editorial Board, and an Editor-in-Chief Emeritus of the journal *Sedimentary Geology*, who continues to serve as a reviewer on request.
Dr E. A. FELTON reviewed papers for the journals *Marine Geology* and *Geology*.
Dr Truswell with the editors of *Shaping a Nation: a Geology of Australia*. In addition to contributing sections of the text of Chapter 3, *Living Australia,* Dr Truswell supervised the re-editing and re-presentation of this chapter, which involved contacting most of the contributors, and re-evaluating much of the original text and illustrations through meetings with the GA team.
Dr Truswell contributed a feature article *Encounters with James Dwight Dana* to The Australian Geologist (TAG) September 2012 issue.

OUTREACH AND WORKSHOPS

Earth Chemistry

Dr J.J. BROCKS, scientific adviser and interviews (in the McArthur River Mine and at RSES) for a Japanese national television science program.
Dr J.J. BROCKS hosted a group of the National Youth Science Forum.
Mr A. CHOPRA co-hosted a stargazing event at the Australian Parliament House as part of the Science Meets Parliament event 'Masterclass in Astronomy' under the guidance of Nobel Laureate Professor B. Schmidt on 17 September 2012.
Mr A. CHOPRA was interviewed by Melanie Tait of ABC 666 Canberra Radio about the review paper on planetary habitability he co-authored with Dr C. LINEWEAVWER on 30 April 2012.
Mr A. CHOPRA was interviewed by Alex Sloan of ABC 666 Canberra Radio

about the 2012 Venus Transit Event at the Mount Stromlo Observatory on 5 June 2012.
Mr A. CHOPRA organised a public telescope observing at ANU campus of 2012 Venus Transit Event on 5 June 2012 (~300 visitors)
Mr A. CHOPRA presented a three minute talk at the 2012 Trans-Tasman 3MT Competition hosted at University of Queensland, Brisbane, Australia.
Mr A. CHOPRA presented a three minute talk in the 2012 NASA Astrobiology FameLab Online Competition.
Mr A. CHOPRA assisted with other RSES staff and students at the 2012 ANU Open Day.
Mr A. CHOPRA's comments on a paper suggesting that life originate in geothermal ponds rather than in oceans by Armen Mulkidjanian et al. (PNAS 2012) were featured in an article written by Nicola Rowe for Cosmos Magazine on 21 February 2012.
Mr A. CHOPRA participated in a workshop on cross-disciplinary research at ANU, organised by Research Student Development Centre, ANU on 21 March.
Dr M. FORSTER supervised PhD students from Royal Holloway University of London, SEARG, both in the field (Indonesia and Italy) for structural geology (8 PhD students, in June and September); and at ANU for argon geochronology (3 PhD students) (Oct-Nov).
Ms A. F. KOMUGABE was interviewed on the ANU website about the use of black corals to determine changes in regional circulation in the Tasman Sea.
Ms A. F. KOMUGABE - Article in the *ANU Reporter* (Autumn 2012) published on: "Chronicles of the Deep" written by: Lucy Wedlock on research done by A.F. Komugabe.
Dr C.H. LINEWEAVER gave a lecture (via Skype)February 10, 2012 "Extending the Atavistic Model for the Origin of Cancer" at the Arizona State University Cancer Workshop (Feb 8-10, 2012)organized by Paul Davies and Charley Lineweaver
Dr C.H. LINEWEAVER attended the November 3-6, 2012 Meeting "Cancer and Oxidative Phosphorylation" at Arizona State University and presented the lecture "Atavism, Sex, Multicellulary and Neotony", November 4, 2012 10:30-11 am.
Dr C.H. LINEWEAVER attended the Australian Exoplanet Workshop December 10-12 and presented a lecture "How Common are Planetary Systems like our Solar System?", Mt Stromlo, December 11, 3-3:15 pm.
Dr C.H. LINEWEAVER talked to National Youth Science Foundation elite Year 10 and 11 students selected from the best Australian high school science students about his research, careers in astronomy and answered questions about astronomy/cosmology/astrobiology. January 20th, 3:30 - 4:30 pm, January 25th 2012, 3:30-4:30 pm, Mt Stromlo Observatory.
Dr C.H. LINEWEAVER gave a lecture "Astrobiology" to year 11 and 12 science students at MacRobertson Girls High School, Melbourne, 12:30 - 1:30 pm, May 31, 2012.
Dr C.H. LINEWEAVER gave the Stanhope Oration "Science, It's Critical" at Conference of Australian Science Teachers Association (CONASTA) Shinedome, ANU 6:40 - 7:40 pm, July 9, 2012 (audience ~ 300 science teachers).
Dr C.H. LINEWEAVER gave a lecture "Exoplanets" to the North Sydney

Astronomical Society, September 20, 2012, St. Ignatius College, North Sydney, 8:00-9:00 pm.
Dr C.H. LINEWEAVER gave a guest lecture on "Black Holes and Cosmology" to Geoff McNamara's Advanced Science Students at Melrose High School, 2-3 pm, October 23, 2012.
Dr C.H. LINEWEAVER has been invited to give a guest lecture in Mumbai, India as part of the India Institute of Technology Bombay, Techfest 2013 "Entropy, Aliens and Multiverses" January 5, 2013.
http://www.techfest.org/home/event/lectures
Dr C.H. LINEWEAVER was interviewed live by Samantha Armytage and Andrew O'Keefe Channel 7, Weekend Sunrise, 9:20 to 9:27 am, Feb 5, 2012.
Dr C.H. LINEWEAVER was interviewed by Graham Phillips on May 16, 2012, 3:30 - 4:30 pm about NASA's Kepler Transit Telescope, Mars Curiosity Rover and Extraterrestrials. The segment on the Mars Curiosity Rover was aired on "Catalyst" Thursday, 8 pm, August 16, 2012
http://www.abc.net.au/catalyst/stories/3568611.htm
Dr C.H. LINEWEAVER was interviewed on TV about the transit of Venus, June 6, 2012 7:40 am http://www.abc.net.au/news/2012-06-06/astronomy-expert-on-transit-of-venus/4054810
http://www.youtube.com/watch?v=UuDO_ggPcFc
Dr C.H. LINEWEAVER was interviewed on ABC TV about the transit of Venus, June 6, 2012 9 am
http://www.veengle.com/s/PACIFIC+VENUS/3.html
Dr C.H. LINEWEAVER was interviewed about the transit of Venus, June 6, 2012 9:30 pm
Dr C.H. LINEWEAVER was interviewed by ABC News Breakfast Show about the landing of Curiosity Rover, Aug 6, 2012, 8:30-8:35 am
http://www.abc.net.au/7.30/content/2012/s3561881.htm
Dr C.H. LINEWEAVER was interviewed by ABC TV, August 6, 2012
http://www.abc.net.au/news/2012-08-06/nasa-rover-to-attempt-mars-landing/4179284
Dr C.H. LINEWEAVER was interviewed on ABC TV about the Curiosity Rover Landing, August 6, 2012
http://www.abc.net.au/7.30/content/2012/s3561881.htm
Dr C.H. LINEWEAVER was interviewed live about new discoveries of NASA's Mars Curiosity Rover, Sunday, August 12, 2012, 8:15-8:21 am, Channel 7, Weekend Sunrise.
Dr C.H. LINEWEAVER was interviewed live about the death of Neil Armstrong, 1st man on the Moon, Sunday, August 26, 2012, 7:38-7:43 am, Channel 7, Weekend Sunrise. http://au.tv.yahoo.com/sunrise/video/-/watch/a0bb8ea8_b46c_33ae_a3b7_627dd0ea7d2f/dr-charley-on-the-impact-of-neil-armstrong/
Dr C.H. LINEWEAVER was interviewed on ABC TV about NASA's Voyager I leaving the Solar System, September 11, 2012
http://www.youtube.com/watch?v=5Ig7ILoEz5Y
Dr C.H. LINEWEAVER was interviewed by ABC TV about Felix Baumgartner's jump from outer space, Monday, October 15, 2012
http://www.abc.net.au/7.30/content/2012/s3611189.htm
Dr C.H. LINEWEAVER was interviewed on ABC National TV about the total solar eclipse, 7:10 am-7:20 am, November 14, 2012

http://www.abc.net.au/news/2012-11-14/astronomer-explains-solar-eclipse/4370510
Dr C.H. LINEWEAVER was interviewed about the total eclipse of the Sun, 7:38 am - 8:15 am 14 November, 2012
http://www.abc.net.au/news/2012-11-14/watch-the-eclipse2c-with-commentary-from-anu-astronomer-charle/4370570
Dr C.H. LINEWEAVER was interviewed about the total eclipse of the Sun, 3pm, SBS TV, 14 November, 2012
Dr.C.H. LINEWEAVER was interviewed live about new discoveries of NASA's Mars Curiosity Rover, December 2, 2012, 9:10-9:20, Channel 7, Weekend Sunrise.
Dr C.H. LINEWEAVER was interviewed by Graham Philips about Voyager the supposed fine-tuning of the universe, 3:30-4:30 pm, December 12, 2012 to be aired in 2013 on ABC TV "Catalyst"
Dr C.H. LINEWEAVER was interviewed with Dr Karl, by Larry and Samantha Armytage of Weekend Sunrise, Channel 7, about the astronomical aspects of the Mayan Calendar and the supposed End-of-the-World, Sunday, 9:10-9:20, December 16, 2012
Dr C.H. LINEWEAVER hosted interview of Paul Davies for ANU TV, recorded May 18, 2012. ~ 28 minutes. Uploaded May 31, 2012
http://www.youtube.com/watch?v=6sjrga5LROc
3,539 hits on Dec 17, 2012
http://www.disclose.tv/action/viewvideo/106097/Are_we_alone_in_the_universe_Dr_Charley_Lineweaver_and_Professor_Paul_Davies/
Dr C.H. LINEWEAVER gave a lecture and was part of a discussion on the origin of life, Hosted by Peter Spinks, Science correspondent for "The Age" Melbourne, The Age Auditorium, 6-8:30 pm, May 30, 2012:
http://www.theage.com.au/technology/sci-tech/the-mystery-behind-the-origin-of-life-20120717-226y1.html
Dr C.H. LINEWEAVER was filmed and interviewed about the evolution of life on Earth, the definition of life and human-like intelligence, by Dustin Welbourne, Chief Scientist of the Canberra Reptile Sanctuary, at Mt Stromlo 1:30 - 2pm, Thursday, October 13, 2011, The video was posted on YouTube as "Interview with a Scientist- Dr Charles H. Lineweaver" www.youtube.com/watch?v=4K09GeJeSmM.
http://www.theastronomers.org/view/644/interview-with-a-scientist-dr-charles-h-lineweaver/
Dr C.H. LINEWEAVER was interviewed by Ginger Gorman, ABC 666 Canberra, the meaning of "space-time", 11:40-12 pm, May 27, 2012
Dr C.H. LINEWEAVER was interviewed by Ginger Gorman, ABC 666 Canberra, the big bang as "fire", 9:50-10:50 pm, June 3, 2012
Dr C.H. LINEWEAVER was interviewed on ABC 666 Canberra, about the transit of Venus, June 6, 2012, 7:32 pm.
Dr C.H. LINEWEAVER was interviewed about the Mars Curiosity Rover, August 6, 2012 4:03-4:08 pm ABC local radio, Queensland
Dr C.H. LINEWEAVER was interviewed about the Mars Curiosity Rover, August 6, 2012 4:40-4:48 pm ABC Skynews
Dr C.H. LINEWEAVER was interviewed ABC 666 Canberra, Drive Show "old, new, borrowed blue" theme, 3:15-3:45 pm, August 15, 2012
Dr C.H. LINEWEAVER was interviewed about the expansion of the universe

on Radio National, Driver Program, 7:30 - 8:30 pm, September 27, 2012
Dr C.H. LINEWEAVER was interviewed by ABC local radio, Queensland, 4:40-4:45 pm September 28, 2012
Dr. C.H. LINEWEAVER was interviewed ABC 666 National, October 12, 2012, 10pm-11pm
Dr C.H. LINEWEAVER was interviewed by Sandy Aloisi for ABC National, November 29, 2012, 5:25-5:30pm
Dr C.H. LINEWEAVER was given a strong endorsement at9:31 am December 13, 2012, 612 ABC Brisbane Mornings, by Dr Karl who "encourages listeners to look up Charley Lineweaver, ANU, and his definition of life.
Dr C.H. LINEWEAVER's 2012 review paper on planetary habitability was the subject of an ABC Science feature news article (27 April 2012). The story was featured in the '*Best of abc.net.au*'.
Dr C.H. Lineweaver's research on cancer was reported in an article "The Astrobiology of Cancer" .
www.spacedaily.com/reports/ The_Astrobiology_Of_Cancer_999.html
Dr C.H. Lineweaver was interviewed by The Age science correspondent, Peter Spinks about the Curiosity Rover results, August 12, 2012.
http://www.canberratimes.com.au/technology/sci-tech/hopes-rise-for-life-on-mars-20121205-2aun6.html
Dr C.H. Lineweaver was interviewed by Andrew Croome, Writer in Residence, Mt Stromlo Observatory, September 2012, see "Life on Other Planets" at http://www.love2read.org.au/writersworking.cfm
Dr C.H. Lineweaver was interviewed by Jessica of Cosmos Magazine, 9:15-9:45 am, November 28, 2012.
Dr C.H. Lineweaver was interviewed by Caitlin of Cosmos Magazine, 4-5pm, October 11, 2012.
Dr C.H. Lineweaver was interviewed by Josh, Masters in Science Communication Student, September 27, 2012
Dr C.H. LINEWEAVER gave a lecture to Australian Science Teachers, Jan 12, 11am -12 pm, ANU Forestry Building (Bldg 48), Rm 103 as part of National Youth Science Program.
Mrs K. STRZEPEK was interviewed by ABC radio (Adelaide) when on board the *Aurora Australis* discussing the scientific interest of Antarctic oceanography. Interview lasted ~ 4minutes. She also conducted an interview for ABC television news onboard the same voyage discussing the student opportunities onboard the ship.
Mrs K. STRZEPEK also was filmed for a documentary that is to be shown on National Geographic channel in 2013 where she was sole presenter.
Dr I.S. WILLIAMS hosted a visit to the SHRIMP laboratory by students attending the National Youth Science Forum, 6th January.
Dr I.S. WILLIAMS hosted a visit to the SHRIMP laboratory by students from Radford College, 23rd March.
Dr I.S. WILLIAMS hosted a tour of the SHRIMP laboratory by students visiting RSES in June as part of the ANU Explore Arts and Science days.
Dr I.S. WILLIAMS hosted a visit to the SHRIMP laboratory by high school science teachers as part of the Confertence of the Australian Science Teachers Association (CONASTA) held at the ANU in July.
Dr I.S. WILLIAMS assisted in providing advice to prospective students at the ANU Open Day, 25th August.

Dr I.S. WILLIAMS arranged and hosted a visit to RSES by a delegation of 30 senior managers from the Chinese Academy of Sciences, 13th September.
Dr I.S. WILLIAMS participated in the making of a short film promoting RSES.

Earth Environment

Dr N.J. ABRAM took over the role of RSES Communications and Outreach co-ordinator in November 2012.
Dr N.J. ABRAM gave talks to all year 3 and 4 students at Turner School about being a scientist working in Antarctica, 6 March 2012.
Dr N.J. ABRAM gave talks to high school students visiting RSES from Melrose High School (March 2012), Gungahlin College (18 September 2012) and Rossmoyne Senior High School (6 December 2012).
Dr N.J. ABRAM was interviewed by ABC Online, ABC Radio, CSIRO Helix Magazine, Crikey and Polar Science Foundation about an Antarctic Peninsula ice core palaeoclimate record published in Nature, 22 August 2012. The ANU and BAS Media releases generated worldwide coverage of the research.
Prof Patrick De Deckker gave a lecture to the University of the Third Age [U3A] in Canberra on climate variability, another lecture on “extraordinary micro-organisms viewed in 3-D” at the Museum of Natural Sciences in Brussels, Belgium, and on geochemical and microbiological dust fingerprinting at the University of Ghent, Belgium.
Dr M.K. GAGAN served as a member of the Science Advisory Board for the Earth Observatory of Singapore (Nanyang Technological University), whose mission is to study and forecast natural phenomena threatening Southeast Asia.
Dr. D.C. “Bear” McPHAIL gave seminars on groundwater in the Lower Murrumbidgee to NSW Office of Water staff in July 2012.
Dr D.C. “Bear” McPHAIL led the Honours Student Challenge between ANU and University of Wollongong students, Moss Vale, NSW in September 2012.
Dr B.N. Opdyke has a regular radio spot on Radio Land Care 2XX discussing climate change issues on a monthly basis.
Prof B.J. PILLANS, Chair, Steering Committee of the National Rock Garden Trust.
Ms Jenna ROBERTS led a three-week trip in July to the United Kingdom with six Year 12 students selected from the National Youth Science Forum to attend the Euroscience Open Forum, and mentored a number of leadership and developmental activities, visited numerous Scottish universities and arranged tours through their Earth Science facilities.
Mr N. SCROXTON was an Editor for the student run blog ‘OnCirculation’. He also gave an outreach talk to Year 8 Science students at Melrose High School, ACT.
Miss C. Thompson was a student volunteer at the 2012 Ocean Sciences Conference in Salt Lake City, USA, 20 February 2012.
Miss C Thompson received financial travel assistance from the Association for the Sciences of Limnology and Oceanography, the ANU Vice-Chancellors HDR Travel Grant and the RSES DA Brown travel scholarship during 2012.
Ms S. TYNAN attended a Science Communication Workshop run by the ANU Centre for Public Awareness of Science, and upon completion of which was awarded the ANU Graduate Short Course Award in Science Communication.

Earth Materials & Processes

PROFESSOR RICHARD ARCULUS presented papers at ‘SW Pacific Workshop, IODP, 9th to 11th October, Sydney and ‘Arc Hydrothermal Drilling, IODP, November 14th to 17th, Lisbon, Portugal.
DR ANDREW BERRY was an invited speaker at the "Synchrotron Geosciences in Australia: Industry Workshop" hosted by the Australian Synchrotron.
PROFESSOR STEPHEN COX provided a one-day structural geology workshop to geoscientists of Gold Fields Australia at Kambalda in October. He also presented a one-day course to geologists of Swan Lake Gold and Integra Resources near Kalgoorlie in October; contributed invited lectures and field teaching at the 2nd EGU Summer School held over 6 days in the Italian Alps in August; provided mentoring and teaching materials to support teaching of Earth Sciences during semester 1 at Merici College, Canberra**.**
MR BRENDAN HANGER assisted with visits from the National Youth Science Forum and the Chinese Academy of Science.
PROFESSOR JOERG HERMANN participated in several tours for High School students from Canberra and the region; organized and delivered four two-hour workshops for 30 school teachers from Canberra high schools.
DR PENNY KING was Membership Committee Chair for Mineralogical Society of America; Organizing Committee for Meteoritcal Society Meeting, Cairns.
DR OLIVER NEBEL visited the clean laboratory facilities in Tübingen, Germany for exchange of ideas in methodology for stable isotope hard rock sample analyses.
DR GREG YAXLEY assisted A/Prof Joerg Hermann with the organisation of a TESEP (Teacher Earth Science Education Program) workshop at RSES and co-ordinated a workshop for science teachers attending the CONASTA conference at ANU in July. Co-ordinated and presented talks to Year 11 and 12 students from Australia and New Zealand, participating in the National Youth Science Forum in January.

Earth Physics

Dr N BALFOUR gave a demonstration of seismometers with National Youth Science Forum visitors.
Dr N BALFOUR hosted a student from Canberra College as part of work experience.
Dr N BALFOUR gave seminar to a class of students at Melrose High School students and mentored for students as part of an ACE Science project.
Dr N BALFOUR gave seminar and ran a workshop at the Australian Science Teachers conference (CONASTA).
Dr N BALFOUR gave a talk to students visiting RSES from Orange High School.
Mr. C. C. CHAPMAN participated in the ANU final of the “3 minute thesis” competition as part of the ANU’s Research Fest, 2012.
Prof P. CUMMINS gave an invited presentation on “Earthquakes and Tsunamis” at the 2012 Conference of Australian Science Teachers

Association (ASTA).
Prof P. CUMMINS gave part of a shared presentation on “Volcanoes and Earthquakes in our Neighbourhood” at 2012 forum of University of the Third Age (U3A)/ Council of the Ageing (COTA)
Dr S. DOWNES visited two primary schools in the ACT to present her research on hydrothermal vents and life as a scientist. Dr. S. DOWNES is also partnered with a primary school through the national Scientists and Mathematicians in Schools program, and has taught students the fundamental concepts of light and sound in nature.
Dr A. McC. HOGG gave a seminar entitled “Oceans & Climate” as part of the Elizabeth Blackburn “Hooked on Science” lecture tour for high school students at the Australian Academy of Science.
Dr G.O HUGHES hosted several visiting groups, such as the National Youth Science Forum and a Chinese research delegation, in the GFD laboratory.
Dr. G. IAFFALDANO - Study on interaction between climate and tectonics reported at one of the top 100 science stories of 2012 by Discover Magazine.
Dr S. MCCLUSKY contributed to an article in the Fairfax Age newspaper on November 13th 2012 entitled “Between a Rock and a Hard Plate”.
Dr S. MCCLUSKY taught a 5-day workshop on “GPS Data Analysis Techniques”
at INSTITUT TEKNOLOGI BANDUNG **(**ITB**)** in Indonesia November 2012.
Dr S. MCCLUSKY contributed to an Australia-India Strategic Research Fund (AISRF) 7-day workshop on Geology, Hazards and Resources of the Himalaya in
Manali, India in November 2012.
DR S. MCCLUSKY presented lectures to grades 1/2 and 3/4 at Aranda Primary School in April 2012, entitled, “Introduction to Earth Science”.
Between January 11-17, Dr. N. RAWLINSON undertook a series of interviews on the subject of seismic imaging of the Newer Volcanics provinces in Victoria. This included interviews on ABC 666, ABC 774, ABC news radio and the Canberra Times. The total equivalent value in advertising for the ANU was estimated at $14,887 (Media Monitors).
Dr M. SALMON gave talks and tours to National Youth Science Forum students and high school students visiting RSES 6th and 20th January.
Dr M. SALMON is the new outreach coordinator for Earth Physics
Dr M. SALMON participated in the Canberra Jason Project mentoring year 7 and 8 students with high academic ability February – June.
Dr M. SALMON helped with the launch of the Australian Seismometers in Schools launch at Melrose High School 30th May.
Dr M. SALMON helped present the Australian Seismometers in Schools workshop at the Conference of the Australian Science Teachers Association, Canberra, 9th July
Dr M. SALMON represented the Australian Seismometers in Schools program with demonstrations at the Geoscience Australia open day 19th August.
Dr M. SALMON helped with the Research School of Earth Sciences booth at University open day 25th of August.
Dr M. SALMON presented the AuSREM model to a workshop with Woodside at RSES on the 17th October.
Dr M. SALMON gave a talk and tour of the seismology facilities to 20 Gungahalin students 30th November.

Dr M. SALMON organised the Rossmoyne School visit to RSES and gave a talk and tour of the seismology facilities 6th December.
Dr M. SALMON presented the Australian Seismometers in Schools program and reported on ANU's activity to the Australian Seismologists meeting Tweed Heads 7th December.
In May, Prof. M. SAMBRIDGE attended to launch of the Australian Seismometers in Schools program at Melrose High school, ACT.
In July, Prof. M. SAMBRIDGE, Drs. N. BALFOUR and M. SALMON gave demonstrations on seismology and earthquakes at the 2012 Conference of the Australian Science Teachers Association, in Canberra.
In September Prof. M. SAMBRIDGE spent a day a Lyneham Primary School, ACT, teaching year 3 and 4 students about earthquakes and plate tectonics.
Dr H TKALČIĆ gave invited seminar talks at the Seoul National University, Seoul and Korean Polar Research Institute, Incheon, on the Earth's core and lithospheric structure using receiver functions.
Dr H TKALČIĆ was invited to develop and teach an Advanced Studies Course workshop on joint inversion of receiver functions and surface waves by the Incorporated Research Institutions of Seismology to be held in Kuwait in January, 2013.
Dr P. TREGONING was interviewed on ABC 891 Adelaide about regional sea level change around Australia. Approximately 10 minute interview with Ian Henschke, broadcast at 9:22 am 13 August.
Dr P. TREGONING was interviewed on 2xx Landcare program on 3 April about the Indian Ocean dipole and how it affects the weather in southeast Australia. 1 hour programme broadcast at 9 am.

Integrated Ocean Drilling Program (IODP)

Professor Exon was an author of the 2011 **Indian Ocean IODP Workshop** reports for *Scientific Drilling* and the IODP website.
He was also on the ANZIC-led organising committee and chaired the **Southwest Pacific IODP Workshop** held at Sydney University in October 2012, and partly funded by ANZIC. Eighty scientists from around the world attended, discussions were fruitful, and a number on new proposals for IODP drilling in the Southwest Pacific will be submitted for the April 2013 deadline. There is a good chance of drilling in the region in 2015-16.

Visiting Fellows

Dr K. A. W. Crook is a member of the Board of Management of the Eden Killer Whale Museum, Eden NSW. During 2012 he has provided assistance and professional advice on the acquisition and display of **replicas** of Devonian fish fossils from sites on the NSW Far South Coast, supplied by Dr Gavin Young of Earth& Marine Sciences, RSES.
Dr E. A. FELTON serves on the Board of the Sapphire Coast Marine Discovery Centre, Eden, NSW, a marine education and research organisation that is supported by ANU's Office of Student Equity. She conducts a range of indoor and outdoor community and school education activities in marine geology, and is a volunteer guide in the Discovery Centre.

Dr E. A. FELTON is a member of the Geoheritage and Geodiversity Reference Group, advising Sapphire Coast Tourism on the geological heritage of SE Australia. In this role she has recently provided scientific oversight and editing of contributions to the Sapphire Coast Tourism's Heritage Tourism Strategy project.
Dr E. A. FELTON provided notes about local geology for the web page of the Eden Access Centre.
DR E. A. FELTON provided geological information to journalist Tim the Yowie Man (Fairfax Media Limited).
Dr Truswell designed and had accepted, a course for U3A entitled *Art and Science in the early exploration of Antarctica,* for presentation in 2013.

TEACHING ACTIVITIES

Earth Chemistry

Dr Y. AMELIN gave two lectures in the course PHYS8205 "Nuclear Fuel Cycle".
Dr J.J. BROCKS taught 'Carbon Cycle' as part of 'Palaeoclimatology' EMSC3027.
Mr A. CHOPRA tutored First Year Advanced Physics courses Physics 1101 & Physics 1201 at ANU.
Mr A. CHOPRA completed the Graduate Teaching Program with merit; organised by Research Student Development Centre, ANU
Mr A. CHOPRA presented a guest lecture to ~40 Year 10 Science class students at Melrose High School in Canberra, ACT on planetary habitability on 8 May 2012.
Dr. M. HONDA co-taught the Honours Writing Course: Atmospheric evolution and mantle structure - Implications from noble gases.
Mr A. J. McCOY-WEST tutored in EMSC2015 (*Chemistry of Planet Earth*) and EMSC3024 (*Magmatism and Metamorphism)*.
Dr D. RUBATTO coordinated and co-taught the second semester course EMSC2015 "Chemistry of Planet Earth"
Dr D. RUBATTO supervised the special topic (CHEM3060) of Mr Luke Cousin on Archean kinzingites.
Mrs K. STRZEPEK demonstrated for the first year course, The Blue Planet, during first semester 2012 (EMSC 1006).
Dr I.S. WILLIAMS gave 10 undergraduate lectures on isotope geochemistry in August-October as part of the EMSC2015 course on the geochemistry of the Earth.
Dr I.S. WILLIAMS supervised a summer scholar and two undergraduates studying special research topics in an isotope geochronology project related to Permian palaeoclimate in eastern Australia.
Dr I.S. WILLIAMS was invited by the Research Student Development Centre to lecturer at the inductions of ANU higher degree students in April and September, to be an academic panelist at a Summer Research Scholars Workshop in December.

Earth Environment

Dr N.J. ABRAM gave guest lectures for the undergraduate courses Earth (EMSC1008) and Climate System Science (EMSC2021).
Dr N.J. ABRAM was an invited speaker at the ANU postgraduate course for "Resilience of Women Research Students", CHELT, 27 August 2012.
Prof Patrick De Deckker taught the course Geobiology and Evolution of Life on Earth (EMSC2019).
Dr. S.M. EGGINS taught part of the course Global Cycles II – The modern Ocean (EMSC3023) in Semester 1.
Dr M.J. ELLWOOD coordinated and taught the third year course Global Cycles II – The modern Ocean (EMSC3023) in Semester 1.
Dr M.K. GAGAN coordinated Palaeoclimatology and Climate Change (EMSC3027, 2nd semester) and delivered 15 lectures, 5 practicals, and examined the course.
Dr M.K. Gagan delivered 12 lectures, 6 practicals and examined a 4-week section on palaeoclimatology for the first year course The Earth (EMSC1008) in Semester 2.
Prof R. GRÜN taught a 6 unit course Scientific dating techniques and isotope analysis for archaeology and palaeoanthropology (BIAN3010/6510) at the Department of Archaeology and Anthropology, ANU, in Semester 2.
Dr D.C. "Bear" McPHAIL convened and taught the course Groundwater (EMSC3025) in Semester 2.
Dr D.C. "Bear" McPHAIL coordinated the Minerals Tertiary Education Council Honours course, Regolith Geoscience and Mineral Exploration, held in April 2012.
Mr S. MEYERINK demonstrated for the course Blue Planet (EMSC1006) taught by Dr P. King in Semester 1.
Dr B.N. Opdyke convened and taught the course Sedimentology and Stratigraphy (EMSC2014) in Semester 1. He also taught the module in field mapping as part of the second year course Introduction to Structural and Field Geology (EMSC2012), and taught 1/3 of the course Paleoclimatology (EMSC3027). Dr B. N. Opdyke also convened and taught the course Coral Reef Studies (EMSC3019).
Mr R.J. OWENS was a teaching assistant for Carbonate Reef Field Studies (EMSC 3019).
Prof B. PILLANS taught in the course Geomorphology: landscape evolution under changing climate (ENVS3026).
Mr N. SCROXTON demonstrated classes and fieldwork for EMSC2012: Introduction to Structural and Field Geology.
Ms S. TYNAN tutored for the courses Hydrology and Landforms (ENVS2020/6022) and Water Resources Management (ENVS3005/6555) at the ANU Fenner School of Environment and Society.

Earth Materials & Processes

PROFESSOR RICHARD ARCULUS taught 3 weeks of EMSC3024
PROFESSOR STEPHEN COX taught EMSC2012 Introduction to Structural and Field Geology, and EMSC3002 Structural Geology and Tectonics, as part of the RSES Education program. He also contributed to a field trip for the

ENVS1008 Earth Science course and co-supervised the M Nat Haz research project of Ms K Hayward.
MS HELEN COCKER tutored labs for EMSC3007 Economic Geology.
MR BRENDAN HANGER acted as demonstrator from the course EMSC2017: *Rocks & Minerals.*
PROFESSOR IAN JACKSON supervised Ph D student Y. LI, final-year engineering student A. CLARK, and visiting French undergraduate intern Pierre Douchin.
DR PENNY KING Convened and taught EMSC1006 – The Blue Planet; Convened and taught EMSC61007 – The Blue Planet (graduate class)
DR OLIVER NEBEL taught a course (Volcanic hazards segment) in the Masters of Disasters program (Natural Hazards).
Dr. JOSE ALBERTO PADRON-NAVARTA taught 2 hours of lectures and 6 hours of practicum. of the course “Magmatism and Metamorphism” (EMSC 3024).
DR GREG YAXLEY convened and taught the new 2nd Year Undergraduate unit EMSC2017 (Rocks and Minerals) in Semester 1

Earth Physics

Prof P.R. CUMMINS delivered lectures on tsunamis in the courses EMSC8707: Understanding Geological Hazards, and EMSC8706: Introduction to Natural Hazards in the Asia ¬Pacific Region .
Dr S. DOWNES taught "Fundamentals of Climate System Science" (EMSC2021) to second year students.
Prof R.W. GRIFFITHS contributed lectures to “The Blue Planet” (EMSC1006).
Dr A.McC. HOGG and Prof R.W. Griffiths taught “Introduction to Geophysical Fluid Dynamics” in the Physics of the Earth Honours Program.
Dr Giampiero IAFFALDANO taught the courses Plate Tectonics and Mantle Dynamics (EMSC8016), EARTH (EMSC1008) and Physics of the Earth (PHYS3070).
Drs R.C. KERR, A.McC. Hogg, J.A. Saenz and Prof R.W. Griffiths taught “Physics of Fluid Flow” (PHYS 3034).
Dr S. MCCLUSKY taught a 5-day workshop on “GPS Data Analysis Techniques”
at INSTITUT TEKNOLOGI BANDUNG (ITB) in Indonesia November 2012.
Dr N. RAWLINSON was Physics of the Earth Honours Convener for 2012
Drs M.L. RODERICK and A.McC. Hogg taught “Fundamentals of Climate System Science” (EMSC 2021).
Dr M. SALMON supervised Kathryn Hayward for her Masters of Natural Hazards project.
Dr E. SAYGIN delivered lecture in earthquakes in Master of Natural Hazards & Disasters program.
Dr H TKALČIĆ coordinated and taught an undergraduate course “Physics of the Earth” with Dr Iaffaldano (PHYS 3070).
Dr P. TREGONING was the Masters Convener at RSES.

Visiting Fellows

Emeritus Professor Richard A. Eggleton. One U3A lecture on climate change.
Dr C Klootwijk assisted paleomagnetic students and staff with operating the ScT cryogenic magnetometer system.

HONOURS AND MASTERS SUPERVISION

Earth Chemistry

Dr M. HONDA supervised the honours project of Ms H. Yeow on the (U-Th)/He dating of diamonds.
Dr C.H. LINEWEAVER supervised physics PhB undergraduate Tim Crundell on a PhB research project: Solar Nebula Chronology, Second Semester, 2012
Dr C.H. LINEWEAVER finished supervising (February 2012) Honours student Tim Bovaird, Thesis Title: "Exoplanet Statistics"
Dr C.H. LINEWEAVER supervised Honours student Lucie James, Thesis Title: "The chemical composition of the rocky planets around Alpha Centauri".
Dr D. RUBATTO supervised the honours project of Mr L. Hogan on the continental margin of the Sesia Zone (Western Alps).
Dr I.S. WILLIAMS helped supervise Ms K. Long in oxygen isotope micro-analysis as part of her honours project on otoliths from Lake Mungo.

Earth Environment

Dr N.J. ABRAM supervised the Honours project of Ms B. Dixon on the Indian Ocean Dipole activity during the Little Ice Age.
Dr N.J. ABRAM supervised the Summer Scholar project of Ms B. Ellis on the Indian Ocean Dipole activity during the Medieval Warm Period.
Prof Patrick De Deckker supervised Honours student Ms Rebecca Kaye on the microfauna of short cores offshore southern Australia spanning the last 300 years of oceanic changes.
Prof R. GRÜN supervised the Honours project of Ms K. Long on Fish otolith geochemistry, environmental conditions and human occupation at Lake Mungo, and also the Masters project of Ms A. Benson on laser ablation depth profiling of U-series and Sr isotopes in human fossils.
Dr D.C. “Bear” McPHAIL supervised the Honours projects of Mr C. Harris-Pascal on the use of uranium isotopes in groundwater of the Lower Murrumbidgee catchment, NSW, and of Mr G. Schöning on aquifer-aquifer-aquitard interaction in the Menindee Lakes area of NSW.
Dr B. N. Opdyke supervised the Honours project of Ms Anna Haiblen.

Earth Materials & Processes

PROFESSOR RICHARD ARCULUS supervised Clare Connolly “Petrology & Geochemistry of the Tabar-Lihir-Tanga-Feni Island Chain, Papua New Guinea (1st Class)
PROFESSOR STEPHEN COX co-supervised (with Dr R Blewett, Geoscience Australia) the honours project of Mr D Erasmus.

Earth Physics

Prof P.R. CUMMINS supervised the honours project of Ms S. Lawrie on the application of InSAR techniques to the study of active faults in Indonesia.
Prof R.W. GRIFFITHS and Dr G.O. Hughes supervised the Honours thesis project of Ms C. VREUGDENHIL (Physics Honours Program) on transient adjustment flows in horizontal convection.
DR G.O. HUGHES and Prof R.W. Griffiths supervised the Honours thesis project of Ms P. Deacon (Physics of the Earth Honours Program) on the energy efficiency of nonlinear mixing in plumes.
Dr Giampiero IAFFALDANO supervised the master thesis of Mr Ingo STOTZ, the summer project of Mr Cong WANG, the ASC of Ms Sharmila SANE and the ASE of Mr Joshua PETRASS.
Dr S. MCCLUSKY marked the AUN honours thesis of Sarah Lawrie.
Dr E. SAYGIN co-supervised along with Dr D. Zolenta-Nantes masters student Rani Barus on a project on building community resiliency from indigenous practice and disaster risk reduction.

Visiting Fellows

Dr C. Klootwijk assisted Anna Haiblen with initial paleomagnetic measurements.
Dr Truswell assisted with required revision of this thesis. Ph.D. thesis Natalie Sinclair (submitted April 2011).
Dr Truswell served as an informal advisor to Luna Brentigani.

OTHER MATTERS

Earth Chemistry

Dr. V.C. BENNETT was elected as the Secretary of the Volcanology, Geochemistry and Petrology (VGP) section of the American Geophysical Union.
Dr V.C. BENNETT is on the Program Committee and is the Early Earth Theme Coordinator, for the 2013 Goldschmidt Conference, Florence, Italy.
Dr V.C. BENNETT was on the Program Committee, and was an organizer of the Early Earth theme for the 2012 International Geological Congress Brisbane, Australia
Dr V.C. BENNETT continues as a member of the ANU Major Equipment

Committee.
Dr J.J. BROCKS, Member of the ANU College of Physical and Mathematical Sciences Advisory Board.
Dr J.J. BROCKS, Founding Member and Custodian of NECTAR, a group supporting early career academics at ANU.
Dr J.J. BROCKS, member of the Academic Steering Committee of the mass spectrometer facility at the Research School of Biology, ANU.
Mr A. CHOPRA, project assistant for 2012 volume of the ANU Undergraduate Research Journal.
Mr A. CHOPRA was invited as a student panelist at the 2012 ResearchFest at ANU to provide advice to mid-phase PhD students on 20 June 2012
Mr A. CHOPRA, member of the organizing committee for the 2012 Australian Space Science Conference hosted at RMIT, Melbourne, Australia.
Mr A. CHOPRA, member of the local organising committee of the 2012 Australian Exoplanet Workshop at ANU.
Mr A. CHOPRA, volunteer for the 2012 ResearchFest at ANU.
Mr A. CHOPRA, co-organiser of monthly Geological Society of Australia (ACT Division) meetings.
Mr A. CHOPRA, organizer for the Planetary Science Institute Seminars at ANU.
Mr A. CHOPRA, co-administrator for the voluntary student outreach program at the Research School of Astronomy and Astrophysics, ANU which offers outreach nights to ~800 high school students every year from around Australia (since 2009).
Dr M. FORSTER manages the ANU node for the joint ANU/John de Laeter argon facility.
Dr M. FORSTER was on the organizing committee for the Australian Indian Scientific Research Fund (AISRF) Workshop held in Manali, NW India from 17-31 October.
Dr M. FORSTER is on the organizing committee for the 2014 Structural Geology and Tectonics Special Group Conference (SGTSG) to be held at Thredbo village, N.S.W., Organizing Committee for 2006 Goldschmidt Conference to held in Melbourne, Victoria.
Mr T. HABER, Member, Organizing Committee for 2012 RSES Student Conference held at RSES on the 20 September.
Dr C.H. LINEWEAVER was elected member of the International Astronomical Union Commission 51 on Bioastronomy.
Dr C.H. LINEWEAVER helped Paul Davies organize the Beyond Center Cancer meeting February 9-11, 2012 at Arizona State University, Arizona, USA
Dr C.H. LINEWEAVER helped organize Paul Davies' visit to ANU, May 17-19, 2012, and introduced Prof. Davies at his "Eerie Silence" lecture at the Crawford School Auditorium, ANU, 11-12 am, May 18, 2012 http://www.youtube.com/watch?v=z5vPLSj3cNs
Dr C.H. LINEWEAVER was on the organizing committee of the Planetary Science theme at the 34th International Geological Congress, Brisbane, August 5-12, 2012
Dr C.H. LINEWEAVER was a member of the Local Organizing Committee of the Meteorological Society Meeting, Cairns, August 12-17, 2012
Dr C.H. LINEWEAVER was on the local organising committee of the 2012

Australian Space Science Conference 24-26 September 2012.
Dr C.H. LINEWEAVER was on the local organising committee of the 2012 Australian Exoplanet Workshop at Mt Stromlo Observatory 10 -13 December 2012.
Dr C.H. LINEWEAVER is a member of the NASA National Astrobiology Institute Focus Group on “Thermodynamics, Disequilibrium and Evolution” convened by Javier Martin-Torres (Caltech), Michael Russell (JPL) and Eugenio Simoncini (Max Planck Institute, Jena)
Dr D. RUBATTO, treasurer and newsletter editor for the Specialist Group in Geochemistry, Petrology and Mineralogy, Geological Society of Australia.
Mrs K. STRZEPEK was the founder, chief administrator and regular contributor to the student run blog ‘OnCirculation’.
Dr I.S. WILLIAMS was an invited member of expert panels reviewing the Centre de Recherches Pétrographiques et Géochimiques, Nancy-Université, France and the UMR GeoRessources Laboratory on behalf of Agence d’Évaluation de la Recherche et de l’Enseignement Supérieur, France, 20-26 January.
Dr I.S. WILLIAMS was an invited member of an expert panel reviewing the Guangzhou Institute of Geochemistry of behalf of the Chinese Academy of Science, 12-16 October.
Dr I.S. WILLIAMS helped design and co-ordinate the construction of a memorial in memory of Profs A.J.R. White and B.W. Chappell, and was MC at the opening ceremony. In association with the opening, he hosted a visit to RSES by Prof S. Ishihara, AIST, Japan.
Dr I.S. WILLIAMS was invited to deliver a eulogy at the funeral of Prof. B.W. Chappell, 27th April

Earth Environment

Dr N.J. ABRAM, Session Convener, PAGES Open Science Meeting, Goa, 2013.
Dr N.J. ABRAM, working group member, PAGE Oceans2k synthesis project.
Dr N.J. ABRAM, working group member, PAGES Sea Ice Proxies working group.
Prof Patrick De Deckker is the President of the Scientific Steering Committee of the Grand Observatoire du Pacifique Sud [GOPS]. He attended their annual meeting in Nouméa and represented the GOPS at the Pace-Net meeting in Brussels. He is also a member of the Lakes Advisory Committee for the Corangamite Shire Council in western Victoria.
Dr M.J. ELLWOOD was involved with the first year enrolment desk for Science.
Dr M.K. GAGAN served on the Science Advisory Board for the Earth Observatory of Singapore, Nanyang Technological University. He served on the ANZIC Science Steering Committee for the Australian Integrated Ocean Drilling Program (IODP) and 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 D.C. “Bear” McPHAIL served on the Steering Committee of the Minerals Tertiary Education Council (Minerals Council of Australia).

Dr D.C. “Bear” McPHAIL served on the Lachlan Branch Committee of the Australian Institute of Mining and Metallurgy.
Dr B.N. Opdyke, Chair, Geological Society of Australia Specialist Group in Sedimentary Geology.
Prof B.J. PILLANS, President, Geological Society of Australia (until August 2012). He was also Co-Chair, Working Group on Lower/Middle Pleistocene Boundary, International Commission on Stratigraphy, and Vice-Chair, Subcommission on Quaternary Stratigraphy, International Commission on Stratigraphy.

Earth Materials & Processes

PROFESSOR RICHARD ARCULUS is a Member and Acting Chair of Steering Committee of Marine National Facility; Ex-officio Member of Scientific Advisory Committee of Marine National Facility; Member and Deputy Chair of Proposal Evaluation Panel of Integrated Ocean Drilling Program
DR ANDREW BERRY is a Member of Medium Energy XAS Beamline Scoping Group, Australian Synchrotron; Member of X-ray Fluorescence Microscopy (XFM) Program Advisory Committee.
PROFESSOR STEPHEN COX During his period of outside studies Professor Cox gave invited lectures in January at the Institute of Geophysics, Academy of Sciences of the Czech Republic, Prague, and at Université Joseph Fourier, Grenoble, France; presented two lectures at the Centre of Excellence in Ore Deposits (CODES) at the University of Tasmania in November. He also serves on the CODES Board.
MR BRENDAN HANGER served as chair of the RSES Student Forum until September 2012.
PROFESSOR JOERG HERMANN organized the theme 22 “Metamorphic rocks and processes” of the 34th International Geological Congress which was held in Brisbane.
PROFESSOR IAN JACKSON served as Executive Committee member and 1st Vice-President, International Association for Seismology and Physics of the Earth’s Interior.

Earth Physics

Dr N BALFOUR gave a seminar at the Pacific Geoscience Centre
Dr N B BALFOUR gave a seminar at the Agency for Meteorology, Climatology and Geophysics, Indonesia (BMKG)
Dr N BALFOUR gave a seminar at Geoscience Australia
Dr N BALFOUR was interview by ABC 666 (aired 5/4/2012) as part of a story about Seismometers in Schools and the ACE Science program at Melrose High School.
Dr N BALFOUR was interview for Canberra Times Story (online and print) – Seismometers in schools mentioned with regard to recording the earthquake near Canberra (20/4/2012 and 21/4/2012)
Dr N BALFOUR was interview for ABC 666 radio May 31st regarding the Australian Seismometers in Schools program
Dr N BALFOUR was interview for Canberra Weekly – 7th June 2012,

regarding the Australian Seismometers in Schools program
Dr N BALFOUR featured in an article for the ANU reporter (August 2012)
Dr N BALFOUR wrote an article for GeoEdLink Newsletter, September 2012, on Australian Seismometers in Schools.
Prof P.R. CUMMINS served as secretary of the Tsunami Commission of the International Union of Geodesy and Geophysics.
Prof P.R. CUMMINS served as Coordinator of the Geological Hazards Theme of the 34th International Geological Congress.
Prof R.W. GRIFFITHS served as a member of the Sectional Committee 4 for Earth, Ocean and Atmospheric Sciences, Australian Academy of Science.
Prof R.W. GRIFFITHS continued to serve as Treasure and Executive Committee member of the Australasian Fluid Mechanics Society.
Dr Giampiero IAFFALDANO served as member of the Early and Mid-Career Researcher Forum (EMCRF) of the Australian Academy of Science.
Dr Giampiero IAFFALDANO was on the Organizing Committee for 2012 Science Pathways conference at the Australian Academy of Science.
Prof B.L.N. KENNETT gave a number of radio interviews on issues related to earthquakes and tsunamis.
Prof B.L.N. KENNETT, Chair National Committee for Earth Sciences and Chair of Working Party on National Geotransects; also Chief National Delegate to the International Union of Geological Science at the IGC Meeting in Brisbane in August.
Dr S. MCCLUSKY served as a member of IAG sub commission 3.2a Global Crustal Deformation, and 3.2b Regional Crustal Deformation.
Dr N RAWLINSON is chair of SGSEG (Specialist Group on Solid Earth Geophysics), Geological Society of Australia
Dr N. RAWLINSON is chair of the RSES OBS steering committee
Dr. N RAWLINSON is chair of the RSES short period recorder steering committee
Dr M. SALMON is a member of the RSES Occupational Health and Safety Committee.
Dr M. SALMON co-authored a talk about AuSREM given at Geoscience Australia on 11th July.
Dr M. SALMON co-authored a talk given at RSES on the Australian Seismological Reference Model.
Dr M. SALMON is a member of the Seismic Instrument Steering Committee providing guidance for the design of new seismic recorders.
Dr M. SALMON created and is maintaining the AuSREM website.
http://rses.anu.edu.au/seismology/AuSREM/
Prof. M. SAMBRIDGE was program leader for the AuScope-Australian Geophysical Observing System (AGOS) components, The inversion laboratory, and Australian Seismometers in Schools Education program.
Prof. M. SAMBRIDGE served as IASPEI representative to the Committee on Mathematical Geophysics.
Dr H TKALČIĆ is an academic manager of the Seismic and Infrasonic facility in Warramunga, Northern Territory.
Dr H TKALČIĆ is a coordinator for the PhB program in the Earth and Marine Sciences.
Dr H TKALČIĆ supervised the PhB and summer project of Don McKinnon on “Studying earthquake source characteristics using Doppler effect”.

Dr H TKALČIĆ supervised an internship project of Debjani Bhowmick from Indian School of Mines on “Noise tomography of Iceland”.
Dr H TKALČIĆ supervised the internship project of Dulcie Head on “Surface wave tomography of Australia using Australian earthquakes”.
Dr H TKALČIĆ supervised an internship project of Archana Jagadisan from IIT Roorkee on “Using teleseismic receiver functions to infer lithospheric structure of Tasmania”.
Dr H TKALČIĆ supervised an internship project of Yunfan Zhang from Princeton University on “Transdimensional seismic moment tensor inversion”.
Dr P. TREGONING, National Delegate, International Association for Geodesy.

IODP

Professors Arculus and Exon will take the lead in building a new ANU-led bid from the ANZIC group for an **ARC/LIEF grant** to cover Australia’s membership of IODP in the five years from October 2013. As part of the documentation in support of this bid, the ANZIC Governing Council has approved a contract for the *Allen Consulting Group* to write a review of the Australian involvement in IODP including making a case for future funding. Professor Exon and Catherine Beasley will play important roles in this activity.
Professor Exon reviewed several research papers during the year.
He is one of the two geoscience representatives on the Technical Advisory Group set up by CSIRO to provide advice on the scientific equipment for the new Australian Research Vessel *The Investigator*, which is being built in Singapore and will be carrying out research in our waters in 2013.
He is also on the Board of the Australian Association for Maritime Affairs, and on its organising committee for a one-day workshop – *Oceans, Industry and Rio+20* - held in Canberra at University House in April. This brought together Department of Science managers, industry representatives and marine scientists to discuss the positions to be taken at the *Rio+10* conference held later in Rio De Janeiro.
Professor Exon administered a number of ANZIC grants for post-cruise studies in two categories: grants for post-cruise science to ANZIC scientist who had participated in recent IODP expeditions, and competitive grants for Australian scientists for post-cruise analytical work on any ocean drilling material.

Visiting Fellows

Dr C. Klootwijk assisted in constructing the new magnetically shielded room at the Black Mountain Paleomagnetic Laboratory.
Dr D.L. STRUSZ continues as a corresponding member of the International Subcommission on Silurian Stratigraphy, and is a participant in ICGP591 (The Early to Middle Palaeozoic Revolution).