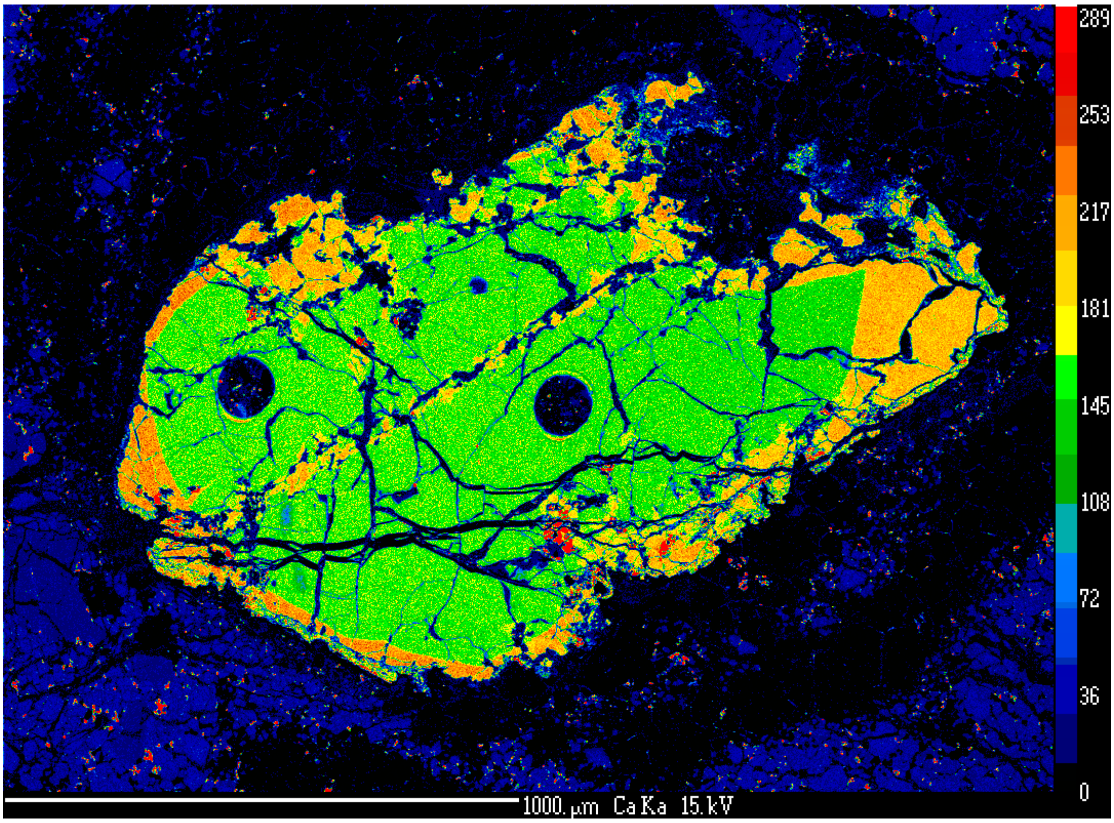
Research School Of Earth Sciences Annual Report 2011



Ca X-ray map of KBD12-Gt4 from the Wesselton kimberlite, produced using the Cameca SX100 Microprobe at RSES

Australian National University

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Director's Review of 2011

The last year has sped by and has seen major developments in the life of the Research School of Earth Sciences (RSES). I have focused my activity on behalf of the School on four major areas of strategic importance: renewal of academic staffing, acquiring the space required for the ongoing activities of the School, achieving financial sustainability, and full integration of teaching activities into RSES. Significant progress has been made on all fronts.

As I noted in my report last year, the biggest strategic challenge for RSES is to maintain and enhance our reputation. This will be challenging because the next 5-10 years are likely to see the retirement of some of the School's most distinguished scientists. Performance benchmarks within RSES are exceptionally high and these standards will only be maintained or enhanced if we can attract scientists of outstanding promise to the RSES. At the beginning of 2011, we undertook a recruitment process to attract high-calibre early-mid career individuals to the School. Four individuals were recruited, including Drs Andrew Berry, Penny King, Simon McCluskey, and Jimin Yu. All have arrived except for Dr Jimin Yu who will commence employment later in 2012.

Construction of a new Earth Sciences building has been a major commitment throughout 2011. Staff, PhD students and Honours students will move in over the summer with the intention of having the building ready for the start of the new teaching semester in February 2012. The main reason for constructing this new building has been to enable co-location of colleagues and students from Building 47. Additional purposes are to provide significant teaching space, to house administrative staff, and to provide a clear front entrance to RSES for the first time in its history. It is also an environmentally sustainable, attractive and modern building that significantly enhances the Jaeger complex, and will benefit the full range of RSES activities. The William Smith map of 1815, purchased by Prof. D.A. Brown, has pride of place in an elevated display case in the foyer (with protection from ultraviolet radiation). Efforts are continuing to secure the space required to relocate the remaining laboratories from Building 47 closer to the Jaeger complex.

Success at the Australian Research Council (with $4M in new funding in 2011) and with a range of other funding agencies has been heartening and is providing funding to support a range of excellent research programs. Global economic conditions and Government policy mean that we are becoming increasingly dependent on new external income sources to support the School's activities. We have recently appointed a Philanthropic Development Manager, Mary Anne King, to help re-engage with alumni and former staff, and to help me to engage with potential philanthropic donors who wish to support the School's activities. RSES will celebrate its 40th anniversary in 2013. We will be working to engage more actively with our alumni in anticipation of this event.

We embarked upon a curriculum review over 2010 and 2011 with the intention of developing an undergraduate Earth science program with a stronger emphasis on quantitative skills and with broader scientific underpinning in addition to the excellent Earth science training that we already provide. More academic staff have become involved in the undergraduate program, which has spread teaching loads across RSES and has exposed our students to a wider range of people and their expertise. The new curriculum will be delivered for the first time in 2012. We look forward to ensuring that this provides the intended positive educational outcomes.

Several individual milestones have conferred great credit to RSES in 2011 and should be mentioned. Prof. Kurt Lambeck was made a Chevalier de l'Odre National de la Légion d'Honneur of the Republic of France. Prof. Brian Kennett was awarded the 2011 Matthew Flinders Medal and Lecture of the Australian Academy of Science "for scientific research of the highest standing in the physical sciences". Prof. Ian Jackson was awarded the 2011 Jaeger Medal of the Australian Academy of Science "for investigations of a high order into the solid Earth or its oceans carried out in Australia or having some connection with Australian Earth science". It was a privilege to be present at the Academy's awards evening and to witness RSES colleagues receive two of the four major awards in the Physical Sciences. Dr Graham Mortimer was awarded a 2011 ANU Vice-Chancellor's Award for Career Achievement. Prof. Trevor Ireland was a member of the Japanese Hayabusa mission in which an unmanned spacecraft landed on an asteroid and returned to Earth with samples. Initial results of this work were published in a series of 4 papers in Science in 2011 (with a photograph on the cover of Science). Dr Geoff Davies was awarded the Mary B. Ansari Best Reference Work Award by the Geoscience Information Society for his book Mantle Convection for Geologists (published by Cambridge University Press). This was the second successive year in which an RSES author has won this international award. Dr Davies was unable to attend the prizegiving ceremony, which was held during the Annual Meeting of the Geological Society of America. I was at the meeting and had the privilege of receiving the award on his behalf. It is gratifying, when attending such meetings, to hear of the esteem with which RSES is held in the international community.

The Jaeger-Hales Lecture is always a major event in the life of RSES. The 2011 Jaeger-Hales Lecture was delivered by Prof. Hugh Taylor of the California Institute of Technology, and was well attended and enjoyed.

I extend my thanks to all RSES colleagues for their efforts during 2011. Much hard work has gone into the many outstanding successes that have been earned and enjoyed this year.

Prof. Andrew P. Roberts
Director, RSES

Honours & Awards

Mr A. CHOPRA was awarded the Best Talk Prize at the 2011 Mt. Stromlo Student Christmas Seminars.
Mr A. CHOPRA was awarded a Vice-Chancellor's 2011 Award for Community Outreach recognising the contributions of the Student Outreach Team at the Research School of Astronomy and Astrophysics at ANU ($4000 for group).
Mr A. CHOPRA was awarded the Best Poster Award for two posters presented at the 2011 European Workshop on Astrobiology.
Mr A. CHOPRA was awarded the 3rd prize at The Space Factor student contest at the 2011 European Workshop on Astrobiology.
Mr A. CHOPRA was awarded a $300 grant from CSRIO and ANU to support education and outreach activities during the 2011 National Science Week Experimenthon at the CSIRO Discovery Centre, Canberra, Australia ($600 grant awarded as a team application with Mr S. HUI and Ms B. FRASL).
Mr A. CHOPRA was awarded a $2500 grant from the Australian Centre for Astrobiology, International Society for the Study of the Origin of Life and Astrobiology Society, and ANU Vice-Chancellor's HDR travel grant to present at the 2011 Origins Conference in Montpellier, France.
Mr A. CHOPRA was awarded a $400 grant from the European Astrobiology Network Association to present at the 2011 European Workshop on Astrobiology in Cologne, Germany.
Mr A. CHOPRA was awarded a $400 grant from the ANU Student ANU Student Recruitment Office to present to present guest lectures at 3 high schools in Perth, Australia.
Mr A. CHOPRA was awarded a $3500 grant from the organising committee to participate in the 2011 Astrobiology Winter School in Hawaii, USA.
Ms B. FRASL received an ANU Pinnacle Student Scholarship for Semester 2.
Mrs K. STRZEPEK was awarded student support to attend the International Symposium on Deep Sea Corals in Amsterdam, 2012.
Dr N.J. ABRAM received a Queen Elizabeth II fellowship from the Australian Research Council.
Ms C. BOEL won the prize for best Honours thesis in 2011 in the School of Archaeology and Anthropology.
Mr N. DARRENOUGUE received an ANU Vice-Chancellor's Travel Grant to attend an international conference, the American Geophysical Union Fall Meeting, San Francisco, USA.
Ms J. MAZERAT was awarded an ANU Vice-Chancellor's Travel Grant to attend the XVIII International Union for Quaternary Research conference, Bern, Switzerland.
Mr I. MOFFAT received an ANU Vice-Chancellor's Travel Grant to attend the XVIII International Union for Quaternary Research conference, Bern, Switzerland.

Mr R. OWENS received an ANU Vice-Chancellor's Travel Grant to attend the Urbino Summer School in Paleoceanography, Urbino, Italy.
Prof. A. P. ROBERTS Guest Professor, Center for Advanced Marine Core Research, Kochi University, Japan Recognition by Nature for "exceptional service as a reviewer".
Miss C. THOMPSON received an ANU Vice-Chancellor's Travel Grant for a cross-institutional visit to the University of Otago in Dunedin, New Zealand.
M r M. WILLMES received an ANU Vice-Chancellor's Travel Grant for fieldwork in the Bordeaux region of France.
Mr C. AUGENSTEIN was awarded a Vice Chancellor HDR travel grant to visit the American Geophysical Union Fall Meeting in San Francisco from December 4-10 2011.
Prof I. JACKSON received the Jaeger Medal of the Australian Academy of Science for career-long contribution to research in Earth Sciences.
Prof. G. LISTER, Dr S. McClusky, M. A. Forster and Prof. Robert Hall have been successful in being awarded an ARC Discovery grant DP120103554 A unified model for the closure dynamics of ancient Tethys constrained by Geodesy, Structural Geology, Argon Geochronology and Tectonic Reconstruction.
Prof. G. LISTER has been successful in being awarded an ARC LIEF grant LE110100047. Events through time: eruptions, extinctions, impacts, orebodies and orogenies. Upgrading the national argon geochronology network. (key personnel LISTER, G., Jourdan, F., Forster, M. and McInnes, B.).
Prof. G. LISTER was awarded an AINSE grant for use of the UWS SIMS facility by PhD candidate Iona Stenhouse.
Dr O. NEBEL was awarded the 'Discovery Early Career Researcher Award' (ARC).
Dr O. NEBEL was awarded the 'Discovery Outstanding Researcher Award' (ARC).
Mr P. STENHOUSE received the 2011 PESA ACT Graduate Award.
Miss D. TANNER received the KSW Campbell for demonstrating undergraduate RSES courses.
Mrs I. ZHUKOVA, PhD Candidate, received AMMRF TAP grant and Vice-chancellor HDR travel grant.
Thomas BODIN received the AGU 2009 Fall meeting Outstanding Student Paper Award. The paper was Seismic Tomography with The Reversible Jump Algorithm. Bodin. T. and Sambridge, M. (2009) AGU Fall Meeting, San Francisco.
Dr A.McC. HOGG presented a Plenary Lecture at the 7th International Symposium for Stratified Flows, Rome in August.
Dr A.McC. HOGG presented an invited Keynote Lecture at the 25th International Union of Geophysics and Geodesy (IUGG) General Assembly, Melbourne in June.
Dr G.O. HUGHES presented an invited Keynote Lecture at the 25th International Union of Geophysics and Geodesy (IUGG) General Assembly, Melbourne in June.

Prof B.L.N. KENNETT received the Flinders Medal, the highest award in the Physical Sciences, from the Australian Academy of Science in May 2011 and deliver the associated Finders Lecture. He also delivered Plenary Lectures at the General Assembly of the International Union of Geodesy and Geophysics at Melbourne in June, and at the "Fragile Earth" meeting in Munich in September organised jointly by the Geological Societies of Germany and America.
Dr H Tkalčić was awarded JSPS Fellowship from Japanese Government for a collaborative work with his Japanese colleagues, and a scientific tour of Japan and lecturing on his research in 2011.

Visiting Fellows

Dr Truswell was awarded Best Presentation for 2010 (jointly) by the Geological Society of Australia, ACT Branch. The paper 'Polar forests on the edge of extinction...' by E.M.Truswell & M.K.Macphail in Australian Systematic Botany (2009) remains among the top downloads for that journal over the past 3 years.

ACADEMIC STAFF

Director and Professor

A.P Roberts, BSc Massey, BSc (Hon) PhD, DS Victoria University (from 1 February 2010)

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
D. Heslop, BSc Durham, PhD Liverpool, Dr habil Bremen
A.M. Hogg, BSc ANU, PhD UWA
G. Hughes, BE ME Auckland, PhD Cambridge
S. McClusky, BSurv PhD NSW
B.N. Opdyke, AB Columbia, MS PhD Michigan
N. Rawlinson, BSc PhD Monash
Dr H Tkalčić, Dip Engineering in Physics, Zagreb, PhD California Berkley
G. Yaxley, BSc PhD Tasmania (ARC Future Fellow)

Research Fellows

A. Abrazhevich, Dip Geology & Geophysics St Petersburg, MPhil Hong Kong, PhD Michigan
L. Ayliffe, BSc (Hons) Flinders, Graduate Diploma Adelaide, PhD ANU
M. Davies, MSc Washington, PhD Oregon State
J. Montillet, BSc MSc Ecole Centrale d' Electronique, MSc. Aalborg, PhD Nottingham
S. Fallon, BA MS San Diego, PhD ANU
M. Forster, BSc MSc PhD Monash
G. Iaffaldano, BSc Rome, PhD Munich
O. Nebel, Diplom Geology Dr. rer. nat. Munster
E.K. Potter, BSc Wollongong, BSc (Hons) PhD ANU
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
A. Halfpenny, MESc PhD Liverpool
T. Iizuka, BSc, MSc, PhD, Tokyo Institute of Technology
J. Mallela, BSc (Hons) Leeds, MSc Heriot-Watt, PhD Manchester Metropolitan
L. Martin, BSc (Hons) MSc Paris XI, PhD Henri Poincare University
S. Pozgay, 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
E. Vanacore, BS Virginia Tech, PhD Rice
M. Ward, BSc (Hons) Florida, CAS Cambridge, PhD Florida State
L. White, BSc (Hons) UNSW

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
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J.D. FitzGerald, BSc James Cook, PhD Monash
S. Hart, BSc (Hons) Melbourne
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 Institute
J. Shelley, BSc, MSc, University of Canterbury (NZ)
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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
S. Hart, BSc (Hons) Melbourne

POST-GRADUATE STUDENTS

PhD Candidates

A. Arad, BSc (Hons) ANU
C. Augenstein, BSc MSc ETH-Zurich
F. Beavis, BA/BSc (Hons) ANU
K. Boston, BSc (Hons) ANU
L. Brentegani, BSc (Biological) Bologna, MSc Ancona
J. Brownlow, BSc (App Geology) UNSW
C. Chapman, BSc (Adv), BE (Hons) Syd, Grad Dipl BMTC
A. Chopra, BSc Univ. WA, BSc (Hons) ANU
A. Clement, BSc (Hons) Melbourne Univ.
M. Crawford, BSc (Hons) Univ. Qld
N. Darrenougue, BSc MSc Univ. Bordeaux
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
E. Gowan, BSc (Geophysics) (Hons) Univ. Manitoba, MSc Vict Univ., Canada
N. Gueneli, Dipl Biochem Kiel, Dipl Geol Kiel
B. Hanger, BEng (Chem) (Hons), BSc Monash, Hons ANU
A. Higgins, BSc (Hons) ANU
J. Hoffmann, BA BSc (Hons) Monash Univ.
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-Universitát Münster
E. Ingham, BSc (Hons) Victoria Univ. Wellington
A. Jarrett, BSc (Hons) ANU
H. Jeon, MSc Seoul National Univ.
J. Jones, Dip Gemmology GAGTL London, BSc (Hons) Auckland Univ.
B. Kallenberg, BSc MSc Freie Univ., Berlin
J. Kang, BSc MSc Korea Univ.
T. Kelly, BSc Univ. Tasmania, BSc (Hons) ANU
E. Kiseeva, BSc MSc St Petersburg State Mine Institute
A. Komugabe, BBiotech/BBus UTS, Hons ANU
C. Krause, BSc (Hons) Macquarie Univ.
J. Lee, BSc (Hons) ANU
H. Li, BSc MSc Peking Univ.
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
J. McDonald, BSc ANU (Trf to MPhil)
S. McKibbin, BSc Univ. Newcastle
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
G. Nash, BA/BSc (Hons) ANU
C. O'Neill BSc (Hons) BEcon ANU
T. O'Kane, BSc (Hons) ANU
R. Owens, BSc (Hons) ANU
S. Pachhai, BSc MSc Uni Tribhuvan, Nepal, Dipl. ICTP, Italy
A. Papuc, BSc (Hons) ANU
J. Park, BSc MSc Korea Univ.
S. Pilia, B Exploration & App Geophysics, Cagliari, MSc (Expl & Geoph) Univ. Pisa
C. Pirard, BSc MSc Univ. de Liege
L. Richardson, BSc (Hons) ANU, MSc Queens Univ. Canada
J. Roberts, BSc (Hons) ANU
J. Robertson, DipABRSM (Piano Perf) Royal Schools of Music, BSc (Hons) Univ. Otago
I. Rosso, BSc MSc, Univ. Turin, Italy
S. Sagar, BGeomEng (Hons) Univ. Melbourne, BSc Univ. Canberra
M. Sapah BSc (Hons) Univ. Ghana
R. Schinteie, Cert Arts MSc BSc GripDip Univ. Auckland
N. Scroxton, MSc Oxford Univ., UK
N. Sinclair, BA/BSc Deakin Univ., BSc (Hons) ANU
P. Sossi, BSc (Hons) Univ. Adelaide; Dip. Lang. (Italian) Univ. Adelaide
I. Stenhouse, BSc (Hons) ANU
P. Stenhouse, BSc (Hons) Univ. Otago, NZ
A. Stepanov, BSc MSc Novosibirsk State Univ.
K. Stewart, BSc ANU
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
B. Wang, BSc (Hons) UTS
T. Whan, BSc (Hons) ANU
L. White, BSc (Hons) Univ. New South Wales
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
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
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

Honours Students

* Mid Year start 2010/2011
# Mid Year start 2011/2012
+ University Medal

Geology Honours

Jason Bennett *
Lauren Burraston
Jackson Carr
Kimberley Chia #
Sarah Christmas
Nathan Coleman #
Lyndsay Dean
Stephanie Doos
Leigh Gibson *
Amy Tiffany Halcon #
Luke Hogan #
Katherine Holland
Lisa Howat *
Oleg Koudashev
Jen Deng Lee
Kelly Mills
Amberley Murray
Emily O'Shea
Rohana Rogan-Darvill#
Rowan Romeyn +
Christopher Rouen#
Jonathon Rousseau
Marita Smith +
Matthew Valetich

Honours Physics of the Earth

Xuerong Qin +
Callum Shakespeare +

Masters Students

Master of Natural Hazards (7512)

Edward Aguinaldo
Tim Anderson
Cameron Baden
Mabelline Cahulogan
Michelle Shelby Canterford
Rosauro de Leon
Christina Griffin
Jose Laud
Neni Marlina
Robbie Morris
Monica Osuchowski
Benjamin Plunkett

Masters Physics of the Earth (7903)

Jingming Duan
Daniel Jaksa
Matthew Knafl
Marco Maldoni
Nandini Ramesh

Graduate Studies Select

Steve Tatham

PhD THESES SUBMITTED

Janaina Nunes Avila - Isotopic Signatures and Systematics of Heavy Elements in Stardust Silicon Carbide Grains

Thomas Bodin - Transdimensional Approaches to Geophysical Inverse Problems

Robert Farla - An Exploratory Study of Dislocation Relaxation in Polycrystalline Olivine

Jill Sutton - Germanium/Silicon and Silicon Isotope Fractionation by Marine Diatoms and Sponges and Utility as Tracers of Silicic Acid Utilization

Tanya Ewing - Hf Isotope Analysis and U-Pb Geochronology of Rutile: Technique Development and Application to a Lower Crustal Section (Ivrea-Verbano Zone, Italy)

Simeon Hui - Microanalysis of Impactors of the Earth and Impact Products from the Moon

Sophie Lewis - Climatic Influences on Stable Water Isotope Variability in Palaeo-Precipitation

Melanie O'Byrne - Headland Wake Flows and the Effects of an Upstream Disturbance

Students awards

A.L. Hales Honours Year Scholarship: Rowan Romeyn and Callum Shakespeare
Mervyn and Katalin Paterson Travel Fellowship: Christopher Chapman (to be taken up in 2012).
D.A. Brown Travel Scholarship: Claire Thompson (to be taken up in 2012).
Robert Hill Memorial Prize: Not awarded
A.E. Ringwood Scholarship: Nur Guneli
John Conrad Jaeger Scholarship: Elizabeth Ingham

Summer Research Scholarships

Siu Man (Vincent) Lee (UNSW) - under the supervision of Michael Ellwood
Don McKinnon (ANU) - under the supervision of Hrvoje Tkalcic
Constance Payne (Victoria University, NZ) - under the supervision of Vickie Bennett
So-Young Park (University of Auckland NZ) - under the supervision of Nick Rawlinson
Richard Skelton (ANU) - under the supervision of Ian Jackson
Morgan Williams (ANU) - under the supervision of John Mavrogenes
Kieran Woolfe (ANU) - under the supervision of Malcolm Sambridge

Student Internships

Ms Mattilda Sheridan of Australian National University; Supervisor: Assoc. Prof John Mavrogenes

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
Hashantha Mendis, BInfTec Deakin (Acting from 19/4/2011)

Information Technology Officer

Duncan Bolt, BSc Sydney
Brian Harrold, BSc ANU
Hashantha Mendis, BInfTech (Multimedia) Deakin University

Receptionist
Shannon Avalos

Area Administrators

Earth Chemistry
Josephine Margo

Earth Environment
Robyn Petch,

Earth Materials
Kay Provins (to 11/8/11)
Mary Hapel (from 1/8/2011)

Earth Physics
Sheryl Kluver, Assoc Diploma in Graphic Communications, Australian Army

IODP Administrator

Sarah Howgego (to 25/11/2011)
Catherine Beasley (from 6/12/2011)

School Librarian

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

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 D. Fitz Gerald, BSc James Cook, PhD Monash
John Foster, BSc Sydney, MSc PhD ANU
Bin Fu, BSc (Hons) Jilin, MSc Nanjing, PhD Vrije (from 18/7/2011)
Sai Main Hui, BSc (Hons) ANU (to 29/11/2011)
Daniel J. Hunt, Adv Dip Mech Eng (Trainee) to 21 February 2009)
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
Sisounthon (Tony) Phimphisane, (to 7/7/2011)
Tristan Redman Ass Dip (Elect Eng) CIT
Hideo Sasaki, Ass Dip CIT
Scott Savage (to 4/11/2011)
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
Igor Yatsevich, BEng Tashkent Polytec Inst, PhD Russian Academy of Sciences
Xiaodong Zhang, PhD LaTrobe

Research Activities 2011

Earth Chemistry

Introduction

Research in Earth Chemistry 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 centre on planetary and early Earth studies, metamorphic and igneous geochemistry, geochemistry of life processes, and development and improvement of methods to determine the chronology of processes at all time scales. Our analytical work involves detailed in situ analysis on the microscale, and chemically concentrating trace elements and molecules from larger samples for high precision analysis by a range of innovative mass spectrometric techniques. As highlighted in this year's research contributions, a variety of analytical approaches have been applied to answering key research questions in tectonics, petrology, solar system studies, paleoclimatology, and paleoecology.

2011 has been a year of strong research productivity as summarized in the following research highlights sections, and with a continuing flow of publications in highest quality international journals.

PhD students Sean McKibben and Lloyd White submitted their theses and are awaiting final examiner's reports. Congratulations to Dr Tanya Ewing, Dr Richard Schintele, Dr Claudia Jones, Dr Janaina Avila and Dr Sargent Bray on successful completion of their PhD programs. New PhD students are Marian Sapah (Supervisor Trevor Ireland) and Nur Gueneli (Ringwood Medal recipient, supervised by Jochen Brocks) Celine Crepisson began an undergraduate internship with Daniela Rubatto; Connie Payne from Victoria University, Wellington N.Z. was a Summer Scholar with Vickie Bennett. Oleg Koudashev (Marnie Foster) and Marita Smith (Jochen Brocks) completed first class Honour's degrees, with Marita receiving a University Medal for her thesis. Laure Martin started a postdoctoral position working with Daniela Rubatto.

We acknowledge the capable handling of administrative matters by Josephine Magro, who became the permanent EC Area Administrator after filling in on a temporary basis in 2010. PhD candidate Madga Huyskens organized our well-attended, weekly seminar series.

As usual Earth Chemistry was host to numerous national and international visitors with a highlight being the 2011 Jaeger-Hales lecturer, Prof. Hugh P. Taylor Jr. (California Institute of Technology). In addition to his public lecture Hugh generated much enthusiasm during the Earth Chemistry organized stable isotope workshop and field trip. We appreciated the fact that he stayed in the School for a significant period after his lecture interacting widely with students and staff.

As is typical within the highly instrument dependent Earth Chemistry group, the past year saw the acquisition of new instruments and the further development of existing mass spectrometers. The next generation SHRIMP SI (Trevor Ireland, Peter Holder and John Foster) designed and built at ANU, with construction completed in 2010, moved from the testing to the data production stage with a highlight being the first ion-probe with the demonstrated capability of being able to precisely measure the isotopic composition of all four sulphur isotopes; this looks set to revolutionize the field of S isotope research by allowing for the precise in situ work at the 20 micron sampling scale. The new Scanning Electron Microscope (funded by an ANU Major Equipment grant led by Daniela Rubatto) was accepted in Dec 2010 and started routine operation in Jan 2011. It was in use for >500 hours in the past year, making a positive impact on sample preparation time for SHRIMP and others users. Jochen Brocks led a successful MEC grant proposal for the acquisition of a new gas chromatograph with flame ionization detector (GC-FID) which is now installed and operational.

Marnie Foster was a co-CI on a successful LIEF proposal to obtain an ARGUS VI mass spectrometer for the ANU Argon Facility. with installation planned for March 2012. This facility will have a focus on 'dating deformation and diffusion experiments'.
After several years of working with the factory on instrument design and development Masahiko Honda was able to take delivery of the long-awaited prototype of a next generation multi-collector noble gas mass spectrometer, the Helix MC. Honda along with and Xiaodong Zhang are currently testing its performance. Also in the noble gas facility a new diode laser heating system was installed enabling the extraction of noble gases from small samples, such as lunar ilmenite single grains and micro-diamonds.
Following on from a successful 2010 ARC LIEF grant, a new Thermo Triton Plus thermal ionization mass spectrometer, overseen by Yuri Amelin and Vickie Bennett was signed off on in April and is now in regular use in the TIMS lab.

Earth Chemistry postgraduate students and academic staff were prominent at national and international conferences, including organization, convening sessions and conference presentations at the Goldschmidt Conference, held in Prague Czech Republic, the Lunar and Planetary Science Conference at Houston in March and the American Geophysical Union meeting in December in San Francisco.

A very sad note to 2011 was the retirement of the original large ion-probe, SHRIMP I. This instrument, brought into existence by the efforts and foresight of emeritus Earth Chemistry Professor Bill Compston, was the first instrument designed for in situ U-Pb dating of zircon, a capability that has revolutionized geochronology. After more than 30 years of continuing service and production of data for hundreds of publications, SHRIMP I was decommissioned, with key components preserved for an eventual display dedicated to this landmark instrument. The former SHRIMP lab is now undergoing much needed refurbishment and will become the new C-14 sample preparation laboratory under the direction of Stewart Fallon.

In staffing matters, in 2012 we look forward to the influx (at least 7) of new PhD student after a highly successful recruiting year; the arrival of the newly appointed thermal ionization facility (TIMS) technical officer Dr. Sonja Zink and the appointment of the new SHRIMP postdoctoral fellow to assist with development of stable isotope applications on the SHRIMP SI.

Dr. Vickie Bennett
Associate Director, Earth Chemistry

Chilly seas along the Late Triassic north African coast: evidence from oxygen isotopic compositions of Sicilian conodonts.

Ian S. Williams[1], Julie A. Trotter[2], Manuel Rigo[3] and Nereo Preto[3]

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[2] School of Earth and Environment, The University of Western Australia, Perth, WA 6009, Australia
[3] Department of Geosciences, University of Padova, 35131 Padova, Italy

During the Triassic most continents were merged, forming the supercontinent of Pangea. Pangea had a huge ocean gulf, Tethys, open on its eastern side. Because of its proximity to such a large land mass, Tethys is thought to have been subject to extreme climatic conditions, including a 'megamonsoon'. Such extreme atmospheric circulation should have caused upwelling of cold sea water along the Tethys coast, but there have been no reports of geological evidence for this.

Conodonts are the fossil mouthparts of small protochordates that were widespread in global tropical oceans from the Late Cambrian to Late Triassic. The oxygen isotopic composition of conodont carbonate fluorapatite depends on the isotopic composition and temperature of the sea water in which the animal lived. Knowing the water composition and measuring conodont compositions, sea water temperatures can be calculated.

Conventional oxygen analyses of bulk Late Triassic conodont samples from the Lagonegro Basin of southern Italy by Rigo and Joachimski (2010) indicated an open ocean water temperature in Tethys of about 28°C, consistent with its known tropical palaeogeographic setting. In contrast, bulk conodont analyses from the Hallstatt-Meliata Basin in Austria, a Tethys marginal basin in the Late Triassic, have given scattered compositions implying a much lower average temperature, about 20°C (Hornung et al., 2007).

The Sicani Basin in Sicily was also located along the Tethys margin in the Late Triassic, southwest of the Hallstatt Basin. We have extracted 90 conodonts representing 16 species from 18 closely-spaced stratigraphic units deposited during the late Carnian to Norian and analysed their oxygen isotopic compositions using the ANU SHRIMP II ion microprobe. This in situ micro-technique allows the analyst to target the best quality material within each conodont fossil, and to check for isotopic homogeneity by analysing each fossil several times. Independently of species or stratigraphic level, the Sicilian conodonts have given almost identical results (~21.3‰) within the small analytical uncertainties, equivalent to a temperature of about 20°C. This is entirely consistent with the results from the Hallstatt-Meliata Basin and with the coastal waters being about 8°C cooler than those in the open ocean. The prediction from climate modeling that there would have been upwelling of cold water along the north coast of Tethys appears to be correct, and the homogeneity of the conodont compositions implies that the upwelling was both strong and sustained throughout the year.

Hornung, T., Brandner, R., Krystyn, L., Joachimski, M.J. & Keim, L. 2007, Multistratigraphic constraints on the NW Tethyan “Carnian Crisis”. Lucas, S.G. and Spielmann, J.A., (eds). The Global Triassic: New Mexico Museum of Natural History and Science Bulletin, v. 41, p. 59-67.

Rigo, M., and Joachimski M., 2010, Palaeoecology of Late Triassic conodonts: Constraints from oxygen isotopes in biogenic apatite: Acta Palaeontologica Polonica, v. 55, p. 471–478.

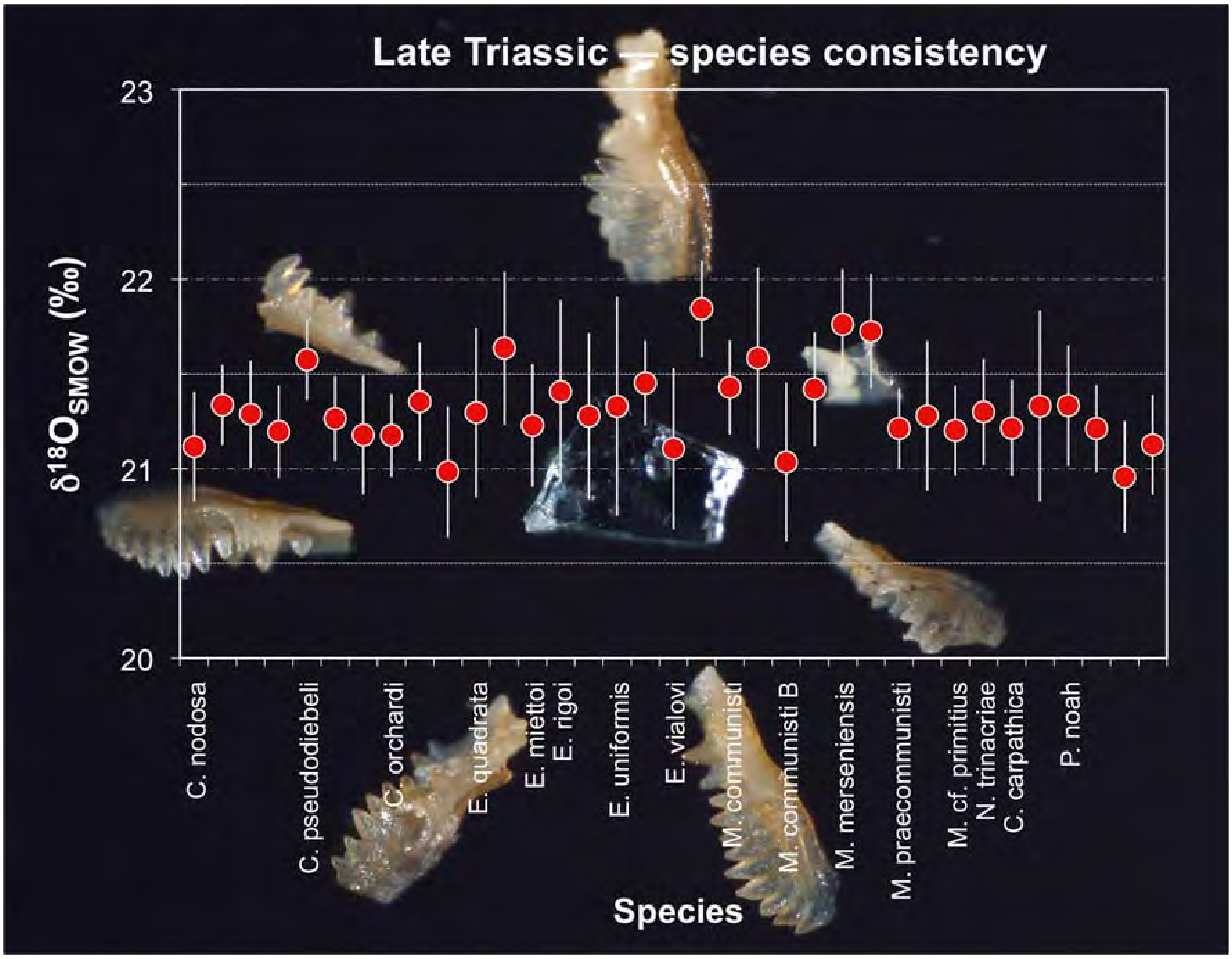

Figure 1. SHRIMP II oxygen isotope analyses of Late Triassic conodonts from the Sicani Basin, Sicily, showing the close similarity in composition between species.

The U-Pb systematics and cooling rate of plutonic angrite NWA 4590

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Due to their rich and unique mineralogy and good preservation, angrites offer an excellent opportunity for studying chronology of one of the oldest known differentiated bodies in the Solar System. It is known that angrites contain at least two U-bearing minerals suitable for precise U-Pb dating: Al, Ti-rich clinopyroxene, and Ca-phosphate merrillite. Combining the ages of these minerals from the same meteorite with the rate of Pb diffusion known from experimental studies makes it possible to calculate cooling rates of meteorite parent bodies and precisely link these cooling rates to the absolute time scale.

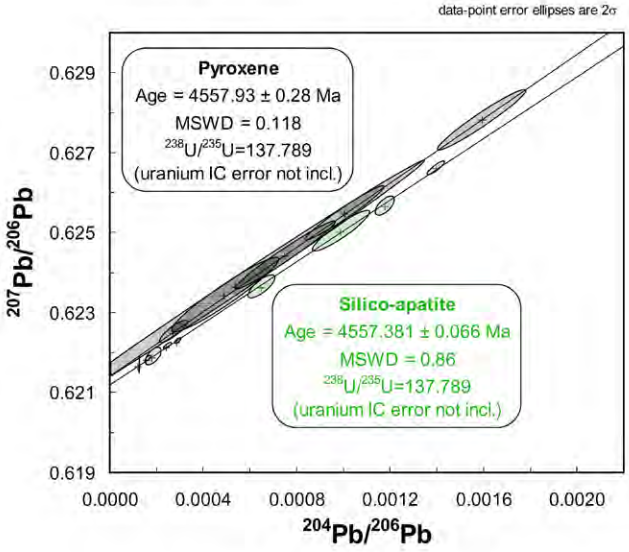

Figure 1. Fig. 1. Pb-Pb isochrons for pyroxene (6 fractions) and silico-phosphate (9 fractions) from angrite NWA 4590. The age errors do not include uncertainty of the $^{238}U/^{235}U$ ratio.

Angrite NWA 4590, a very fresh coarse-grained igneous cumulate rock composed of Al-Ti-rich clinopyroxene, anorthite, Ca-rich olivine with kirschsteinite exsolution, ulvöspinel, and accessory minerals, is one of the most suitable meteorites for such determination. Among other accessory minerals, NWA 4590 contains merrillite, a mineral that was successfully used in U-Pb dating of other meteorites. Here we report the uranium isotopic composition of NWA 4590, and results of a detailed U-Pb study of rock-forming and accessory minerals, including silico-phosphate – the U-rich mineral that appears to be the major host of uranium in this meteorite.

Uranium isotope composition was analysed at the University of Otago. U-Pb analyses were carried out at the Geological Survey of Canada and the Australian National University. Two whole rock U isotope analyses yielded consistent values with the weighted average $^{238}U/^{235}U$ ratio of 137.789±0.021, reported relative to the value of 137.836 in the CRM-145 standard. This $^{238}U/^{235}U$ ratio in NWA 4590 is lower than the "terrestrial" value, but is higher than the Allende meteorite whole rock and chondrule value. The $^{238}U/^{235}U$ ratio in NWA 4590 is also almost identical to the value in the angrite D'Orbigny, suggesting that U isotopic composition in the angrite parent body is homogeneous.

A Pb-Pb isochron for six pyroxene fractions (Fig.1) five analyses at the GSC, and one at the ANU) yielded the age of 4557.93±0.28 Ma, calculated using the measured $^{238}U/^{235}U$ ratio of 137.789. Including the error of $^{238}U/^{235}U$ ratio introduces additional age uncertainty of 0.22 Ma, and increases the total age error to ±0.36 Ma.

The NWA 4590 contains silico-phosphate – a mineral with 8-9% SiO_2 that is structurally identical to apatite, and contains 11-22 ppm U. A Pb-Pb isochron for nine silico-phosphate fractions (Fig.1) yielded the age of 4557.381±0.066 Ma (or ±0.23 Ma, including uncertainty in the $^{238}U/^{235}U$ ratio), calculated using the measured 238U/235U ratio of 137.789. The U-Pb systems in all pyroxene and silico-phosphate fractions are concordant or less than 2% discordant, thus confirming the closed-system behaviour and reliability of the ages.

The age difference of 0.55±0.29 Ma between pyroxene and silico-phosphate can be interpreted as a result of later closure of Pb diffusion in silico-phosphate a in slowly cooling rock. Assuming the difference in closure temperature of 296±50 Ma for Pb diffusion in pyroxene and silico-phosphate, this age difference corresponds to the cooling rate of 540±290 K/Ma. This cooling rate is 20-100 times faster than the cooling rate of the parent body of metal-rich ordinary chondrites. Fast cooling could imply a small size of the angrite parent body, but may also be a result of a rapid cooling after breakdown at 4557-4558 Ma.

Far travelled zircons in the mountains of northern Norway

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The Norwegian mountains form part of a much larger mountain (orogenic) belt that resulted from the collision between old continents known as Laurentia and Baltica to form part of a developing supercontinent. The orogenic belt was rejuvenated when the supercontinent was dismembered by rifting and subsequent opening of the Norwegian-Greenland Sea by ocean floor spreading during the Cenozoic (from ca. 75 Ma) so that fragments of the belt are now to be found in Norway and Sweden, on the eastern margin of Greenland and in the British Isles.

The orogenic belt is largely composed of sedimentary and volcanic rocks accumulated on, and outboard of, the margins of Laurentia and Baltica between approximately 1000 and 400 Ma ago, after they were separated by break-up of an earlier supercontinent known as Rodinia. These rocks have suffered several episodes of deformation and metamorphism and, in Scandinavia, large sheets (nappes) of these rocks have been thrust several hundred kilometers eastwards over Norway and into Sweden. Progressively higher nappes are encountered moving westwards from the edge of the belt in Sweden to the Norwegian coast. In northern Norway much of the country is occupied by the highest nappe complexes, collectively known as the Uppermost Allochthon, which is now generally believed to have been derived from Laurentia.

It is also hypothesized that much of the observed tectonic history in the Uppermost Allochthon took place on the Laurentian margin prior to collision with Baltica. However, the processes by which the nappes were detached from their Laurentian roots and translated to the margin of Baltica remain obscure: the geochronological control on the igneous, metamorphic and deformational events does not yet permit a 'deconstruction' of the tectonic history back to the earliest events. Such deconstructions require comprehensive data on, and analysis of, major transects across the whole belt. The present project, undertaken with the cooperation of the Norwegian Geological Survey, contributes to achieving such a goal in a transect across the Uppermost Allochthon, which links with a similar study being undertaken by others in Sweden.

Figure 1. View NE from highly deformed marble of the Gildeskål nappe to schists of the Rødingsfjell nappe on Sandhornøy. The well defined break in slope on Sandhornet marks the nappe boundary, now dipping to the east as a result of folding after nappe emplacement.

Figure 2. Frost shattered quartzite in a layer forming the summit of Sandhornet within the dominant schists.

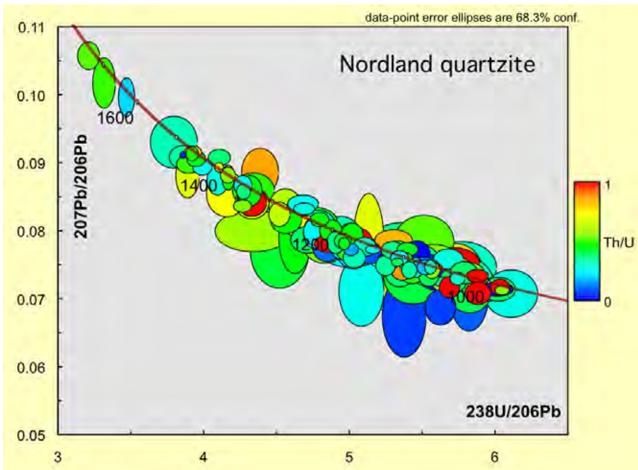

Figure 3. Part of the spectrum of zircon analyses from a quartzite sample similar to that in Figure 2.

The project area lies between 66º 15´N and 67º 20´ N, with particular focus on an E-W transect south of the town of Bodø. In this area the nappes are dominated by unfossiliferous marble groups with subordinate schist and gneiss groups, all of uncertain age. They can be divided into three main nappes, which have been folded after nappe emplacement into a broad NNE-trending synformal structure. The lowermost nappe in the east, the Fauske nappe, thus appears to correlate with the Gildeskål marble nappe in the west, while the overlying schist nappes both appear to be relatively thin developments of the widespread Rødingsfjell Nappe Complex (Fig. 1). Overlying these, in the central part of the area, is the Beiarn Nappe Complex, with higher metamorphic grade schists and gneisses underlying the Sokumfjell marble group, and with abundant granitoid intrusions.

Quartzite samples have been taken to examine the differences between the main nappe units and also to examine the lateral variation within the nappes.

All of these major tectonic units contain some quartzite layers (Fig. 2), which offer the opportunity to obtain information on the age and geochemical characteristics of the source rocks and maximum depositional age of the quartzites (Fig. 3). These will allow a critical comparison with possible source areas in both Laurentia and Baltica and with similar data from the lower nappes in Sweden. Complementary work on the metamorphic and igneous rocks is providing evidence for the age of the protoliths of the metasediments and constraining the age of key deformational events.

Solar-wind exposure effects on lunar grains:

Oxygen isotope signature implanted on the surface of lunar metal spherules

Barbara Frasl, Trevor R. Ireland and Peter Holden

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A new generation of SHRIMP, optimized for stable light isotopes: SHRIMP SI, is used to characterize the isotopic composition of oxygen implanted on the surfaces of individual lunar grains to characterise the composition of the solar wind.

This research focuses on the stable isotope signature of implanted ions in the surface of lunar metal spherules. Analysing these surfaces is an attempt to identify the oxygen isotope signature (^{16}O, ^{17}O and ^{18}O) of the Sun, which in turn represents the original composition of the solar nebula.

The oxygen isotope measurements were one of the first undertaken on SHRIMP SI, which was commissioned earlier this year. Calibration measurements on standards, FC-1 & Temora ilmenites, were performed to test the collection method, as well as optimizing the setup for resolution, especially for the ^{17}O and ^{16}OH mass peak. Additionally, we did an interference study on the high OH-mineral goethite to document the behaviour of the ^{16}OH mass peak and its tail influencing the ^{17}O scan.

The final data was collected in both multiple and single collection, running long measurements on the lunar grains, one for about an hour each. This should provide us with a deep profile penetrating from the surface a few hundred nanometers into the grain (*Figure 1*).

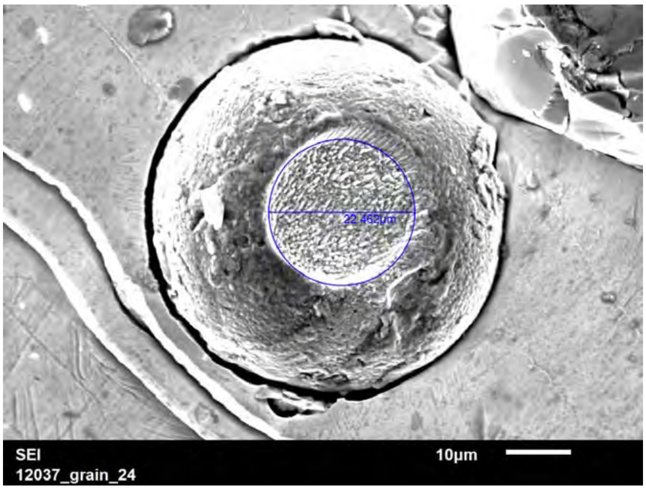

Figure 1. Secondary electron image of a SHRIMP SI primary ion beam pit (encircled in blue) on a lunar metal grain of an Apollo 12 soil.

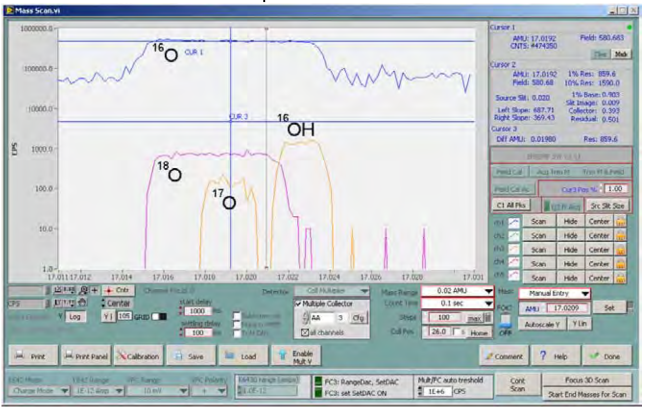

Figure 2. Mass scan on SHRIMP SI for a metal grain of an Apollo 12 soil. ^{16}O [blue line] is measured on Faraday Cup; while ^{18}O (pink line), ^{17}O & ^{16}OH (orange line) are collected in electron multipliers. The mass peaks for ^{17}O (orange peak on the left) & ^{16}OH (orange peak on the right) are well resolved.

During multiple collection ^{16}O was measured on a Faraday Cup, while ^{17}O and ^{18}O on two separate electron multipliers. Additionally, ^{16}OH and an interference position for the ^{16}OH tail were analysed sequentially on the same electron multiplier as ^{17}O. *Figure 2* shows a mass scan on a lunar grain for ^{16}O, ^{17}O, ^{16}OH and ^{18}O in multiple collector mode. It also demonstrates the well-defined resolution between the ^{17}O and ^{16}OH mass peak. Additionally, it was decided to add measurements for ^{16}O and ^{18}O on the same electron multiplier as ^{17}O for single collection.

The main goal is to understand solar wind exposure effect on lunar soils and the implications for oxygen isotopic fractionation.

Unravelling the Shimla klippe: Microstructures and $^{40}Ar/^{39}Ar$ geochronology

Jia-Urnn Lee and Marnie Forster

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

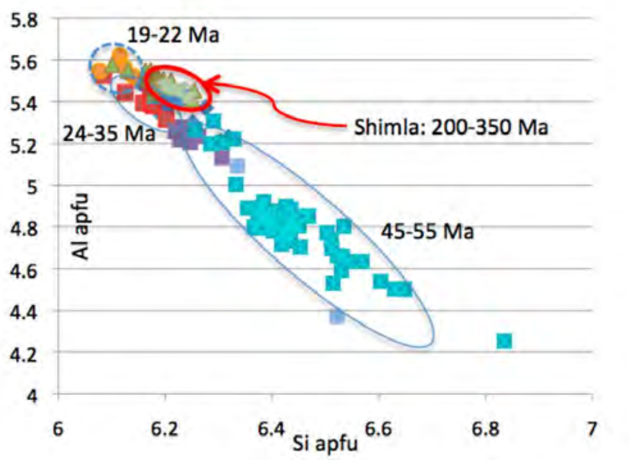

Figure 1. Si vs Al of white micas from Shimla klippe rocks in relation to other Himalayan white micas. The plot suggests a trend whereby older white micas have high Si-low Al, whereas younger white micas have recrystallised to have low Si-high Al. The Shimla rocks have anomalously old argon apparent ages even though the white micas have low Si-high Al. Their geochemistry is similar to other Himalayan structures that have recorded Oligo-Miocene ages Analyses are taken from a range of structural fabrics and ages are $^{40}Ar/^{39}Ar$ apparent ages. Argon geochronology was undertaken on these white micas so as to correlate micro-chemical data with argon geochronology data. [Ladakh analyses are courtesy of ANU Argon Facility, Dr Marnie Forster].

The Himalaya orogen consists generally of four main crustal-scale tectonic sheets that overlie each other. From south to north and ascending through the structural pile these are: the Sub-Himalaya, the Lesser Himalaya, the Greater Himalaya and the Tethyan Himalaya. Often klippes of the Greater Himalaya are exposed in the underlying Lesser Himalaya, where the surrounding Greater Himalayan sheet has been eroded away. The Shimla klippe (of Greater Himalayan origin) is one such tectonic lens of medium metamorphic grade. It consists of garnet bearing rocks of the Jutogh Group (part of the Greater Himalaya) overlying the low-grade Lesser Himalayan rocks. The klippe was emplaced by the Jutogh Thrust into its current day position. This thrust is considered to be a branch of the Main Central Thrust (MCT), the major ductile shear zone that, in much of the Himalaya, juxtaposes the Greater Himalaya against the Lesser Himalaya. Studying the klippe provides insight into the structural, thermal and geochronological evolution of these tectonic sheets.

For the past few decades, rocks in the Shimla klippe have been thought to record Miocene-Pliocene cooling ages, reflecting the period of deformation along the Main Central Thrust. Microstructural analysis shows ongoing garnet growth within the shear zone, and indicates that temperature conditions were sufficient for white mica recrystallisation during (MCT) shear zone activity. Similarly geochemistry of white micas of the Jutogh rocks suggests that they have a similar Si-Al composition as other Himalayan white micas of Oligo-Miocene age. However preliminary $^{40}Ar/^{39}Ar$ analysis of white micas on overlying Jutogh Group rocks close to the klippe contact yielded unexpected results. Miocene-Pliocene apparent ages related to cooling or deformation along the MCT were expected. However, Mesozoic-Paleozoic (~200-350 Ma) ages were obtained from rocks in this klippe instead. The age disparity between these rocks and the expected age range of the MCT (16-24 Ma) suggests that: a) the klippe may not have been emplaced by the MCT; or b) that the Jutogh Thrust is not a branch of the MCT. This is an ongoing study to investigate the nature of the old ages of the rocks and the nature of the thrust system that underlies the Shimla klippe.

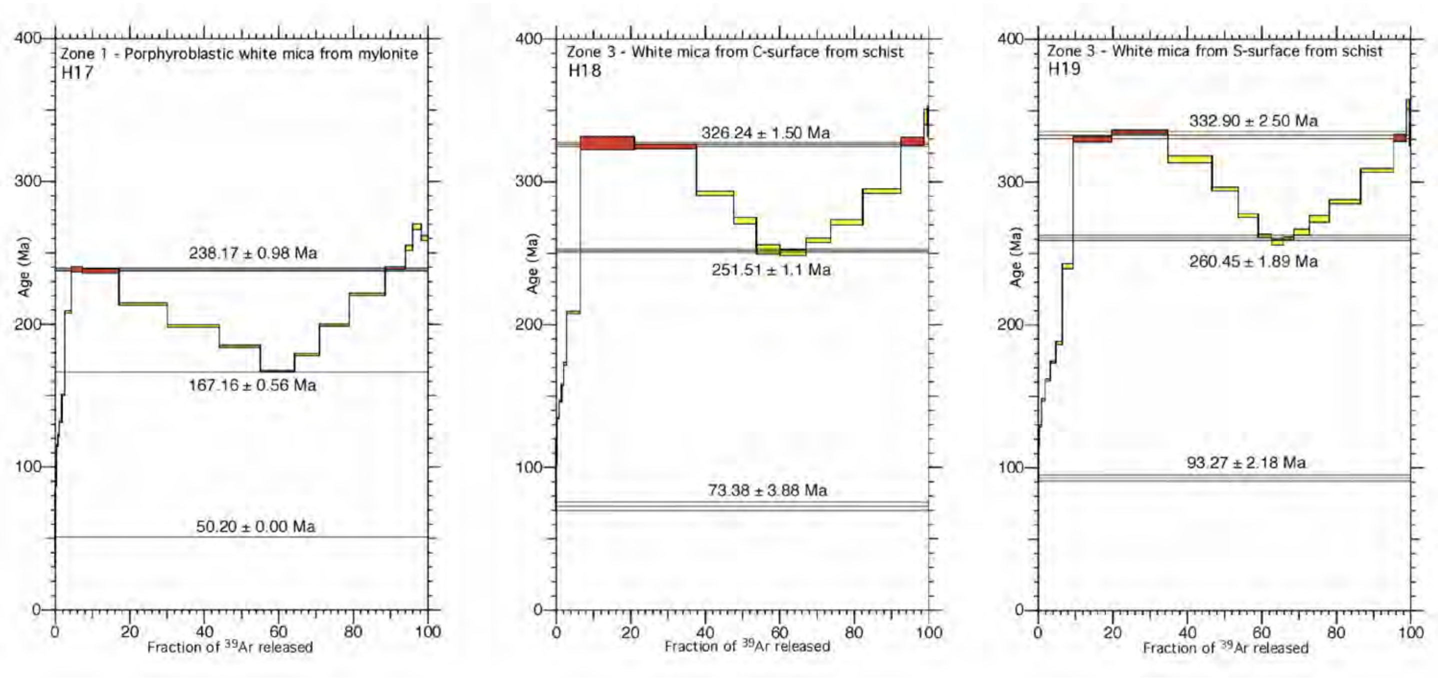

Figure 2. Preliminary $^{40}Ar/^{39}Ar$ age spectra of Jutogh rocks within the Shimla klippe showing mainly Mesozoic apparent ages in what is expected to be Miocene-age rocks. A thermal event that occurred before ~55 Ma has only partially reset the argon isotopic system, thus preserving old ages. The staircase-shaped spectra are characteric of white micas that have argon gas in different retentivity sites that outgas at different times. York and Arrhenius plots for these samples (not shown here) indicate that sites of higher argon retentivity outgas during higher temperature intervals of the experiment.

Chilly seas along the Late Triassic southern European coast: evidence from oxygen isotopic compositions of Sicilian conodonts

I.S. Williams[1], J.A. Trotter[2], N. Preto[3] and M. Rigo[3]

[1] *Research School of Earth Sciences, Australian National University, Canberra, ACT 0200, Australia*
[2] *School of Earth and Environment, The University of Western Australia, Perth, WA 6009, Australia*
[3] *Department of Geosciences, University of Padova, 35131 Padova, Italy*

During the Triassic most continents were merged, forming the supercontinent of Pangea. Pangea had a huge ocean gulf, Tethys, open on its eastern side. Because of its proximity to such a large land mass, Tethys is thought to have been subject to extreme climatic conditions, including a 'megamonsoon'. Such extreme atmospheric circulation should have caused upwelling of cold sea water along the Tethys coast, but there have been no reports of geological evidence for this.

Conodonts are the fossil mouthparts of small protochordates that were widespread in global tropical oceans from the Late Cambrian to Late Triassic. The oxygen isotopic composition of conodont carbonate fluorapatite depends on the isotopic composition and temperature of the sea water in which the animal lived. Knowing the water composition and measuring conodont compositions, sea water temperatures can be calculated.

Conventional oxygen analyses of bulk Late Triassic conodont samples from the Lagonegro Basin of southern Italy by Rigo and Joachimski (2010) indicated an open ocean water temperature in Tethys of about 28°C, consistent with its known tropical palaeogeographic setting. In contrast, bulk conodont analyses from the Hallstatt-Meliata Basin in Austria, a Tethys marginal basin in the Late Triassic, have given scattered compositions implying a much lower average temperature, about 20°C (Hornung et al., 2007).

The Sicani Basin in Sicily was also located along the Tethys margin in the Late Triassic, southwest of the Hallstatt Basin. We have extracted 90 conodonts representing 16 species from 18 closely-spaced stratigraphic units deposited during the late Carnian to Norian and analysed their oxygen isotopic compositions using the ANU SHRIMP II ion microprobe. This in situ micro-technique allows the analyst to target the best quality material within each conodont fossil, and to check for isotopic homogeneity by analysing each fossil several times. Independently of species or stratigraphic level, the Sicilian conodonts have given almost identical results (~21.3‰) within the small analytical uncertainties, equivalent to a temperature of about 20°C. This is entirely consistent with the results from the Hallstatt-Meliata Basin and with the coastal waters being about 8°C cooler than those in the open ocean. The prediction from climate modeling that there would have been upwelling of cold water along the north coast of Tethys appears to be correct, and the homogeneity of the conodont compositions implies that it was both strong and sustained.

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Rigo, M., and Joachimski M., 2010, Palaeoecology of Late Triassic conodonts: Constraints from oxygen isotopes in biogenic apatite: Acta Palaeontologica Polonica, v. 55, p. 471–478.

Figure 1. SHRIMP II oxygen isotope analyses of Late Triassic conodonts from the Sicani Basin, Sicily, showing the close similarity in composition between species.

Geochronology of accessory allanite and monazite in the Barrovian metamorphic sequence of the Central Alps, Switzerland.

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[1] Research School of Earth Sciences, Australian National University, Canberra, ACT 0200, Australia
[2] Institute of Geological Sciences, University of Bern, Switzerland

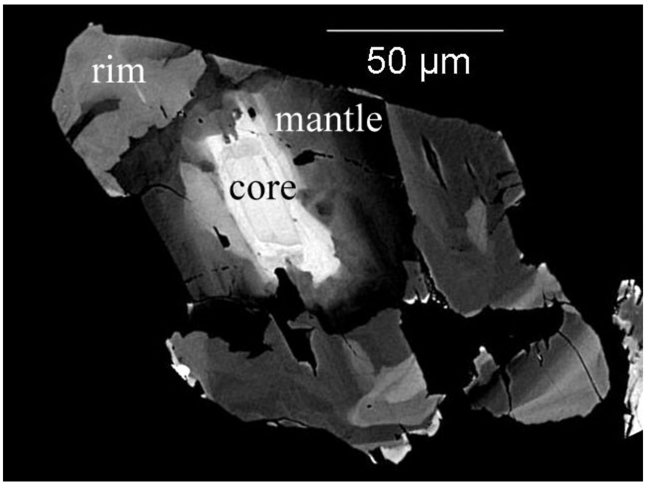

Figure 1. BSE image of allanite with complex zoning. Allanite cores are overgrown by a mantle of lower REE content, which is in turn overgrown by an outer rim of allanite. Allanite rims are approximately 7 Ma younger than cores

Allanite and monazite can undergo metamorphic reactions under greenschist and amphibolite facies conditions (allanite replacement of detrital monazite and monazite replacement of allanite, respectively). This makes them suitable chronometers for metamorphic terrains of medium grade. We investigated allanite $[(Ca,REE,Th)_2(Fe^{2+},Al)_3Si_3O_{12}(OH)]$ and monazite $[(Ce,La,Th)PO_4]$ in samples from the Lepontine dome (Central Alps, Switzerland) in order to gain insight into the timing and duration of Barrovian metamorphism which occurred during the late stages of orogenesis.

The five investigated metasediments (one quartzite, one quartzofeldspathic conglomerate and three metapelites) contain either monazite (two samples) or allanite (three samples). Allanite cores yield Th-Pb SHRIMP ages ranging from ~ 32 Ma to ~ 26 Ma. Inclusions, trace element chemistry and textures suggest that allanite cores do not date regional amphibolite facies metamorphism, but an earlier event in the samples' evolution, possibly at greenschist facies conditions. The range of ages returned from allanite cores in different samples may reflect the different temperatures under which allanite was stable in different bulk rock compositions. Further investigation will determine if this greenschist facies stage represents an early and distinct metamorphic event or prograde stage to later amphibolite facies metamorphism.

Allanite grains in one sample have complex zoning and a datable allanite rim in addition to the core (Figure 1). Allanite rims return an age of ~ 20 Ma, significantly younger than the age of the cores in the same grain (~ 27 Ma). The age of allanite rims is within error of the age of monazites in two samples (~ 22 Ma). Inclusions of relic allanite in monazite suggest that monazite growth was at the expense of allanite – a reaction that takes place under amphibolite facies conditions. Combined with mineral textures, inclusions and trace element chemistry, the allanite rim and monazite ages are interpreted as dating amphibolite facies metamorphism in the Lepontine dome.

Noble gas and carbon isotope ratios in Argyle diamonds, Western Australia

Evidence for a deeply-subducted volatile component

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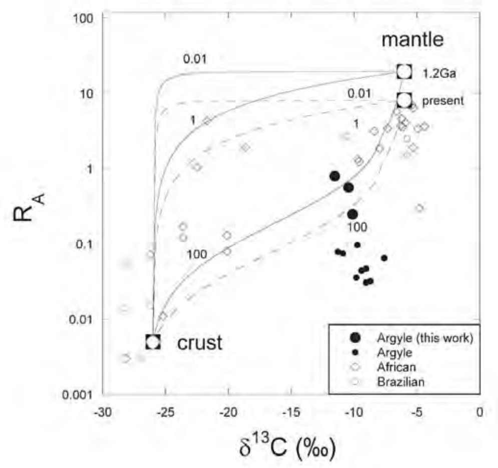

Fig. 1

Figure 1. $^{3}He/^{4}He$ vs. d^{13}C for Argyle diamonds (filled circles), African (open circles) and Brazilian (crosses) diamonds. Mixing curves are calculated with two endmembers; mantle (8.1 R_A (present-day), 19.5 R_A (1.2Ga); d^{13}C = -6.0‰) and crust (0.005 R_A; d^{13}C = -26.0‰), with valuable 'r' values, where r = $(^{12}C/^{4}He)_{mantle}/(^{12}C/^{4}He)_{crust}$, as indicated in the diagram. While majority of data from African and Brazilian diamonds locate in the region showing general mixing trend between the mantle and crustal components, those from Argyle locate the area where ^{4}He is enriched. The ^{4}He enrichment could be explained by in-situ produced radiogenic ^{4}He from decay of U and Th.

Diamonds have unique characteristics which make them potentially very useful time capsules of noble gases from the mantle: (1) most diamonds appear to be derived from 150 km to 200 km depth in the earth, (2) diamonds cover a wide range of crystallization ages of between 1.0 and 3.5 billion years, and (3) diamonds are inert and are largely unaffected by the transporting kimberlite magma or subsequent interactions with the crust or atmosphere. Thus, diamonds provide a direct window into the ancient mantle. As part of a broader investigation into the evolution of the noble gases through time, we undertook noble gas and carbon isotope ratio (d^{13}C) analyses of three diamonds from the Argyle lamproite to test for the possible presence of deeply-subducted volatile components, and to further constrain the noble gas evolution of Earth's mantle. The Argyle diamonds are characterized by mantle ^{3}He (with $^{3}He/^{4}He$ ratios of 0.79 R_A to 0.25 R_A, where R_A is the atmospheric $^{3}He/^{4}He$ ratio of 1.4 x 10^{-6}); small excess Ar and Xe isotope anomalies relative to atmospheric components; and d^{13}C values of -10.1 to -11.5‰.

Helium and carbon isotope ratios observed in the Argyle diamonds are compared with those from African (De Beers Pool, Finsch , Jwaneng, Orapa, Zaire, Premier, Central African Republic, and unknown) and Brazilian (Sao Luiz and unknown) diamonds (Fig. 1). Whereas the helium and carbon isotope data form general mixing trends between mantle and crustal end-member components, the data for Argyle diamonds plots below the mixing trends (Figure 1), indicating that the Argyle diamonds are enriched in radiogenic ^{4}He. The ^{4}He enrichment in the Argyle diamonds is likely to be attributed to in-situ radiogenic ^{4}He produced from U and Th within the diamonds.

The carbon isotope ratios of the Argyle diamonds (= -11.0‰) can be explained by mixing of mantle and crustal components, with ~25% of the carbon estimated to be derived from recycled sedimentary organic carbon. These data support recent results from analyses of subducted serpentitnites, and imply that significant amounts of crustal helium and atmospheric noble gases were subducted to the mantle depths of at least 150-200 km in the region where the Argyle diamonds formed. These subducted noble gases were mixed with mantle noble gases, to produce the mixed noble gas systematics observed in the Argyle diamonds.

The oldest carotane pigments in the geological record

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Figure 1.

Hydrocarbon biomarkers are the molecular fossils of natural products such as lipids and pigments. They can yield a wealth of information about early microbial ecosystems and are particularly valuable when preserved in billion-years-old (Ga) sedimentary rocks where conventional body fossils are often lacking.

The oldest know biomarkers come from 1.64 billion-years-old consolidated sediments that were deposited in an ancient sea in northern Australia, just west of the present Gulf of Carpentaria. According to our research, these ancient seas were a toxic broth devoid of oxygen but rich in hydrogen sulfide. The marine waters harboured phototrophic green and purple sulfur bacteria (Chlorobiaceae and Chromatiaceae, respectively), but were hostile to eukaryotic algae. It was an ecosystem unlike anything we know of later in the Earth's history [1, 2].

In our continued hunt for new biomarkers in these ancient rocks, we looked for traces of carotanes. Carotanes are the hydrocarbon fossils of carotenoids, pigments that are responsible for the red colour of tomatoes, the orange of carrots and the yellow of canary birds, but may also serve as light harvesting antennae in photosynthetic microorganisms. However, carotenoids are exceedingly difficult to study in the geological record because of their low preservation potential. Preservation of the hydrocarbon equivalents of carotenoid molecules is rare due to their tendency to break into smaller units or undergo complex rearrangement reactions [3]. In rare instances where intact carotenoid hydrocarbons are preserved by suitable conditions, they are often subsequently cleaved into smaller fragments by increasing temperatures during burial of the host sediment.

To create a search pattern for carotenoid breakdown products, we simulated the natural geological degradation of the orange pigment β-carotene in the laboratory. Heating β-carotene in moist clay at high pressures generated a mixture of systematic cleavage products. Using the cleavage products as a new standard we were able to identify carotane fragments in deep sections of the 1.64 billion-years-old Barney Creek Formation [3]. The molecules were potentially generated by oxygen-producing, green-coloured cyanobacteria. They represent the oldest evidence for molecules of this class in the geological record, more than 1 billion years older than previous discoveries.

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Zr-in-rutile thermometry provides a robust record of peak metamorphic conditions in the lower crust (Ivrea–Verbano Zone, Italy)

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Rutile (TiO_2) occurs as an accessory mineral in a range of high grade metamorphic rock types. The temperature experienced by such rocks can be determined from the concentration of zirconium (Zr) in rutile, which is temperature dependent for rutile grown in equilibrium with quartz and zircon (e.g. Zack et al., 2004; Watson et al., 2006). In high temperature settings, an understanding of the robustness of this system to resetting is important for interpretation of the calculated temperatures.

The Ivrea–Verbano Zone (IVZ) in northern Italy is a classic lower crustal section that experienced high temperature metamorphism and partial melting (Fig. 1A) in the Permian (e.g. Vavra et al. 1999). We used thirteen samples of granulite facies metapelites from the IVZ to investigate the robustness of the Zr-in-rutile thermometer under the high temperature conditions that characterise the base of the continental crust. Although resetting of Zr-in-rutile temperatures to ~750–800 ºC occurred in some grains from each sample, most samples also preserve a record of peak metamorphic conditions of ³900 ºC. These temperatures are consistent with the observed mineral assemblage (Luvizotto and Zack, 2009) and the high degree of melt extraction experienced by the metapelites (e.g. Demarchi et al. 1998). The base of the metapelite sequence has been intruded by voluminous mantle-derived magmatic rocks. Narrow slivers of metapelite incorporated into this gabbro (Fig. 1B) have peak Zr-in-rutile temperatures in excess of 1000 ºC. The strong thermal overprint associated with the intrusion of the gabbro is not recorded by any other thermometer, including the Ti-in-zircon and Fe–Mg thermometers.

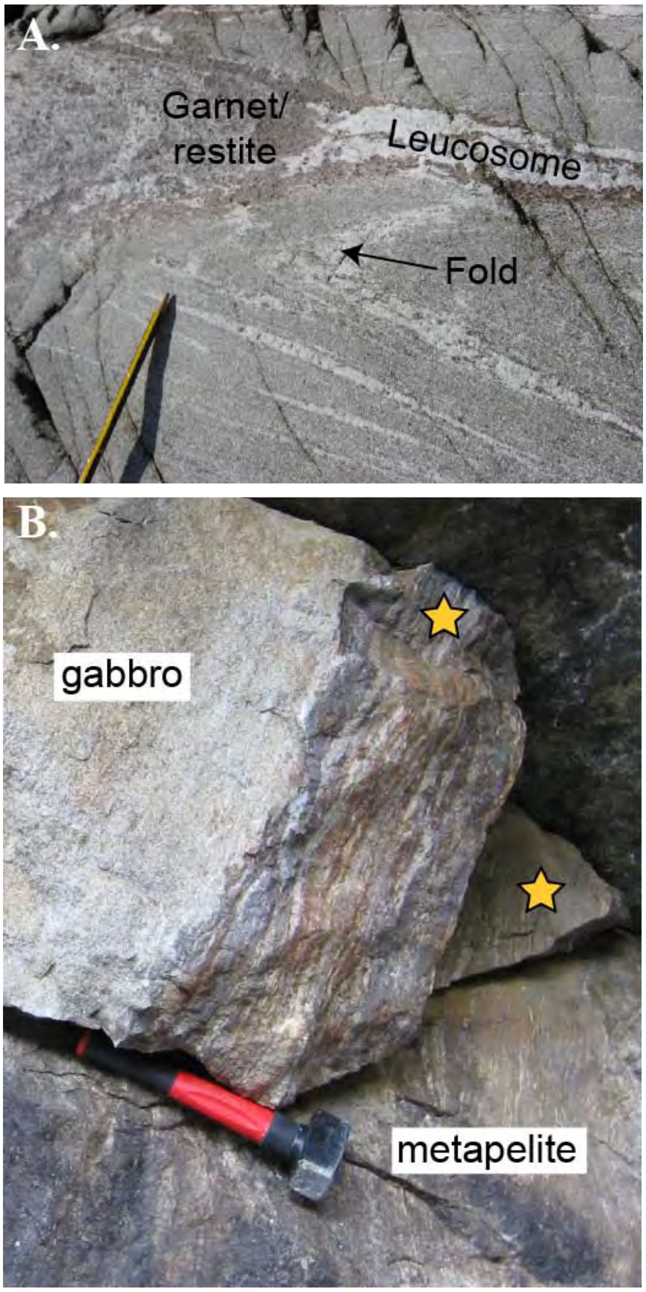

Figure 1. Sampled granulite facies metapelites from the IVZ in the field. (A) Sample locality in the main metapelitic sequence. Abundant leucosome (white) testifies to significant partial melting under high temperature conditions. (B) ~1 m thick sliver of metapelite incorporated into gabbro, with the location of two samples marked by stars.

The robustness of the Zr-in-rutile thermometer in the IVZ is demonstrated by the high peak temperatures recorded, and their consistency with the geological setting of each sample. In the IVZ, Zr-in-rutile thermometry provides the best constraints on peak thermal conditions. These results demonstrate that the Zr-in-rutile thermometer is an important tool for constraining the thermal evolution of the lower crust.

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Rapid crustal recycling from magma to mud to magma

zircon O isotopes from the early Permian S-type granites in the New England Orogen

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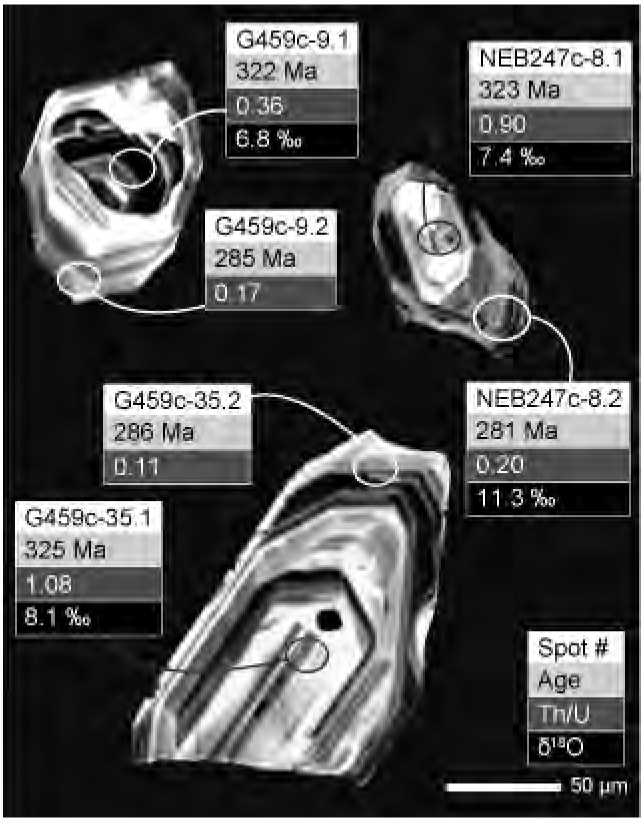

Figure 1. Cathodoluminescence images of typical Carboniferous inherited zircon cores mantled by a melt-precipitated rim. Their ages, Th/U ratios and $\delta^{18}O_{zrn}$ values are shown.

Early Permian S-type monzogranites of the Bundarra and Hillgrove supersuites, New England Orogen, eastern Australia, have chemical and isotopic compositions indicative of a young, weathered, volcanogenic sedimentary source. Based on their low $^{87}Sr/^{86}Sr$ ratios, it was argued that deposition, burial and partial melting of a volcanogenic source to form the granite magmas must have occurred rapidly. We have tested it by determining the ages and oxygen isotopic compositions of inherited source-rock zircon (distinguished from melt-precipitated zircon by its oxygen isotopic composition) from four plutons of the two supersuites, and hence the maximum likely time interval between deposition of the source rocks and their magmatic re-processing. We have confirmed that the source of those granites was dominated by weathered igneous components and demonstrated that the youngest of those components is little older than the granites themselves, indicating exceptionally rapid crustal recycling near the eastern Gondwana margin in the late Carboniferous to early Permian.

All of the analysed zircon is regarded as magmatic: both the melt-precipitated component and the older cores inherited from the source rocks. The former occurred in two modes, an early phase as cores and a later phase as overgrowths. These three components were clearly distinguishable by zoning features, age, Th/U ratios and O isotopic compositions.

High $\delta^{18}O_{zrn}$ values of melt-precipitated zircon (~ 11.5‰) confirm that the high granite $\delta^{18}O_{WR}$ values are a primary magmatic feature. Abundant inherited detrital zircon cores with a range of dates (360–300 Ma) and distinctly lower $\delta^{18}O_{zrn}$ values (~ 5–10‰) were derived from mostly young (Carboniferous) volcanogenic rocks that became less primitive with time. The age difference between the youngest inherited zircon population and the oldest melt-precipitated zircon is ~ 15 Ma. An arc-related volcanogenic sedimentary pile built up over about 50 Ma was weathered, buried, and partially melted, producing voluminous peraluminous magmas (i.e. magma to mud to magma), within ~ 15 Ma of the youngest source sediment being deposited. The short time intervals involved demonstrate the rapidity with which the "Rock Cycle" from igneous to sedimentary to metamorphic to igneous rock can occur.

Measuring these small time intervals (distinguishing the extremely rapid crustal recycling) would not have been possible without the use of micro-scale, in situ O isotopic fingerprinting, particularly in rocks as old as Palaeozoic.

Geochemistry of UHP melting

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The gneisses of the Kokchetav metamorphic complex were depleted in several major and trace elements during partial melting (Shatsky et al., 1999). We examined the major and trace element compositions of the metapelitic UHP and non-UHP samples from the Barchi Kol’ area. The composition of the UHP gneisses is interpreted in the light of experimental studies and provides constraints on the melting history, mineral assemblage during melting and efficiency of melt extraction.

The Kokchetav UHP gneisses that underwent melting are depleted in K_2O and enriched in TiO_2, FeO, MgO and MnO with respect to their protolith. LREE, Th and U are also strongly depleted (50-98 %). Concentrations of HFSE (Zr, Hf, Nb) and LILE (Rb, Cs, Sr with exception of Ba) are generally similar in UHP and non–UHP rocks. Whereas in the protolith of the UHP gneisses, LREE, Th and U are mostly concentrated in monazite, this mineral is very rare in the UHP gneisses. Gneisses with strong depletion in LREE (<10 ppm) have very low Th/U<0.6, while in semi-depleted samples (10 ppm<LREE>60 ppm) Th/U is 1.6-6, close to the value of the non UHP rocks (4-6).

A net loss of 10-40 % of melt from UHP gneisses is estimated from the depletion of elements that are abundant in granitic magmas (K) and the enrichment in incompatible elements (Fe, Mg, Mn and Ti). The efficiency of the melt extraction can be estimated from the residual fraction of LREE: assuming complete dissolution of monazite/allanite in the melt, 98-50 % of the melt produced during peak metamorphism was eventually extracted. The amount of melt loss and the efficiency of melt extraction are not correlated.

During UHP melting, the mineral assemblage of gneisses was Grt, Coe, Phe, ±Cpx, Rt and Zrn. Very low concentrations of LREE in several ultra-depleted UHP gneisses indicate that melt extraction occurred at high temperatures (850-1000 °C) during metamorphic peak conditions, when LREE solubility in melt was high enough for the complete dissolution of monazite/allanite. In contrast, relatively low solubility of rutile and zircon did not change HFSE contents significantly. In the most depleted samples, the main host for Th and U became zircon (which has preference for U), the melt extraction was very efficient and rocks acquired a low Th/U (<0.6).In the least depleted samples, melt extraction was less efficient and the LREE concentration reflects that of the residual melt.

The high temperature extraction of melt can explain the observed concentrations of LREE, Th and U in the Kokchetav gneisses. The melts extracted from metapelites were necessarily rich in LREE and with moderate concentration of HFSE.

Shatsky, V., Jagoutz, E., Sobolev, N., Kozmenko, O., Parkhomenko, V. & Troesch, M. (1999). Geochemistry and age of ultrahigh pressure metamorphic rocks from the Kokchetav massif (Northern Kazakhstan). Contributions To Mineralogy And Petrology, **137**, 185–205.

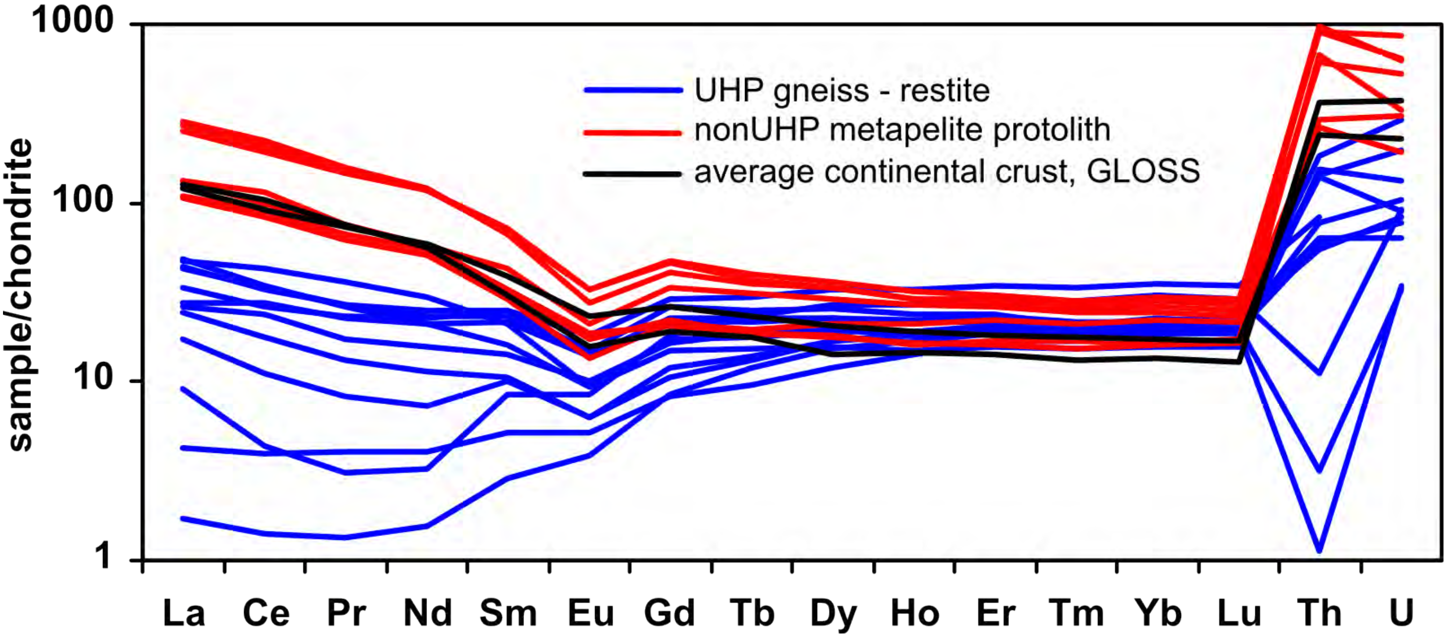

Figure 1. Chondrite normalized REE, Th and U pattern of the bulk rock compositions of UHP gneisses in comparison with non-UHP rocks of the Kokchetav complex and estimates of the average upper continental crust composition.

How variable is the oxygen isotopic composition of the upper mantle?

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Oxygen is a major constituent of the Earth comprising ~50% of the minerals that make up the Earth's mantle and crust. Geochemists have been increasingly finding that the mantle is heterogeneous on all scales of examination, from greater than 1000 km to less than 1 cm, for a range of trace element isotopic systems including Rb-Sr, Sm-Nd, U-Pb, and Re-Os. The oxygen isotopic composition of the upper mantle, however, is generally considered to be well known and relatively invariant (e.g. Chazot et al., 1997; Mattey et al., 1994). This assumption of homogeneity is largely based on the extensive database for mantle melts (i.e. basalts and their phenocrysts), with only a limited number of direct analyses of mantle peridotite available. As part of our studies of the mantle lithosphere of the Southern Ocean we are determining the oxygen isotopic compositions of olivines in mantle peridotites from a range of environments including the Massif du Sud ophiolite (New Caledonia) and mantle xenoliths from Australia, New Zealand and Antarctica.

Analyses are made using the SHRIMP II (sensitive high resolution microprobe) and with San Carlos olivine as the primary standard. This in situ approach allows us to target areas of well preserved olivine even within serpentinised peridotites. Our initial results suggest that the isotopic composition of the upper mantle as recorded in spinel peridotites is more variable than previously suggested. As variations in oxygen isotopic compositions are generated by low temperature, typically near-surface fractionation processes, oxygen isotopic differences in olivines may reflect regions of large scale fluid ingress into the mantle. As such, when used in conjunction with radiogenic isotope data, oxygen isotope data may provide new views of the timing and scale of fluid exchange between crust and mantle.

Chazot, G., Lowry, D., Menzies, M. and Mattey, D., 1997. Oxygen isotopic composition of hydrous and anhydrous mantle peridotites. Geochimica et Cosmochimica Acta, 61(1): 161-169.
Mattey, D., Lowry, D. and Macpherson, C., 1994. Oxygen isotope composition of mantle peridotite. Earth and Planetary Science Letters, 128(3-4): 231-241.

Figure 1. Partially serpentinised olivine phenocryst from the Massif du Sud New Caledonia in transmitted (left) and reflected light (right). Two SHRIMP analysis spots (30 micron diameter) are visible on the right panel.

Timing of the closure of the ancient Tethys Ocean that separated Eurasia and Gondwana

Figure 1. The Indus Suture Zone marks the supposed deep suture between Eurasia and India. Analysis of data must be done at all scales within a structural framework.

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Our understanding of Plate Tectonics has continued to advance since the late 1960s, in particular with knowledge of what is happening beneath the surface. Data from seismology and tomography provides 3D views 100 - 1000 km below the Earths' surface. But to understand plate tectonic movements and processes we also need to understand the timing of major events. In this aspect what the rocks have to tell us is of vital importance, although we must learn how to extrapolate information gleaned on the micro-scale to constrain different hypotheses as to how large-scale tectonic movements take place. This is the intent of the "Closing Tethys" project recently funded by the Australian Research Council.

The best places to work to collect data that time critical events during the closure of the ancient Tethys Ocean are in the exhumed roots of mountain belts that mark the effects of collision. Of particular interest are deep cutting suture zones with ductile deformation and rocks that have been at pressure and temperature of the deep crust or mantle rocks have been brought to the surface, and thus in the "accessible crust" provide a long history of information. These key locations are "orogenic listening posts" that sensitively record the effects of events during closure of Tethys. We have chosen five such, spread over a distance of ~12,000km along the northern boundary of this ancient ocean.

Dating sequences of events that record effects related to the movement of the plates can be done by dating the ductile fabrics that form as the plate moves and deforms. We can sample critical locations, and interrogate suitable rocks as to when events took place in locations such as the high-pressure belts of Greece and Turkey, the deep sutures of the Himalaya or the early high-pressure rocks beneath obducted sheets in SE Asia. In this aspect the argon isotopic system is the key geochronological tool at our disposal, providing information that allows constraints as to the nature and origin of the geodynamic processes involved in forming and/or modifying specific fabrics, as well as absolute timing and duration constraints in the relative chronology of events in a specific region.

Argon geochronology is the only geochronometer that allows direct dating of common rock forming minerals in fabrics. Therefore it has been the geochronometer of choice in this work, and it will continue to be used to date events in key locations along the Tethyan belt. There is an additional advantage in using the argon geochronometer, since we can engage in geospeedometry to determine how long individual rocks endured peak conditions, *e.g.*, we can tell how long a particular ductile shear zone operated by dating different elements of its microstructure, or we can place a limit on the maximum duration of heating during individual metamorphic events.

Figure 2. The Himalaya orogeny making a collisional zone between Eurasia and India> The ancient 'Tethys Ocean' now lies fragmented along this belt.

The redox evolution of ancient Australian Oceans

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Neoproterozoic oceans (1,000 -542 Million years ago) were transitioning from an anoxic and/or euxinic (anoxic and sulfidic) ocean to one more oxygenated. Complex organisms were also evolving in these oceans, with the first appearance of animal fossils in the geological record. We seek to gain an understanding of the relationships between biogeochemical cycles occurring in Australian Neoproterozoic oceans and the evolution of organisms that inhabit them by studying both inorganic and organic proxies.

The speciation of Iron is a powerful paleo-redox proxy which can identify anoxic, oxic and euxinic conditions. We are currently setting up a new iron speciation laboratory and anticipate to be analyzing Australian samples early in 2012. Analysis of Australian samples from the Wallara-1 drillcore, central Australia was conducted with Dr Poulton at the Newcastle University, Newcastle Upon Tyne, UK.

Our preliminary results indicate that the oceans were dominantly ferruginous (iron rich) though not sulfidic in the Neoproterozoic of Australia. Our data also shows oxygenation occurring almost immediately after the Sturtian Glaciation. This is much earlier than previously reported and is a potentially very exciting result. Future work will consist of normalising the data against aluminium to remove any potential biases of lithology. We are also in the process of sampling and analysing more samples from across Australia to obtain a larger database of spatial and temporal Neoproterozoic ocean chemistry.

Yo-Yo subduction recorded by accessory minerals in the Sesia Zone, Western Alps

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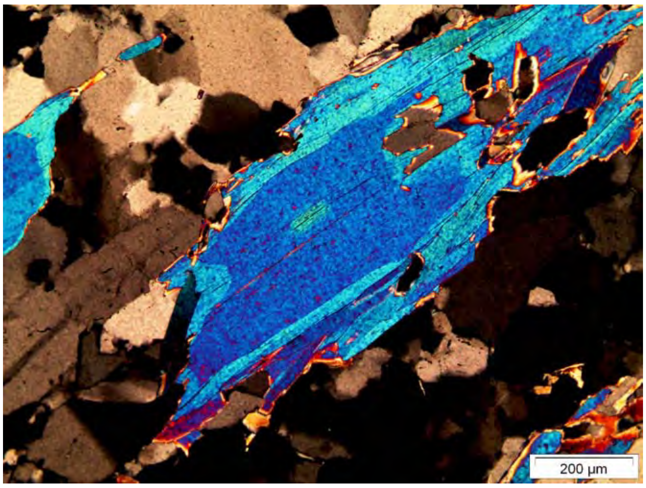

Figure 1. Photomicrograph of zoned phengite grains (crossed polarizer) that testify to Yo-Yo subduction, i.e. two distinct episodes of high-pressure metamorphism separated by a low-pressure event.

The high-pressure rocks eclogite and blueschist form during subduction of the Earth’s crust to mantle depths at convergent plate margins. Previous studies of such rocks have documented single cycles of fast burial and exhumation during subduction. This contrasts with the complex dynamics suggested by tectonic models that predict multiple subduction cycles of individual rock units.

We investigated the microstructures, chemical composition and U-Pb age (SHRIMP ion microprobe) of multiple generations of metamorphic minerals in eclogite-facies rocks from the Sesia Zone in the Italian Western Alps. The minerals white mica, garnet, allanite and zircon each exhibit multiple generations of overgrowths. The pressure-dependent variations in the Si-content of white mica, and key trace element signatures of distinct zircon and allanite growth zones allow identification of two distinct episodes of high-pressure metamorphism at ~79-75 Ma and 70-65 Ma, separated by a short lived exhumation.

This study provides evidence that crustal slices of the Sesia Zone experienced two cycles of burial to mantle depths in less than 20 million years. The observations from the micro- and meso-scale can be linked to Cretaceous plate motions and plate margin geometry through ages, and indicates that oblique convergence involving a distal continental margin was responsible for this Yo-Yo subduction.

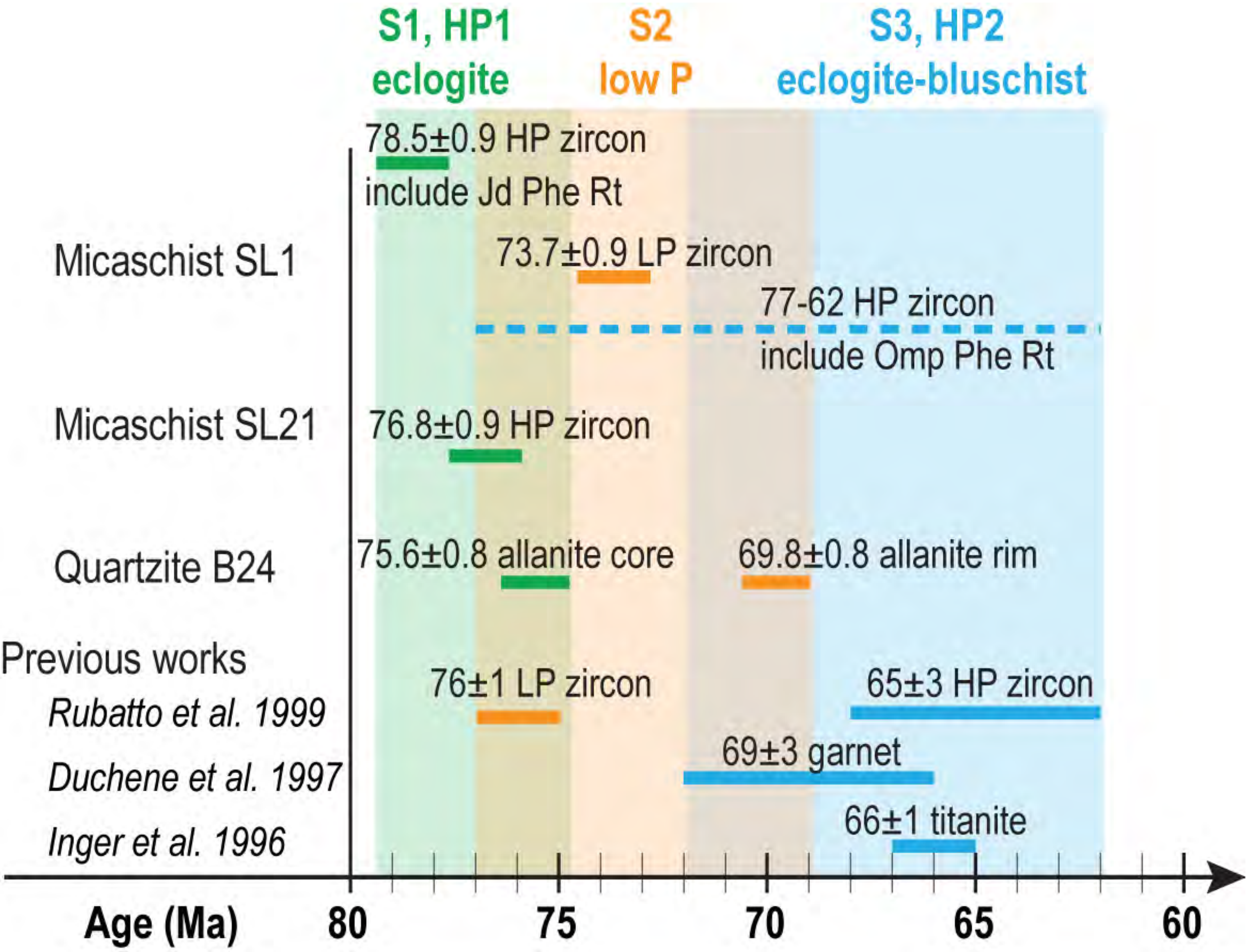

Figure 2. Summary of ages for the Sesia high-pressure unit from this study and previous works. This chronology indicates a subduction-exhumation-subduction cycle within 15 Ma.

Research Activities 2011

Earth Environment

Introduction

In 2011, we welcomed four new staff members. Dr A. Abrajevitch and Dr. D. Heslop joined the palaeomagnetics group of Prof. A. Roberts, Dr. M. Davies will work with Profs A. Roberts and P. De Deckker on new dating methods on marine cores together with Prof. L.K. Fifield (Nuclear Physics, RSPSE), and Dr. N. Abram joins Dr. M. Gagan to work on isotopic fingerprinting of natural disasters. We are very pleased to announce that Dr. J. Yu, presently at Lamont Doherty Observatory, has accepted a position at RSES and will join Dr S. Eggins and Dr. M. Ellwood to investigate new isotopic proxies to understand the interaction between climate change and ocean chemistry. He will take up his position in 2012.

Five new PhD students joined Earth Environment in 2011: Ms C. Krause to work under the supervision of Dr. M. Gagan, Mr S. Meyerink and Ms M. Samanta to work with Dr. M. Ellwood, Mr M. Willmes with Prof. R. Grün, and Mr B. Wang with Dr. D.C. McPhail.

Two of our PhD students submitted their theses: Ms J. Sutton, supervised by Dr M. Ellwood, on germanium/silicon and silicon isotope fractionation by marine diatoms and sponges and utility as tracers of silicic acid utilization, and Ms S. Lewis, supervised by Dr S. Eggins, on climatic influences on stable water isotope variability in palaeo-precipitation.

ARC grants awarded for funding beginning in 2011 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. N. Abram was funded to investigate how climate change, great earthquakes, and volcanic disasters pose risks for environmental, economic, and social harm in rapidly developing Australasia. Prof. P. De Deckker will establish pre-industrial baselines for sea surface temperatures over the last millennium for the Australian region and provide data of importance to global climatology and oceanography that precede instrumental records. Dr S. Eggins will investigate the effect of ocean acidification and climate change on Southern Ocean planktic foraminifers. The results of controlled culture experiments will be compared to recent marine records. Dr. M. Ellwood will determine the role iron plays in influencing phytoplankton growth, which ultimately regulates the drawdown of carbon dioxide by the oceans. Prof. R. Grün will reconstruct the migrations of prehistoric populations through direct dating and isotopic tracking of their mobility patterns. Prof. A. Roberts will study the magnetism of dust deposits in marine sediments to understand how Australian dust influences climate in order to better predict the influence of humans on future climate.

In 2011, Dr. D. Heslop was successful in obtaining ARC funding beginning in 2012 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.

The high research profile of Earth Environment is documented by the numerous publications in world leading journals such as Geochimica et Cosmochimica Acta, Earth and Planetary Science Letters and Quaternary Science Reviews.

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 2011 research activities were possible without our dedicated technical staff, Mr. J. Cali, Mrs. J Cowley, Mr. L. Kinsley, Mrs. L. McMorrow, Dr. G. Mortimer, Mrs. H. Scott-Gagan, and Mrs J. Shelley. A number of casual staff have also assisted our research efforts. I am particularly grateful to our Area Administrator, Mrs. R. Petch, who always goes the extra mile.

Professor Rainer Grün
Associate Director, Earth Environment

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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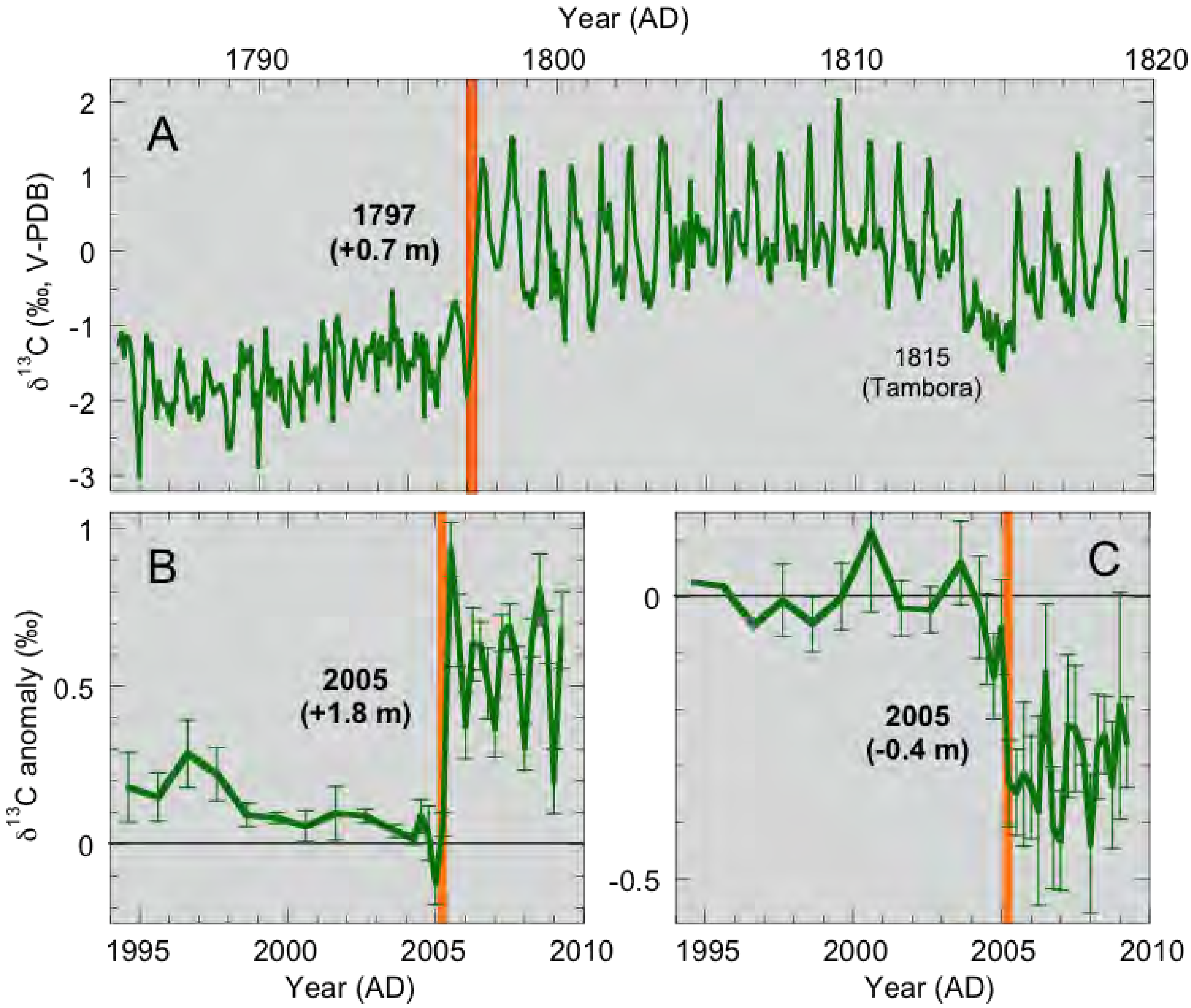

Figure 2. The coral $\delta^{13}C$ response to co-seismic uplift and subsidence. (**A**) Profile of skeletal $\delta^{13}C$ in a *Porites* microatoll from Sipora Island, Mentawai Island group. The record shows a sharp increase in $\delta^{13}C$ marking co-seismic uplift of 0.7 m during the M_w 8.7-8.9 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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Dramatic Vegetation Changes on the Island of Flores 71,000 years ago

Did the Toba super-eruption cause widespread vegetation and ecosystem collapse on the island of Flores, or should we be looking at a much closer source?

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The Toba super-eruption, 71,000 years ago, is the largest known Quaternary eruption, erupting 2800km^3 of dense rock equivalent material (Rose & Chesner, 1990) over 280 times bigger than the 1992 Pinatubo eruption. The eruption spread ash from the eruption site in North-western Sumatra as far as the Arabian Peninsula in the west, and the South China Sea in the east. Yet the climatic impacts of the eruption are hard to discern as the eruption occurred during a period of rapid cooling in the earth's history. To what extent did the volcano contribute to this cooling is hotly contested with much of the debate centred over correlation versus causation (Rampino & Self 1992, Oppenheimer 2002). The global impact of the Toba super-eruption should be built up from a mosaic of evidence from multiple studies analysing more local impacts.

The island of Flores is located 2700km to the South-east of Toba in the Indonesian archipelago, well outside the currently known limits of ash fall. Much of Flores is karst terrain, containing caves and speleothems (precipitated cave deposits - stalagmites, stalactites and flowstones) that record, through the changing chemistry of each precipitating layer, fluctuating conditions in the precipitating environment. With volcanic sulphate introduced to the cave system through dissolution in rain and then groundwater, the concentration of sulphate in speleothems serves as a proxy for volcanic activity. By analysing the sulphur content of flowstones growing around 71ka we are able to build up a volcanic history of the Indonesia region and pinpoint the Toba eruption. Meanwhile stable isotopes records, also garnered from flowstones and stalagmites, reveal changes in climate. Oxygen isotopes detail regional changes in rainfall patterns while the carbon isotope record highlights changes in the vegetation above the cave, a much more local response to forcing.

The main feature of our results is the massive carbon isotope anomaly (5‰) of long duration, up to 1000 years. Such a carbon anomaly is likely caused by a widespread vegetation change. The positive direction of the change suggests a switch from plants using the C3 photosynthetic pathway (mainly trees) to those using the C4 pathway (such as grasses). Further preliminary evidence not shown here indicates that the vegetation may have been wiped out completely with carbon isotope values approaching bedrock. That the largest change in the carbon isotopes is coincident with the largest sulphate spike in the record (at 70.82ka) implies that the cause of this anomaly could be volcanic in nature. For example an ash fall of just 10cm is sufficient to wipe out all vegetation. A little while later, as the carbon anomaly begins to fall, a second sulphate spike, from a further eruption, triggers a collapse in the recovering vegetation.

Figure 1. Section of flowstone core LR07-G3b used in this study. Piece is approximately 25cm long.

But can we attribute this volcanic event to Toba? After all Flores is located upwind of the Toba ash-fall and is itself a volcanic island. But Toba could have influenced the island in ways other than ash, by altering rainfall patterns or from acid rain destroying the local seed base. The a priori assumption should not be that Toba causes this large anomaly, just because it is coincident.

The sulphate record reveals further evidence. The large step change in the sulphate record at 71.13 years some 300 years before the largest spike, is much more reminiscent of the sulphate spikes that are found in ice cores. Both the carbon and oxygen isotopes rise following this step change, indicating a much more regional or global change in climate. Could it be that this is the Toba eruption, causing widespread change and stressing the local vegetation before a local eruption triggered the ecosystem collapse.

Whether or not this major event in Flores' history can be attributed to the Toba super-eruption, a massive vegetation change on the island, lasting for almost a millennium, is a fascinating story in its own right.

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Rampino, M.R. & Self, S. (1992), *Volcanic winter and accelerated glaciation following the Toba super-eruption*. Nature, vol. 359, p.50.

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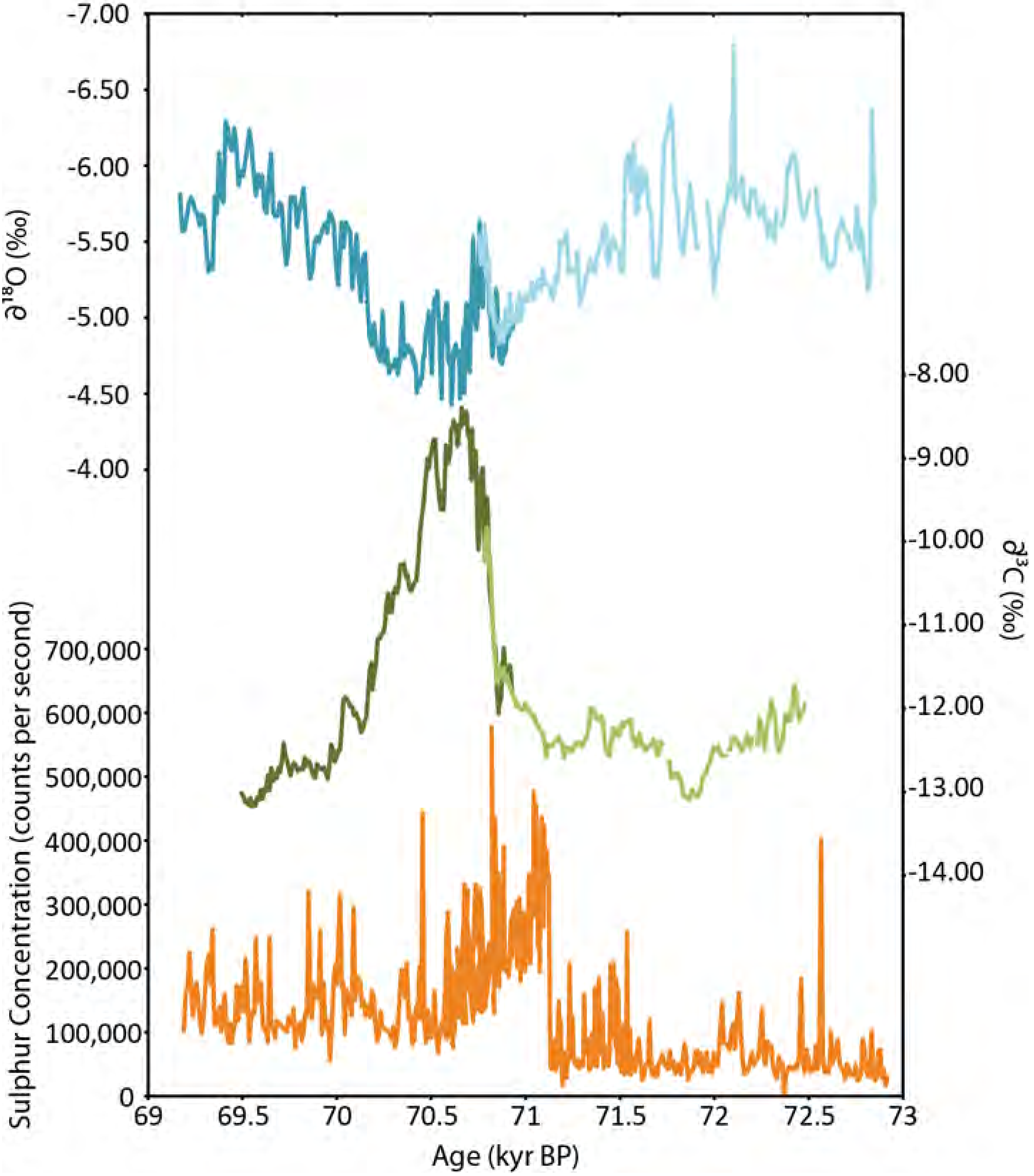

Figure 2. Analysis of approximately 13cm of the flowstone LR07-G3b from Liang Luar, Flores, Indonesia showing Oxygen Isotopes (blue), Carbon isotopes (green) and Sulphur concentration (Orange) through the Toba super-eruption.

Rewriting human evolution with lasers

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At RSES we have developed laser ablation analysis for the rapid assessment of U-series age estimates on bones. While the method can only provide minimum age estimates, it can provide essential new insights into the complexities of human evolution. Let's take, for example, Wadjak man. All scientists agree that the human fossils from Wadjak, which were found in East Java between 1888 and 1890, represent *Homo sapiens* and are large and very robust. They have been with other robust skulls in the region, such as the more ancient Ngandong hominins, and late Pleistocene-early Holocene ones from Australia. Thus far, their age was based on a radiocarbon result of 6,560 ± 140 BP. Based on this Holocene result a number of evolutionary connections were made, e.g. to the Holocene fossils of Keilor. However, the radiocarbon analysis was based on a step heating technique that has provided more or less recent ages when applied to samples that were undoubtedly older than 50,000 years. Applying laser ablation U-series to a fragment of a human, we could establish an age of more than 40,000 years (Figure 1), as actually expected by the excavator Dubois in 1922.

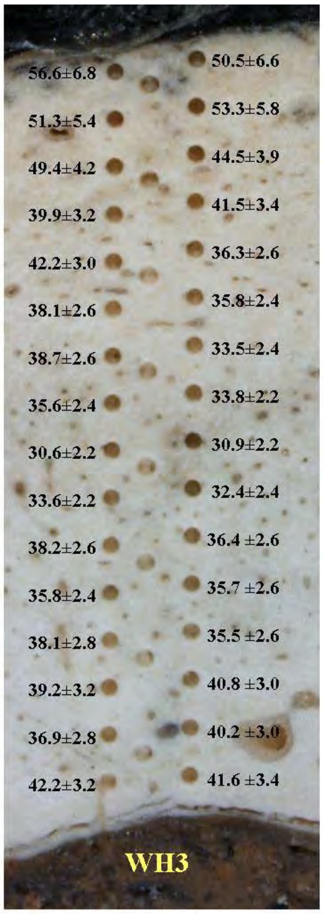

Figure 1. Laser ablation U-series age estimates on a bone of Wadjak Man

From the perspective of time, the role for Wajak as a "Proto-Australian becomes more tenable. As a number of have also seen "Asian" characteristics in the Wajak skulls, an interesting question arises: "how old is the Asian face, and where did it originate?". Because of the new dating results from Wajak, Indonesia may contribute to the answer. Moreover, a Pleistocene age for the Wajak human fossils means that they are also relevant to the ongoing debate about the age and fate of the Ngandong humans, the status of the Liang Bua *Homo floresiensis* remains, and new evidence of archaic gene flow into recent Melanesian populations.

Climatic and natural hazards in southern Australasia

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Figure 1. Collecting a drill core from a fossil coral block in southern Sumatra. In this region massive coral colonies are raised out of the ocean during large earthquakes and tsunamis, provideing a unique opportunity to develop palaeoenvironmental histories extending back thousands of years. Photo courtesy of Gavin Dunbar.

A new 5-year research project funded by the Australian Research Council has started this year in the Earth Environment group of RSES. This research program is designed to reconstruct the history of catastrophic droughts, great earthquakes and volcanic disasters in southern Australasia to more fully understand their ongoing impacts on human history. The research, which draws together a team of experts from around the world, will address three major questions:

- What is the history of Indian Ocean Dipole rainfall extremes, and what perspective does this give to recent strengthening (Abram et al., 2008) of the Indian Ocean Dipole?
- How often do great-earthquakes occur in Sumatra, and are there recurrent precursors to these devastating seismic events?
- Did the Toba super-eruption alter global climate and early human dispersal through Australasia?

To answer these questions we will be developing environmental reconstructions from a vast array of speleothem and coral archives from southern Sumatra (Fig. 1), and using state of the art general circulation models to test the physical processes controlling climate changes in the past. Work is already underway to map out the zone of maximum Indian Ocean Dipole variability and to generate a near-continuous baseline of IOD climate variability extending back 1000 years. Coral geoechemistry is also being developed as a new tool for reconstructing the history of great earthquakes along the Sumatran subduction zone (Gagan et al., 2011). Speleothems from southern Sumatra will be used to develop a continuous millennial-scale history of changing rainfall in the Indian Ocean Dipole region to complement the high-resolution windows obtained from coral records. The novel use of speleothem isotope and trace element chemistry will also track the climatic and landscape impacts of large eruptions on the Indonesian archipelago, including the ~74 ka Toba super eruption.

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A record of 300 years of sea-surface temperatures from the Tasman Sea

Past oceanic temperatures in the Australian region

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Figure 1. Photograph of the SS2011-T04 team, in front of the multicorer, that includes the ANU-Bordeaux-Indiana State University group and the MNF science crew. From left to right are: Patrick De Deckker, Tara Martin [MNF], Sabine Schmidt. Alicia Navidad [MNF], Lindsay Macdonald [MNF], Rebecca Kaye, Ashley Burkett, Lyndsay Dean, Marita Smith, Maureen Davies, Chris Munday, Lindsay Pender [MNF], Graham Nash, and Sam Eggins. Six students are members of this team

Our project aims at generating high-resolution records of sea-surface temperature [SST] changes that occurred the oceans surrounding Australia over the last few centuries. We had 2 voyages in 2011 on the Australian Marine National Facility RV Southern Surveyor , with the first one in May in the Tasman Sea [cruise SS2011-T01, from Hobart to Brisbane], whereas voyage 2 did cover the ocean south of Australia [going from Fremantle to Hobart [SS2011-T04 in November 2011]. A variety of innovative proxies are being employed on the samples we collected and will be used for comparison with lake records on mainland Australia. Our objectives are to obtain short cores along the Australian coastline, at approximately 1,000 m water depth, across a broad temperature gradient. The innovation is to use 3 different organic biomarkers [Uk37, TEX86 and DIX] that can be used to reconsruct past SST, backed up with a sound chronology done by Dr Sabihe Schmidt in Bordeaux.

Figure 2. Photograph showing the multicorer being fixed to the rear deck after returning with sediment in the tubes. The sediment-water interface is clearly visible in several of the tubes. The sediments were sliced into half centimetre layers to be analysed for a variety of purposes [SST proxies, dating, sediment properties, coccoliths, foraminifers and stable isotopes, pollen, charcoal].

Preliminary results from the Tasman Sea cruise show that, for the last 300 years, SSTs did not increase uniformly as predicted by the Hockey Stick curve of Mann et al., (2008) but that there are areas of unchanged SST offshore southern Queensland whereas, further south, the last 50 years saw a variety of SST changes, some going up, others going down.

Figure 3. Photograph showing the multicorer being fixed to the rear deck after returning with sediment in the tubes. The sediment-water interface is clearly visible in several of the tubes. The sediments were sliced in half centimeter intervals for a variety of analyses.

The composition of Australian aeorosols

Geochemical and microbiological fingerprinting of Australian airborne dust

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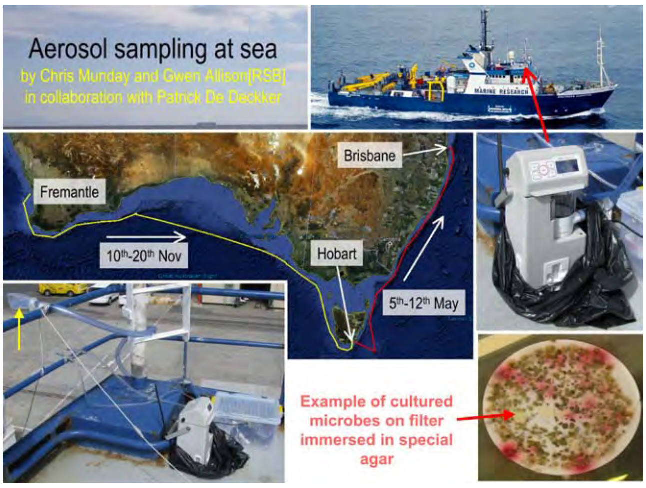

Figure 1. Photographs showing on top right th RV Southern Surveyor and below the air sampler that was placed above the bridge at the ship. Below shows the itinerary of both voyages held in 2011 during which time we also cored the sea floor for sea-surface temperature reconstructions. At bottom left are the pictures of the air sampler and filter from which Chris Munday grew microbes on an agar plate before DNA sequencing.

This year, we had an extensive field trip to central Australia to collect dust in source areas. Locations such as salt lakes, their margins, where groundwater seeps and 'fluffy' evaporative sediments are produced, and dune fields. Samples were specifically targeted for their grain size and inorganic chemical composition, as well as their microbiological composition. Mr Chris Munday and Dr Gwen Allison concentrated on collecting the microflora that is being analysed at ANU by extracting the DNA from growth culture for eventual microbe identification. Sedimentological investigations are currently being carried out at NIOZ by Dr Stuut and the inorganic chemical analyses are being done at RSES in collaboration with Dr Marc Norman. Prof. Tapper gathered a lot of meteorological parameters while we flew at different altitudes above the arid landscape, east of the Flinders Ranges and up to Lake Eyre, and during which time Chris Munday deployed an aeorosol sampler to collect microbes from the air. Prof. Tapper will provide the meteorological data for correlation with the microbial counts and identifications.

On two occasions this year, Chris Munday together with Patrick De Deckker also spent time on the CSIRO ship Southern Surveyor, once in the Tasman Sea on a voyage between Hobart and Brisbane, and a second one in the eastern Indian Ocean between Fremantle and Hobart, and deployed the same aerosol sampler used on the plane to extract microbes from the top of the ship. Results from those analyses are pending.

Coralline red algae record historical mining activity in New Caledonia.

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[2] Institut de Recherche pour le Développement, Nouméa, New Caledonia

Mining in New Caledonia has been a major economic activity since the end of the 19th century. From the early 1960s to the late 1970s, nickel-extraction mining has taken place in the Coulée River region, in the vicinity of the French island's main city, Nouméa. We analysed three, 8- to 10-cm diameter rhodoliths (coralline red algae nodules) from the Ricaudy Reef, located in one of the bays surrounding Nouméa. The rhodoliths were dated by radiocarbon, in combination with growth band counting and Mg/Ca cycles and are up to 42-46 years-old. Major and trace elements composition was determined using Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA.ICP-MS).

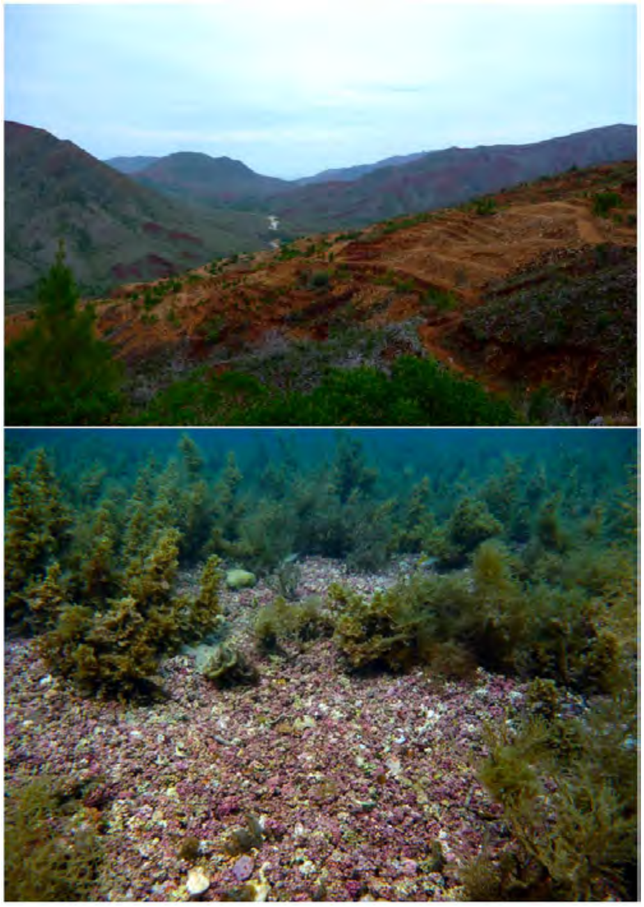

Figure 1. From the mine to the lagoon. Top: The terraces of the former Olympia nickel-mine (now being revegetated) overlook the Coulee River as a glimpse of the New Caledonian SW lagoon appears in the background. Bottom: Rhodolith bed on the edge of the Ricaudy Reef, 4-m deep and ~2 km from the Coulee rivermouth.

Results show that the influence of mining activity in the Coulée River region is recorded in the coralline red algae's high-Mg calcite skeleton through higher Mn, Fe and Ni concentrations. Both Mn and Fe display similar trends as the intensity of mining production over the 1963-1976 period. The variations in Ni concentrations are better correlated to the Ni content of the extracted material. Based on the Ni results, two stages in the mining production can be distinguished. The first one, corresponding to the early period of industrial mining in the late 1960s, is characterised by higher Ni concentrations in the extracted material (saprolite layers), and the second one being the peak of mining production, ~1970, when a material poorer in Ni was excavated but in higher quantities (laterite layers).

After the mining activity stopped in 1981, the concentrations of Mn, Fe and Ni in the rhodoliths decreased but remained high for more than 10 years before reaching their modern-day values. This work shows that tropical coralline red algae can be used as reliable archives of past environmental pollution in coastal waters.

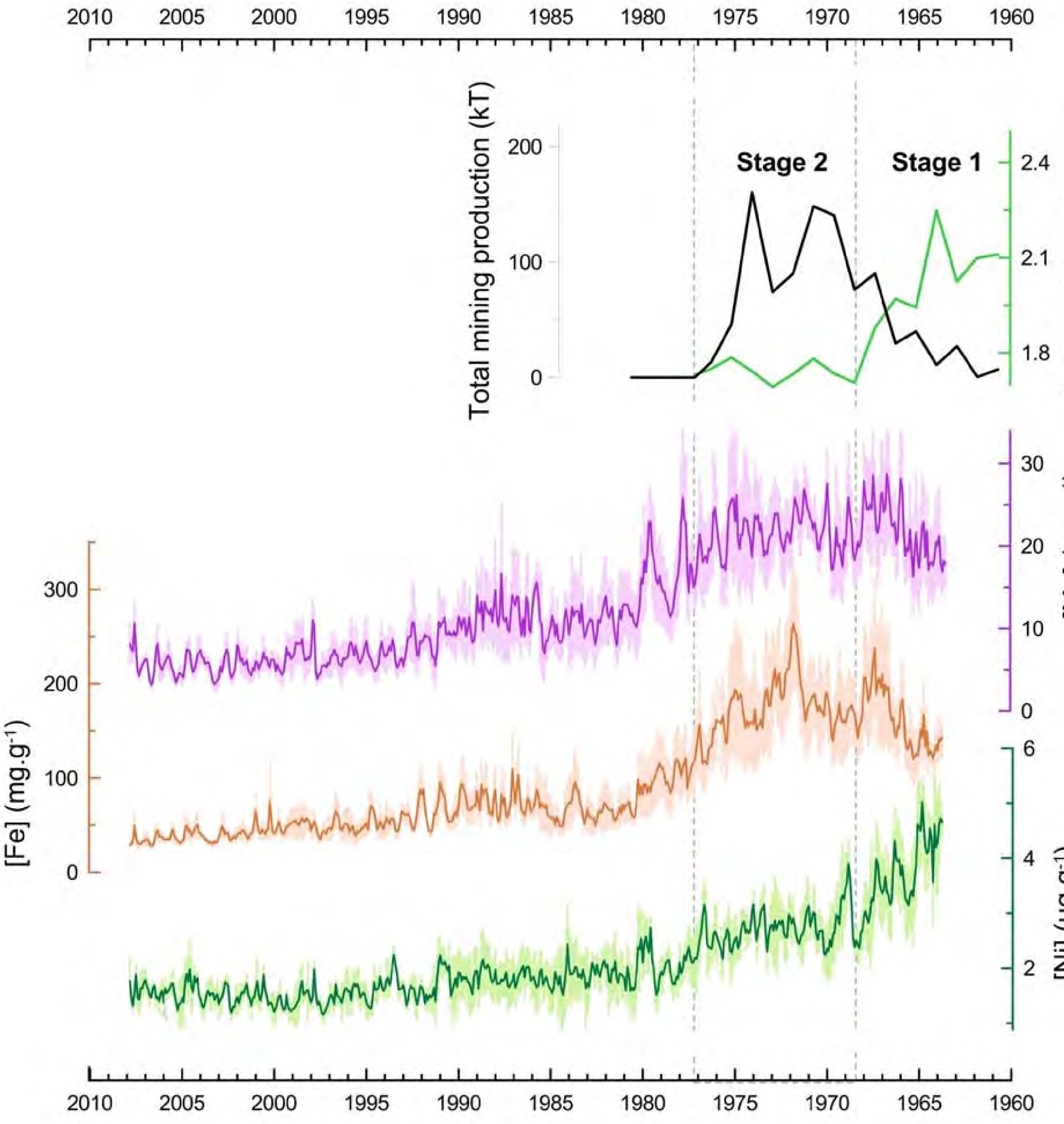

Figure 2. Average concentration of Mn, Fe and Ni in the rhodoliths for the 1962-2008 period (thick lines - shaded areas are $2\sigma_M$ - n=5), compared to the total mining activity (black line) and the nickel content of the extracted material (green line) for the 1960-1976 period.

“Unmixing” Magnetic Mixtures

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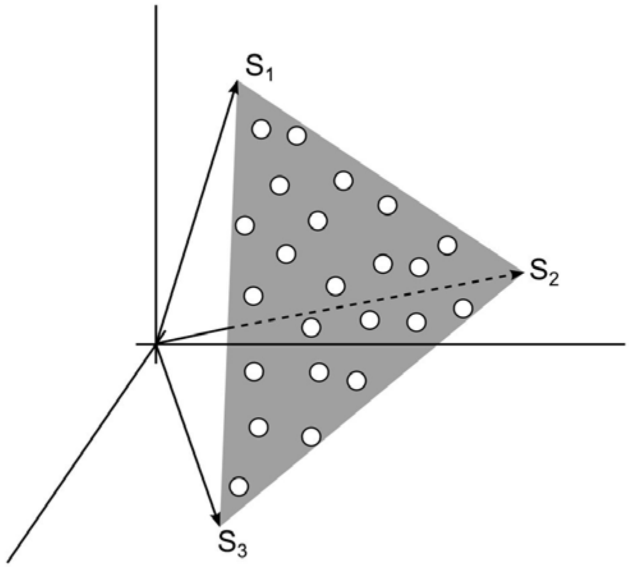

Figure 1. Illustration of a 3 component mixing model. The sample observations (open symbols) are projected into a low dimensional space and are enclosed by a simplex (shaded) that acts as an empirically determined mixing space. The positions of the corners of the simplex (S_1, S_2 and S_3) correspond to the compositions of the components that make up the observations within the mixing space. The position of a given sample within the simplex defines the proportions in which S_1, S_2 and S_3 must be mixed together to provide a best-fit representation of that sample.

Most sediments contain a mixture of different magnetic minerals that may be fluvial, aeolian, biological or authigenic in origin. When analysed in the laboratory, such sediments produce a mixed signal, averaged over the whole magnetic mineral assemblage. Such averaged information makes the extraction of process-specific information, which can be employed in environmental reconstructions, a challenge. We have developed a new approach to separating such magnetic information into a collection of parts, where each part corresponds to the contribution of magnetic minerals from a single origin. This quantitative analysis therefore focuses on characterization of processes that control the composition of a magnetic mineral assemblage.

The developed inversion method is geometric in nature and based on the fundamentals of linear mixing theory. Mixing theory tells us a collection of samples that contains *n* different magnetic components can be represented fully in *n*-1 dimensional space, irrespective of how many different magnetic minerals are contained within the sediment. Additionally, if we can enclose the positions of the samples in the *n*-1 dimensional space within a simplex (where a 2D simplex is a triangle, a 3D simplex is a tetrahedron, etc.), the corners of the simplex will correspond to the compositions of the *n* different magnetic components. In turn, the position of any sample within the simplex tells us in what proportions the different magnetic components are present in that sample (Figure 1).

The unmixing concept is simple to state but difficult to apply because for any data set there exists an infinite number of simplex mixing models that explain the observations. We therefore constrain the simplex further to ensure that the mixing model is not only mathematically possible but also geologically feasible. This is done by finding the smallest volume simplex that encloses all of the data points. Thus, the corners of the simplex are positioned close to the observations and we can assume that they represent geologically reasonable compositions.

We have applied our new approach to a variety of different sample sets, including marine and lake sediments. This shows that the concept is valid, but it still requires further development to address fundamental questions such as determining the number of components from which a collection of samples is composed. The approach is not limited to magnetic data, but can be applied to any data set that exhibits linear mixing, for example, grain size spectra and elemental compositions.

The Indo-Australian Monsoon of the Last 25 ka: A Continuous Stalagmite Record from Sulawesi, Indonesia

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Figure 1. Sample collection site, Sulawesi, Indonesia.

A number of prominent records of the Asian Monsoon over the last 100 000 years have been published for the Northern Hemisphere, however, there remains a large gap in our understanding of the southern counterpart of the Asian Monsoon, referred to here as the Indo-Australian Monsoon. We have developed a continuous paleo-monsoon record from southwest Sulawesi, Indonesia, spanning the period 25 000 years to present. We have used a stalagmite, collected in Indonesia (fig 1), and analysed the isotopic composition of the calcium carbonate ($\delta^{18}O$) along the central growth axis, to give us an indication of the amount of rainfall that fell in this region at 50 year intervals, over the last 25 000 years. This site is in a key location to document changes in Austral-summer monsoon rainfall, as well as tracking north-south migrations of the inter-tropical convergence zone. This new record documents a strong intensification of the Indo-Australian monsoon through the deglaciation that lags the warming of tropical sea surface temperatures and also documents isotopic changes associated with the flooding of the Sunda Shelf. Millennial-scale variability in this new record also allows for an examination of how northern hemisphere climate events propagate through the tropics and into the southern hemisphere.

The World Heritage *Fragum* Shell Ridges of Shark Bay

Pebble Ridge Morphologies Constructed from the Hydraulic Equivalent of Coarse Sand

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Figure 1. Present-day beach ridge composed of shells of *Fragum erugatum*. Note evidence of recent wave erosion. Hamelin Pool, Shark Bay.

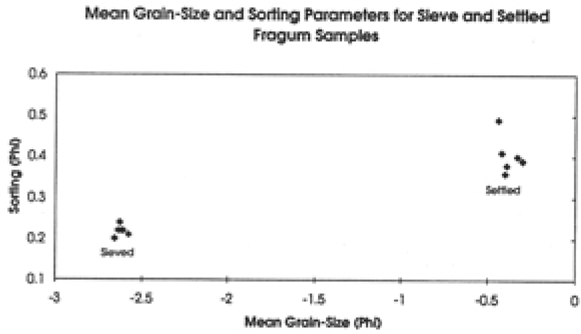

Figure 2. Comparison of the mechanical and hydraulic size of disarticulated *Fragum erugatum* shells from a modern Hamelin Pool beach ridge.

Spectacular shell beaches occur around the margins of Lharidon Bight and Hamelin Pool, two embayments of Shark Bay, Western Australia (Teichert 1946). These features of exceptional natural beauty form one of the criteria for the inclusion of Shark Bay on the World Heritage List of the IUCN in 1991. They have developed since the peak of the Holocene transgression, when sea level reached about 2m above its present level in Hamelin Pool. Since 4000 years BP the shell ridges have been increasingly dominated by the remains of the small bivalve *Fragum erugatum* that flourished in the increasingly saline waters of the two embayments (Burne 1992). Percolating rainwater leads to rapid vadose cementation of the shell deposits to form coquinas. These have been locally quarried for building stone. This unusual lithology provides an interesting analogue for the deposition of the productive coquina reservoir rocks of the Lagoa Feia Formation (lower Cretaceous), Campos Basin, offshore Brazil (Sette et al., 2007).

Whilst it is clear that these shell ridges were deposited by waves rather than by aoelian processes (figure 1), their significant relief and steep profile has led some to conclude that they must have formed from marine inundations generated by tropical cyclones (e.g. Nott, 2011).

Many carbonate grains have a hydraulic equivalent size much less than their actual size (Burne 1991). Kench and McLean (1994) have further shown that the mechanical grain–sizes of mixed (size, shape, density and composition) carbonate sediments do not reflect the hydraulic characteristics of carbonate sediment and may lead to inappropriate interpretations of the environmental energy levels required for entrainment, transport and deposition of material. The shell ridges of Shark Bay clearly demonstrate this disparity. Individual *Fragum* shells are very light, but the ridges they construct have steep angles of repose and are reminiscent of storm ridges constructed by pebbles. We therefore undertook experiments to compare the mechanical and hydraulic size distribution of *Fragum* shells that construct the ridges. We found that the sieve diameter of disarticulated Fragum shells averaged ~ -2.6 phi but their average settling diameter was only ~ -0.4 phi (figure 2). Thus, while this material will form ridge structures with an angle of repose of up to 43 degrees, a slope typical of pebble ridges, they will behave hydraulically as though they were grains of coarse sand. The shape of the *Fragum* shells complicates their hydraulic behaviour. In fact, when concave up, they are capable of floating. We conclude from this analysis that the shell ridges of Shark Bay do not require the power of cyclonic waves to form. This conclusion is supported by the fact that shell ridges are not restricted to the embayment heads, but are widely distributed around the shores of Lharidon Bight and Hamelin Pool.

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Seasonal variations in the coral environmental proxies from the southern Great Barrier Reef

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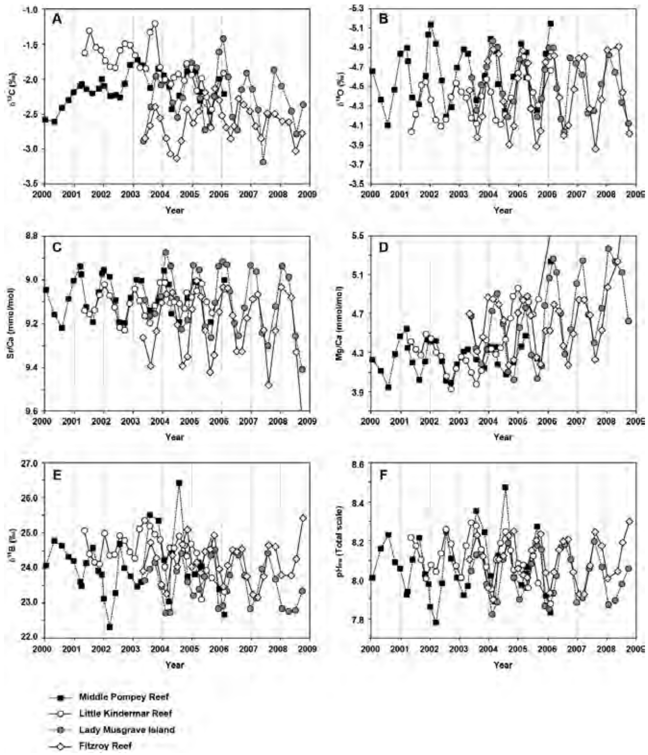

Figure 1. Time series seasonal variation of coral environmental proxies from year 2000 to 2008; (A) carbon and (B) oxygen isotopic compositions, (C) Sr/Ca and (D) Mg/Ca ratios, (E) boron isotopes, and (F) seawater pH. Data from Middle Pompey and Little Kindermar reefs are from January 2000 to February 2006 and samples from Lady Musgrave Island and Fitzroy Reef contain records from June 2003 to September 2008. All data are approximately two-month intervals. Higher than 9.6 mmol/mol of Sr/Ca and 5.5 mmol/mol of Mg/Ca ratio were omitted in (C) and (D). Y axes in (B) and (C) are inverted.

The seasonal temperature and pH records in coral skeleton might help to predict the effects of future global warming and ocean acidification on coral growth due to their large variations. However, only a few data sets have been reported relating to seawater pH. Boron isotopic composition of coral skeleton can preserve the information of seawater pH when and where they have deposited; thus a key for palaeo-seawater pH reconstruction. We have observed multi-proxy coral records including chemical (Sr/Ca and Mg/Ca) and isotopic (O, C, and B) compositions of four *Porites* corals from the southern Great Barrier Reef (GBR). All proxies we measured show clear seasonal variation for five-year observation periods, showing temperature and productivity variations through the year. We also provide the first intra-colony observation of skeletal B isotope compositions and the results suggest there are no significant changes in B isotopic values (~24 ‰ in average) among colonies in the similar environment, which suggests the usefulness of B isotopic composition to reconstruct paleo-pH variations in the ocean.

Nutrient signals in coral cores.

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Figure 1. A slow growing *Porites* coral

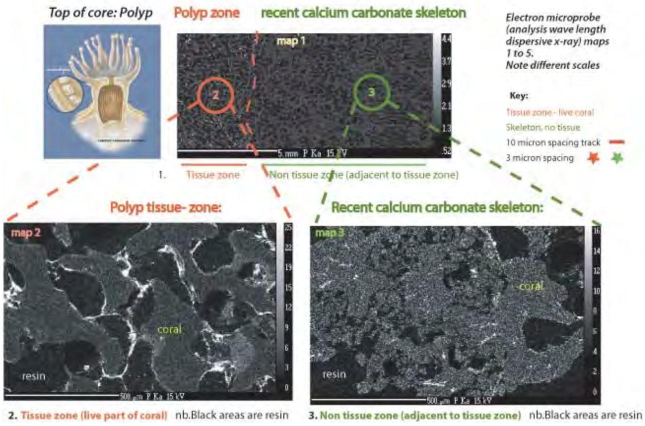

Figure 2. Electron microprobe images mapping phosphorus along a coral core

Increased landbased runoff (e.g. sediments and nutrients) is a major environmental threat that has been linked to deteriorating reef health worldwide. Unfortunately, long-term records of nutrient runoff are limited. As corals are long lived, slow growing, and lay down annual growth rings (like trees) it has been suggested that phosphorus captured in coral skeletons as they grow could provide us with a historical archive of shifting phosphorus levels in seawater (Fig.1). However, how corals (which are part plant and part animal) incorporate phosphorus is poorly understood. In order to investigate this further we used two complimentary techniques: 1) laser ablation inductively coupled plasma mass spectrometry (this is where we use a laser to sample micron sized pieces of coral skeleton and analyse the particles for phosphorus), and 2) X-ray mapping of phosphorus in the skeleton at a micron scale (~3–5 microns) using Electronprobe microanalysis enabling us to create fine scale images (maps) of phosphorus along the coral Skelton.

As corals grow they deposit a calcium carbonate skeleton. Interestingly, it is only the outer layer of a coral (tissue zone) which is alive, and actively growing. Sclerochronology (aging of coral growth rings in the skeleton) combined with isotope and trace metal chemistry of coral skeletons can provide a high resolution, long-term archive of changing environmental conditions and shifts in reef health. Our analyses (Fig. 2) identified high phosphorus levels in the living tissue zone (polyp) of the coral. The calcium carbonate skeleton in the tissue zone had low, uniform levels of phosphorus, similar to older sections of the coral core. Below the tissue layer, phosphrus was incorporated homogenously in the skeleton for extended periods (e.g., 5 mm growth bands). However, sections of the core (~1 cm down-core) displayed fine-scale elevated phosphorus concentrations associated with the presence of phosphorus-rich, often elongate (10–100 lm long), heterogeneities within the skeleton, the origin of these phosphorus- rich heterogeneities and their mode of incorporation is still unclear. In conclusion, our findings support the continued development of this promising potential nutrient proxy and biomonitor.

Mallela J, Hermann J, Rapp R, Eggins S (2011) Fine-scale phosphorus distribution in coral skeletons: combining X-ray mapping by electronprobe microanalysis and LA-ICP-MS. Coral Reefs 30:813-818 http://www.springerlink.com/content/j7754u58u97u6166/

Research Activities 2011

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

Dynamic permeability and the evolution of fluid pathways in fault networks

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This project combines geochemistry and structural studies of an exceptionally well exposed, calcite-rich vein system in a limestone-hosted normal fault network in the Jabal Akhdar dome area, Oman. Structural and microstructural observations are used in conjunction with high spatial resolution C/O stable isotope, Sr isotope and trace element analysis to study 4D variations in vein mineral chemistry. The vein chemistry is used to map the distribution and evolution of geochemical fronts within the vein system. The geometry and distribution of geochemical fronts will be used to constrain flow directions. Reactive transport modeling of geochemical profiles along fluid pathways will be used to map 4D variations in fluid flux.

The majority of the fieldwork in Oman has focused on a single 25km long normal fault system called the Dar Al Baydha (DAB) Fault and an adjacent subsidiary fault network. Mapping along this fault system has defined a close temporal and spatial relationship between extension veins and fault veins (Fig. 1a), indicating that the system formed under near-lithostatic fluid pressures and low differential stress. Complex mutually crosscutting vein networks within the proximal damage zone of the DAB Fault indicate that fluid flow in this system was episodic (Fig. 1b).

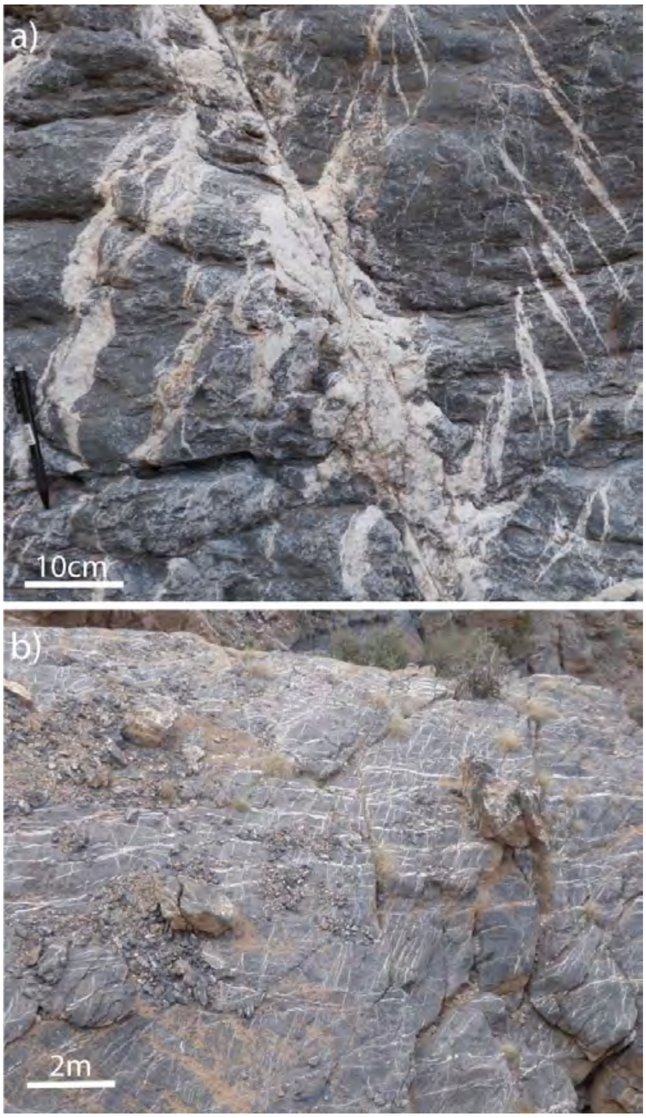

Figure 1. Figure 1a: Extension veins connected to a larger through going fault vein on a strand of the NBF. This close association between extension veins and fault veins indicates near-lithostatic fluid pressures and low differential stress. 1b: Complex vein network adjacent to the NBF. Since these veins cannot have all been open to flow simultaneously, formation of this network must have involved episodic fracturing and sealing.

^{18}O of vein calcite follows a depletion trend from host rock values (> 25 ‰) down to 13 ‰ (Fig. 2). The ^{18}O depleted vein calcite is clearly out of equilibrium with the host rock, indicating the influence of an external reservoir. An up-section shift in median d^{18}O towards host rock values indicates that this external reservoir entered the system through episodic breaching of a seal near the base of the carbonate sequence.

Assuming that the most depleted vein d^{18}O represents an essentially fluid-buffered composition then the ^{18}O of calcite can be converted to an equivalent ^{18}O of water for a given temperature (O'Neil et al. 1969). This gives a range of 4.2-8.1 ‰ (T = 200-300°C), which is consistent with a number of potential sources including metamorphic fluids and meteoric fluids that have partially equilibriated with the host rock. The along-strike distribution of fluid flux on the DAB Fault is highly variable. Structural complexity is the first order control on this variation, with features such as jogs, splays and termination zones hosting strongly depleted ^{18}O vein chemistry and thus high fluid flux. In contrast, the geochemical front in planar segments is more than 2500m lower in the system than for some structural complexities, indicating much lower fluid flux.

The DAB Fault is bounded by a network of low to moderate displacement faults. Mapping in this network by Arndt et al (2010) indicates displacements between 1 and 60m. Sampling has identified veins with depleted ^{18}O similar to the most depleted analyses from the DAB Fault. This indicates that networks of low to moderate displacement faults are capable of hosting fluid fluxes similar to those on large, high displacement faults. Depleted ^{18}O veins within the low to moderate displacement fault network are localised in zones of structural complexity similar to the DAB Fault.

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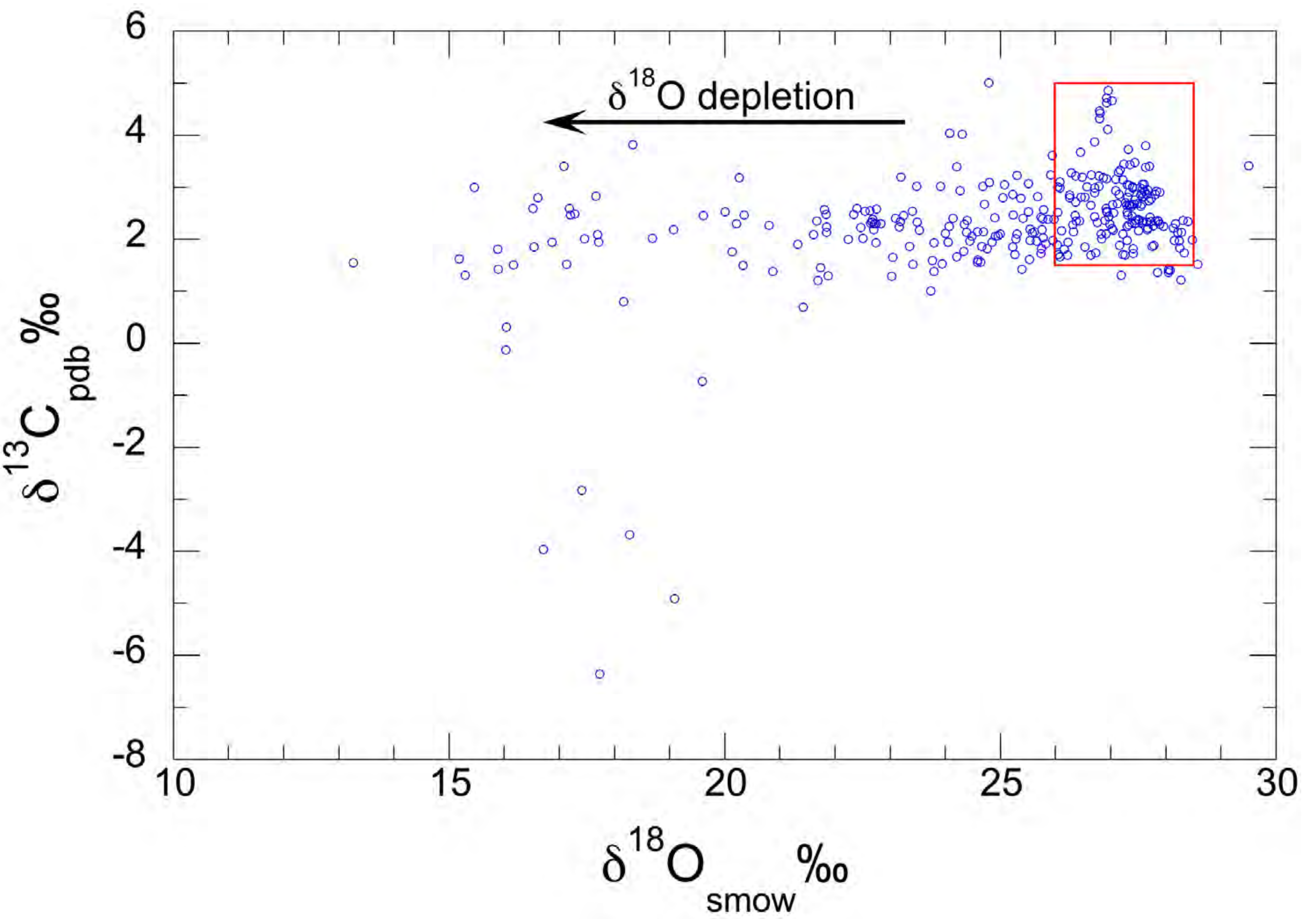

Figure 2. Figure 2: All calcite vein analyses. There is a strong cluster of samples in the distal host rock field (red box, >26 ‰) and a tail of decreasing d^{18}O (minimum = 13 ‰). This tail of decreasing d^{18}O indicates the influence of an ^{18}O depleted external reservoir.

Rheology & Seismic-Wave Attenuation in the Earth's Upper Mantle

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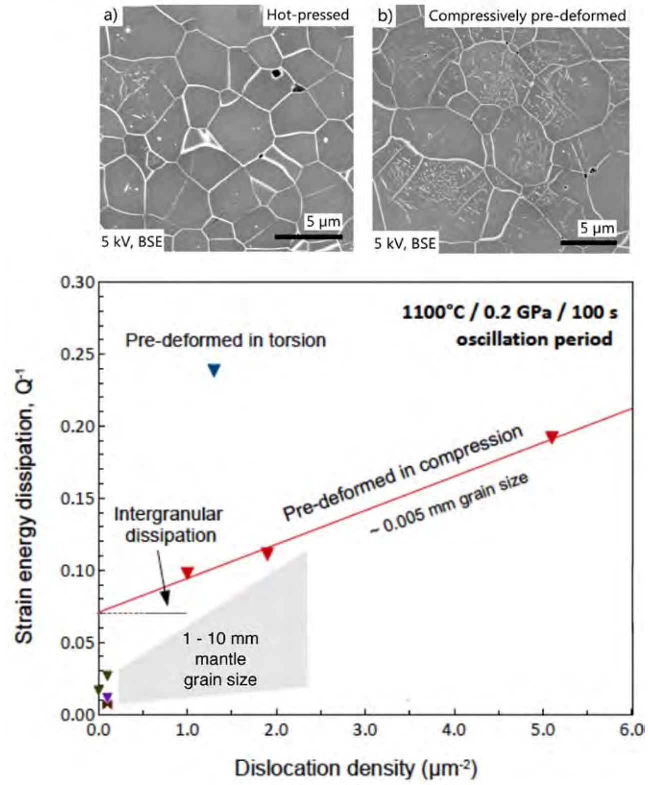

Figure 1. Fig. 1 Back-scattered electron images of oxidised grain boundaries and dislocations in hot-pressed and compressively pre-deformed specimens. Torsional forced oscillation testing of such materials reveals a clear positive correlation (red line) between strain-energy dissipation and dislocation 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).

Both the rheology and seismic properties of the Earth's upper-mantle are potentially sensitive to the incorporation of 'water' into the crystal structure of the dominant nominally anhydrous mineral olivine $(Mg,Fe)_2SiO_4$. We have recently prepared dense polycrystalline samples of Ti-doped olivine by hot-pressing synthetic powders. Particularly for those specimens hot-pressed in sealed Pt capsules, prepared by newly developed laser-welding techniques, the presence of Ti enhances the incorporation of water as a defect involving Ti/Mg substitution and the double protonation of an adjacent Si vacancy – as revealed by infrared spectroscopy. This defect is stable during high-temperature testing and significantly affects the physical properties of mantle rocks at low water contents. Exploratory compressive deformation experiments yield strain rates for diffusion creep that are an order of magnitude greater for Ti-doped olivine, even for water contents below detection levels. In parallel with this work, we have analysed seismic-frequency torsional forced-oscillation data, obtained under conditions of simultaneously high pressure and temperature on similarly prepared polycrystalline olivine specimens. The results show that the strain-energy dissipation increases systematically with the density of line defects, called dislocations, introduced during prior compressive deformation, and that even stronger dissipation is characteristic of a torsionally pre-deformed specimen with a population of dislocations more favourably oriented for re-activation during the forced-oscillation testing (Fig. 1). These results, compared with other relevant information in Fig. 1, suggest that dislocations introduced during tectonic deformation, might be responsible for reduced seismic wave speeds and appreciable attenuation (shaded region) in the Earth's upper mantle, and that such behaviour may be anisotropic – varying with the relative orientation between the prevailing (or fossil) tectonic stress field and that of a passing shear wave. Augmentation of our unique dataset through the conduct of additional torsional forced-oscillation experiments on polycrystalline olivine specimens prepared from a natural (San Carlos) precursor will provide a critical further test of this hypothesis.

Seismic Properties of Cracked and Fluid-Saturated Crustal Rocks

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An understanding of the influence of fluids on the seismic properties of the cracked and porous rocks of the Earth's upper crust finds application in scenarios ranging from earthquake fault zones to the sequestration of carbon dioxide. In particular, it is expected that wave speeds will be strongly frequency dependent – on account of the stress-induced flow of fluid between different parts of the pore/crack network on appropriate timescales. Fluid flow timescales are sensitive to the aspect ratios of individual cracks and pores and the nature of their interconnection, and accordingly it is desirable to perform laboratory measurements of seismic properties on materials with simple crack/pore networks. To this end, soda-lime-silica glass beads have been sintered in air at high temperature, for periods chosen to yield residual porosities in the range 3-10 %. Some such specimens have been subjected to thermal cracking by quenching from high temperature into water (Fig. 1). Selected specimens, sandwiched between alumina torsion rods within an annealed copper jacket, have been tested under conditions of independently controlled argon confining and pore-fluid pressures. The return to pore-pressure equilibrium following imposition of a pore-pressure differential across the specimen allows in situ measurement of permeability. The permeability thus inferred is systematically greater for thermally cracked specimens and decreases monotonically with increasing effective pressure (the difference between confining and pore-fluid pressures) – reflecting partial crack closure (Fig. 1). The shear modulus (rigidity) inferred from low-frequency (sub-Hz) torsional oscillation measurements is also sensitive to crack closure – increasing systematically with increasing effective pressure. In parallel with this work on sintered glass beads, substantial progress is being made in the development of improved strategies for flexural-oscillation testing, and in the analysis and interpretation of combined forced-oscillation and high-frequency ultrasonic data for thermally cracked quartzites – that reveal suggesting significant frequency dependence between Hz and MHz frequencies for water-saturated samples.

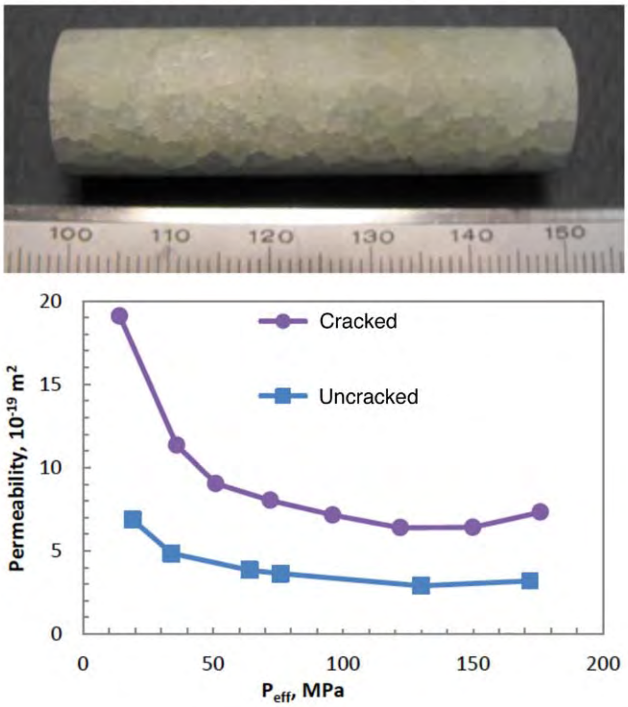

Figure 1. Fig. 1 Synthetic specimen of ~3% porosity and 0.2% crack porosity prepared by sintering glass beads followed by thermal cracking. Permeability, measured in situ, is systematically higher for the thermally cracked specimen and decreases with increasing effective pressure.

Platinum group element abundances in the upper continental crust revisited

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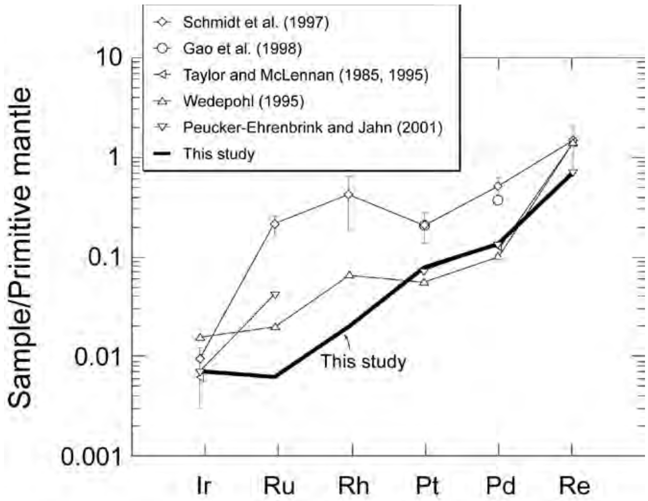

Figure 1. Concentrations of platinum group elements and Re in the upper continental crust. Our estimates for the UCC, after omitting one sample with an anomalously high Pt content, are shown as a thick solid line. See text for discussion. Primitive mantle values are from McDonough and Sun (1995).

Platinum group element (PGE) abundances in the upper continental crust (UCC) are poorly constrained with published values varying by up to an order of magnitude. We evaluated the validity of loess as a proxy for PGE abundances in the UCC by measuring these elements in 7 Chinese loess samples using a precise Ni-sulfide fire assay – isotope dilution with ICP-MS method. Major and trace elements of the Chinese loess show a typical upper crustal composition and PGE abundances are consistent with literature data on Chinese loess, except for Ru, which is a factor of 10 lower than published values. We argue that the high Ru contents reported by Peucker-Ehrenbrink and Jahn (2001) are an analytical artifact resulted from an underestimation of the Ni-argide interference on Ru. This is supported by the fact that no source for loess is significantly enriched in Ru and no transport and deposition processes are likely to enrich Ru in loess. The strong positive correlations between PGEs (except for Pt) and with other compatible elements such as Fe_2O_3, Ni, Cr, Co suggest that host phases for the PGEs are likely to be solid particulates (e.g. sulfide) rather than dissolved forms during the loess formation. The effect of eolian fractionation on PGE in loess may have been limited because Chinese loess from different places shows similar PGE patterns with restricted variations. Using a compilation of PGE data for loess from China, Argentina and Europe, including our results but excluding one sample with anomalously high Pt, we propose a revised average PGE concentrations for global loess of Ir=0.022 ppb, Ru=0.030 ppb, Rh=0.018 ppb, Pt=0.599 ppb, and Pd= 0.526 ppb, and suggest that this is the best estimate the PGE concentrations in the UCC.

Particle fluidization in fault zones: implications for transitory, rupture-controlled fluid flow regimes

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At depth in the continental seismogenic regime, the permeability of active fault zones is expected to vary substantially during the seismic cycle. Fault rupture events can generate large, transitory increases in permeability in the rupture zone. Especially at elevated temperatures in fluid-active environments, interseismic sealing and healing of fault damage products progressively decreases fault permeability. Where fault ruptures breach overpressured fluid reservoirs, high permeability fault segments provide high fluid flux conduits that facillitate fluid redistribution between reservoirs in the Earth's crust.

Fault damage products within the Rusey Fault (North Cornwall, UK) and the Roamane Fault (Enga Province, PNG) provide insights about the dynamics of fluid flow and transient fluid flow velocities where fault ruptures have breached overpressured fluid reservoirs. These faults contain a type of breccia in which angular rock fragments are mantled by accretionary, spheroidal overgrowths of minerals which were deposited from hydrothermal fluids present in the fault zones (Figure 1). None of the rock fragments are in contact with each other. But the spheroidal, mantled aggregates are in contact with each other. In most cases the mantled aggregates are well cemented together, but remnant pososity is sometimes present between the spheroids. The overgrowth mantles typically comprise elongate crystals radiating outwards from the surface of the core rock fragment. Concentric banding is sometimes also present in the hydrothermal overgrowths.

Particularly in the Rusey Fault, the accretionary breccias form lenticular to sub-planar, fault-parallel layers, each up to several tens of centimetres thick. Adjacvent layers are characterised by different ranges of clast sizes and different clast to cement matrix ratios. Up to twenty adjaent layers are present within the 3m wide core of the fault zone. Some layers truncate others and many breccia layers exhibit distinct grainsize grading. Many rock fragments in the breccias are fragments of wall-rock, cataclasite and quartz veins. Importantly, some clasts are fragments of earlier generations of cemented accretionary breccia. This indicates that the breccias were cemented during interseismic periods prior to subsequent fault slip and brecciation events.

The distinctive textures of accretionary breccias are interpreted to have formed by fluidization of fault damage products, together with hydrothermal mineral coating of rock fragments while in a turbulent fluidized state during rapid fluid upflow through dilatant fault segments. Knowledge of the physics of fluidization processes places constraints on flow velocities during repeated, transitory fluidization events within the fault zones. Particle size distributions in the Rusey and Roamane Faults indicate that minimum fluid velocities required for fluidization were approximately $0.1ms^{-1}$; maximum flow velocities were typically in the range 1- $2ms^{-1}$ (Figure 2). The maximum flow rates correspond to fluid fluxes greater than 500 litres per second per 10m strike length of fault.

The internal strcutures of the Rusey and Roamane Faults indicate that they acted repeatedly as conduits for transiently fast fluid flow, most probably in repsonse to fault ruptures repeatedly breaching overpressured fluid reservoirs. The distribution of high, transitory fluid fluxes in faults has implications for the disribution fluid-driven seismicity, including aftershocks and swarm behaviour, downstream from the high flux zones. High flow rates also have implications for ore deposition processes in fracture-controlled hydrothermal flow systems. High fluid velocities can be associated with substantial advective heat transport and will promote severe chemical disequilibrium.

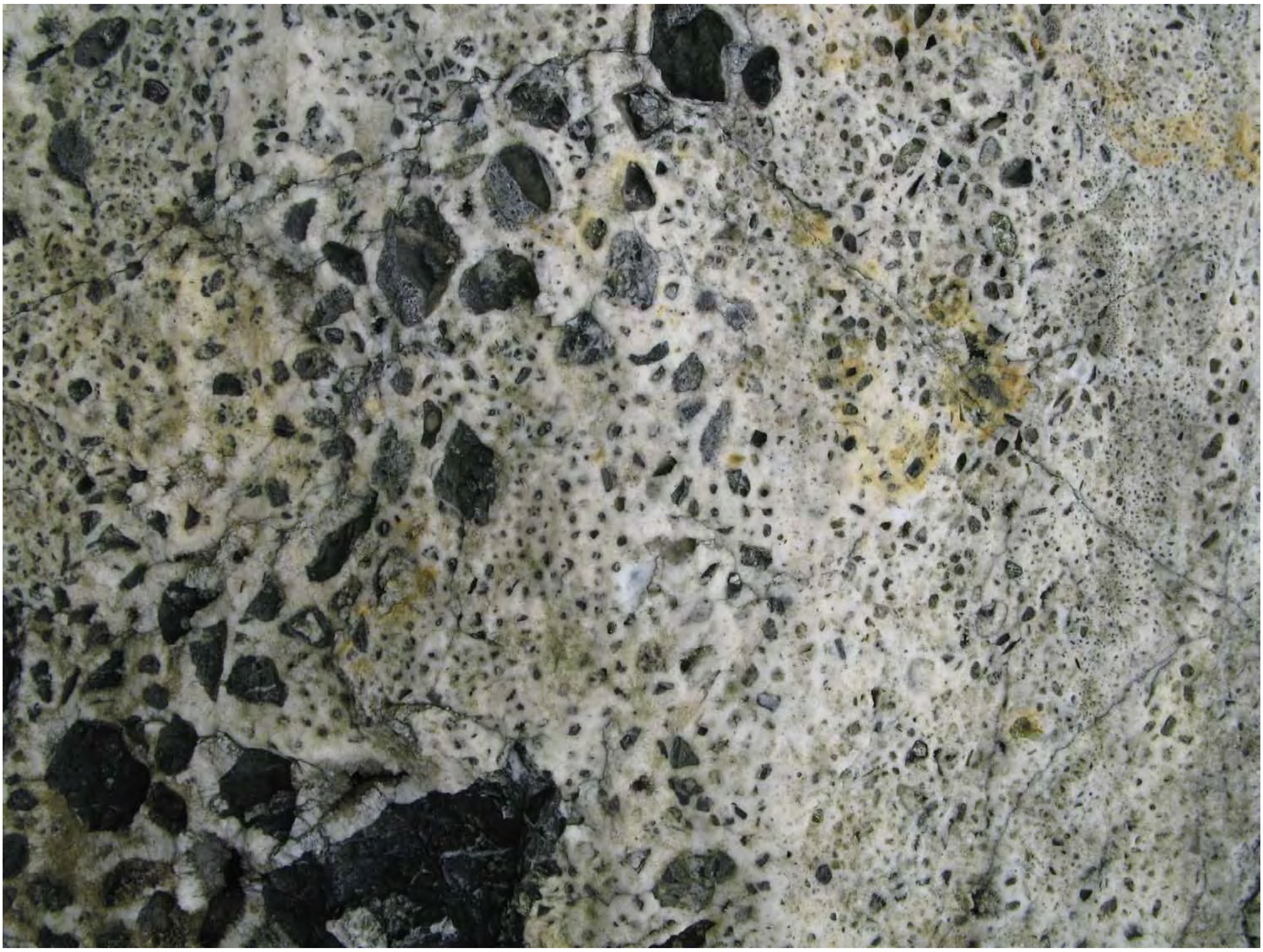

Figure 1. Accretionary fault breccia, Rusey Fault, North Cornwall, UK. Individual rock fragments (dark-coloured) are surrounded by a quartz cement matrix to form spheroidal, mantled particles. Note grainsize grading within the breccia. IMG 8996. Field of view 20 cm wide.

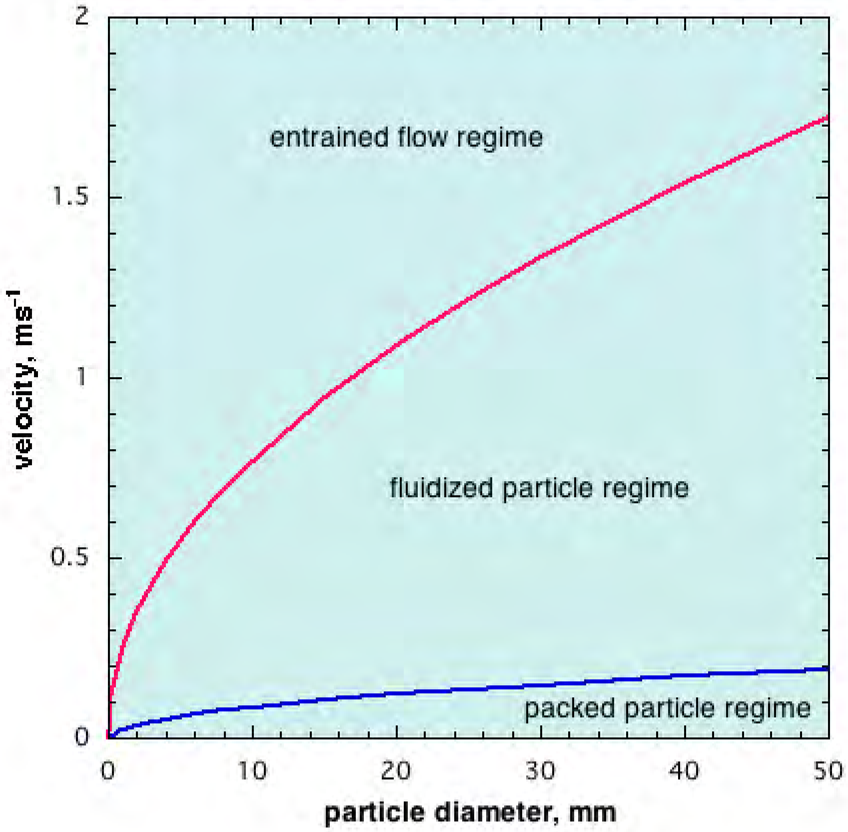

Figure 2. Plot of particle sizes versus fluid flow velocities showing the conditions for fluidization and entrained flow regimes in the Rusey Fault.

Selenium speciation in silicate glasses

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Selenium is a Group 16 element, lying below sulfur and oxygen in the Periodic Table. The chemistry of sulfur and selenium are broadly similar-both elements have 2- (sulfide/selenide), 4+ (sulfite/selenite) and 6+ (sulfate/selenate) valence states, and selenium frequently substitutes for sulfur in sulfide and sulfate minerals. In high temperature environments, such as silicate melts and hydrothermal fluids, sulfur is only found as S^{2-} and S^{6+}. Sulfite, S^{4+} is either unstable or a very minor species.

We have synthesised basaltic and dacitic silicate glasses doped with selenium under a variety of redox conditions, varying from reduced (in equilibrium with graphite) to very oxidised (in equilibrium with pure O^2 from PtO^2 decomposition). The speciation of selenium in the glasses was investigated by Se *K*-edge XANES (X-ray absorption near edge structure) at the Australian National Beamline Facility (ANBF), Photon Factory, Tsukuba, Japan. Comparison of Se *K*-edge XANES spectra from our silicate glasses with spectra collected from selenium minerals representing Se^{2-}, Se^0, Se^{4+} and Se^{6+} oxidation states revealed that selenium occurs as Se^{2-} at low oxygen fugacity (fO_2) and Se^{4+} at moderate and oxidising fO_2. Selenium 6+ was stable, but at geologically unreasonably high fO_2.

The results are surprising as selenium was assumed to behave in a geochemically simiar fashion to sulfur, with only 2- and 6+ valence states. The large stability region for Se^{4+} suggests that sulfur and selenium will behave similarly in silicate melts only under reducing conditions when both are in the 2- valence state. At higher fO_2, sulfur will be 6+ whilst selenium is 4+.

Jenner et. al. (2010) suggested that the assumed selenide to selenate transition occurred at higher fO_2 than the sulfide-sulfate transition, based on differences in the behavior of sulfur and selenium analysed in sea-floor silicate glasses. The present results suggest that the selenide-selenite transition occurs at higher fO_2 than the sulfide-sulfate transition.

The different redox systematics of selenium relative to sulfur are responsible for the retention of selenium in silicate glasses that have lost all their sulfur due to degassing. Knowledge of sulfur-selenium ratios, and selenium contents of natural glasses can be employed to calculate pre-eruptive sulfur contents (Jenner et. al. 2010), and thus permit more accurate modelling of volcanic sulfur emissions.

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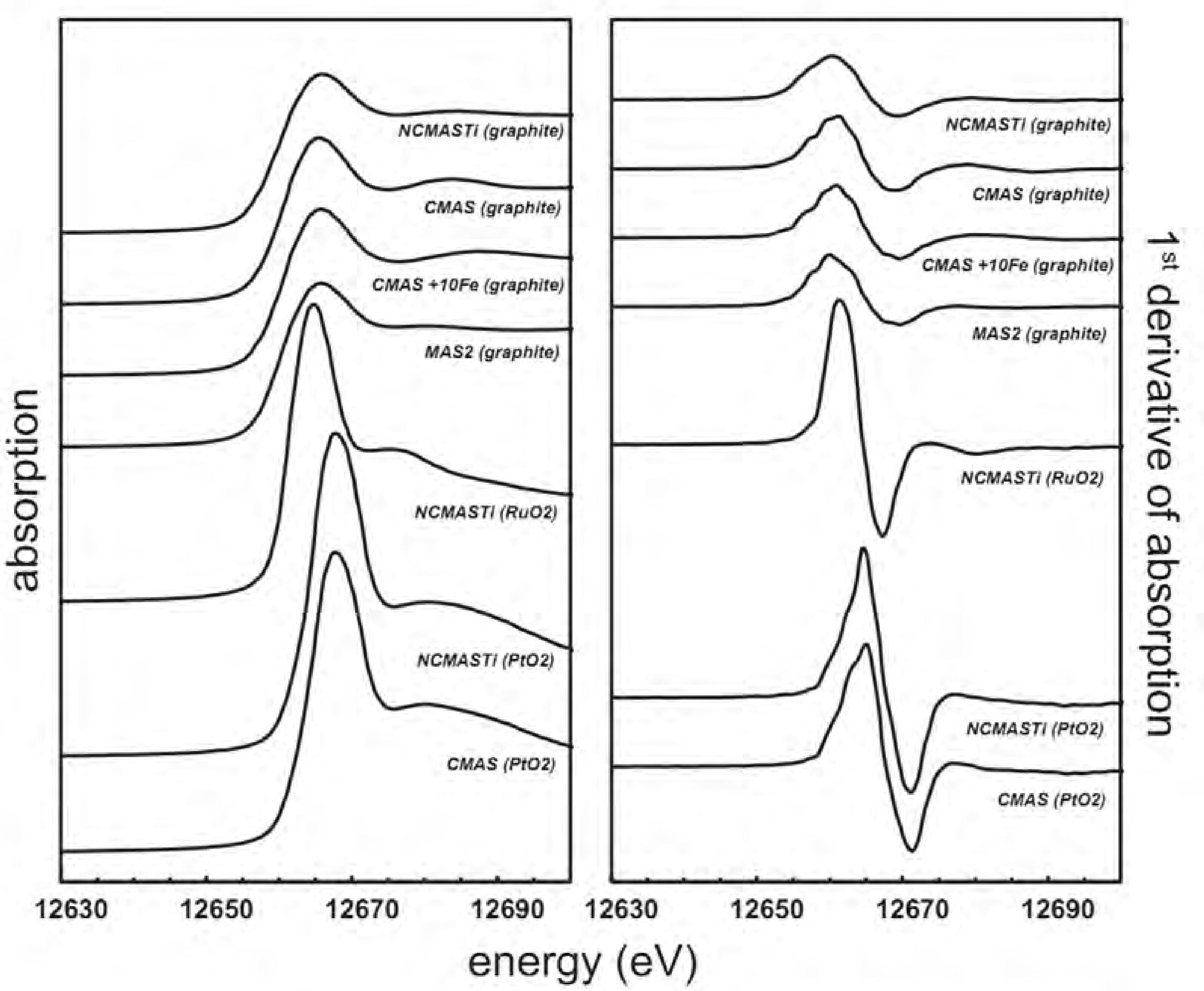

Figure 1. Se *K*-edge XANES spectra of synthetic anhydrous basaltic glass samples. Spectra offset for clarity. Labels refer to glass composition and the redox controlling mineral is in brackets. A change in the redox state of selenium is visible between the graphite, Ru-RuO_2 and PtO_2 equilibrated glasses. Graphite equilibrated glasses have a low intensity absorption feature, and E_0 energy (maximum of 1st derivative) of ~12,660 eV, regardless of composition. The Ru-RuO_2 equilibrated sample has an intense edge feature, and and an E_0 energy of ~12,661 eV. The PtO_2-bearing sample also has an intense edge feature, but the E_0 energy is higher, ~12,665 eV. The three groups of samples are interpreted to represent selenide (Se^{2-}), selenite (Se^{4+}) and selenate (Se^{6+}), respectively, by analogy with model compounds.

Arc Peridotite Xenoliths

A detailed petrological study of a pristine xenolith suite, West Bismarck Arc

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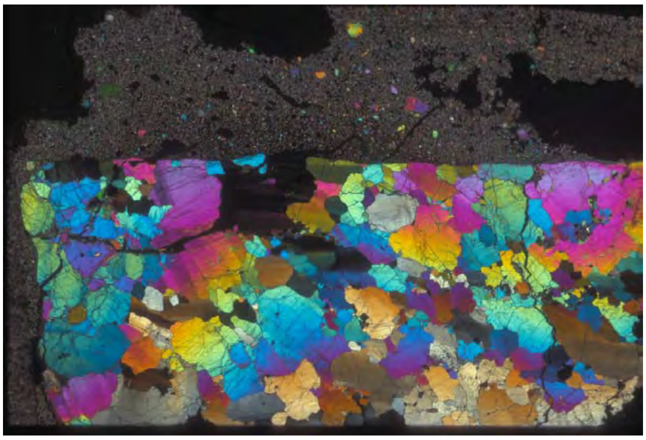

Figure 1. A whole polarised thin section scan of a dunite sample with surrounding host rock.

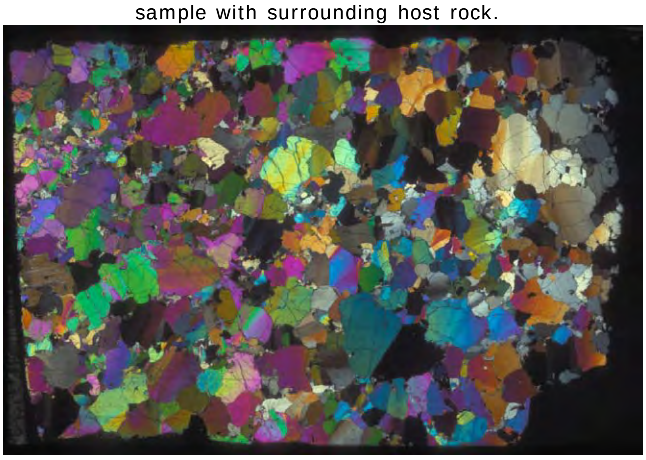

Figure 2. A whole polarised thin section scan of a harzburgite sample.

During the Marine National Facility Voyage (SS06-2007; WeBiVE) a suite of pristine xenoliths was recovered from three volcanic cones northwest of Ritter Volcano, the most westerly volcano in the New Britain-West Bismarck Arc system of Papua New Guinea. The xenoliths are pristine (serpentine-free), predominantly harzburgitic but also include dunite, orthopyroxenite, and a single gabbro. Wedge-derived peridotites are extremely rare even in well-explored sub-aerial arcs and the Ritter suite is the first global occurrence of peridotites recovered from an active submarine volcanic arc front edifice.

The peridotites occur as rounded (≤15cm diameter) and angular blocks and fragments. The host basalt is a Cr spinel-olivine-diopsidic augite-bearing, medium-K tholeiite. It is the most MgO-rich basalt (~15wt%) reported in the West-Bismarck - New Britain Arc system. These values are unlikely to be totally derived from the (partially) cumulative nature of olivine, as these values are consistent for the entire basaltic suite, not just the phyric samples.

Petrological analyses of the xenoliths show complex textural relationships between the constituent minerals olivine (Fo_{96-86}), orthopyroxene, clinopyroxene, and spinel. The spinel is highly refractory with Cr/(Cr+Al) > 0.9 accompanied by high $Mg/(Mg+Fe^{2+})$ consistent with quenching from high-temperature. Within the spinel, silicate melt inclusions are abundant and exhibit an extremely wide range of chemical compositions. Also present are incipient melt channels along grain boundaries within the xenoliths. These melt features are interpreted to reflect melting during rapid decompression of the peridotites during host basalt eruption.

The question of whether these samples are cumulates or mantle-derived has been partially addressed by the extremely refractory nature of these peridotites in conjunction with a low alumina content, which is indicative of low-T peridotites, not high-T cumulates, lending credence to the fact these are extremely refractory residues from increasing degrees of partial melting not cumulates from an Mg-rich magma.

Deformation textures include olivine kink-banding and wavy exsolution lamellae in the pyroxene. Secondary clinopyroxene reflects some metasomatism. Bulk trace element characteristics include relatively unfractionated rare earth element abundances (0.6 to 1*chondritic), elevated Pb/Ce (>1), and negative Nb, Ta, Zr, Hf, and Ti anomalies. Temperature ranges from ~900 to 1100^{o}C; fO_2 ranges from ΔFMQ-1.3 to +1.5.

These samples show extremely refractory, relatively reduced harzburgites are present in the mantle section beneath a modern subduction system. In many respects, these lithologies mimic those from ancient cratonic lithosphere, deemed to be solely characteristic of Archean lithospheric stabilisation. Ongoing detailed mineralogical and petrological studies will provide important insight into the mantle below the New Britain-West Bismarck Island Arc.

Transition Metal Stable Isotopes at High Temperatures

Figure 1. Column elution curves for Cu, Fe and Zn in acids of different molarity in AG1-X8 anion exchange resin. The curves highlight their efficient separation from the matrix and each other. Cr and Ni are separated by further chromatography.

A Natural and Experimental Study

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The advent of Multiple Collector ICP-MS a decade ago has facilitated the investigation of previously unstudied stable isotope systems. Due to their small relative mass differences, equilibrium fractionation of such heavy metal isotopes is vanishingly small during high temperature processes. However, because stable isotope fractionation is sensitive to differences in the bonding environment of the element, it elucidates the nature of processes, both today and in the past. In order to be able to efficiently study these variations, the element of interest must be efficiently separated from the remaining matrix of the sample.To this end, we have developed an ion exchange chromatography procedure that quantitatively separates Cu, Fe, Zn, Cr and Ni in silicate and meteorite samples (Fig. 1).

The goal of this work is to better characterise the conditions of planetary accretion (including volatile loss and core-formation) and terrestrial magmatism. For example, Fe isotopes, owing to the multiple oxidation states of Fe (Fe^0, Fe^{2+} and Fe^{3+}), are redox-sensitive, and reveal differences in the formation of igneous rocks in different tectonic environments. Conversely, Zn, due to its high volatility, may be used to explore variations in the impact history of planets. Zn isotopes are fractionated during vaporisation, and as such the isotopic composition of the Earth can be compared with that of meteorites and other terrestrial planets to investigate the extent of volatile loss and determine whether meteorites represent plausible matches for the composition of the Earth.

Significantly, an experimental underpinning to the isotopic phenomena observed in natural rocks is glaringly lacking. As such, performing experiments at defined temperatures, pressures and oxygen fugacities then provide important constraints on such variables in natural settings. Preliminary experiments performed on a mixture of Fo_{90} olivine $(Mg_{0.9}Fe_{0.1})_2SiO_4$ and Fe metal (Fe^0) show measurable differences in their iron isotope compositions at 1400^{o}C at redox conditions relevant to core formation (Iron Wüstite -0.5). Experiments and theoretical results predict that metallic iron is marginally heavier than Fe^{2+}-bearing silicates at ambient pressures. However, the Earth's mantle shows an Fe isotope composition essentially indistinguishable from ordinary and carbonaceous chondrite meteorites, suggesting core formation occurred at temperatures that were elevated enough to render any fractionation between metal and silicate negligible.

Studies on Archaean komatiites, however, show an evolution from 3.5Ga to 2.7Ga in their Fe isotope composition from $\delta^{57}Fe$ = -0.1 ‰ to +0.05 ‰. This increase may correspond to a secular increase in mantle oxidation state across this period, which then may provide a conceivable source of oxygen to the atmosphere by affecting the speciation of magmatic volatiles.

Figure 2. Komatiites from the Pilbara region (3.5 - 3.2Ga) span an Fe isotope range from �57Fe = -0.15� to + 0.15�. Contrastingly, younger komatiites from Alexo (2.7Ga, Dauphas et al., 2010), are displaced to higher �57Fe at the Cr content of the primitive mantle (2520 ppm).

Melting of altered oceanic crust and consequences for the deep carbon cycle in subduction zones

Figure 1. *Backscattered image of Ca and carbonate-rich pools in the 4.5 GPa, 900°C experiment.*

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The deep carbon cycle is much less explored and understood than the exogene carbon cycle, even though it has great influence on the long-term greenhouse gas concentrations in the Earth atmosphere. A key aspect of the deep carbon cycle is how CO_2 is released from subducted altered oceanic crust. Geochemical studies and estimations of carbon fluxes (e.g. Wallace 2005) suggest that most subducted carbon is sent back to the atmosphere via arc magmatism, which conflicts with experimental studies (Yaxley & Green, 1994; Poli et al., 2009) and thermodynamic modeling (e.g. Kerrick & Connolly, 2001) showing that most of the carbon is retained in carbonates in the slab.

Experimental studies are hampered by the difficulty of estimating the composition of the fluid in equilibrium with the solid assemblages composing the metamorphosed altered oceanic crust. To solve the CO_2-dilemma, we have developed a new method where the composition of the gas present in the capsule after the experiment is directly analysed with a gas chromatograph equipped with a thermal conductivity detector (GC-TCD). This method, combined with infra red measurements in melt-bearing experiments, allows, for the first time, the direct determination of the molar $X_{CO2}=n_{CO2}/(n_{CO2}+n_{H2O})$ in the experimental fluid.

As altered oceanic crust is the most important C reservoir in the slab, we conducted experiments with a starting material made of a synthetic K_2O, CO_2 and H_2O-bearing basaltic composition at 3.0 and 3.5 GPa, 700 - 800°C and at 4.5 GPa, 800-900°C in a piston-cylinder apparatus. The experimental results indicate that the solidus occurs between 700 and 750°C at both 3.0 and 3.5 GPa. At T<750°C, dolomite and magnesite coexist with garnet, omphacite, phengite, epidote, coesite, rutile ± kyanite. At 700°C, the fluid is composed of water and CO_2 and characterised by a $X_{CO2}<6$ mol.%, which decreases with increasing pressure. At T≥750°C, Mg-calcite±dolomite coexist with melt, garnet, omphacite, epidote, rutile ± coesite and phengite. The carbonate solubility at 3 Gpa is similar to what is observed in subsolidus conditions but it increases with increasing pressure. This result is supported by the experiments at 4.5 GPa, in which carbonate minerals are not observed at T≥900°C and where Ca and carbonate-rich pools or squeletal crystals can be observed in the glass at T≥850°C (Fig. 1), indicative of a high carbonate solubility.

In the newest set of thermal models (Syracuse et al., 2010), a large number of subduction zones will reach temperatures where the top of the altered basalt layer will undergo partial melting. Therefore, we suggest that partial melting of altered basalts can resolve the CO_2 dilemma, reconciling the large observed proportion of CO_2 recycled through arc magmatism with the phase relations and petrology of the subducted crust. Our results suggest that significant amounts of subducted C can be brought back to the atmosphere via arc magmatism on relatively short time scales of less than 10 Ma.

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Mapping Fe^{3+} distribution in mantle garnet using Fe K-edge XANES

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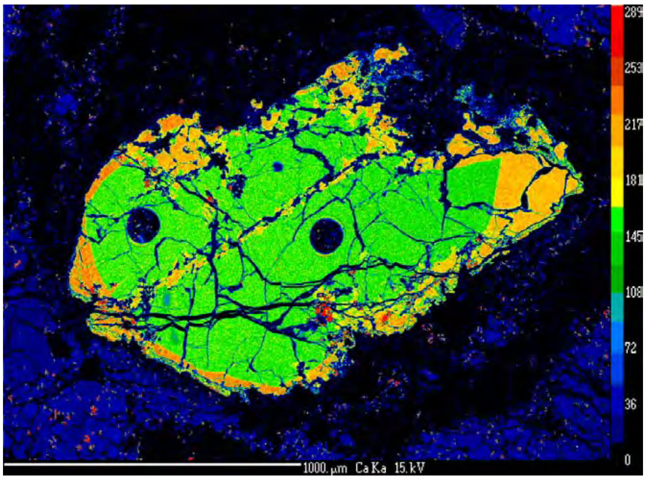

Figure 1. Ca X-ray map of KBD12-Gt4 from the Wesselton kimberlite, produced using the Cameca SX100 Microprobe at RSES.

Our understanding of how metasomatism occurs in the Earth's mantle can be deepened by investigating mantle peridotite xenoliths to determine the conditions under which their constituent minerals, particularly garnet, formed. Analysis of the chemical compositions of individual mineral phases is used to determine both the pressure and temperature at which the assemblage formed. The redox conditions of the mantle when the minerals were formed can be determined if the oxygen fugacity (fO_2) is known, which can be calculated based upon the amount of Fe^{3+} relative to Fe^{2+} in the garnet.

We have examined a suite of garnet peridotite xenoliths from the Wesselton kimberlite pipe, South Africa using electron probe microanalysis (EPMA) and laser ablation inductively coupled plasma mass spectroscopy (LA-ICP-MS) at RSES. EPMA revealed strong major element zonation in two garnet crystals from one sample, particularly in Ca, Fe, Mg, Cr, Ti and Al, with a Ca elemental X-ray map shown in Figure 1. Garnet stoichiometry predicts that Fe^{3+} will also be zoned in the crystals.

The distribution of $Fe^{3+}/\Sigma Fe$ on the two zoned garnets in a sample of garnet peridotite from the Wesselton kimberlite (South Africa) was mapped using the Fe K-edge XANES during March 2011, and the resulting map is shown in Figure 2. This is the first time that Fe^{3+} has been mapped at high resolution in garnet. This map also proves that the metasomatic agent responsible for the formation of the overgrowth rim on the garnet was more oxidised than the original environment.

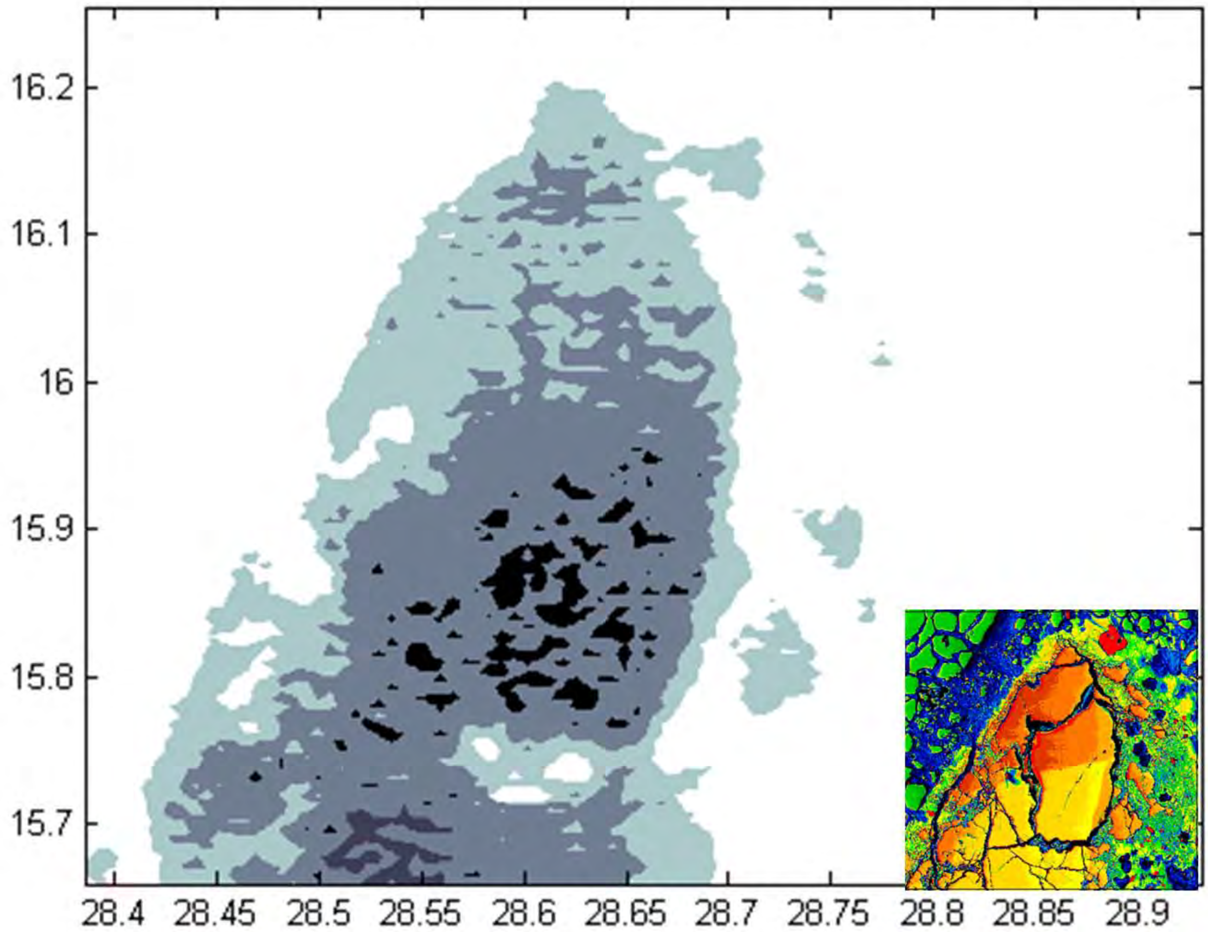

Figure 2. Map of $Fe^{3+}/\sum Fe$ created using Fe K-edge XANES spectroscopy for KBD12-Gt4, with dark colours indicating low values. The inset image is a false colour BSE image of the area mapped.

Application of Fe K-Edge XANES Determinations of $Fe^{3+}/\sum Fe$ in Garnet to Peridotite Xenoliths from the Udachnaya Kimberlite

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The garnet structure can accommodate both Fe^{2+} and Fe^{3+}. Garnet $Fe^{3+}/\sum Fe$ in kimberlite-bourne peridotite xenoliths can be used to determine the oxygen fugacity (fO_2) of the cratonic lithosphere. This is important as an indicator of diamond (versus carbonate) stability. In cratonic lithosphere the fO_2 of peridotite is expected to broadly decrease with increasing depth, and is consistent with graphite or diamond stability. However metasomatic events may locally perturb this trend, possibly leading to oxidation that could result in diamond breakdown or resorption. Such events will usually be recorded by the coexisting garnet.

$Fe^{3+}/\sum Fe$ of garnets has traditionally been determined by Mössbauer Spectroscopy of powdered samples. This lacks spatial resolution and the data for each measurement take several days to acquire. X-ray Absorption Near Edge Structure (XANES) spectroscopy is now commonly being used to determine $Fe^{3+}/\sum Fe$ in minerals, is capable of micron spatial resolution and spectra can be recorded in ~15 minutes. We have recently reported a new method for quantifying $Fe^{3+}/\sum Fe$ from the XANES spectra of mantle garnets with an accuracy and precision comparable to Mössbauer Spectroscopy.

We applied the XANES technique to investigate the fO_2-depth variation in the Siberian Craton using a suite of fresh garnet lherzolites from the Udachnaya East kimberlite. Garnet $Fe^{3+}/\sum Fe$ was detemined using XANES spectroscopy on the X-ray Fluorescence Microscopy beamline of the Australian Synchrotron. XANES spectra were recorded in fluorescence mode from garnets prepared as either polished thin sections or electron probe mounts. A calibration curve relating the spectra to $Fe^{3+}/\sum Fe$ of mantle garnets previously analysed by Mössbauer spectroscopy allowed garnet unknowns to be quantified.

Thermobarometry established that the samples range in pressure from 3.9-7.1 GPa and lie along a typical cratonic geotherm. Several samples exhibit elevated abundances of Ti, Zr and Y in garnet and clinopyroxene, clear evidence for metasomatic enrichment consistent with an earlier study of another Udachnaya xenolith suite. Others are less or unaffected by metasomatism, with very low abundances of these elements.

$D\log_{10}[fO_2]^{FMQ}$ varies from -2.5 to -5.9 log units and broadly decreases with increasing pressure. The metasomatised samples all derive from P > 5 GPa and almost all exhibit a resolvable shift to fO_2 values ≈1.5-2.0 log units higher than the unmetasomatised ones, at given pressure.

Al diffusion in olivine: an experimental study

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We performed a series of experiments of Al diffusion in San Carlos olivine and synthetic forsterite at 1300^{o}C and log fO2 = -0.7; -5.7 and atmosphere pressure. In order to provide an inside into mechanism of alumina substitution into olivine, activities of SiO_2, MgO and Al_2O_3 were buffered in all runs. Four mineral associations were used: (a) forsterite – periclase – spinel; (b) forsterite – spinel – sapphirine; (c) forsterite – sapphirine – cordierite; (d) forsterite – cordierite – enstatite and the results analysed by LAICPMS. Each profile was fitted to a one – dimensional diffusion model in a semi-infinite medium with a source reservoir maintained at constant concentration.

The concentration of Al at the interface in equilibrium with the high silica activity buffer (d) is 5 times higher than in case of the low silica activity buffer (a), changing from 50 ± 12 ppm to 220 ± 30 ppm. The solubility of Al in S.C.O. is 2 - 4 times higher than in forsterite (430 ± 50 ppm). These concentrations are 2-4 times lower then those calculated from olivine-spinel geothermometer (940 ± 170 ppm) [1] and obtained by partitioning experiments (755 ± 25 ppm) [3] at temperature of interest.

High rate diffusion of Al in S.C.O. and forsterite was obtained: $\log D_{Al/Fo}$ = -15.6 ÷ -13.2 (m^2/s) and $\log D_{Al/Ol}$ = -15.1 ÷ -14.4 (m^2/s). No dependence of Al diffusion rate on oxygen fugacity has been observed. The rate of Al diffusion was strongly controlled by activity of major cations (Si, Mg): there are 2 order of magnitude difference between diffusion coefficients of Al in forsterite in low and high silica activity experiments: $\log D_{Al/Fo(a)}$ = -15.5 ± 0.1 (σ) (buffer *a* with activities of a_{SiO2} = 0.01 and a_{MgO} = 1.00) compare to $\log D_{Al/Fo(c)}$ = -13.3 ± 0.1 (σ) (buffer *d* with activities of a_{SiO2} = 0.58 and a_{MgO} = 0.14). This difference suggests that the mechanism of Al substitution into the olivine lattice requires an ochtohidral site vacansy.

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Quartz isn't always just quartz...

Unravelling the hidden history of quartz evolution in high-temperature hydrothermal environments.

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Quartz is used almost exclusively in hydrothermal systems to unravel fluid histories. The morphology, fluid inclusions and isotopic signature of quartz constrain the temperature, fluid composition and provenance of hydrothermal fluids. In order to uncover the hidden history of quartz evolution, we have been studying euhedral quartz crystals from feeder zones beneath the El Indio Cu-Au deposit. These crystals show evidence of precursor high-temperature opal that has since evolved to quartz. High-temperature environments likely accelerate maturation (and subsequent dehydration) to euhedral quartz. Thus, although precursor metastable phases such as opal are rarely seen in many high-temperature hydrothermal environments (i.e. magmatic-hydrothermal systems and metamorphic environments), they are probably common. The occurrence of precursor opal in quartz raises questions on the validity of current estimates of temperatures and fluid provenance in many hydrothermal systems, as fluid inclusions record the P-T conditions of inversion rather than primary deposition. We also demonstrate that the extreme fractionation of $\delta^{18}O$ in 'evolved' quartz is inherited during maturation from opal.

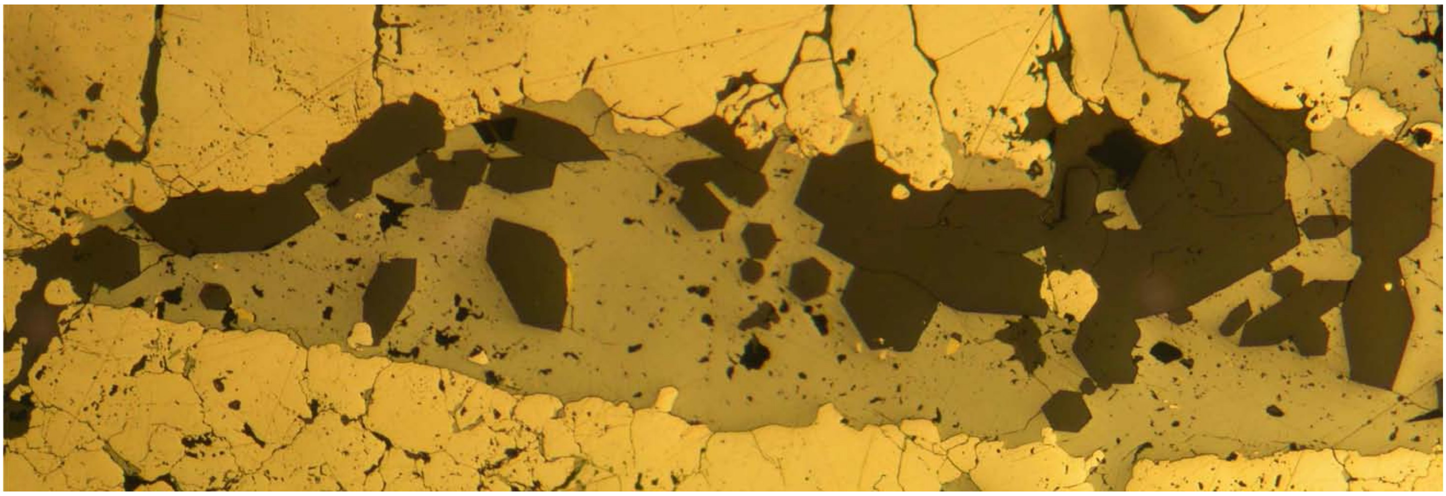

Figure 1. Quartz crystals giving up their secrets. Reflected light photomicrograph showing quartz microcrystals (dark grey; ~100 µm) in high-grade ore (light grey) from the El Indio Cu-Au deposit, Chile.

First continental roots down-under: an outback window into Hadaean craton foundations

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The foundation of our continents is its lithospheric root, the area between crust and convecting mantle that buoyantly underpins the old cratons. In principle, it's the melting of the mantle that forms this lithosphere: the freezing melt constitutes the essence of the crust we walk on. The melt-depleted remnants in the mantle make up the relatively cold sphere that forms the transition between mantle and crust, either oceanic (below the oceans) or continental (sub-continental lithospheric mantle, SCLM, below our continents) in nature. In order to decipher when and how the first continents formed in the dark ages of the planet, it boils down to the question: when did the first SCLM form to support a continent to float on it?

To answer this question, we searched for a window in the SCLM underpinning the Yilgarn craton in Western Australia, which hosts the oldest reported minerals on Earth (Jack Hills zircons dating back to 4.4 billion years). We analysed the geochemical signatures from drill cores penetrating a gigantic, remote intrusion (Windimurra layered mafic intrusion) that revealed an isotope anomaly with a unique fingerprint of its mantle source. The mineralogy of this source must have been a refractory assemblage of the mantle minerals olivine, orthopyroxene and garnet, all of which, and in this combination, characteristic for SCLM. The radiogenic nature of the isotope signals reveals an age of this SCLM that corresponds to the formation of the oldest terrestrial minerals, i.e., > 4 Ga ago. Based on our findings, it seems possible that our continents and their cratonal roots have been established in the infant stages of the planet; a prerequisite for the establishment of free surface water and the subsequent evolution of life.

Where does India end and Eurasia begin?

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The Himalayan mountain chain is thought to have formed because the Indian plate ploughed into the Eurasian continent, causing the rocks to buckle and thicken and to be uplifted. However, there is considerable debate within the scientific community about when this process occurred. Our team has been trying to understand more about the process of continental collision and when India and Eurasia collided. We have therefore been dating the age of rocks from where many scientists consider to be the Eurasian side of the border between the Indian and Eurasian continents. We found that the rocks that we dated had an age "fingerprint" that was more characteristic of the rocks being a part of the Indian plate than Eurasia. This work supported earlier results obtained from nearby fossils which had been largely forgotten about, or gone unnotticed by the scientific community. The outcomes of this work indicate that it is much more difficult to identify the location of the ancient plate boundary between India and Asia than had previously been considered.

While it is a challenge trying to understand what the earth looked like many millions of years ago and the location of Earth's ancient plate boundaries, it is not all for academic purposes. It is important that we understand how earth's plate boundaries evolved as this is where we think most of the world's major gold and copper deposits form. A better understanding of how plates move over time will likely lead to improvements in the way that we search for mineral deposits, and potentially to a better understanding of earthquake occurrences.

This research was published in the journal Geochemistry, Geophysics, Geosystems and can be found here:
http://www.agu.org/pubs/crossref/2011/2011GC003726.shtml

Does India's slow-down mark its collision with Eurasia?

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The Earth's surface is divided into a number of tectonic plates that move about the surface of the Earth due to heat which drives convection currents in the mantle and differences in a plates' density which causes the edges of some plates to sink (subduct), while others float as they are more bouyant. The tectonic plates move relatively slow (about the rate at which your fingernails grow), but over many millions of years they can travel thousands of kilometres. We can get an idea of how far the plates have traveled by using patterns that are created on the seafloor as the continents move away from one another to create the world's oceans. However, some tectonic plates travel faster than others and there are several different explanations as to why this happens.

The Indian plate was one of the fastest plates to move about the surface of the Earth over the past 100 million years. However, previous reconstructions of the tectonic plates have shown that the Indian plate slowed down considerably at about 50 million years ago. This period of deceleration is one of the key pieces of evidence that is used to support the timing of India's collision with Eurasia at about 50 million years ago and led to the creation of the Himalayan mountain chain. However, there is other evidence that indicates that India might have collided with Eurasia at around 35 million years ago. This is quite a long period of time. We therefore re-investigated all of the tectonic reconstructions of India's position in the past to gain a better understanding of India's velocity.

Our review showed that many of the previous models either relied on very old datasets or that they smoothed out any variation in India's velocity. We therefore created a new reconstruction of the Indian plate using the most up-to-date data that we could find. This showed that India rocketed northward between 100 million years ago and 65 million years ago, but rapidly decelerated after this point in time (Figure 1). Previous models only addressed India's deceleration and not its rapid acceleration. We therefore suspect that India's slow down might not be because it rammed into another continent, but that the one of the driving forces that was pulling the Indian plate rapidly northward ceased at around 65 million years ago. What is also interesting is that many of the sharp changes in plate velocity also correspond to major periods of deformation and metamorphism that we can now observe on the Earth's surface.

These results were published in the Journal of Geodynamics and can be found here:
http://dx.doi.org/10.1016/j.jog.2011.06.006

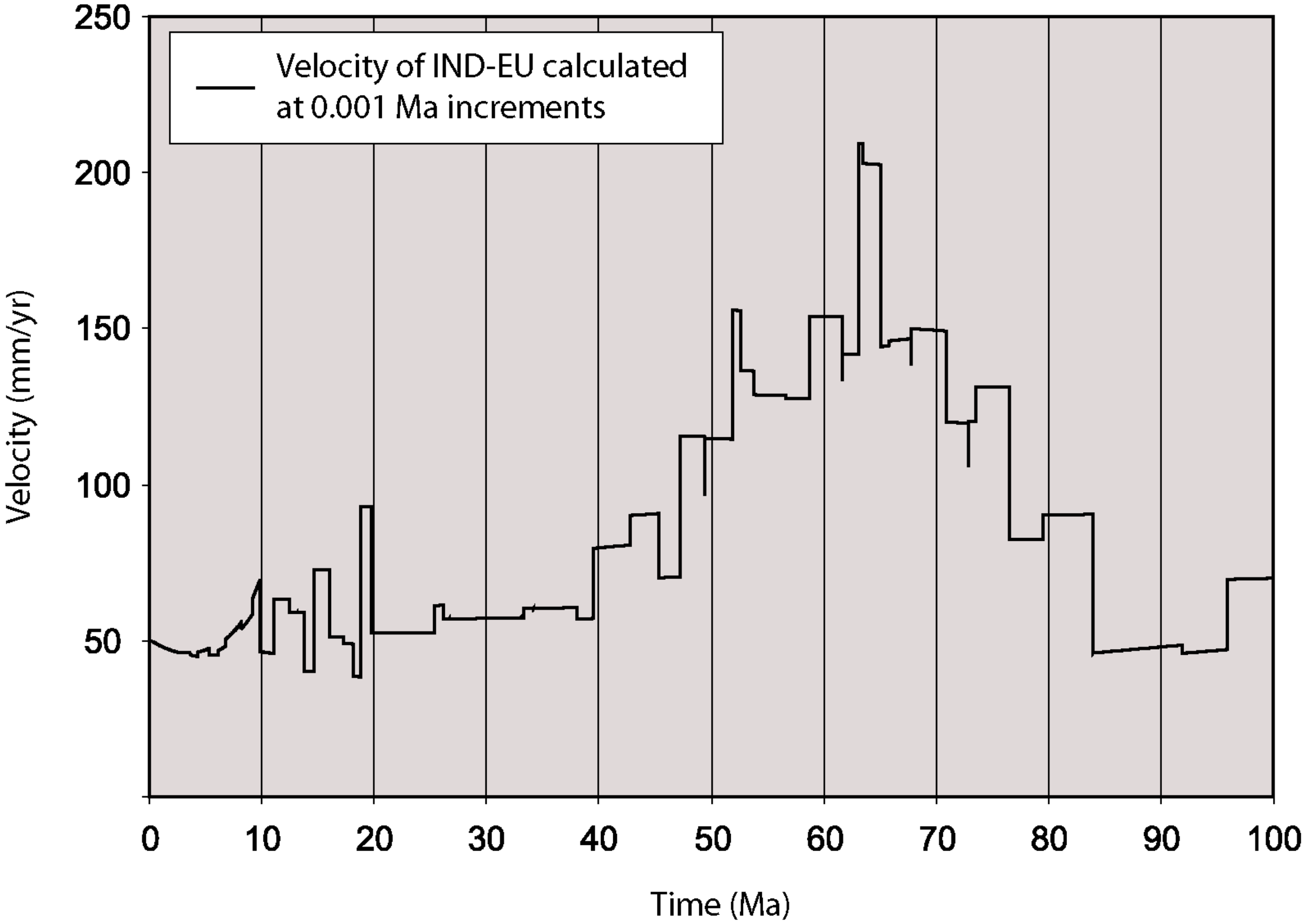

Figure 1. Velocity of the Indian plate relative to Eurasia over the past 100 million years (Ma).

Experimental determination of diffusion rates between garnet & ilmenite using pulsed laser deposition of thin films

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Experiments were run to determine the diffusion rate of Fe and Mn in garnet from an ilmenite thin film. In these experiments the ilmenite was deposited on one side of three Alm-Pyr garnet cubes as a thin film ~100nm thick; production of the thin film was by pulsed laser deposition (Fig.1). Experiments were performed in a one atmosphere furnace with oxygen fugacity controlled by a gas mixture of CO_2 and CO. Experiments were run at an fO_2 of 10^{-16} and $10^{-17.5}$ at temperatures and durations of 800°C for 47 hrs and 850°C for 22 hrs, respectively. These experiments were carried out with assistance from Prof Sumit Chakraborty and Dr Ralf Dohmen.

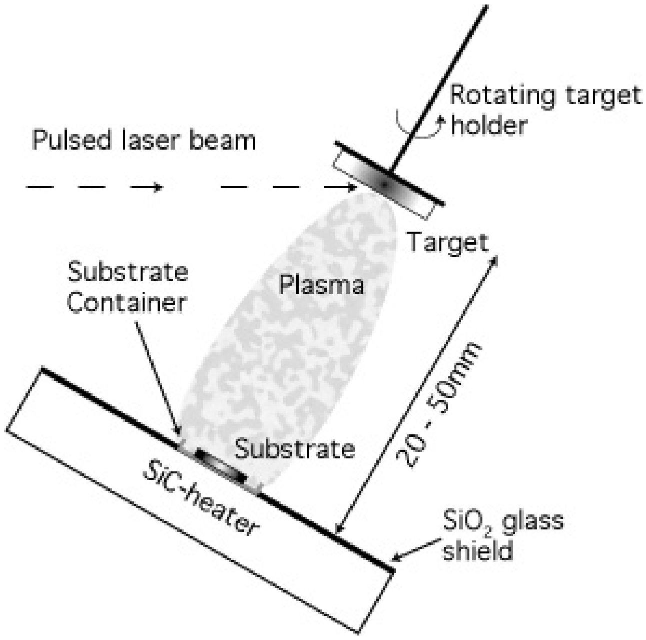

Figure 1. Illustration of the pulsed laser deposition set up at the Institut für Geologie, Mineralogie und Geophysik (RUB). Figure was modified from (Dohmen et al., 2002).

Analysis of the experiments was carried out using the Secondary Ion Mass Spectrometer (SIMS) at UWS funded by an AINSE research award. The experiments showed no measurable diffusion profiles. It was observed that the ilmenite thin film was thinner (~50nm) than estimated; this was measured using the profilometer at the UWS facility. Also, the Mn content of the ilmenite used as the target in the production of the ilmenite thin film was relatively low. This was identified as a possible cause for the lack of diffusion. These experiments will be re-run with a revised experimental design. A new ilmenite crystal with a higher Mn content has been selected as a target for the new experiments and the run times for the experiments will be extended to produce diffusion profiles of a measurable length. The temperature and oxygen fugacity for these new experiments will be kept the same.

The structure of subucting lithospheric slabs

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The structure of subducting slabs is something we can think about by using geophysical data to examine their geometry. Direct observation is difficult, for once a slab subducts, all available evidence suggests that it does not come back. It is on a one way journey towards the deep mantle.

So why do petrologists talk about "yo yo subduction"? In its more surficial levels, a subducting slab is perhaps overlain by a subduction channel, but this is likely to be relatively narrow (*i.e.* considerably less than 1km thick). Terrane stacks often overlie the subduction channel, however, caused by successions of accretion events as material is sliced from the downgoing slab, or from the overlying lithosphere. Terrane stacks can be very thick, and may extend a considerable distance (100-1000 km) from the active subduction zone.

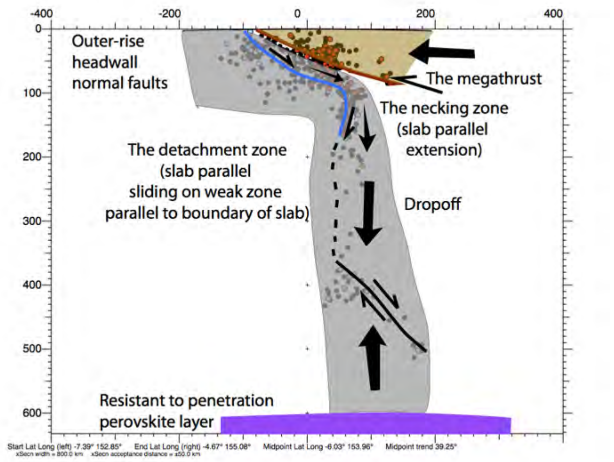

Figure 1. Program *eQuakes* has been written to allow the geometry of fault plane solutions to be statistically analysed. Surprisingly, such analysis shows that well-defined orientation groups are present in hypocentre clusters, allowing recognition of active movement zones within subducting slabs. Here we illustrate a section through the NE New Ireland slab, where delamination is apparently taking place, leading to slab sheeting, and dropoff. The dropping-off slab sheet is impacting on a relatively strong spinel-perovskite transition. Faults inferred have Mohr-Coulomb geometry, suggesting dilational effects due to phase transitions is involved in zones where catastrophic shear failure is taking place. There is no suggestion that the slab will bounce back, so "yo yo subduction" is unlikely. Subducting slabs make a one way trip to the deep mantle. They never come back.

Petrologists confuse the subduction channel with the overlying terrane stack, and introduce concepts such as "yo yo subduction" to explain factors such as the oscillation of pressure in rocks within the terrane stack. Such effects have long been recognised, and simply explained by the effect of tectonic mode switches that alternatively distend the terrane stack (leading to a pressure decrease recorded by mineral assemblages in a particular rock) and then shorten it (so that same rock now records a pressure increase). The concept of "yo yo subduction" is thus deprecated.

The effects of oscillating epochs of shortening and extension dominate the geology of the crustal and mantle rocks that overlie individual subduction zones. This behaviour is driven by changes in the relative velocity of the retreating subduction hinge, and it is appropriately described as "accordion tectonics". "Accordion tectonics" was first described in New Caledonia, by Tim Rawling, and then again recorded in the Western Alps, by Marco Beltrando.

There is more to the structure of subducting slabs than the material that is scraped off, sliced off, and accreted to the over-riding terrane stack, however. The structure of a subducting slab can be dominated by rips and tears, and also by delamination on weak zones within the slab itself such as result from dehydration reactions. These structures can be analysed using a combination of methods, here illustrated using Program *eQuakes* to recognise the effects of slab sheeting and dropoff.

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.

This year saw the commencement 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 largely on ocean modeling. Two new Postdoctoral Fellows were appointed to the CoE, Drs. S. Downes and A. Klocker. Dr. G.O. Hughes started his ARC Future Fellowship during the year. Ph.D. studies K. Stewart, submitted his PhD thesis and moved to a Postdoctoral research position at Johns Hopkins University, USA. Three undergraduate students who had completed research projects in Earth Physics were awarded University Medals during the year. They are C. Shakespeare and X. Qin who both did their Honours projects in Geophysical Fluid Dynamics, and D. Leykam, a Ph.B. student in Physics who completed special research projects, one in Mathematical Geophysics and the other in Seismology. During the year Dr. N. Balfour joined Seismology to pursue research interests in earthquake sources and also take charge of the outreach program AuSIS, Australian Seismometers in Schools program. Earth Physics staff were successful in applications for ARC Discovery, Linkage, and LIEF during the year.

Seismology

The Seismology group at RSES has carried out a series of field experiments in the last year. The EAL2 experiment, which covers a large region of central northern New South Wales with an array of 53 stations, was installed in mid-2010 and removed in mid-2011. The goal of the experiment is to image the crust and upper mantle beneath the northern Lachlan Orogen by exploiting the Earth's natural seismicity. It also represents a single movement of the larger WOMBAT transportable array experiment, which seeks to cover much of southeast Australia with passive seismic arrays by moving a large array from place to place. The EAL3 experiment, which involved the deployment of 42 stations in northeastern New South Wales in November 2011, represents the next phase of WOMBAT, which to date has installed more than 15 arrays with a cumulative total of over 600 stations. In July 2011, 24 broadband stations were deployed in southern Victoria, northern Tasmania, and the Bass Strait Islands as part of the BASS experiment. This is a joint venture between RSES and the University of Tasmania, and aims to image the crust and lithosphere beneath Bass strait by exploiting ambient seismic noise. In Queensland, the 31 station MINQ-B array, which was deployed in September 2010 in the Cloncurry-Julia Creek Region, was retrieved in mid 2011. The goal of this experiment is to image lithospheric structure in the vicinity of the Mt. Isa Inlier.

In other seismological studies of the deep interior resulted in observational evidence that the complex rotational dynamics of the Earth's inner core appear to be in close relationship with the geomagnetic field. An analysis technique known as partition modeling, was applied to the analysis of newly observed collection of earthquake doublets found by the group. Results indicate that the Earth's inner core shuffles, exhibiting both prograde and retrograde rotation in the reference frame of the mantle. An exciting result is that all three time-intervals in which the inner core distinctively accelerates with respect to the rest of the planet are in agreement with known occurrences of geomagnetic jerks. Because there is also a documented correlation between the geomagnetic jerks and the Length of Day time series, this all points to the same source and works in favour of a differential rotation rather than processes at the inner core boundary.

In **Geophysical Fluid Dynamics** exciting new results revealed a substantial role for buoyancy in driving the ocean circulation, and show turbulent mixing contributes to governing the global rate of overturning in the oceans. The overturning continually ventilates the ocean depths with cold dense polar water from the surface, and also carries heat from equatorial to polar regions. Laboratory experiments demonstrated how overturning is likely to be faster for more rapid small-scale mixing of density (or heat), supporting earlier theoretical modelling in RSES. The experiments also showed that a well-known methodology previously used to infer the rate of mixing in the oceans over-estimates the actual mixing rate. In a closely related study, computer models of the circulation in the Southern Ocean showed that surface buoyancy fluxes play a major role in driving the flow. Globally, an analysis of the ocean's energy budget showed that surface buoyancy fluxes and surface wind stress provide comparable sources of energy to the circulation. These conclusions are in contrast with an existing school of thought in which the energy input by buoyancy fluxes is neglected. They show instead a subtle inter-dependence of buoyancy and wind forcing, and the work will lead to a better understanding of how the circulation, water conditions and heat transport will change with global warming.

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. Establishment of the new inversion AuScope funded laboratory took place during the year. 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. During this year programmers have been seconded from the ANU supercomputing Facility to build the first suite of software for release in early 2012.

In lithosphere dynamics attention has been focused on applying new inversion methods, developed in the group, to the reconstruction of the Earth's past plate motions from finite rotations of the Lithosphere. It has been found that the largest kinematic changes across ridges are actually due to the observational noise in finite rotations. Upon noise removal a formal analysis of the spectral content associated with spreading-rate records excludes contributions from periods shorter than 0.5 – 1 Myr since mid/late Cenozoic. This supports the notion that the figure of current plate motions from space geodesy remained stable, and may therefore be extended back in time, for longer than ever thought.

Geodynamics research activity increased in 2011 with the addition of three new staff, involved in the development of a web interface and software for the analysis of space gravity data and the assessment of GPS time series. In addition, two international students were hosted (from Toulouse and Princeton) for several months, both of whom participated in the analysis of GRACE observations. In-house software was developed to process raw GRACE observations in order to generate estimates of the temporal gravity field of the Earth, and were also made official members of NASA's GRACE Science Team. Terrestrial gravity surveys were conducted in Western Australia and Central Australia using both the absolute gravimeter and relative tide meters. Advances were made in the software used for modelling of the response of the Earth to changes in continental ice loads, in particular the inclusion of degree-1 deformation and higher resolution coastlines and bathymetry models.

Professor Malcolm Sambridge
Associate Director, Earth Physics

Extending the Global Database of Geomagnetic Excursions

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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.

Varying mechanical coupling along the Andean margin: Implications for trench curvature, shortening and topography

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Convergent margins often exhibit spatial and temporal correlations between trench curvature, overriding plate shortening and topography uplift that provide insights into the dynamics of subduction. The Andean of this class of tectonics systems. There is distinctive evidence that the degree of mechanical couplingsystem, where the Nazca plate plunges beneath continental South America, is commonly regarded as the archetype between converging plates, i.e. the amount of resistive force mutually transmitted in the direction opposite toof this class of tectonics systems. There is distinctive evidence that the degree of mechanical coupling between converging plates, i.e. the amount of resistive force mutually transmitted in the direction opposite to their motions, may be at the present-day significantly higher along the central Andean margin compared to the northern and southern limbs. However quantitative estimates of such resistance are still missing and would be desirable. Here we present laboratory models of subduction performed to investigate quantitatively how strong lateral coupling variations need to be to result in trench curvature, tectonic shortening and distribution of topography comparable to estimates from the Andean margin. The analogue of a two-layers Newtonian lithosphere/upper mantle system is established in a silicone putty/glucose syrup tank-model where lateral coupling variations along the interface between subducting and overriding plates are pre-imposed. Despite the simplicity of our setup, we estimate that coupling in the central margin as large as 20% of the driving force is sufficient to significantly inhibit the ability of the experimental overriding plate to slide above the subducting one. As a consequence, the central margin deforms and shortens more than elsewhere while the trench remains stationary, as opposed to the advancing lateral limbs. This causes the margin to evolve into a peculiar shape similar to the present-day trench of the Andean system.

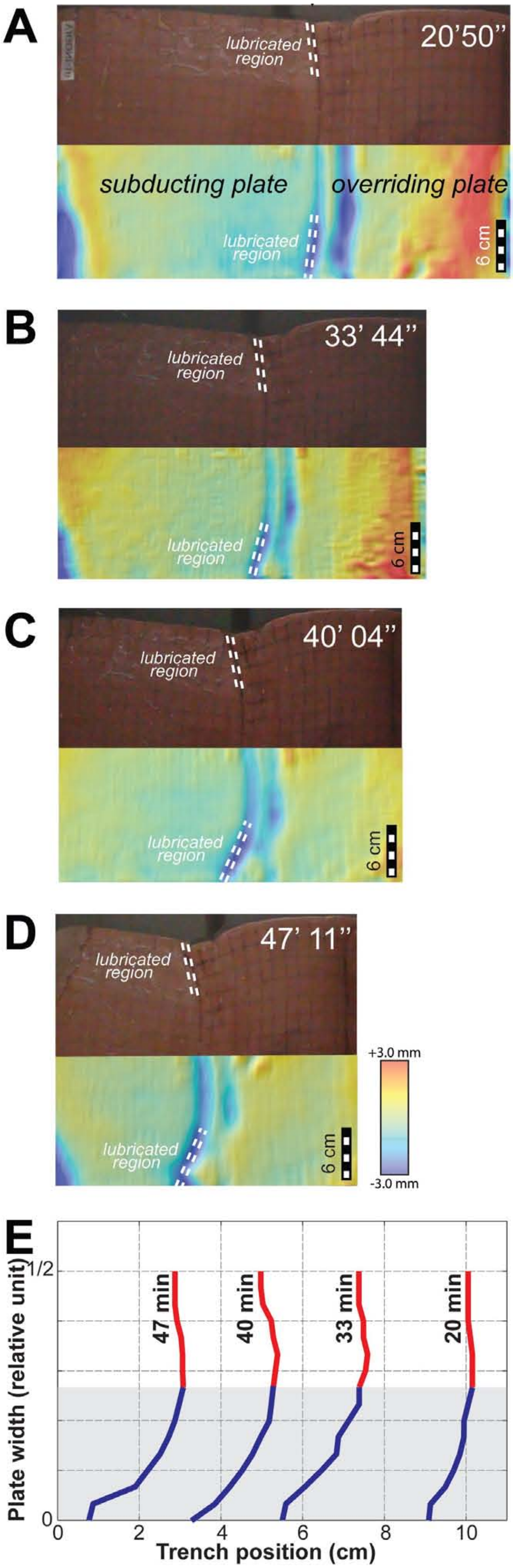
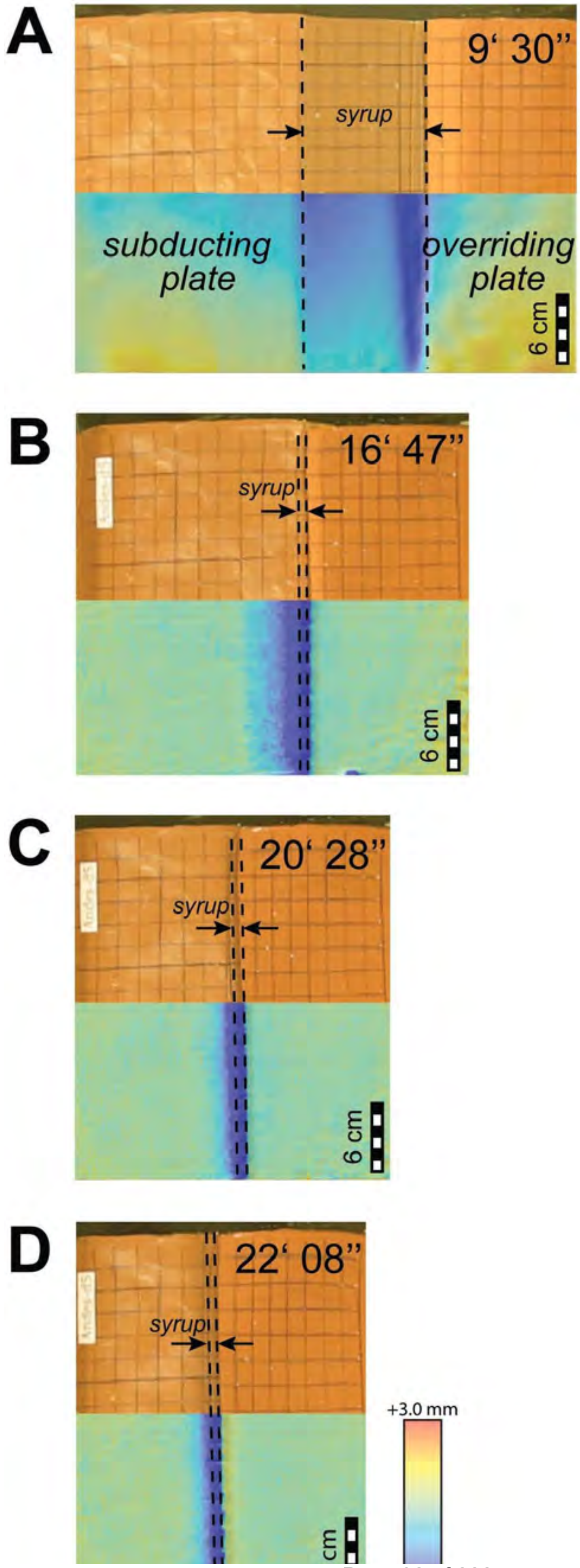


Figure 1. Trench evolution of laboratory model 1: (A–D) snapshots of the process. Elapsed time from model start is in

the upper-right corner. The subducting plate moves toward the overriding one from left to right. The upper half of each panel is a picture of the plates, where 2x2 cm**2 squares are outlined to detect deformation. The lower half is a laser-scanned image of plate relief (offset from the beginning of the model) acquired at the same moment: red represents bulging upwards, blue is bulging downwards. Note that the model plates are manually attached to the pistons, therefore the peripheral regions naturally bulge upwards or downwards, and are thus detected as anomalous. (E) Evolution of half-trench through time, as detected through the laser-scanned images. Red on white is the portion of trench with no lubricant paste, hence featuring high coupling. Blue on gray is one of the lateral edges with lubricant paste, thus featuring average coupling.



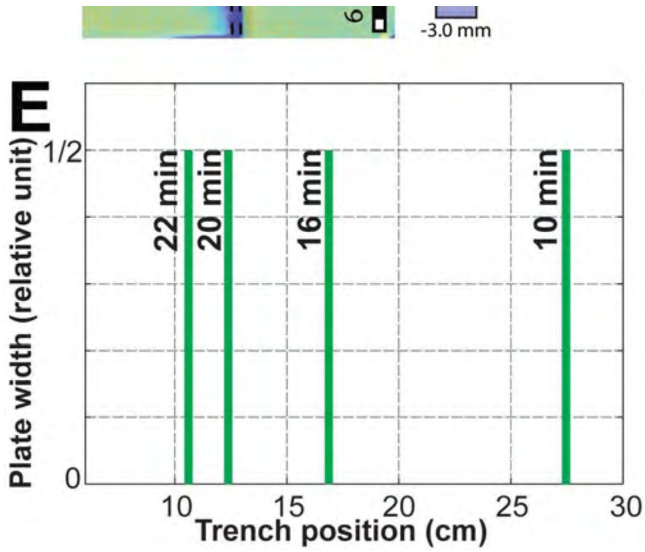

6
-3.0 mm
E
Plate width (relative unit)
1/2
0
22 min
20 min
16 min
10 min
10
15
20
25
30
Trench position (cm)

Figure 2.

Crustal Structure of Australia from Ambient Seismic Noise Tomography

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Surface wave tomography for Australian crustal structure has been carried out using group velocity measurements in the period range 1-32 s extracted from stacked correlations of ambient noise between station pairs. Both Rayleigh wave and Love wave group velocity maps are constructed for each period using the vertical and transverse component of the Green's function estimates from the ambient noise. The full suite of portable broadband deployments and permanent stations on the continent have been used with over 250 stations in all and up to 7500 paths.

Local group dispersion information is collated for a distribution of points across the continent and inverted for a 1D SV wavespeed profile using a Neighbourhood Algorithm method. The resulting set of 1D models are then interpolated to produce the final 3D wavespeed model.

The group velocity maps show the strong influence of thick sediments at shorter periods, and distinct fast zones associated with cratonic regions. Below the sediments the 3D shear wavespeed model displays significant heterogeneity with only moderate correlation with surface tectonic features. For example, there is no evident expression of the Tasman Line marking the eastern edge of Precambrian outcrop.

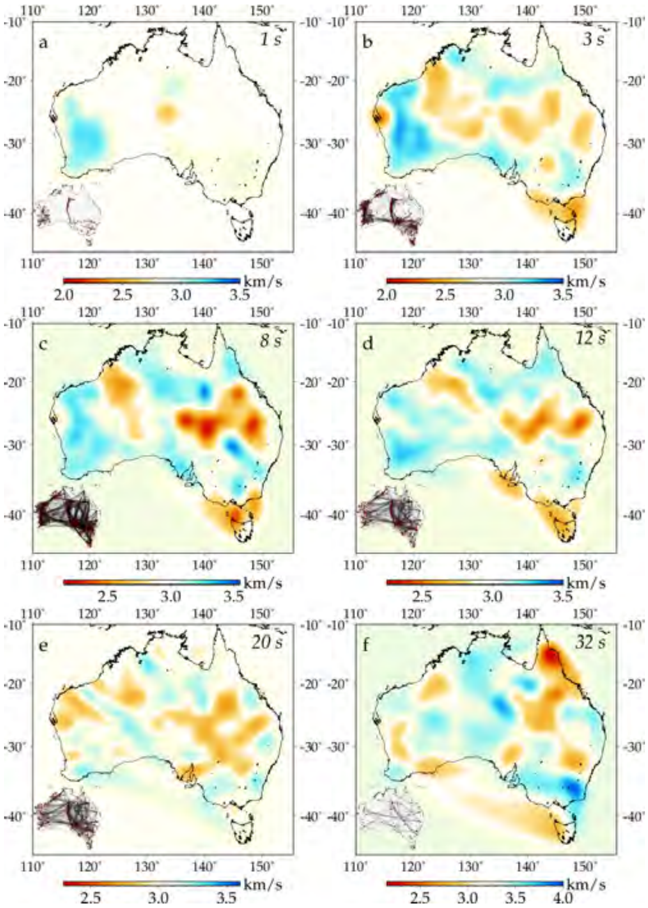

Figure 1. Rayleigh wave group velocity tomography for the period range of 1-32 s created from passage time measurements taken from the Green functions estimates from ambient seismic noise correlations.

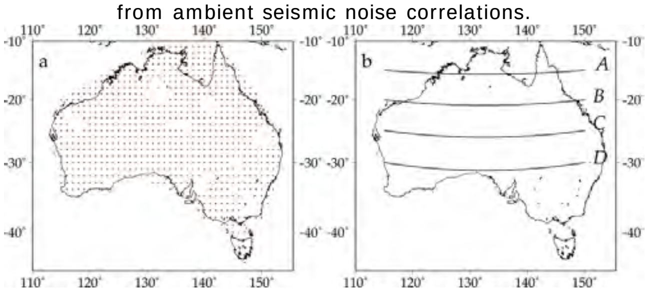

Figure 2. a) Spatial sampling points used in 1D inversion. b) Locations of vertical cross-sections A-D.

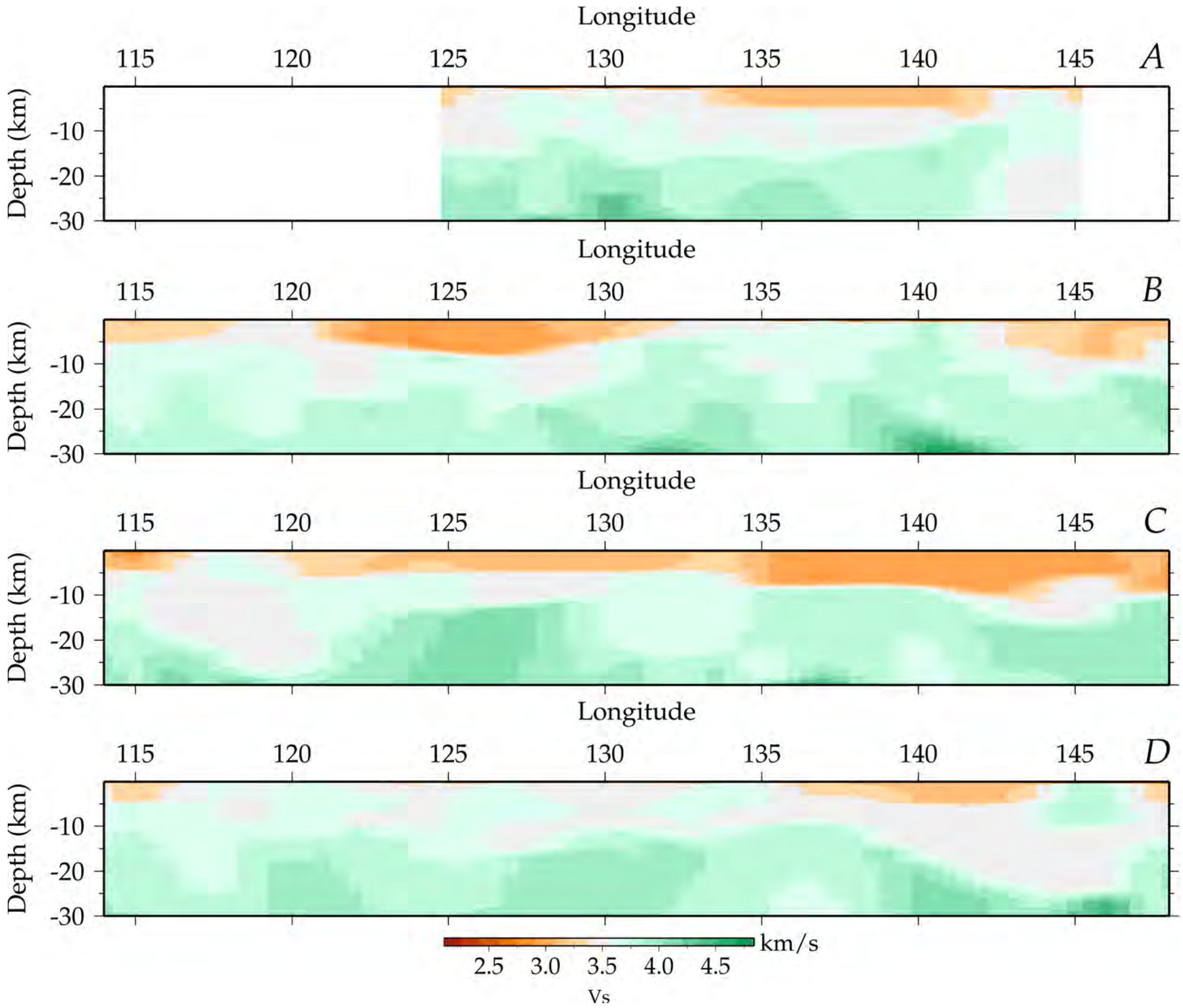

Figure 3. The shear velocity-depth sections along lines A, B, C, and D given in Figure 2b.

Self Adaptive Surface Reconstruction from Multiple Datasets

An Example for the Australian Moho

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Surface fitting, regular gridding or data interpolation are problems often occuring in many fields of geosciences. They all are treated with a well known general statistical tool : regression analysis. Some noisy records of a continuous function (e.g. temperature, gravity, concentration in stable isotopes) are recorded at some discrete locations in space or time, and the problem consists on recovering this unknown function. One-dimensional examples include time series analysis of geochemical proxies. Two-dimensional examples (i.e. surface reconstruction) include gridding of satellite measurements or maping potential fields.

Here we propose to apply a reversible jump algorithm to the 2D regression problem. The problem is solved in a Bayesian framework where the solution is the posterior probability distribution, i.e. the probability of the unknown parameters given the data. Instead of seeking a best fitting surface within an optimization framework, one seeks an ensemble of solutions that represents the posterior distribution and derives properties of that ensemble for inspection.

Here we show results in a case where the Moho discontinuity (i.e. the base of the crust) across Australia is reconstructed from a set of various seismic data (i.e. reflection, refraction, receiver functions, tomography). At any point on the map, the solution is represented as a complete probability distribution for Moho depth. Figure 1 shows the "average map" where the mean of the distribution is plotted at each pixel. Figure 2 shows the complete distribution along two cross-sections shown in Figure 1. It is interesting to note that the posterior distribution can be bi-modal (lower panel in Figure 2), and hence this scheme is able to fully account for non-linearity in regression problems.

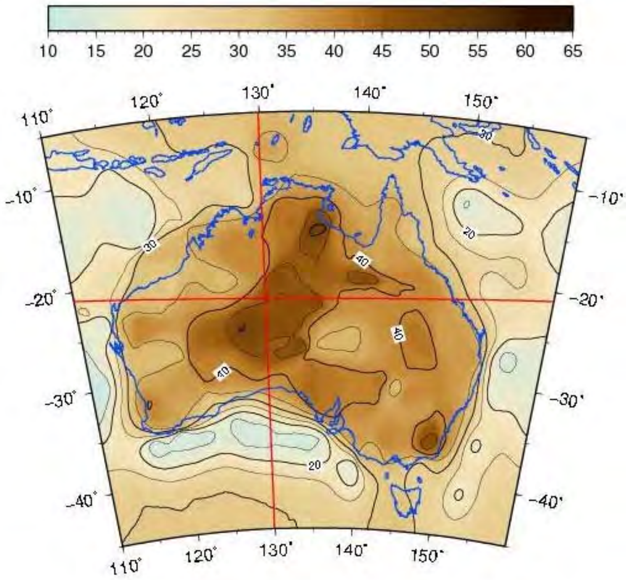

Figure 1. Average map (km) for Moho surface constructed from the reversible junp algorithm. At each pixel of the map is ploted the expected moho depth, i.e. the mean value of the posterior probability distribution.

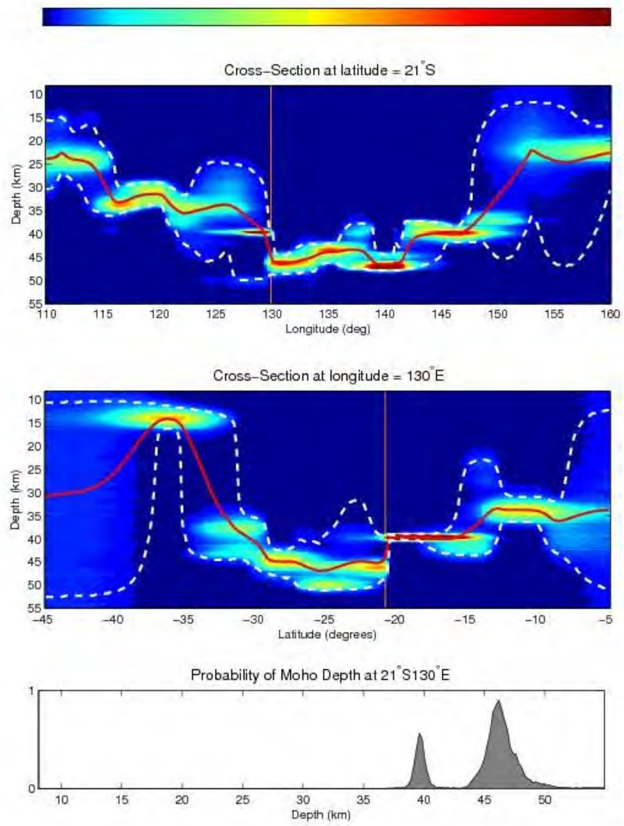

Figure 2. Full posterior probability distribution for moho depth along the lines shown in red in Figure 1 (red is high probability and blue is low). White dashed lines show the 95% credible interval, and red lines folow the mean of the distributionat each location. The last panel show the full probability distribbution where the 2 lines intersect.

AuSREM – Australian Seismological Reference Earth Model

Michelle Salmon and Brian Kennett

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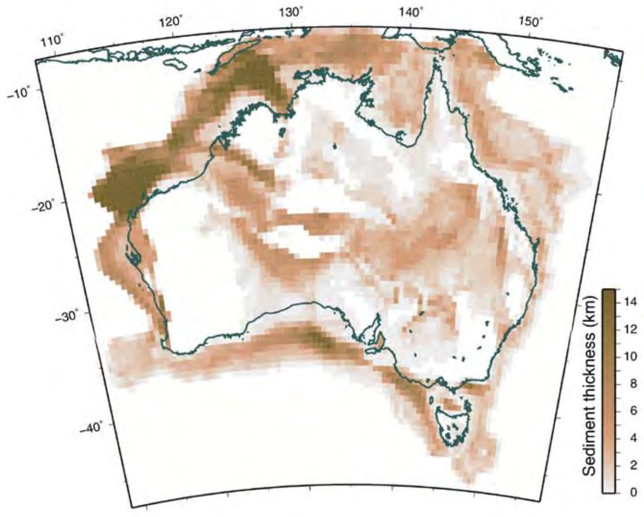

Figure 1. Phanerozoic sediment thickness. Initial sediment thickness is taken from the OZ SEEBASE compilation that used gravity, magnetic seismic reflection information to build a model of the sediment distribution on-shore and off-shore.

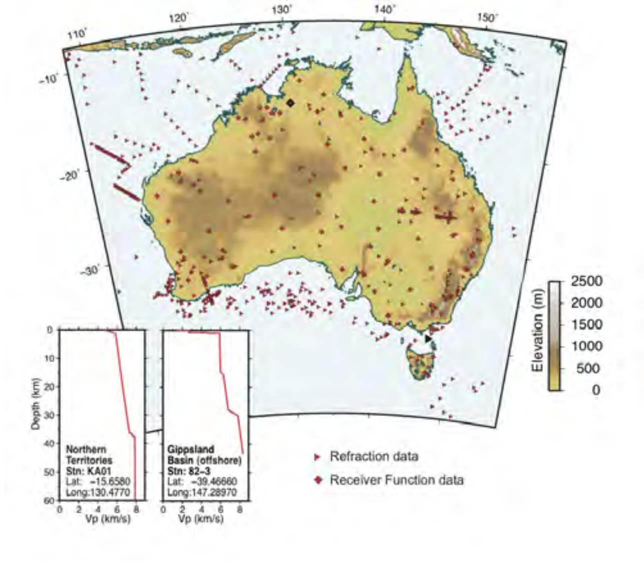

Figure 2. 1D velocity models. P-wave velocity models are currently available at 744 locations shown. This information has been obtained from refraction surveys (courtesy of Geoscience Australia) and receiver function modeling. Two examples of velocity profiles are shown, a receiver function profile (KA01 Northern Territories) and a refraction profile (82-3 Offshore Gippsland Basin).

Seismic data coverage of Australia has greatly increased over the last 10 years, providing an opportunity to update the seismological model of the continent. 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.

The AuSREM project aims to produce a fully interpolable seismological model of the Australian continent with a 0.5-degree resolution down to 350 km depth. It will include a detailed crustal model of P-wave speed (figure 2.), S-wave speed, density and depth to major boundaries such as the base of sediment cover (figure 1.) and the Moho. The mantle component of the model is likely to be less detailed but will also include P-wave speed, S-wave speed and density.

This project is a collaborative effort relying on the integration of a wide variety of data sources. For the crustal component data sources include refraction surveys, receiver function studies, reflection surveys, crustal tomography, gravity interpretation and sediment thickness databases. The mantle component will rely mainly on tomography.

Progress of this project can be followed on the AuSREM website http://rses.anu.edu.au/seismology/AuSREM/ Ultimately this model will be publicly available and will provide a base model for other research.

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

Building a Dual Purpose Network: The Australian Seismometers in Schools Program (AuSIS)

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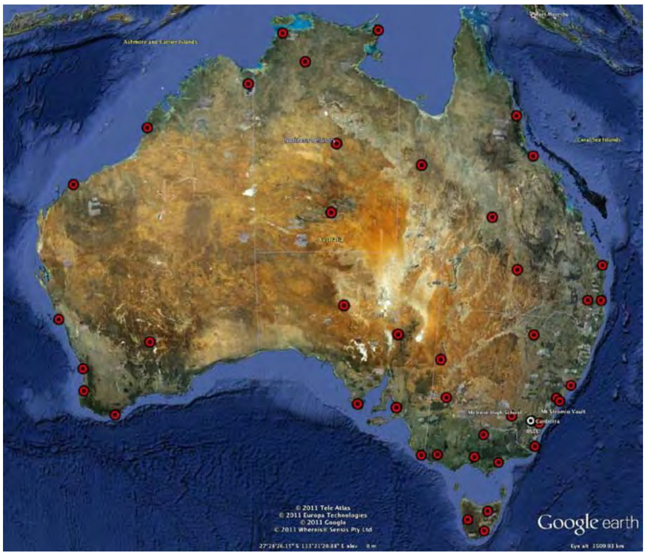

Figure 1. *Figure 1. Map of potential sites for AuSIS instruments (yellow). Existing sites in ACT are shown in red. The locations and the number of stations per state will probably change depending on response from schools and logistical considerations.*

Over the next four years AuSIS will build a network of 40-45 seismometers installed in high schools across the nation (see Figure 1). These will provide real-time monitoring of the Australian continent and raise awareness of geoscience. Although the project's goals are primarily education and outreach focused, it is also an excellent opportunity for research. The continuous waveform recordings that schools collect will be publicly available online to researchers and could complement networks run by government and state agencies. The high quality of these broadband instruments will also be advantageous for advanced seismological research, such as studies of lithospheric structure.

A recent measure of the potential success of the program occurred during a 48-hour test of one of the sensors at a school in Canberra where two distant earthquakes were recorded. One of the events was an Mw 6.9 in Taiwan that occurred during school hours and was very clearly recorded at all three test sites in Canberra (see Figure 2). Students at the school site were excited and curious at how they could record earthquakes that occurred so far away. These instruments are now being installed in three schools as part of a pilot program in and around the ACT.

Due to the expanse of Australia and remoteness of many communities the program requires local experts and enthusiasts get involved so that they can provide support and share their knowledge with schools. A growing community of institutional and individual volunteers is forming to support the program within their local state or territory.

Long-term storage of data for research purposes will be aligned with community standards at internationally accessible and supported data management centres, such as IRIS. AuSIS is funded by the Education component of AuScope Australian Geophysical Observing System (AGOS).

Figure 2. *Figure 2. Seismic waveforms of an earthquake in Taiwan recorded at three test sites in Canberra.*

Seismic structure of the southeast Australian lithosphere from surface and body wave tomography

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Teleseismic arrival time residuals from the WOMBAT transportable seismic array experiment are inverted to construct a high-resolution 3-D P-wave velocity model of the upper mantle beneath southeast Australia. In order to address one of the principal limitations of teleseismic tomography - that long wavelength structure is filtered out when data from multiple arrays operating at different times are used - an initial model with lower spatial resolution, derived from surface tomography, is constructed to preserve the broad scale features that would otherwise be lost. Although the absolute velocities of the final model are not strongly constrained due to the assumption of radial Vp/Vs ratios and differences in regularisation, the relative variations appear robust across all scales. These reveal a wealth of features that can be related to the geology and tectonic history of the region, the most significant being (1) an easterly dipping velocity transition zone which involves a higher velocity Delamerian Orogen extending beneath the Western Subprovince of a lower velocity Lachlan Orogen; (2) a distinct region of low velocity in the upper mantle north of Melbourne, which can be associated with recent Quaternary hot-spot volcanism; (3) a gradual east-southeast decrease in velocity towards the coast, which is consistent with lithospheric stretching and thinning near a passive margin; (4) a zone of high velocity north of Adelaide that may correspond to the presence of the Palaeoproterozoic Curnamona Province at depth. These results have important implications for the Palaeozoic evolution of the east margin of Gondwana, the subsequent break-up of Australia and Antarctica and opening of the Tasman Sea.

Tectonophysics article in press
http://www.sciencedirect.com/science/journal/aip/00401951

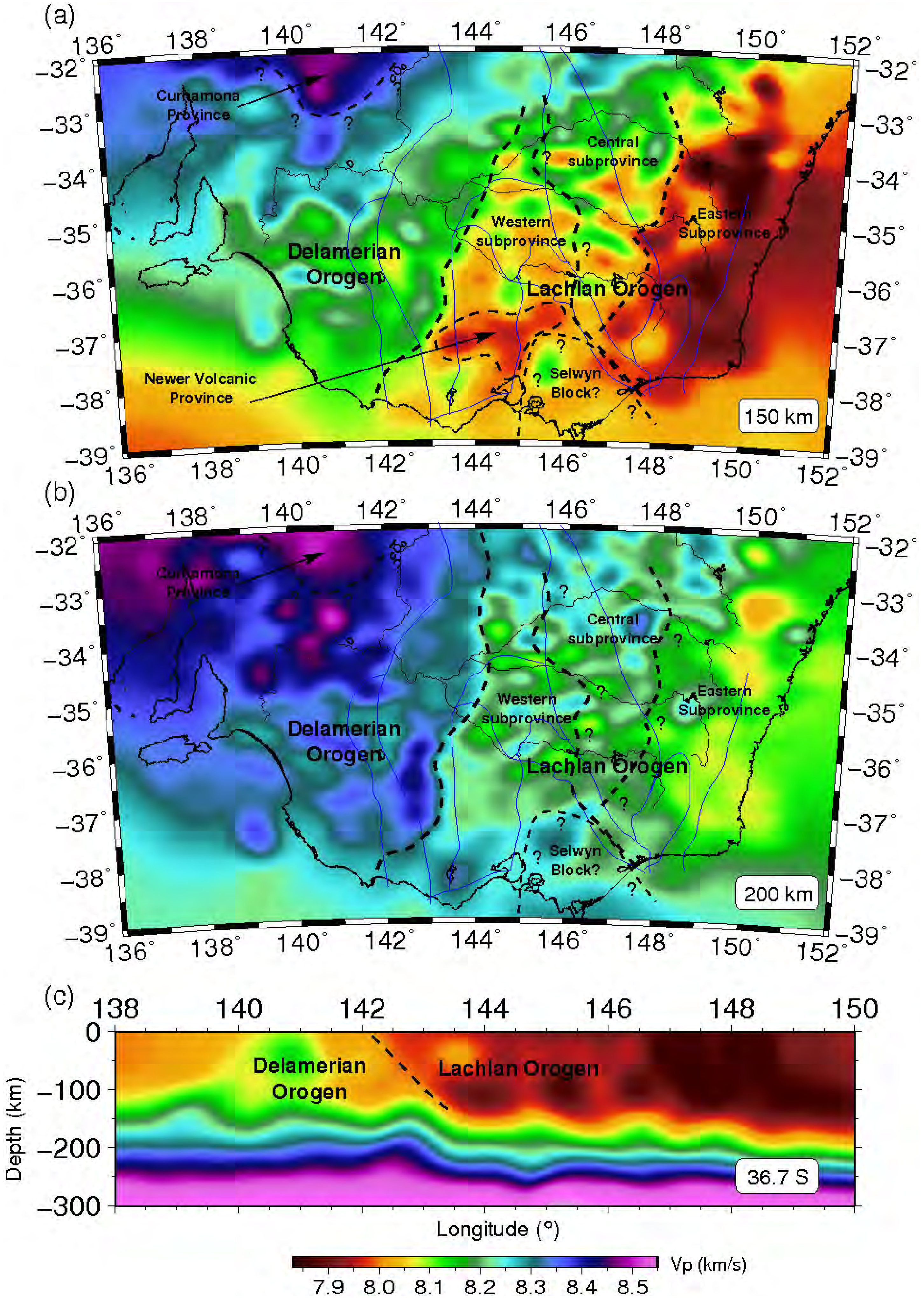
(a)
Curnamona Province
Central subprovince
Eastern Subprovince
Western subprovince
Delamerian Orogen
Lachlan Orogen
Newer Volcanic Province
Selwyn Block?
150 km
(b)
Curnamona Province
Central subprovince
Eastern Subprovince
Western subprovince
Delamerian Orogen
Lachlan Orogen
Selwyn Block?
200 km
(c)
Delamerian Orogen
Lachlan Orogen
36.7 S
Depth (km)
Longitude (°)
Vp (km/s)
7.9
8.0
8.1
8.2
8.3
8.4
8.5

Figure 1. A selection of slices through the surface wave and body wave solution model with a number of features highlighted. Blue lines indicate the location of observed and inferred terrane boundaries at the surface. (a) Slice at 150km depth; (b) slice at 200 km depth; (c) E-W section at 36.7^{o} south

3-D Structure of Flinders Ranges from Local Earthquake Tomography

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The Flinders Ranges, situated in the Adelaide Fold Belt, South Australia, comprise a Paleoproterozoic to Mesoproterozoic cratonic basement overlain by a thick sequence of Neoptroterozoic to Cambrian rift sediments. The crystalline basement is characterized by enrichment in heat producing elements with high surface heat flow rates that average 90 mWm^{-2}. The area lies within a region of relatively high active intra-plate deformation that manifests as a distinct concentration in seismic activity as well as a present-day topographic relief. Furthermore, unlike most other stable continents, maximum horizontal compressive stress trajectories in the Australian crust do not align with absolute plate velocity, and have a particularly complicated configuration in the Flinders Ranges area.
In this study, local earthquake tomography is carried out in order to simultaneously improve hypocenter locations and 3-D variations in velocity structure, with the goal of improving our understanding of crustal structure, rheology, and the mechanism responsible for localized deformation in a region of major geological and tectonic significance. The data used for this purpose are traveltimes from 411 local earthquakes recorded by a temporary network of 29 broadband seismometers deployed between 2003 and 2005.

A tomographic inversion package called FMTOMO is used to perform Local Earthquake Tomography. It uses a grid-based eikonal solver, known as Fast Marching Method (FMM), to solve the forward problem of traveltime prediction. A gradient based subspace inversion scheme is used to solve the inverse problem of adjusting model parameters to satisfy observed data subject to damping and smoothing regularization. This is applied iteratively together with FMM and the relocation alghoritm in order to address the non-linear nature of the inverse problem. The source relocation is performed using a grid-search approach which finds the minimum misfit in the FMM traveltime grid of an objective function that is based on the difference between observed and predicted traveltimes. In this study 2653 P traveltimes are used, however, the dataset also includes several S, Pn, Sn, PmP and SmS phases. The grid spacing to perform the forward step, as well as the non-linear relocation, was approximately 1.6 Km in both depth, latitude and longitude with a total of more than 2 milions nodes. The velocity inversion was carried out using damping and smoothing factors equal to 1.0. The final solution model reduces the data misfit variance by 43% which corresponds to an RMS reduction from 519 ms to 299 ms.

It has been suggested that in the Flinders Ranges, in part due to high surface heat flows, the crust is particular weak and thin, showing a brittle deformation in the shallow area and a deeper ductile but non-seismogenic deformation. However, our preliminary results show that seismicity can be observed at all crustal depths. In particular, seismicity in the horizontal slice and cross sections (Fig. 1 and 2) show two main clusters (SZ1 and SZ2) in a range from 10 to 25 Km depth, usually at the contact between positive and negative anomalies.

Future work will begin by investigating solution non-uniqueness in order to to evaluate how well constrained the recovered model features are. The S wave data and different crustal phases will also be used to build on the initial results .

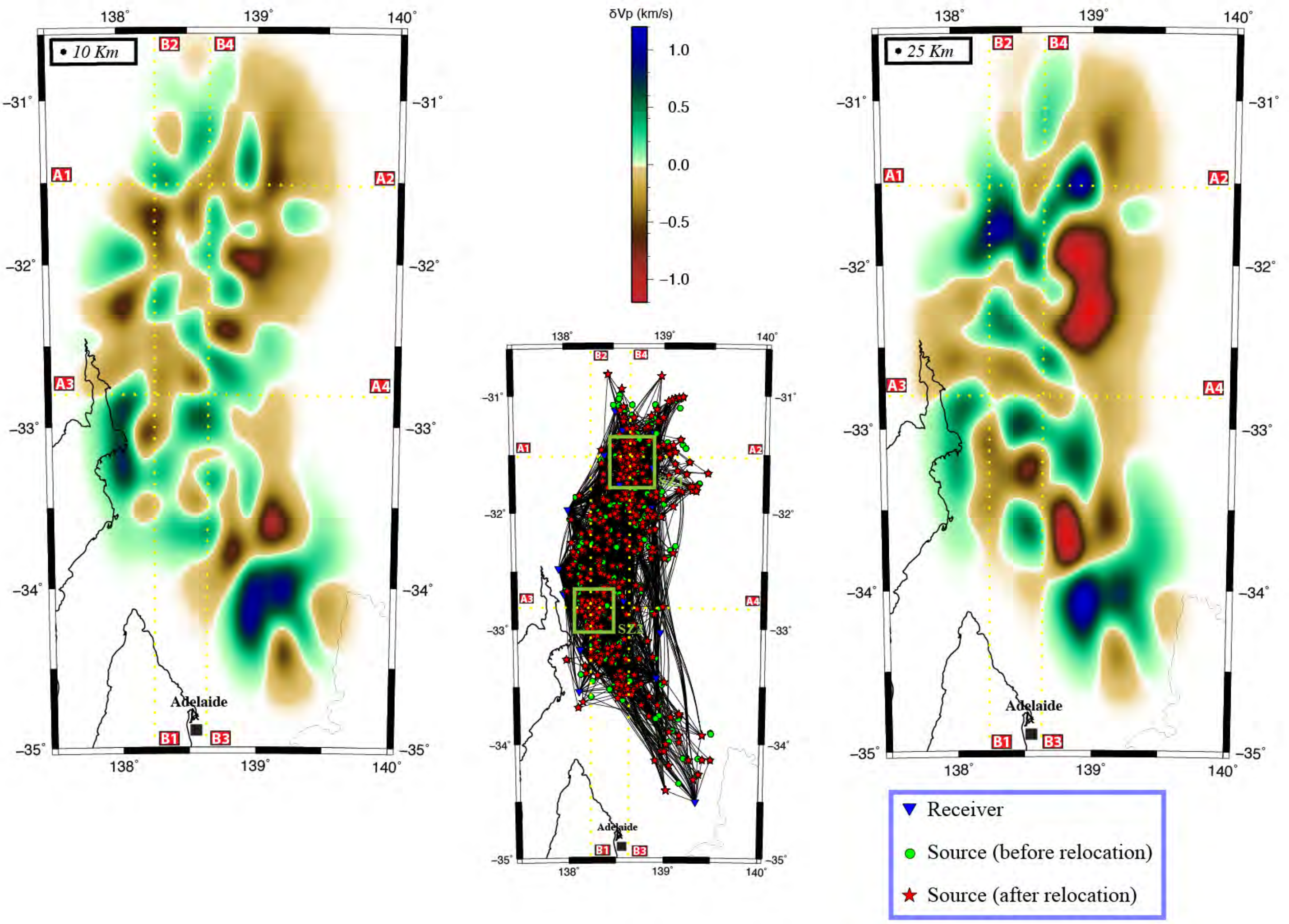

Figure 1. Depth slides plus ray path.

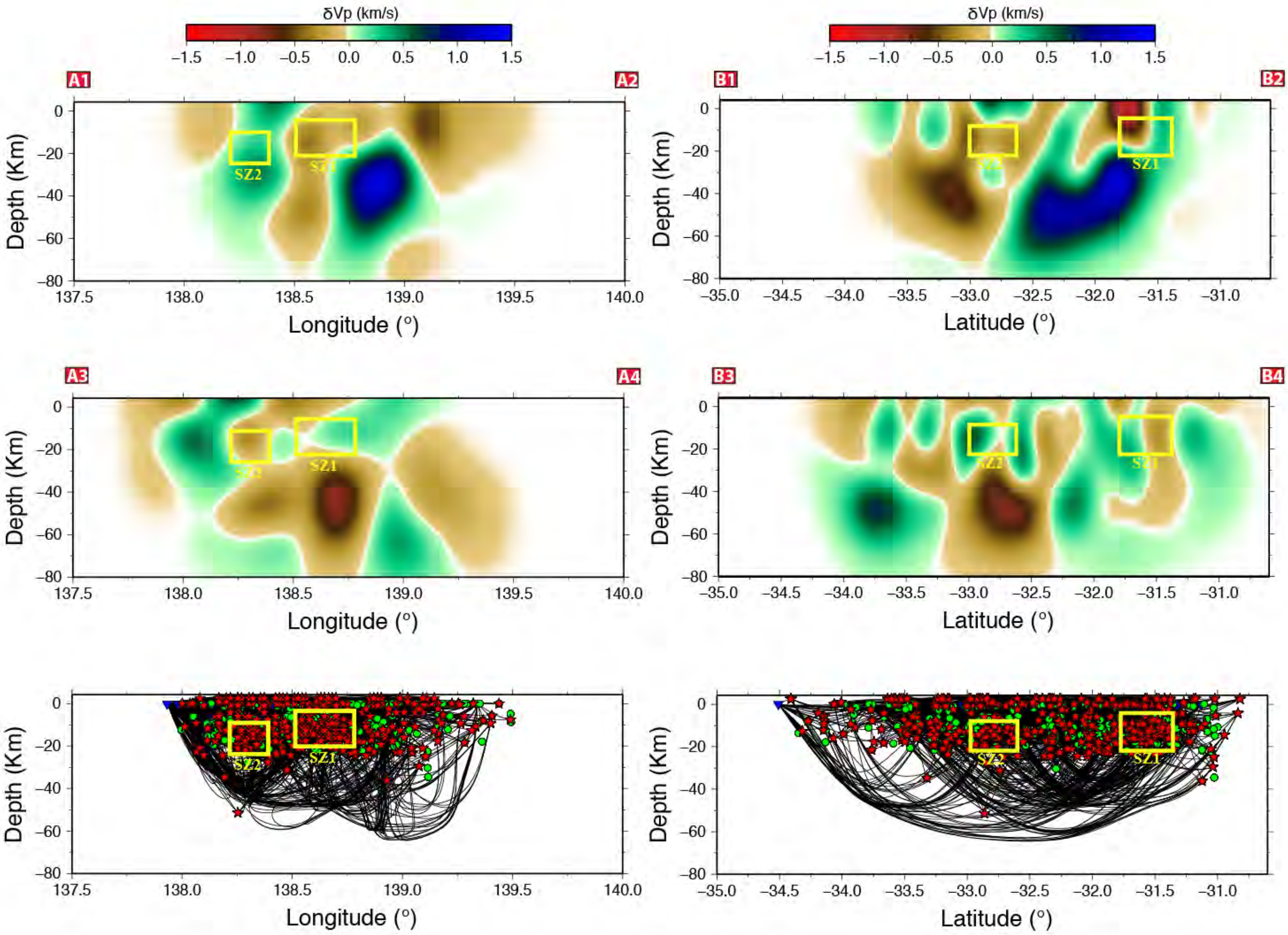

Figure 2. Crosse sections plus ray path. Refer to depth slides for position.

AusMoho: the variation of Moho depth across Australia

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A new comprehensive model for Moho depth across Australia and its immediate environment has been developed by utilising multiple sources of information.
Since 2004 more than 7 000 km of full-crustal reflection profiles have been collected across Australia to give a total of more than 12 000 km, providing valuable new constraints on crustal structure. A further set of hitherto unexploited results comes from 150 receiver functions distributed across the continent, mostly from portable receiver sites. These new data sets provide a dramatic increase in data coverage compared with previous studies, and reveal the complex structure of the Australian continent in considerable detail.

On-shore and off-shore refraction experiments are supplemented by receiver functions from a large number of portable stations and the recently augmented set of permanent stations, and Moho picks from the full suite of reflection transects. The composite data set (Figure 1) provides a much denser sampler of most of the continent than before, though coverage remains low in the remote areas of the Simpson and Great Sandy deserts. The various datasets provide multiple estimates of the depth to Moho in many regions and the consistency between the different techniques is high. In a number of instances, differences in estimates for Moho depth can be associated with the aspects of the structure highlighted by the particular methods.

The new results allow considerable refinement of the patterns of Moho depth across the continent compared to the last compilation in 2003. As can be seen in Figure 2, some of the thinnest crust lies beneath the Archean cratons in the Pilbara and the southern part of the Yilgarn. Thick crust is encountered beneath parts of the Proterozoic in Central Australia, and beneath the Paleozoic Lachlan fold belt in southeastern Australia. The refined data indicate a number of zones of sharp contrast in depth to Moho, notably in the southern part of Central Australia where there is a considerable east-west gradient. The most recent reflection work in Western Australia has had a considerable influence on the map of Moho depth and has enlarged the area with thicker crust (> 40 km thick).

AusMoho Model
http://rses.anu.edu.au/seismology/AuSREM/ausmoho.html

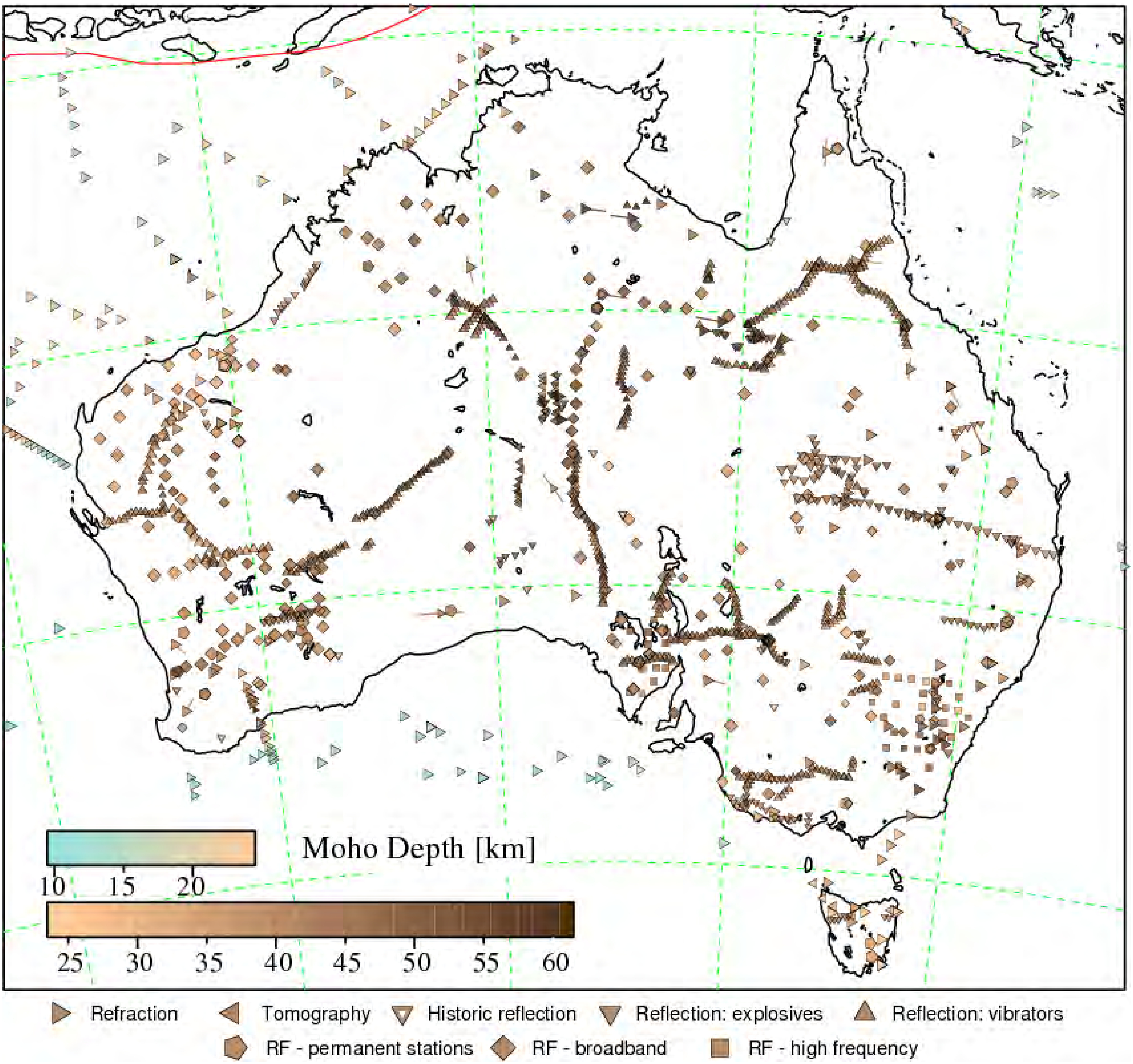

Figure 1. Compilation of all the different styles of Moho estimates with symbol coding by the class of data used. The size of the symbols increases with the reliability of the results. Line segments indicate the sampling from refraction experiments. In general, there is close correspondence between the estimates derived from different techniques.

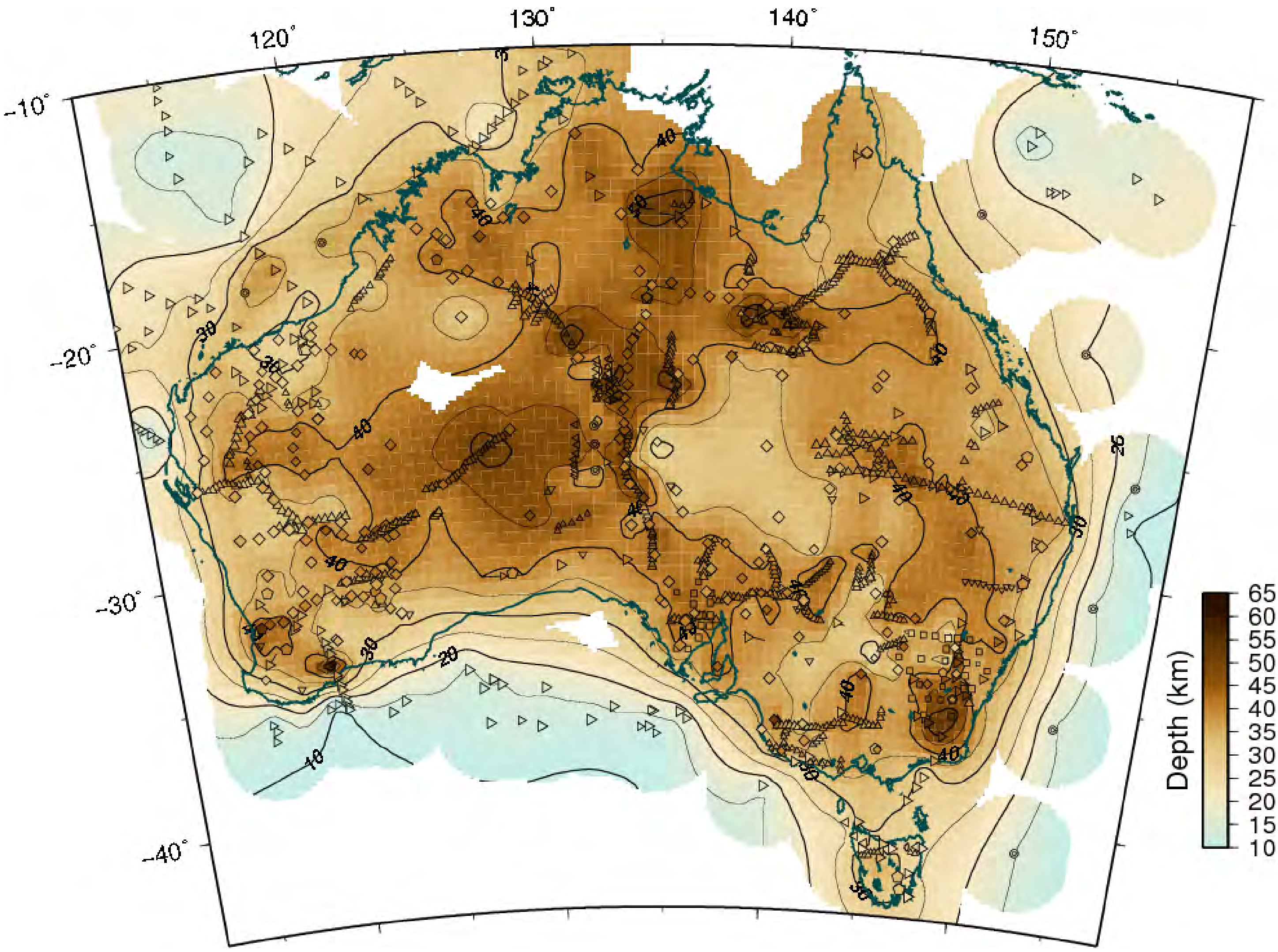

Figure 2. Moho surface constructed from the full set of estimates displayed in Figure 1. The surface is constructed by interpolating weighted averages for each 0.5x0.5deg cell, the size of the pixels in the image. The original results are superimposed on the interpolated surface using the same colour coding, shown at the right with depths in kilometres. Additional control points based on the gravity analysis by Aitken (2010) are indicated by double circles; these extra points, applied with low weighting, help define features with strong directionality and constrain, to some extent, the continent-ocean margin to the east of Australia

Signals from Noise: High-Resolution Maps of the Southeast Australian Crust

Mallory Young and Nick Rawlinson

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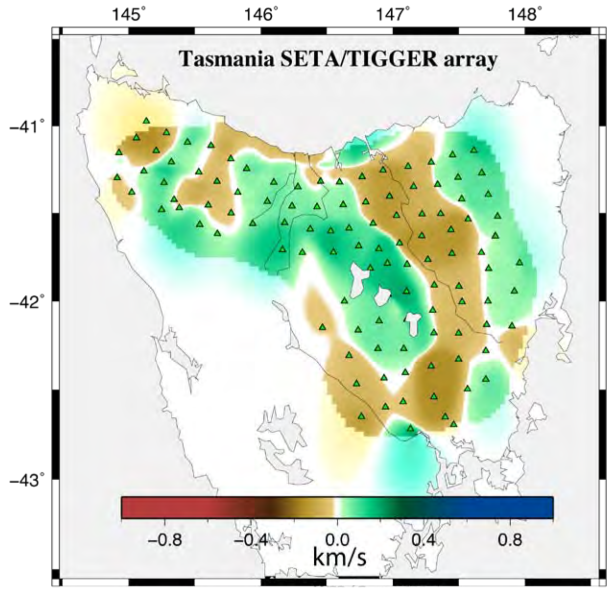

Figure 1. Map of phase velocity variations in Tasmania for a period of 6.0 sec as derived from the ambient noise method. Velocities are shown relative to a mean velocity of 3.1 km/s. The brown, north-south running band of lower velocities may be indicative of anomalous heat flow. Station locations are shown by green triangles. Approximately 2000 ray paths were used in the inversion.

In most seismological studies, data noise is a pollutant, but for ambient noise tomography methods, it provides the key to deciphering the Earth's structure. This novel approach to seismic imaging uses the “static” recorded by seismometers to map the underlying crust. Although mainly generated by the force of ocean waves on the shore, ambient noise is also the product of microseisms, turbulence, and cultural and industrial activity. When there is enough ambient noise, the cross-correlation of the noise recorded at two simultaneously operating seismometers can yield valuable information about the velocity structure between the two stations. In the case of very densely-spaced arrays, it is possible to resolve structure on the order of metres. These high-frequency maps can reveal tectonic boundaries, regions of intense fracturing, the structure of sedimentary basins, and the presence of anomalous heat flow. With appropriate sources of background noise, this new imaging method can probe the crust at multiple scales, with application at both the tectonic and exploration scales. One exciting area of research involves imaging deep sedimentary basins in 3-D, which traditionally lies in the realm of much more expensive active source methods.

This project seeks to improve the imaging potential of ambient noise methods. So far, the approach has been successfully applied to the closely-spaced WOMBAT subarrays in Tasmania. The resulting 3-D velocity maps support results from previous wide-angle tomography and surface heat flow studies and yield information about the crustal structure from 1 to ~14 km depth with a lateral resolution on the scale of several kilometers. One of the prominent features of the maps is a pronounced low velocity zone that coincides with the Tamar conductivity anomaly. This is a region of elevated conductivity and heat flow that runs along the Tamar River Valley. Velocity perturbations reveal valuable information about crustal temperature variations. As anomalously low velocities are often an indicator of increased heat flux, ambient noise tomography can be a valuable tool when assessing geothermal energy sources. The maps also clearly discriminate between regions of hard rock and sediment. Future work will focus on developing new techniques for extracting more information from ambient noise and on the application of the method to new geographical areas.

The Shuffling Rotation of the Earth's Inner Core

Hrvoje Tkalčić, Mallory Young, Thomas Bodin, Silvie Ngo and Malcolm Sambridge

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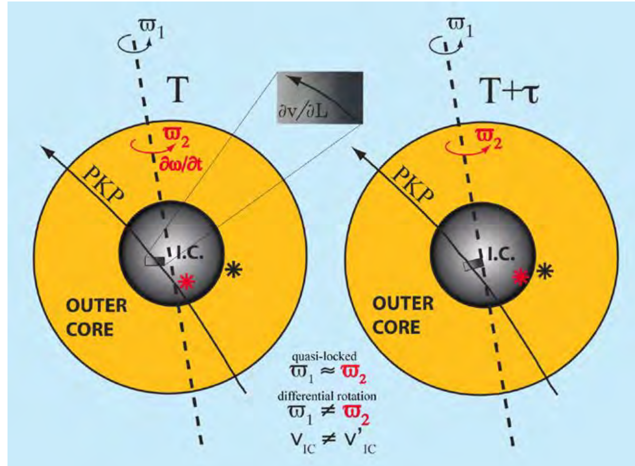

Figure 1. A schematic representation of Earth's cross-section, PKPdf ray-paths used for probing temporal changes in the inner core, and the mechanism proposed to explain temporal variations in PKPdf travel times: it relies on a known marker, a heterogeneity patch in the inner core with a lateral velocity gradient ∂v/∂L.The obtained rotation of the inner core is not steady – it is characterized by time intervals of both quasi-locked and differentially rotating inner core.

We present strong observational evidence from a newly observed collection of earthquake doublets that the Earth's inner core "shuffles" exhibiting both prograde and retrograde rotation in the reference frame of the mantle.

This discovery is significant on several levels. First, the observed pattern consists of intermittent intervals of quasi-locked and differentially rotating inner core with respect to the Earth's mantle. This means that the angular alignment of the inner core and mantle oscillates in time over the past five decades. Jolting temporal changes are revealed, indicating that during the excursions from the quasi-locked state, the Earth's inner core can rotate both faster and slower than the rest of the planet, thus exhibiting both eastward and westward rotation. According to our results, a short time interval (on the order of one to two years) is needed for the inner core to accelerate to a rotation rate of several degrees per year, and typically a slightly longer time is needed to decelerate down to a negligibly small differential rotation rate. These time scales are in agreement with experimental spin-up times obtained when the magnetic torque alone is used to accelerate the inner core.

Second, the correlation between the observed acceleration in the inner core rotation rate and the observed geomagnetic jerks is statistically highly significant. If we assume a very conservative time width of 2 years for an overlap between an observed geomagnetic jerk and the observed change in the rotation rate in the period from 1969 and 2008, the probability for an individual overlap is 1/20. We then obtain a chance of about 1/500 that the observed geomagnetic jerks and the observed changes in the rotation rate are coincidental. Namely, all three of the most dramatic changes in the rotation rate that we observe correlate with known geomagnetic jerks. Because there is also a documented correlation between the geomagnetic jerks and the Length of Day time series, this all points to the same source and works in favor of a differential rotation rather than processes at the inner core boundary.

Last but not least, when we integrate the rotation rate over different time intervals, it is possible to explain discrepancies between the body wave and normal modes results for the rate of the inner core rotation found by previous authors. We show that the integrated shift in angular alignment and average rotation rates (previously determined to be constant) in normal mode studies are much smaller that those for the body waves. This reconciliation between the differences in the estimated rotation rates from body wave and normal modes studies is one of the most significant results of this study.

The repeating earthquakes from the South Atlantic generate elastic waves that traverse the Earth's mantle and core, and are recorded by the seismographs located in the northern hemisphere. The waveform doublets produced by repeating earthquakes present a reliable probe, which can reveal temporal changes exhibited by the inner core due to the fact that the mantle effects are minimized. We observe new waveform-doublets at the College station, Alaska, and analyse all existing doublets recorded at that station using state of the art mathematical methods. The complex temporal pattern of differences in travel times between the first and the second event of a doublet is impossible to explain with a simple linear-fit approach. An ensemble approach utilizing transdimensional and hierarchical Bayesian analysis proves to be a powerful approach in this case, relaxing the choices on model parameterization and revealing hitherto unseen complex dynamics of the Earth's inner core.

Structural controls on the Mw 9.0 2011 Offshore-Tohoku earthquake

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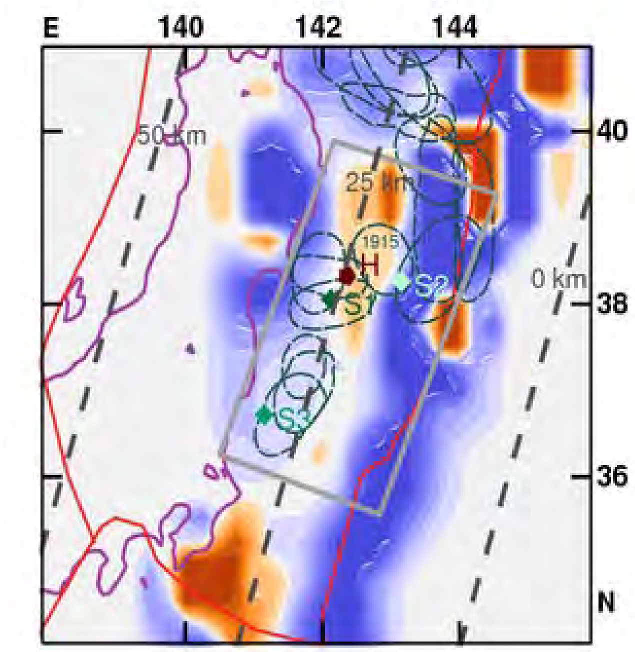

Figure 1. Detail of a joint tomographic image derived from the relative variations of the shear wavespeed and bulk-sound speed from the reference model ak135 on a inclined plane through the upper part of the subduction zone off the east coast of Honshu Japan; reference point: 142E, 38N, 25 km depth, plane with dip azimuth 195 deg, dip angle 10 degThe locations of the hypocentre and the points of initiation of high frequency energy from Furumura et al (2011) are marked, and the outlines of the rupture areas of historical earthquakes are shown by dashed lines. The depths on the inclined plane are indicated by dashed lines at 0, 25 and 50 km depth.

The great earthquake of 2011 March 11 off the east coast of Honshu Japan was much bigger than expected at Mw 9.0 and produced a devastating tsunami. Events in the last few centuries had not exceeded M 7.9, yet this event produced slip in the near trench zone that was at least 50 m with a distinct trace at the sea bed. The deformation in Japan is dominated by the effects of the large slip near the trench where the Pacific plate subducts, but seismological data recorded at teleseismic distances and the high frequency data from Honshu point to substantial release of energy at greater depth than the point of initiation.

Joint seismic tomography exploiting P and S wave arrivals conducted before the 2011 Offshore Tohoku earthquake reveals an area comparable to the faulting surface for the 2011 March 11 event with different properties from other areas along the shallow part of the subduction zone. The differences are revealed by using a measure relative variations in shear wavespeed and bulk-sound speed. Within the faulting area there are patches on the subduction zone (light orange in Figure1), that appear to separate portions of the rupture with very different character; in these regions the shear wavespeed is slightly reduced.

On the down-dip side of this anomalous zone there is strong short-period radiation, whilst the largest slip occurs up-dip with most energy release at longer periods.
Segmentation of the slip process can be imaged by back projection of seismograms from the US Array; the areas of greatest energy release at short periods lie down-dip from the orange anomalies. The main seismic moment release determined from broad-band seismograms lies on the updip side of the same anomalies. The structural variations on the subduction zone thus separate two regions with fundamental differences in the rupture process, stronger long-period radiation up-dip and stronger short-period radiation down-dip.

These variations in the character of the energy release during this great earthquake are likely to reflect features brought into the subduction zone with the Pacific plate, which may have acted as asperities that allowed this event to build up 30-40 m of strain in the near trench zone, making it much bigger than expected.

Minor changes in the character of the subducted plate can have a significant influence on the behaviour of a great earthquake, as has also been seen for the 2004 Sumatra-Andaman event (Kennett & Cummins, 2005).

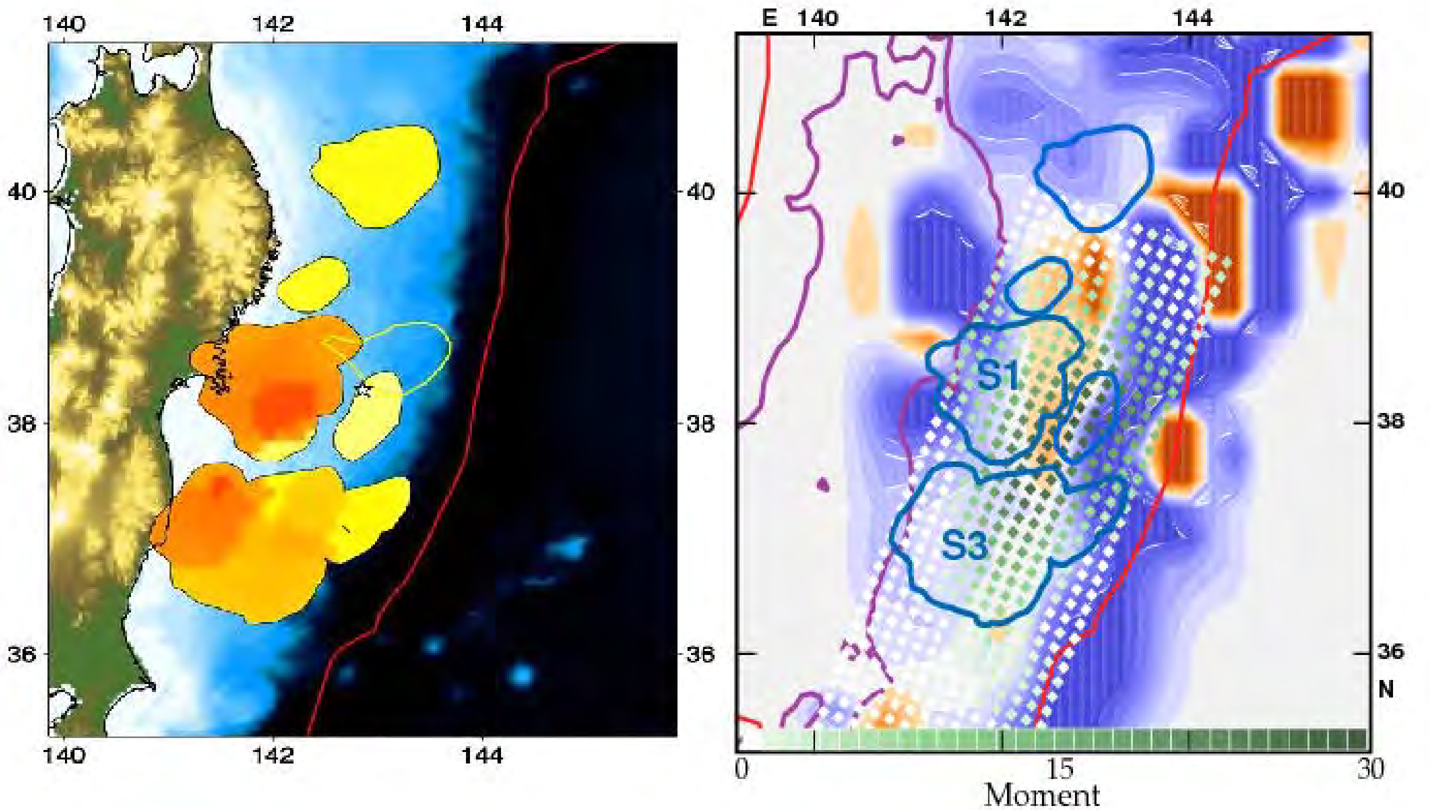

Figure 2. Comparison of the seismic moment release model of Ammon et al. (2011), and the back-projection image of the 2011 Offshore-Tohoku event using the US array (Kiser 2011), and the joint tomographic image on the same inclined plane through the subduction zone as used in Figure 1. The patches of strongest energy release shown in red tones in the left hand panel lie outside the regions with negative anomalies in the joint tomography. The two major sub-events in the main event are indicated as S1, S3 in order of occurrence to correspond with the high-frequency initiation identified by Furumura et al. (2011). The open contour in the left hand panel corresponds to the M 7.1 foreshock on 2011 March 9. The moment release in units of 10^{19} Nm is indicated by the colour code shown at the base of the right hand panel.

A New Conceptual Model for the Antarctic Circumpolar Current

(and the Global Ocean Overturning)

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The Antarctic Circumpolar Current (ACC) is the strongest ocean current on the planet, yet there is no real consensus on the factors that control its transport or sensitivity to change. We have derived a new conceptual model for the ACC, including predictions for the relative influence of surface buoyancy forcing and wind stress forcing upon the current. As a by-product, the model also yields scaling predictions for the strength of the ocean overturning circulation in both hemispheres.

The model consists of three layers (see Fig. 1) which represent the surface waters, North Atlantic Deep Water and Antarctic Bottom Water respectively. The model predicts that the primary determinant of ocean circulation is cooling in the high Southern latitudes, and wind stress over the Antarctic Circumpolar Current. The model is tested against an idealised, eddy-permitting simulation of an Atlantic-sized ocean basin; the overturning circulation of this model is shown in Figure 2. The simulations both support model scaling and provide additional evidence for the coupled nature of surface wind and buoyancy forcing in governing the global ocean overturning and the ACC.

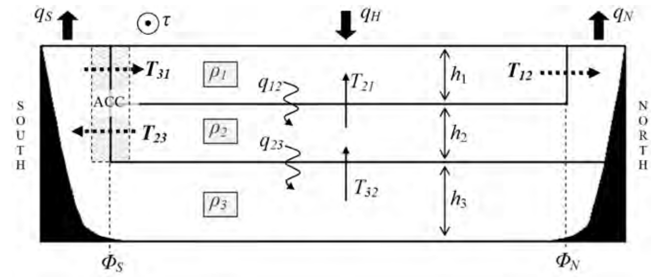

Figure 1. The three layer structure of the conceptual model of the ocean overturning, showing layers and inter-layer transports.

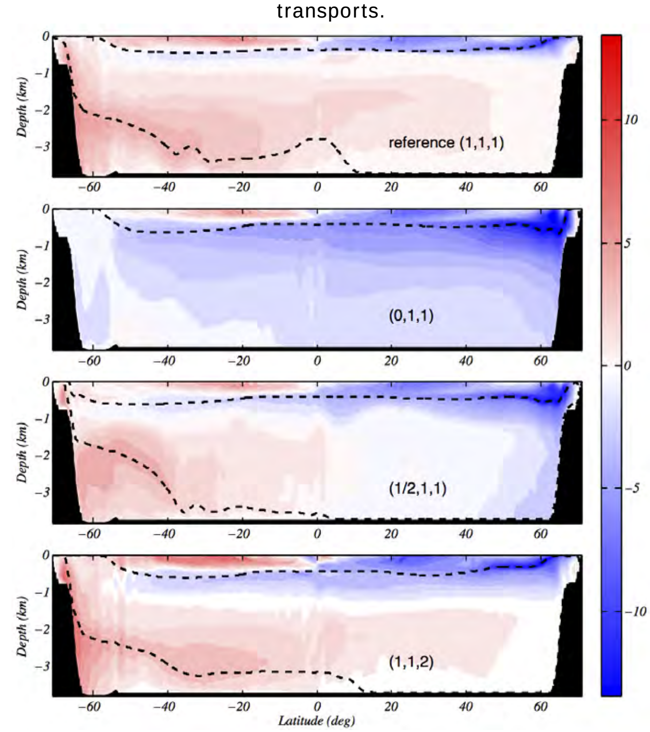

Figure 2. A sample of the overturning circulation for 4 different model simulations. (a) Reference case; (b) Without Antarctic cooling; (c) Half strength Antarctic cooling; (d) Doubled Southern Ocean winds.

The Effects of Turbulent Mixing on the Global Ocean Overturning

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The overturning of the global oceans is thought to be a result of interplay between surface buoyancy forcing, wind-driven upwelling and turbulent mixing. This circulation contributes to the poleward transport of heat that maintains the thermal state of the climate system. Larger rates of turbulent mixing are known to accommodate a more rapid overturning, but a detailed physical understanding of the coupling between mixing and the oceanic circulation is yet to emerge.

We examine this relationship through idealized laboratory experiments with an overturning circulation forced by salt and freshwater fluxes at the surface and subjected to mechanical mixing at a known rate. The mixing was generated by horizontal rods, which were yo-yoed continuously through the depth of the water column. The distribution of density with depth and the rates of overturning for the equilibrated circulations were measured. When the imposed stirring was the dominant contributor to the total mixing rate, there is good agreement between the measurements and our previously published theoretical predictions. For small stirring rates the circulation was insensitive to the mechanical mixing, and was greater than that expected for the case of a stratification maintained by a balance between molecular diffusion and advection. This behaviour is attributed to mixing by instabilities in the convective flow and entrainment into the turbulent plume.

Application of these physical principles to the oceans suggests that turbulent mixing (due to energy sourced from winds and tides) acts primarily to deepen the thermocline. Mixing thereby influences the properties of the abyssal ocean by modifying the upper ocean environment through which the dense plumes sink and from which they entrain water and heat. The bulk transport in the plumes, and not vertical mixing throughout the interior as was previously thought, is the crucial for mechanism for transporting heat to large depths.

Figure 1. Dye visualization of an equilibrated overturning circulation in the experiments. A flux of saline water (dyed) is imposed at the upper left-hand corner. The rest of the surface is maintained at a fixed density by a continuously replenished layer of fresh water, the source of which is located in the upper right-hand corner. The dye marks the turbulent plume that sinks full-depth against the endwall and outflows along the base as a gravity current. This dyed water is gradually lifted by relatively younger dense water and is largely entrained back into the plume.

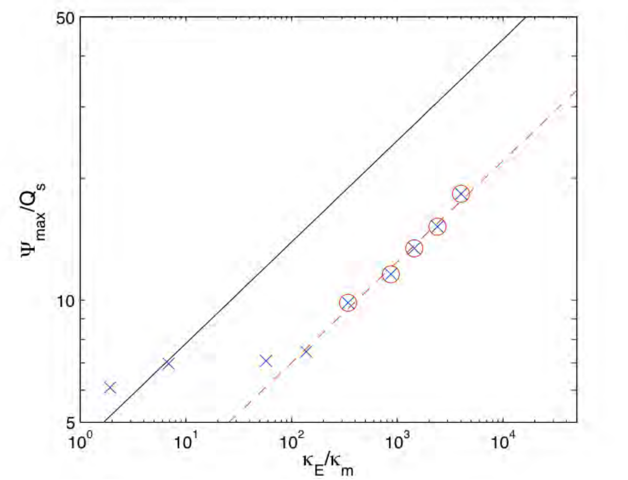

Figure 2. The measured rate of overturning as a function of the imposed rate of mixing. The blue crosses represent the measured data, and the red circles highlight those data used to find the red dashed power-law line of best fit. The solid black line is the solution predicted by the theory of Hughes et al. (2007); the experiments and theory return identical slopes but differ by a factor of 2.

Isothermal dynamics of channelled viscoplastic lava flows

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

A clear understanding of the interaction of lava rheology and flow dynamics forms a crucial basis for the interpretation of lava flow morphology, the design of predictive models for lava flow emplacement and the development of mitigation strategies to minimize flow hazards to people or property (Figure 1). 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.

In a major study (Robertson & Kerr 2011), we have analysed the influence of a viscoplastic rheology on the dynamics of lava flows. Using a multigrid-based augmented Lagrangian scheme, we found a numerical solution for the flow of a Bingham fluid in a rectangular channel. The numerical results show that an internal viscoplastic rheology significantly modifies the velocity distribution within a lava flow through the development of plug regions whose size is determined by the magnitude of the yield strength. The flow rate, maximum surface velocity and central plug dimensions were determined as functions of the channel geometry and fluid rheology, and comparisons between these and several limiting analytical solutions confirmed the accuracy of the numerical method used. The results were also compared to incorrect models that have been proposed previously in the literature. Several algorithms that extended the results to different sets of measured initial parameters were outlined; these calculate: (a) the flow depth when the fluid rheology (viscosity and yield strength) and downstream flow rate are given, (b) the flow depth when the fluid rheology and maximum downstream surface velocity are given, (c) the flow rate and fluid rheology when the flow depth, maximum surface velocity and surface plug width are given, and (d) the flow depth and rheology when the flow rate, maximum surface velocity and surface plug width are given. The use of these algorithms was demonstrated by considering the dynamics of a typical lava flow on Mount Etna, using measured rheological parameters and field observations.

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

Paper in press:
http://www.agu.org/journals/jb/papersinpress.shtml#id2011JB008550

Figure 1. 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.

How quickly does the ocean adjust to changes in surface forcing?

Ross W. Griffiths, Graham O. Hughes and Nicola Maher

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

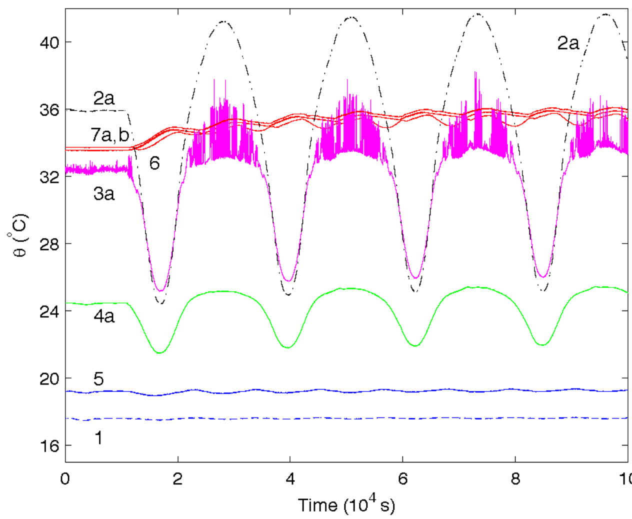

Figure 1. An example of temperatures measured in experiments with a periodic 'see-saw' in surface heat flux forcing in northern and southern hemispheres (heating in regions near both ends of the basin, the two ends oscillating out of phase). In this case the period (6.3 hours) was approximately four times the internal exponential adjustment time for the basin. The traces show the high and low temperatures at the forcing boundary (two broken lines) and at a range of depths and latitudes in the thermocline (blue, green, purple) and deep interior (red). The large, rapid variability (or noise) in the destabilized regions of the thermocline (purple) indicate vigorous penetrative convection that deepens the surface mixed layer.

The deep overturning circulation of the oceans, how it works and how it changes, remains somewhat mysterious and controversial. It is therefore difficult to determine with any confidence how it changed during past climate fluctuations such as the ice-ages, whether it had reached equilibrium with modern surface heat fluxes before the beginning of anthropogenic global warming, and how it may respond to future climate change. Laboratory experiments carried out at RSES provide insights into the time required for the temperature stratification in the oceans to adjust following changes in the surface heat fluxes.

In the experiments an overturning circulation is driven by heating and cooling at the surface of a model ocean basin so as to mimic the equator-to-pole gradient of heating in the oceans. Once the flow and stratification have equilibrated to a constant forcing, the applied temperature difference (or heat throughput) is altered. For a single step change in surface forcing the subsequent adjustment of the circulation reveals internal timescales, which can then be attributed to specific processes of adjustment. The circulation adjusts exponentially in time, with a timescale determined by turbulent mixing of heat from the surface into the thermocline and convective transport of heat in the deep interior.

Alternatively, when a sinusoidal oscillation in the forcing is applied (figure 1), the period of the oscillation is an imposed timescale that may be small or long compared with the internal timescale: both the mean circulation and the amplitude of its fluctuations vary accordingly to the ratio of timescales. In this case the experiments show that the circulation is more vigorous than with steady forcing. There is episodic sinking of dense water and interior (abyssal) temperature fluctuations increase with both forcing period and amplitude. However, the forcing period must be extremely long for the abyssal temperature to be close to equilibrium with the surface conditions. Extrapolating the results to the oceans we estimate that even the 100,000 yr period of the longest glacial (Milankovitch) cycle is too rapid for the ocean to have 'kept up with' the warming surface conditions and that the present ocean is cooler than it would likely be had surface temperatures been steady at present values.

Griffiths, R.W., Maher, N. and Hughes, G.O. Ocean stratification under oscillatory surface buoyancy forcing. *J. Marine Res*., in press.

Leaky LMS Algorithm and Fractional Brownian Motion Model for GNSS Receiver Position Estimation

Jean-Philippe Montillet[1] and Kegen Yu[1]

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[2] *SNAP lab, University of New South Wales*

This paper presents a new approach for smoothing long time series of position estimates of ground GNSS (global navigation satellite system) receivers. The fractional Brownian motion (fBm) model is employed to describe the position coordinate estimates that have long-range dependencies. A new and low-complexity method is proposed to estimate the Hurst parameter and the simulation results show that the new method achieves good accuracy and low complexity. A modified leaky least mean squares (ML-LMS) estimator is proposed to filter the long time series of the position coordinate estimates, which uses the Hurst parameter estimates to update the filter tap weights. Simulation results demonstrate that this ML-LMS estimator outperforms the classic LMS estimator considerably in terms of both accuracy and convergence.

Accepted paper for the IEEE VTC fall '11
www.ieeevtc.org/vtc2011fall/accepted_papers.pdf

The anatomy of interglacial sea levels

The relationship between sea levels and ice volumes during the Last Interglacial

Kurt Lambeck[1, 2], Anthony Purcell[1] and Andrea Dutton[3]

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The elevations and chronology of interglacial shorelines provide information on ice volumes for these earlier periods compared with today. However, the relationship between sea levels and ice volumes is not simple because of the planet's deformational, gravitational and rotational response to changes in ice-water loads (glacio-hydro isostasy). In particular, the pattern of global sea level for a given interglacial will be a function of the earth and ocean response to ice loads applied before, during, and after the epoch in question. We have examined the role of glacio-hydro isostasy during these glacial cycles to make three key points.

1) Interglacial sea levels cannot be interpreted directly in terms of ice volume.

2) Interglacial sea levels exhibit substantial spatial variability because of the Earth's isostatic response to changing ice and water loads. Therefore, observations from different localities should not be combined into a single sea-level function without first correcting for differential isostatic effects.

3) If the effects of isostatic factors are ignored, simplistic interpretations of interglacial sea levels can lead to serious errors in the inferred ice volumes during the interglacials.

Article PDF

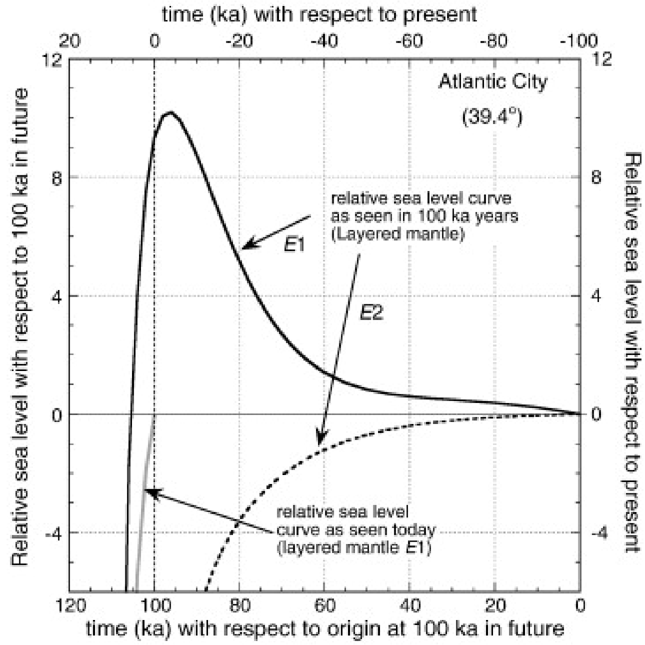

Figure 1. Figure showing sea level change due to melting of an ice sheet at 6000 years BP (grey line), and the same sea level curve (solid black line) as it would appear 100 000 years in the future. The apparent elevation of the latter above the former does not indicate a change in ice volume but the change in sea level due to more complete isostatic compensation.

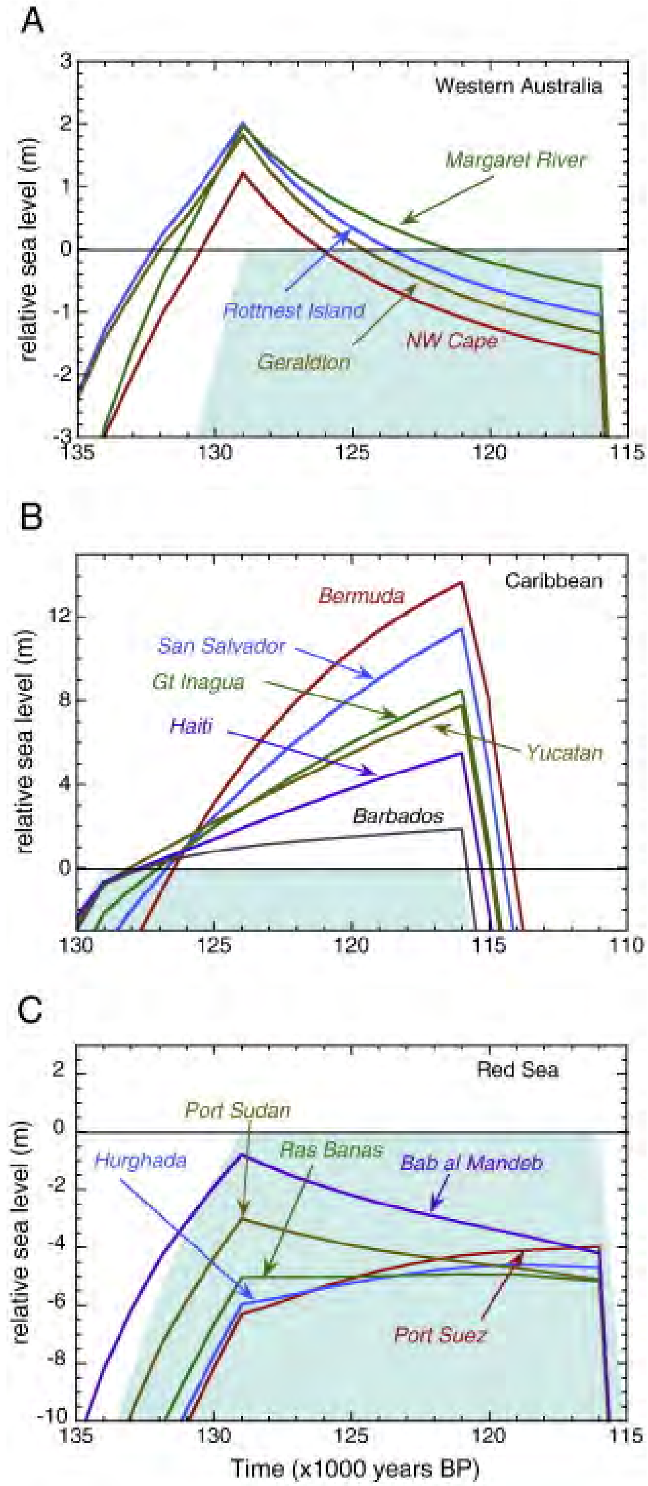

Figure 2. Figure illustrating the spatial variability between sea level curves through the interglacial for sites in the same regions: A) Western Australia, B) The Caribbean, and C) The Red Sea. The observed differences in behaviour are due to variations in isostatic response.

http://www.sciencedirect.com/science/article/pii/S0012821X11004900

Reconstruction of the Laurentide Ice Sheet

Evan James Gowan[1], Anthony Purcell[1], Kurt Lambeck[1], Paul Tregoining[1] and Thomas James[2]

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[2] *Natural Resources Canada, 9860 West Saanich Road, Sidney, BC, Canada, V8L 4B2*

The Laurentide ice sheet covered much of northern North America during the Last Glacial Maximum, 24-18 kyr BP (before present). The large volume of ice that accumulated in the ice sheet caused a significant drop in global sea level, and the weight of the ice deformed the earth. Rebound due to the delayed response of the mantle to unloading after the ice melted is ongoing. Accurate reconstructions of the ice sheet are necessary to determine its impact on sea-level and to explain ongoing geodynamic processes.

The Laurentide ice sheet completely melted over a period of 12-15 kyr. The chronology of the retreat of the ice sheet from its maximum position is largely constrained by radiocarbon dates from preserved organisms that populated regions after ice had melted. Additional constraints come from cosmogenic exposure dates from erratic boulders that were deposited after the melting of ice, and from optical dating of postglacial sand deposits. Since chronological constraints are spatially variable, and only give a minimum timing of deglaciation, determining the timing of deglaciation is challenging. Initial work has been done to create a map of the statistical probability of deglaciation. The maps give a maximum possible extent for the Laurentide ice sheet, based on available data. The initial results show that the timing of deglaciation in the southwestern portion of the Laurentide ice sheet may be later that in previous reconstructions (Dyke, 2004). This is due to the rejection of questionable bulk sediment radiocarbon dates, and the addition of data from focused studies in Alberta and Saskatchewan.

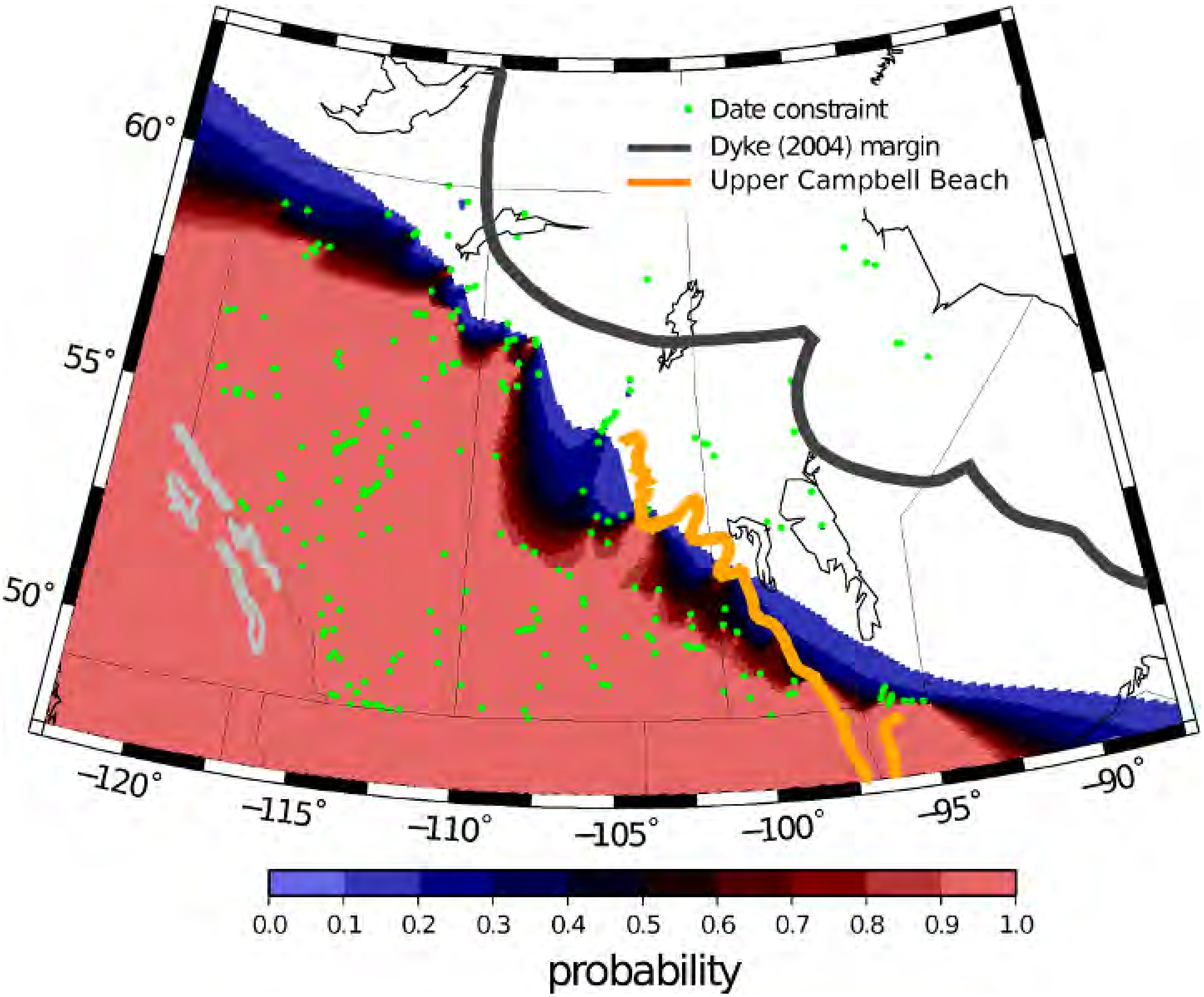

Figure 1. Probability map of deglaciation of the Laurentide Ice Sheet at 10 kyr BP. Northern limit of the Upper Campbell Beach indicates where the margin likely was at this time. Grey line indicates the margin position at this time by Dyke (2004).

Developing temporal gravity fields from GRACE observations

E-K Potter, S. McClusky, P. Tregoning [1] and TA Herring[2]

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[2] *Department of Earth, Atmosphere and Planetary Sciences, Massachusetts Institute of Technology*

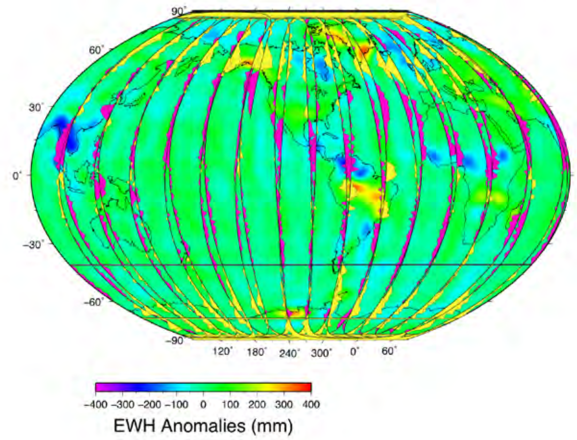

Figure 1. Range-rate residuals from the analysis of one day of observations from the GRACE mission. Changes in mass are expressed in terms of the equivalent water height (EWH) required to cause the observed change in gravity.

The Gravity Recovery and Climate Experiment (GRACE) space gravity mission has been providing information since 2002 that has enabled scientists to study changes in mass distribution over the Earth. Specifically, this allows estimates of changes in continental water storage (droughts, floods, groundwater studies), oceanic signals (currents, ocean tides) and, importantly, the rate of melting of polar glaciers and ice sheets. The key observations that make the GRACE mission unique are the accurate measurements of changes in distance between the two satellites, flying in tandem at an altitude of ~450 km. Temporal changes in the distribution of mass on the Earth can be estimated because the motion of the satellites are affected by the gravitational changes caused by the mass distribution changes. This is how the geophysical information is extracted from the GRACE observations.

Through funding provided by the Australian Space Research Program and the Australian Research Council, a multi-faceted approach has begun to develop and enhance Australia's capability to analyse data from the GRACE mission and to prepare for the successor mission, GRACE Follow On.

A team of scientists at RSES have developed software to process the GRACE observations (known as "Level -1B data") to generate global estimates of mass changes. Starting with the GPS estimates of the positions of the satellites (accurate to ~1-2 cm), our in-house software computes the orbits of each satellite using orbit dynamics theory and the onboard accelerometer measurements for information of atmospheric drag force, solar radiation pressure and thrusting events. Then, we estimate adjustments to the GPS positions making use of the inter-satellite range (and range rate) observations, which are several orders of magnitude more accurate.

Software development is ongoing but initial results are promising. Figure 1 shows the differences between observations and our best-fitting model for a 24 hour period in 2005 (so-called "range-rate residuals"). Our residuals match well in sign and magnitude with those of one of the available international GRACE analysis solutions (the background field plotted in Figure 1 shows the GRACE anomaly field estimated by the French Groupe de Recherche de Geodesie Spatiale).

GRACE Follow On website
http://rses.anu.edu.au/geodynamics/GRACE_Follow_on

NASA's GRACE Mission
http://www.csr.utexas.edu/grace/

Research Activities 2011

PRISE

Introduction

The PRISE group operates as an externally funded group within the Research School of Earth Sciences, providing expertise and supervised external access to the Research School's specialised equipment in the areas of geochronology, geochemistry and archaeometry. PRISE academic staff are also involved in research projects supported by successful grant applications, as well as supervising activities of both RSES and international postgraduate students.

As in previous years, PRISE staff maintained an active involvement in wide-ranging collaborative research projects with academic colleagues throughout the world, in addition to the provision of research and analytical skills to industry and Government agencies on a commercial basis. These collaborative projects are an important source of income for the group and therefore for the School, helping to fund technical support staff. A total of $498,528 was paid to Areas within the School for 2011 instrument use and invoice overheads.

During 2011 PRISE hosted twenty-three local and international visitors, most of whom were involved in collaborative projects using the SHRIMP, Laser ablation ICPMS and/or TIMS analytical facilities. PRISE staff also participated in fieldwork in Antarctica, Botswana, Cambodia, Chile and South Australia.

Following the departure of Emma Mathews in late 2010, we were pleased to welcome Dr Bin Fu, who joined the team in July to provide much-needed technical support. His expertise and commitment are very much appreciated.

Some areas of current research include:

- Multi-isotopic and trace element zircon studies to constrain magmatic evolution of plate margins and continental reconstructions; combined U-Th-Pb, Lu-Hf, Ti geothermometry, trace and REE chemistry, and oxygen isotope studies.
- Geological connection between West Antarctica and Patagonia since the late Paleozoic: Tectonism, Paleogeography, Biogeography and Paleoclimate.
- Development of in situ sulphur isotope analytical protocols for the SHRIMP, including new protocols for the analysis of the minor isotopes ^{33}S and ^{36}S.
- Use of sulphur isotopes to aid in understanding the origin and conditions of formation of metal sulphides and sulphates. Developments and characterisation of new S sulphide and sulphate isotope standards.

- Bioarchaeology in early Cambodian populations and *in situ* oxygen, carbon and strontium analysis of human teeth (ARC-funded Discovery Project).
- Placing realistic constraints on the timing of world-wide Neoproterozoic glacial events: a critical examination of the “Snowball Earth” hypothesis.
- The growth, geochronology, evolution and mineralisation of cratons.
- Understanding the migrations of prehistoric populations through direct dating and isotopic tracking of their mobility patterns (ARC-funded Discovery Project).

Associate Professor Mark Fanning
Manager, PRISE

Research Activities 2011

IODP

AUSTRALIAN IODP OFFICE IN 2011

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; www.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. Ms Sarah Howgego, the Program Administrator, was replaced late in the year by Ms Catherine Beasley.

Dr Neville Exon
Program Scientist, Australian IODP Office

Research Activities 2011

Visiting Fellows

Absolute calibration of satellite altimeters in Bass Strait, Australia

CS Watson, [1], N White[2], J Church[2], R Burgette[1], P Tregoning[3] and R Coleman[4]

[1] Surveying and Spatial Science Group, School of Geography and Environmental Studies, University of Tasmania, Tasmania, Australia

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

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

[4] Institute for Marine and Antarctic Studies, University of Tasmania, Tasmania, Australia

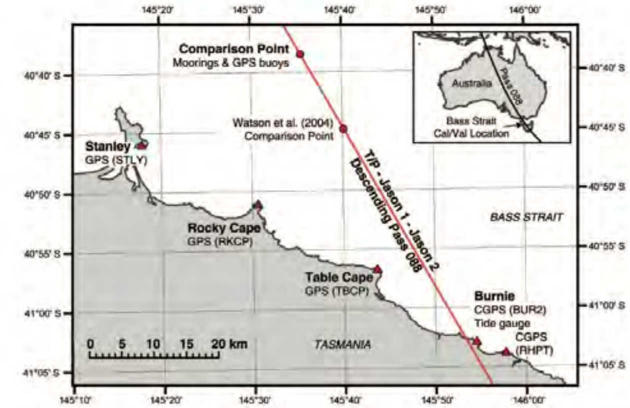

Figure 1. Location of the altimeter absolute calibration sites in Bass Strait (Watson et al., 2011).

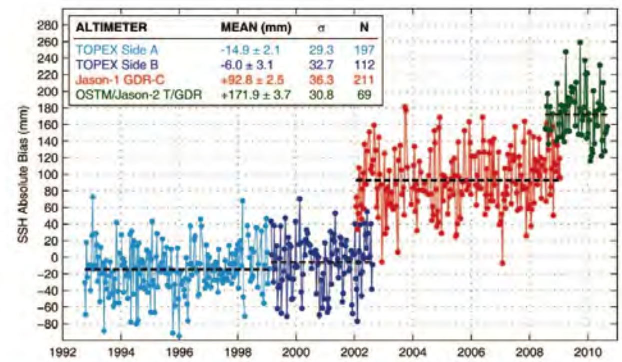

Figure 2. Estimated absolute sea surface height biases for the Topex, Jason-1 and Jason-2 satellite altimetry missions (Watson et al., 2011).

Satellite altimetry is a space-geodetic technique that has proven invaluable in studies of ocean circulation, ocean tides, sea level rise and mass balance changes of glaciers and ice sheets. The process involves instruments onboard satellites "pinging" the Earth with a laser or radar signals and measuring the time it takes for the signal to return to the satellite. If the height of the satellite is calculated accurately (from knowing the orbit of the satellite) then the height of the reflecting surface (e.g. the ocean, an ice surface) can be deduced. Changes in the height with time provide information on, for example global sea level rise or the rate of melting of Greenland/Antarctica.

For the ocean altimeters, the absolute biases in the instrumentation onboard the satellites can be determined if the height of the ocean surface is measured independently. The aim of this study was to derive absolute bias estimates through experiments involving measuring the sea surface height in Bass Strait (Figure 1) using floating buoys equipped with GPS systems, ocean bottom pressure measurements and a nearby tide gauge at Burnie (Watson et al., 2011). The sea surface heights estimated from the altimetery measurements are compared to the in-situ observations, with the difference being attributed to calibration errors in the satellite instrumentation.

The resulting absolute biases for multiple altimeter satellites (Topex A/B, Jason-1, Jason-2) are shown in Figure 2. While the bias for each altimeter is relatively constant (standard deviation of mean estimates are typically < 4 mm), there are significant differences in the biases between missions. This highlights the need to perform these calibration/validation experiments in order to be able to monitor sea level rise over time spans longer than individual space missions.

Watson, CS, N. White, J. Church, R. Burgette, P. Tregoning and R. Coleman (2011), Absolute Calibration in Bass Strait, Australia: TOPEX/Poseidon, Jason-1 and OSTM/Jason-2, Marine Geodesy 34:3-4, 242-260 http://dx.doi.org/10.1080/01490419.2011.584834

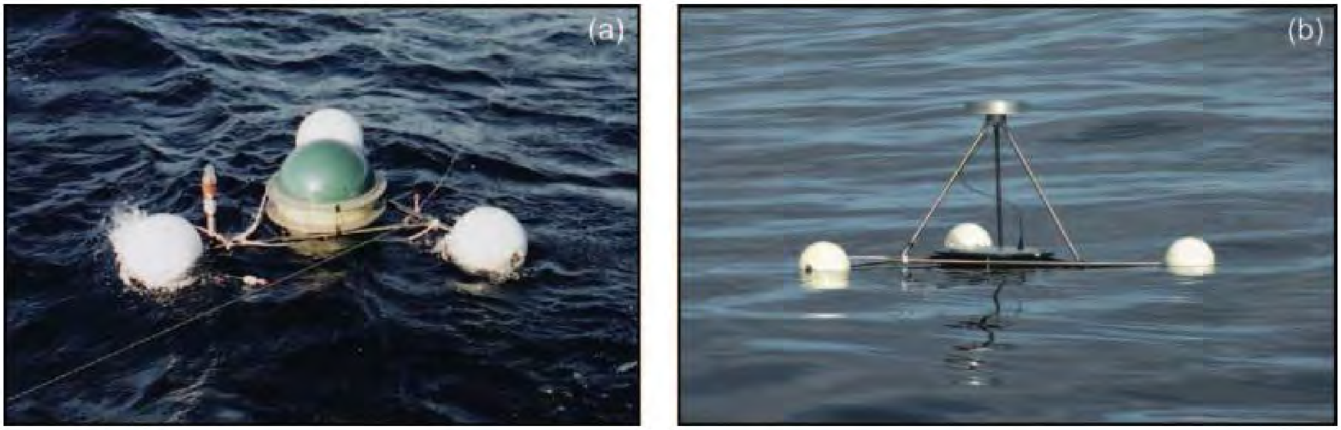

Figure 3. Floating GPS buoys used to measure directly the height of the sea surface in Bass Strait (Watson et al., 2011)

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 2011 two members of the group, Tristan Redman and Hideo Sasaki, graduated from the Australian National University's Trainee Technical Officer program and were employed by the school as technical officers. The program involves four years part time study, provides peer support and on the job training to ensure graduates are given the best start to their careers. Our graduates both completed Advanced Diplomas of Electronics Engineering at the Canberra Institute of Technology and have been essential to the success of major projects this year.

The Electronics Group has developed numerous engineering projects during 2011 and fabricated several complex projects from previous designs. The Group has contributed to the seamless transfer of instrumentation from the Earth and Marine Sciences building 47 to Earth Sciences by performing various upgrades to apparatuses. Maintenance tasks have occupied the Group steadily during the year, the distribution of labour can be observed in table 1 below.

Table 1
RSES Electronics Group Resource Distribution 2011

Labour totals	**hours**	**%**
Administration total	630	9
Maintenance total	1426	20
R&D	4827	68
Total	***7048***	

Administration		
Electronics Group overheads	478	76
Union, EBA	37	6
OHS Electrical Safety Testing	20	3
Study leave + other	95	15
Total	***630***	
Maintenance		
Earth Chemistry	972	68
Earth Environment	168	12
Earth Materials & Processes	176	13
Earth Physics	60	4
External clients+ other	50	3
Total	***1426***	
Research and Development		
Earth Chemistry	2550	53
Earth Environment	374	8
Earth Materials & Processes	164	3
Earth Physics	1626	37
External clients + other	113	2
Total	***4827***	

Electronic Engineering Highlights

SHRIMP SI Refinement (Latimore, Cummins, Corrigan, Cassar, Schram, Redman, Sasaki)

During 2011 the Electronics Group has been involved with fine tuning SHRIMP SI. After the instrument was commissioned in 2010 considerable effort by the Group was required to investigate noise interferences inhibiting the mass spectrometers background performance. The noise fluctuations require careful monitoring and thoughtful analysis. The Group discovered mechanical vibration and temperature fluctuations were inducing interference to sensitive electrometer inputs and have made corrections to eliminate the problems. Improvements to the accuracy of the SHRIMP SI's sample stage were developed during this period. The sample position repetition was failing to meet the requirement for automation of the mass spectrometer as implemented on SHRIMP 2 and RG. The Group reassembled the stage mechanics and reprogrammed the digital closed loop system parameters to eliminate position errors and enable autonomous sample manipulation. SHRIMP SI's data acquisition system has received new commands enabling faster data transfer rates improving the mass spectrometers analytical ability.

ANU Short Period Seismic Recorder Pre-Production (Redman, Corrigan, Latimore, Cummins)

The IFLEX project is an innovative fast responding electrometer developed by Norm Schram of the Electronics Group. During 2010 IFLEX was implemented onto Earth Chemistry's SHRIMP 2/SI and utilised to analyse Faraday cup electron flows. The project involves considerable research into electrometer design, bias current elimination and stabilisation. The IFLEX has enabled the SHRIMP SI users to capture data in charge capacitor mode that allows a 2 to 3 fold improvement in instrument precision. In order to implement the IFLEX, the group worked on improvements to the data acquisition systems of SHRIMP 2 and SI which involved a new electrometer controller circuit, temperature stabilisation circuit and microprocessor.

Short Period Seismic Recorder (Andrew Latimore, Tristan Redman, Derek Corrigan, Daniel Cummins)

This year the Electronics Group continued development of the ANU Short Period Seismic Recorder project. During 2010 the Group began development of a new digital short period seismic recording system. The project specifications involved designing a rugged, high dynamic range, ultra low power, 24-bit digital acquisition system that recorded onto secure digital storage media. The unit records 3 axes of seismic data synchronised to a global positioning system corrected time-base. The device can acquire seismic data at periods up to 1000 samples per second. By mid 2011 the Electronics group successfully finished design and construction of 5 fully operational pre-production prototypes. These recorders are currently enduring field testing at Mount Stromlo and other locations to gather vital information on data accuracy and robustness before the final production will begin in 2012. A further order of two recorders have been constructed and tested intended for field work in 2012, these models will be the first of the new design deployed into an area of seismic interest. The Electronics Group in conjunction with the Mechanical Workshop successfully produced the pre-production units within the time frame, however the production of 250 units will stretch our resources beyond capability. As a consequence we have researched equipping our operation with state of the art fabrication technology to ensure we can meet the demanding schedule and improve our assembly ability for all Earth Sciences customers.

Finnigan MAT 261 Mass Spectrometer Upgrade (Schram)

This year there has seen steady progress with the development of new electronics for the Finigan MAT 261 mass spectrometer. This project once complete will reform the aging machine into an automated computer controlled modern mass spectrometer. The Electronics Group has developed systems to integrate with existing electronics to ensure future serviceability and minimize rebuilding working systems. The developments include 8 digital 32-bit counters for beam current measurements, stepper motor controllers to computer automate the high voltage source electrostatic deflection plates and sample carousel selection. The new electronics will communicate to a new personal computer running Labview firmware allowing the operator access to all system parameters and incorporate mass analysis software for acquiring data and tuning the mass spectrometer.

IPCMS Laser Aperture Control Automation (Corrigan)

The Inductively Coupled Plasma Mass Spectrometer's Laser ablation device required engineering an automated aperture changing system. The Electronics Group during 2011 designed and constructed a novel mechanism and encoder electronics to allow the operator to select one of ten apertures. This technique enables the laser flight tube to remain oxygen free which reduces setup duration and assist to maintain a clean environment for the sensitive UV laser. The aperture control hardware incorporates digital position feedback and innovative mechanical arrangement to secure the mechanism during laser operation and allowing precision movement to the next aperture location.

AMS Graphitization Furnace Automation (Sasaki, Cassar)

The Accelerator Mass Spectrometer facility's sample preparation laboratory manually operates two multiple channel graphitization furnace lines. During 2011 the Electronics group continued development of a new automated line controlling 20 graphitization channels and operating 20 liquid nitrogen molecular traps simultaneously. The interface is touch screen controlled running Labview firmware and once setup will autonomously release each sample into the system and measure the required volume. The system will modify the volume by compressing or extending bellows until the required volume is established before passing the sample to one of 20 furnace channels. 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 (Cummins, Sasaki, Redman)

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

- OHS electrical testing and tagging (Electronics Group)
- MAT 261 upgrade (Norm Scram)
- Laser ablation cell drafting, design and assembly (Derek Corrigan)
- Piston cylinder electrical upgrade (David Cassar)
- Tesla Tamer assembly and testing (Daniel Cummins)
- J1PC tuning and implementation (David Cassar)

Research Support

Electronics Group

Research School of Earth Sciences Engineering Workshop Annual Report 2011

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

Introduction

The Engineering Workshop supports the school by manufacturing non standard hardware. RSES workshop staff pride themselves on working closely with technical and academic staff to complete high quality, well designed and functional instrumentation and equipment. Starting with either a brief design concepts or full Engineering drawings, the workshop team makes use of advanced workshop machinery to produce vacuum components and instrumentation, high pressure components, field work equipment, lab equipment, consumables and specialised sample preparation.

Several other mechanical workshop facilities of this type exist at ANU and all maintain close ties with each other. Resources, such as tooling, machinery and administrative duties are shared to avoid excess duplication. Workloads are also distributed when time gets tight. This close collaboration extends machining possibilities across the Colleges and increases the manufacturing potential of ANU.

TIG welded vacuum feed throughs

RSES Engineering Workshop Highlights

Some of the main projects of 2011 are listed below

- SHRIMP SI Electron Gun and fitment of new Optical Rails to SHRIMP 2 (All RSES workshop staff)
- AMS Graphitization Line (Carl Were, Geoff Woodward)
- High Temperature Furnace Cooling Jackets (Ben Tranter, Brent Butler)
- ICPMS Automated Aperture and Shutter Mechanisms (Brent Butler, Ben Tranter)
- Seismic Recorder Hardware (David Thomson, Carl Were, Andrew Wilson)

Table 1 **RSES Engineering Workshop Resource Distribution 2011**		
Labour totals	**hours**	**%**
Uncharged Jobs	1559	22.4
Research Support	5395	77.5
External work	9	0.1
Total	***6964***	
Uncharged Jobs		
Staff Training	375	5.4
Administration	709	10.2
Workshop Infrastructure	210	3.0
Machine Maintenance	140	2.0
Other	125	1.8
Total	***1559***	
Research Support Distribution		
Earth Chemistry	2412	34.5
Earth Environment	1439	20.7
Earth Materials & Processes	965	13.9
Earth Physics	409	5.9
External clients+ other	179	2.6
Total	***5404***	

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(Listed alphabetically within research areas)

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Visiting Fellows

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NATIONAL AND INTERNATIONAL LINKS 2011

COLLABORATION WITH AUSTRALIAN UNIVERSITIES, CSIRO & INDUSTRY

Earth Chemistry

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

Dr Y. AMELIN with Prof Ray 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 investigations of greater than 3.7 billion year old rocks to reveal early Earth chemical processes and potential life habitats.

Dr J.J. BROCKS with Prof S. George and S. Bray (Macquarie University), The organic geochemistry, geochronology and microbial history of saline Lake Tyrrell in outback Victoria.

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

Dr J.J. BROCKS with Prof Patrick 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 Kliti Grice and many other researchers from Australia and overseas, Organic Matter in Minerals Formation (a CSIRO Flagship Cluster program).

Dr S.J. FALLON with Dr R. Thresher (CSIRO, Climate from Deep Sea Corals); Dr J. Lough (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.A. FORSTER is collaborating with Prof McInes and Dr Jourdan at Curtin University, Dr Rosenbaum and Prof. Vasconcelos at University of Queensland, Dr Cooke and Dr Harris at University of Tasmania, Prof Giles and Prof Collins at University of Adelaide, Prof Aitchison at University of Sydney, Dr Daczko at Macquarie University,

Dr Collins at James Cook University (now University of Newcastle), Prof McCuaig, Prof Miller at University of Western Australia, and Prof McWilliams, Dr Evans and Dr Zwingmann at CSIRO in association with the ARC LIEF grant and the Australian Argon Facility.

Dr M.A. FORSTER with Curtin University John de Laeter, Fred Jourdan, as Node managers for the Australian Argon Facility between Curtin University and RSES.

Dr M.A. FORSTER with CODES, University of Tasmania, David Cooke, 40Ar/39Ar geochronology research on the Philippines.

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), 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.

Ms A.F. KOMUGABE, Dr Ron Thresher (CSIRO MAR, Hobart) is on my supervisory panel.

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.

Dr L. MARTIN collaborates with Dr M.-A. Kakzmarek (Curtin University) and Pr G. Clarke (University of Sydney), on the significance of texture and zoning in eclogitic garnet crystals.

Emeritus Professor Ian McDOUGALL is an Honorary Professor in the School of Earth Sciences, University of Queensland, where he is 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 written up and will appear shortly in an international journal.

Dr D. RUBATTO collaborates with Dr Gideon Rosenbaum and Mr Penfei Li, University of Queensland, Brisbane, on chronology of magmatism in the New England Orocline

Dr D. RUBATTO collaborates with Dr Glen Phillips, University of Newcastle, on the chronology of high pressure rocks in the New England Fold Belt, Australia.

Mrs K. STRZEPEK, with Dr A. Revill (CSIRO), Dr R. Leeming (CSIRO), Dr R. Thresher (CSIRO), Dr. C. Smith (Latrobe University).

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

Dr I.S. WILLIAMS with Prof B.W. Chappell (University of Wollongong) – granite geochemistry.

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.

Earth Environment

Dr L. K. AYLLIFFE collaborates with Dr G.J. Prideaux (Flinders University), Dr J. Hellstrom (University of Melbourne), Dr R.N. Drysdale (University of Newcastle), Dr J-X Zhao (University of Queensland).

Prof P. De Deckker collaborates with Dr D. Wilkins from the Antarctic Division on the Holocene history and dating of crater lakes; Dr J. Reeves of RMIT on ostracod taxonomy and ecology; with Prof C. Murray-Wallace of the University of Wollongong on the palaeoenvironmental reconstruction of the Lacepede Shelf offshore South Australia; and with Prof N. Tapper of Monash University on airborne dust.

Dr S.M. EGGINS, Mr L. KINSLEY and Mr D. CORRIGAN collaborate with Photon Machines Inc. on development of the ANU HelEx laser ablation systems. Dr S.M. EGGINS and Mr L. KINSLEY collaborate with Prof. S. Frisia of the University of Newcastle on the application of trace elements in speleothems to high resolution reconstructions of environmental change. Dr S.M. EGGINS also collaborates with Prof. J. Nott and Ms J. Haig of James Cook University on the application of trace elements in speleothems to the reconstruction of environmental change in the tropics of the Australian region, and with Dr A. Dosseto of the University of Wollongong on the application of laser ablation microanalysis to U-series disequilibria in regolith.

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

Dr M.K. GAGAN collaborates with Dr J. Lough (Australian Institute of Marine Science) and Dr G. Meyers (CSIRO Marine and Atmospheric Research) on ARC *Discovery* Grant DP0663227 (2006-2011): The Indian Ocean Dipole, Australasian drought, and the great-earthquake cycle: Long-term perspectives for improved prediction; and 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 modeling of Quaternary climate-volcano-environment impacts in southern Australasia; and with Prof J. Pandolfi (University of Queensland) on ARC *Linkage* grant LP110200128 (2011-2014): Links between marine biotic evolution and carbonate platform and petroleum development in the South China Sea.

Prof R. GRüN collaborates with Prof M. SPRIGGS (ANU School of Archaeology and Anthropology), 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) as part of a three-year ARC grant "Understanding the migrations of prehistoric populations through direct dating and isotopic tracking of their mobility patterns" for 2011 to 2013.

Ms C. KRAUSE collaborates with Dr John Hellstrom, University of Melbourne – collaboration on dating of stable isotope record.

Dr D.C. McPhail collaborates with Prof J. Brugger and Dr F. Reith (Adelaide University), Dr J. Moreau (University of Melbourne) and Mr S. Hore (Primary

Industry and Resources South Australia) on the fractionation of uranium isotopes in the regolith; and 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 B. Maher at the University of Canberra for his PhD Research

Dr B. Opdyke collaborates with University of Queensland (The Free Ocean Carbon Experiment or FOCE); with Gregg Brunskill formerly of The Australian Institute of Marine Science; with Kathy Burns of The Australian Institute of Marine Science and Ken Cadeira of Stanford University on ocean acidification projects.

Prof B.J. PILLANS collaborates with Prof M. Morwood and Dr B. Jones (University of Wollongong) on the Quaternary stratigraphy of Soa Basin, Flores, Indonesia; and with Dr B. Kohn (University of Melbourne) on apatite fission track thermochronology and landscape evolution in the Tanami Desert. He also collaborates with Dr K. Mulvaney (Rio Tinto Iron Ore) on Aboriginal rock art, Burrup Peninsula, WA.

Professor A.P. ROBERTS collaborates with CSIRO, Curtin University of Technology, The University of Queensland, The University of Sydney, The University of Western Australia (all in relation to a LIEF grant application).

Ms J. Roberts collaborates with Dr Anu Kumar, Dr Ali Shareef, Dr Jun Du, and Ecotoxicology team at CSIRO Land and Water; with Dr C. Hepplewhite, technicians and staff of Lower Molonglo Water Quality Control Centre, Actew Corporation; and with Mr J. Gourley and Mr P. Maiden at Australian Laboratory Services.

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

Miss C. THOMPSON collaborates with Dr A. Bowie (University of Tasmania, ACE CRC), Dr C. Hassler (University of Technology, Sydney).

Earth Materials & Processes

Prof R. ARCULUS and Professor Simon Turner (Macquarie University); Professor Leonid Danyushevsky (University of Tasmania); Professor David Gust (Queensland University of Technology); Dr Kurt Knesel (University of Queensland); Dr Tim Ivanic (Geological Survey of Western Australia)

Mr C. AUGENSTEIN collaborated with the head of the Geological Institute of the ETH Zurich in Switzerland, Prof Jean-Pierre Burg. PhD candidate Filippo Schenker also from ETH Zurich visited the structure and tectonics research team at the RSES for 2 1/2 months from October to mid-December to use the facilities of the argon laboratory and to learn about argon data processing and interpretation.

Prof I.H. CAMPBELL and Dr C. ALLEN with Professor R. Cass and Dr R. Squire, (Monash University); Understanding the stratigraphic and structural architecture of late Archean basins and the context of their gold deposits.

Prof I.H. CAMPBELL and Dr C. ALLEN with Dr A. Harris (Newcrest Mining); U-Pb dating, O and Hf and Ce 4+/3+ measurements of zircons from felsic intrusions associated with major porphyry Cu-Au deposits.

Prof I.H. CAMPBELL and Dr C. ALLEN with Dr Scott Bryan (Queensland Institute of Technology); geochronology and geochemistry of heat producing granites from Queensland.

Prof I.H. CAMPBELL, Dr Y. AMELIN and Dr C. ALLEN with Professor R. Cass. Dr R Weinberg and Dr R. Squire, (Monash University), Dr M. Wingate (Geological Survey of Western Australia) and Dr W. Bleeker (Geological Survey of Canada); Prospectively of late Archaean basaltic and gabbroic rocks associated with major gold and base-metal deposits.

Prof S. F. COX is collaborating with Prof D Cooke, University of Tasmania, on aspects of the development of fracture-controlled flow systems in intrusion-related hydrothermal ore systems. This collaboration forms part of the activities in the ARC Centre for Excellence in Ore Deposits.

Mr B.J. HANGER collaborates with Prof. V. Kamenetsky (University of Tasmania) on the petrology of the Wesselton kimberlite pipe, South Africa.

Dr J. HERMANN collaborates with Dr. C. Spandler (James Cook University, Townsville), on element recycling in subduction zones.

Dr J. HERMANN collaborates with Dr. C. Gregory (Curtin University, Perth) on the timing of Barrovian metamorphism in the Central Alps.

Dr J. HERMANN collaborates with Dr. M. Turner (Macquarie University, Sydney) on water incorporation into clinopyroxene.

Prof I. JACKSON collaborated with Z. Stachurski (Dept. of Engineering, CECS, ANU).

Prof G. LISTER, in conjunction with the creation of an ANU-JdL joint argon facility, has begun collaboration with Dr F. Jourdan, Prof B. McInnes, S. Reddy and Z-X. Li, Curtin University of Technology; Dr G. Rosenbaum and P. Vasconcelos, The University of Queensland; Prof D. Cooke and Dr A. Harris, University of Tasmania; Prof D. Giles and Prof A. Collins, The University of Adelaide; Prof J. Aitchison, University of Hong Kong, Dr N. Daczko, Macquarie University; Prof W. Collins, James Cook University; Prof. T.C. McCuaig and Prof. J. Miller, The University of Western Australia; and Dr M.A. Forster, Prof B. Pillians and Prof R. Grun, The Australian National University; Dr H. Zwigmann, Dr N. Evans and Prof M. McWilliams, CSIRO. The intended facility has attracted widespread national and international support, and it has been awarded an equipment grant by the Australian Research Council.

Prof G. LISTER has an ongoing collaboration with Prof W. Collins at James Cook University working with on dating movement zones in far north Queensland.

Prof G. LISTER has continued collaboration with the NCRIS NanoSIMS Facility at UWA and the AINSE SIMS at UWS for microprofiling enabling garnet-ilmenite geospeedometry.

Dr J.A MAVROGENES collaborates with Dr A Tomkin (Monash University), Dr R Hough (CSIRO) Dr D Kamenetsky (University of Tasmania), Dr T Mernagh (Geoscience Australia) and Dr A Hack (Newcastle University).

Dr O. NEBEL worked together with Prof. Jon Woodhead (Melbourne University) on Ocean Island Basalts from the Islands of Pitcairn, Mangaia and the Tasmantid Seamounts.

Dr O. NEBEL collaborated with Prof. Martin van Kranendonk on a project focusing on the genesis and origin of Archean komatiites from the Pilbara region.

Prof. H. 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.

Mr P. STENHOUSE and Prof. S. F. Cox collaborate with Prof. J. Urai, M. Arndt and S. Virgo, RWTH-Aachen, Germany, on the fracture-controlled fluid flow in the Jabal Akhdar dome of Oman.

Mr J. WYKES collaborated with Dr. C. E. MANNING and Dr. R. C. NEWTON, Department of Earth and Space Sciences, University of California Los Angeles on the solubility of silicate mineral in aqueous fluids at upper mantle P-T conditions.

Dr G.M. YAXLEY with Prof V Kamenetsky (University of Tasmania), Drs G Nichols and E Belousova (Macquarie University), Dr Roland Maas (University of Melbourne).

Earth Physics

Dr N Balfour collaborates with Craig O'Neill (Macquarie University), Gary Gibson and Tim Rawling (University of Melbourne) on Seismometers in Schools. Matthew Knafl (Geoscience Australia) on induced seismicity and for 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.

Prof P. CUMMINS Geoscience Australia, Dr V. Brando (CSIRO)

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 new Australian ocean model.

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

Dr G. Iaffaldano collaborates Prof Dietmar Mueller and Dr Christian Heine (University of Sydney)

AuScope

Prof B.L.N. Kennett acted as coordinator of the Earth Imaging component of AuScope until 2010 June 30, with particular responsibilities for the transect component.
He has been involved with the interpretation of the reflection transect across the Capricorn Orogen in Western Australia that was half funded by AuScope.

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 Jean-Philippe MONTILLET is collaborating with Dr Kegen Yu (UNSW – SNAP lab) in some work on statistical GPS time series analysis.

Dr Jean-Philippe MONTILLET is collaborating with Prof. Alan McIntosh and Dr. Pierre Portal – Mathematical Sciences institute –ANU: collaboration on nonlinear operator theory and some application to the energy function.

Dr M.L. RODERICK with Dr R. Donohue, Mr T. VanNeil, Dr T. McVicar of CSIRO, Hydrologic impacts of climate change.

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)

Dr M.L. RODERICK with Prof G Farquhar (RSB, ANU), Prof Mark Adams (University of Sydney), Prof David Tissue (University of Western Sydney), Hydrologic impacts of bushfires.

Ms I. ROSSO and Dr A.McC. HOGG with AssocProf. 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 participated in the Capricorn Origin Seismic and Magnetotellutic (MT) Workshop at the Geological Survey of Western Australia.

Dr. M. SALMON collaborated with Dr. A. Aitkin (University of Western Australia) to improve the gravity model of the Australian Moho.

Prof. M. SAMBRIDGE with Dr. A. Reading (Univ. of Tasmania) on inference methods applied to geological problems. 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 and Dr. N. Balfour 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.

Dr E. SAYGIN collaborates with Geoscience Australia.

Dr H TKALČIĆ collaborates with Dr. A. Reading (University of Tasmania) on different projects to study lithospheric structure of Australia.

Dr P. TREGONING with Geoscience Australia, Dr M. Leblanc (James Cook University), Dr C. Watson (University of Tasmania), Drs K. Fleming, M. Kuhn and W. Featherstone (Curtin University), and Drs A. van Dijk and R. Crosbie (CSIRO).

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, as 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 Central Australia 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.

RSES Professors Andrew Roberts, Richard Arculus and Neville Exon are on the Governing Council of ANZIC, and 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 Professor D. Phillips and Dr Bin Fu (University of Melbourne) on constraining the timing of metamorphism in the Bendigo goldfields using monazite.

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.

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

Visiting Fellows

Dr R.V. Burne collaborates with CSIRO on quantitative sedimentology as applied to microbialites.

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 J. 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 collaborated with Dr P.W. Schmidt (CSIRO) as guest editor for a special volume on paleomagnetism and rock magnetism for the Australian Journal of Earth Sciences.

KEITH SCOTT with CSIRO Earth Science and Resource Engineering (Jon Huntington and Rob Hough) and Minerals and Metals Group (Vladimir David and Ben Johnson).

INTERNATIONAL COLLABORATION

Earth Chemistry

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

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

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

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

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

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

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

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

Dr V.C. BENNETT with Dr. A. D. Brandon (University of Houston) on development and application of high precision isotopic methods to reconstruct the early histories of the Earth and Moon.

Dr V.C. BENNETT with Dr J. Baker and 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 (University of Maryland) on determining the age structure of the southern ocean basin through rhenium-osmium isotope analyses of mantle peridotites.

Ms K. BOSTON collaborates with Prof Martin Engi of the University of Bern, Switzerland.

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

Dr J.J. BROCKS with Prof Nicholas Butterfield, Maria Pawlowska (University of Cambridge) and Richard Schinteie (RSES, ANU), The Paleontology and organic geochemistry of Mesoproterozoic successions from Russia, and Molecular Taphonomic Models of the Proterozoic.

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

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

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, S. Silenzi (ICRAM, Italy) on Mediterranean sea level and radiocarbon reservoir ages.

Dr M.A. FORSTER collaborates with Prof. Hall, Dr Cottam and Dr Watkinson. South East Research Group, Royal Holloway University of London.

Dr M.A. FORSTER is collaborating with Dr Lozios, Dr Soukis, Ms Moustaka, The University of Athens, joint research project on Evia, Greece.

Dr M.A. FORSTER is collaborating with ETH, Switzerland, Prof Burg, research project on Rhodope, Greece, based on 40Ar/39Ar geochronology.

Dr M.A. FORSTER is collaborating with Prof. Ahmad, Kashmir University, India, on research project in Ladakh, India, and as an advisor to my PhD student Jia-Urnn Lee.

Dr M.A. FORSTER is collaborating with Prof. Suparka, Bandung Technical Institute, Indonesia, on research project in Indonesia, and as a joint supervisor to PhD student Musri Mawaleda.

Dr M.A. FORSTER is collaborating with Prof Imran, Dr Nur, Dr Sufradin, Dr Jaya, Dr Irfan and Dr Kaharuddin at Hasanuddin University, Sulawesi, Indonesia, research on Sulawesi.

Dr M. HONDA collaborates with Dr J. Harris (The University of Glasgow, UK), Dr D. Araújo (Universidade de Brasília) and Dr T. Matsumoto (International Atomic Energy Agency, Austria) 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.

Dr C.H. LINEWEAVER participated in Michael Liu's unsuccessful NICI bid for time on Gemini to conduct a direct imaging survey for exoplanets.

Dr L. MARTIN collaborates with Pr S. Duchene (LMTG, Toulouse, France), Dr E. Deloule (CRPG, Nancy, France) and Pr O. Vanderhaeghe (G2R, Nancy, France) on the metamorphic evolution of Ikaria Island (Greece). Dr. L. Martin collaborates with Pr M. Ballevre (University of Rennes, France) on the significance of texture and zoning in eclogitic garnet crystals.

Emeritus Professor Ian McDOUGALL is 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 M. Engi, Mr Daniele Regis and Miss Paola Manzotti University of Bern, Switzerland, on the chronology of Alpine subduction and Permian extension in the Western Alps.

Dr D. RUBATTO collaborates with Prof R. Carosi, University of Pisa, Italy and Dr D. Visona, University of Padova, Italy on the chronology of granite formation and deformation in the Himalaya.

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.

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 Dr Pierre Vonlanthen, University of Lausanne, Switzerland on the deformation and recrystallization of zircon.

Dr D. RUBATTO collaborates with Dr Benita Putlitz, University of Lausanne, Switzerland on the oxygen isotope composition of monazite and garnet.

Dr D. RUBATTO collaborates with Prof Kurt Stüwe and Miss Deta Gasser, University of Graz, Austria on the response of monazite to metamorphism in the Chugach Metamorphic Complex, Alaska.

Dr D. RUBATTO collaborates with Dr Antonio Acosta-Vigil, University of Granada, Spain on the geochronology of migmatisation in the Ronda Complex, Spain.

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

Mr A. STEPANOV collaborates with Dr A. Korsakov, Institute of Geology and Mineralogy, Novosibirsk, on the geochemistry of UHP rocks from the Kokchetav metamorphic complex.

Mr A. STEPANOV collaborated with CY Wang, Guangzhou Institute of Geochemistry, China, on the interpretation of detrital zircons from Russia.

Mr A. STEPANOV collaborated with O. P. Yuryeva, V. A. Nadolinny from Institute of Inorganic Chemistry SB RAS, Russia on diamonds spectroscopy.

Mr A. STEPANOV collaborated with M. Perrakid, from National Technical University of Athens, Greece and K. De Gusseme, P. Vandenabeele, from Ghent University, Belgium on Raman spectroscopy.

Mrs K. STRZEPEK collaborates with Dr T. Guilderson, Lawrence Livermore National Laboratories, in an advisory role for her PhD panel.

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. Dr Williams and Prof. Rutland visited Norway for 10 days in July to collect samples for this project.

Dr I.S. WILLIAMS with Dr J. Wiszniewska and Dr E. Krzeminska (Polish Geological Institute, Warsaw). The evolution of the basement beneath the East European Platform in Poland. Drs. Wiszniewska and Krzeminska visited RSES for 4 weeks in May-June to work with Dr Williams on this project.

Dr I.S. WILLIAMS with Prof. F. Bea, Dr P. Montero and Dr C. Talavera (University of Granada, Spain). Training in the operation of the SHRIMP II ion microprobe. The Neoproterozoic evolution of northern Gondwana. Prof. Bea visited ASI and RSES for 3 weeks in March-April for advanced training prior to the delivery of his new SHRIMP IIe/MC.

Dr I.S. WILLIAMS with Dr P. Fiannacca, Dr. R. Cirrincione and Prof. A. Pezzino (University of Catania, Sicily). The evolution of the basement of Sicily. Dr Williams visited the University of Catania for a week in July to work on this project.

Dr I.S. WILLIAMS with Prof. D. Liu and Dr. Z. Ji (Chinese Academy of Geological Sciences, Beijing). Permo-Triassic palaeoclimate in Tibet. Prof. Liu and Dr Ji visited RSES for 2 weeks in May to work with Dr Williams 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 Rigo visited RSES for a week in January to work with Dr Williams on this project.

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.J. ABRAM collaborates with Dr R. Mulvaney and Dr E.W. Wolff from the British Antarctic Survey, on palaeoclimate reconstructions from the James Ross Island ice core and sea ice proxies in Antarctic and Greenland ice cores.

Mr N. DARRENOUGUE collaborates with Dr. C. Payri and Dr. G. Cabioch from the Institut de Recherche pour le Développement (IRD), Nouméa, New Caledonia.

Prof P. De Deckker is collaborating with Dr S. Schmidt from the University of Bordeaux I on dating marine sediments using a variety of nuclides; with Professor S. Schouten and his student R. Lopez from NIOZ in Holland on lipid biomarkers in deep-sea marine cores; Dr J.-B. Stuut also from NIOZ, on airborne dust and deep-sea sediments and their composition; with Dr A. Wegner of AWI in Germany and Dr P. Gabrielli of Ohio State University on the composition of dust in ice cores from Antarctica; with Dr R. Abed from the University of Oman and the microbiology of Australian airborne dust; with Dr M. Moros and PhD student K. Perner of the Baltic Sea Research Institute on the faunal composition and isotopic composition of deep-sea core offshore South Australia; with Dr T. Rathburn and his PhD student A. Burkett from Indiana State University on deep-sea foraminifera from the Australian region.

Dr S.M. EGGINS collaborates with Prof. H.J. Spero, University California Davis, with Dr B. Hoenisch, Lamont Doherty Earth Observatory, Columbia University NY, and with Dr G. Dunbar, Victoria University, Wellington, NZ, on paleoproxy development in modern foraminifers. Dr S.M. EGGINS and Mr L. KINSLEY collaborate with Dr

N. Prouty of the United States Geological Survey (Santa Cruz), on the application of trace element in 'Porites' corals as environmental monitors.

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, with Dr D. Vance (University of Bristol, UK) on isotope fractionation in diatoms and zinc isotopes in oceanic waters.

Dr M.K. GAGAN works with Prof W. Hantoro and Dr D. Natawidjaja (Indonesian Institute of Sciences), Prof Z. Liu (University of Wisconsin – Madison), and Prof K. Sieh (Earth Observatory of Singapore) on ARC *Discovery* Grant DP0663227 (2006-2011): The Indian Ocean Dipole, Australasian drought, and the great-earthquake cycle: Long-term perspectives for improved prediction; and with Prof W. Hantoro (Indonesian Institute of Sciences), Prof L. Edwards and Dr H. Cheng (University of Minnesota), and Dr G. Schmidt (NASA Goddard Institute for Space Studies) 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. He also collaborates with Dr D. Natawidjaja and Prof W. Hantoro (Indonesian Institute of Sciences), Assoc. Prof. C.-C. Shen (National Taiwan University), Prof K. Sieh (Earth Observatory of Singapore), Prof L. Edwards and Dr H. Cheng (University of Minnesota), and Dr G. Schmidt (NASA Goddard Institute for Space Studies) 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), Assoc. Prof Y. Yokoyama (University of Tokyo) and the Expedition Scientists of Integrated Ocean Drilling Program (IODP) Expedition 325: Great Barrier Reef Environmental Changes.

Prof R. GRüN collaborates with Prof M. Mussi, Universita de Roma “La Sapienza”, Italy, on early hominids in Ethiopa; 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, and Dr. M Duval (Centro Nacional de Investigación sobre la Evolución Humana, Burgos) 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; 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. He collaborates with many international scholars on the timing of modern human evolution. He has collected hominid samples Skhul, Qafzeh, Tabun, Kebara and Amud, Israel (Prof Y. Rak, Department of Anatomy, Haifa University), Broken Hill, Omo 1, Wadjak, Iwo Eleru (Prof C.B. Stringer, Natural History Museum, London). He collaborates with Dr J. Brink, Bloemfontein, on the dating of a range of sites in South Africa, including the newly discovered human site of Cornelia. Prof R. Grün collaborates with 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; and continues collaborations with Dr A. Pike, University of Bristol, UK, on uranium uptake of bones, and 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 D. Heslop collaborates with Dr A. Govin, MARUM, University of Bremen, Germany, on the elemental composition of Atlantic surface sediments; and with Dr C. Necula, Faculty of Geology and Geophysics, Universitatea din Bucuresti, Romania, on the processes controlling the grain size of magnetic minerals in European loess deposits.

Dr D.C. McPhail with Dr U. Morgenstern, GNS Science, New Zealand, on tritium and groundwater ages in the Lower Murrumbidgee catchment, NSW;

and 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 collaborates with and collected samples for Prof P. Boyd at the University of Otago during the GP13 transect of the Geotraces program in the South Pacific.

Dr B. Opdyke is collaborating with Mr K. Caldeira of Stanford University on ocean acidification projects.

Mr R.J. Owens collaborates with Mr J. Caves, Department of Environmental Earth System Science, Stanford University, California, USA, on Cenezoic Sr/Ca in planktonic foraminifera and seawater Sr/Ca modelling.

Prof B.J. PILLANS collaborates with Prof J. Ogg (Purdue University, USA), Prof F. Gradstein (University of Oslo, Norway) and Prof P. Gibbard (Cambridge University) on a new book, "The Geological Time Scale 2012", Cambridge University Press; and with Dr T. Barrows (Exeter University) on Southern Hemisphere Late Pleistocene glacial chronologies.

Professor A.P. ROBERTS published papers in 2011 with co-authors in: Australia, France, Italy, Japan, Netherlands, New Zealand, People's Republic of China, Spain, Taiwan, U.K., U.S.A.

Mr N. SCROXTON collaborates with Prof W. Hantoro (Indonesian Institute of Sciences), Dr B.W. Suwargadi, and Dr H. Rifai (State University of Padang, Jalan, Indonesia) on Indonesian Stalagmites; and with Dr G. Dunbar (University of Victoria, New Zealand) on Indonesian stalagmites.

Miss C. THOMPSON collaborates with Dr S. Sander (University of Otago, New Zealand).

Earth Materials & Processes

Prof R. ARCULUS and Professor Jon Blundy (University of Bristol); Professor Jon Davidson (University of Durham); Professor Katie Kelley (University of Rhode Island); Professor Ken Rubin (University of Hawaii); Drs Ed Baker, John Lupton, Joseph Resing (NOAA, USA); Dr Cornel de Ronde (GNS, NZ)

Prof I.H. CAMPBELL and Dr C. ALLEN with Professor Jim Gill (University of California at Santa Cruz); zircon age patterns of Fijian sands, and their and oxygen and hafnium isotope composition

Prof I.H. CAMPBELL and Dr C. ALLEN with Professor Barbara Nash and Dr Henrietta Cathey (University of Utah); age, and oxygen and hafnium isotope composition of zircon from ancient Yellowstone volcanic centres

Prof I.H. CAMPBELL and Dr C. ALLEN with Dr Scott Bryan (University of Queensland/Kingston University, London) and Mr Aldo Ramos (Kingston University); age and inheritance history of zircons from the Sierra Madre Occidental.

Prof I.H. CAMPBELL and graduate student J. Park with Professor S. Gao (Chinese University of Geosciences, Wuhan) on the platinum group element geochemistry of Chinese loess.

Prof S F COX and Mr Paul Stenhouse are collaborating with Professor Janos Urai (RWTH-Aachen, Germany) on using exceptionally well-exposed vein systems, associated with fault zones in Oman, to explore the distribution of fluid flow during the evolution of the fault system. Cox is also collaborating with G Pennock and M Drury (University of Utrecht) and A Barnhoorn (Technical University of Delft) in the application of focussed ion beam scanning electron microscopy for microstructural charcterisation of deformed minerals.

Mr B.J. HANGER collaborates with Dr A.J. Berry (Imperial College, London) on synchrotron methods for the quantitative mapping of the oxidation stateof iron in mantle garnet.

Prof I. 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), J. Kung (National Cheng-Kung University, Taiwan), R.C. Liebermann (Stony Brook University), Y. Kono (Carnegie Institution of Washington), and S.J.S. Morris and L.C. Lee (University of California, Berkeley) in the laboratory measurement and modelling of seismic properties.

Prof G. LISTER has continued collaboration with Prof Robert Hall, South East Asia Research Group, Royal Holloway University of London, on the 4D SE Asia project.

Prof G. LISTER has continued collaboration with Prof Jean-Pierre Burg, ETH Zurich, Switzerland, on the evolution of the Lepontine culmination in the Swiss Alps.

Prof G. LISTER has continued collaboration with Prof Sumit Chakraborty, Ruhr University Bochum, Germany, on garnet-ilmenite geospeedometry.

Dr J.A MAVROGENES collaborates with Prof R. Frost (University of Wyoming) and Prof C Manning (UCLA) and M Frenz (University of Bern).

Dr O. NEBEL was involved in international collaboration research with the Free University Amsterdam, The Netherlands.

Prof. H. O’NEILL is collaborating with Dr Andrew Berry, Imperial College, University of London, UK, and 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 is working with Prof. Herbert Palme of the Senckenberg Forschungsinstitut und Naturmuseum, Frankfurt, Germany on refining estimates of the chemical composition of the Earth. He continues to work Dr. Frances Jenner of the Department of Terrestrial Magnetism, Carnegie Institution of Washington, on the trace-element geochemistry of mid-ocean ridge basaltic glasses.

Mr L.WHITE with Professor Talat Ahmad (University of Kashmir / University of Delhi, India).

Dr G.M. YAXLEY collaborates with Dr A. Berry, Imperial College London and Dr H. Höfer and Prof A. Woodland, Institut für Geowissenschaften, Universität Frankfurt, on synchrotron-based XANES measurements of Fe3+ in upper mantle garnets.

Dr G.M. YAXLEY collaborates with Prof Marc Hirschmann, University of Minnesota, on a high pressure experimental study of the earth's deep carbon cycle.

Earth Physics

Dr N BALFOUR collaborated with Dr J Cassidy and Dr S Dosso on crustal seismicity in British Columbia.

Thomas BODIN collaborated with Kerry Gallagher, Universite de Rennes, France, on various aspect of transdimensional inverse methods. Thomas visited Kerry in Rennes in May 2010.

Prof P. CUMMINS collaborates with Prof D. Wiens, Dept. Earth and Plenetary Sciences, Washington University in St. Louis, and with Dr. T. Baba, Japan Agency for Marine-Earth Science and Technology, on modeling the source processes of subduction zone earthquakes.

Prof. P. CUMMINS collaborates with Prof. Sri Widiyantoro and Dr. Irwan Meilano on understanding crustal structure and earthquake activity in Indonesia.
Dr Neda DARBEHESHTI, attended the 2011 GRACE Science Team Meeting in Austin (August 8-10).

Dr A.McC. HOGG, Prof R.W. Griffiths and Dr M.L. Ward with Dr P. Berloff, Imperial College London, UK, and Prof W.K. Dewar, Florida State University, USA on the ocean energy cascade.

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 new Australian ocean model.

Dr A.McC. HOGG with Dr Sergey Kravtsov and Mr J. Peters, University of Wisconsin-Milwaukee, USA, and Prof. I Kamenkovich, University of Miami, USA, on Sea Surface Temperature trends in the Southern Ocean.

Dr G. IAFFALDANO collaborated with Prof Eric Calais and Ms Sarah Stamps (Purdue University)

Dr G. IAFFALDANO collaborated with Dr Laurent Husson (Geosciences Rennes)

Dr G. IAFFALDANO collaborated with Prof Claudio Faccenna, Dr Francesca Funiciello, Dr Erika Di Giuseppe (Univ. Roma 3)

Dr G. IAFFALDANO collaborated with Prof Hans-Peter Bunge (LMU Munich)

Prof KENNETT continues to collaborate with Dr S Fishwick, University of Leicester, UK, Dr A. Fichtner, University of Utrecht, the Netherlands, and Dr K. Yoshizawa, University of Hokkaido on surface wave tomography. All three visited Canberra in June for discussions on the structure beneath Australia in connection with the construction of the AuSREM seismological model.

Prof KENNETT has collaborated with Dr T. Furumura at the Earthquake Research Institute, University of Tokyo, Japan on a variety of issues in seismic wave propagation, particularly the long range propagation of high frequency seismic waves.

Dr R.C. KERR with Prof. M. Lesher, Laurentian University, Canada, and Dr D. Williams, Arizona State University, USA, on komatiitic basalt lava flows.

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; A. Prof. R. Bendick, Dept of Geosciences, Univ. Montanna, Missoula, MT, USA, on the style and scaling of extension in the African Rift system.

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 Jean-Philippe MONTILLET, Dr. Craig Hancock and Mr Lukasz Bonenberg (University of Nottingham, UK) are collaborating on a long term research work (LOCATA – precise positioning in urban canyons and ubiquitous positioning). The purpose is to integrate two types of positioning technologies within a software (synchronization and navigation engine).

Dr POZGAY collaborates with Washington University in St Louis, MO, USA.

Dr A. PURCELL collaborates with Dr J. Yu, Lamont-Doherty Earth Observatory, Columbia University on the reconstruction of coral extent during the last glacial cycle.

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.L. RODERICK with Dr S. Schymanski (ETH-Zurich) and Prof M. Sivapalan (University of Illinois at Urbana-Champaign), on the inclusion of vegetation in hydrologic models.

Dr M. SALMON collaborates with Prof T. Stern, Victoria University of Wellington, New Zealand on a project mapping the Moho of Oceania.

Dr M. SALMON collaborates with Dr P. Arroucau, North Carolina Central University, USA on a project to use short period arrays for ambient noise tomography.

Prof. M. SAMBRIDGE with Prof. K. Gallagher (Univ. of Rennes, France) on Bayesian methods of data inference, Drs. E. Debayle (Univ. of Lyon, France) and C. Zaroli (Univ. of Nice, France) on mantle imaging with body waves.

Dr. E. SAYGIN collaborates with Prof. T. Taymaz, Geophysical Engineering, Istanbul Technical University, Dr. L. Vanacore, School of Earth and Environment, University of Leeds, and Dr. A. Fichtner, Department of Earth Sciences, Utrecht University on the crustal structure of Turkey.

Dr. H TKALČIĆ collaborates with Prof. V Cormier, University of Connecticut, and 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 PhD student J. Stipcevic, University of Zagreb, on lithospheric structure of Croatia and the Adriatic Sea, with Dr. A Fichtner, Utrecht University on earthquake sources, and with Dr. Y Chen, 3D Array Technologies, United States, on lithospheric structure of China.

Dr P. TREGONING collaborates with Dr R. King and Prof. T.A. Herring (Massachussets Institute of Technology) and Dr G. Ramillien (CNRS, Toulouse, France).

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 (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.

Mr 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.

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

Mr 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.

Mr 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.

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

Mr 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.

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

Mr 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.

Visiting Fellows

DR R.V.BURNE has collaborative links with: Prof. J. Paul (Göttingen University, Germany); Dr T. Peryt (Geological Institute, Poland); Mr G. Izuno (University of Tokyo, Japan); the U.K. Nature Conservancy on the origin and development of the North Cornish coastline; and Prof R. Summons (MIT, USA) on the genesis of ooids.
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 Prof. D Ravat (University of Kentucky) on interpretation of Australian lithospheric magnetic anomalies.
Dr W. Mayer continued his collaboration with the Muséum national d'histoire naturelle, in Paris, on the description and interpretation of the geological collections made by various French expeditions to Australia between 1801 and 1841.

Dr Truswell collaborates with Dr E.Domack (Hamilton College New York) on sedimentary sequences from the East Antarctic margin. With Dr Sophie Warny
(Louisiana State University) on Cenozoic vegetation history of Antarctica.

COOPERATION WITH GOVERNMENT AND INDUSTRY

Earth Chemistry

Dr V.C. BENNETT and Dr M. Honda with Dr M.J. van Kranendonk (Geological Survey of Western Australia); Determining early atmosphere compositions through noble gas investigations of the Archean Pilbara sediments.

Dr J.J. BROCKS with Nur Güeneli 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.A. FORSTER is collaborating with Dr Geoff Fraser at Geoscience Australia on 40Ar/39Ar geochronology analysis.

Dr M.A. FORSTER is industry-based collaboration with Petrobras E&P EXP/GEAT, Chile, on 40Ar/39Ar geochronology.

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 I.S. 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. He provided advanced training in SHRIMP operation and maintenance to Dr C. Talavera (University of Granada, Spain) who returned to Spain in June after a stay of ~18 months. In May-June he spent about three weeks in Spain assisting with the installation of the SHRIMP IIe/MC at the University of Granada and in November he spent a week in Tokyo assisting with training the operators in negative ion analysis and the retuning of the NIPR SHRIMP II after its upgrade.

Dr I.S. WILLIAMS and Ms Heejin Jeon are collaborating with Dr P. Blevin (Geological Survey of New South Wales) in an isotopic study of the Late Palaeozoic granites of southeastern Australia.

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

Prof P. De Deckker collaborates with Dr D. Cohen of ANSTO on the composition of Australian aerosols.

Prof R. GRüN worked with the Australian Government's Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) on the experimental set-up of a study of energy dependent ionisation efficiencies in alanine dosimeters and tooth enamel.

Dr D.C. McPhail collaborates with Dr W. McLean and Ms E. Webb (Parsons Brinckerhoff, Sydney) on groundwater dynamics in the Lower Murrumbidgee catchment, NSW; with Mr P. Kumar and Dr M. Williams of the NSW Office of Water on groundwater in the Lower Murrumbidgee catchment, NSW; with Dr W. McLean (Parsons Brinckerhoff, Sydney) and Dr K. Meredith (ANSTO) on dating groundwater using 14C; with the Minerals Tertiary Education Council (Honours Geoscience program of the Minerals Council of Australia); and with the Australian Institute of Mining and Metallurgy (AusIMM) for the Lachlan Branch and its professional and student members.

Dr B. Opdyke is part of an ANU team organising a national effort to put an Ocean Acidification action plan in place and this includes interacting with CSIRO, AIMS and Government.

Prof B.J. PILLANS collaborates with Dr P. Morris (Geological Survey of Western Australia) on the geochronology of regolith/landform evolution in the Kalgoorlie region, WA.

Earth Materials & Processes

Prof R. ARCULUS collaborates with Dr Peter Crowhurst (Nautilus Minerals); Dr Richard Langford (Flinders Mines); Dr Tim McConachy (Blue Water Metals).

Prof S.F.COX has collaborated with GoldFields Australia Limited in a PhD project "Deformational Controls on Dynamics of Fluid Flow, Hydrothermal Alteration and Ore Genesis, Argo Gold Deposit, WA", and also on an Honours project on the structural evolution of the Athena gold deposit.

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

Prof G. LISTER has continued collaboration with AngloGold Ashanti, Newmont, Teck and Marengo Mining in support of the 4D Porphyry project.

Dr J.A MAVROGENES collaborates with Newcrest Mining.

Dr O. NEBEL undertook research (ARC linkage grant) in collaboration with The Western Australian Geologic Survey (T. Ivanic) and Flinders Mines Ltd.

Earth Physics

Prof P. CUMMINS with Geoscience Australia in Disaster Risk Reduction in the Australian region, and with the AusAID-funded Australia-Indonesia Facility for Disaster Reduction (AIFDR) to improve the assessment of earthquake hazard in Indonesia. Prof P. CUMMINS works with the Applied Geoscience and Technology Div., Secretariat of the Pacific Community, on the assessment of tsunami hazard and risk in Pacific Island Countries.

Dr G. IAFFALDANO, Associate editor of Annals of Geophysics

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

Dr M.L. RODERICK with J. Alexandra (Murray-Darling Basin Authority), Special Issue in the Journal, Water Resources Research, on Water Availability in the Murray-Darling Basin

Dr M. SALMON provided the AusMoho grid data to Dr H. Sheldon (CSIRO) for modelling of the Perth Basin.

Dr M. SALMON provided the AusMoho grid data to M. Zengerer (Consulting Geophysicist Adelaide) as a background for detailed gravity model in North Queensland.

Dr H TKALČIĆ cooperates with Dr A Gorbatov and E Leask of Geoscience Australia on the determination of seismic sources in Australia and surroundings in real time using Geoscience Australia stations.

Dr P. TREGONING collaborates with Dr J. Dawson and Mr G. Johnston (Geoscience Australia).

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 C. Macaulay of Shell International Exploration and Production Inc., USA, on sulphur isotope studies of sulphide- and sulphate-bearing veins in shales, including the characterization of new sulphate standards for *in situ* SIMS analyses.

Dr R.A. ARMSTRONG with J. Hollis, E. Beyer, J. Whelan and L. Glass of the Northern Territory Geological Survey on the geochronology, provenance and history of selected areas of the Northern Territory, using U-Pb, oxygen and Hf isotope studies.

Dr 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.

Visiting Fellows

Dr R.V.BURNE has collaborative links with Dr. A. Kendrick (Marine Science Program, Department of Environment and Conservation, Western Australia); Ms S. Hancock & Mr R. Chaple (Parks and Visitor Services, Department of Environment and Conservation, Western Australia); and Geoscience Australia in preparing on-line publications of several important reports that have remained unpublished for the past 15 years.

Dr E.A. FELTON is a collaborator with First Investigator Prof B.J. Pillans, RSES and others, in an ARC Linkage Project “Enigmatic Lake George - Changing environments, sustainable sand”, which was re-submitted to the ARC in November 2011.

Dr P.J. JONES with Dr J.R. Laurie (Geoscience Australia), on palaeontological studies of Ostracoda from the Mississippian rocks of the Bonaparte Basin, northwestern Australia.

Dr C. Klootwijk collaborated with Dr B. Musgrave (NSWGS) as guest editor for a special volume on paleomagnetism and rock magnetism for the Australian Journal of Earth Sciences.

Dr C. Klootwijk collaborates with Dr P. Milligan (Geoscience Australia) on interpretation of Australian lithospheric magnetic anomalies. Ongoing cooperation with Geoscience Australia’s Antarctic research team(Drs C.Carlson, A.Post, J.Smith, P.T.Harris) on identification of sedimentary sequences from the East Antarctic margin.With Dr

J.Laurie (Geoscience Auustralia) on ‘Living Australia’ chapter for Geology of Australia volume, for IGC 2012.

Dr D.L. STRUSZ collaborates with Dr I. Percival (New South Wales Geological Survey) on the Silurian fanuas of the Quidong Basin near Delegate, southern NSW.

Staff Activities 2011

CONFERENCES AND OUTSIDE STUDIES

Earth Chemistry

Dr Y. AMELIN, 42nd Lunar and planetary Science Conference, The Woodlands, TX, USA, March 1-5, 2010. Oral presentation and two poster presentations. Followed by 5 day stay at Q-Z. Yin's lab at the University of California Davis, Hf isotope analysis of angrites.

Dr Y. AMELIN, 10th Australian Space Science Conference, Brisbane, Canberra, ACT, September 26 - 39, 2011. Oral presentation.

Dr Y. AMELIN, Workshop on Formation of the First Solids in the Solar System, Kauai, HI, USA, November 7-9, 2011. Oral and poster presentations as the first author, and two-co-authored presentations. Followed by visit to the University of Hawaii for initial petrologic and mineralogical characterisation of refractory inclusions from a newly discovered CV chondrite NWA 4502.

Dr Y. AMELIN, two poster presentations at the annual Meteoritical Society meeting in London, UK. Amelin is the first author but not attending the meeting (posters presented by a co-author).

Dr Y. AMELIN, oral presentation by a co-author at the Fall meeting of the American Geophysical Union (Amelin is the first author but not attending the meeting).

Dr V.C. BENNETT, Goldschmidt Conference, Prague, C, 13-18 June presented an invited talk in the symposium on Geology, Age and Origin of the Oldest Terrestrial Rocks and Minerals entitled, "Limited early continents from the
chemistry of Eoarchean rocks".

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

Ms K. BOSTON, Biennial Conference of the Specialist Group in Geochemistry, Mineralogy and Petrology, Murramarang, NSW, 20-25 November 2011, presented a poster entitled "Geochronology of accessory allanite and monazite in the Barrovian metamorphic sequence of the Central Alps, Switzerland."

Dr J.J. BROCKS – Oral presentation 'Archean molecular fossils and a late rise of oxygenic photosynthesis?', The Evolution of Photosynthesis and Oxygenation of the Earth Symposium, 29 – 29 June 2011, Sydney.

Dr J.J. BROCKS — Oral presentation ‘Archean molecular fossils and a late rise of oxygenic photosynthesis?’, 20-Annual V. M. Goldschmidt Conference Prague, Czech Republic, 14 – 19 August 2011.

Dr J.J. BROCKS – Oral presentation ‘Molecular fossils and the late rise of eukaryotes and oxygenic photosynthesis’, 25th International Meeting on Organic Geochemistry, Interlaken, Switzerland, 18 – 23 September 2011.

Mr A. CHOPRA, Stromlo Student Christmas Seminars in Canberra, Australia, 11 November, presented a talk entitled “CSI:Life”.

Mr A. CHOPRA, Australian Space Sciences Conference in Canberra, Australia, 28 September, presented a talk entitled “What can the elemental abundances tell us about the site of the origin of life?”

Mr A. CHOPRA, Research School of Earth Sciences Student Conference in Canberra, Australia, 22 September, presented a talk entitled “Where did it happen?”

Mr A. CHOPRA, 2011 Origins Conference in Montpellier, France and the 2011 European Workshop on Astrobiology in Cologne, Germany, July, presented a poster entitled “What do the elemental abundances tell us about the universality of life?”

Mr A. CHOPRA, 2011 Origins Conference in Montpellier, France and the 2011 European Workshop on Astrobiology in Cologne, Germany, July, presented a poster entitled “Elemental insights into the site of the origin and early evolution of life on Earth.”

Mr A. CHOPRA, 2011 European Workshop on Astrobiology in Cologne, Germany 13 July, presented a talk entitled “What do the elemental abundances tell us about the universality of life?”

Mr A. CHOPRA, 2011 UHNAI Astrobiology Winter School, Hawaii, USA, 5 January, presented a poster entitled “What do the elemental abundances tell us about life in the universe?”

Ms T.A. EWING, Goldschmidt 2011, Prague, Czech Republic, 14–19 August, presented a paper entitled “Insights into lower crustal evolution from Hf isotope and Zr thermometry data for rutile”.

Ms T.A. EWING, Biennial Conference of the Specialist Group in Geochemistry, Mineralogy and Petrology, Geological Society of Australia, Murramarang, Australia, 20–25 November, presented a paper entitled “Decoupled Zr thermometry and U–Pb geochronology of rutile record metamorphism and exhumation of the lower crust”.

Dr S. FALLON, attended the International Accelerator Mass Spectrometer Conference (AMS-12) in Wellington New Zealand and presented two papers “Three years on: an update on the ANU SSAMS” and “Bomb Radiocarbon at the Source: Coral D14C from Enewetak Atoll during the 1950s”.

Dr S. FALLON, attended the 6th International Symposium on Radiocarbon and Archaeology in Pafos, Cyprus.

Dr M.A. FORSTER attended the 36th Indonesia Association of Geophysicists and the 40th Indonesian Association of Geologists: “Exploring Eastern Indonesia”, Makassar, Indonesia, 26-29th September 2011.

Dr M.A. FORSTER undertook fieldwork on the southeastern arm of Sulawesi, Indonesia, with Prof. Suparka and PhD student Mr. Mawaleda from Bandung Institute of Technology, Java, 29th September till 2nd October.

Dr M.A. FORSTER undertook fieldwork on the island of Palawan, Philippines, with Dr Cottam, SE Asia Research Group, Royal Holloway University of London. 21st May till the 3rd June 2011.

Ms B. FRASL, 42th Lunar and Planetary Science Conference, Houston, USA, 7-11. March, presented a paper entitled “Isotopic compositions of solar He and Ne in single lunar olivine grains of lunar soil 10084”.

Dr M. HONDA and Dr X. Zhang were invited by Thermo-Fisher Scientific in Bremen, Germany to inspect a new generation multi-collector Helix-MC noble gas mass spectrometer and to attend the software training course for the Qtegra software package for the Noble Gas Mass Spectrometers. They also attended TANG3O (Thermochronology and Noble Gas Geochemistry and Geochronology Organization) meeting held in Melbourne, and Dr M. Honda presented talks on “Noble gases and carbon in Argyle diamonds” and “The HELIX Multi-Collector Mass Spectrometer”.

Ms M. HUYSKENS attended the XVII International Congress on the Carboniferous and Permian 3-8 July 2011.

Ms M. HUYSKENS attended the Goldschmidt Conference 14-19 August 2011 in Prague and presented a poster with the title: A new highly effective silicagel emitter for lead isotopic measurements.

Ms M. HUYSKENS visited the geochronology lab in Geneva from 22 August -2 September.

Mrs A. JARRETT attended the Astrobiology Graduate Conference, Montana USA from June 5th – 8th.

Mrs A. JARRETT attended the International Geobiology Course, California USA from 12th June – 12th July.

Mrs A. JARRETT conducted field work in Darwin and Alice Springs, Australia from 4th -18th May.

Ms H. JEON, Goldschmidt 2011 Conference, Prague, Czech Republic, 14-19 August, presented a paper entitled “Secular Trends in Granite Zircon εHf–δ18O, Australian Tasmanides”.

Ms A. F. KOMUGABE, 48th Australian Marine Sciences Association (AMSA) Conference, 3 - 7 July 2011 in Fremantle, Western Australia, presented a paper entitled ‘Can Black Corals Unravel the Mysteries of the Deep? A Study of Trace Element Composition in Antipatharian Skeletons’.

Dr C.H. LINEWEAVER attended and presented "Is the Sun a Typical Star? " at the Gordon Research Conference "The Origins of Planetary Systems" in Mt Holyoke, Massachusetts, 11-22 July, 2011.

Dr C.H. LINEWEAVER presented a talk "Entropy, Cosmology and the Maximum Entropy Production Principle" at the international conference on "Maximum Entropy Production", RSB, ANU, 9am, September 14, 2011.

Dr C.H. LINEWEAVER chaired a session and presented a talk co-authored with Aditya Chopra: "What can life on Earth tell us about life in the Universe?" at the 11th Australian Space Science Conference Planetary Science Session, 2:30-2:45 pm Thursday, September 29, 2011, Canberra, Australia, www.nssa.com.au/ocs/viewabstract.php?id=388&cf=13

Dr L. MARTIN attended the Biennial Conference of the Specialist Group in Geochemistry, Mineralogy and Petrology (SGGMP) of the Geological Society of Australia, Murramarang, Australia, 21-25 November 2011, presented a talk entitled "Carbon recycling in subduction zones: insight from gas chromatography analysis applied to partial melting experiments on altered oceanic crust." and a poster entitled "Superzoned garnet crystals in a lawsonitite from Alpine Corsica record a complex P-T and fluid history".

Dr L. MARTIN presented (but did not attend) a poster entitled “Experimental determination of CO2/H2O in subduction zone fluids by GC-TCD analysis” at the Goldschmidt Conference in Prague (14-19 August 2011).

Emeritus Professor Ian McDOUGALL was a participant in a workshop organized by the Turkana Basin Institute and held at the Turkwel facility, near Lodwar, Kenya, in September. This was the tenth Stony Brook Human Evolution Workshop under the title: Geological History of the Turkana basin.

Professor McDOUGALL also attended a one day workshop of the TANG3O group in Melbourne in October.

Dr D. RUBATTO, Biennial Conference of the GSA Specialist Group in Geochemistry, Petrology and Mineralogy, Murramarang 20-25 November.

Mr A. STEPANOV, Eclogite conference, Czech Republic, Marianske Lazne, August, presented a talk entitled “Melting of the Kokchetav UHP gneisses”.

Mr A. STEPANOV, Eclogite conference, Czech Republic, Marianske Lazne, August, presented a poster entitled “Melt inclusions in a UHP gneiss from the Kokchetav complex”.

Mr A. STEPANOV, Goldschmidt conference, Czech Republic, Prague, August, presented a talk entitled “Experimental study of monazite/melt partitioning”.

Mr A. STEPANOV, SGGMP, Murramarang, November, presented a talk entitled “Tracing ultra-high-pressure metamorphism and melting using zircon trace element composition”.

Mrs K. STRZEPEK presented two posters at the Accelerator Mass Spectrometry Conference in Wellington, 21-25 March, titled “When size really does matter; measurement of ultra-small samples at the ANU Radiocarbon Dating Laboratory" and "Lose 5,000 radiocarbon years in just one hour; improved backgrounds using zinc reduction for graphite target preparation".

Dr I.S. WILLIAMS privately funded his travel to Norway in June to attend the Eurogranites 2011 conference, then to Spain in July to attend the Hutton VII conference, at which he was an invited speaker. He presented a keynote lecture on "Granite petrogenesis in the Bega Batholith, southeastern Australia: new perspectives from zircon U-Pb, O and Hf isotopes".

Dr I.S. WILLIAMS privately funded his travel to Norway in July to work with Prof. R.W. Rutland and Dr A. Solli collecting samples for their joint project on the evolution of the Norwegian Caledonian nappes.

Dr I.S. WILLIAMS privately funded his travel to Sicily in July to work with Drs P. Fiannacca and R. Cirrincione, preparing some of their joint work on the Sicilian basement for publication. While there he gave a lecture at the University of Catania entitled "From oldest to hottest: Dating complex metamorphic rocks with the SHRIMP ion probe".

Dr I.S. WILLIAMS visited the National Institute of Polar Research, Tachikawa, Japan, in November, where he gave a lecture entitled "Solving geological problems by SHRIMP microanalysis of radiogenic and stable isotopes".

Earth Environment

Dr A. Abrajevitch attended the International Union of Geodesy and Geophysics (IUGG) General Assembly, Melbourne, Australia, 27 June - 8 July and presented a paper entitled "Diagenetic sensitivity of paleoenvironmental proxies: A rock magnetic study of Australian continental margin sediments." She attended the American Geophysical Union Conference, San Francisco, USA, 5-9 December, presented an invited paper entitled "Diagenetic Sensitivity of Rock Magnetic Environmental Proxies".

Dr L. AYLIFFE conducted fieldwork in Indonesia, 11 June to 24 July, and with Ms C. KRAUSE, attended the AINSE AusIntimate workshop held at ANSTO from 12-15 December.

Mr N. DARRENOUGUE, American Geophysical Union Conference, San Francisco, USA, 5-9 December, presented a poster entitled "Rhodolith-forming coralline red algae record half-a-century of sea-surface temperature variations and mining history", and conducted fieldwork in New Caledonia from 7-12 February and from 24 August to 3 September.

Dr S.M. EGGINS attended the Conference on Ocean Acidification, Shine Dome, Canberra, in June 2011.

Dr S.M. EGGINS and Mr G.J. Nash sampled live and fossil Anadara trapezia along a coastal transect from Westernport Bay to Tuggerah Lakes from 28 October to 4 November, and from Lake Macquarie to Gladstone from 6-13 December.

Dr S.M. EGGINS and Ms K. HOLLAND undertook field-based studies of planktic foraminifers at the Wrigley Centre for Environmental Studies, Santa Catalina, California, from 18-27 July and 18 July to 28 August respectively.

Dr M.K. GAGAN attended the Australia-Indonesia Environmental Science Workshop, ANU Shine Dome, Canberra, 18-19 April, presented an invited paper entitled "Earthquake supercycle terminations in Sumatra over the last 5,500 years", and attended the American Geophysical Union Fall Meeting, San Francisco, USA, 5-9 December, presented an invited paper entitled "Orbital- and millennial-scale changes in the Australasian monsoon over the last 470,000 years".

Prof R. GRÜN attended the Italian-Australian Workshop on New Scientific Techniques in Cultural Heritage as an invited speaker and presented a talk entitled "Laser ablation ICP-MS scanning of isotopes in human fossils", 14-17 April. He attended the 13th International Luminescence and Electronic Spin Resonance Dating (LED) conference, Torun, Poland, 9-14 July, and presented a talk entitled "Ionization efficiencies of alanine dosimeters and tooth enamel irradiated by gamma and X-ray sources", and attended the International Union for Quaternary Research (INQUA) conference, 20 – 27 July. He conducted fieldwork with PhD student Mr M. Willmes and Honours student Ms C. Boel in the Bordeaux region, France, 16 May – 1 June, and conducted fieldwork at Melka Kunture, Ethiopia as part of a collaborative team led by Prof M. Mussi, Universita di Roma, Italy, 17 November to 2 December.

Dr D. HESLOP attended the 2011 IUGG General Assembly, Melbourne, 28 June to 5 July, and presented a paper entitled "The Decomposition of Hysteresis Loops into Environmentally Meaningful Mixing Models".

Ms C. KRAUSE presented at the AINSE INTIMATE conference at Lucas Heights, NSW, 13-15 December, and conducted fieldwork at Tumut NSW, 9-10 November.

Ms J. MAZERAT attended the XVIII International Union for Quaternary Research, Bern, Switzerland, 21-27 July 2011, and presented a talk entitled "The 8.2ka event in southern Australasia: a different response between the ocean and atmosphere?"

Dr D.C. McPhail conducted fieldwork in the Lower Murrumbidgee catchment, NSW, in January, May and July 2011, and in the Northern Flinders Ranges, SA, in May 2011. He presented "Groundwater-surface water interaction in the Lower Peel River, NSW" at the 4th Australasian Hydrogeology Research Conference in Cairns, Qld in July 2011, and led ANU Honours students to present at the AusIMM Student Challenge in Moss Vale, NSW in September 2011.

Dr B. Opdyke attended the Geological Society of America meeting in Minneapolis USA and presented the paper "Discovering Dolomite".

Mr R.J. Owens attended the 8th Urbino Summer School in Paleoclimatology (USSP), Urbino University, Italy, July 13 – August 2, and presented the poster "Sr/Ca in Planktonic Foraminifera: a proxy for surface ocean carbonate saturation state?" He attended the Symposium on "Ocean acidification and implications for living marine resources in the Southern Hemisphere" at the Shine Dome, Canberra, Australia, June 15-17.

Prof B.J. Pillans attended the 14th Biennial conference of the Australian & New Zealand Geomorphology Group (ANZGG) in Oamaru, New Zealand, from 31 January to 4 February 2011 and presented a paper: Weathering history of rock surfaces associated with Aboriginal rock art, Burrup Peninsula, Western Australia", and attended a joint INQUA-EAQUA Workshop in Zanzibar, Tanzania, from 7-12 February 2011 and presented an oral paper: "Stratigraphy and chronology in Quaternary Research. He attended the 18th International Union for Quaternary Research (INQUA) Congress in Bern, Switzerland, from 20 - 27 July 2011 and presented a poster paper: "Erosion rates of rock surfaces associated with Aboriginal rock art, Burrup Peninsula, Western Australia". He conducted fieldwork in Western Australia in May 2011 and September 2011 with Prof. L.K. Fifield (ANU) and Dr P. Morris (GSWA) to collect samples for regolith geochronology, and in Indonesia n July 2011 with Dr B. Jones (University of Wollongong) on the Quaternary stratigraphy of Soa Basin, Flores.

Ms J. Roberts attended the ALS/Actew Research and Development Workshop, October 2011.

Miss C. THOMPSON attended and presented at the RSES Student Conference, and visited the chemical oceanography labs at the University of Otago to supplement PhD research by learning a voltammetric technique for the measurement of organic copper chelators in seawater.

Earth Materials & Processes

Prof R. ARCULUS attended Goldschmidt Conference (August, Prague); American Geophysical Union Meeting (December 4-10, San Francisco)

Mr C. AUGENSTEIN gave a talk titled "The Alpine "orogenic lid" - upper plate of a metamorphic core complex?" at the American Geophysical Union Fall Meeting in San Francisco from December 4-10.

Prof I.H. CAMPBELL attended an International Symposium in Beijing on "Craton fromation and destruction" where he gave an invited talk entitled "What detrital zircons tell us about craton formation".

Prof I.H. CAMPBELL attended the final sponsors meeting of a joint LINKAGE project with Professor R. Cass and Dr R. Squire, (Monash University); entitled "Understanding the stratigraphic and structural architecture of late Archean basins and the context of their gold deposits" where he gave a talk on "Dykes, sills and Magma chambers".

Prof I.H. CAMPBELL attended the International Union of Geophysics and Geodacy in Melbourne where he co-convened a session to honour Geoff Davies and gave a talk entitles "Did the formation of D" cause the Archaean-Proterozoic boundary?".

In June, Prof S.F. COX presented a lecture on “Fault Mechanics and Fluid-Driven Failure in High Fluid Flux Regimes” at the IUGG meerting in Melbourne. He also co-convened a symposium on “Fluids in the crust and mantle: geodynamic and seismological consequences - geophysical and geological constraints” a that conference.

From August 2011 to January 2012 Prof S.F.COX engaged in outside studies at RWTH-University of Aachen, working with Prof Janos Urai and his group on aspects of coupling between fluid flow and crustal deformation processes. During his stay in Europe, Cox also presented invited lectures at Ruhr Univerity (Bochum, Germany), Katholieke Universiteit Leuven (Belgium), ETH-Zurich, Ludwig Maximilian University (Munich), Technical University of Delft (Netherlands), Utrecht University (Netherlands) and Charles University (Prague).

Mr B.J HANGER gave an oral presentation and volunteered at the XXV General Assembly of the International Union of Geodesy and Geophysics, July 2011, Melbourne; and presented at poster at the Biennial Meeting of the Specialist Group for Geochemistry, Petrology and Mineralogy, Geological Society of Australia, November 2011, Murramarang, NSW.

Prof I. JACKSON participated as an invited Discussion Leader at the Gordon Research Conference on the Earth’s Interior (South Hadley, Massachusetts, June), in discussions with colleagues at Stony Brook (May), Yale (June), and Boston Universities (June), including research seminars at each of the latter, and attended and presented papers at the General Assembly of the International Union for Geodesy and Geophysics (Melbourne, July).

Miss S. McALPINE studied with Prof J. BLUNDY, Department of Earth Sciences, University of Bristol, United Kingdom on the cumulative vs. xenocrystic nature of peridotites from the West Bismarck Arc.

Miss S. McALPINE, Goldschimdt Conference 2011, Prague, Czech Republic, 14-19 August, presentated a talk entitled “Pristine mantle xenoliths from the active Bismarck Arc”.

Miss S. McALPINE, Biennial Conference of the Specialist Group in Geochemistry, Mineralogy and Petrology, Murramarang, Australia, 20-25 November, presented a poster entitled “A detailed petrological study of a pristine xenolith suite, West-Bismarck Arc”.

Dr O. NEBEL attended the IGCC conference in Melbourne and the Goldschmidt Conference in Prague and gave oral presentations on his recent research.

Prof. H. O’NEILL gave a keynote lecture at the Goldschmidt 2011 conference in Prague in August.

Prof H. O’NEILL conducted experiments using synchrotron X-rays at the Diamond Light Source, UK, in May.

Mr P. STENHOUSE attended the IUGG Conference in Melbourne, 28 June-7 July, 2011.

Mr P. STENHOUSE attended the CAGS summer school on geological storage of carbon, 21-25 August, 2011.

Mr P. STENHOUSE attended the Advanced Structural Geology for Petroleum Exploration short course, 24-27 October, 2011.

Mr P. STENHOUSE attended the FRLP workshops on project management during October and November, 2011.

Mr P. STENHOUSE conducted fieldwork from 12 January to 4 March in Oman.

Miss D. TANNER, ECROFI XXI, 21st Biennial Conference, Leoben, 9-11 August, presented a paper entitled “Fluids in high-sulfidation gold deposits: insights from in situ stable isotopes and noble gas analyses”.

Miss D. TANNER, Goldschmidt 2011, Prague, 14-19 August, presented a poster entitled “Oxygen isotope chemistry beneath paleo-fumaroles”.

Miss D. TANNER, SGGMP 2011 Biennial Conference, Canberra, 20-25 November, presented a poster entitled “Amagmatic chromite in olivine-bearing Merensky Reef”.

Dr G.M. YAXLEY, IUGG XXV General Assembly, Melbourne, Australia, 27 June-8 July, presented a paper entitled “Mineral compositional controls on REE patterns in cratonic garnet lherzolite xenoliths and implications for mantle metasomatism”.

Dr J.A MAVROGENES presented a talk at the 2011 Goldschmidt Conference in Prague, 11-14 August.

Dr J.A MAVROGENES presented a talk at the ECROFI 2011 Conference held in Leoben Austria 8 – 11 August.

Mr L. WHITE, attended Goldschmidt 2011, Prague, Czech Republic, 14-19 August and presented a paper entitled: “Correlated Uranium Concentration, Radiation Damage and Increased SHRIMP U/Pb ages of Zircon.

Mr J. WYKES, attended the University of California Los Angeles from June 2010 to June 2011 as the 2009 Fulbright Postgraduate Scholar in Science and Engineering sponsored by BHP Billiton.

Mr J. WYKES, attended Goldschmidt 2011 Conference, Prague, Czech Republic, August 14-19, presented a paper entitled: “XANES investigation of selenium speciation in silicate glasses”.

Mr J. WYKES, attended 2011 Mineralogical Society of America Short Course: Sulfur in Magmas and Melts, Goslar, Germany, August 21-23.

Mr J. WYKES was the author of a paper entitled “Forsterite solubility in NaCl-H2O fluids at upper mantle P-T conditions” presented at the 2011 AGU Fall Meeting in San Francisco, USA, December 5-9.

Dr G.M. YAXLEY, Goldschmidt 2011, Prague, Czech Republic, 14-19 August, presented a paper entitled “Redox profile through the Siberian craton: Fe K-edge XANES determination of Fe^{3+}/Fe^{2+} in garnet from peridotite xenoliths of the Udachnaya kimberlite".

Dr G.M. YAXLEY, Biennial Conference of the SGGMP, Murramarang, Australia, 21-25 November, presented a poster entitled "Application of Fe K-Edge XANES Determinations of $Fe^{3+}/\sum Fe$ in Garnet to Peridotite Xenoliths from the Udachnaya Kimberlite".

Dr G.M.YAXLEY visited Profs Alan Woodland and Gerhard Brey at the Institut für Mineralogie, Universität Frankfurt during August.

Graduate Student YUNXING XUE was sponsored by the Society of Economic Geologists (SEG) to attend the SEG student fieldtrip to Chile to investigate the iron oxide copper gold deposits and gold-silver districts in Northern Chile.

Graduate student I. ZHUKOVA attended the Goldschmidt congress in Prague where she gave a talk entitled "Al diffusion in olivine: an experimental study".

Earth Physics

Dr N BALFOUR prepared a poster for IUGG entitled "A National Seismometers in Schools Project in Australia" and for AGU entitled "The Australian Seismometers in Schools Project: Building Relationships Between Scientists, Schools and Local Enthusiasts"

Dr N BALFOUR attended and presented an RSES update at the Australian Seismologists Meeting in Adelaide.

Dr N BALFOUR attended the Joint IEA - GIA / IPGT Induced Seismicity Working Group Meeting in Melbourne.

Self-Adaptive Tomography With the Reversible Jump Algorithm. Bodin, T., Sambridge, M. and Gallagher, K. (2010) /EGU/ General Assembly, Vienna , Austria.

A Hierarchical Bayes Formulation of Inverse Problems. Application to Joint Inversion of Receiver Function and Surface wave Dispersion. Bodin, T., Sambridge, M., Tkalcic, H., Gallagher, K. and Arroucau, P. (2010), AGU Fall Meeting, San Fransisco.

Mr C.C. CHAPMAN, the 18th Conference of the Australian Meteorological and Oceanographic Society (in conjunction with the Meteorological Society of New Zealand), Wellington, NZ, February, presented a paper entitled "Immersed Boundary Methods for the representation of coastlines in high-resolution numerical models of the Southern Ocean"; the American Meteorological Society's 18th Conference on Atmospheric and Oceanic Fluid Dynamics, Spokane, WA, USA, June, presented a paper entitled "Rapid Changes in Frontal Position in a simplified model of the Southern Ocean"; the International Union of Geodesy and Geophysics Conference, Melbourne, June-July, presented a paper entitled "Rapid Changes in Frontal Position in a simplified model of the Southern Ocean".

Prof P. CUMMINS, XXV IUGG General Assembly of the International Union of Geodesy and Geophysics presented three papers entitled “Earthquake and Tsunami Generation along the Margin of the Australian Plate: What does it tell us About Seismic Coupling and its variability”, “Improved Earthquake Hazard Assessment for Indonesia”, and “2011 Tohoku Earthquake: The Sensitivity of Tsunami Inundation to Differences in Rupture Models”
Prof P. CUMMINS, 10th Annual Meeting of the Asia-Oceania Geosciences Society presented a paper entitled “Toward Using W Phase and Near Field Earthquake Waveforms in Regional and Local Tsunami Warning”
Dr Neda DARBEHESHTI MXXVth IUGG General Assembly, Melbourne, Australia, 28 june-7 July 2011, presented a paper entitled “Tuning a gravimetric quasigeoid to GPS-levelling by non-stationary least-squares collocation N. Darbeheshti & W.E. Featherstone.”

Dr A.McC. HOGG, the American Meteorological Society’s 18th Conference on Atmospheric and Oceanic Fluid Dynamics, Spokane WA, June, presented a paper entitled “Sensitivity of the overturning circulation in the Southern Ocean to changes in wind forcing”; the International Union of Geodesy and Geophysics Conference, Melbourne, June-July, presented a paper entitled “Dynamics and transport of the Antarctic Circumpolar Current”; the 7th International Symposium on Stratified Flows, Rome, August, presented a paper entitled “Ocean Mixing Induced by Hydraulically Controlled Flow”; Japan Australia workshop on Polar Ocean Modelling, Tokyo, November, presented a paper entitled “What Controls the Global Ocean Stratification & Circulation in Eddy-permitting Models?”.

Dr G.O. HUGHES, the International Union of Geodesy and Geophysics Conference, Melbourne, June-July, presented a paper entitled “Mixing and energetics of the ocean overturning circulation”; the 7th International Symposium on Stratified Flows, Rome, August, presented a paper entitled “Horizontal convection from an energetics viewpoint”.

Prof B.L.N. KENNETT attended the General Assembly of the International Union of Geodesy and Geophysics in July where he gave a Plenary Lecture and an invited talk on Mantle tomography. In August he gave a talk on combining seismology and mineral physics at the Goldschmidt meeting in Prague, and then spent the next two months in Munich. At the beginning of September he gave a Plenary Lecture at the “Fragile Earth” meeting in Munich in September organised jointly by the Geological Societies of Germany and America, and a talk on the influence of structure in the subduction zone on the 2011 Offshore-Tohuku earthquake in Japan. Whilst in Munich he gave a seminar in the Munich GeoCentre series “frontiers of Earth Science” and also made short visits to Bayreuth and Copenhagen where he gave seminars. In December he gave an invited talk at the Fall Meeting of the American geophysical Union in the session on the Future of Structural Seismology.

Dr R.C. KERR, the International Union of Geodesy and Geophysics Conference, Melbourne, June-July, presented a paper entitled “The gravitational stability of mantle plumes”.

Dr S. MCCLUSKY, 2010 AGU Fall Meeting, San Francisco, Calif., 13-17 Dec, 2010,, presented an invited paper entitled, Assimilation of Heterogeneous Continuous and Episodic GNSS Observations for Board Scale Earth Science Studies, S. McClusky, R. Reilinger, T. Uzel, K. Eren, A. Dindar.

Dr S. MCCLUSKY, 2011 IUGG Meeting, Melbourne, Australia, June 28th – July 7th, 2011, presented an invited paper entitled, Great Earthquakes and the Stability of the Australian Plate: Implications for Terrestrial Reference Frame Definition, S. McClusky, P. Tregoning, C. Watson, R. Burgette, S. Lejeune.

Ms A.K. MORRISON, the American Meteorological Society's 18th Conference on Atmospheric and Oceanic Fluid Dynamics, Spokane WA, June, presented a paper entitled "Sensitivity of Southern Ocean Overturning to Buoyancy Forcing"; the International Union of Geodesy and Geophysics Conference, Melbourne, June-July, presented a poster entitled "Sensitivity of Southern Ocean Overturning to Buoyancy Forcing"; the American Geophysical Union Fall Annual Meeting, San Francisco, December, presented a paper "Sensitivity of Southern Ocean Overturning to Buoyancy Forcing".

Dr. A. PURCELL, at XXV IUGG General Assembly, Melbourne, Australia, 28 June - 7 July 2011, presented two papers. One entitled "Incorporating Lake-loading into Calculations of Post-Glacial Rebound and Sea-Level Change". And a second entitled "Deriving GIA-induced Uplift Rates from Observations of Gravitational Potential".

Dr N. RAWLINSON attended the EGU General Assembly in Vienna and presented a paper titled "Seismic imaging results from a transportable array experiment in southeast Australia"

Dr N. RAWLINSON attended the AGU Fall Meeting in San Francisco and presented a paper titled "New Results from WOMBAT: Seismic Attenuation Tomography in Southeast Australia"

Mr J.C. ROBERTSON, the International Union of Geodesy and Geophysics Conference, Melbourne, June-July, presented papers entitled "Isothermal kinetics of channeled viscoplastic lava flows" and "Effects of internal rheology on the dynamics of solidifying lava flows"; the American Geophysical Union Fall Annual Meeting, San Francisco, December, presented a paper "Channeled lava dynamics: implications for Hawaiian lava studies"; the Geological Society of NZ Conference, Nelson, December, presented a paper entitled "Channeled viscoplastic lava dynamics".

Dr M.L. RODERICK, American Geophysical Union Conference, San Francisco, USA, 5-9 December, convened a session titled "Evaporation and Water Transport Dynamics in the ABL".

Dr M.L. RODERICK, American Geophysical Union Conference, San Francisco, USA, 5-9 December, presented a paper titled "Drought or climate change? Distinguishing change from variability in observations and climate model projections of rainfall"

Dr M.L. RODERICK, American Geophysical Union Conference, San Francisco, USA, 5-9 December, presented a paper titled “Does past performance guarantee future skill of climate models? A new approach to an important problem”

Dr M.L. RODERICK, ANU Climate Change Institute, Canberra, 22 August, presented a paper titled “Introducing the ARC Centre of Excellence for Climate System Science”

Dr M.L. RODERICK, European Geosciences Union, Vienna, 3-8 April, presented the Dooge Memorial Lecture titled “Robust responses of the terrestrial component of the hydrological cycle to global warming”

Dr M.L. RODERICK, Max Planck Institute for Biogeochemistry, Jena, 14 April, presented the MPI Colloquium titled “Robust responses of the terrestrial component of the hydrological cycle to global warming”

Dr M.L. RODERICK, International Union of Geodesy and Geophysics, Melbourne, 1 July, presented the keynote address titled “Climate Variability versus Climate Change: How do you tell the difference”

Dr M.L. RODERICK, International Symposium on Environmental Changes and Efficient Use of Agricultural Resources, Chinese Academy of Sciences, Shijiazhuang, 20-22 October, presented the keynote address titled “Climate change, water availability and vegetation”

Dr M.L. RODERICK, Chinese Academy of Sciences, Urumqi, 28 October, presented the Academy Colloquium titled “Climate change, water availability and vegetation”

Ms I. ROSSO, the International Union of Geodesy and Geophysics Conference, Melbourne, June-July.

Dr J.A. SAENZ, the International Union of Geodesy and Geophysics Conference, Melbourne, June-July, presented a paper entitled “Mechanisms and rates of energy transfer affecting the global overturning circulation”.

M. SALMON and B. KENNETT. AuSREM – Australian Seismological Reference Earth Model, AGU 2011 S21B-2198

M. SALMON and B. KENNETT, AuSREM – Australian Seismological Reference Earth Model, IUGG Melbourne 28 June –7 July 2011

M. SALMON, B. KENNETT, E. SAYGIN, AuSREM - Australian Seismological Reference Earth Model, EGU Vienna April 4 – 9 2011

M. SALMON conducted fieldwork in Northern Queensland for the MINQ Seismic array September 2011.

Prof. M. SAMBRIDGE, attended and gave presentations at the IASPEI component of the International Union of Geodesy and Geophysics meeting in Melbourne, in June/July.

Dr. E. SaAYGIN, European Geosciences Union General Assembly 2011, Vienna, Austria, 03 – 08 April 2011, presented a paper entitled “The Crustal Structure of Australian Continent from Seismic Ambient Noise”.

Dr. E. SAYGIN, American Geophysical Union, Fall Meeting 2011, San Francisco, USA, 05-09 December 2011, presented a paper entitled “Crustal Structure of Australia from Ambient Seismic Noise Tomography”.

Dr E. Saygin conducted fieldwork in the Jakarta metro area from 20-30 September.

Mr K.D. STEWART, the Graduate School of Oceanography, University of Rhode Island, Narragansett, August, presented a paper entitled “The Effects of Topographic Sills and Mixing on the Global Ocean Density Structure”; the Scripps Institute of Oceanography, La Jolla, September, presented a paper entitled “The Effects of Topographic Sills and Mixing on the Global Ocean Density Structure”; the Johns Hopkins University, Baltimore, September, presented a paper entitled “The Effects of Topographic Sills and Mixing on the Global Ocean Density Structure”; the Geophysical Fluid Dynamics Laboratory, Princeton University, Princeton, September, presented a paper entitled “The Effects of Topographic Sills on the Global Ocean Density Structure”.

Dr H TKALČIĆ gave an invited talk entitled “The inner core of the Earth from a seismological perspective” at the Union session of the IUGG General Assembly in Melbourne, June 2011.

Dr H TKALČIĆ coauthored 5 presentations and gave a talk entitled “Shuffling rotation of the Earth’s inner core” in the special session on the terrestrial cores at the AGU Fall Meeting in San Francisco, December 2011.

Dr H TKALČIĆ gave a talk on “The new paradigm for imaging lithosphere using receiver functions from the hierarchical Bayes algorithm” at the EGU Meeting in Vienna, April 2011.

Dr H TKALČIĆ spent 5 weeks in Japan (Jan/Feb) working on the Earth’s core using Hi-net dense array.

Dr P. TREGONING, International Union of Geodesy and Geophysics conference, Melbourne, 28 June – 10 July, presented a paper entitled “Simultaneous inversion of GRACE, GPS and ocean bottom pressure observations”.

Dr P. TREGONING, International Union of Geodesy and Geophysics conference, Melbourne, 28 June – 10 July, co-authored a paper entitled “Deriving GIA-induced Uplift Rates from observations of Gravitational Potential”

Dr P. TREGONING, International Union of Geodesy and Geophysics conference, Melbourne, 28 June – 10 July, co-authored a paper entitled “Great Earthquakes and the Stability of the Australian Plate: Implications for Terrestrial Reference Frame Definition”

Dr P. TREGONING, International Union of Geodesy and Geophysics conference, Melbourne, 28 June – 10 July, co-authored a paper entitled “Draconitic Biases in GPS Versus GRACE Estimates of Hydrology”

M.K. YOUNG, attended the Fall American Geophysical Union Meeting, San Francisco, USA, 5-9 December, and presented a paper entitled “New P-wave Images of the Core Mantle Boundary Region from a Bayesian Inversion of PKP, PcP, and P4KP Differential Travel Times.”

M.K. YOUNG, attended the 25th International Union of Geodesy and Geophysics General Assembly, Melbourne, 28 June - 7 July, and presented two papers entitled “On the Differential Rotation of the Earth's Inner Core from Testing the Nature of Differences in Repetitive Seismic Waveforms” and “Group and Phase Velocity Variations in Tasmania from Ambient Seismic Noise.”

M.K. YOUNG conducted field work to deploy the EAL3 seismic array in New South Wales from 9-18 November.

Integrated Ocean Drilling Program (IODP)

Professor Neville Exon attended the Asian Marine Geology Conference in Goa, India, in October, and gave a paper on Australia’s role in scientific ocean drilling in the past.

Professor Exon is on the organising committees of two Symposia at the International Geological Congress to be held in Brisbane in August 2012: one deals with IODP and the other with marine minerals.

He initiated and is on the organising committee of a proposed Southwest Pacific IODP Workshop to be held at Sydney University in October 2012.

PRISE

Dr R.A. ARMSTRONG (funded by AusAid), 23rd Colloquium of African Geology, Johannesburg, 8-14 January, presented an invited paper entitled “Advances in *in situ* stable isotope studies using SHRIMP”.

Dr R.A. ARMSTRONG undertook field work in the Lobatse area, Botswana, 15-19 January.

Dr R.A. ARMSTRONG undertook field work in the Siep Riep area, Cambodia, 7-13 June as part of his ARC-funded research.

Mr C.M. FANNING conducted fieldwork in southern Victoria Land and the Transantarctic Mountains, Antarctica from 17 November 2010 to 12 January.

Mr C.M. FANNING conducted fieldwork in northern Chile from 24-30 October.

Visiting Fellows

Dr E.A. FELTON attended the Sapphire Coast Marine Discovery Centre's Marine Science Forum 'Food for Thought' at Eden on 26-27 March.

Dr E.A. FELTON co-authored "Overturned mega boulders on coastal cliff-tops and in bedrock river channels: can cosmogenic nuclides constrain tsunami and palaeo-flood events in Australia?" (D. Fink, T. Fujioka, C. Mifsud, G. Nanson, A. Felton, K. Crook, A. Switzer), presented at the 12th International AMS Conference, Wellington, New Zealand, March 2011.

Dr E.A. FELTON co-authored "Overturned mega boulders on coastal cliff-tops and in bedrock river channels: can cosmogenic nuclides constrain tsunami and palaeo-flood events in Australia?" (D. Fink, T. Fujioka, C. Mifsud, G. Nanson, A. Felton, K. Crook, A. Switzer), presented at the XVIII INQUA Congress, Berne, July 2011.

Dr W. Mayer. Baudin's naturalists in Australia: Early surveys of the fauna, flora and the geology of the country's coastal regions, 1801-1803. The Freycinet Map of 1811 - 200th Anniversary of the publication of the first map of Australia. Symposium held at The National Library of Australia, 19 June 2011.

Dr Scott:Assessment of aeolian dust properties in the Port Hedland area and implications for future air quality management strategies. Clean Air Society of Australia and New Zealand Conference. 31 July-2 August, Auckland.

Dr Scott: Siderite chemistry as an exploration guide to Proterozoic stratiform Pb-Zn-Ag mineralisation, Australia. 25th International Applied Geochemistry Symposium. 22-26 August, Rovaniemi, Finland.

Dr Scott: Detecting distal footprints of ore deposits under cover. 11th Biennial Society for Geology Applied to Mineral Deposits Meeting. 26-29 September, Antofagasta, Chile.

Dr D.L. STRUSZ took part in a meeting in Ludlow (UK) of the International Subcommittee on Silurian Stratigraphy, to examine the reliability of the previously chosen stratotype sections for Silurian Series and Stages.

Dr Truswell presented a paper entitled ' Thulia: a Tale of the Antarctic (1843) and its musical setting' to the conference 'Antarctica and Music' ANU, June 26 – 29th.-it deals inter alia with J.D.Dana, pioneer geologist in Australia.

Dr Truswell is presenting a paper ' Dredging up Mawson: implications for the geology of coastal East Antarctica' in the Mawson Symposium, Royal Society of Tasmania & Australian Antarctic Division. November 30/December 1. Hobart.

Dr Truswell presented an exhibition of drawings (jointly with R.E.Barwick) entitled 'Reflecting on Sullivans Creek' Foyer Gallery ANU, February 28 – March 12th.

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, PALAIOS, a Journal of the Society of Sedimentary Geology.
Dr M.A. FORSTER, Editor for the Journal of the Virtual Explorer.
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 L. MARTIN reviews publications for Lithos, The Journal of Metamorphic Geology and The Journal of Structural Geology.
Dr D. RUBATTO, Associated Editor, Lithos.
Dr D. RUBATTO, Editorial Board, Chemical Geology
Dr D. RUBATTO, Editorial Review Board, Journal of Metamorphic Geology.

Earth Environment

Dr N.J. ABRAM is Editor of the journal publication Climate of the Past.
Prof P. De DECKKER is on the editorial boards of Palaeoclimatology, Palaeoeceology, Palaeogeography, as well as Marine Micropalentology, and the Journal of Paleolimnology.
Dr S.M. EGGINS is on the Editorial Board of Quaternary Geochronology.
Dr. M.J. ELLWOOD is an Associate Editor for Marine and Freshwater Research.
Prof R. GRüN is Editor-in-Chief of Quaternary Geochronology, Associate Editor of the Journal of Archaeological and Anthropological Sciences, and a member of the Editorial Boardsof Quaternary Science Reviews and Radiation Measurements.
Dr B. Opdyke has completed a four-year term as Science Editor for the journal Geology.
Prof B.J. PILLANS is on the Editorial Board of Quaternary Science Reviews.

Earth Materials & Processes

Prof S F COX continued as a member of the Editorial Advisory Boards of *Journal of Structural Geology* and *Geofluids*.
Prof. I. JACKSON, Member Editorial Board, Physics of the Earth and Planetary Interiors, Earth and Planetary Science Letters.
Prof. G. LISTER is an Associate Editor for the *Journal of Geophysical Research, Solid Earth* and routinely reviews for several professional journals.
Prof. H. O'NEILL is on the Editorial Board, Chemical Geology

Earth Physics

Prof R.W. GRIFFITHS, Associate Editor, Journal of Fluid Mechanics, Cambridge University Press.
Dr G. IAFFALDANO, Associate editor of Annals of Geophysics
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 POZGAY acted as peer-reviewer of various scientific journal articles.
Dr N. RAWLINSON, member of Editorial Board, Tectonophysics
Dr. M.L. RODERICK, Associate Editor, Water Resources Research (American Geophysical Union).
Dr MONTILLET reviewed a couple of papers for the conference IEEE VTC (fall) 2011.
Dr P. TREGONING, Associate Editor, Journal of Geophysical Research (solid Earth).

PRISE

Dr R.A. ARMSTRONG, Editorial Board, Journal of African Earth Sciences.

IODP

Professor Neville Exon is involved in writing and editing various IODP documents, including the ANZIC Annual Report, reports relating to the Indian Ocean IODP Workshop, and the proposal for a Southwest Pacific IODP Workshop in Sydney in 2012.
Professor Richard Arculus was one of a small group of writers and editors who produced the IODP Science Plan for 2013-2023 – Illuminating Earth's Past, Present, and Future. This was published in mid-2011.

Visiting Fellows

Dr R.V.BURNE has reviewed papers for GEOLOGY and PNAS.
Dr E.A. FELTON reviewed papers for the journals Marine Geology, Geology, and International Journal of Earth Science.
Dr C. Klootwijk was Guest Editor Special Volume on Paleomagnetism and Rock Magnetism for the Australian Journal of Earth Sciences.
Dr Mayer has been appointed to the position of Editor of publications for INHIGEO (International Commission for the History of Geological Sciences), for
the period 1012-2016
KEITH SCOTT has continued on the Editorial Board for the Book "Shaping a nation: A geology of Australia" being produced for the 34th International Geological Congress (Brisbane).
He is also editing a special Australasian issue of Episodes (27 papers) to be published in March 2012.

OUTREACH AND WORKSHOPS

Earth Chemistry

Mr A. CHOPRA participated in a workshop on journal article writing for scientists organised by Research Student Development Centre, ANU on 24 August.
Mr A. CHOPRA participated in a workshop on media skills for researchers organised by the Communications and External Liaison Office at ANU on 6 September.
Mr A. CHOPRA's comments were featured in SBS and ABC TV news stories on the 2011 Nobel Prize for Physics awarded to Brian Schmidt et al. on 5 October.
Mr A. CHOPRA assisted with other RSES staff and students in organising hands-on astronomy and planetary science based activities at the 2011 National Science Week event hosted at CSIRO Discovery Centre on 13-21 August.
Mr A. CHOPRA assisted with other RSAA and RSES staff and students at the 2011 ANU Open Day on 28 August.
Mr A. CHOPRA assisted with demonstrations and observing with other RSAA staff and students at the 2011 Mt. Stromlo Open Day on 4 December.
Mr A. CHOPRA organised a premiere screening of the movie "First Orbit" and led a discussion session on space activities on the 50th Anniversary of man's first orbit in space at UniLodge ANU on 12 April.
Dr M.A. FORSTER was invited to give a lecture to Hasanuddin University, Sulawesi: Titled Tectonics and Geochronology: Dating Deformation. September 25th, 2011.
Dr M.A. FORSTER was invited to visit Bandung Institute of Technology, Java, Indonesia, by Prof. Suparka. 2nd October, 2011.
Dr M.A. FORSTER was invited to South East Research Group, Royal Holloway University of London by Prof. Hall, Dr Cottam and Dr Watkinson. 21st March till 28th March 2011.
Dr M.A. FORSTER attended a workshop given by Thermo Fisher Scientific. Workshop was on 'Imhotep Software Package' for the new noble gas mass spectrometers (based on the Argus VI), Bremen, Germany. 28th till 31st March 2011.
Dr M.A. FORSTER was invited to South East Research Group, Royal Holloway University of London to give workshop to the PhD students on 40Ar/39Ar geochronology and dating deformation.
Dr C.H. LINEWEAVER talked to National Youth Science Foundation elite Year 10 and 11 students selected from the best high school science students from around the country about his research, careers in astronomy and answered questions about astronomy/cosmology/astrobiology. 3:30- 4:30 pm, RSAA January 7, 2011 and January 21, 2011 4-5 pm, and January 24, 2011, 11am to 12 pm.
Dr C.H. LINEWEAVER participated in a panel discussion at Mt Stromlo with female Korean astronaut and Danial Bayliss about human space flight, the International Space Station, Mars and the colonization of space. January 27, 2011 6pm to 7:30 pm.
Dr C.H. LINEWEAVER gave a guest lecture on "Are We Alone?" to year 11

students at Gungahlin College hosted by Peter Smythe, 3-4 pm, Monday, February 28, 2011.
Dr C.H. LINEWEAVER was invited as a distinguished professor to give a series of 6 lectures at Bogazici University, Bebek/Istanbul, Turkey, April 29 to May 8, 2011, hosted by Prof Alpar Sevgen, Physics Department. The 6 lectures consisted of two research seminars, three undergraduate lectures and a public lecture: "Are We Alone?" May 3, 3-4pm .
Dr C.H. LINEWEAVER gave a short public lecture and participated in a panel discussion (with Prof Phil Diamond) at Questacon, Canberra on the Square Kilometer Array (SKA), 6:30 to 8:30 pm, Friday, May 20, 2011.
Dr C.H. LINEWEAVER gave a Science Week talk "Our Earth, Other Earths and the Universe", Finkel Auditorium, 6 pm to 7:30 pm, August 19, 2011.
Dr C.H. LINEWEAVER gave a guest lecture on "Are We Alone?" to year 11 students at Ginnindera College, organized by Sarah Taylor, 12-1pm, Friday, September 2, 2011.
Dr C.H. LINEWEAVER gave a lecture on Black Holes and Entropy, to Year 10 students at Melrose High School, organized by Geoff McNamara, 2-3pm, Tuesday, August 30, 2011.
Dr C.H. LINEWEAVER helped host a star-gazing night at Mt Stromlo for the Korean Ambassador and family, 7pm - 9pm, Saturday, September 3, 2011.
Dr C.H. LINEWEAVER gave an invited lecture to the Canberra Skeptics, "J'accuse: Aliens and Free Will, the gods of choice for atheists", 6-7:30 pm, CSIRO Discovery Theatre, Tuesday September 13, 2011.
Dr C.H. LINEWEAVER participated in a panel discussion recorded for Radio National about "Life, the Universe and Everything" at the Coonabarabran Festival of the Stars Open Day. Also performed on the guitar the song "Evolving a Life Form" at the Royal Hotel, Coonabarabran, NSW, 6:30 pm - 9pm, Saturday, October 15th.
Dr C.H. LINEWEAVER gave a Star-gazing talk at an ANU Law School Retreat at Kioloa, NSW, 10pm, Friday, March 11, 2011.
Dr C.H. LINEWEAVER gave a lecture "Intergalactic Diplomacy" to the ACT Diplomatic Corps, including several dozen ambassadors and ANU VC Ian Young, at Mt Stromlo, 6 pm, March 14th, 2011
Dr C.H. LINEWEAVER gave a lecture to the Canberra Astronomical Society at Mt Stromlo on "Increasing Complexity in the Universe?" hosted by Kim Rawlings, 8 pm, March 17, 2011.
Dr C.H. LINEWEAVER gave the keynote lecture "Is Who Alone?" at the Annual Queensland Astrofest, Duckadang, Queensland, 3-4 pm, Sunday, July 30, 2011
Dr C.H. LINEWEAVER gave a lecture "Does the Universe Contain an Infinite Number of Kevin Rudds?" at Burgmann College, ANU, 7-8:30 pm, Tuesday, August 9, 2011.
Dr C.H. LINEWEAVER gave the keynote lecture at the ANU PhB Student Research Conference on "My Life as a Graduate Student and the 2006 Physics Nobel Prize", 2:15 to 2:50 pm, Bambi Seminar Rm, Peter Baume Bldg. Wednesday, October 26, 2011.
Dr C.H. LINEWEAVER gave a Mt Stromlo Open Day lecture "Are We Alone?" Duffield Lecture Theatre, 2:30 - 3:30 pm, Mt Stromlo Observatory, Canberra, Sunday, December 4, 2011.
Dr C.H. LINEWEAVER provided topical interviews for television science

programs including “Catalyst” and ABC News, 6 times in 2011.
Dr C.H. LINEWEAVER was interviewed on a wide range of science topics for radio programs 11 times in 2011.
Mrs K. STRZEPEK has spoken about her activities at the University’s welcome to summer scholars for three years running (Nov 2009, 2010, 2011). She has also spoken at the Universities Open Day on a panel of Graduate Students. She has also spoken about her experiences at Melba Copland High School, St Francis Xavier High School and to students visiting from Rossmoyne High School. She is also founder of the RSES Blog “Oncirculation” that will go live at the end of December.
Dr I.S. WILLIAMS hosted a visit to the SHRIMP laboratory by students attending the National Youth Science Forum, 15th and 27th January.
Dr I.S. WILLIAMS helped to organise the April visit to RSES by the Jaeger-Hales lecturer, Prof. Hugh P. Taylor Jr, and arranged a 2-day Workshop on Stable Isotopes, at which Prof. Taylor was guest speaker. He also arranged a 3-day field trip for the workshop participants.
Dr I.S. WILLIAMS assisted in providing advice to prospective students at the ANU Open Day, 27th August.

Earth Environment

Dr N.J. ABRAM was featured in the video reflections collection for the “Scott’s Last Expedition” exhibition, prepared by the Natural History Museum and touring Sydney-London-Christchurch in 2011-2012. She was profiled for “How does she do it?” article, The Times newspaper, London UK, and featured in the BBC television series “Men of Rock”, interviewed by Dr Iain Stewart. She also featured in a profile article about the British Antarctic Survey in the Cambridge News newspaper.
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 B. Opdyke is part of a monthly radio show that discusses environmental issues on local radio 2XX.
Prof B.J. PILLANS is Chair of the Steering Committee of the National Rock Garden Trust.

Earth Materials & Processes

Prof R. ARCULUS Alteration Haloes (Science-Art exhibition, results of a research voyage, CSIRO Discovery Centre); interview Classic FM (Margaret Throsby); numerous interviews on radio & TV re Chilean Volcano; lectures at Australian National Botanic Gardens & U3A.
Prof S.F. COX provided a 2-day workshop on “Structural Processes and Controls on the Formation of Lode Gold Systems” to Goldfields Ltd geoscientists at Kalgoorlie in July. He also provided a half day of lectures to Goldfields geoscientists in Perth.
In September, Prof COX provided a 3-day workshop on “Structure, permeability and fluid flow at depth in the Earth’s crust” to a group of 35 graduate students and post-doctoral fellows, from various universities across Europe, as part of his outside studies program visit to RWTH-Aachen University in Germany.

Prof. G. LISTER has run industry workshops as part of the 4D porphyry project.
Prof. G. LISTER lectured at SEARG RHUL on “Closing Tethys”.
Dr J.A MAVROGENES was part of a College of Science Outreach Tour of Central Victoria.
Dr J. A MAVROGENES presented talks to three groups of visiting students and visited two local schools.
Miss S. McALPINE participated in the Scientists in Schools initiative, with weekly in class visits to Yr 8 Science, Amaroo School, ACT.
Mr L. WHITE was interviewed by ABC radio about the plate boundary between India and Eurasia. Approximately 10 minute interview with Louise Maher, ABC 666 radio, broadcast at 3:15 pm 2 November.
Dr G.M. YAXLEY was involved in organisation of the biennial conference of the Specialist Group in Geochemistry, Mineralogy and Petrology of the Geological Society of Australia, held at Murramarang Resort in late November.
Dr G.M. YAXLEY was lead convenor of a session at the IUGG 2011 conference held in Melbourne in June-July.
Dr G.M. YAXLEY undertook fieldwork on Norfolk Island in May, with members of the Petrochemistry and Experimental Petrology Group.
Dr G.M. YAXLEY coordinated two visits to RSES from Year 11-12 students participating in the National Youth Science Summer School in January.

Earth Physics

Dr N BALFOUR had an interview with the Canberra Times (17/9/2011) regarding seismometers recording explosions from the Mitchell fire. Story quoted in was entitled “Inner north residents told to stay indoors after late wind change”.
Dr N BALFOUR had a radio interview with ABC 666 (16/9/2011) discussing seismometers in schools and how the instruments recorded explosions from the Mitchell fire.
Dr N BALFOUR wrote an article for the AEES newsletter (#3 August 2011) on the Australian Seismometers in Schools program.
Dr. N. BALFOUR and Prof. M. Sambridge began a new outreach project Australian Seismometers in schools. A four year program to put 40 seismometers in Australian high schools across the nation. The project is a collaboration with Macquarie Univ. and is part of the education component of the AuScope-AGOS program funded by the Federal Government through the Education Investment Fund (EIF3).
Mr C.C. CHAPMAN presented at the ANU Climate Change Institute expo, August.
Prof P. CUMMINS, 2011 Asia Antelope users Group Meeting, delivered invited paper entitled “Australian Science Applications Using Antelope”.
Prof. P. CUMMINS delivered a public lecture entitled lecture on great earthquakes at the U. Melbourne Panel Discussion “What’s up with all These Earthquakes”.
Prof. Phil R. CUMMINS delivered a lecture entitled “Lessons from Recent Tsunamigenic Earthquakes Worldwide” at the Australia–Indonesia Environmental Science Workshop, organised by the Australian Academy of Sciences.

Dr Neda DARBEHESHTI GRACE Workshop at ANU Kioloa Coastal Campus - 15 to 17 November 2011, presented a paper entitled “Improving the spatial resolution of GRACE Results”

Members of the Geophysical Fluid Dynamics Group presented tours of the GFD Laboratory and fluid flow demonstrations during visits of high school and undergraduate students, the interested public during National Science Week, and the National Youth Science Forum.

Dr. A.McC. HOGG, Dr. M.L. WARD and Dr. J.A. SAENZ participated in the planning workshop for the ARC Center of Excellence in Climate System Sciences, Robertson, September.

Dr G. IAFFALDANO had a radio interview with SBS (Broadcasting in Italian)

Dr G. IAFFALDANO had a radio interview with Robyn Williams (The science show on ABC)

Dr G. IAFFALDANO had two feature articles on The Australian Geographic

Dr G. IAFFALDANO had several clips originated by two media releases.

Prof B.L.N. KENNETT gave a number of radio interviews on issues related to earthquakes and tsunamis.

Dr S. MCCLUSKY was interviewed live on ABC 891 morning’s radio on March 15th 2011 at 11:40 am. The interview lasting 15 minutes was about crustal deformation resulting from the March 11th 2010 Tohoku great earthquake.

Dr. MONTILLET and its co-author published a conference paper in IEEE VTC 2011 (Poster Presentation).

Ms A.K. MORRISON participated as a fellow at the Geophysical Fluid Dynamics Summer Program, Woods Hole Oceanographic Institute, June – August.

Dr POZGAY was featured in Canberra’s CityNews and Melbourne’s The Age, both featuring the Master of Natural Hazards & Disasters program. She was active in outreach and student recruitment with both CAP and CPMS teams.

Dr N. RAWLINSON was interviewed on ABC 666 on November 1 2011 at 4.20pm on the subject of a successful ARC LIEF grant. He was also interviewed on the same subject for an article that appeared in the Canberra Times the following day.

Dr M.L. RODERICK and Dr A.M. HOGG organised the annual workshop of the ARC Centre of Excellence for Climate System Science, Robertson, NSW, 27-30 September.

Dr M. SALMON helped with the Research School of Earth Sciences booth at University open day

Dr M. SaALMON helped organise the RSES demonstrations at the National Science Week at CSIRO

Dr M. SALMON gave talks and tours to National Youth Science Forum students and high school students visiting RSES

Prof. M. SAMBRIDGE attended a workshop on uncertainty analysis in geophysical inverse problems in Leiden, The Netherlands in Nov.

Prof. M. SAMBRIDGE attended a NICTA workshop on Machine learning approaches to Geothermal exploration and characterization, in Sydney in September.

Dr H TKALČIĆ gave a series of invited seminar talks at the University of Tokyo, University of Kyoto, Tohoku University, University of Hokkaido,

JAMSTEC and Disaster Prevention Research Institute in Kyoto, on the Earth's core and the 100th anniversary of the discovery of Moho.
Dr H TKALČIĆ gave a seminar talk at the University of Zagreb, Faculty of Science, on Benford's Law in geosciences.
Dr H TKALČIĆ was interviewed by the Croatian National Radio-Television on the core research and on the Benford's Law.
Dr P. TREGONING was interviewed on radio about technical aspects of the GPS system. Approximately 8 minute interview with Genevieve Jacobs on ABC666, 28 February.
Dr P. TREGONING was interviewed for online article about the 2011 Japan earthquake, The Conversation, 16 June.
Dr P. TREGONING was interviewed for newspaper article about joining the Science Team of the NASA GRACE mission. Canberra Times, 17 September.
Dr P. TREGONING was interviewed for newspaper article about the Australian Space Research Program. The Australian Financial Review, 31 October.
Dr P. TREGONING was invited to present information on the GRACE Follow On mission at the CSIRO Tweetup event. Tidbinbilla Deep Space Network tracking station, 25 November.
Dr P. TREGONING was invited to talk about climate change to Year 11 students at Canberra Grammar School as part of the "Australian Studies" course.
M.K. YOUNG volunteered at this year's Experimentathon/Family Science Spectacular, held at the Discovery Centre, CSIRO, from the 12th to 14th of August in honour of National Science Week.

Integrated Ocean Drilling Program (IODP)

ANZIC partnered India in setting up a very successful Indian Ocean IODP Workshop, held in Goa, India, in October 2011. Professor Neville Exon (RSES) instigated the Workshop and he and Professor Stephen Gallagher (University of Melbourne) were part of the three-man organising committee. The workshop drew funding from AIO, IODP-MI, Ocean Leadership (US), and individual member countries. Ten Australians, including Professor Exon and Professor Richard Arculus from RSES, and one New Zealander were funded to attend by AIO.
Professor Exon gave a paper, and is an author of forthcoming Indian Ocean workshop reports for *EOS*, *Scientific Drilling* and the IODP website. He is also on the organising committee of a proposed Southwest Pacific IODP Workshop to be held at Sydney University in October 2012.

Visiting Fellows

Dr E.A. FELTON serves on the Board of the Sapphire Coast Marine Discovery Centre, Eden, NSW, a marine education and research organisation. She is executive officer to the Centre's Research Advisory Group. She also conducts educational beach geology walks for the general public, and is a volunteer guide in the Discovery Centre.
Dr E.A. FELTON prepared and presented a display for the Sapphire Coast Marine Discovery Centre illustrating and explaining the effects of the Tohoku, Japan, tsunami in Twofold Bay, Eden NSW.

Dr E.A. FELTON gave a presentation about tsunami in SE Australia at Merimbula Probus Club.
Dr Truswell presented a talk “Antarctica, Glossopteris and a Sexual Revolution” on Robyn Williams’ ABC Radio National Program Ockams Razor, broadcast at 8.45am on March 6th. Above talk presented to Australian Botanic Gardens 17th March. Talk ‘Writing a life in Science’ Independent Scholars Association, National Library of Australia 9th February. Talk ‘All at sea in search of the forests’ National Library of Australia 16th August. Workshop, Geoscience Australia – Antarctic margin data, November 8th. Instigated with Dr P.T.Harris.

TEACHING ACTIVITIES

Earth Chemistry

Dr Y. AMELIN gave two lectures in the course PHYS8205 “Nuclear Fuel Cycle”.
Dr J.J. BROCKS taught the ‘Carbon Cycle’ as part of the ‘Global Cycles’ course EMSC3027.
Mr A. CHOPRA presented a guest lecture to ~20 Year 8 Science class students at Melrose High School in Canberra, ACT on life in extreme environments on 20 October.
Mr A. CHOPRA presented a guest lecture to ~20 Year 12 Science class students at Trinity College in Perth, WA on life in extreme environments on 1 July.
Mr A. CHOPRA presented a guest lecture to ~60 Year 12 Science class students at Methodist Ladies College in Perth, WA on life in extreme environments in particular hydrothermal vents in the deep sea on 1 July.
Mr A. CHOPRA presented a guest lecture to ~20 Year 8 Science Extension class students at Rossmoyne Senior High School in Perth, WA on life in extreme environments on 1 July.
Mr A. CHOPRA presented a guest lecture to ~30 Year 12 Human Biology class students at Rossmoyne Senior High School in Perth, WA on astrobiology topics on 1 July.
Mr A. CHOPRA presented a guest lecture to ~60 Year 10 Science Discovery class at Rossmoyne Senior High School students in Perth, WA on life at hydrothermal vents and recent research voyages on 1 July.
Mr A. CHOPRA presented an invited “Future Focus” seminar to ~100 Year 11-12 students at Rossmoyne Senior High School students in Perth, WA. During this seminar I shared my experiences during my high school and undergraduate life.
Mr A. CHOPRA presented a talk to summer scholars at the Research School of Astronomy and Astrophysics, ANU on the topic “Questions in Astrobiology” on 19 January.
Dr M.A. FORSTER co-taught 3rd year subject EMSC 3024 Magmatism & Metamorphism (with Dr J. Hermann - the practical sessions and several lectures).
Ms B. FRASL was teaching assistant for the undergraduate course Chemistry of the Earth and Ocean (EMSC2015).

Ms A. F. KOMUGABE tutored and demonstrated the Blue Planet (EMSC1006) in second semester.
Dr C.H. LINEWEAVER team-taught with Prof T. Ireland, the EMSC 3022, Planetary Science Course, Feb-July, 2011.
Dr C.H. LINEWEAVER was invited as a distinguished professor to give a series of 6 lectures at Bogazici University, Bebek/Istanbul, Turkey, April 29 to May 8, 2011, hosted by Prof Alpar Sevgen, Physics Department. Two lectures were research seminars to colleagues (listed under seminars). Three lectures were to undergraduates: May 2, 9 am - 10 am "Cosmology" May 2, 2-3pm "Life, Gravity and the Second Law of Thermodynamics" May 4, 9-10 am "Darwinism and Astrobiology".
Dr L. MARTIN co-supervised Eleanor Peterson (B. Sc student) during December 2010 (Chemical characterisation of garnet-bearing rocks from Broken Hill, co-supervisor: Oliver Nebel).
Dr D. RUBATTO coordinated and co-taught the second semester course EMSC2015 "Chemistry of Planet Earth"
Dr D. RUBATTO was a tutor at the third year field course EMSC3001.
Dr I.S. WILLIAMS gave 10 undergraduate lectures on isotope geochemistry in October-November as part of the EMSC2015 course on the geochemistry of the Earth.
Dr I.S. WILLIAMS assisted with the March undergraduate field excursion to the Kosciuszko region.
Dr I.S. WILLIAMS led a sampling trip to the south coast in December for undergraduates working with him on special research topics related to Permian palaeoclimate.
Dr I.S. WILLIAMS was an invited lecturer at the induction of ANU higher degree students in September.

Earth Environment

Prof P. De DECKKER taught the course Marine Palaeontology and Evolution of Life on Earth (EMSC2019), coordinated and contributed to more than half the teaching and assessment of the course entitled Resources & Environment (EMSC2016).
Dr S.M. EGGINS, with Dr M.J. ELLWOOD, taught an Honours level short-course on Quantitative Analysis in Research.
Dr S.M. EGGINS taught modules on Origin of Earth, Introductory Global Cycles and Field Studies in the first year course Blue Planet (EMSC 1006), and supervised third year '3 Special Topics' courses, two in Earth and Marine Science and one in Chemistry.
Dr M.J. ELLWOOD and Dr S.M. EGGINS taught the six-unit third year course Global Cycles II – the modern Ocean (EMSC 3023).
Dr M.J. ELLWOOD coordinated and taught in the first year course The Blue Planet (EMSC1006), and taught in the second year course Analytical Chemistry (CHEM2207).
Dr M.K. GAGAN co-convened Chemistry of the Earth and Oceans (EMSC2015) and delivered 15 lectures, 5 practicals, and examined the course.
Prof R. GRÜN taught the School of Archaeology and Anthropology six-unit course Scientific Dating Techniques and Isotope Analysis for Archaeology and Palaeoanthropology (BIAN 3010/6510).

Dr D.C. McPhail co-convened and taught 50% of Environmental Chemistry (CHEM2204), a joint second year course with RSC and RSES, and convened and taught the Groundwater course (EMSC3025).
Dr D.C. McPhail coordinated with Prof. Brad Pillans the Minerals Tertiary Education Council Honours course, Regolith Geoscience and Mineral Exploration, held in April 2011.
Mr S. Meyerink worked as a demonstrator during The Blue Planet (EMSC1006) first year course taught by Dr M.J. Ellwood, and assisted with assessments.
Mr G.J. Nash demonstrated for Prof P. De Deckker and assisted with field studies for the second year Palaeontology course (EMSC2019), and presented a guest presentation on methane seeps off the Costa Rica Margin for Dr P. Blackwell's RSBS second year marine biology course.
Dr B. Opdyke taught the Surficial Processes (EMSC2014) course, and conducted the field portion of the second year Structural and Field Geology course (EMSC2012).
Dr B. Opdyke convened and taught half of the third year Global Cycles course (EMSC3027), and taught the third year Coral Reefs (EMSC3019) course.
Mr R.J. Owens was a teaching assistant for Sedimentology and Stratigraphy (EMSC2014) convened by Dr B. Opdyke, and was a personal tutor to Mr R. Williams through the Indigenous Tutorial Assistance Scheme (ITAS) for the Sedimentology and Stratigraphy course (EMSC2014).
Prof B. PILLANS gave nine lectures in the Environmental and Regolith Geoscience (EMSC2016) second year undergraduate course.
Ms J. Roberts tutored for the Water Resources Management course (combined third year and postgraduate class), assisting Dr Sara Beavis.
Mr N. SCROXTON demonstrated on the second year Mapping field course in Taemas (EMSC2012).
Miss C. THOMPSON worked with Summer Scholar Miss A. Robinson (Lincoln University, New Zealand) and RSES intern Mrs M. Samanta on copper toxicity to blue-green algal blooms in Lake Burley Griffin, ACT.

Earth Materials & Processes

Prof R. ARCULUS taught EMSC2020 Lithosphere (50%); EMSC3024 Magmatism and Metamorphism (50%)
Prof S F 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 the ENVS1004 Australia's Environment course.
Mr B.J. HANGER demonstrated laboratory classes and a field trip to Eden, NSW for the course EMSC1006: The Blue Planet.
Prof I. JACKSON coordinated and co-taught EMSC8011 Introduction to Earth Materials (with Prof. H. O'NEILL) and co-taught PHYS3070 Physics of the Earth (with Dr. H. TKALCIC), and supervised the 4th-year engineering project of M. OLIN and two Ph. B. projects of R. SKELTON.
Prof. G. LISTER assisted Prof. S. COX in his third year structural geology course.
Prof. G. LISTER is the Chair of Panel for four PhD candidates, and supervised and co-supervised a total of five PhD candidates: Lloyd White,

Clemens Augenstein, Iona Stenhouse, Jia-Urnn Lee and Tomas O'Kane.
Dr J.A MAVROGENES taught half of Australia's Environment (ENVS1004) and Economic Geology (EMSC 3007).
Dr O. NEBEL taught courses in volcanic hazards (Natural Hazard and Disaster Management)
Prof. H. O'NEILL gave part of the second year course Chemistry of the Earth and Oceans (EMSC 2015).
Mr P. STENHOUSE assisted on several undergraduate fieldtrips.
Miss D. TANNER tutored the 3rd year course Economic Geology (EMSC 3007) and presented one lecture.
Miss D. TANNER tutored the 1st year field course Earth Science in the Field (EMSC 1007).

Earth Physics

Prof P. CUMMINS delivered lectures in tsunami science in Geological Hazards (EMSC8707) and in Understanding Natural Hazards (EMSC8706).
Drs G.O. HUGHES, A.McC. HOGG and R.C. KERR, and Prof R.W. GRIFFITHS taught Physics of Fluid Flows (PHYS3034) and Current Topics in Geophysical Fluid Dynamics (EMSC8004).
Prof R.W. GRIFFITHS, Dr G.O. HUGHES and Dr A.McC. HOGG taught Special Topics course (EMSC3050).
Dr A.McC. HOGG contributed lectures and laboratories to The Blue Planet (EMSC1006). Dr HUGHES supervised an add-on research project in EMSC1006.
Dr A.McC. HOGG supervised an Advanced Studies Course.
Dr G. IAFFALDANO taught and convened EMSC8016
Dr G. IAFFALDANO was a guest lecturer in PHYS3070
Prof B.L.N. KENNETT – a number of students took the on-line course EMSC8015 "Imaging the Earth".
Dr POZGAY taught two Master level classes, Introduction to Natural Hazards and Understanding Geological Hazards; co-supervised eight Master student research projects; convened the Master of Natural Hazards & Disasters program; and supervised an undergraduate Special Topic student.
Dr N. RAWLINSON was Physics of the Earth Honours Convener for 2011
Dr N. RAWLINSON delivered EMSC8002 (Seismology) as a reading course in Semester 1 and Semester 2.
Dr M.L. RODERICK convened the Bachelor of Global and Ocean Science (Hons) degree program.
Dr M.L. RODERICK taught part of the third year course, Global Cycles and Paleooceanography (EMSC3027) - {A contribution to a course taught by Brad Opdyke}
Prof. M. SAMBRIDGE gave a guest lecture in the 3rd year undergraduate course (PHYS3070) 'Physics of the Earth'.
Dr. E. SAYGIN taught the geophysics part of Introduction to Earth Science in the Field (EMSC 1007).
Dr P. TREGONING taught the Master of Science course "Polar melting, climate change and sea level rise" (EMSC8009) and convened the MSc (specialising in Earth Physics) masters program.
Dr P. TREGONING supervised the Special Topics research project of Puvanesavari Rajan on the analysis of GRACE data.

Dr H TKALČIĆ coordinated and taught an undergraduate course “Physics of the Earth” with Prof I Jackson (PHYS 3070).
M.K. YOUNG was a student demonstrator for the Physics of the Earth Honours PHYS3070 course.

Visiting Fellows

KEITH SCOTT led the Minerals Tertiary Education Council-sponsored “Regolith Geoscience and Mineral Exploration” Honours course (April 2011).

HONOURS AND MASTERS SUPERVISION

Earth Chemistry

Dr J.J. BROCKS supervised the honours project of Ms Marita Smith on “Australasian Sea Surface Temperatures over the past millennium”.
Dr M.A. FORSTER supervised the honours project of Mr Oleg Koudashev: Titled ‘Microstructurally Focused Argon Geochronology on Two Classic High Pressure Terranes’.
Dr C.H. LINEWEAVER supervised RSAA Physics Honours Student Tim Bovaird “The Statistical Exploration of Exoplanets" Feb - Nov 2011.
Dr C.H. LINEWEAVER supervised physics undergraduate Callum Waugh on a 3rd year research project: Terraforming Mars, First Semester 2010.
Dr C.H. LINEWEAVER supervised 3rd year physics PhD student Kaitlin Cook on an Advanced Study Course research project “Investigating the Elementary Composition of the Earth, Comets and Jupiter” completed July 2, 2010.
Dr C.H. LINEWEAVER began supervising Honours student Lucie James, in astrobiology research.
Dr D. RUBATTO supervised the honours project of Mr Luke Hogan on the continental margin of the Sesia Zone (Western Alps).
Dr I.S. WILLIAMS helped supervise Ms E. O'Shea in oxygen isotope micro-analysis as part of her honours project on the growth of corals.

Earth Environment

Dr N.J. ABRAM supervised the Natural Hazards Masters research project of Mr B. Plunkett on the optimum region of Indian Ocean Dipole activity.
Prof P. De DECKKER supervised two Honours students, Ms L. Dean on her project on the microfauna and sediments of Two Fold Bay, Eden, NSW, and Ms M. Smith (co-supervised with Dr J.J. Brocks) on her project on 300 years of sea-surface temperatures in the Tasman Sea.
Dr S.M. EGGINS supervised the Honours projects of Ms K. Holland on the ‘Mg Isotope fractionation in planktic foraminifer *Orbulina universa*’ and Ms E. O’Shea on ‘Carbon sources in the scleractinian coral*Acropora pulchra*’. Dr S.M. EGGINS also supervised the mid-year start Honours projects of Ms R. Dargill on the ‘Temperature and inorganic carbon system controls on U incorporation in scleractinian corals’ and Mr C. Rouen on ‘Temperature and inorganic carbon system controls on B incorporation in scleractinian corals’. In addition, Dr S.M. EGGINS and Dr M.J. ELLWOOD co-supervised the mid-year start Honours project of Ms R. Dargill on the ‘Development and

Application of a UV-Vis system for automated analysis of seawater *p*H'.
Dr M.J. ELLWOOD supervised the Honours project of Mr J. Rousseau.
Prof R. GRÜN supervised School of Archaeology and Anthropology Honours student Ms C. Boel, who won the annual prize for best Honours thesis in 2011 in the School of Archaeology and Anthropology.
Dr D.C. McPhail supervised the Honours project of Mr. J. Carr on the Hydrogeochemistry of groundwater in the Coleambally region of New South Wales, and co-supervised with Dr. Éva Papp the Honours project of Ms L. Burraston on the Hydrogeophysics of groundwater in the Lower Murrumbidgee catchment, NSW.
Dr B. Opdyke supervised the Honours project of Jen Deng Lee on the Seismic Stratigraphy of the offshore northern Perth Basin.

Earth Materials & Processes

Prof. R. ARCULUS supervised projects of Matt Valetich
Prof S.F. COX supervised the projects of Lisa Howat and Leigh Gibson.
Dr J. MAVROGENES supervised the honours projects of Mr J Bennett on the effect of Ni and C on sulfur solubility in mafic melts and A Murray on the Geology of the Wallaby Deposit, W.A.
Dr G.M. YAXLEY supervised a Special Topics student (Clare Connolly) who performed an experimental investigation of Ni-in-garnet thermometry.

Earth Physics

Dr P. CUMMINS supervised the Masters research of Mr. Amalfi Omang, Mr. Ariska Rudyanto and Mr. Indra Gunawan.
Dr P. CUMMINS supervised the PhD research of Mr.Jakir Hossen.
Prof R.W. GRIFFITHS and Dr G.O HUGHES supervised the Honours thesis project of Ms. X. QIN on the effects of bottom slope on turbulent mixing efficiency in dense currents.
Dr A.McC. HOGG supervised the Honours thesis project of Mr C. SHAKESPEARE on a conceptual model of the ocean overturning circulation.
Prof. M. SAMBRIDGE co-supervised along with Prof. P. Cummins (RSES) and Prof. S. Roberts (MSI) honours student Ms Micaela Hartley on a project on multi-pathing in heterogeneous seismic media.
Dr H TKALČIĆ supervised the PhB project of Richard Skelton on "Heterogeneities in the deep mantle using body waves".
Dr H TKALČIĆ supervised the PhB project of HongAn Le on "Using spectrograms for determination of onset times of seismic signals".
Dr H TKALČIĆ supervised the internship project of Aleksandra Denisenko on "Regional time-domain moment tensor inversion".
Dr H TKALČIĆ supervised the internship project of Caroline Bartlett on "Using PcP-P and ScS-S differential travel times to determine the nature of deep mantle heterogeneities".
Dr H TKALČIĆ supervised the summer internship project of Don McKinnon on "Using normal modes to determine splitting functions sensitive to the Earth's core".
Dr P. TREGONING supervised the honours project of Miss Sarah Christmas on the 2000 New Ireland earthquake, Papua New Guinea.

Visiting Fellows

Dr C Klootwijk was examiner for the Honours Thesis of Stephanie Doos “A Geophysical and Hydrogeological Approach to Delineating the Great Chesney Fault, Cobar, NSW”.
Dr Truswell served as Ph.D. thesis advisor to Natalie Sinclair (submitted April 29th) Honours Examiner Jeng Den Lee 1/2nd November. Advisor (informal) Ph.D student Luna Brentagani (ongoing).

OTHER MATTERS

Earth Chemistry

Dr Y. AMELIN, oversaw installation and acceptance of Triton Plus and developed procedures for using this instrument. Explored in detail the performance of the multiple ion counter detector array of Triton Plus.
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 is on the Program Committee and is an organizer of the Early Earth theme and is a session chair for the 2012 International Geological Congress to be held in Brisbane, Australia
Dr V.C. BENNETT is on the Board of Directors of the Geochemical Society.
Dr V.C. BENNETT is the Chair of the 2012 Goldschmidt Medal selection committee, Geochemical Society.
Dr V.C. BENNETT is a member of the Kuno Award Committee of the American Geophysical Union.
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 2011 volume of the ANU Undergraduate Research Journal and served on the editor selection panel.
Mr A. CHOPRA participated in the research cruise, to study submarine volcanoes on the Kermadec Arc, off the coast of New Zealand (on-board RV Tangaroa, 23 February – 21 March, GNS expedition TAN1104).
Mr A. CHOPRA assisted in set-up a Chemical Inventory System at the Research School of Earth Sciences.
Mr A. CHOPRA, student representative on the OH&S Committee at RSES, ANU (since June 2011).
Mr A. CHOPRA, co-administrator for the Stromlo Student Wiki.
Mr A. CHOPRA, organiser for the Planetary Science Institute Seminars at ANU.
Mr A. CHOPRA, co-organiser of the 2011 RSES Student Conference at ANU on 22 September.
Mr A. CHOPRA, local organising committee for the 2011 Australian Space Science Conference at ANU on 28 September.

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.
Mr A. CHOPRA continues to lead the EARTHRISE (Education and Research through Interesting Space Experiments) program at ANU involving low cost balloon borne near-space experiments such as high-altitude photography and atmospheric profiling. The proposal was awarded a $1600 seed grant by the Directors at RSES and the Research School of Astronomy and Astrophysics, ANU for a demonstration flight. The program offers graduate and undergraduate students project management, teaching and scientific research opportunities.
Dr M.A. FORSTER is the Chair of the RSES, OH&S Committee.
Dr M.A. FORSTER setting up the RSES ANU node of the new joint Argon Facility for 40Ar/39Ar geochronology.
Ms B. FRASL, Member, ACT Division Committee, Geological Society of Australia.
Ms M. HUYSKENS organizes weekly Earth Chemistry group meetings and seminars.
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 C.H. LINEWEAVER is a member of the Local Organizing Committee of the Meteorological Society Meeting, Cairns, August 12-17, 2012.
Dr C.H. LINEWEAVER is on the organizing committee of the Planetary Science theme at the 34th International Geological Congress, Brisbane, August 5-12, 2012.
Dr C.H. LINEWEAVER conceived and planned, as part of the Scientific Organizing Committee with Prof Roderick Dewar (RSBS, ANU) and Prof Robert Niven (ADFA) an international conference on the Maximum Entropy Production Principle, at the Research School of Biology, ANU, September 12-14, 2011. See webpage at http://biology.anu.edu.au/ps/MEP/
Dr D. RUBATTO, treasurer of the Specialist Group in Geochemistry, Petrology and Mineralogy, Geological Society of Australia.
Dr D. RUBATTO, organizing committee of the Biennial Conference of the Specialist Group in Geochemistry, Petrology and Mineralogy, Geological Society of Australia.

Earth Environment

Dr N.J. ABRAM consulted for the working group 1 palaeoclimate chapter of the IPCC 5th assessment report, and is an invited participant of the PAGES sea ice proxy working group.
Prof P. De DECKKER is the President of the Scientific Steering Committee of the Grand Observatoire du Pacifique Sud. He is also a member of the Lakes Advisory Committee for the Corangamite Shire Council in western Victoria.
Dr S.M. EGGINS serves as a member the Board of the Climate Change Institute, The Australian National University. He serves as a member of the Research Advisory Group, South Marine Discovery Centre.
Dr M.J. ELLWOOD supervised Summer Scholar Ms A. ROBINSON (Lincoln

University, New Zealand). He supervised Masters student, Mrs M. Samanta, and PhD students, Miss C. Thompson and Mr S. Meyerink.
Dr M.K. GAGAN served on the Science Advisory Board for the Earth Observatory of Singapore, Nanyang Technological University, and attended the 3rd annual Board meeting held in February at NTU. He served on the ANZIC Science Steering Committee for the Australian Integrated Ocean Drilling Program (IODP). He 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, and he led a field expedition to sample speleothems in Sulawesi and Flores, Indonesia, from 12 June to 23 July.
Prof R. GRÜN is the Chairman of the Standing Scientific Committee for the International Conference Series on Luminescence and Electron Spin Resonance Dating.
Ms C. KRAUSE was on the organising committee for the annual RSES Student Conference.
Dr D.C. McPhail served on the Steering Committee of the Minerals Tertiary Education Council (Minerals Council of Australia), and on the Lachlan Branch Committee of the Australian Institute of Mining and Metallurgy.
Dr B. Opdyke is the Chair of the Sedimentary Geology Specialist group of the Geological Society of Australia. He completed two years as Chair of the ACT division of the Geological Society of Australia in April 2011.
Prof B.J. PILLANS is the President, Stratigraphy & Chronology Commission, International Union for Quaternary Research. He is the President, Geological Society of Australia and the Chair of the Working Group on Lower/Middle Pleistocene Boundary, International Commission on Stratigraphy.
Ms J. Roberts conducted several fieldwork and research trips, performing analyses with CSIRO Land and Water, and completing her midterm review, and completed an ANU graduate short course in Science Communication.
Mr N. SCROXTON conducted fieldwork on the islands of Flores and Sulawesi in Indonesia from 12 June to 25 July, caving and collecting speleological samples.
Miss C. THOMPSON completed four weeks of fieldwork collecting water samples from the Tasman Sea on the research vessel Southern Surveyor during the GP13 research voyage.

Earth Materials & Processes

Prof R. ARCULUS continued as a of Member Steering Committee, Marine National Facility; Deputy Chair, Proposal Evaluation Panel of the Integrated Ocean Drilling Program
Prof I.H.CAMPBELL was Secretary General of the Commission for the Evolution of the Solid Earth, a sub-commission of the International Mineralogical Association; and is co-leader of the Commission for Large Igneous Provinces (LIP).
Prof S.F. COX continued in the position of Associate Director (Education) for RSES until the end of January.
Mr B.J. HANGER served as chair of the RSES Student Forum from May 2011.
Prof I. JACKSON served as Executive Committee member and Vice-President, International Association for Seismology and Physics of the

Earth’s Interior, as a member of the Scientific Program Committee for the 2011 IUGG General Assembly in Melbourne, and as co-convener of three symposia at that meeting.
Prof. G. LISTER is the Chair of the committee charged with developing the Reconciliation Action Plan (RAP) for the College of Physical and Mathematical Sciences.
Dr J.A MAVROGENES served on the Organising Committee of the 2011 SGGMP meeting held at Murramarang NSW in Dec 2011.
Prof H.O’NEILL is chair of the Specialist Group for Geochemistry, Mineralogy and Petrology (SGGMP) of the Geological Society of Australia.
Dr G.M. YAXLEY served as Secretary of the Specialist Group in Geochemistry, Mineralogy and Petrology of the Geological Society of Australia.
Dr G.M. YAXLEY was awarded 5 days beamtime at the XFM beamline of the Australian Synchrotron in Melbourne, from 9-13 March, for collaborative work with Dr A. Berry (Imperial College London) and Mr B. Hanger (PhD student, RSES).

Earth Physics

Dr N BALFOUR is working with Geoff McNamara at Melrose High School and Garry Knight at Daramalan College installing seismometers in their schools.
Prof P. CUMMINS served as coordinator of the Natural Hazards Theme for the 2012 International Geological Congress.
Prof. P. CUMMINS was nominated to the Intersessional Task Team on Hazard Assessment Related to Highest Potential Tsunami Source Areas of the UNESCO IOC Working Group on Tsunamis and Other Hazards Related to Sea-Level Warning and Mitigation Systems (TOWS-WG).
Prof R.W. GRIFFITHS continued as a member of the Australian Research Council College of Experts.
Prof B.L.N. KENNETT, Chair National Committee for Earth Sciences and Chair of Working Party on National Geotransects.
Dr S. MCCLUSKY served as a member of IAG sub commission 3.2a Global Crustal Deformation, and 3.2b Regional Crustal Deformation.
Dr A. PURCELL works as part of the GRACE Science team under the direction of Dr. P. Tregoning on “Ground Validation and Background Models for GRACE Data Analysis”
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 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 served on the AuScope Ltd II steering committee.
Prof. M. SAMBRIDGE was appointed 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 liaison for the PhB program in the Earth Sciences for geophysics.
Dr P. TREGONING, Australian delegate to the International Association for Geodesy.
Dr P. TREGONING, Chair, AuScope Geospatial Gravity subcommittee.
Dr P. TREGONING, Stream Leader (1.1 The Antarctic Ice Sheet), Australian Antarctic Division.
Dr P. TREGONING, member, NASA GRACE Science Team.

IODP

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 1.5 day seminar – *The Sea and the Environment – Opportunities, Constraints and Risks* - to be held at the *Pacific 2012 International Maritime Exposition* in Sydney in February 2012.

Visiting Fellows

Dr P.J. JONES examined the Earth Science content of a Masters thesis for the Masters of Natural Hazards & Disasters program, for J.M. Laud entitled ‘ Vulnerability of Settlements, Infrastructures, Agriculture, and Tourism along the Coastal Zones of Legaspi City, Philippines to the Impacts of Sea Level Rise’.
Dr P.J. JONES frequently held discussions with Prof. P. De Deckker on many different palaeontological issues and interacted at times with several of his students.
Dr P.J. JONES, Corresponding member of the Subcommission on Carboniferous Stratigraphy of the International Stratigraphic Commission, International Union of Geological Sciences
Dr D.L. STRUSZ is a corresponding Member of the International Subcommittee on Silurian Stratigraphy of the International Union of Geological Science.
Dr E. Truswell serves on the Council of the National Science Summer School (National Youth Science Forum)
Dr Truswell serves on the selection committee, Dorothy Hill Award, Australian Academy of Science.
Dr Truswell serves on the Australian National Committee for the International Geoscience Co-operation Program (IGCP). UNESCO International Geosciences Program.