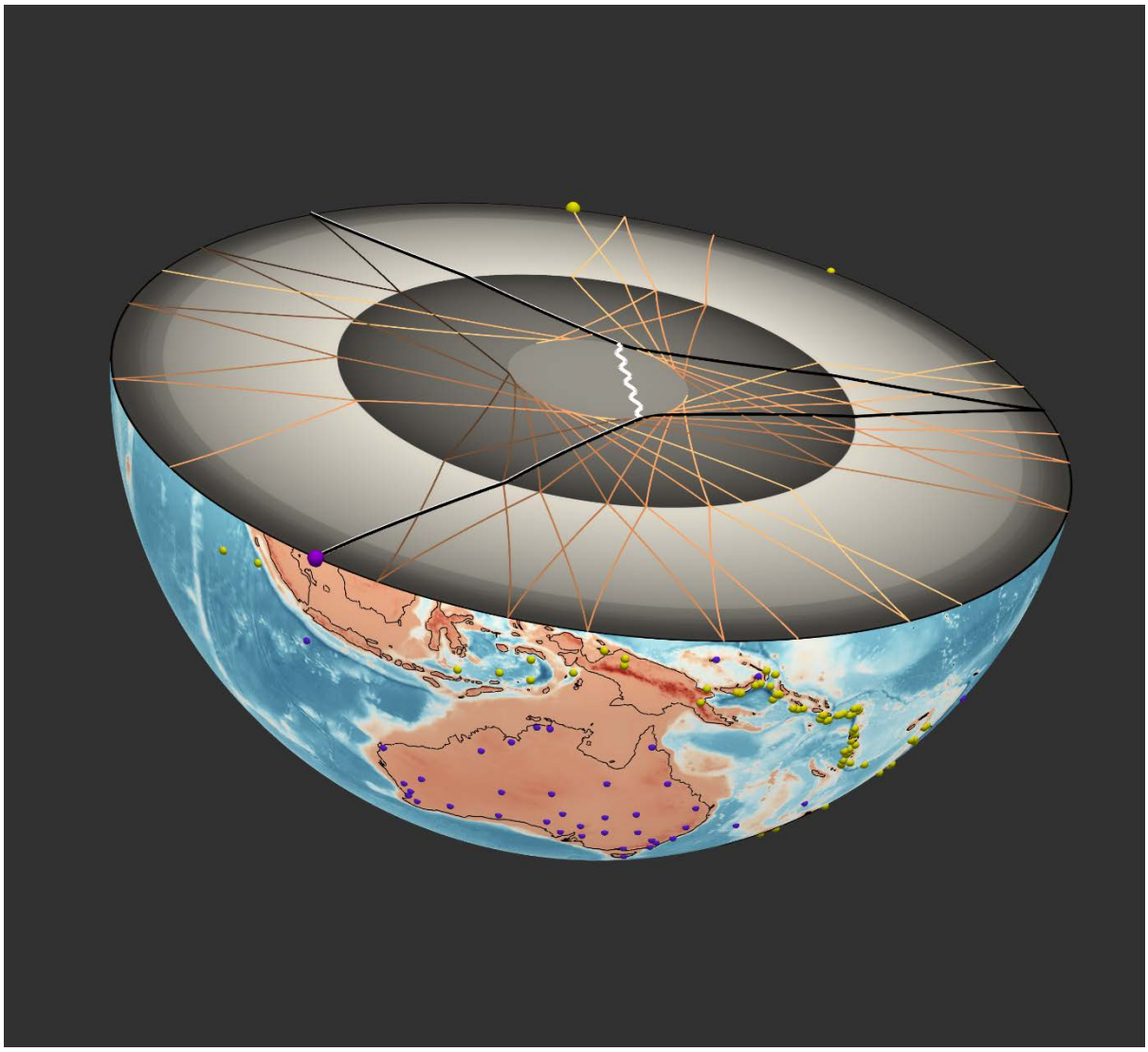
Research School of Earth Sciences
Annual Report 2018



Detection of shear waves in the Earth's inner core.

Image credit: Thanh-Son Pham and Hrvoje Tkalčić

Australian National University

TABLE OF CONTENTS

DIRECTOR'S REVIEW OF 2018

2018 has been a highly successful year for the School by many measures ranging from high quality research publications, a significant increase in awarded research funding, major changes to the School's education program now implemented, and major awards received by current and emeritus staff.

Significant changes in academic staffing occurred with Dr Callum Shakespeare being offered a tenure-track position into the Climate Fluid Physics group, and Dr Mark Kendrick being converted to a continuing position in the Geochemistry and Cosmochemistry group. Professor Stephen Cox and Professor Brad Pillans retired in mid-2018, but both continue to be highly research active. Associate Professors Andy Hogg, Penny King, and Hrvoje Tkalcic were all promoted to Level E (Professor), Dr Rhodri Davies was promoted to Level D (A/Professor) and Dr Katharine Grant to Level B (Research Fellow).

New professional staff arrivals included Shanti Devi, Matt Francis, and Larisa Medenis who joined the School's administration team in various roles. Daniel Cummins left the Electronics Group to take a position in industry, Marilee Farrer retired from the Director's EA role, and Dr Kate Holland resigned from her Teaching Assistant to take a graduate opportunity in the ACT government.

2018 saw a return to higher levels of success in Australian Research Council (ARC) category 1 funding, with six ARC Discovery grants led by RSES CIs ($2.02M) and two externally led Discovery grants with RSES CIs ($0.96M), a Future Fellowship awarded to Dr Bishakhdatta Gayen and two ARC DECRA fellowships, awarded to Dr Caroline Eakin and Dr Katharine Grant. Other notable funding include a very large $1.1M from the National Institute of Advanced Industrial Science and Technology (AIST) Japan to Professor Andrew Roberts and Dr David Heslop. Associate Professor Meghan Miller and Dr Caroline Eakin both received large start-up grants through the new ANU Futures Scheme

The School produced many research highlights during 2018, among the most notable being:

- PhD student Ilya Bobrovskiy and A/Prof Jochen Brocks' discovery of ancient steroids which established *Dickinsonia*, the Edicacaran fossil, was a multicellular animal, published in *Science* and rated by the American Academy of Science among the top ten science discoveries of 2018.
- A/Prof Hrvoje Tkalcic and PhD student Thanh-Son Phams' discovery and report in *Science* (see cover photo of this annual report) of J waves from the Earth's inner core, using a new correlation wavefield tomography technique.
- PhD student Chris Cline, A/Prof Andrew Berry, and Emeritus Professor Ian Jacksons' discovery of the influence of redox state on the seismic properties of upper mantle olivine published in *Nature*.

A full list of publications can be found in the details of this report.

In November the School hosted Professor Carol Frost (University of Wyoming) who

delivered the inaugural Chappell Lecture, in honour of the late Professor Bruce Chappell. Professor Frost is a distinguished petrologist who has been Division Director for Earth Sciences at the US National Science Foundation from 2014-2018 and will be the incoming and 100th President of the Mineralogical Society of America in 2019.

RSES academics were again recipients of major national and international honours. Most notable being the award of the 2018 Prime Ministers Prize for Science to Emeritus Professor Kurt Lambeck for his outstanding 50-year career contribution to the field of geodesy. Dr Rhodri Davies received the Anton Hales Medal, an early career honour awarded by the Australian Academy of Science, for his outstanding contributions to understanding solid Earth structure and evolution. A/Prof Penny King was elected a fellow of the Mineralogical Society of America.

The School graduated fifteen PhD students, one MPhil, eight Master of Earth Science (Advanced) students and ten Honours (4th year) students. The number of students enrolled in the new Master of Earth Science (Advanced) program increased significantly to 28. The School now has ~140 enrolled HDR students, comprising 6 MPhil students and over 130 PhD students.

A major review of the School's Education program was completed during 2018 leading to the introduction of a new core course structure to underpin Earth Science, and new Geophysics and Climate Science majors. Future admissions to the new Masters of Earth Science (Advanced) program were significantly impacted by the University's load capping restrictions introduced late in 2018. This represents a significant challenge to one of the School's primary growth initiatives and the School will need to evaluate how best to maintain this important program on a sustainable footing in future.

The School's primary academic activities in research, education, research training, and engagement continue to be supported by the expertise and extraordinary levels of commitment of its professional administrative and technical staff. Their efforts have been critical to the School maintaining is ranking among the top university geoscience programs in the world (9th in the world for Earth and Marine Science, 2018 QS World University rankings by subject).

Professor Stephen Eggins

Director, Research School of Earth Science

STAFF AND STUDENT LISTS

ACADEMIC STAFF

Director

S.M. Eggins, BAppSci UNSW, PhD Tasmania

Associate Directors

Research	E. Rohling, BSc, MSc, PhD Utrecht
Higher Degree Research	S.C. McClusky, BSurv PhD UNSW
Education	J.A. Mavrogenes, BS Beloit, MS Missouri-Rolla, PhD Virginia Tech
Engagement	M.S. Miller, BA Whittier, MSc Columbia, MEng Cornell, PhD ANU
Experience	G.M. Yaxley, BSc PhD Tasmania
Projects	P. Tregoning, BSurv PhD UNSW
Benchmarking	V.C. Bennett, BSc PhD UCLA

Distinguished Professor

H.St.C. O'Neill, BA Oxford, PhD Manchester, FAA, FRS [ARC Laureate Fellow]

Professors

V.C. Bennett, BSc PhD UCLA

I.H. Campbell, BSc UWA, PhD DIC London

S.F. Cox, BSc Tasmania, PhD Monash (to 30/06/18)

P.R. Cummins, BA Physics, PhD UC Berkeley

S.M. Eggins, BAppSci UNSW, PhD Tasmania

T.R. Ireland, BSc Otago, PhD ANU

G.S. Lister, BSc Qld, BSc (Hons) James Cook, PhD ANU

B.J. Pillans, BSc PhD ANU, HonFRSNZ (to 31/07/18)

A.P. Roberts, BSc Massey, BSc (Hons) PhD DS Victoria (Wellington)

M.L. Roderick, BAppSc QUT, PGDipGIS Qld, PhD Curtin

E. Rohling, BSc, MSc, PhD Utrecht [ARC Laureate Fellow]

M.S. Sambridge, BSc Loughborough, PhD ANU, FAA, FRAS

G.M. Yaxley, BSc PhD Tasmania

Senior Fellows

N.J. Abram, BSC Advanced (Hons) Sydney, PhD ANU [ARC Future Fellow]

Y. Amelin, MSc PhD Leningrad State

L.K. Armand, BSc (Flinders), BSc(Hons) PhD ANU

A.J. Berry, BSc (Hons) Sydney, DPhil Oxford

J.J. Brocks, Dip Freiburg, PhD Sydney

M.J. Ellwood, BSc (Hons) PhD Otago

S.J. Fallon, BA MS San Diego, PhD ANU

D.C. Heslop, BSc Durham, PhD Liverpool, Dr habil Bremen

A.M. Hogg, BSc ANU, PhD UWA

P.L. King, BSc (Hons) ANU, PhD Arizona State [ARC Future Fellow]

J.A. Mavrogenes, BS Beloit, MS Missouri-Rolla, PhD Virginia Tech

S.C. McClusky, BSurv PhD UNSW

M.S. Miller, BA Whittier, MSc Columbia, MEng Cornell, PhD ANU

H. Tkalčić, Dip Engineering in Physics, Zagreb, PhD California Berkley

P. Tregoning, BSurv PhD UNSW

J. Yu, BSc MSc Nanjing University, PhD Cambridge [ARC Future Fellow]

Fellows

D.R. Davies, MSci PhD Cardiff, UK [ARC Future Fellow]

M.A. Forster, BSc MSc PhD Monash

B. Gayen, PhD UC San Diego, USA [ARC Future Fellow]

M.A. Kendrick, BSc Edinburgh, PhD Manchester [ARC Future Fellow]

B.N. Opdyke, AB Columbia, MS PhD Michigan

A. Valentine, BA MSc Cambridge, DPhil Oxford [ARC DECRA Fellow]

Research Fellows

J. Avila, BSc MSc UFRGS, PhD ANU

O. Branson, BSc (Hons) Bristol, MSc Southampton, PhD Cambridge

A. Burnham, MSci MA Cambridge, PhD Imperial College London

N.C. Constantinou, BSc, MSci, PhD Athens, Greece (from 28/05/18)

C. Eakin, MSc Imperial College London, PhD Yale [ARC DECRA Fellow]

A. Kiss, BSc (Hons), PhD ANU

C. Le Losq, MSc, PhD IPGP, France

G. Mallmann, BSc MSc UFRGS, Brazil, PhD ANU [ARC DECRA Fellow]

A. Morrison, BSc (Hons) ANU, GradDipEd Canberra, PhD ANU [ARC DECRA Fellow]

J. Pownall, PhD Royal Holloway University of London [ARC DECRA Fellow]

A. Purcell, BSc (Hons), PhD ANU

C. Shakespeare, BSc (Hons) ANU, PhD Cambridge [ARC DECRA Fellow]

K. Stewart, BSc (Hons), PhD ANU

B. Tauzin, PhD Strasbourg

A.M. Ukkola, BSc MRes Bristol PhD Macquarie (from 19/02/18)

R. Wood, BSc (Hons) Durham, MSc DPhil Oxford [ARC DECRA Fellow]

Postdoctoral Fellows

S. Allgeyer, PhD Paris Diderot, France

J. Amies, (from 15/11/18)

P. Barrett, BSc Rochester MSc PhD Washington (from 14/05/18)

C. Frigo, BSc Padova, MSc Bayerisches, PhD Innsbruck (from 29/10/18)

K. Grant, BSc Southampton, MSc JCU, PhD Southampton

B. Hejrani, BSc Kurdistan, MSc Tehran, PhD Aarhus, Denmark

F. Hibbert, PhD St Andrews, UK

K. Holland, BSc (Hons), PhD ANU

P. Hu, PhD ANU & Chinese Academy of Sciences

J. Pfeffer, MSc Joseph Fourier, Grenoble, France, PhD Strasbourg

L. Van Maldegem, BSc Avans, MSc Leeds, PhD Bremen (from 15/01/18)

L. Waszek, BA (Hons) MSci PhD Cantab [ARC DECRA Fellow]

N. Wright, BSc, PhD Sydney (from 5/02/18)

D. Yin, PhD Tsinghua, Beijing

Emeritus Academics

R.J. Arculus, BSc PhD Durham, FAIMM

K.S.W. Campbell, MSc PhD Queensland, FAA

J.M.A Chappell, BSc MSc Auckland, PhD ANU, FAA, HonFRSNZ (dec 3/10/18)

W. Compston, BSc PhD DSc (Hon) WAust, FAA, FRS

S.F. Cox, BSc Tasmania, PhD Monash (from 1/07/18)

P. DeDeckker, BA MSc (Hons) Macquarie, PhD DSc Adelaide

R.A. Eggleton, BSc (Hons) Adelaide, PhD Wisconsin, DSc Adelaide

D.J. Ellis, MSc Melbourne, PhD Tasmania

N.F. Exon, BSc (Hons) NSW, PhD Kiel

J.D. Fitzgerald, BSc James Cook, PhD Monash

D.H. Green, BSc MSc DSc DLitt (Hon) Tasmania, PhD Cambridge, FAA, FRS

R.W. Griffiths, BSc PhD ANU, FAIP, FAA

I.N.S. Jackson, BSc Qld, PhD ANU, FAA

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

K. Lambeck, BSurv NSW, DPhil DSc Oxford, FAA, FRS

I. McDougall, BSc Tasmania, PhD ANU, FAA (dec 10/11/18)

M.D. Norman, MSc Tennessee, PhD Rice

M.S. Paterson, BSc Adelaide, PhD Cambridge, FAA

B.J. Pillans, BSc PhD ANU, HonFRSNZ (to 31/07/18)

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

I.S. Williams, BSc PhD ANU

Honorary Academics

R.A. Armstrong, BSc MSc Natal, PhD Witwatersrand

R.V. Burne, BSc Wales, DPhil Oxford (from 12/03/18)

H. Davies,

C.M. Fanning, BSc Adelaide

C.B. Foster, BSc (Hons) Adelaide, PhD Queensland

A. Gerson, PhD Strathclyde, Scotland

G.M. Gibson, BSc Edinburgh, PhD Otago (from 10/11/18)

R. Grün, Diplo Geol, Dr.rer.nat.habil Köln, DSc ANU, FAAH

M. Honda, MSc PhD Tokyo

R.C. Kerr, BSc Qld, PhD Cambridge, FAIP

A.M. Leitch, (from 22/10/18)

G. Marino, MSc (cum laude) ‘Federico II’ of Naples; PhD Utrecht (from 1/04/18)

R.P. Rapp, BA State University of New York, PhD Rensselaer Polytechnic Institute

D. Rubatto, BSc MSc Turin, PhD ETH Zürich

N. Williams, BSc (Hons) ANU, MPhil PhD Yale

Visiting Fellows

A. Acosta-Vigil, PhD Granada (to 31/10/18)

C. Alibert, MS Paris VII, first thesis ENS Paris, State thesis, CRPG, Nancy

C. Bryant, PhD ANU (to 30/06/18)

Y. Cao, (to 19/10/18)

G.F. Davies, MSc Monash, PhD CalTech

M.H. Davies (28/02/18 – 31/05/18)

P. de Caritat de Peruzzis, PhD ANU

H.U. Faul (to 5/11/18)

G.M. Gibson, BSc Edinburgh, PhD Otago (to 9/11/18)

A. Glickson (from 1/08/18)

S. Hirabayashi (from 1/10/18)

X. Huang (from 23/07/18)

J. Hunter (from 21/05/18)

A.L. Jacques, BSc (Hons) Western Australia, PhD Tasmania

T. Jones (to 5/10/18)

S.C. Kramer (to 4/05/18)

Y. Liang (from 1/07/18)

F.E.M. Lilley, (from 16/05/18)

J. Mallela, BSc (Hons) Leeds, MSc Heriot-Watt, PhD West Indies (from 30/04/18)

T.P. Mernagh, PhD Newcastle

R. Metzler (from 1/07/18)

J. Munroe (to 31/03/18)

R.W.R. Rutland, BSc PhD London, FTSE

M. Sapah, PhD ANU (from 31/7/18)

C. Vreugdenhil, PhD ANU (from 10/04/18)

H. Wei (from 1/09/18)

F. Williams (from 16/04/18)

C. Wilson (5/02/18 – 9/03/18)

Y. Yokoyama (from 1/06/18)

PROFESSIONAL STAFF

School Manager

G.F.M. Pearson, BA, BTh, MBA, FAIM

Executive Assistant to the Director and the School Manager

M. Farrer (to 25/07/18)

S. Devi (from 20/09/18)

Senior Administration Officer

B.J. Armstrong, BSc UNISA, South Africa

Building and Facilities Officer

E. Ward, Cert V Frontline Management, Quest/ANU

Student Administrator HDR

V. Riddle

Student Administrator Coursework

T. Asher

Communications Officer

L. Medenis (from 3/09/18)

Education Officer

B. Harrold, BSc ANU

Teaching Assistant

K. Holland, PhD ANU

Receptionist

T. Asher

Research Group Administrators

E. Arnold – Earth Dynamics; Seismology & Mathematical Geophysics

J. Magro – Experimental Petrology; Geochemistry & Cosmochemistry

M. Francis (from 19/03/18) – Biogeochemistry; Palaeoenvironments; Climate & Fluid Physics

IODP Administrator

C. Beasley, BA (Sustainable Systems) ANU

Centre Administrator for Centre of Excellence Climate Extremes

A. Bryleva, BPublicAdmin Lomonosov Moscow State, Cert III Bus Adm CIT

Electronics Group Manager

A. Latimore, BEng University of Canberra

Electronics Group

D. Cassar, AdvDipEng CIT

D. Cummins, AdvDipEng CIT (to 18/08/18)

T. Redman, AssocDip(Elect Eng) CIT

H. Sasaki, AssocDip CIT

L. Materne, (from 30/07/18)

Mechanical Engineering Workshop Manager

A. Wilson, AssocDipMechEng CIT, Cert III Engineering (Mechanical) Trade

Mechanical Engineering Workshop

B. Butler, Cert III Mechanical Engineering Sydney Institute, Cert III Engineering-Mechanical Trade (Toolmaking)

C. Were, AdDipMechEng CIT, Cert III Engineering (Mechanical) Trade

G. Woodward, Cert-Fitting and Machining Trade

School Laboratory Manager

D. Cassar, AdvDipEng CIT

Research Officers

A. Arcidiaco, BAppSc GradDip SAInst

J. Byrne, BSc (Hons) ANU, PhD Monash

A. Heerdegen, BSc (Hons) Massey, PhD ANU

P. Holden, BSc Lancaster, PhD St. Andrews

G. Luton, BSurv UNSW

H.W.S. McQueen, BSc Qld, MSc York, PhD ANU

S. Mousavi, BSc, MSc, Tehran University, PhD Leipzig

L. Rodriguez Sanz, BSc Venezuela, MEnvStudies, PhD Autonomous (Barcelona)

M. Salmon, BSc (Hons) PhD Victoria (Wellington)

Technical Officers

J. Cali, BAppSc QIT

D. Clark, Cert III Metal Fabrication AdvDipEng CIT

T.G. Enge, PhD Wollongong (from 4/12/18)

R. Erigela,

R. Esmay, BSc (Sr Thesis) SUNY Purchase

B. Fu, BSc Chungchun, MSc Nanjing, PhD Vrije

J. Hope, BSc JCUNQ

P. Lanc, AssocDip Bus (Applied Computing) CIT

H. Miller, AdDipMechEng CIT

G. Nash, BSc Hons ANU

S. Paxton, AssocDip Applied Geoscience CIT, FGAA

S. Rayapaty, BEng Jawaharlal Nehru Technological University, MIT University of Canberra

A. Rummery, Cert III CIT (x3)

D. Scott, AssocDipMechEng CIT

J. Tatapudi,

D. Thomson, Cert-Fitting and Machining Trade

U. Troitzsch, Diplom Technische Universität Darmstadt, PhD ANU

D. Vasegh, AssocDeg Khajeh Nasireddin Toosi University of Technology (Iran)

X. Zhang, PhD LaTrobe

X. Zhao, BSc Jilin University, PhD Southampton

S. Zink, BSc Hanover, Diploma (MSc) Hanover

POST-GRADUATE STUDENTS

PhD Candidates

Amies, Jessica
Andrew, Sarah
Anenburg, Michael
Baruleva, Olga
Bean, Lynne
Bobrovskiy, Ilya
Bonning, Geoffrey
Cajal Contreras, Yamila
Carr, Patrick
Chen, Bei
Chen, Fangqin
Chen, Mimi
Chopping, Richard
Cipta, Athanasius
Cline II, Christopher
Connolly, Clare
Costa de Lima, Thuany
Crisp, Laura
Dai, Yuhao
Devi, Riteshma
Ducommun-Dit-Verron, Joelle
Di, Yankun
Durgalakshmi
Duvernay, Thomas
Ellis, Bethany
Emetc, Veronika
Hayward, Kathryn
Hu, Yuzhi
Huang, Zhijie
James, Hannah
Jena, Smruti
Jones, Timothy
Kinsley, Jordan
Kirby, Rachel
Kou, Yingxin
Koudashev, Oleg
Krestianinov, Evgenii
Lakey, Shayne
Li, Yuwei
Liu, Li
Liyanage, Tharika
Loiselle, Liane
Long, Kelsie
Lowczak, Jessica
Maharaj, Prayna
Makushkina, Anna
Manceau, Rose
Mare, Eleanor
Martin, Hayden
Martinez Moreno, Josue
Masoumi, Salim
Mathews, Christopher
Pranantyo, I. Ryan
Prichard, Jennifer
Qian, Yao
Qu, Tongzhang
Rajabi, Sareh
Rama, Jemima
Renggli, Christian
Roosmawati, Nova
Ry, Rexha
Samanta, Moneesha
Schoneveld, Louise
Scicchitano, Maria
Sebastian, Nita
Sieber, Melanie
Skelton, Richard
Smith, Tegan
Sohail, Taimoor
Sommer, Johanna
Stephenson, Joanne
Sudholz, Zachary
Tambiah, Charles
Tian, Siyuan
Timmerman, Suzette
Tolley, James
Tyler, Perinne
Tynan, Sarah

Fang, Bowen	McConachie, Shannon	Valetich, Matthew
Fang, Fang	McGirr, Rebecca	Vinnichenko, Galina
Farmer, Nicholas	Miller, Laura	Wang, Sheng
Fouladi Moghaddam, Negin	Misztela, Monika	Ward, Josephine
Gai, Congcong	Mondal, Mainak	Wei, Yi
Gauthiez-Putallaz, Laure	Nand, Vikashni	Whan, Tarun
Gibson, Angus	Nash, Graham	Williams, Morgan
Goodarzi, Patrick	Nugroho, Hendro	Wu, Jiade
Gray, Sharon	Ogunsami, Abdulwaheed	Wu, Yang
Grun, Robin	O'Neill, Cameron	Wurtzel, Jennifer
Hao, Hongda	Owens, Ryan	Zannat, Umma
Harazin, Kathleen	Pasic, Bozana	Zhang, Ping
Hargreaves, Jessica	Penny, Tiah	Zhao, Song
Hawkins, Rhys	Pham, Thanh	Zheng, Siru
Haynes, Marcus	Piedrahita Velez, Victor	Zhu, Ziyi

Contro De Godoy, Bruna	Transferred to Research School of Biology - April 2018
Zhou, Yifei	Transferred to South Australia - September 2018

MPhil Candidates

Baeza, Leonardo	Muston, Jack
Carrasco Godoy, Carlos	Qu, Tongzhang (Transferred to PhD 5/12/18)
Creighton, Reuben	Yuguru, Samuel

Master of Earth Sciences (Advanced)

Agrawal, Shubham	Rozenbaks, Peteris (completed)
Chen, Xiaoyu (completed)	Shao, Yujia
Egorova, Angelina	Sharma, Aditya
He, Nini	Song, Cheng (completed)
Hu, Shangyu	Su, Xiaoyu
Huang, Baoyi	Tian, Yanjie
Lin, Yucheng	Wang, Chuang (completed)

Liu, Wenbing
Marris, Kristen
Merriman, Prudence (completed)
Naina, (completed)
Nie, Ruoran
Palm, Andrew (completed)
Patil, Suchir
Wang, Dianao
Williamson, Faye
Yeung, Ho Sonia
Zhang, Xihan
Zhao, Siyuan (completed)
Zhou, Jingwei
Zhou, Qianhui

Honours completions

Baile, Riley
Ingles, Chris
Krause, James
Lang, Tandong
Macdonald, Alice
Macleod, Fergus
Morell, Hugh
Robb, Katherine
Teh, Matthew
Weirman, Alyssa

UNDERGRADUATE AND POSTGRADUATE COURSES

Earth & Marine Science Programme

Semester 1	**Course description**	**Convenor,** Teaching staff	**Number of students**
EMSC1006/4006/6107	Blue Planet	**K. Holland**, P. King, S. Eggins	153
EMSC2012/4012/6031	Introduction to Structural & Field Geology	**S. Cox,** K. Hayward	14
EMSC2014/4014/6014	Sedimentology & Stratigraphy	**B. Opdyke**	21
EMSC2017/4017/6017	Rocks and Minerals	**G. Yaxley,** G. Mallmann	35
EMSC2022	Introduction to Global Geophysics	**M. Miller,** D. Heslop, P. Tregoning, S. McClusky	24
EMSC3002/4002/6030	Structural Geology & Tectonics	**S. Cox**	14
EMSC3023/4023/6023	Marine Biogeochemistry	**M. Ellwood,** S. Fallon, O. Branson	29
EMSC3024/4024/6024	Magmatism & Metamorphism	**G. Yaxley,** H. O'Neill, A. Burnham, J. Pownall, R. Arculus, I. Campbell	14

EMSC3032/4032/6032	Melting Polar Ice Sheets	**P. Tregoning**	12
EMSC4017/8017	Research Methods and Proposal	**M. Forster,** A. Roberts, T. Ireland, D. Vasegh, B. Harrold	12
EMSC4018/8018	Advanced Water and Marine Geosciences	**M. Ellwood**	2
EMSC4121/8021	Advanced Geochemistry, Petrology and Tectonics	**A. Burnham,** H. O'Neill, V. Bennett, Y. Amelin, A.L. Jaques	5
EMSC4122/8022	Analytical Techniques	**V. Bennett,** A. Burnham	5
EMSC4123/8023	Data Analysis	**D. Heslop**	5
EMSC4706/8706	Natural Hazards	**P. Cummins**	11
Winter			
EMSC3001	Field Geology	K. Hayward (Run by University of Queensland)	7
Semester 2			
EMSC1008/6008	Earth	**A. Berry,** C. Eakin, A. Burnham	60
EMSC2015/4015/6015	Chemistry of the Earth	**T. Ireland,** Y. Amelin, I. Williams	22
EMSC2019/4019/6019	Geobiology & Evolution of Life on Earth	**J. Brocks,** L. Armand, P. DeDeckker	44
EMSC2021/4021/6021	Climate System Science	**M. Roderick,** C. Shakespeare	18
EMSC3007/6007	Economic Geology	**J. Mavrogenes**	10
EMSC3022/6022	Planetary Science	**C. Lineweaver,** T. Ireland	54
EMSC3025/4025/6025	Groundwater	**J. Mavrogenes, C.**L. Moore	30
EMSC3027/4027/6027	Palaeoclimatology & Climate Change	**J. Yu,** N. Abram, K. Grant	18
EMSC4017/8017	Research Methods and Proposal	**D.R. Davies,** D. Heslop, B. Kennett, A. Roberts, P. Tregoning	8

EMSC4020/8024	Analytical Techniques and Data Analysis	**D. Heslop, V. Bennett,** A. Burnham	8
EMSC4123/8023	Data Analysis	**D. Heslop,** M. Sambridge	9
EMSC4109/8109	Advanced Earth Physics	**S. McClusky,** H. Tkalčić, I. Jackson, B. Tauzin	5
EMSC8014	Computational Geoscience	**A. Valentine,** O. Branson, C. Le Losq	10
EMSC8705	Special Topics - Research Proposal & Presentation	**D.R. Davies,** B. Opdyke, A. Kiss	2
EMSC8705	Research Orientation	**D.R. Davies,** O. Branson, A. Berry, M. Roderick, P. King, C. Le Losq, F. Hibbert, B. Tauzin, L. Waszek, D. Heslop, P. Tregoning	4
Spring			
EMSC3019/6119	Coral Reef Field Studies	**S. Fallon,** O. Branson	21
New Colombo Plan			
EMSC3050	NCP Field trip (Indonesia)	**P. Cummins**	6
EMSC3050	NCP Field trip (Japan)	**D. Heslop,** J. Mavrogenes, S. Mousavi	17
Special topics			
EMSC3050/4050/ 6805/8014	Research project (6 units)	R. Arculus, J. Brocks, A. Burnham, S. Cox, N. Constantinou, P. Cummins, C. Eakin, S. Fallon, M. Forster, F. Hibbert, G. Lister, G. Mallmann, J. Mavrogenes, S. McClusky, M. Miller, B. Tauzin, I. Williams, P. Tregoning	21

Physics Programme (Research School of Physics & Engineering)

PHYS2201	Classical Mechanics	A. Hogg	32
PHYS2205	Physics for Future Leaders	A. Hirsch	20
PHYS3034/4034	Physics of Fluid Flows	**K. Stewart,** A.Hogg, B. Gayen	28
PHYS3070	Physics of the Earth	**H.Tkalčić,** D.R. Davies, A. Valentine	10

Archaeology Programme (Research School of Humanities & the Arts, School of Archaeology and Anthropology)

ARCH1111	Archaeology Uncovered	R. Wood	69
ARCH2041	Introduction to Environmental Archaeology	R. Wood	29
ARCH8032	Introduction to Archaeological Science	R. Wood	17

Biological Anthropology Programme (Research School of Humanities & the Arts, School of Archaeology and Anthropology)

BIAN3010/6510	Scientific Dating in Archaeology and Palaeoenvironmental Studies	**R. Wood,** K. Grant, D. Heslop	33
BIAN8009	Stable Isotopes in Archaeology and Biological Anthropology	**R. Wood,** N. Abram, I. Williams, H. James	7

Environmental Science Programme (Fenner School of Environment & Society)

ENVS3013	Climatology	A. Hirsch	50

THESES AND AWARDS

PhD theses completed (Supervisor in parentheses)

Cline II, Christopher "Viscoelastic Relaxation in Olivine: An Experimental Study of Alternative Mechanisms" (Ian Jackson)

Dai, Yuhao "Reconstructing Seawater Carbonate Chemistry Using B/Ca in Foraminiferal Shells" (Jimin Yu)

Hawkins, Rhys "Advances in Trans-dimensional Geophysical Inference" (Malcolm Sambridge)

Jones, Timothy "From Source to Surface: the Dynamics of Heterogeneous Mantle Plumes" (Rhodri Davies)

Koudashev, Oleg "Large-Scale Structure and Geochronology of Porphyry and Epithermal Deposits along the Northern Collisional Margin of the Australian Continental Lithosphere" (Marnie Forster)

Mare, Eleanor "Silicate Melt Under Pressure: Coordination Changes and Trace Element Partitioning" (Hugh O'Neill)

Masoumi, Salim "GPS Tropospheric Modelling: New Developments and Insights" (Simon McClusky)

Rajabi, Sareh "Dating Events Within the Crystalline Series of the Himalaya, The Kullu Valley, NW India" (Marnie Forster)

Renggli, Christian "Volcanic Gases and the Reaction of Sulfur Dioxide with Aluminosilicate Glasses" (Penny King)

Samanta, Moneesha "Zinc Isotopes as a Tool to Investigate Zinc Biogeochemical Cycling in the SW Pacific Ocean" (Michael Ellwood)

Schoneveld, Louise "Partitioning of Trace Elements between Plagioclase, Clinopyroxene and Melt" (Hugh O'Neill)

Scicchitano, Maria "Oxygen Isotopes as Tracers and Stopwatches for Rock-fluid Interaction in the Crust: New Analytical and Experimental Developments" (Ian Williams)

Skelton, Richard "Nanoscale Simulation of Crystal Defects with Application to Mantle Minerals" (Ian Jackson)

Tynan, Sarah "Interpreting Environmental Change Using Bivalve Shell Geochemistry" (Brad Opdyke)

Wurtzel, Jennifer "Reading the Rain in Rocks: A Late Deglacial-Holocene Speleothem Record from Sumatra, Indonesia" (Nerilie Abram)

MPhil thesis completed (Supervisor in parentheses)

Yuguru, Samuel "Insights into a Novel Approach for Aqueous Species' Solubilities Investigations in Low-Density Fluids Beyond the Critical Point of Pure Water" (Greg Yaxley)

STAFF HONOURS & AWARDS

	AWARD	AWARDING BODY
Dr A. Berry, Dr C. Eakin	ANU Colleges of Science Excellence in Teaching (Team) Award	Australian National University Colleges of Science
Prof. J. J. Brocks	Best paper award	Organic Geochemistry Division of the Geochemical Society
Dr A. Burnham	KSW Campbell Award for Teaching Excellence	RSES Awards Committee
Prof. P. Cummins	Bridge Fellowship	Japan Society for the Promotion of Science
Dr D. R. Davies	Anton Hales Medal	Australian Academy of Sciences
Em. Prof. P. De Deckker	Officer in the Order of Leopold II	Belgian Government
Em. Prof. N. Exon	W.R. Browne Award	Australian Geological Society
Dr P.L. King	Fellow (Elected)	Mineralogical Society of America
Em. Prof. K. Lambeck	2018 Prime Minister's Prize for Science	Australian Government Department of Industry, Innovation and Science
Adele Morrison	2018 Meyers Medal	Australian Meteorological and Oceanographic Society
Prof. H. O'Neill	Forschungsaufenthalte	Alexander-von-Humboldt-Stiftung
Prof. A.P. Roberts	Excellent researcher	Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology, Tsukuba, Japan
Prof. M. Sambridge	Elected to Council of the Australian Academy of Science.	Australian Academy of Science.
Dr K. Stewart	Vice Chancellor's Teaching Enhancement Grant	Australian National University
Ms. R. Anandawansha, **Dr L. Waszek**	Four Corners Meeting best graduate student poster	American Society of Physics

STUDENT HONOURS & AWARDS

Higher Degree Research	
Australian Meteorological and Oceanographic Society Uwe Radok Award for best PhD thesis	Catherine Vreugdenhil (PhD completed 2017)
DA Brown Travel Fellowship	Tharika Liyanage
Jaeger Scholarship	Tharika Liyanage
Mervyn & Katalin Paterson Fellowship	Jordan Kinsley, Anna Makushkina & Jessica Hargreaves
Ringwood Scholarship	Prayna Maharaj
Robert Hill Memorial Prize	Hannah James
Sue Kesson Experimental Petrology Student Travel Grant	Melanie Sieber & Nicholas Farmer
Coursework	
A L Hales Honours Scholarship	Ruth Moorman
John and Kerry Lovering Scholarship	Not awarded this year
Scholarship in Regolith Science	Matthew Teh

RESEARCH ACTIVITIES

BIOGEOCHEMISTRY

Group leader: Michael Ellwood

Academic members: L. Armand, P. Barrett, O. Branson, J. Brocks, S. Eggins, S. Fallon, L. van Maldegem, R. Wood

The biogeochemistry group at RSES has had a busy and productive year. The group continues to focus on its research strengths in the areas of marine and terrestrial science.

A few examples of the group's research include:

- understanding the tempo and mode of evolution of complex life on Earth;
- understanding carbonate chemistry cycling at One Tree Island;
- the cycling of trace elements in the Tasman Sea and the Southern Ocean;
- the pollution history of Gladstone harbour;
- evolution of the Great Barrier Reef;
- diversity of Australian lungfish and
- evolution of human occupation of Lake Mungo.

The group also participated in field campaigns to the Great Barrier Reef, the Southern Ocean, and the Tasman Sea.

Members of the group developed software for analysis of LA-ICPMS data and organised conferences, including the Negative Emissions Conference held at the Australian Academy of Sciences' Shine Dome.

The group continued to publish high impacting papers with notable additions to the following top-ranking journals: Nature, Science, Nature Geoscience, Nature Ecology & Evolution, Science Advances, PloS One, The Holocene, Proceedings of the National Academy of Sciences.

During 2018 group members continued to contribute to the undergraduate teaching program within RSES. Courses

Prayna Maharaj (left) and Riteshma Devi (right) who managed the registration desk at the Negative Emissions Conference

taught by academic group members include: Marine Biogeochemistry, Coral Reef Field Studies, Geobiology and The Blue Planet.

The group welcomed two new staff members: Pamela Barrett joined the group as a Post-doctoral Fellow in Marine Biogeochemistry and Lennart van Maldegem joined the group as a Post-doctoral Fellow in Geobiology.

CLIMATE & FLUID PHYSICS

Group Leader: Andy Hogg

Academic members: N. Constantinou, A. Hogg, R. Kerr, A. Kiss, A. Morrison, M. Roderick, C. Shakespeare, K. Stewart, A. Ukkola, N. Wright, Y.Yang, D. Yin

The Climate & Fluid Physics group conducts research into fluid physics and thermodynamic processes that are relevant to the Earth system. Our current research priorities include oceanic convection, ice-ocean interactions, the energy balance of the land surface and the large-scale circulation of the ocean. Our research profile includes funded contributions from the ARC Centre of Excellence for Climate Extremes and the Consortium for Ocean-Sea Ice Modelling in Australia (COSIMA; see cosima.org.au).

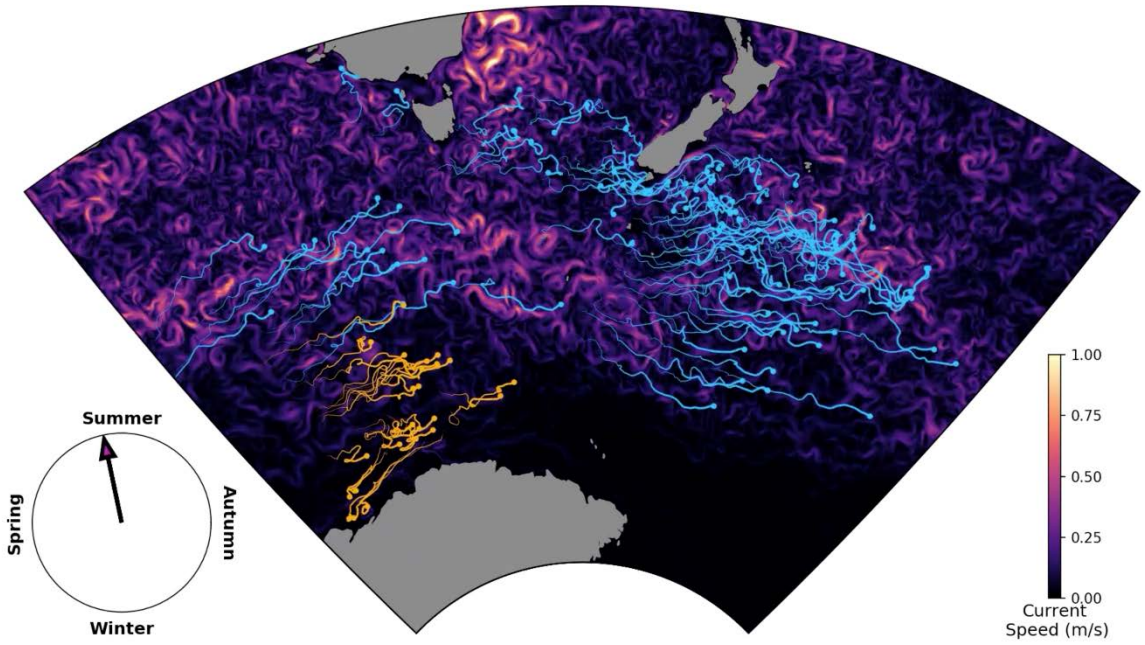
This year saw the complete release of ACCESS-OM2 (the ocean-sea ice component of Australia's ACCESS climate model) which is coordinated by COSIMA. ACCESS-OM2 is currently available at 3 different resolutions (1°, 0.25° and 0.1°) with a consistent set of parameters. We have completed full spinup and evaluation simulations, with a model evaluation exercise underway.

We continued our work on the global water cycle and drought. Early in the year saw new collaborative research (with Tsinghua University and the Research School of Biology at ANU) on how to assess stationarity in rainfall data (Sun et al 2018). Recently we have been applying these new concepts to the Australian rainfall record with the surprising conclusion that rainfall has, for the most part, remained stationary over the last 120 years in many (but not all) parts of Australia. We intend to build on that work in the coming year and combine those analyses with new approaches to assess hydrologic variability over the global land surface. We anticipate a new framework that fully incorporates climate variability into assessments of change in the global water cycle.

Continuing with the theme of water, over the past decade, climate scientists have published numerous articles arguing that global warming will be accompanied by an overall increase in aridity. However, one of the great puzzles in climate science, now known as “aridity paradox”, is that inter-glacial periods with higher levels of atmospheric CO_2 are generally thought to be warmer, wetter and greener while glacial periods with lower levels of atmospheric CO_2 are colder, drier and browner. We first identified this important paradox and have been steadily working on the topic since 2015. At the end of 2018 we have finally been able to resolve the paradox. In brief, it

turns out that the assessments of increasing aridity with warming were not actually based on climate model projections. Instead they were based on off-line assessments that ignored the critical response of vegetation to rising levels of atmospheric CO_2. In particular, vegetation shows a direct biochemical response to rising atmospheric CO_2 by an increase in the water use efficiency of photosynthesis. This water use efficiency effect had not been factored into previous assessments. When that effect is incorporated, we have been able to demonstrate that in terms of long-term averages, current climate models project a higher CO_2 world to be warmer, wetter and greener (Yang et al 2018). This turns out to be consistent with the geological record and with modern observations over the last 50 years.

While developing ACCESS-OM2, we have continued to make scientific progress using existing modelling tools. We used a Lagrangian tracking approach to estimate the pathway of floating kelp around the Southern Ocean, showing for the first time that kelp is able to float to Antarctic beaches (Fraser et al. 2018). The critical step in this study was to recognise the role played by huge surface waves in the Southern Ocean in pushing the kelp southwards during storm events. This landmark study was published in Nature Climate Change and has received significant attention.



Simulations of kelp floating in the Southern Ocean. Particles were released from South Georgia, and travel around Antarctic, before a small percentage of the particles (those coloured orange) made it to the Antarctic coastline.

At the fundamental level, we have continued our world-leading research into the dynamics of internal waves and their role in forcing larger-scale, eddying ocean flows. Atmospheric scientists have long known that internal waves play a first-order role in sustaining the atmosphere's overturning circulation, known as the Brewer-Dobson circulation. Our recent ultra-high resolution "wave resolving" simulations show a

similar behaviour in the ocean, with tidally generated waves at the ocean bottom propagating up and driving enhanced eddy fields in the upper ocean (Shakespeare & Hogg, 2018). We are now looking to parameterise these effects in global ocean models (e.g. ACCESS-OM2) and evaluate their impact on global circulation.

On a different note, in early 2018 data that came from spacecraft Juno revealed that the zonal jets in the atmosphere of Jupiter (i.e., Jupiter's coloured stripes) continue for 3,000km deep beneath the cloud tops. This is about 5% of the gaseous giant's radius, but there was no explanation for why the jets terminate at that particular depth. In collaboration with Lawrence Livermore National Laboratory (USA), we developed a theory that describes how zonal jets, turbulence, and magnetic fields interact. Using principles from statistical physics of turbulent systems, they devised a mathematical model which predicts that when magnetic fields are strong enough the jets shut down (Constantinou & Parker 2018). This theory offers a partial explanation as to why the jets terminate at about 3,000km, since at around that depth the pressure inside Jupiter becomes so high that the fluid gets ionized and starts being conductive. This paper drew a lot of media attention when it was published in August.

Staff news

Callum Shakespeare began his tenure-track appointment.

Bishakhdatta Gayen and Yifei Zhou departed the group.

Nicky Wright, Anna Ukkola and Navid Constantinou all joined the group, funded by the ARC Centre of Excellence for Climate Extremes.

Yuting Yang joined the group from CSIRO Land and Water for a brief six month period before departing Australia for a tenured appointment in the Department of Hydraulic Engineering at Tsinghua University in Beijing. During his stay, Yuting was funded by the ARC Centre of Excellence for Climate System Science.

Andy Hogg was promoted to Professor.

Student news

Jemima Rama joined the group as a PhD student, working on internal waves with Callum Shakespeare.

Emeritus, Honorary staff and Visitors

Emeritus Professor Stewart Turner has renounced his Honorary position as a result of declining health, formally concluding a long association with the group.

Prof Ross Griffiths remains as an active Emeritus member of the group.

Dr Claire Carouge remains as a long-term visitor from UNSW, heading the Computational Modelling Support team for the ARC Centre of Excellence for Climate Extremes.

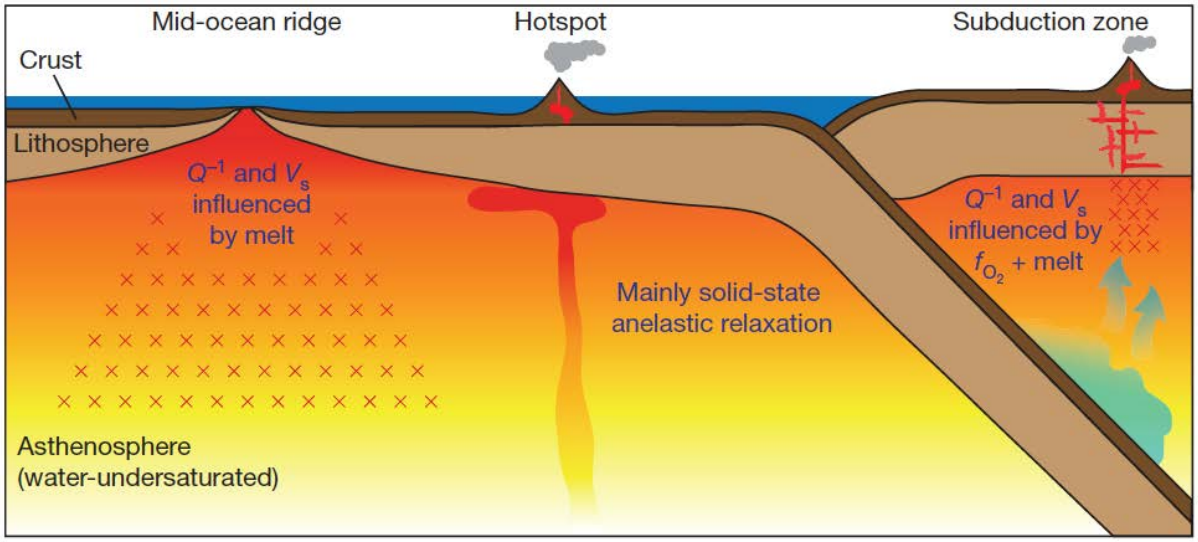
Dr Annette Hirsch (UNSW) also sits in the group as a long-term visitor, working in the Drought Research Programs of the ARC Centre of Excellence for Climate Extremes.

EARTH DYNAMICS

Group Leader: Dr Paul Tregoning

Academic members: S. Allgeyer, S. Cox, M. Forster, B. Gayen, G. Lister, S. McClusky, J. Pfeffer, A. Purcell

The interpretation of upper-mantle seismic tomography models took a step forward with new findings concerning the influence of redox conditions, reported in Nature by PhD student Chris Cline et al., that represent the culmination of a long-term high-risk project.



The factors considered responsible for reduced wave speeds (VS) and the attenuation (Q-1) of seismic shear waves in various tectonic settings within the Earth's upper mantle. The newly discovered influence of redox conditions (expressed as oxygen fugacity fO2) has implications especially for the mantle wedge region above the cold and oxidized tectonic plate sinking back into the hot mantle on the right

Successful collaboration with Geoscience Australia has led to positive advances on the National Argon Map, and involvement in the MinEx CRC, where $^{40}Ar/^{39}Ar$ research on the tectonic evolution and architecture of the Australian lithosphere is the focus. The National Argon Map and Argon Repository includes collaboration between Dr Marnie Forster and partners at Geoscience Australia, Curtin University, University of Melbourne, University of Queensland and the Geological Surveys of New South Wales, South Australia and Victoria. Dr Forster was also involved in TANG3O (Thermochronology and Noble Gas, Geochemistry and Geochronology Organisation), another national collaboration.

Research has continued into capture of the initiation of rupture in laboratory earthquakes, including the development of a new assembly configuration to capture the dynamic evolution of both stress and displacement on microsecond timescales, and the development of a novel method to quantify pressures on fault contacts using changes in glass molecular structure. New techniques are being applied to understanding the role fluids play in influencing the dynamic behaviour of faults.

Dr Julia Pfeffer developed a new method to model steric (density related) sea level changes based on the analysis of typical patterns of the ocean and climate variability (climate mode fingerprints).

After the successful launch by NASA/DLR of the GRACE Follow-On mission in May 2018, the ANU GRACE software was modified to be ready for GRACE Follow-On data. Presentations were made at the GRACE Science Team Meeting in Potsdam, Germany on removing temperature effects from accelerometer measurements (Rebecca McGirr) and on regularisation strategies for gravity field estimation (Paul Tregoning).

Staff news

At the end of June Professor Stephen Cox retired to an Emeritus Professor position at RSES.

Dr Achraf Koulali left RSES to take up a 2-year appointment at the University of Newcastle upon Tyne and Dr Jon Pownall left to travel and then pursue other opportunities.

Drs Julia Pfeffer and Sebastien Allgeyer began working in the Seismology and Mathematical Geophysics group.

Dr Bishak Gayen joined the Earth Dynamics group in September.

Dr Marnie Forster stepped down from the position of Convenor of the Master of Science (Advanced) in July, after 3 years in this role.

Dr Simon McClusky took on the role of Associate Director HDR and Dr Paul Tregoning was Acting Director for ~ 3 months during 2018.

Student news

Christopher Cline (now at the NASA Johnson Space Center, Houston) and Richard Skelton (who has accepted a postdoctoral position at Xiamen University in China) completed PhD degrees in Rock Physics during 2018 (supervisor: Ian Jackson).

Siyuan Tian submitted her thesis at the end of August and now has a 1-year contract in the Fenner School (supervisor: Paul Tregoning).

Veronika Emetc submitted her thesis in September and is now working with the NSW Department of Transport on a 6-month internship (supervisor: Paul Tregoning).

Rebecca McGirr commenced her PhD in March. Her work will focus on estimating present-day mass loss and ongoing glacial isostatic adjustment in Antarctica (supervisor: Paul Tregoning).

Negin Moghaddam commenced her PhD in July. She will be studying tectonic deformation measured by InSAR (supervisor: Simon McClusky)

Aditya Sharma commenced his Masters research project on arsenic contamination of groundwater in eastern India (supervisor: Paul Tregoning)

Siyuan Zhang completed his Masters research project on crustal deformation in Indonesia (supervisor: Simon McClusky)

Tongzhang Qu, working on chemical influences on the seismic properties of upper-mantle materials, transferred from MPhil to PhD candidature (supervisor: Ian Jackson)

Ruoran Nie commenced her Master of Science (Advanced) in February 2018 and will complete in December 2019. Her research project is on the exhumation of HP/LT rocks in the central Aegean (supervisor: Marnie Forster)

Sonia Ho Yeung commenced her Master of Science (Advanced) in February 2018 and will complete in December 2019. Her research project is on the timing of extreme extension in the central Aegean (supervisor: Marnie Forster)

Kristen Marris commenced her Master of Science (Advanced) in 2017 as a part-time student, changing to being a full-time student 2nd Semester 2018. She will complete in December 2019. Her research project is on the timing and character of the Tuff Marker Beds in the Mt Isa region (supervisor: Marnie Forster)

Emeritus, Honorary staff and Visitors

Emeritus Professor Stephen Cox is exploring relationships between injected fluid volumes and cumulative moment release to quantify volumetric flow rates and fluid production rates associated with natural, contemporary injection-driven earthquake swarms.

Earth Dynamcis hosted two Princeton undergraduates, Katharine Schassler and Rohan Joshi, for 8 weeks as part of their International Intern Program. Katharine worked on elements of the analysis of GRACE data, while Rohan worked on estimating deformation of the Australian continent using GPS data.

Dr Lesley Wyborn (GA and ANDS) is collaborating with Marnie Forster on building a global network for a Geochemical and Geochronological database with the aim of linking the National Argon collaborative project nationally and internationally.

Extended travel and outcomes

Kathryn Hayward spent 3 weeks visiting Ecole Normale Supérieure in Paris, to work with Professor Alexandre Schubnel using specialised equipment to record acoustic emissions and dynamic strain measurements during fast slip on faults. Data acquired during this collaboration provides important additional information for the projects undertaken in the High Pressure Rock Physics Lab at RSES.

Outreach activities & Service roles external to ANU

Dr Julia Pfeffer mentored two groups of students (Telopea Park School) for their scientific project on the Astrolabe ship. The Earth Dynamics group also hosted Year 12 from Daramalan College and presented research activities regarding ocean modelling (Dr Bishak Gayen), sea level rise (Dr Julia Pfeffer) and estimating the temporal gravity field of the Earth from satellite measurements (Rebecca McGirr).

Paul Tregoning hosted a work experience student from Narrabundah College and ran a research project for a Year 10 student from Daramalan College.

Em. Prof. Stephen Cox contributed to a 2-day workshop on “Applied Structural Geology of precious metal bearing hydrothermal mineral systems” at the annual conference of the Society of Economic Geologists in Keystone, Colorado in September. At the invitation of BHP and the Australasian Institute of Mining and Metallurgy, he presented a 2-day workshop on “Deformation Processes and Structural Analysis in Fracture-controlled Hydrothermal Systems”. He also presented a lecture on “Injection-driven failure and the dynamics of fluid migration in intrusion-related hydrothermal systems: insights from coupled hydro-mechanical modelling” to the local branches of the Australasian Institute of Mining and Metallurgy in Roxby Downs and Adelaide and gave an invited keynote lecture on “Injection-driven failure and fault mechanics in high fluid flux regimes” at the annual conference of the UK Tectonic Studies Group at Plymouth University in January.

EXPERIMENTAL PETROLOGY

Group leader: Andrew Berry

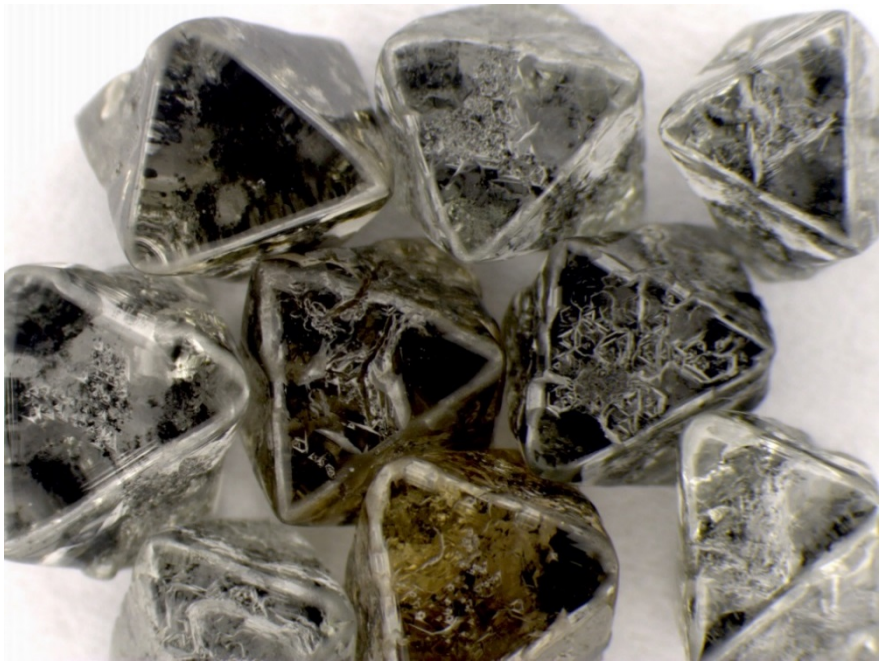
Academic members: A. Acosta-Vigil, A. Burnham, I. Campbell, C. Frigo, C. Le Losq, G. Mallmann, J. Mavrogenes, H. O’Neill, G. Yaxley

The Experimental Petrology group comprised five members of continuing academic staff (Berry, Campbell Mavrogenes, O'Neill and Yaxley), five postdoctoral fellows (Acosta-Vigil, Burnham, Frigo, Le Losq and Mallmann), 19 PhD students and two technical staff. Antonio Acosta-Vigil left us to take up a continuing position at Universidad de Granada, while we welcomed Corinne Frigo who will work with Hugh O'Neill and Richard Arculus on peridotite melting. PhD students James Tolley (now a postdoc at CODES, University of Tasmania), Melanie Sieber (postdoc at GFZ Potsdam), and Hongda Hao (postdoc at Laurentian University) all submitted their theses, while Eleanor Mare (postdoc at St Andrews) and Louise Schoenveld (postdoc at CSIRO, Perth) both graduated. Zachary Sudholz joined us to do a PhD on a Geoscience Australia funded project on the lithosphere under the North Australian Craton. The Group also supervised 3 Masters and 2 Honours students in 2018.

Research highlights include

i. a paper in Nature, which was the subject of a News & Views article (doi: 10.1038/d41586-018-02828-y), on how the redox state of the mantle affects its seismic properties (doi:10.1038/nature25764)
ii. two papers in Earth and Planetary Science Letters on the oxidation state of iron in mid-ocean ridge basalts (doi.org/10.1016/j.epsl.2017.11.032 and doi.org/10.1016/j.epsl.2018.10.002)
iii. a paper on using experimental petrology to investigate V isotope fractionation (doi:10.1007/s00410-018-1451-8)

iv. a paper in EPSL on the carbonation of antigorite by C-O-H fluids in the forearc, which identified a previously unrecognised reservoir of C in the mantle (doi: 10.1016/j.epsl.2018.05.027) and
v. yet another paper in EPSL, this one on the timescale of metasomatic processes in the mantle, which used diffusion profiles to constrain the duration of an event that occurred over 100 million years ago to a few 10s of years (doi:10.1016/j.epsl.2017.10.021).



Diamond octahedra from Argyle, Western Australia (edge length ~ 6 mm). We are using the composition of diamonds, and their mineral inclusions, to investigate the Earth's mantle.

In the laboratory, a new digital temperature and gas control system has been commissioned for our five 1 atm gas-mixing furnaces. We continue to operate 11 piston cylinders (4 of which are fully automated for both pressure and temperature) and a multi-anvil. Our old Cameca SX100 electron microprobe was decommissioned, coinciding with the full operation of a JEOL JXA-8530F Field Emission Gun Probe (funded by an ARC LIEF grant led by Greg Yaxley) installed in and operated by the Centre for Advanced Microscopy.

Berry and Yaxley were awarded an ARC Discovery Grant on the geochemistry of REE elements, while Berry, O'Neill, Burnham, Mallmann, and Mavrogenes were all awarded beamtime at synchrotron light sources.

The Sue Kesson Experimental Petrology Student Travel Grant, awarded jointly to Nick Farmer and Melanie Sieber, allowed Farmer to undertake multi-anvil experiments at Universität Bayreuth and the Advanced Photon Source, USA, and Sieber to visit her co-supervisor and former Experimental Petrology group member Jörg Hermann at the Universität Bern and attend the Experimental Mineralogy, Petrology and Geochemistry Conference in Clermont-Ferrand.

Hugh O'Neill was awarded a Forschungsaufenthalt from the Alexander von Humboldt Stiftung that enabled him to spend three months at the Universität Münster, and Andrew Berry was awarded a visiting Professorship by the Institut de Physique du

Globe de Paris, where he spent two months. Andrew Berry was also a member of the Advisory Panel of the MEX (Medium Energy XAS) beamline being built by the Australian Synchrotron. Greg Yaxley represented Australia at the Chikyu IODP Board Meeting in Kobe and served on the ANZIC Science Committee. He also continued his involvement in the Deep Carbon Observatory, which is a privately funded international research programme on all aspects of C in the Earth. Ian Campbell served on the Fellowship Committee of the American Geophysical Union. Finally, Andrew Berry and Caroline Eakin (from the Seismology and Mathematical Geophysics Group) were awarded the Colleges of Science Award for Teaching Excellence.

We also benefited from the contributions of Richard Arculus (Emeritus) and Lynton Jaques (Visiting Fellow) who co-supervise a number of PhD students. Andrea Gerson (Adjunct Professor) is involved with our research on critical metals while Yi Cao (Visitor from the Chinese University of Geoscience, Beijing) worked with Ian Campbell on the Pt group element geochemistry of the Tongling region in China.

GEOCHEMISTRY AND COSMOCHEMISTRY

Group Leader: Trevor Ireland

Academic members: Y. Amelin, J. Avila, V. Bennett, M. Honda, M. Kendrick, P. King, I. Williams

2018 Overview

Geochemistry and Cosmochemistry has its roots in the original Geochronology and Isotope Geochemistry Group of RSES. As such it encompasses a long history covering isotope analytical work (SHRIMP, TIMS, noble gases), but G&C now has new directions in geochemistry with the SpecE lab (spectroscopy, characterization and experiments) and X-ray diffraction (XRD) laboratory (mineralogy).

In the SpecE lab, a new dry air purge system has been installed in the IR spectrometer allowing for much improved analysis of trace volatiles in minerals and glasses. We can now mount a heating/cooling gas-flow stage on the microscope for in situ experiments of dehydration and gas uptake. A portable laboratory for undertaking toxic gas reactions with solids is now set up. The three older XRD instruments have been replaced with a new state-of-the-art XRD that includes micro-XRD capabilities, a slurry cell and also automated sample changing for up to 45 samples.

SHRIMP has shifted dramatically over the years from an instrument used primarily for U-Pb geochronology in zircon, to three instruments used for a variety of analyses including stable isotopes, trace elements, as well as geochronology. This year has seen some dramatic improvements in our capabilities for measuring minor isotopes of sulfur and oxygen. This is based on the charge mode capability developed at RSES Electronics for measuring small ion currents on Faraday cups. This has allowed us to move away from multipliers with inherent drift, and resistive mode on Faraday cups, which is susceptible to significant background noise. This has allowed us to improve

our analyses to precision levels around 0.2 ‰ for measurements of $\Delta^{17}O$ and $\Delta^{36}S$ in meteoritic materials and sulphides respectively. The latter achievement gives us an unprecedented capability in assessing the involvement of biogeochemical reactions in the reduction of sulfur in mineral deposits. These capabilities are indeed world-leading, but are based on many years of investment and development from many areas of RSES.

The SPIDE^{2}R Lab has diversified its analytical scope by developing the methods for isotopic analysis by total sample evaporation under controlled conditions. This method has been applied to absolute isotopic ratio determination of potassium and calcium for precise first principles calibration of the ^{40}K-^{40}Ar geochronometer and Mg/Ca paleothermometry. This development is supported by our novel method for chemical separation of potassium from rocks, minerals and waters using Eichrom Sr-spec resin. The methods of U-Pb dating have been further refined for precise dating of ungrouped meteorites with unusual mineralogy and chemical composition. A breakthrough project completed in the SPIDE^{2}R lab this year is Pb-isotopic and Rb-Sr analysis of micro-inclusions in diamonds containing picogram quantities of Pb and Sr (part of a PhD project by S. Timmerman) that allowed a direct insight into the composition of the mantle transition zone.

A capability for vacuum encapsulating fine grained samples was developed in the noble gas and halogen laboratory and exploited to determine halogen abundances in whole rock sample powders from irradiation-produced noble gas isotopes. This was significant for enabling precise iodine and bromine measurements in seafloor samples recovered by the International Ocean Drilling Program (IODP) for the first time. The Helix-MC *Plus* multi-collector noble gas mass spectrometer and its dedicated gas handling system are functioning well. During the year, in collaboration with Thermo-Fisher Scientific, we completed development of a collector automation kit for the mass spectrometer, which is now commercially available. This year one was sold to the University of Manchester. Utilising the mass spectrometer, high quality noble gas data from minute amounts of well-characterised diamonds were produced, including super-deep diamonds from Brazil. These results are useful to constrain the structure of the mantle and how it has changed since Earth's formation.

Geochemistry & Cosmochemistry Xmas Party 2018. Congratulations Janaina!

Other Highlights:

Vickie Bennett is co-editor of a major new reference work: Earth's Oldest Rocks 2nd edition, Elsevier. 1114 pp. (2018) Eds. Van Kranendonk, M.J., **Bennett, V.** and Hoffman, E.

Penny King was elected to Fellow of the Mineralogical Society of America.

Staff news

Assoc. Prof. Masahiko Honda and Prof. Ian Williams formally retired this year, but remain active in the group in their new roles as emeritus faculty.

Mark Kendrick was converted to a continuing faculty position.

Penny King was promoted to Professor.

George Gibson was appointed to Honorary Associate Professor.

We note with great sadness the passing of Emeritus Professor Ian MacDougall, who for many years was leader of the Geochemistry group. His presence in the School will be missed.

Student news

PhD theses submitted/completed:

Patrick Carr - (Supervisor: V. Bennett and M. Norman) "Tourmaline geochemistry and cassiterite geochronology of highly evolved tin granites and their hydrothermal systems in eastern Australia." Thesis submitted July 2018. He is currently working at University College, London.

Suzette Timmerman - (M. Honda, L. Jaques and A. Burnham) "Diamonds – time capsules of volatiles and the key to dynamic Earth evolution." Thesis submitted December 2018. Accepted a postdoctoral position at University of Muenster, Germany.

Christian Renggli – (P. King) "Volcanic Gases and the Reaction of Sulfur Dioxide with Aluminosilicate Glasses." Thesis awarded. Now a Swiss National Science Fellow at University of Muenster, Germany.

Morgan Williams - (MA Kendrick and T Ireland) "Tracing fluids from the seafloor to deep subduction environments." Thesis submitted Feb 2018. Now a Postdoctoral Researcher at CSIRO, Perth.

PhD Milestones:

Li Liu and Liane Loiselle (Supervisor, T. Ireland), Jennifer Prichard (M. Norman and V. Bennett), Suzette Timmerman (M. Honda) and Mimi Chen (I. Campbell and Y. Amelin) completed their PhD thesis oral presentations.

New PhD students:

Bowen Fang (Supervisor V. Bennett): Thesis topic: "Variations of Hf-Nd Isotopic Pattern in Ancient and Modern Rocks as A Monitor of Source and Process".

Yankun Di (Supervisor Y. Amelin): Thesis topic: “Formation time of the first solids in the Solar System”.

Yevgenii Krestianinov (Supervisor Y. Amelin): Thesis topic: “The early history of asteroids: accretion, differentiation, and magmatism”.

Durgalakshmi (Supervisor: Ian Williams) Thesis topic: “The petrogenesis, chronology and thermal history of a possible late Archaean crustal cross-section, Tamil Nadu, southern India”.

Rachel Kirby (Supervisor P. King, transferred to G&C from another part of the School) Thesis topic: “Impacts on Chondritic Bodies: Analytical, Modelling and Experimental Studies of the Geochemical Processes and Products”.

MPhil Student:

Leonardo Baeza (Supervisor T. Ireland) submitted his thesis “Oxygen isotopic compositions of chondrules from Ordinary Chondrites: insights into the inner solar system planetary reservoir”.

M Earth Science (Advanced) students:

Andrew Palm (Supervisor P. King) “High Temperature Reactions Between SO_2 and Basaltic Glasses: Element Fractionation, Mineral Formation and Thermodynamic Models”.

P. Merriman (Supervisor B. Pillans and P. King) “Draining the Swamp: Variability in Soil Productivity and Infiltration in Dry Lagoon, NSW”

Honours students:

K. Robb (Supervisor P. King) “Hornblende in I-type granites of the Bega Batholith, Lachlan Fold Belt, Australia: Petrography, Chemistry and Barometry”

R. Baile (Supervisor P. King) “Evaluating Carbonate Formation from Gas-Solid Reactions in the Early Solar System: Evidence from Geochemical Models and the Tagish Lake Carbonaceous Chondrite Meteorite”

A Weirman (Supervisor P. King) “Tufa and Microbialites from Lake Gnotuk, western Victoria”

Outreach activities & Service roles external to ANU

Trevor Ireland completed his term as President of The Meteoritical Society in 2018.

Vickie Bennett began her term as Vice-President (President-elect) of the Geochemical Society.

Conference Organisation:

- Franco-Australian Astrobiology and Exoplanet School and Workshop (Convenor Charley Lineweaver and co-conveners).
- Elizabeth and Frederick White Conference on Gas-Solid Processes (Convenor Penny King).

- Workshop on Metrology, Goldschmidt Conference, Boston (Yuri Amelin and co-conveners).
- Mineralogical Society of America Short Course on Gas solid reactions, Goldschmidt Conference, Boston (Penny King and co-conveners).
- Special Session on Melt, Gas, and Redox Evolution in Magmatic Systems: Commemorating the accomplishments of John R. Holloway (1940-2017) - Gas-(Fluid)-Solid Reactions at High Temperatures, Goldschmidt Conference, Boston (Christian Renggli and co-conveners).

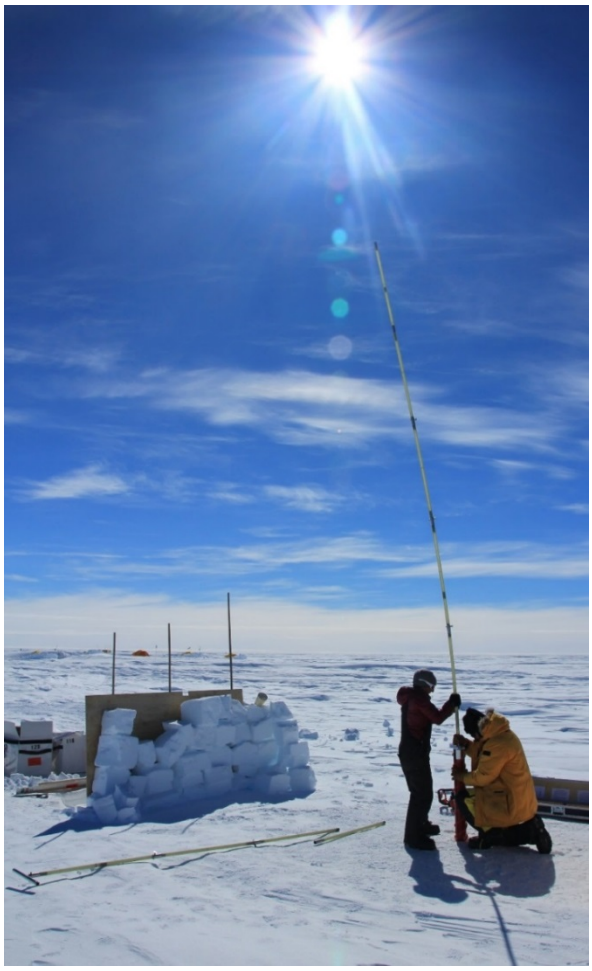
PALAEOENVIRONMENTS

Group Leaders: Bradley Opdyke & Jimin Yu

Academic members: N. Abram, K. Grant, D. Heslop, F. Hibbert, G. Marino, B. Pillans, A. Roberts, E. Rohling, N. Wright

Highlights for 2018:

Nerilie Abram continued her work as a Coordinating Lead Author on the IPCC Special Report on the Ocean and Cryosphere in a Changing Climate, which is due to be released in September 2019. As part of an international team (building upon a workshop held in Bern in 2017), she also co-authored a review paper on palaeoclimate evidence for changes associated with warming of 2°C and beyond (Fischer *et al.*, 2018, Nature Geoscience). Nerilie also led the in-field science team drilling an ice core from the Mount Brown South site in East Antarctica. The team recovered a 295m core that should provide 1,000 years of climate history, and the project was funded through an Australian Antarctic Science Program grant led by Tessa Vance (ACE CRC). In addition, fieldwork to collect coral core samples from Christmas Island (for Jessica Hargreaves' PhD project; Hargreaves, Abram, Mallela, Branson) was completed in October-November 2018 (funded through a Future Fellowship, Abram).



Shallow ice core drilling in Antarctica

Research led by Andrew Roberts and Dave Heslop revealed the surprising rapidity with which magnetic reversals occur (one or two centuries to millenia) using a multi-decadally resolved geomagnetic excursion record from a radiometrically dated Chinese speleothem (Chou *et al.*, 2018). In addition, Roberts *et al.* (2018) critique of the widely used Day diagram, used to classify magnetic mineral assemblages, and the many issues (at least 10) that result in large variations in the distribution of data within in Day diagrams. They argue that this ambiguity undermines the use of Day diagrams to diagnose sample particle size, mineralogy, and domain states and that there is an urgent need to adopt new approaches for diagnosing the properties of magnetic mineral assemblages.

The relationship between palaeoceanographic conditions of the Southern Coral Sea and the North Atlantic during Heinrich Events of the last 30 ka (led by PhD student Ryan Owens, supervisor Brad Opdyke) was presented at AGCC (October). Brad also presented preliminary findings from the recent cruise to the Sabrina Shelf, Antarctica, in Davos. Work on Lake George (Pillans, Opyke) was presented in Stockholm, and there will be a dedicated session at AQUA (see below) focusing on this unique southern hemisphere palaeoclimate record.

Eelco Rohling was in one of the finalist teams in the ANU's Grand Challenges initiative ("Enhanced Earth Systems"). The project aimed to demonstrate the economic viability and environmental gains of landcover change for CO_2 drawdown. Eelco was also involved in collaboration exploring the international governance arrangements that will be required to facilitate negative emissions research - an essential component of reaching the Paris Agreement targets (Brent et al., 2018, Nature Climate Change). Using observational and geological constraints on the potential CO_2 pathways required to achieve the 1.5 °C and 2°C warming targets (Paris Agreements), Eelco and collaborators (Goodwin *et al.*, 2018) suggest these warming targets will be reached in ~17 and 35-41 years, respectively, if the carbon emission rate remains at present-day values.

Research involving Jimin Yu demonstrated the drawdown of atmospheric CO_2 over the middle Miocene was probably caused by combined effects of increased shelf carbonate weathering, expanded land biosphere carbon storage and a sluggish deep Pacific meridional overturning circulation (Ma *et al.*, 2018). On shorter timescales, Southern Hemisphere westerlies were found to be a driver of the early deglacial atmospheric CO_2 rise through enhanced Southern Ocean upwelling (Menviel *et al.*, 2018).

Funding awarded: Five members of the palaeoenvironments group enjoyed ARC grant success – Jimin Yu, Andrew Roberts/Dave Heslop (DPs); Katharine Grant (DECRA); Eelco Rohling (LEIF). Jimin was also successful in a MEC bid for an iCAP ICP-MS and a PrepFAST MC system.

Other activities:

Jimin and his student Yuhao Dai successfully developed a method to reliably measure boron isotopes for marine carbonates using the Neptune plus. This method is very

close to being ready to use, after completing the final column chemistry work (either manual or using their new MEC-funded PrepFAST MC).

The group had a strong presence at the Australian Quaternary Association conference (AQUA, December, 2018) with a special session on Lake George (Brad Opdyke, Brad Pillans) and oral presentations by Patrick De Deckker, Katharine Grant, Fiona Hibbert, Brad Opdyke, Brad Pillans and Nicky Wright.

Open access datasets:

Hibbert & Rohling published a comprehensive online database of sea level indicators for the last 25 ka, including code for probabilistic calculation of past sea levels (Hibbert *et al*., 2018 Scientific Data)

Staff news

Dr Nicky Wright joined the group in February (joint with Climate and Fluid Physics). Nicky is working with Nerilie Abram as a postdoctoral researcher of the Centre of Excellence for Climate Extremes, and came to RSES after completing a PhD at the University of Sydney.

Dr Jennifer Wurtzel left the ANU and is now working at the NSW Department of Primary Industries.

Dr Katharine Grant was promoted to Research Fellow

Student news

New starters:

- Yingxin Kou (supervisor: Rohling)
- Song Zhao (started Dec. 2018; supervisor: Grant; topic: Long-term variability of the Australian monsoon)
- Congcong Gai (supervisor: Roberts)
- Yuzhi Hu (supervisor: Eggins)
- Jessica Hargreaves (started March 2018; supervisor: Abram; topic: variability of the Indian Ocean Dipole throughout the Last Millennium and its response to large volcanic eruptions).

Thesis submissions/conferral of PhD:

Yuhao Dai (supervised by Jimin Yu) obtained his PhD, which focussed on Boron proxies and the Mg-palaeothermometer in planktonic foraminifera.

Jennifer Wurtzel (supervised by Nerilie Abram) completed her PhD and published a 16,000 year reconstruction of rainfall from a Sumatran speleothem (Wurtzel *et al*., 2018, EPSL). She was awarded the 2017 Robert Hill Memorial Award for scientific excellence and communication, and took up a permanent job with the NSW Department of Primary Industries working on drought assessments for agriculture.

Jessica Amies (supervised by Eelco Rohling) submitted her thesis in October 2018 and has started a post-doctoral position at RSES to work on the Mediterranean sea-level method.

Emeritus, Honorary staff and Visitors

Research by Bob Burne on ancient and modern microbialites continued in collaboration with SEES, University of Queensland, Göttingen University, RSPE ANU and Southwest Petroleum University Chengdu. A new model for the growth and limiting size of ooids based on biofilm growth and organomineralisation has been developed from our studies of Triassic oolites in China and Germany, as well as various modern occurrences. Research continues on the microbialtes associated with various lakes and cenotes in south east South Australia.

Patrick de Deckker completed a comprehensive review of MIS4 (currently in press), two multidisciplinary papers on short cores from offshore Tasmania reconstructing conditions for the last 450k years, as well reviews of Australian dust and dolomite in Australian lakes (both currently in review).

Extended travel

Sabrina Shelf, Antarctica (Opdyke)

Israel, Alps, Japan (Andrews, Heslop)

Antarctica (Abram), Christmas Island (Abram, Hargreaves, Mallela, Branson)

Outreach activities & Service roles external to ANU

Members of the group have taken to the airwaves in 2018. Eelco Rohling made it onto Radio Sputnik (Moscow), giving a palaeo-perspective about current unprecedented rates of CO_2 rise, and Brad Oydyke has a regular monthly radio spot talking about various climate change issues on Radio Landcare (2XX FM radio, Tuesday mornings). Brad also gave an invited talk to local Landcare groups at a Climate Change Forum (Yass, May)

Eelco Rohling published another popular science book this year, “The climate question: natural cycles, human impact, future outlook” (Oxford University Press), in addition to several mainstream articles for Cosmos Magazine (threats to the world’s reefs), Natural History (exploration of the deep ocean) and Zocalo Public Square (lessons for the future of the oceans from the geological record).

Several members volunteered their time for the Girls into Earth and Marine Science (GEMS) programme and various school visits

SEISMOLOGY & MATHEMATICAL GEOPHYSICS

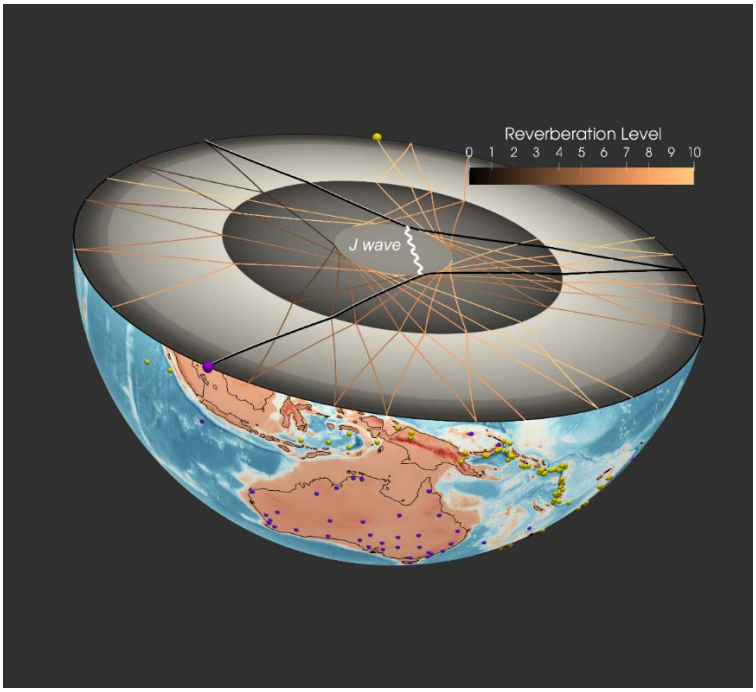
Group Leader: Hrvoje Tkalčić

Academic members: P. Cummins, D.R. Davies, C. Eakin, B. Hejrani, M. Miller, M. Mustac, M. Sambridge, B. Tauzin, A. Valentine, L. Waszek

2018 Overview

Notable achievements of the Group's members include the 2018 Hales Medal awarded to Dr Rhodri Davies, the Marie-Sklodowska Curie Fellowship awarded to Dr Benoit Tauzin, and a DECRA award to Dr Caroline Eakin. In addition, Dr Caroline Eakin and A/Prof Meghan Miller were each awarded ANU Futures Grants.

Research highlights on Earth structure start with groundbreaking research published in Geophysical Research Letters by PhD student Son Pham and others, in which the nature of Earth's correlation wavefield was explained. This was followed by the work published in Science that solved an 80-year-long quest for the Holy Grail of body wave seismology to detect shear waves in the Earth's inner core and infer shear properties of the Earth's centre. No less significant work in global seismology ranged from reporting global observations of mid-mantle reflectors and petrologic characterisation of the mantle transition zone to mapping the Alaskan Moho and subduction zones, inferring the properties of the Antarctic ice cover, and explaining the role of oceanic transform faults in seafloor spreading. Furthermore, the group led and published theoretical work on Earth's correlation wavefield and various aspects of inverse problems. The group also published a new mean land-surface temperature model for the Australian continent.



Detection of shear waves in the Earth's inner core

Another research direction that the Group successfully pursued was the physics of seismic sources and tsunamis, with highlights on the source mechanism inversion of the 2016 Petermann Ranges earthquake, and an improved understanding of megathrusts in Sumatra and Japan, in collaboration with Earth Dynamics Group. The group continued to link geochemical and seismological observations to constrain the dynamics of mantle plumes (with 2 papers published in Earth and Planetary Science Letters) and also quantified the crucial role of mantle plumes in the force-balance governing tectonic plate motions (published in Nature Geosciences).

New directions of the Group include the exploration of the Southern Oceans. The Group's maiden voyage to the Macquarie Ridge Complex region will take place in March 2020, after our bid for the ship time on RV Investigator to the Marine National Facility was successful earlier this year. The Group's notable deployments in Australia during 2018 include those in the Lake Eyre and a spiral-arm array in Northern Territory, aided by the Warramunga staff, Mr Joel Tatapudi and Mr Rajesh Erigela. Overseas, the group deployed new instruments in the Alaska Range of the USA, an aftershock deployment on Lombok, and continues to maintain a broadband array in NTT in Indonesia and Timor-Leste.

Earlier this year, we completed complex negotiations on the Warramunga station maintenance and operation with the UN in Vienna. The Group continues to run Warramunga on behalf of the United Nations and the Australian Government.

A/Prof Meghan Miller is now directing AuScope Earth Imaging Program working with Dr Michelle Salmon and Professor Malcolm Sambridge in the Australian Seismometers in Schools Program (AuSiS). She is also assisted by ANU Visitor, Dr Alexey Goncharov, on the OBS fleet maintenance. AuSiS extended their network of high school seismometers with the welcome addition of a new instrument in the Anangu Pitjantjatjara Yankunytjatjara community in Pukatja, SA. This year the Group has been working towards FAIR data principles with the launch of the new AusPass data server (auspass.edu.au), which will eventually serve all of ANU's seismic data to the broader international research community. The portal provides easy access to our own researchers and ensures that the Group will be given credit for the data collected from experiments we lead.

Two international excursions for ANU undergraduate students were conducted under the New Colombo Plan Program: Dr Sima Mousavi co-led a trip to the University of Tokyo to study natural hazards and Prof Phil Cummins led a separate group to study in Indonesia.

Staff news

Dr Benoit Tauzin was awarded the Marie Sklodowska-Curie Fellowship and started his 2 year stay in the group as Visiting Research Fellow.

Mr Sam Gubicak started a casual position as an assistant at Warramunga station.

Mr Alejandro Lara started a casual position as a field assistant.

Dr Babak Hejrani started his 0.6FTE appointment in Geoscience Australia and remains working in the group with 0.4FTE.

Dr Marija Mustać accepted a research position at the University of Zagreb and left her postdoctoral position in the group.

Dr Rhys Hawkins left to take up a postdoctoral position at the University of Lyon.

Dr Caroline Eakin was awarded an ARC DECRA and the College of Science Teaching award.

Dr Andrew Valentine started his appointment as a DECRA fellow.

Dr Meghan Miller started her appointment as Associate Director for Engagement.

Dr Rhodri Davies was awarded tenure, received the 2018 Anton Hales medal from the Australian Academy of Sciences, was promoted to Associate Professor, and started his appointment as Associate Director for Honours & Masters Education.

A/Prof Hrvoje Tkalčić was promoted to Professor.

Student news

Our current PhD students are

Thuany Patricia Costa de Lima (PhD; supervisors Hrvoje Tkalčić and Lauren Waszek)

Hendro Nugroho (PhD; supervisor Meghan Miller)

Nova Roosmawati (PhD; supervisor Meghan Miller)

Rexha Ry (PhD; supervisor Phil Cummins)

Sheng Wang (PhD; supervisor Hrvoje Tkalčić)

Yi Wei (PhD; supervisors Malcolm Sambridge and Andrew Valentine)

Ping Zhang (PhD; supervisor Meghan Miller)

Tim Jones was awarded his PhD and has moved to a prestigious Fellowship at the Carnegie Institute, Washington DC.

MESA students:

Angelina Egorova (supervisor Hrvoje Tkalčić)

Chuang Wang (supervisor Benoit Tauzin; defended his Thesis)

Emeritus, Honorary staff and Visitors in the group and their contributions

Emeritus Professor Brian L.N. Kennett continues with strong international presence and high publication output. This year, he also published the book “The Australian Continent: A Geophysical Perspective”.

Professor Andreas Fichtner was a group visitor from ETH as a long-term collaborator on several projects with the group members.

Professor Fabrice Fontaine was a group visitor from the University of Reunion as a long-term collaborator with Dr Tkalčić and Professor Kennett.

Dr Satoru Tanaka and Dr Tashiki Ohtaki were the group's visitors from JAMSTEC. We have a memorandum of understanding between RSES and JAMSTEC regarding the use of passive broadband seismic data deployed by the two groups.

Dr Alexey Goncharov is visiting the group as the OBS Science coordinator.

Dr Cian Wilson and Dr Stephan Kramer visited the group to continue development and validation of state-of-the-art computational tools for geodynamical research.

Extended travel and outcomes

A/Prof Meghan Miller attended and taught at the CIDER Summer Program at the Kavli Institute of Theoretical Physics at UC Santa Barbara.

Dr Caroline Eakin sailed on the Pacific ORCA voyage aboard the Kilo Moana deploying Ocean Bottom Seismometers in the central Pacific Ocean.

Outreach activities & Service roles external to ANU

Group members continue to be involved in numerous editorial boards and external committees' activities as listed elsewhere in this report.

This year group members gave science talks at the following schools: Melrose High School, ACT, Oak Valley School, SA, Georgiana Malloy Anglican School, WA, St Anne's Primary School, WA, St Josephs College, WA, Kulin District High School, WA, Kincumber High School, NSW, Snowy Mountain Grammar, NSW, and Roxby Downs High School, SA.

A/Prof Hrvoje Tkalčić has been elected a member of ARC College of Experts. He gave numerous interviews to the newspapers, radio and television on the Group's research results and the role of seismology in nuclear non-proliferation.

The Group continues to maintain and operate the Warramunga Seismic and Infrasound Station in Northern Territory on behalf of the Comprehensive Nuclear Test Ban Treaty Organisation at the United Nations to fulfil Australia's international obligations.

AUSTRALIAN AND NEW ZEALAND IODP CONSORTIUM (ANZIC) OFFICE

Group Leader: A/Prof. Leanne Armand (Program Scientist).

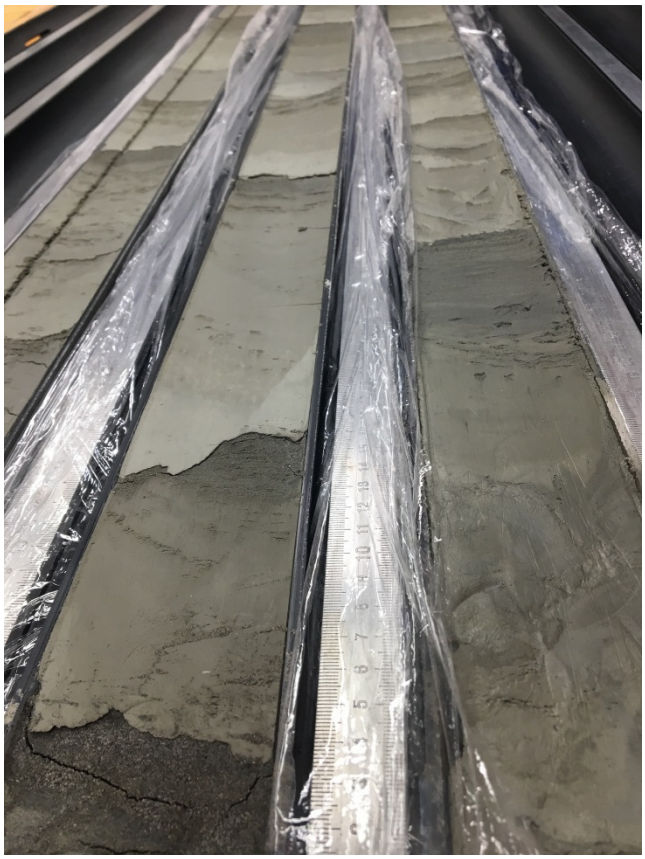
The Australian and New Zealand International Ocean Discovery Program Consortium (ANZIC) office, hosted in RSES at ANU, was very busy in 2018 as ANZIC scientists participated on six expeditions and another successful round of Legacy Grants were awarded to 11 ANZIC consortium members to the combined total of $140K.

The six 2018 IODP expeditions were:

- Exp. 372 – Creeping Gas Hydrate Slides and Hikurangi LWD
- Exp. 374 – Ross Sea West Antarctic Ice Sheet History
- Exp. 375 – Hikurangi Subduction Margin Observatory
- Exp. 376 – Brothers Arc Flux
- Exp. 358 – NanTroSEIZE Plate Deep Boundary Riser 4 (JAMSTEC/Chikyu)
- Exp. 381 – Corinth Active Rift Development (ECORD/Mission Specific Platform)

Significantly, four IODP Expeditions occurred in the Australian and New Zealand region on the RV JOIDES Resolution. The national economic impact to both Australia and New Zealand in having these Expeditions berth at local ports over the last few years has been estimated to be in the order of A$17.7M (US$13M).

ANZIC sailed a total of 17 scientists (an excellent outcome given our official quota within the program is one berth per expedition), inclusive of four Co-Chief Scientists, and four Outreach and Education Officers. One of the previously scheduled 2018 Expeditions, 378 South Pacific Paleogene Climate, for which we have secured two scientific berths, was deferred to 2020 due to mechanical difficulties of one of the RV JOIDES Resolution propeller shafts. The shaft was repaired and both propellors replaced whilst the ship was in dry-dock. The four regional voyages also enabled the ANZIC members to showcase the RV JOIDES Resolution to politicians, scientists, students, science educators and industry personnel whilst in port.



Split core sections aboard the RV *JOIDES Resolution*

In other activities, ANZIC continues to perform as a training pipeline for Marine Geoscience in Australia, offering

a) an undergraduate Masterclass to 20 high performing second and third year students currently run by New Zealand ANZIC partners headed by GNS;

b) participation on the International IODP School of Rock, this year held in Auckland, New Zealand, for five Australian and four New Zealand science educators, and

c) providing $140,000 in small analytical grants for research using previously cored IODP material.

Other national activities included representation at Science Meets Parliament, a seat on the National Marine Science Committee (NMSC) and both an IODP session and booth at the Geological Society of Australia's biannual conference in collaboration with our JAMSTEC colleagues, in Adelaide, and also at the NZ Geoscience Society meeting in Napier, New Zealand.

Australian Geoscience Council Convention (AGCC), Adelaide, October 2018

Publication data are not yet complete for 2018, however, the latest data provided in the recent 2017 Annual Report, show there were 1405 peer-reviewed IODP publications altogether, 198 with Australian and New Zealand co-authors (11.8% and 3.8%, respectively, of all publications). Of all IODP publications, there were 329 in the

top tier journals or within the top 20 Earth Science Journals. ANZIC members published 27 of these works (8%).

Program Scientist, Leanne Armand represented ANZIC at international IODP governance meetings in Goa, India, and at international science planning meetings in Venice, Italy, Kobe, Japan, La Hague, Netherlands, and Washington DC, USA. The ANZIC Governing Council and the Science Committee have met four and two times, respectively, to oversee governance and the selection of scientists to represent ANZIC in all IODP related matters. She also attends and represents ANZIC at the National Marine Science Committee (NMSC), which meets 4 times a year, and Science and Technology Australia (STA) meetings and/or events twice a year.

Staff news

The ANZIC Office welcomed Larisa Medenis as the new Communications Officer mid-year, and will say farewell to Catherine Beasley as the ANZIC Administrator at the end of 2018. A new ANZIC Administrator will be appointed in the new year.

Visitors to the ANZIC Office in 2018 included:

Dr Maureen Walczak, a research scientist in the College of Earth, Ocean, and Atmospheric Sciences at Oregon State University. Maureen's visit, supported by the American Australian Association, allowed her to work with collaborators and post-doctoral mentors at the ANU Research School of Earth Sciences on manuscripts stemming from her involvement as an ANZIC scientist in IODP Expedition 341: Southern Alaska Margin Tectonics, Climate, and Sedimentation.

Professor Yusuke Yokoyama of the University of Tokyo completed a PhD at the ANU in 2000 and led IODP Expedition 325, Great Barrier Reef Environment as Co-chief Scientist. Yusuke's is visiting ANU to conduct paleoclimate research using data obtained from IODP Exp325 Great Barrier Reef Environment.

Dr Rob McKay from the Victoria University of Wellington, who provided a presentation on his recent Exp. 374 to the Ross Sea and also completed his hand over of his Chair of the ANZIC Science Committee role.

Prof. Neville Exon and Dr Elizabeth Truswell were honorary staff associated with the ANZIC Office in 2018. Both are contributing to major works related to IODP history, accomplishments and or research, which will be published in 2019.

RESEARCH SUPPORT

ELECTRONICS GROUP

Andrew Latimore (Group Manager), Tristan Redman, Daniel Cummins, David Cassar, Hideo Sasaki.

Overview

The Electronics Group provides technical support and engineering design services to the Research School of Earth Sciences, ANU academic research and partners. The Group consists of one engineer and four technical officers. The Electronics Group holds the responsibility for maintaining and developing electronic systems within the Research School of Earth Sciences and offers services to all ANU facilities. The Electronics Group services include; Advanced printed circuit board design and construction, electronic engineering design, advanced electronic diagnostics, Ion Microprobe and Mass-spectrometer fault diagnostics and repair services.

During 2018 the demand for electronic design, fabrication and support was consistently high, contributing 67% of the Electronics Group's labour distribution this year. The Group utilised 13% of resources on maintenance tasks and 10% on administrative tasks. The major development projects are summarised below.

terraSAWR

This year the Electronics Group completed 50 new terraSAWR seismic digital recorders and developed new features into the devices including, satellite telemetry and internal GPS antenna. This will allow the user to receive daily, state of health reports from the recorder in any location in the world.

PSIKA High Pressure Reactor

The Electronics Group in conjunction with the Mechanical workshop refurbished and re-engineered an existing PSIKA high pressure apparatus that compresses liquified samples. The project involved designing a new pressure and temperature control system, new user interface and interlocks. The refurbishment now allows the client safe, stable, repeatable performance enabling the apparatus to be utilised for various scientific analysis.

PSIKA high pressure reactor

Reef Ranger

The Reef Ranger is a new portable, quality low cost, conductivity, temperature and depth probe with digital recording, housed in a unique enclosure designed to withstand marine conditions up to depth of 50 meters. The project was developed by the Electronics Group in conjunction with Mechanical workshop. The Reef Rangers are an instrument that will allow students and researchers to analyse sea water salinity, at high resolution. The devices record conductivity at 0.01µS, temperature at 0.01 ^{0}C and pressure at 0.2 mbar resolution recording for up to 120 hours.

Sensitive High Resolution Ion Microprobe (SHRIMP) Electronics

This year the Electronics Group has continued to supply Australian Scientific Instruments Pty LTD with Electronic system for new SHRIMP projects. All new SHRIMP sales include electronics designed and constructed by RSES Electronics Group including

- *FC4* Magnetic field controller with new bipolar functionality and Fuzzy Control algorithm
- *TT4* Tesla Tamer magnet field sensors
- *IFLEX* Electrometers
- Magnet housekeeper

Other significant achievements of the Electronics Group this year include

- *Cvar*, vibrating reed electrometer with advanced digital control loop.
- Laser physics developments – Photodiode boards, PZT mirror, HV amp mk3, homodyne photodiode, LIDO broadband PD.
- SHRIMP sample micro-CNC mill motor controller
- ANU Seismic Recorder battery charger MRK II
- Laser servo amplifier 1GHz
- RIG #1 laser interferometer
- Laser Photodiode detectors
- Helix MC motor controller
- One Atmosphere Furnace Interface (OAFI) implementation
- Sample Strip heater controller
- 18 channel natural convection plate heater

Staff news

This year we sadly lost a long serving member of the Electronics Group, Daniel Cummins. We were fortunate to welcome Luke Materne into the Group on secondment from the Research School of Physics and Engineering Electronics Unit.

Training

This year the Electronics Group has been involved in training Brent Butler, who is completing a Certificate III in Electronics Engineering. Brent is a member of the

Mechanical Workshop, who is gaining valuable knowledge in electronics to improve his technical skills.

Hideo Sasaki has successfully completed this year's units of his Bachelor of Engineering in Electronics degree.

Committees and School Support

This year, David Cassar has continued to support the School as Laboratory Manger. Andrew Latimore and David Cassar are RSES representatives on the WHS committee.

MECHANICAL WORKSHOP

Andrew Wilson (Workshop Manager), Carl Were, Brent Butler, Geoff Woodward, Hayden Miller (1/2 time share with Rock Physics)

Overview

Workshop requests from within RSES decreased again in 2018. Work from other areas of ANU kept us well occupied, but relatively minimal full external work was done.

Internal charge rate: $100/hour + materials, consumables and running costs.

ANU and External Rate: $135/hour + materials, consumables and running costs.

This was the first year of the credit based cost recovery system in RSES.

Turnaround time on requests was generally short, however larger fixed cost projects from the Research School of Astronomy and Astrophysics and Research School of Chemistry at times limited our flexibility here.

The ANU Technical Workshop services review continued this year, with implementation of an ANU wide work management system the key focus. The system will enable all ANU staff and students to log jobs to any Mechanical or Electronics Workshop on campus. The system will see most of the larger workshops logging data using a unified system for the first time. The system, developed by the company Idea Elan, is due to be up and running imminently.

Significant investment in training was made this year with Brent Butler and Hayden Miller undertaking Certificate 3 level training in Electronics and Communications Engineering. It is envisaged that this course will provide improved mechanical design where electronics systems need to be implemented.

Brent Butler also trained up on several critical tasks for RSAA. He assisted RSAA at their request while they sought to replace their recently retired workshop manager.

The core work undertaken in 2018 included:

SHRIMP Maintenance and Development, including near completion of the new Multi-Collector for SHRIMP SI (Prof Trevor Ireland)

In a collaborative effort, RSPE and RSES Mechanical Workshops manufactured the bulk of components required for a Laser Launch Telescope (LLT) for RSAA. The EOS 1.8m laser tracking facility at Mt Stromlo is used to accurately track space debris. Its purpose is the prevention of collisions between satellites and space debris. To improve image quality, the ANU is developing an Adaptive Optics system for this instrument, which makes use of a laser guide star. This guide star is projected onto the Earth's upper atmosphere with the LLT.

RSES Electronics Group and RSES Mechanical Workshop took on the task of a major refurbishment and upgrade of the high pressure reactor at the Research School of Chemistry. This reactor is used to run chemical experiments at pressures up to 20kBar. This project was in the order of 500 hours of Mech workshop time and was funded through an RSC MEC Grant.

Dr Stewart Fallon kept us well occupied with some interesting developments:

A new detector was fitted to the Accelerator MS, requiring a new vacuum housing and detector mounts to be designed and built.

For the AMS line new five port Ultra-Torr manifolds were designed and machined from solid stainless steel, which has the advantages of no welds and minimal internal volume.

In addition the "Reef Ranger" sea water probe, mostly an electronics development, with some Mechanical Workshop input and manufacture was an excellent example of workshop staff implementing their electronics training to incorporate sensitive electronics components into a durable compact device.

2018 Resource Distribution		
Labour Totals	**Hours**	**% logged hours**
Non-billable Hours	2034	35%
Total billed Hours	3850	65%
Total logged hours	5884	
Billable Distribution (Internal RSES/External)		
Research Support RSES	2330	40%
Other Clients (ANU and External)	1520	26%
Non-Billable Distribution		
Training	778	13%
Administration (Including quotes for work that did not eventuate)	882	15%
Workshop Equipment, Servicing and Repairs	295	5%
Other	77	1%

Outreach activities

Delivery of Coral Coring Equipment to Dr Eleanor John of University of Fiji.

New Soil Temperature Probes for CSIRO Canberra.

Delivery of a Detector Automation Kit for Helix MC Plus for Prof Raymond Burgess, University of Manchester.

RESEARCH GRANTS AWARDED DURING 2018

A/Prof. Y. Amelin, Prof. Q-Z. Yin 'The history of accretion in our Solar System'; Australian Research Council Discovery Grant; 2019-2022; $300,000.

A/Prof. A.J. Berry, Dr A.D. Burnham, Ms L.A. Miller 'The oxidation state of cerium as an indicator of the ore-fertility of mountain belts.'; Australian Nuclear Science and Technology Organisation; 2018; $1,720 (in-kind value $65,568).

Prof. H.StC. O'Neill, A/Prof. A.J. Berry, Dr A.D. Burnham, Ms L.A. Miller 'The geochemical behaviour of copper in ore generating magmas'; Australian Nuclear Science and Technology Organisation; 2018; $1,720 (in-kind value $98,352).

A/Prof. A.J. Berry, Prof. G.M. Yaxley, Prof. A.R. Gerson, A/Prof. C. Spandler 'The geochemistry of rare earth elements in carbonate melts'; Australian Research Council Discovery Grant; 2019-2021; $270,000.

Dr A.D. Burnham, Prof. S.F. Cox 'XANES mapping of Ti in quartz associated with copper and gold mineralisation'; Australian Nuclear Science and Technology Organisation; 2018; $1,720.

Dr A.D. Burnham, Dr C. Le Losq, Prof. H. St C. O'Neill 'Structural environment of trace elements in silicate melts as a function of pressure'; Australian Nuclear Science and Technology Organisation 2018; $1,720.

Dr S. Mikhail, Dr G. Bromiley, Dr I. Buisman, **Dr A.D. Burnham,** Dr C-J de Hoog, Dr C. Hayward, Dr E. Mare, **Prof. G.M. Yaxley** 'Microanalysis of nitrogen in silicate minerals and glasses'; Carnegie Trust for the Universities of Scotland; 2018-2019; £9,788.

Prof. Phil Cummins, A/Prof. Meghan Miller, A/Prof. Simon McClusky 'Australia-Indonesia Tectonics Observatory (AITO)'; ANU Major Equipment Committee Grant; 2018; $126,000.

Dr D.R. Davies 'Probing the lithosphere using mafic geochemistry: spatio-temporal constraints on the lithosphere's evolution across Northern Australia'; Geosciences Australia; 2018-2020; $120,000.

Dr C.M. Eakin 'What's Shaking Down Under?'; Australian Research Council Discovery Early Career Researcher Award (DECRA); 2019-2021; $404,000.

Dr C.M. Eakin 'Our Watery Planet: The New Era of Seismology'; ANU Futures Scheme; 2020-2022; $399,600.

Prof S. Wilhelm, Dr G. LeCleir, Dr B. Twining, Dr D. Ohnemus, Prof P. Boyd, Dr A. Buchan, **A/Prof. M. Ellwood**, Dr D. Talmy 'Algal, Bacterial and Viral Interactions as the Backdrop to Marine Carbon and Trace Metal Cycling'; Joint Genome Institute (JGI), U.S. Department of Energy (DOE); 2019; DNA/RNA sequencing and analyses.

Dr D. Sinclair, **A/Prof. S. Fallon,** D. Tracy, E. Behrens 'Reconstructing Baseline Ocean Data Around NZ for Marine Management and Forecasting Models'; New Zealand Ministry of Business, Innovation and Employment – Smart Ideas Fund; 2018-2020; $987,366.

Dr B. Gayen 'Spanning 10 billion scales from millimetre turbulence to global circulation'; Australian Research Council Future Fellowship; 2019-2022; $695,125.

Dr K.M.Grant 'Long-term variability of the Australian monsoon'; Australian Research Council Discovery Early Career Researcher Award (DECRA); 2019-2021; $350,000.

Dr F.D. Hibbert 'Early career funding to attend PALSEA2-QUIGS conference'; PALSEA2/INQUA; 2018; US$1,800 (~AU$2,500).

Prof. M. England, **A/Prof. A. Hogg, Dr A. Morrison,** Dr P. Spence, Dr S. Griffies 'Risks of rapid ocean warming at the Antarctic continental margin.'; Australian Research Council Discovery Grant; 2019-2022; $582,500.

Prof. S. Turner, **Prof. T. Ireland,** Prof. J. Hermann 'Role of Water in Earth and Planetary Evolution'; Australian Research Council Discovery Project; 2019-2021; $380,000.

Ms H. James, Ms B. Ellis, and A/Prof M.S. Miller 'Girls into geoscience'; National Science Week ACT Seed Grant; 2018; $954.

A/Prof. P.L. King 'Conference on "High Temperature Gas-Solid Processes"'; Joint Colleges of Sciences; 2018; $10,000.

A/Prof. P.L. King, A/Prof. J. Brocks, L. Schneider, A. Sheppard, **Dr R. Woods** 'Advanced X-ray diffraction capabilities to enable interdisciplinary research at ANU'; ANU Major Equipment Program; 2018; $304k total: $233k MEC, ~$71k others.

A/Prof. P.L. King, Dr T. Jones 'Radiocarbon dating of calcium oxalate mineral crusts in association with western Arnhem Land rock art'; Australian Institute of Nuclear Science and Engineering; 2018; 15 samples funded.

Dr G. Mallmann 'Assessing the redox equilibrium imposed by solid metal-oxide buffers in high pressure and temperature experiments with geological materials'; Australian Nuclear Science and Technology Organisation – Australian Synchrotron; 2018; $1,670.

Dr. S. Roeske, Dr. J. Benowitz, **A/Prof. M.S. Miller** 'Crustal-scale shortening and related thickening along a transpressive shear zone - where did the slip on the Denali fault system go?'; National Science Foundation – Tectonics Program; 2018-2020; US$327,000.

A/Prof. M.S. Miller 'Establishing large-N seismic capability'; ANU Futures Award; 2018-2020; $400,000.

A/Prof. M.S. Miller 'Earth imaging and sounding project'; AuScope NCRIS; 2018-2019; $1,380,000.

A/Prof. M.S. Miller, Prof. M. Sambridge 'Australian seismometers in school program (Ausis)'; AuScope NCRIS; 2018-2019; $400,000.

A/Prof. M.S. Miller, with seven co-investigators 'Linking incoming plate faulting and intermediate depth seismicity'; Cooperative Institute for Dynamic Earth Research (CIDER); 2018; US$5,000.

A/Prof. M. Miller, Prof. M. Sambridge, Dr. M. Salmon 'AuScope NCRIS Project Plan 2018-2019: Earth Imaging – Seismometers in Schools'; NCRIS – AuScope Ltd.; 2017-2018; $210,000.

Prof. H. O'Neill 'Phase relations in the system MgO-ZnO at high pressure'; Australian Synchrotron; 2018; $4,825.

Prof. C. Moritz, Prof. A Manning, **Prof. B. Pillans** 'Gene Streams: a new Virtual Reality tool for teaching ecology, geology and evolution'; ANU Teaching Enhancement Grant; 2019; $10,000.

Prof. A.P. Roberts, Dr H. Oda, **A/Prof. D. Heslop** 'Machine learning and FORC diagrams'; National Institute of Advanced Industrial Science and Technology (AIST), Japan; 2018-2019; $1,100,000 (100 Million Yen).

Prof. A.P. Roberts, A/Prof. D. Heslop, Dr J. Scealy 'Tracing plumes from source to surface'; Australian Research Council Discovery Grant; 2019-2021; $360,000.

Prof. M. Roderick, Dr C. Shakespeare, 'Limits to Ocean Surface Temperature in Future Climates'; Australian Research Council Discovery Grant; 2019-2021; $270,000.

Prof. M. Sambridge., Dr. A. Valentine 'Engagement project in Data Analytics and Inversion'; CSIRO – Future Science Platform for deep Earth Imaging; 2018-2019; $48,500.

Prof. M. Sambridge, Dr. A. Valentine 'CSIRO Ph.D Scholarships+ on costs'; CSIRO – Future Science Platform for deep Earth Imaging; 2018-2021; $275,000.

Prof. C. Michaut, **Dr B. Tauzin,** Prof. C. Quantin, Dr. L. Pan 'Nature and Dichotomy of the Martian Crust'; NASA-CNES (France); 2018-2020; €18,576.

Dr. B. Tauzin 'Non-linear Bayesian partition modeling of the Earth's mantle transition zone'; European Commission, H2020 program; 2018-2021; €270,918.

A/Prof. H. Tkalcic, Prof. M. Coffin, **Dr C.M. Eakin,** Prof. N. Rawlinson, Prof. J. Stock 'IN2020_V02: Probing the Australian-Pacific plate boundary: Macquarie Ridge in 3D'; Marine National Facilities (MNF) Primary Granted Voyage; 2020; 24 days ship time, equivalent to $3,360,000.

A/Prof H. Tkalčić 'Budget for Thirteenth Contract Year for International Monitoring System (IMS) Primary Seismic Station PS02 and IMS Infrasound Station IS07 in Warramunga, Australia (Amendment No. 11) '; Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization; 2018; Amount awarded not for public disclosure.

A/Prof. P. Tregoning, A/Prof. S. McClusky, Dr S. Bettadpur 'GRACE Follow-On: Validation of measurements and initial results'; Australian Research Council Discovery Project; 2019-2021; $485,000.

Dr A.P. Valentine, Prof. M. Sambridge, Dr D.R. Davies, Dr. J. Hauser, Prof. J. Trampert 'Unleashing the power of data: the next generation of geophysical inference'; CSIRO; 2019-2021; $270,000.

Mr J. Garcia, **Dr L Waszek** 'Development of computational tools for use in seismic computational analysis'; New Mexico Alliance for Minority Participation; 2018; US$2,500.

Mr A. Eagon, **Dr L. Waszek** 'Graduate Fellowship'; New Mexico Space Grant Consortium; 2018-2019; US$10,000.

A/Prof. J. Yu, Prof. R. Anderson, Prof. Z. Jin, Prof. N. Thouveny 'Deep Atlantic's role in millennial atmospheric CO2 changes'; Australian Research Council Discovery Project; 2019-2021;$330,000.

A/Prof. J. Yu, Prof. S.M. Eggins, A/Prof. M.J. Ellwood, A/Prof. S.J. Fallon, Prof. E.J. Rohling 'Replacement of an obsolete quadrupole Inductively-Coupled-Plasma Mass Spectrometer'; ANU Major Equipment Committee; 2018; $146,000.

PEER-REVIEWED PUBLICATIONS

Abrajevitch, A., Pillans B.J., Roberts A.P., Kodama K. (2018) Magnetic properties and paleomagnetism of Zebra Rock, Western Australia: chemical remanence acquisition in hematite pigment and Ediacaran geomagnetic field behavior. Geochemistry, Geophysics, Geosystems 19:732-748.

Adam P., Schaeffer P., Paulus S., **Brocks J.J.** (2018) Synthesis of 26-methyl cholestane and identification of cryostanes in mid-Neoproterozoic sediments. Organic Geochemistry 115:246-249.

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Al-Attar D., Crawford O., **Valentine A.P.,** Trampert J. (2018) Hamilton's principle and normal mode coupling in an aspherical planet with a fluid core. Geophysical Journal International 214:485-507.

Amelin Y. (2018) Early Solar System Materials, Processes, and Chronology. In: Van Kranendonk M.J., **Bennett V.C.,** Hoffmann J.E. (Eds), Earth's Oldest Rocks, second edition, Elsevier 1078 pp.

Anenburg M., Burnham A.D., Mavrogenes J. (2018) REE redistribution textures in altered fluorapatite: symplectites, veins, and phosphate-silicate-carbonate assemblages from the Nolans Bore P-REE-Th deposit, Northern Territory, Australia. Canadian Mineralogist 56:1-24, doi:10.3749/canmin.1700038.

Anenburg M., Mavrogenes J.A. (2018) Carbonatitic versus hydrothermal origin for fluorapatite REE-Th deposits: Experimental study of REE transport and crustal "antiskarn" metasomatism. American Journal of Science 318:335-366, doi:10.2475/03.2018.03.

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Ao H., **Roberts A.P.,** Dekkers M.J., Liu X.D, **Rohling E.J.,**. Shi Z.G, An Z.S., **Zhao X.** (2018) Reply to Zhang et al.: Late Miocene–Pliocene magnetochronology of the Shilou Red Clay on the eastern Chinese Loess Plateau. Earth and Planetary Science Letters 503:252-255.

Armand L.K., O'Brien P.E., Armbrecht L., Barker H., Caburlotto A., Connell T., Cotterle D., Duffy M., Edwards S., Evangelinos D., Fazey J., Flint A., Focardi A., Gifford S., Holder L., Hughes P., Lawler K.-A., Lieser J.L., Leventer A., Lewis M., Martin T., Morgan N., Lopez-Quiroz A., Malakov K., Noble T., **Opdyke B.,** Palmer R., Perera R., Pirotta V., Post A., Romeo R., Simmons J., Thost D., Tynan S., Young A. (2018)

Interactions of the Totten Glacier with the Southern Ocean through multiple glacial cycles (IN2017-V01): Post-survey report. Research School of Earth Sciences, College of Science, ANU, Canberra.

Armbrecht L. H., Lowe V., Escutia C., Iwai M., McKay R., **Armand L.K.** (2018) Variability in diatom and silicoflagellate assemblages during mid-Pliocene glacial-interglacial cycles determined in Hole U1361A of IODP Expedition 318, Antarctic Wilkes Land Margin. Marine Micropalaenotology 139:28-41, doi:10.1016/j.marmicro.2017.10.008.

Attanayake J., Thomas C., Cormier V.F., **Miller M.S.,** Koper K.D. (2018) Irregular transition layer beneath the Earth's inner core boundary from observations of antipodal PKIKP and PKIIKP waves. Geochemistry, Geophysics, Geosystems 19, doi:10.1029/2018GC007562.

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