

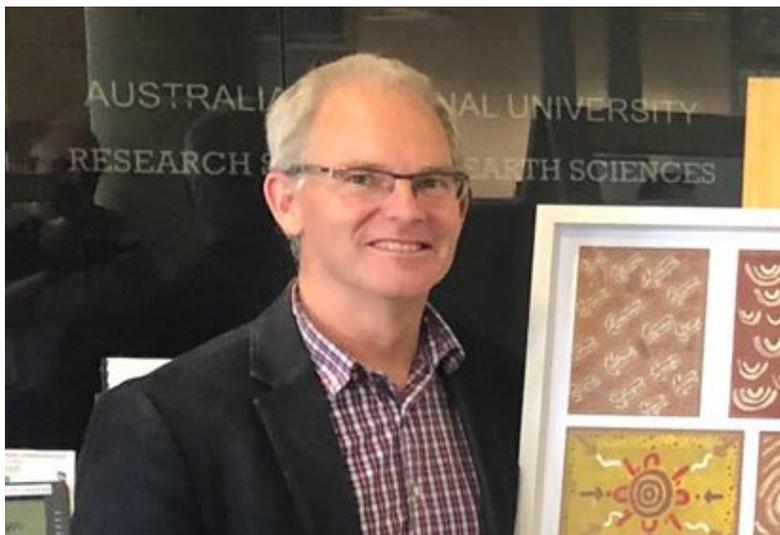


Australian
National
University

Annual Report 2019

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From the Director

2019 has been a truly good year for the School, particularly in regard to securing external funding that will underpin research activity in future years and for the honours and awards received that recognize the achievements of current and past researchers.

Perhaps the highlight for the year occurred in January when Ilya Bobrovskiy (RSES PhD scholar) and colleagues at the ANU were awarded one of the Top 10 Scientific Breakthroughs of the Year for 2018 by Science magazine for the discovery of cholesterol-like molecules associated with Dickinsonia. The discovery revealed this famous Ediacaran species to be animal confirming other evidence suggesting some Ediacarans were among the earliest animals on Earth. Details of other research achievements and publications throughout the year can be found within the Annual Report.

2019 was the 50th anniversary of the moon landing, which provided the School with an opportunity to celebrate the breakthrough discoveries about the origin of the Earth and Moon made by Professor Ross Taylor and other RSES researchers. The School also hosted the 60th anniversary of the Department of Geology at ANU which saw many alumni welcomed back to the ANU and

into the RSES community.

Professor Louis Moresi joined our faculty from the University of Melbourne, while we farewelled several high quality early to mid-career researchers to take up positions elsewhere including Bishak Gayen, Mark Kendrick, Oscar Branson and Charles LeLosq.

Nerilie Abram, Andrew Berry, Jochen Brocks, Michael Ellwood, and Paul Tregoning are congratulated for their successful promotion to level E (Professor), reflecting the strength of mid-career academics within the School, and personal achievement of academic excellence and their valued service contributions to the university and disciplines.

Multiple academic staff received prestigious awards including Nerilie Abram who was awarded the Priestley Medal by the Australian Meteorological & Oceanographic Society, Jochen Brocks who received the inaugural Geoff Eglinton Award from the European Association of Organic Geochemists and the Geochemical Society, Andrew Roberts received the Axford Medal from the Asia Oceania Geoscience Society, Eelco Rohling was named a highly cited researcher in 2019 by Publons, and Ian Campbell received the

Haddon Forrester King Medal from the Australian Academy of Science. Most notably Penny King was awarded the Joanne Simpson Medal for Mid-Career Scientists in Earth & Space Sciences by the American Geophysical Union and additionally made a Fellow of the both the American Geophysical Union and the Mineralogical Society of America.

Among emeritus staff, Patrick de Deckker was awarded the prestigious Brady Medal by The Micropalaeontological Society, Mark Norman received the Distinguished Service award of the Geochemical Society, and Brad Pillans received the 2018-19 ANZGG medal of Australian & New Zealand Geomorphology Group. Special congratulations are due to Brian Kennett who was awarded an Order of Australia (AO) for his distinguished service to the earth sciences as a leading academic and researcher, particularly in the field of seismology, and to Neville Exon who was awarded an Order of Australia (AM) for his service to marine geoscience.

The School was highly successful in obtaining external funding, a clear highlight being award of over \$3 million in ARC Discovery projects, with 7 successful RSES-led grants (41% success rate) at an average awarded amount of \$437k (all significant increases over previous years).

Lastly I would like to point out that the School has retained its top ten QS World subject ranking at 9th in Earth and Marine Sciences for the second year in a row. This is testimony to the extraordinary academic strength and outstanding reputation that continues to be generated by the collective efforts of all the Schools' academic and professional staff and students.

Professor Steve Eggins
School Director

Staff lists

ACADEMIC STAFF

Director S.M. Eggins, BAppSci UNSW, PhD Tasmania

Associate Directors

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

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

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

Honours and Masters D.R. Davies, MSci PhD Cardiff, UK

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

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

S.M. Eggins, BAppSci UNSW, PhD Tasmania

A.McC. Hogg, BSc ANU, PhD UWA

T.R. Ireland, BSc Otago, PhD ANU

P.L. King, BSc (Hons) ANU, PhD Arizona State

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

L.N. Moresi, BA (Hons) Cambridge, DPhil Oxford (from 05/02/2019)

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

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

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
D.R. Davies, MSci PhD Cardiff, UK [ARC Future Fellow]
M.J. Ellwood, BSc (Hons) PhD Otago
S.J. Fallon, BA MS San Diego, PhD ANU
D.C. Heslop, BSc (Hons) Durham, PhD Liverpool, Dr habil Bremen
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
P. Tregoning, BSurv PhD UNSW
J. Yu, BSc MSc Nanjing University, PhD Cambridge [ARC Future Fellow]

Fellows

M.A. Forster, BSc MSc PhD Monash
B. Gayen, PhD UC San Diego, USA [ARC Future Fellow] (to 30/01/2019)
M.A. Kendrick, BSc Edinburgh, PhD Manchester [ARC Future Fellow] (to 29/06/19)
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 (to 28/09/2019)
A. Burnham, MSci MA Cambridge, PhD Imperial College London
N.C. Constantinou, BSc, MSci, PhD Athens, Greece
C. Eakin, MSci Imperial College London, PhD Yale [ARC DECRA Fellow]
K. Grant, BSc Southampton, MSc JCU, PhD Southampton [ARC DECRA Fellow]
A. Kiss, BSc (Hons), PhD ANU
C. Le Losq, MSc, PhD IPGP, France (to 31/08/19)

ACADEMIC STAFF CONT.

Research Fellows cont.

A. Morrison, BSc (Hons) ANU, GradDipEd Canberra, PhD ANU [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
R. Wood, BSc (Hons) Durham, MSc DPhil Oxford [ARC DECRA Fellow]

Postdoctoral Fellows

S. Allgeyer, PhD Paris Diderot, France
J. Amies, (to 02/11/2019)
P. Barrett, BSc Rochester MSc PhD Washington
C. Frigo, BSc Padova, MSc Bayerisches, PhD Innsbruck
S. Ghelichkhan, (from 11/11/2019)
B. Hejrani, BSc Kurdistan, MSc Tehran, PhD Aarhus, Denmark
F. Hibbert, PhD St Andrews, UK
P. Hu, PhD ANU & Chinese Academy of Sciences
J. Pfeffer, MSc Joseph Fourier, Grenoble, France, PhD Strasbourg
R. Pickle, MSc Brown, PhD Auckland
L. Van Maldegem, BSc Avans, MSc Leeds, PhD Bremen
L. Waszek, BA (Hons) MSci PhD Cambridge [ARC DECRA Fellow]
N. Wright, BSc, PhD Sydney
D. Yin, PhD Tsinghua, Beijing

Emeritus Academics

R.J. Arculus, BSc PhD Durham, FAIMM
W. Compston, BSc PhD DSc (Hon) WAust, FAA, FRS
S.F. Cox, BSc Tasmania, PhD Monash
P. De Deckker, BA MSc (Hons) Macquarie, PhD DSc Adelaide, FAA
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

Emeritus Academics
cont.

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, AO, FAA, FRS
K. Lambeck, BSurv NSW, DPhil DSc Oxford, AO, FAA, FRS
M.D. Norman, MSc Tennessee, PhD Rice
M.S. Paterson, BSc Adelaide, PhD Cambridge, FAA
B.J. Pillans, BSc PhD ANU, HonFRSNZ
S.R. Taylor, BSc (Hons) MSc New Zealand, PhD Indiana, MA DSc Oxford, HonAC, FAA
I.S. Williams, BSc PhD ANU

Honorary Academics

R.A. Armstrong, BSc MSc Natal, PhD Witwatersrand
R.V. Burne, BSc Wales, DPhil Oxford
H. Davies
T. Esat
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
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, (to 31/05/19)
F. Lilley, (from 01/06/19)
G. Marino, MSc (cum laude) 'Federico II' of Naples; PhD Utrecht
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

ACADEMIC STAFF cont.

Visiting Fellows

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

C. Bryant

G.F. Davies, MSc Monash, PhD CalTech

P. de Caritat de Peruzzis, PhD ANU

Y. Gao (from 10/03/2019 to 10/06/2019)

A. Glickson

S. Hirabayashi (to 31/03/2019)

K. Holland

X. Huang

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

C. Klootwijk

Y. Liang

T. Long (from 10/03/2019–10/06/2019)

J. Mallela, BSc (Hons) Leeds, MSc Heriot-Watt, PhD West Indies (to 29/04/2019)

T.P. Mernagh, PhD Newcastle

R. Metzler (to 30/06/2019)

J. Moores (from 04/02/2019–04/04/2019)

C. Pigram

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

M. Sapah, PhD ANU (to 30/7/19)

T. Takagawa (from 01/04/2019)

E. Truswell, B.Sc Hons (UWA); Ph.D. (Cambridge), B.A (Visual arts) (ANU)

C. Vreugdenhil, PhD ANU (to 09/04/2019)

H. Wei (from 1/09/18)

F. Williams

L. Wyborn

Y. Yokoyama (to 31/05/2019)

PROFESSIONAL STAFF

School Manager	G.F.M. Pearson, BA, BTh, MBA, FAIM
Executive Assistant to the Director and the School Manager	S. Devi
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 (to 21/02/2019) T. Penny (from 03/06/2019)
Education Support Officer	
RSES & ANZIC-IODP Communications Officer	L. Medenis
Education Officer	B. Harrold, BSc ANU
Receptionist	T. Asher (to 21/02/2019) M. Sadler (from 06/05/2019)
Research Group Administrators	E. Arnold - Earth Dynamics; Seismology & Mathematical Geophysics J. Magro - Experimental Petrology; Geochemistry & Cosmochemistry M. Francis - Biogeochemistry; Palaeoenvironments; Climate & Fluid Physics
ANZIC -IODP Administrator	K. Kenney (from 18/02/2019)
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 T. Redman, AssocDip (Elect Eng) CIT H. Sasaki, AssocDip CIT L. Materne

PROFESSIONAL STAFF cont.

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 (to 10/07/2019)

X. Zhang (from 20/07/2019)

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

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

Technical Officers cont.	S. Rayapaty, BEng Jawaharlal Nehru Technological University, MIT University of Canberra
	A. Rummery, Cert III CIT (x3)
	D. Scott, AssocDipMechEng CIT
	J. Shelley, MSc Canterbury
	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	Agrawal, Shubham	Hargreaves, Jessica	Patkar, Aditya
	Amarathunga, Udara	Haynes, Marcus	Penny, Tiah
	Baeza, Leonardo	Hayward, Kathryn	Piedrahita Velez, Victor
	Baile, Riley	Huang, Zhijie	Pranantyo, Ignatius
	Bean, Lynne	Jackson, Sarah	Prichard, Jennifer
	Bishop, Caleb	James, Hannah	Qian, Yao
	Bonning, Geoffrey	Ji, Xuan	Qu, Tongzhang
	Cajal Contreras, Yamila	Kinsley, Jordan	Rama, Jemima
	Chandler, Ross	Kirby, Rachel	Roosmawati, Nova
	Chen, Bei	Kou, Yingxin	Ry, Rexha
	Chen, Fanqin	Krestianinov, Evgenii	Sakti, Artadi
	Chen, Mimi	Lawler, Kelly-Anne	Scheiter, Matthias
	Chopping, Richard	Li, Yuwei	Sebastian, Nita
	Connolly, Clare L	iyanage, Tharika	Sohail, Taimoor
	Costa de Lima, Thuany	Loiselle, Liane	Sommer, Johanna

POST-GRADUATE STUDENTS cont.

PhD Candidates cont.	Crisp, Laura	Lowczak, Jessica	Stephenson, Joanne
	Devi, Riteshma	Maharaj, Prayna	Sudholz, Zachary
	Di, Yankun	Makushkina, Anna	Tambiah, Charles
	Ducommun-Dit-Verron, Joelle	Manceau, Rose	Turunctur, Buse
	Durgalakshmi	Martin, Hayden	Tyler, Perinne
	Duvernay, Thomas	Martinez Moreno, Josue	Valetich, Matthew
	Eggins, Sam	Mathews, Christopher	Vinnichenko, Galina
	Ellis, Bethany	McConachie, Shannon	Wang, Sheng
	Fang, Bowen	McGirr, Rebecca	Ward, Josephine
	Fang, Fang	Miller, Laura	Wei, Yi (Zack)
	Farmer, Nicholas	Misztela, Monika	Whan, Tarun
	Fouladi Moghaddam, Negin	Naina	Wu, Jiade
	Gai, Congcong	Nash, Graham	Wu, Yang
	Gao, Yajie	Nugroho, Hendro	Zhang, Ping
	Goodarzi, Patrick	Ogunsami, Abdulwaheed	Zhao, Siyuan
	Gray, Sharon	O'Neill, Cameron	Zhao, Song
	Grun, Robin	Owens, Ryan	Zheng, Siru
	Harazin, Kathleen	Pasic, Bozana	Zhu, Ziyi

MPhil Candidates	Baruleva, Olga	Creighton, Reuben	Muston, Jack
	Carrasco Godoy, Carlos	Moller, Brun	

Master of Earth Sciences (Advanced)	Agrawal, Shubham (completed)	Lin, Yucheng (completed)
	Arcot Parthiban, Ramkumar	Liu, Wenbing (completed)
	Cao, Shan	Nie, Ruoran (completed)
	Egorova, Angelina (completed)	Oborski, Emily
	He, Nini (completed)	Patil, Suchir
	Hu, Shangyu (completed)	Shao, Yujia (completed)
	Huang, Baoyi	Sharma, Aditya (completed)

**Master of Earth
Sciences (Advanced)
cont.**

Su, Xiaoyu	Zhang, Xihan (completed)
Tian, Yanjie (completed)	Zhao, Yi
Xing, Tianyue	Zhou, Jin (completed)
Wang, Xiaoran	Zhou, Jingwei
Williamson, Faye	Zhou, Qianhui (completed)
Yeung, Ho Sonia (completed)	

Honours completions

Choo, Darren	Parige, Reuben
Culvenor, James	Pyke, Callum
Huang, Ruotong	Shaw, Callum
Lissogourski, Denis	Sun, Yaojia
Moorman, Ruth	Velzeboer, Nick

Undergraduate and postgraduate courses

Earth & Marine Science Programme

Semester 1	Course description	Convenor, Teaching staff	No. of Students
EMSC1006/4006/6107	Blue Planet	J. Mavrogenes, P. King, B. Opdyke	171
EMSC2022	Introduction to Global Geophysics	M. Miller, D. Heslop, L. Moresi	40
EMSC2023	Fundamentals of Geology	G. Yaxley, B. Opdyke, S. Cox	38
EMSC3020	Geobiology & Evolution of Life on Earth	J. Brocks, L. van Maldegem, B. Opdyke	20
EMSC3023/4023/6023	Marine Biogeochemistry	M. Ellwood, S. Fallon	25
EMSC3024/4024/6024	Magmatism & Metamorphism	A. Burnham, H. O'Neill, I. Campbell, R. Arculus, A. Berry, D. Ellis	16
EMSC3032/4032/6032	Melting Polar Ice Sheets	P. Tregoning	18
EMSC3033	Applied Geophysics	C. Eakin, D. Heslop	6
EMSC4017/8017	Research Methods and Proposal	A. Roberts, P. Tregoning	8
EMSC4020	Foundations of Analytical Techniques and Data Science	D. Heslop, M. Ellwood	11
EMSC4033	Computational Geosciences: Problem-solving, Logical Thinking and Programming.	A. Valentine, C. Le Losq, O. Branson	10
EMSC4109	Advanced Earth Physics	S. McClusky, L. Moresi, I. Jackson, B. Tauzin	1
EMSC4121/8021	Advanced Geochemistry, Petrology and Tectonics	A. Burnham, H. O'Neill, V. Bennett, Y. Amelin	4

EMSC4122/8022	Analytical Techniques	Yaxley, G.	2
EMSC4123/8023	Data Analysis	D. Heslop, M. Sambridge	4
EMSC4706/8706	Natural Hazards	P. Cummins	18
EMSC8032	Research Proposal & Presentation	R. Davies	5
EMSC8034	Research Orientation: Big Questions in the Earth Sciences	R. Davies, A. Berry, M. Roderick, P. King, P. Tregoning, D. Heslop, O. Branson, C. Le Losq, L. Wasczek, F. Hibbert	2
Winter			
EMSC3001	Field Geology	J. Mavrogenes, S. Cox (Run by University of Queensland)	3
Semester 2			
EMSC1008/6008	Earth	A. Berry, C. Eakin	76
EMSC2024/6124	Geochemistry	T. Ireland, Y. Amelin	17
EMSC2021/4021/6021	Climate System Science	M. Roderick, C. Shakespeare	48
EMSC3002/4002/6030	Structural Geology & Tectonics	G. Lister	13
EMSC3007/6007	Economic Geology	J. Mavrogenes	11
EMSC3022/6022	Planetary Science	P. King, C. Lineweaver	39
EMSC3025/4025/6025	Groundwater	L. Moore	19
EMSC3027/4027/6027	Palaeoclimatology & Climate Change	Rohling, E./ K. Grant J. Yu, F. Hibbert	14
EMSC4017/8017	Research Methods and Proposal	A. Roberts, P. Tregoning	6
EMSC4033/8033	Computational Geosciences: Problem-solving, Logical Thinking and Programming.	A. Valentine, M. Klöcking	5
EMSC4123/8023	Data Analysis	M. Sambridge	7

Semester 2 cont.

EMSC8032	Research Proposal & Presentation	R. Davies	2
EMSC8034	Research Orientation: Big Questions in the Earth Science	R. Davies/ D. Heslop A. Berry, M. Roderick, P. King, S. Mousavi, J. Pfeffer, M. Klöcking, F. Hibbert, P. Barrett,	3

Spring

EMSC3019/6119	Coral Reef Field Studies	S. Fallon	21
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New Colombo Plan

EMSC3050	NCP Field trip (Indonesia)	P. Cummins	9
EMSC3050	NCP Field trip (Japan)	D. Heslop, P. Hu	10

Special Topics

EMSC3050/4050/ 6805/8014	Research project (6 units)	EMSC3050: B. Opdyke, C. Shakespeare, J. Yu, D. Heslop, J. Brocks, J. Mavrogenes x4, K. Stewart, P. Cummins, S. Fallon EMSC8014: T. Purcell, B. Opdyke x 2, C. Eakin, G. Lister x 5, P. Tregoning	20
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Physics Programme (Research School of Physics & Engineering)

PHYS2201	Classical Mechanics	A. Hogg	72
PHYS3070	Physics of the Earth	H. Tkalčić, L. Moresi	12
PHYS3202	Fluids & Plasma	A. Hogg, K. Stewart	11

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

ARCH1111	Archaeology Uncovered	R. Wood	79
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ARCH8032	Introduction to Archaeological Science	R. Wood	23
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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	21
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Environmental Science Programme (Fenner School of Environment & Society)

ENVS3029	Palaeo-Environmental Reconstruction	R.Wood	32
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Thesis and awards



PhD theses completed (Supervisor in parentheses)

- Amies, Jessica “Deconvolving Eastern Mediterranean Planktic Foraminiferal $\delta^{18}O$; a Focus on Sapropels and Sea-level Reconstruction” (Eelco Rohling)
- Andrew, Sarah “Investigating the Multiplicative Effects of Climate Change on Southern Ocean Phytoplankton” (Michael Ellwood)
- Anenburg, Michael “Controls on Critical Metals in Magmatic and Hydrothermal Systems” (John Mavrogenes)
- Bobrovskiy, Ilya “Biomarkers and the Dawn of Animal Life” (Jochen Brocks)
- Carr, Patrick “Highly Evolved Tin Granites and their Hydrothermal Systems in Eastern Australia; New Temporal and Compositional Insights into Granite Genesis and Magmatic-Hydrothermal Mineralisation Process” (Victoria Bennett)
- Cipta, Athanasius “Site and Basin Effects on Seismic Hazard in Indonesia: Sulawesi and Jakarta Case Studies” (Phil Cummins)

- Emetc, Veronika “Combining Physics-based and Statistics-based Approaches to Model Calving in Antarctica” (Paul Tregoning)
- Gauthiez-Putallaz, Laure “Tracing Fluids During Medium to Ultra-high Pressure Metamorphism: Insights by Combined In Situ Oxygen Isotopes and Trace Element Analysis (Daniela Rubatto)
- Gibson, Angus “An Adaptive Vertical Coordinate for Idealised and Global Ocean Modelling” (Andy Hogg)
- Hao, Hongda “Platinum-group Element Geochemistry of Mid-ocean Ridge Basalt, and the Northparkes and Escondida Porphyry Systems (Ian Campbell)
- Lakey, Shayne “Chlorite Stability in the Subduction Zone (Joerg Hermann)
- Liu, Li “Multiple Sulphur Isotopic Compositions of Archean Records Determined by SHRIMP-SI (Trevor Ireland)
- Long, Kelsie “Golden Perch (*Macquaria Ambigua*) Otolith Microchemistry: Modern Validations and Ancient Applications” (Ian Williams)
- Mondal, Mainak “The Role of Convection on the Basal Melting of Antarctic Ice Shelves” (Bishakdatta Gayen)
- Nand, Vickashni “Development and Application of the Carbonate Measurement System to Monitor Ocean pH and Alkalinity” (Michael Ellwood)
- Pham, Thanh Son “Advancing Correlation Methods of Earthquake Coda in Seismic Body Wave Studies” (Hrvoje Tkalčić)
- Sieber, Melanie “Experimental Investigation of the Fluid Driven Carbonation of Serpentinites and Spinel Peridotites: Implications for the Carbon and Trace Element Cycle in the Forearc Region of the Mantle Wedge” (Greg Yaxley)
- Smith, Tegan “Palaeoenvironmental and Landscape Evolution of the Lake Mulurulu Lunette, Willandra Lakes World Heritage Area, New South Wales” (Stephen Eggins)
- Tian, Siyuan “Monitoring and Forecasting Droughts Through the Assimilation of Satellite Water Observations” (Paul Tregoning)
- Timmerman, Suzette “Diamonds - Time Capsules of Volatiles and the Key to Dynamic Earth Evolution” (Antony Burnham)
- Tolley, James “Geochemistry of Rare Earth Elements in Carbonatites” (Andrew Berry)
- Williams, Morgan “Tracing Fluids from Seafloor to Deep Subduction: An In-situ Geochemical Investigation of Fluid-Mobile Elements in Oceanic Crust” (Mark Kendrick)
- Zannat, Umma “Network Effect in Geocentre Motion Induced by Geophysical Processes” (Paul Tregoning)

MPhil thesis completed (Supervisor in parentheses)

- Baeza, Leonardo “Ordinary Chondrites Chondrule Oxygen Isotope Systematics: Insights into the Inner Solar System Planetary Reservoir” (Trevor Ireland)
- Baruleva, Olga “The Geological Architecture of the Iron-Oxide Copper-Gold (IOCG) Corridor at the Mt Isa Inlier (Gordon Lister)

Staff Honours and Awards

Staff Member	Awards	Awarding Body
Nerilie Abram	Priestley Medal	Australian Meteorological & Oceanographic Society
Jochen Brocks	Inaugural Geoff Eglinton Award for “the most innovative, novel, groundbreaking subject/ research”	European Association of Organic Geochemists and the Geochemical Society
Ian Campbell	Haddon Forrester King Medal	Australian Academy of Science
Patrick de Deckker (Emeritus)	Brady Medal	The Micropalaeontological Society
Neville Exon (Emeritus)	Order of Australia (AM)	Council for the Order of Australia
Brian Kennett	Order of Australia (AO)	Council for the Order of Australia
Penny King	Joanne Simpson Medal for Mid-Career Scientists in Earth & Space Sciences	American Geophysical Union
Penny King	Fellow	American Geophysical Union
Penny King	Fellow	Mineralogical Society of America
Mark Norman (Emeritus)	Distinguished Service award	Geochemical Society
Brad Pillans	2018-19 ANZGG medal	Australian & New Zealand Geomorphology Group
Andrew Roberts	Axford Medal for “academic excellence and unselfish scientific cooperation in Asia and Oceania”	Asia Oceania Geoscience Society.

Student Honours and Awards

Higher Degree Research

Award	Student
DA Brown Travel Fellowship	Sarah Jackson
Mervyn & Katalin Paterson Fellowship	Kelly Lawler, Tharika Liyange and Zachary Sudholz
Ringwood Scholarship	Jemima Rama
Robert Hill Memorial Prize	Kathryn Hayward
Sue Kesson Experimental Petrology Student Travel Grant	Laura Miller

Coursework

Award	Student
A L Hales Honours Scholarship	Callum Shaw and James Culvenor
Edward Irving Geophysics Award	Darcy Bedward
ASEG Award Applied Geophysics	Madison Wait
John and Kerry Lovering Scholarship	Emily Oborski



BIOGEOCHEMISTRY

Group leader

Michael Ellwood

Academic members

Leanne Armand, Pamela Barrett, Oscar Branson, Jochen Brocks,, Steve Eggins, Stewart Fallon, Lennart van Maldegem, Rachel Wood

Overview

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. Research highlights include characterising the dawn of animals across the Ediacaran period between 635–541 million years ago. The rise of multicellular animals was demonstrated through the use of biomarkers which provide a new dimension understanding the evolution of Ediacara biota.

A second highlight is the understanding of development of Neolithic food-producing cultures during the mid-Holocene. This work provided evidence for dog domestication and pig management in northern Vietnam during this period and represented an early expansion of farming communities.

Australian lungfish are perhaps one of the world's oldest living vertebrates, yet little is known about their life history. Radio-carbon analysis of lungfish scales indicates that fish can be up to 80 years old.

The Armand team (incl. post-doc H. Sadatzki, PhD student K.A. Lawler) continued their focus on analysing the East Antarctic cores recovered on the slope of the Sabrina Coast, north of the Totten Glacier. Outputs were focused on contributions to the International Conference of

Palaeoceanography held in Sydney (four posters – two in house and two external collaborators); where a full day side meeting was hosted by Armand, P. O'Brien (MQ) and A. Post for the international community to share findings and plan for additional sampling of the cores for new investigations. Four papers were submitted post this meeting, two are expected to be published in early 2020 and the others mid 2020.

Finally, iron isotope analyses of lake waters from Lake Cadagno within the Swiss Alps revealed a large isotope transition in mid-water column consistent with long-term deepwater anoxia. These results show that this lake is a good analogue to past shallow-water systems with experiencing anoxia.

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

In 2019 group members continue to contribute to the undergraduate teaching program within RSES. Courses taught by academic group members include: Marine biogeochemistry, Coral Reef Field Studies, Geobiology, Geochemistry, Analytical Techniques and Data Science.

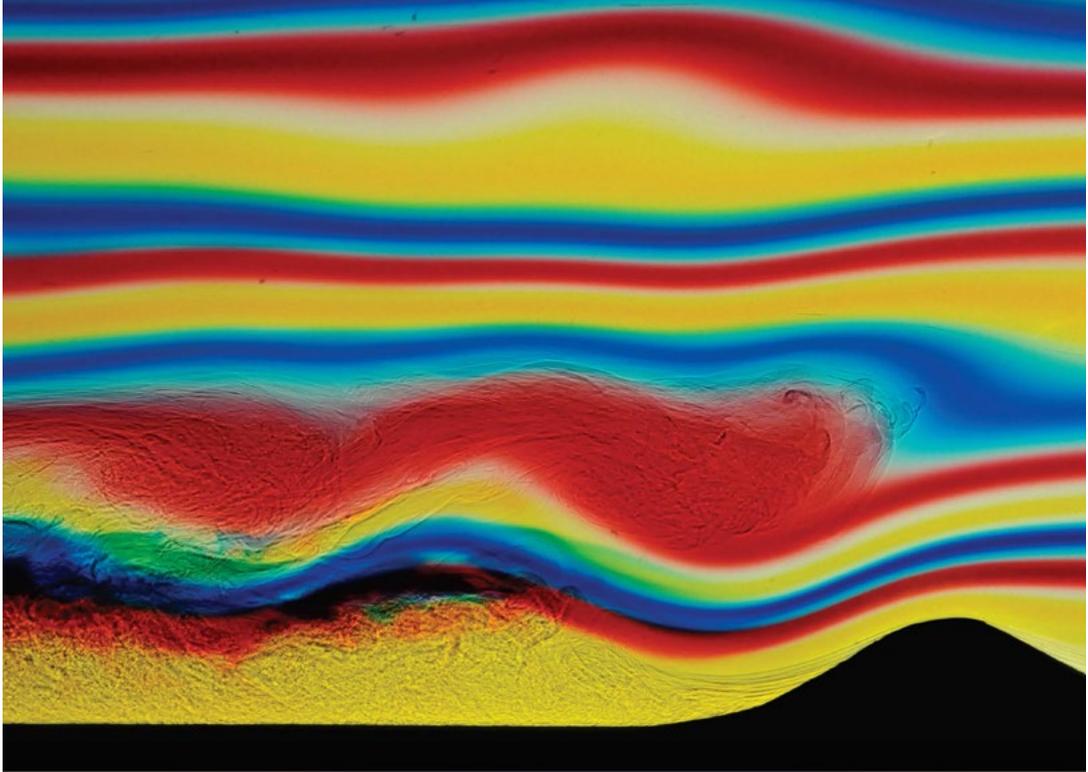
Inaugural Bear McPhail Award in teaching was given to the Geobiology course EMSC3020 taught by group members Jochen Brocks, Lennart van Maldegem and Bradley Opdyke, and TA's Tharika Liyanage and Jordan Kinsely (both PhD students in the Biogeochem Group), and with fantastic guest contributions from Prof Simon Haberle and Dr Shimona Kealy from the School of Culture, History and Language.

Staff Changes

- Oscar Branson left the Marine Biogeochemistry group to take an academic position at Cambridge University
- Arrival of H. Sadazski, PhD Bergen, Norway to work with Leanne Armand
- Jochen Brocks promoted to Professor
- Michael Ellwood promoted to Professor

Students

- PhD student Caleb Bishop joined us from the University of Adelaide working on the evolution of the biosphere and environment across the Neoproterozoic Snowball Earth intervals
- Honours student Claire Patterson, searching for the oldest molecular evidence for land plants
- PhD student Sam Eggins joined the Marine Biogeochemistry group
- PhD student Kelly-Anne Lawler joined the Marine Paleontology group
- Honours student Yaojia Sun joined the Marine Biogeochemistry group



CLIMATE AND FLUID PHYSICS

Group leader

Andy Hogg

Academic members

Navid Constantinou, Ross Kerr, Andrew Kiss, Adele Morrison, Michael Roderick, Callum Shakespeare, Kial Stewart, Anna Ukkola, Nicky Wright, Y. Yang, Dongqin Yin

Overview

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 model development, internal waves, Southern Ocean circulation and the energy balance of the land surface. Our research profile includes funded contributions from the ARC Centre of Excellence for Climate Extremes (CLEX) and the Consortium for Ocean-Sea Ice Modelling in Australia (COSIMA).

This year, the group has continued their efforts in global ocean-sea ice modelling, primarily with the ACCESS-OM2, a global ocean and sea ice model suite at three resolutions. This modeling effort is funded through the COSIMA consortium, which includes collaborators from ANU, UNSW, UTas, CSIRO, BoM and AAD. The model suite is suitable for multi-century climate projection experiments and shorter experiments at higher resolution, and underpins about 30 research projects across several Australian institutions (e.g. Oke et al., 2019; Pilo et al., 2019). A major

technical paper has been published (Kiss et al., 2020), which provides technical details for the model and assesses its performance relative to observations. In addition, we led an international effort to develop a process for obtaining and evaluating “Repeat Year Forcing” (RYF) datasets based on the recently released Japanese atmospheric reanalysis JRA55 (Stewart et al., 2020).

Internal waves are important for transporting energy and momentum from the ocean boundaries into the ocean interior. The breaking of these waves drives larger-scale oceanic flows and acts to sustain the ocean’s overturning circulation. Many processes generate internal waves, including so-called “spontaneous generation”, where waves are emitted internal to the ocean, in the absence of direct forcing: 2019 saw a review article published on this topic (Shakespeare, 2019). The group also investigated internal wave generation occurring at hills on the ocean sea floor when both oscillatory (tides) and steady flows interact with topography (Shakespeare and Hogg, 2019). In such situations, the wave generation by the oscillatory and steady motions are coupled together, leading to unique properties of the generated waves. Experiments in the Geophysical Fluid Dynamics Laboratory explored this phenomenon, demonstrating that internal waves can be generated by oscillatory motions of higher frequency than previously believed. These results have significant consequences for our understanding of the role and importance of internal waves in the ocean’s energy budget.

The Southern Ocean is key in controlling our climate as it drives most of the global ocean uptake of anthropogenic heat and carbon. However, due to scarce observations, we know very little about how the Southern Ocean circulation has responded to climate change so far. Small-scale processes (mesoscale-length scales of 20km-300km) play a leading role in controlling the large-scale circulation in the Southern Ocean. This year we have continued ongoing efforts in better understanding the Southern Ocean circulation and its effect on the global climate. Our efforts concentrate on (i) process-model studies that provide deep insight into the physics and processes involved and (ii) studies using global ocean model output and observational datasets.

(i) A student-led paper from the group investigated how resolving fine-scale features (of length-scales few centimetres; way below the scales global ocean models can capture) influences the response of the large-scale overturning circulation and Antarctic Circumpolar Current to wind stress changes in a very high resolution turbulence resolving model (Sohail et al. 2019). Work led by a postdoc of the group shed light into the crucial role that the bathymetry plays in controlling the response of the Antarctic Circumpolar Current to increasing winds and, further, delineate the different mechanism in play (i.e., barotropic versus baroclinic processes) (Constantinou & Hogg 2019).

(ii) Another student-led paper developed a new algorithm for separating out coherent mesoscale eddies from other small-scale processes, and demonstrated a consistent strengthening of the kinetic energy of the eddy field, driven by an increase in wind forcing (Martínez-Moreno et al., 2019; see Figure 1). Collaborations with US researchers included a project quantifying mechanism driving recent changes in Southern Ocean ventilation (Vaugh et al. 2019), and a project assessing mechanisms controlling the differing patterns of observed carbon and heat storage in the Southern Ocean (Chen et al. 2019).

We continued our work on the surface energy balance, climate and water. One of the great

confusions in recent years has been that the land surface would become drier as the earth warms (several papers recently have been arguing in favour of this). However, examination of direct climate model output has found that, on average, we expect slightly more rainfall and runoff with warming with a large projected increase in vegetation greenness. This year we published work in *Nature Climate Change* that reconciled these two different viewpoints. In brief, we found that many previous assessments had ignored the important and large effects of increasing atmospheric CO₂ on the water use efficiency of vegetation (Yang et al 2019). Moving away from models, we have for the first time, investigated the stationarity of the Australian climate over the last 120 years (Ukkola et al. 2019) and found that while the increase in air temperature is non-stationary, the local water cycle over Australia has remained well within the bounds of stationarity in most regions. Examining long-term data complements group activities on the underlying mechanical and thermodynamic processes and we also concluded a long-term theoretical investigation into how evaporation from the ocean responds to variations in both incoming radiation and surface temperature (Yang & Roderick, 2019). Using global ocean surface measurements, we were able to show for the first time that the observed monthly evaporation over the global ocean occurs at the maximum rate possible.

We have now taken our theoretical work on oceanic surface process into the laboratory. With the support of the Australian Research Council we have completed the design and construction of a new purpose-built wind tunnel. The wind tunnel is equipped with sensors for measuring temperature, humidity and wind and for imaging longwave radiation from an evaporating surface using a dedicated thermal camera. The first application is to investigate how a change in the incoming longwave radiation is partitioned between evaporation and outgoing longwave radiation at a water surface. This is a direct experimental analogue of our previous theoretical work on oceanic evaporation and is designed to find out how warm the ocean surface can become under greenhouse forcing. This is actually a central question in climate change; but has not previously been investigated in a laboratory setting. Our work will be the first on this critical topic.

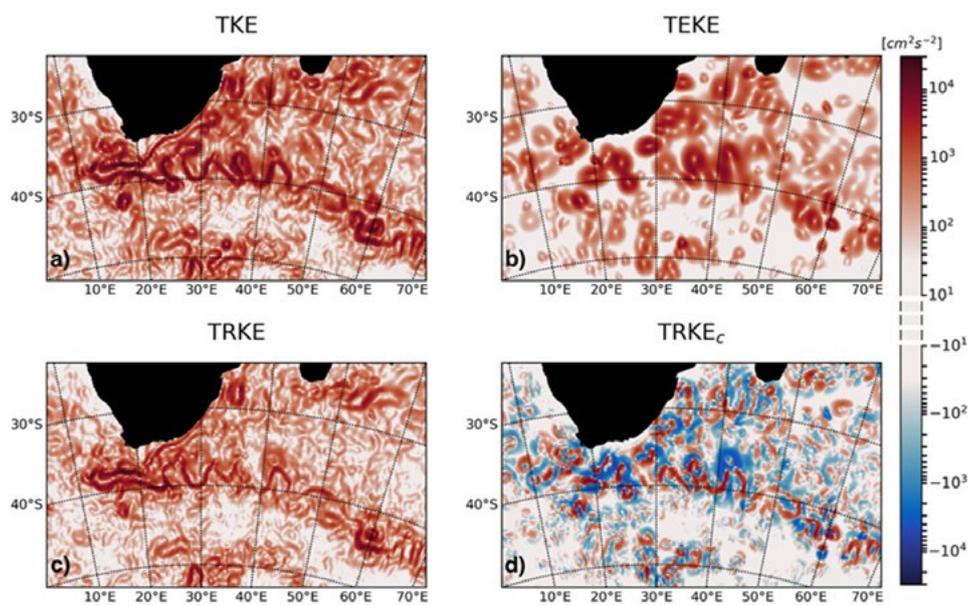


Figure 1: Snapshot of (a) the transient kinetic energy field; (b) energy attributed to eddies; (c) non-

Staff news

- Angus Gibson joined the group as a Research Software Engineer.
- Chathuranga Jayarathne has joined the group as an assistant in the GFD laboratory.
- Dongqin Yin completed her three years at ANU and has returned to a Faculty position in China.
- Anna Ukkola was awarded a DECRA to be held at UNSW, and will be leaving us in 2020.

Student news

- Ruth Moorman, Nick Velzeboer and Callum Shaw all completed their Honours year.
- Shangyu Hu and Xihan Zhang graduated from their Master of Earth Science (Advanced).
- Angus Gibson graduated from his PhD.
- Taimoor Sohail submitted his PhD and left to take up a postdoctoral position at UNSW.

Emeritus, Honorary staff and Visitors

- Yvan Dossmann (Université de Lorraine) and Henk Dijkstra (Utrecht University) visited the group for extended research visits.
- 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 Paige Martin (University of Michigan), Dr Annette Hirsch (UNSW) and Yiling Liu also sit in the group as long-term visitors.



EARTH DYNAMICS

Group leader

Paul Tregoning

Academic members

Sebastien Allgeyer, Stephen Cox, Marnie Forster, B. Gayen, Gordon Lister, Simon McClusky, Julia Pfeffer, Anthony Purcell

Overview

Structure Tectonics and Argon Geochronology succeeded in having ANU invited to become a member of the MinEx CRC, with the research proposed by Dr Marnie Forster in terms of the National Drilling Initiative (NDI) drawing particular interest, and support from five of the Australian geological surveys, working with GA to provide the first national argon data repository, and a bid to AuScope for support of a National Argon Map. Naina became the first MinEx CRC PhD candidate.

The TEAR (Tectonics, Exploration, Architecture and Resources) project continues the involvement of Structure Tectonics in the science of mineral exploration, focused on the Americas and Western Tethys. These activities led to a steady stream of visitors, and workshops at RSES, Perth and Denver. Four Masters of Earth Sciences (Advanced) students graduated, and three Masters of Philosophy theses were submitted. Courses taught included third year, an advanced structural mapping field short course (including drones with Simon McClusky) at Bermagui, and a two-week short course and workshop on argon diffusion modelling workshop at RSES.

In a collaboration with Dr Y Yukutake (Hot Springs Research Institute of Kanagawa Prefecture, Japan), Stephen Cox has been applying relationships between cumulative seismic moment

release and injected fluid volume to quantify fluid fluxes and map subsurface fluid pathways in the seismically-active magmatic-hydrothermal system beneath Hakone caldera in Japan.

PhD student, Kathryn Hayward has continued experimental studies of the role frictional melting in influencing fault mechanics. Particular attention has focused on microstructural characterisation of flash heating and consequent melting at micron-scale asperity contacts. The results highlight the role of visco-elastic properties of melts on fault asperity strength and behaviour.

Low-frequency measurements of seismic properties continued with focus on fluid-saturated synthetic glass media (PhD student Abdulwaheed Ògúnsàmi) with crystal applications, and high-temperature viscoelastic relaxation in olivine-pyroxene mixtures (PhD student Tongzhang Qu) relevant to the upper mantle.

Three PhD students graduated from the Earth Dynamics group in 2019: Dr Veronika Emetc, Dr Siyuan Tian and Dr Jami Zannat, while Rebecca McGirr passed her PhD mid-term exam. The GRACE team were selected to be members of the GRACE Follow-On Science Team and several presentations were made at the Science Team meeting in Pasadena in October 2019. We were also awarded two contracts from Geoscience Australia to investigate total water storage changes in northern Australia, in particular how it relates to changes in the Great Artesian Basin aquifer.

Simon McClusky took an extended sabbatical in 2019, during which time he was embedded within Geoscience Australia to provide expert advice for the Positioning Australia multi-GNSS National Positioning Infrastructure (NPI) software project. The aim of this project is to provide reliable real-time positioning data accurate to 3-10 centimetres available to users in every corner of Australia and NZ via Satellite Based Augmentation (SBAS).

We are running two AuScope projects through ANU – the Underworld geodynamics modelling software suite (www.underworldcode.org) and the AuScope Simulation Cloud (www.underworldcode.org/auscope-cloud).

Staff news

- Professor Louis Moresi joined RSES and became a member of Earth Dynamics.
- Dr Romain Beucher joined the Earth Dynamics group, transferring from University of Melbourne to continue working with Professor Louis Moresi
- Drs Julia Pfeffer and Sebastien Allgeyer returned to the Earth Dynamics group, working on an ARC-funded project and a Geoscience Australia contract.

Student news

- Naina, PhD candidate, Timing and evolution of the Delamerian orogeny at the Gondwana boundary, working with Dr Marnie Forster, supported by MinEx CRC.
- Nidnueng Nakrong, PhD candidate, Tectonic Reconstruction of the Americas, working with Professor Gordon Lister, supported by a Royal Thai scholarship.
- Master of Philosophy thesis submissions: Jack Muston, Reuben Creighton and Olga Baruleva.
- Siyuan Tian, Veronika Emetc and Jami Zannat were awarded their PhDs in June (supervisor: Paul Tregoning). Siyuan is working in the Fenner School. Veronika is now working with the NSW Department of Transport and Jami works at Geoscience Australia.
- Aditya Sharma (supervisor: Paul Tregoning), Ruoran Nie, Kristen Marris, Sonia Ho Yeung (supervisor: Marnie Forster), Nini He and Qianhui Zhou (supervisor: Gordon Lister) all graduated with a Master of Science (Advanced) degree.
- Siyuan Zhao commenced his PhD and will be investigating the active tectonics and seismic hazards in eastern Indonesian and West Papua (supervisor: Simon McClusky)

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.
- Emeritus Prof Ian Jackson continued with the supervision of PhD students Abdulwaheed Ògúnsàmi and Tongzhang Qu, and with collaborative research on high-temperature viscoelastic relaxation with Chris Cline (NASA Johnson Space Center), Ulrich Faul (MIT) and Katharina Marquardt (Imperial College London) - funded by a newly awarded ARC Discovery grant.
- Earth Dynamics hosted one Princeton undergraduate, Luke Begley, for 8 weeks as part of the International Intern Program. Luke worked on assessing the relation between spatial resolution and the accuracy with which mass change in Antarctica can be estimated using GRACE data.
- Venkata Naga Gopivikram visited Earth Dynamics for two months as part of the new Future Research Talent Travel Award, an agreement established between ANU and the top-ranked institutions in India. Vikram worked on deriving glacial isostatic adjustment estimates in Greenland from a combination of GPS and GRACE data.
- Structure Tectonics hosted Dr Arun Ojha from IIT Roorkee, India, for several weeks, as part of the TEAR project. Arun developed several 3D slab-models for the pacific rim during his stay. We anticipate he will be able to return once travel restrictions are lifted.

Extended travel and outcomes

- Under the auspices of a Japan Society for Promotion of Science Travelling Fellowship, Stephen Cox spent a month in Japan, visiting Chiba University, Tohoku University and the Hot Springs Research Institute (HSRI) of Kanagawa prefecture. He presented a keynote lecture at the 2019

International Slow Earthquake Workshop, provided a 1-day workshop for graduate students at the Tohoku University, and progressed a research collaboration with Dr Y Yukutake (HSRI). He also joined field trips with undergraduate and postgraduate students from Hokkaido University, University of Tokyo and Tohoku University.

Outreach activities & service roles external to ANU

Editorial Boards

- Physics of the Earth and Planetary Interiors, Earth and Planetary Science Letters (Ian Jackson)
- Journal of Geophysical Research–Solid Earth (Paul Tregoning)
- Marnie Forster: Setting up a National collaborative project, the National Argon Map and Argon Repository, a Geoscience initiative collaborating with ANU and involving, Curtin Uni, Melb Uni, Qld Uni, GS NSW, GS SA, GS Vic.
- Marnie Forster: involvement inTANG30 (Thermochronology and Noble Gas, Geochemistry and Geochronology Organisation) as a National Collaboration.
- Marnie Forster: RSES Argon Facility undertaking training and supervision of students from RSES and other Australian and international universities who are undertaking $40\text{Ar}/39\text{Ar}$ geochronology for their research.
- Louis Moresi leads the national Simulation, Analysis and Modelling component of AuScope.
- Louis Moresi was elected chair of the executive committee for the Computational Infrastructure for Geodynamics (CIG) organisation (www.geodynamics.org) for 2019/2020.
- Stephen Cox contributed to a 2-day workshop on “Applied structural geology of gold and base metal bearing hydrothermal mineralizing systems” in Toronto, and presented a half-day training workshop on “The dynamics of permeability enhancement and fluid flow in over-pressured, fracture-controlled, hydrothermal systems” to mining and exploration geologists in central Victoria.

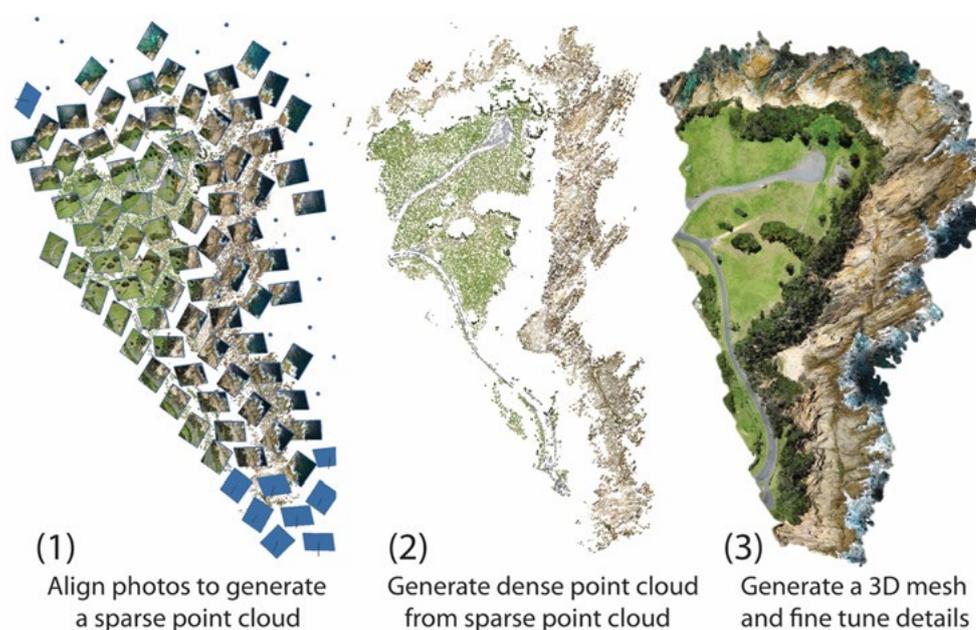


Figure 1. Creation of a continuous digital scene from incomplete aerial photographs–drone mapping at Bermagui taught by Dr Simon McClusky



EXPERIMENTAL PETROLOGY

Group leader

Andrew Berry

Academic members

Antonio Acosta-Vigil, Antony Burnham, Ian Campbell, Corinne Frigo, Charles Le Losq, G. Mallmann, John Mavrogenes, Hugh O'Neill, Greg Yaxley

Overview

The Experimental Petrology group comprised five members of continuing academic staff (Andrew Berry, Ian Campbell, John Mavrogenes, Hugh O'Neill, and Greg Yaxley), three research/postdoctoral fellows (Antony Burnham, Charles Le Losq, and Corinne Frigo), 16 PhD students, and two technical staff.

Research highlights

Research highlights include a paper in *Science* on the isotopic signatures of fluid inclusions in diamonds from the Earth's transition zone (doi:10.1126/science.aax5293), a paper in *EPSL* on the origin and distribution through time of S-type granites (doi.org/10.1016/j.epsl.2020.116140), work on the oxidation state and coordination environment of antimony in silicate melts (doi.org/10.1016/j.chemgeo.2019.06.017), a new method to determine the oxidation state of iron in basalts using Raman spectroscopy (doi.org/10.2138/am-2019-6887), and a review of CO₂-rich melts in the Earth (doi/10.1017/9781108677950.006). We also hosted a workshop at RSES on "Subduction zone magmas and their ore deposits" that was attended by over 60 people from domestic and international Universities, CSIRO, GA and mining companies.

Lab news

In the laboratory, we continue to operate five 1 atm gas-mixing furnaces, 11 piston cylinders (4 of which are fully automated for both pressure and temperature), and a multi-anvil. We also operate a LA-ICPMS and have access to a JEOL JXA-8530F Field Emission Gun Probe in the ANU Centre for Advanced Microscopy. The group is regularly awarded beamtime at national and international synchrotron facilities.

Staff news

- Ian Campbell was awarded the Haddon Forrester King Medal by the Australian Academy of Science for his life-long contribution to the discovery, evaluation and exploitation of mineral deposits. Ian also served on the Fellowship Committee of the American Geophysical Union.
- Greg Yaxley was awarded a 3-month extension of his Alexander von Humboldt Fellowship to the Institute for Mineralogy at the Goethe University, Frankfurt, Germany, where he conducted multi-anvil experiments at the pressure-temperature conditions of the 410 km seismic discontinuity to determine the amount of water required to melt the mantle at this depth.
- Andrew Berry was a member of the Advisory Panel of the MEX (Medium Energy XAS) beamline being built by the Australian Synchrotron.
- Andrew Berry and Caroline Eakin (from the Seismology and Mathematical Geophysics Group) were nominated for a Vice-Chancellor's Citation for Outstanding Contribution to Student Learning.
- Charles Le Losq left us in August to take up a continuing position at the Institut de Physique du Globe de Paris.
- The Group benefited from the contributions of Richard Arculus (Emeritus), Lynton Jaques (Visiting Fellow) and Andrea Gerson (Adjunct Professor).

Student news

- The 2019 Sue Kesson PhD Student Travel Grant was awarded to Laura Miller to enable her to attend the APS/IIT X-ray Absorption Spectroscopy Summer School in Chicago.
- PhD students James Tolley (now a postdoc at University of Tasmania) and Hongda Hao (postdoc at Laurentian University) both graduated in July.



GEOCHEMISTRY AND COSMOCHEMISTRY

Group leader	Trevor Ireland
Academic members	Yuri Amelin, Janaina Avila, Vickie Bennett, Masahiko Honda, Mark Kendrick, Penny King, Marc Norman, Ian Williams
Professional staff	Peter Holden, Peter Lanc, Dave Thomson, Sonja Zink

Overview

This year saw several highlights in space exploration of direct relevance to RSES. We saw the JAXA Hayabusa 2 mission complete a successful imaging and sampling campaign at asteroid Ryugu (Watanabe et al., 2019, *Science* 364, 268), and the arrival of NASA's Osiris-REx at asteroid Bennu (Lauretta et al., 2019, *Nature* 568, 55). It was also the fiftieth anniversary of the Apollo XI landing on the moon. The lunar samples were analysed here at RSES and we played a major role in the analysis of those extraordinary materials and in establishing their planetary context. Data collected by the Curiosity rover on Mars was used to show diurnal changes in methane abundances by RSES Visitor John Moores and Penny King (Moores et al., 2019, *Geophys. Res. Lett.*, 46, 9430).

As a bit of a milestone in international representation and leadership, Vickie Bennett is now the President of the Geochemical Society, the first scientist outside of Europe or North America to be elected to this position, and Trevor Ireland is the Past President of the Meteoritical Society.

Penny King continues in her roles on various committees for the Mineralogical Society of America, American Geophysical Union and the Australian Academy of Science. Penny King was promoted to

Professor and became a Fellow of the American Geophysical Union (AGU) and the Mineralogical Society of America. She was awarded the AGU's Joanne Simpson Medal for Mid-Career Scientists in Earth & Space Sciences.

Research highlights

Our ability to measure minor S isotopes is exemplified in two publications by our graduated PhD researcher Ms Li Liu. The first paper (Liu et al. *Geochim. Cosmochim. Acta* 273, 354) demonstrates that pyrite transformation to pyrrhotite does produce any shift in $\Delta^{33}\text{S}$ and $\Delta^{36}\text{S}$ to extremely high levels of precision ($<0.005\text{‰}$ in $\Delta^{33}\text{S}$, and $<0.2\text{‰}$ in $\Delta^{36}\text{S}$). The second paper (Liu et al. *Chemical Geology* 532, 119369) addresses a furphy associated with a sulfur isotopic composition being connected to a particular pyrite morphology.

A series of papers examining the interaction between S-rich gases and magmatic rocks show the role of these reactions in the evolution of planetary surfaces. We investigated minerals deposited by magmatic vapours in Nekvasil et al. (2019, *J Geophys. Res. Planets*, 124, 1592). We also showed how vapours may react with glasses near the surface to produce a range of distinctive minerals observed on Earth and other planetary bodies (Renggli et al. 2019; *J Geophys. Res. Planets*, 124, 2563). The fundamental controls on these types of reactions was explored in another paper by Renggli et al. (2019, *Contr. Mineral. Petrol.*, 174, 3).

Laboratories and Facilities

SHRIMP

The three SHRIMPs operating in the J5 facility all saw extensive operation in 2019. SHRIMP SI was particularly busy with its unique capabilities for measuring minor stable isotopes.

The new multiple collector (funded in part by ANU MEC) was completed with installation in December. The new aspect of this design is the movement of the collector slit rather than the Faraday cup itself. This allows us to maintain the fixed solid connection between the Faraday cup and the electrometer, which we think is essential for charge mode operation. The movement of the collector slit in line with the incoming beam also makes tuning far simpler than our previous configuration. We've already collected data from the collector and everything looks good.

The past year saw the final delivery of a SHRIMP from Australian Scientific Instruments in Fyshwick. The intellectual property associated with ASI has been transferred to Dunyi Technology Corporation and RSES will maintain close links with DTC as they seek to continue the SHRIMP brand.

SPIDE2R/TIMS:

The priority in operation of the SPIDE2R lab in 2019 was large-scale high precision Sr and Nd isotopic work. New multi-dynamic procedure for high precision Sr isotope analysis (Di et al., in preparation) enabled extensive initial $^{87}\text{Sr}/^{86}\text{Sr}$ and nucleosynthetic $^{84}\text{Sr}/^{86}\text{Sr}$ study of a wide variety of the oldest solar system solids, including refractory inclusions and the oldest achondrites. These data will allow to refine the chronology of accretion and asteroid formation in the solar protoplanetary disk.

Publication highlights include the application of exceptionally low blank procedures developed at the SPIDE2R lab, which made possible the study Pb and Sr isotope variations in fluid inclusions in superdeep mantle diamonds (Timmerman et al. (2019) *Science* 365, 692–694). Novel dissolution and chemical separation procedures enabled the first precise and reliable isotope dilution U-Pb dating of cassiterite,

an important ore mineral (Carr et al. (2020) *Chemical Geology* 539, Article 119539). Both these studies attracted broad attention of Earth scientists and public media.

Variations in the ^{142}Nd isotopic compositions of ancient terrestrial rocks, which arise from differences in the Sm/Nd ratios in Earth's different chemical domains that formed during the first 400 million years of Earth history (whilst the now extinct parent isotope ^{146}Sm was actively decaying) provide a direct record of Hadean planetary processes. A large-scale, integrated study of $^{142}\text{Nd}/^{144}\text{Nd}$ variations in a wide range of the oldest terrestrial rocks was initiated in 2019 following the development of new, more efficient chemical separation methods (Bennett et al, in prep.) and high precision multi-dynamic methods on the Triton Plus. Measurements started in late October 2019 after Faraday cup liner replacement, and continued (with exceptions for fire and hailstorm interruptions) at full speed until the ANU was switched to remote operation in March 2020.

SPEC-E Lab

Charles Le Losq departed from RSES and Corinne Frigo took on helping in the IR spectroscopy laboratory. Sarah McIntyre, Terry Mernagh and Penny King set up a system to flow gases through an environmental chamber for in situ reaction monitoring. Amongst other projects, the handheld spectrometer is being used to assess the best approaches to clean the Sydney Harbour Bridge.

Outreach

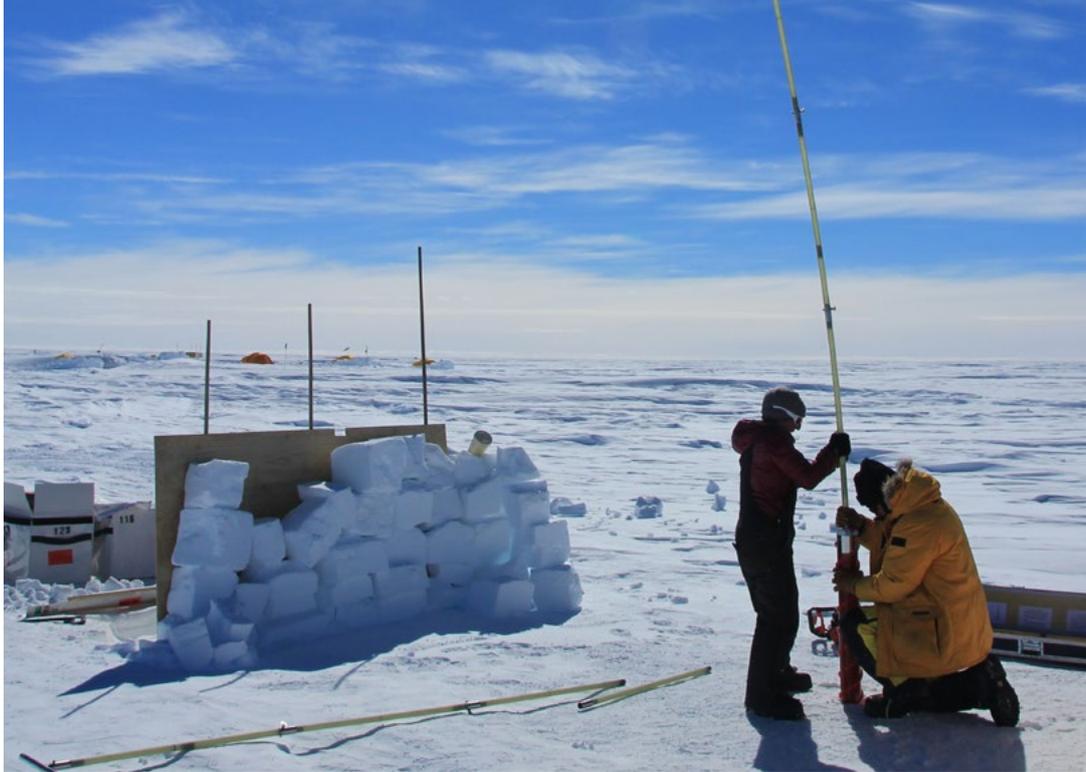
A number of people participated in the celebration of the Apollo landings with a number of media presentations by Dr Marc Norman, Prof. Trevor Ireland and Prof. Penny King. Prof. Penny King was involved in a public discussion panel and separate media release on Mars research and a presenter for "Science in the Pub". Mr Geoff Bonning also deserves special mention for his efforts running presentations on meteorites and in bringing planetary sciences across to the general public during Apollo week.

Staff news

- Dr Marc Norman received a Distinguished Service Award from the Geochemical Society in recognition of his 7 years of leadership as Executive Editor of *Geochimica et Cosmochimica Acta*, the leading geochemistry journal. Dr. Mark Kendrick departed RSES to take a position at University of Queensland.

Student news

- Mr Leonardo Baeza and Mr Aditya Patkar commenced PhD studies under the supervision of Trevor Ireland. Ms Perinne Tyler submitted her thesis on "Archean sulfur reservoirs of the Kaapvaal Craton". Dr Li Liu was awarded a PhD for her thesis entitled "Multiple Sulphur Isotopic Compositions of Archean Records Determined by SHRIMP-SI". Mr Bruno Moller commenced a MPhil study under the supervision of Yuri Amelin. Ms Emily Oborski commenced a MESA project under the supervision of Penny King. Ms Fatin Mahdini and Mr Afiq Yahyah completed Honours theses in Engineering co-supervised by Penny King.
- Dr Pat Carr was awarded his PhD with a thesis entitled "Tourmaline geochemistry and cassiterite geochronology of highly evolved tin granites and their hydrothermal systems in eastern Australia" supervised by Vickie Bennett and Marc Norman. Ms Jennifer Prichard submitted her PhD thesis (supervisors Norman and Bennett) on "Geochemical Modelling of Shallow Fractionation and Deep Mantle Melting Below Mauna Loa Volcano, Hawaii".



PALAEOENVIRONMENTS

Group leader

Katharine Grant

Academic members

Nerilie Abram, David Heslop, Fiona Hibbert, Brad Opdyke, Brad Pillans, Andrew Roberts, Eelco Rohling, Nicky Wright, J. YuJia Liu and Xiang Zhao

Research highlights

Eelco Rohling, Fiona Hibbert, Katharine Grant, Andrew Roberts, and Jimin Yu published a widely-viewed study in *Nature Communications* which showed that ice melt in the last interglacial period caused global seas to rise ~10 metres above the present level. Furthermore, they found that sea levels rose at up to 3 metres per century, far exceeding the ~0.3-metre rise observed over the past 150 years. The ice melted first in Antarctica, then a few thousand years later in Greenland. This research shows that Antarctica, long thought to be the “sleeping giant” of sea level rise, is actually a key player. Its ice sheets can change quickly, and in ways that could have huge implications for coastal communities and infrastructure in future. The paper was one of the most read *Nature Communications* articles of 2019.

Bradley Opdyke published a study in *Deep Sea Research* on the differing water masses off the South Australian margin with former PhD Student Laura Richardson. He also published with former Honours student, Anna Haiblen, with Andrew Roberts and David Heslop in *Paleoceanography and Paleoclimatology* a climate record from the South Australian margin of the Eocene-Oligocene boundary and the dramatic events associated with that time.

Jimin Yu led a study published in Nature Communications which looked at past carbon cycle changes and their impacts on atmospheric CO₂. The study shows that CO₂ absorption in the North Atlantic was twice as efficient during the Last Glacial Maximum compared to the Holocene. This new estimate -based on geochemical data from multiple sediment cores -is crucial for understanding the processes that led to past atmospheric CO₂ changes, and may help to constrain future carbon cycle and climate changes in the face of on-going atmospheric CO₂ rise.

Other news

Nerilie Abram was the Convening Lead Author of the Intergovernmental Panel on Climate Change IPCC Special Report on the Ocean and Frozen Regions in a Changing Climate. She presented a summary of the findings at a special event organised by ANU's Climate Change Institute, and was also interviewed on ABC radio.

Eelco Rohling published his second book: "The Climate Question: Natural Cycles, Human Impact, Future Outlook". The book illustrates the impact of large climate changes and uses this as context for the impacts of modern changes, in order to help people understand the potential scale of impacts in the immediate future, and how long it may take for nature to recover. He compares natural climate variations (before humans) with industrial-age changes, thereby providing an understanding of the differences and similarities between natural climate changes and those caused by humans.

2019 saw the triennial International Conference on Palaeoceanography come to the southern hemisphere for the first time –and to Sydney! This allowed a great representation from our palaeoenvironments group, including four members on the Organising/Scientific Committees (Stewart Fallon, Katharine Grant, Eelco Rohling, Jimin Yu).

Katharine Grant, Fiona Hibbert, and Eelco Rohling wrote the most-read article in The Conversation for 2019, which received >595,000 views. It was widely republished, including in Cosmos magazine. Nerilie was the next most-read contributor to The Conversation –a top 4 for RSES Palaeoenvironments!

Awards

Nerilie Abram was awarded the 2019 Priestley Medal from the Australian Meteorological & Oceanographic Society (AMOS). The Priestley Medal recognises personal excellence in meteorological, oceanographic or climate research carried out substantially within Australia by a mid-career scientist no older than 45 years. It commemorates the life-long contributions of Dr C H B Priestley, the first Chief of the CSIRO Division of Meteorological Physics, to meteorological and oceanographic research. Nerilie is also part of the ANU Climate team that won the Vice-Chancellor's Award for Impact and Engagement.

Patrick de Deckker was awarded the Brady Medal from The Micropalaeontological Society for a major influence on micropalaeontology via a substantial body of excellent research.

Andrew Roberts was awarded the Axford Medal from the Asia Oceania Geoscience Society. This prestigious award recognises “academic excellence and unselfish scientific cooperation in Asia and Oceania”.

Congratulations also to Eelco Rohling on being named one of the world’s most highly cited researchers in his field for 2019 by Publons.

Funding

Congratulations to Andrew Roberts and Dave Heslop for their ARC DP success, as well as an ANU MEC grant for a replacement magnetic susceptibility meter. Triple success for Andrew as he also scored a major grant from the National Natural Science Foundation of China led by Prof Jinhua Li from the Chinese Academy of Sciences. Palaeoenvironments members were also successful in many other smaller grants (see RSES Annual Report -Funding). Eelco Rohling won an ARC DP together with Prof Gavin Foster from Southampton, UK. Congratulations also go to Laura Rodriguez Sanz, Tiah Penny and Xiang Zhao who were all awarded RSES professional staff professional development funding for 2020. Laura travelled to Zurich from December to February to work in the clumped isotopes lab of Prof. Stefano Bernasconi at ETH; Tiah hopes to travel to the US to attend an education conference; and Xiang hopes to visit other leading palaeomagnetic labs in Europe and the USA. Sarah Jackson was awarded a SCAR Fellowship to support a research visit to the University of Copenhagen and British Antarctic Survey from October to February.

Staff news

- Henrik Sadatzki joined us from Bergen to commence a post-doc with Leanne Armand, working on sea ice biomarkers to reconstruct Southern Ocean palaeoclimate change.
- We welcomed back Pengxiang Hu, a post-doctoral researcher who is working with Andrew Roberts and the environmental magnetics team.
- We farewelled Jess Amies and Fiona Hibbert. Jess is now an Industry Scientist & Consultant at the UK Met Office and Fiona is undertaking a 2-year Marie Curie Fellowship at York University (UK).
- Nerilie Abram was promoted to a full Professor.

Student news

We welcomed five new PhDs in 2019: Udara Amarathunga (supervisor: Eelco Rohling); Sarah Jackson (supervisor: Nerilie Abram), Xuan Ji (supervisor: Jimin Yu); Kelly Lawler (supervisor: Leanne Armand); Victor Piedrahita (supervisor: Andrew Roberts); Song Zhao (supervisor: Katharine Grant).



SEISMOLOGY AND MATHEMATICAL GEOPHYSICS

Group leader

Hrvoje Tkalčić

Academic members

Phil Cummins, Rhodrie Davies, Caroline Eakin, Babak Hejrani,
Meghan Miller, Marija Mustac, Malcolm Sambridge, Benoît Tauzin,
Andrew Valentine, Lauren Waszek

Overview

Notable achievements of the Group's members this year include the ARC awards exceeding 1.5M, the US DoE award exceeding 0.5M and Marine National Facility grants in ship time for the investigation of the Macquarie Complex Ridge in the Southern Ocean exceeding 5M. The first voyage on RV Investigator is scheduled for March/April 2020. Twelve group members and affiliates will participate in the first voyage. The project to investigate the subsurface of the Macquarie Ridge Complex and large earthquakes occurring in that region is a multidisciplinary, multi-institutional and international collaboration led by RSES/ANU, and joined by UTAS, Caltech and Cambridge. ARC Linkage Project to study lithospheric structure of southwestern Australia by using telemetered broadband and strong motion seismometers was funded in collaboration with GSWA, GA, and DFES.

Research highlights on Earth structure start with a groundbreaking research published in Nature Geoscience by Davies, Valentine, Eakin and others, in which they used observational

constraints on residual topography beneath the world's oceans to generate a robust estimate of the power spectrum of Earth's oceanic residual topography. Their study resolved the long-standing debate on the spatial distribution, wavelength and amplitude of present-day dynamic topography, reconciling key predictions of mantle flow models with inferences from the geological record and emphasising the key role that Earth's deep interior plays in shaping the surface of our planet. Another groundbreaking research, on earthquakes and tsunamis in Indonesia, led by Cummins and his former PhD student Pranantyo, has just been accepted for publication in *Nature Geoscience*. Overall, the group published over 30 peer-reviewed articles on topics ranging from observational to theoretical, including contributions to understanding Earth's structure and dynamics as well as seismic sources.

In 2019 a new collaboration was formalized between group members and the CSIRO Future Science Platform for Deep Earth Imaging. This sees CSIRO providing financial support for two new Ph.D. projects, Matthias Scheiter and Buse Turunctur who arrived during the year and started their projects in machine learning and geophysical inversion and PhD student Ping Zhang's Banda arc imaging project. Late in the year a second multi-year project was initiated which will see further support from CSIRO to help establish a new venture known as 'In-Lab' where staff from the group and CSIRO join together to pursue projects of mutual interest in mathematical geophysics. This project will involve multiple exchange visits of staff and students between ANU in Canberra and CSIRO in Perth over the next two years. This year also saw the second year completed of a three-year collaborative project on seismic data analysis and imaging of the Australian continent, between group members and Geoscience Australia in support of GA's exploring for the future initiative.

AuScope funded Kimberley array of eight broadband seismometers, with state of health telemetry, was installed in June 2019 in northern Western Australia. The ANU Global Research Partnership Grant was awarded to Miller to establish an academic exchange program with Caltech.

This year also marked the completion of the Banda Arc deployment of 20 broadband seismometers across Nusa Tenggara Timur region of Indonesia and Timor-Leste (Miller). Installation of the AuScope funded Lake Eyre Basin seismic deployment completed in 2019 (with the aid of a helicopter) after overcoming delays due to Lake Eyre floods and soaring temperatures in the Simpson Desert (Eakin). This new network of 40 seismometers will continue to operate for another year with the goal to investigate the nature of the Gawler Craton margin, as well as mysterious seismicity within the Simpson Desert, home to one of the largest earthquakes ever recorded in Australia.

The Group continues to operate Warramunga on behalf of the United Nations and the Australian Government. The year 2019 fortunately passed without fire-or flood-related incidents.

Staff news

- Marthe Kloecking, Sia Ghelichkhan, and Robert Pickle joined the group as Postdoctoral Fellows.
- Dr Babak Hejrani was promoted to academic level B.



AUSTRALIAN AND NEW ZEALAND IODP CONSORTIUM (ANZIC)

Group leader

Leanne Armand

Overview

The Australian and New Zealand International Ocean Discovery Program Consortium (ANZIC) is composed of 16 universities (13 Aust., 3 NZ) and four government agencies (2 Aust., 2 NZ). Our activities are steered by the ANZIC Governing Council and the ANZIC Science Committee, whilst the ANZIC Program Office, hosted at the Research School of Earth Sciences at the Australian National University, manages activities under the leadership of the ANZIC Program Scientist. Membership of the consortium enables participation in the International Ocean Discovery Program, which undertakes scientific ocean drilling across the Earth's oceans. Ocean drilling addresses scientific problems of global interest by taking continuous cores of rocks and sediments that address four broad themes: deep life, planetary dynamics, climate and geohazards. Two large coring vessels, JOIDES Resolution and Chikyu, and alternative mission-specific ship-based coring-platforms, are used and our participation on these 2-month expeditions provides international training and research opportunities to the Australian and New Zealand research community.

2019 was a significant year for ANZIC as a consortium, for scientists and also within the office. At the international consortium level, five ANZIC scientists participated in four expeditions as detailed below:

- Expedition 385 (NanTroSEIZE Plate Boundary Deep Riser 4) on DV Chikyu (7 October 2018-31 March 2019). ANZIC participant: Toby Colson (University of Western Australia).
- Expedition 379 (Amundsen Sea West Antarctic Ice Sheet History) on RV JOIDES Resolution. 18 January -20 March 2019. ANZIC participant: Joe Prebble (GNS-Science) as a Palynologist.
- Expedition 383 (Dynamics of Pacific Antarctic Circumpolar Current DYNAPACC) on RVJOIDES Resolution. 20 May -20 July 2019. ANZIC participants: Christina Riesselman-University of Otago (Diatom Paleontologist); Christopher Moy-University of Otago (Sedimentologist).
- Expedition 382 (Iceberg Alley and Subantarctic Ice and Ocean Dynamics) on RV JOIDES Resolution. 20 March-20 May 2019. ANZIC participant: Linda Armbrecht -University of Adelaide (Diatom Paleontologist).

ANZIC connected with all consortium partners with a Roadshow over the first two months of the year, thus providing an update on general activities and an understanding to geoscientists and biogeoscientists of the opportunities available for them through IODP in the coming year. This opportunity also enabled consortium members to reflect on their success through the program and their willingness to continue with membership post-2020 when the current phase of funding through the ARC LIEF grant comes to an end. The ANZIC Strategy Team, lead by the Program Scientist. Leanne Armand submitted a National Collaborative Research Infrastructure Strategy (NCRIS) submission to the Dept of Education and Training, Research Infrastructure section. The submission outlines a new 10-year program, identified as the Oceania Scientific Drilling Program (OSDP) to replace ANZIC. An outcome on the submission is not expected until late 2020.

As part of the worldwide effort to develop the next Scientific framework for scientific ocean drilling, the ANZIC Ocean Planet Workshop was held over 3 days in April 2019 at the ANU, bringing together 75 experts from Australia, New Zealand, and abroad, to formulate research themes and define new challenges for a new strategic plan for global scientific ocean drilling. Many attendees were early and mid-career researchers, highlighting the wide interest in continued engagement in this international program. The outcome from the meeting included the ANZIC Ocean Planet Workshop report, "Ocean Planet: An ANZIC workshop report focused on future research challenges and opportunities for collaborative international scientific ocean drilling" (<http://hdl.handle.net/1885/197025>) and a meeting report in EOS (<https://eos.org/meeting-reports/australia-new-zealand-plan-for-future-scientific-ocean-drilling>). An additional four international planning workshop outcomes were held in Japan, Europe, China and the US to capture the opinions of the science communities based in those regions. These workshops assessed the continuing relevance of the 2013-2023 science plan and each workshop has provided input toward the next stage of designing the post Science Strategic Plan (2024-2050) for scientific ocean drilling. The plan is expected to be completed by mid 2020.

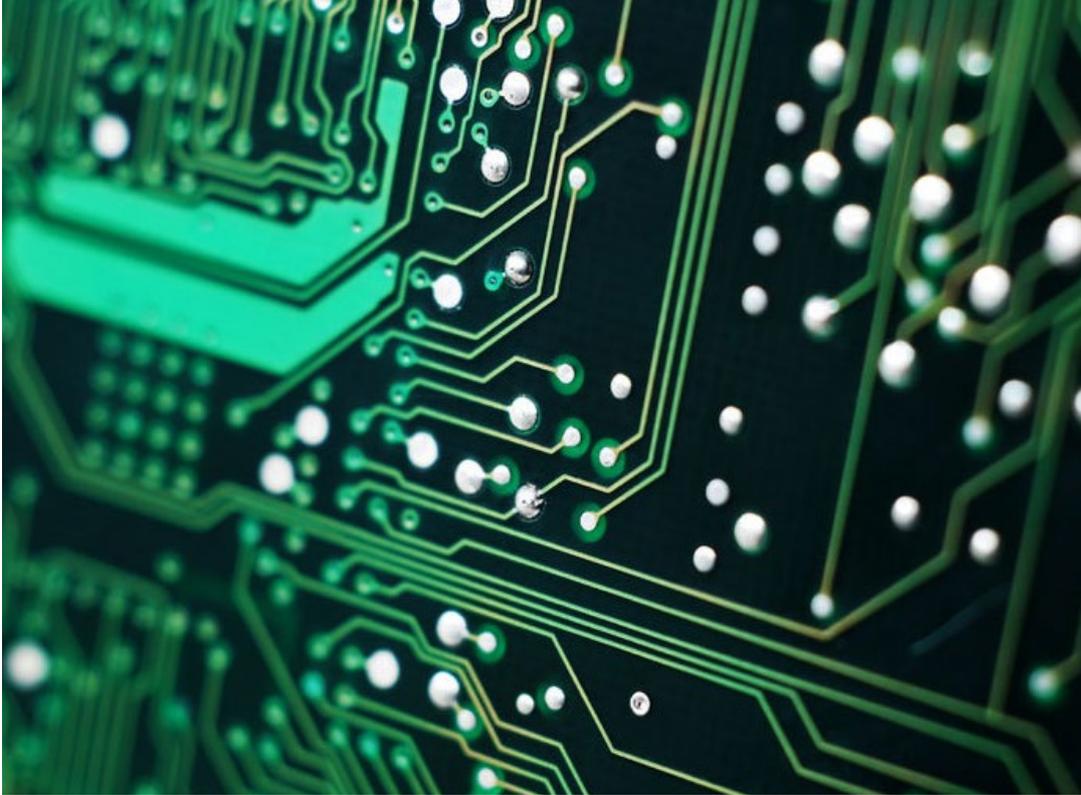
A new IODP Code of Conduct was developed and released in 2019 having input from all 24 nations. It is available from: <http://www.iodp.org/top-resources/program-documents/policies-and-guidelines>. Nationally, ANZIC supported eight Legacy grants up to \$120,000 to conduct analyses on pre-existing IODP-collected material. One of these grants was awarded to a RSES team led by K. Grant in the Palaeoenvironments Group (Project: Australian Monsoon variability through the Pleistocene).

ANZIC also awarded the Geoscience Masterclass to a Sydney university consortium led by Simon George at Macquarie University. There were 18 student participants from 15 institutions, and another three from New Zealand. The Masterclass was organised by Macquarie University (S. George and S. Loehr) and the University of Sydney (J. Webster and M. Seton) and CSIRO (J. Parr) and had contributions for many other university and institutional staff. Bushfires along the south coast and smoke haze interrupted plans for field work at Kioloa, but the students still gained practical experience in marine geoscience through boat trips out of the Sydney Institute of Marine Science, including obtaining piston cores, grab samples and chemistry data from Sydney Harbour, and worked on freshly obtained sediment core samples. The field trip was changed to the Illawarra, NSW to look at Late Permian outcrops, and finished the course with a visit to the Geological Survey of NSW core store at Londonderry.

Locally within the ANZIC Office, we welcomed Kelly Kenney as the new ANZIC Administrator having farewelled Catherine Beasley at the end of 2018. Kelly is a welcomed team member and has been working hard to bring her diverse experience in managing the administration of NGOs to ANZIC. She has been instrumental in updating procedures and providing vital financial input to the NCRIS bid to aid in the continuation of ANZIC into the future.

Finally, we congratulate Neville Exon, our previous Program Scientist, on being awarded an Order of Australia, Member (AM) in the General Division for his significant service to marine geology and to higher education. The Order of Australia confers the highest recognition for outstanding achievement and service in Australia, and is the principal means of recognising outstanding members of the community at a national level. Our community thanks Neville for his many contributions over the years to ANZIC and IODP.





Electronics Group

Group leader

Andrew Latimore

Group members

Tristan Redman, David Cassar, Hideo Sasaki, Brent Butler.

Overview

The Electronics Group provides Electronic Engineering service and technical support to all Research School of Earth Sciences' and Australian National University's academic research. The Group holds the responsibility for maintaining and servicing electronic systems within RSES and offers a development facility able to engineer innovative electronic solutions. The Group is equipped with a circuit production facility utilising an automated component placement machine and reflow oven. The Electronics Group endeavours to ensure the Research School of Earth Sciences remains a state-of-the-art institution and achieves the strategic goals of the University.

2019 Highlights

Sodium test loop control system.

During 2019 the RSES Electronics Group was employed to develop an electrical control system for monitoring and manipulation of liquid sodium test loop facility for the Research School of Engineering and Computer Sciences (CECS). This project is led by Dr Joe Coventry and is the basis for analysing and testing new energy storage technology for renewable technologies like concentrated solar high-temperature power systems. In thermochemical storage, the temperature of the substance is critical to maintain liquid form, the control system is required to heat and monitor fluid line to hundreds of degrees centigrade to allow the flow of sodium through to a test solar concentrator. The facility will allow researchers to accurately monitor power generated and stored and keep the volatile sodium in a safe environment. The RSES Electronics Group has completed the construction of the electronic controls and will be implementing the design during 2020.

Laser ablation addition to Accelerator Mass Spectrometer, LA-AMS.

The Research School of Earth Sciences Radiocarbon Dating Laboratory is developing a sample laser ablation system to extend the sample preparation capability of the facility. RSES designed laser ablation sample cell technology is currently operating on two Inductively Coupled Mass Spectrometer facilities within the Research School of Earth Sciences. The LA-AMS project will utilise this proven sample cell technology and adapt it to operate on the Radiocarbon Dating Laboratory's AMS. During 2019 the Electronics Group developed a new sample cell stage motor controller system and gas control system for use with a new compact excimer laser.

Atom interferometer data acquisition system.

The Research School of Physics, Department of Quantum Science Atomlaser & Quantum Sensor Group has developed gravity sensing technology and has engaged the RSES Electronics group to design electronics hardware for the facility. During 2019 the Electronics Group developed a unique circuit including high speed analogue to digital conversion (ADC), high speed digital to analogue conversion (DAC), ultra-high 32bit resolution ADC, and digital I/O capability. The design needed to fit inside an enclosure the size of a can of beans. The Electronics Group successfully designed and constructed the circuit within the restraints and improved our experience in compact design techniques.

Moku Pro ADC and DAC systems.

The Electronics Group collaboration with Liquid Instruments PTY LTD continued through 2019. The Group developed high speed data acquisition printed circuit boards for the latest generation of Moku laboratory instruments called Moku Pro. Liquid Instruments is a successful spin off company originating from ANU. RSES Electronics Group has been a vital prototyping facility for the company and has made the transition from idea to commercial product possible.

Desert Fireball Network Node remote power system.

During 2019 the Electronics Group developed and constructed two remote power stations for the Desert Fireball Network project for Geochemistry & Cosmochemistry Group. The project will allow a meteoroid monitoring and tracking station to be installed near Wagga Wagga NSW and one in Mt Stromlo ACT. These stations will contribute to the Desert Fireball Network allowing accurate triangulation and recovery of meteorites across Australia.

Shrimp SI new multiple collector system

During 2019 the Electronics Group assisted the Geochemistry & Cosmochemistry Group with implementing the latest generation multiple collector system to SHRIMP SI. The new collector includes up to five faraday cup detectors each with piezo motor actuators for entry slit spatial tuning.

Staff changes

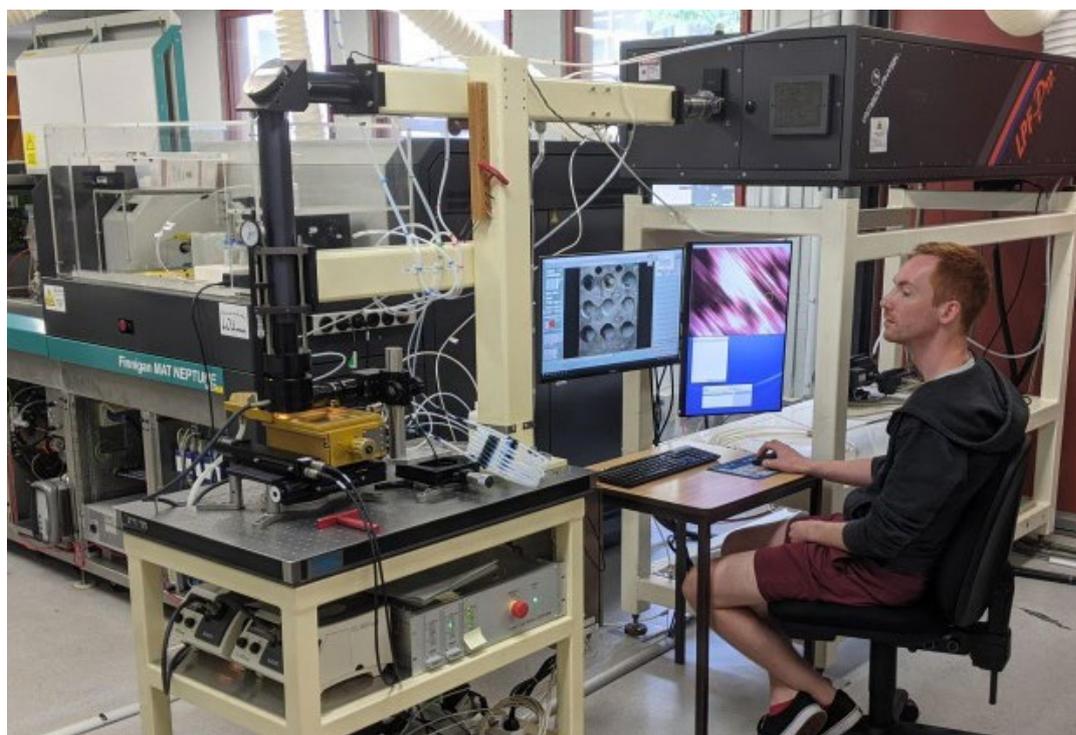
This year Luke Materne continued to work for RSES until his secondment finished in March. Luke was on secondment from the Research School of Physical Science Electronics Unit.

Students and 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 years 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

Group

Andrew Wilson (Workshop Manager), Carl Were, Brent Butler, Geoff Woodward, Hayden Miller (1/2 time share with Rock Physics), Brooke Roy (Apprentice fitter and Machinist, 50:50 Share with RSPE)

Overview

Mechanical job requests from within RSES were very low, the lowest ever recorded. Work from other areas of ANU was virtually nil, as was full external work.

Internal charge rate: \$100/hour + materials, consumables and running costs.
ANU and External Rate: \$135/hour + materials, consumables and running costs.

Turnaround time on Mech Workshop requests was very short throughout the year. In January 2019 we welcomed Brooke Roy to the team. Brooke commenced an apprenticeship in fitting and machining. This apprenticeship was part of the ANU Indigenous Trainee Program and was a joint position with RSPE Mechanical Workshop. Brooke will continue her second year of training with RSPE in 2020. The lean year for us was in some ways positive as a high-level teaching and supervision was committed towards Brooke's training.

In a year with a relatively low machining workload, staff spent extra time with training and administration. Staff familiarised themselves with the newly introduced Technical Workshop Work Management System, learned new skills to assist the Electronics group with their workload and began the significant task of implementation of the new WHS Management System. Brent Butler and Hayden Miller continued Certificate 3 level training in Electronics and Communications Engineering. One FTE was committed to training with Brooke. The ANU Technical Workshop Work Management System (TWWMS) was introduced at the

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The ANU Technical Workshop Work Management System (TWWMS) was introduced at the beginning of January 2019 providing the ability for all ANU staff to log jobs to any Mechanical or Electronics Workshop on campus. Due to vastly differing charge rates across the ANU, the system is yet to fulfil its full potential to enable effective sharing of workloads across campus. So far the system has fulfilled its duty as a good time keeping system. The success of the system for job logging was a little mixed with a variety usability issues for staff. With continued support and improvement, the system should result in a useful portal to open up our services more broadly and more easily across campus.

The core work undertaken in 2019 included:

- SHRIMP Maintenance and Development, Including completion and commissioning of the new Multi-Collector for SHRIMP SI-Prof Trevor Ireland.
- General support for some of the RSES labs -Dr Stewart Fallon, Dr Michael Ellwood, Prof Ian Jackson/Prof Stephen Cox.
- 500-degree Dry block, Pyrolysis Heater -Prof Jochen Brocks
- High Temperature Tantalum crucibles -Dr M Forster
- ANU Sol Invictus solar car -Suspension and steering components -ANU Student run team (mostly from) from College Engineering and Computer Science. The team went on to complete the Darwin to Adelaide challenge, a distance of over 3000km.



Bake your PhD, Steve Eggins, Robin Grun, Keith Nugent, winner Božana Pašić, Rebecca McGir and Tharika Liyanage.

Student Activities

Student representatives Božana Pašić
Yajie Gao

Overview

2019 was an exciting year for student activities and events across the undergraduate and postgraduate cohorts. The ANU Earth and Marine Sciences Society held their annual “Geoball” at the Rex Hotel. The AusIMM Canberra Student Chapter held their annual Students Meet Industry Night. The postgraduate student cohort has had a busy year with two major events taking place, the Student Conference and the annual PhD Dinner, in addition to regular student meetings and get-togethers.

Stucon

Stucon, the 5th annual RSES HDR Student Conference was held at RSES with the main highlight being the Bake Your PhD challenge. The competition was judged by Deputy Vice-Chancellor Professor Keith Nugent, RSES School Director Professor Steve Eggins, and previous champion Tharika Liyanage. Cakes were judged according to how well they depict the research, creativity, and of course how tasty they were. PhD student Božana Pašić walked away with first prize for her depiction of the internal structure of black opals.

PhD Dinner

The annual PhD Dinner was held at the Labour Club in the city and was a chance for all the PhD students to relax and connect beyond their usual research groups. It was a wonderful night with awards given for “Best Office Mate”, “Messiest Desk”, “Night Owl” and more!

ANU Earth and Marine Sciences Society (EMSS)

EMS is the undergraduate student society for students studying the earth and marine sciences at the ANU. Their activities include BBQs, trivia nights, movie nights and expert lectures. The annual Geoball is a chance for the whole school to gather and celebrate the year with mock and official awards presented as well as great food and drink. The theme for this year was Snowball Earth – highlighting the times during Earth’s history where the planet was covered in ice. The event saw student achievements highlighted with official award, as well as mingling between students, staff and academics. (mostly from) from College Engineering and Computer Science.

AuSIMM

The AusIMM Canberra Student Chapter is a part of the AusIMM, the association for students, professionals and academics within the mining industry. Each year, the Chapter holds their annual Students Meet Industry Night, where they invite representatives from the mining industry, academia and government to come and interact with students. The aim of this event is to foster closer relationships between students and industry, government and academia, ensuring a strong start to their mining focused career. This year the Chapter hosted representatives from Geoscience Australia and RSES (Gold Sponsors of the event), Newcrest Mining, Evolution Mining, Regis Resources, the New South Wales Geological Survey and Heron Resources. Both the exhibition style portion and dinner were a great success with many students receiving career guidance for the future. (I don’t have any photos, I think you took some).

Staff vs Students events

Every year the students organise staff vs student sporting events. This year was a soccer match and lawn bowls at the Ruc in O’connor: Staff were victorious in both the lawn bowls and the October Staff vs Students soccer match.





Outreach Events

Including several annual undergraduate field trips, RSES participates in ANU Open Days, National Science Week and the College of Science's activities. Some of our programs and events hosted at RSES are below:

14-18 January 2019 - National Youth Science Forum (NYSF) - Summer School

RSES has hosted several groups of Year 12 science students and a group of teachers from around Australia as part of NYSF. Students visited our Geophysics Fluid Dynamics (GFD) Laboratory, rolled out the evolution of life on a toilet paper timeline, looked at crustal deformation using a sandbox experiment and were introduced to seismology.

20-27 January 2019 - Australian Science Olympiads Summer School

The Australian Science Olympiads holiday residential science program is for secondary school students who are invited to attend based on their performance in the Olympiad Exams. Over 30 young scientists from Australia spent two weeks at RSES as part of the program. The students work schedule was intense covering the equivalent of first year university studies in Earth studies.

19 March 2019 - Visitors from the Gunbalanya township

RSES hosted visitors from the Gunbalanya township in western Arnhem Land, Northern Territory (Manilakarr Traditional Owners and Njanjma Aboriginal Corporation) and Victoria (Taungurung Clans Aboriginal Corporation and the Gunaikurnai Land and Waters Aboriginal Corporation). This visit was part of a larger effort to support and to develop an innovative approach to integrate indigenous knowledge and learning systems into our existing tertiary education research and training.

29 April - 3 May 2019 - Australian Ocean Modelling “Summer” School (AOMSS)

30 Honours, Masters, PhD and postdocs, including five from RSES attended AOMSS at Lake Pedder, Tasmania. The primary lecturers were Stephen Griffies (from NOAA’s GFD Lab) and RSES’s Prof. Andy Hogg. The school is designed to cover the mathematical foundations of ocean modelling, through to an applied understanding of parameterisations in (and limitations of) ocean models.

9 June 2019 - Girls Day 2019

Girls from years 7 and 8 had the opportunity to visit RSES and accompany women working in STEM. 15 students attended from Canberra Girls Grammar and Daramalan learning all about earthquakes and seismology.

19 July 2019 - Girls Into Earth & Marine Sciences (GEMS)

GEMS is a school holiday program hosted by RSES and partnered with Geoscience Australia. The one day workshop was aimed at Year 9 and 10 girls in the ACT to showcase and expose students to the diverse range of Earth science careers. GEMS is an initiative of PhD students Hannah James and Bethany Ellis who last year won a grant to host the event. This year we have partnered with Geoscience Australia to make GEMS an annual event.

8 - 11 August 2019 - National Science Week

This year’s National Science Week included a contingent of volunteers representing RSES and at the Shine Dome, showcasing Earth Sciences over two days.



Geology 60th Reunion

Sixty years of history
and reminiscences
1959 - 2019





13-14 September, RSES hosted the Geology 60th Reunion with many alumni and friends coming from all over Australia and some internationally to celebrate. This history of the Department of Geology at ANU, which later became the Department of Earth and Marine Science is today reflected in RSES classrooms and in the field, through the people, the research, student activities and the accomplishments of alumni.

Day one of the reunion included, lunch, speeches, and RSES school and lab tours. In the evening a “Past, Present & Future” panel session was held with guest speakers; Steve Hill, Penny King, Dominique Tanner and Clinton Rivers who talked about their journeys, memories and inspirations.

On day two, alumni and guests embarked on a tour of the new Kambri precinct. The event finished with the Reunion Dinner at University House. The night was hosted by Sarah O’Callaghan and Richard Arculus, and the first enrolled ANU Geology student, Ian Lambert, all giving speeches. We are looking forward to our 70th reunion.





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