



Australian
National
University

Annual Report 2020

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Professor Stephen Eggins
School Director (to 31/10/2020)



Professor Dorrit Jacob
School Director (from 1/11/2020)

From the Directors

2020 has been among the most challenging years in the School's almost 50 year history.

The year commenced with a two week shutdown of the university and School due to smoke and other impacts of the 'Black Summer'. During this time Canberra's air quality rated as the worst city in the world on multiple days. Many staff and students were directly threatened and impacted by the fires while holidaying at the coast over New Year and later when the locus of fires shifted to the southern ACT and around Micelago. Just as we were emerging from the bushfire crisis later in January the ANU campus, especially those parts near the lake and Black Mountain, was struck by a once in a century supercell hailstorm. The Electronics Workshop on the top floor of Jaeger suffered significant water damage, and the heritage roof of the Old Hospital Building was extensively damaged with some terracotta tile completely holed. Much the School's rooftop infrastructure, in particular air handling and exhaust units varied from being inoperable to obliterated. Virtually every car parked on campus was written off by insurance companies. The effect on the School has been long lasting, with research activities dependent on fume cupboard exhaust unable to resume for at least 6 months and some longer.

Ultimately, the fires and storm impacts were merely the beginning, with the Corona virus pandemic causing on-campus activity to cease from Week 3 through until mid-May. Aided by a one-week pause to teaching, staff managed to migrate all courses on-line for the rest of semester 1. Large classes continued to be delivered on-line and most fieldwork activities were abandoned in semester 2. The financial costs of the crises, including the reduced income from international student enrollments created a serious budget crisis for the university. This ultimately played out through cascading budget cuts imposed by the University and College of Science, in the School being impacted to a greater extent than many other parts of the university and College. The School's budget allocation imposed the need to reduce the Schools salary expenditure by 30%, resulting in many academic and professional staff being offered and taking voluntary redundancy packages offered by the university.

Despite the rolling setbacks and challenges to the School, we can be immensely proud of how we have managed to prevail, and we can also remain cognizant of the extent to which many were and continue to be deeply affected by these compounding events. This includes our undergraduate students, who have been denied the value and opportunities afforded by a full on-campus experience, our postgraduate research students whose progress has been stalled or substantially hindered, and our staff, many of whom have demonstrated extraordinary commitment and dedication to the School and ANU yet have had to make a difficult choice to prematurely end their positions with the university.

On a far more positive forward looking note it has been a truly good year for the School for securing external funding that will underpin research activity for year to come, particularly success in securing major ARC SRI funding for Antarctic and Southern Ocean science.

Lastly I would like to note the School has retained its top ten QS World subject ranking at 9th in Earth and Marine Sciences for the year in a row, and obtained rankings of 6th for Geology and 12th for Geophysics, two new subject rankings that were announced for the first time. This is testimony to the outstanding reputation and achievements the School continues to generate through the collective efforts of all our academic and professional staff and students.



Professor Stephen Eggins

School Director (to 31/10/2020)

Addendum - With my role as Director coming finishing at the end of October, it has been immensely reassuring to be able to hand over to Professor Dorrit Jacob, knowing that the School is in safe and committed hands at such an important and challenging time. Moreover, as I have also decided to take a voluntary redundancy from February 2021, I wish the School and Dorrit every success for the future, and note the enormous privilege it has been to serve the School as Director for the past 5 years.

Staff lists

ACADEMIC STAFF

Director	S.M. Eggins, BAppSci UNSW, PhD UTasa (to 31/10/2020) D. Jacob, Dr. rer. nat. Georg August University Germany (equivalent PhD) Diplom in Mineralogy, Johannes Gutenberg Univ, Germany (equivalent MSc) (from 01/11/2020)
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Associate Directors

Research	P. Tregoning, BSurv PhD UNSW
Higher Degree Research	S.J. Fallon, BA MS San Diego, PhD ANU
Education	J.A. Mavrogenes, BS Beloit, MS Missouri-Rolla, PhD Virginia Tech
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]
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Professors	N.J. Abram, BSc Advanced (Hons) Sydney, PhD ANU [ARC Future Fellow] V.C. Bennett, BSc PhD UCLA A.J. Berry, BSc (Hons) Sydney, DPhil Oxford J.J. Brocks, Dip Freiburg, PhD Sydney I.H. Campbell, BSc UWA, PhD DIC London P.R. Cummins, BA Physics, PhD UC Berkeley S.M. Eggins, BAppSci UNSW, PhD Tasmania M.J. Ellwood, BSc (Hons) PhD Otago 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
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Professors cont.

M.L. Roderick, BAppSc QUT, PGDipGIS Qld, PhD Curtin (to 31/07/2020)
E. Rohling, BSc MSc PhD Utrecht
M.S. Sambridge, BSc Loughborough, PhD ANU, FAA, FRAS
H. Tkalčić, DipEng in Physics Zagreb, PhD UC Berkley
P. Tregoning, BSurv PhD UNSW
G.M. Yaxley, BSc PhD Tasmania

Senior Fellows

Y. Amelin, MSc PhD Leningrad State
L.K. Armand, BSc (Flinders), BSc (Hons) PhD ANU
D.R. Davies, MSci PhD Cardiff, UK [ARC Future Fellow]
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
J. Yu, BSc MSc Nanjing University, PhD Cambridge [ARC Future Fellow]

Fellows

M.A. Forster, BSc MSc PhD Monash
B.N. Opdyke, AB Columbia, MS PhD Michigan
A. Valentine, BA MSc Cambridge, DPhil Oxford [ARC DECRA Fellow]

Research Fellows

S. Allgeyer, PhD Paris Diderot, France
J. Avila, BSc MSc UFRGS, PhD ANU
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, BSc MSc UWA, PhD Stanford
T. Esat, BSc Univ College London, MSc Queens Univ Canada, PhD ANU
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

J. Amies, MSc (Hons) Southampton, PhD ANU (to 30/10/2020)
G.F. Davies, MSc Monash, PhD CalTech
P. de Caritat de Peruzzis, PhD ANU (to 21/07/2020)
H. Dijkstra, Bachelor MSc PhD Groningen (to 13/02/2020)
A. Glickson, BSc MSc PhD UWA (to 29/03/2020)
F. Hibbert, BSc (Hons) London, MSc Nottingham, PhD St Andrews
A.L. Jacques, BSc (Hons) UWA, PhD UTas (to 31/03/2020)
T.P. Mernagh, PhD Newcastle (to 28/04/2020)
L. Moore, BSc (Hons) Auckland, PhD ANU, Grad Cert Higher Ed Univ Canberra (to 29/03/2020)
J. Moores, BAppSci Toronto, PhD Arizona (to 02/02/2020)
T. Takagawa, BS MSc PhD Kyoto (to 30/03/2020)
F. Williams, MSc PhD Southampton (to 13/04/2020)
S-Y. Yang, BSc PhD Nanjing (to 11/12/2020)
Y. Zhao, BSc China Univ of Petroleum (to 14/01/2020)

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
Education Support Officer	T. Penny

**RSES & ANZIC-IODP
Communications
Officer**

L. Medenis, AssocDip CIT

Education Officer

B. Harrold, BSc ANU

Receptionist

M. Sadler

**Research Group
Administrators**

E. Arnold - Earth Dynamics; Seismology & Mathematical Geophysics (to 31/10/2020)

J. Magro - Experimental Petrology; Geochemistry & Cosmochemistry

M. Francis– Biogeochemistry; Palaeoenvironments; Climate & Fluid Physics (to 11/01/2020)

A. Daley - Biogeochemistry; Palaeoenvironments; Climate & Fluid Physics (from 10/03/2020)

**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)

B. Roy (Apprentice Fitter/Turner)

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 to 31/07/2020)

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

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

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

Research Software Engineer

A. Gibson, BCompSci (Hons) PhD ANU

Technical Officers

J. Cali, BAppSc QIT (to 29/08/2020)

T. Cheng, BEng Hefei College, China, PhD USTC China

D. Clark, Cert III Metal Fabrication AdvDipEng CIT

T.G. Enge, PhD Wollongong

R. Erigela, BTech Jawaharlal Nehru Technological University, PGDip NIELIT-India, MScEng Swinburne

R. Esmay, BSc (Sr Thesis) SUNY Purchase

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

J. Hope, BSc James Cook B. Knowles, BSc Wollongong (from 14/09/2020)

Technical Officers cont.	P. Hu, PhD ANU & Chinese Academy of Sciences (from 01/04/2020)
	B. Knowles, BSc Wollongong (from 14/09/2020)
	P. Lanc, AssocDip Bus (Applied Computing) CIT
	H. Miller, AdDipMechEng CIT
	S. Mousavi, BSc MSc, Tehran University, PhD Leipzig
	S. Paxton, AssocDip Applied Geoscience CIT, FGAA (to 19/12/2020)
	S. Rayapaty, BEng Jawaharlal Nehru Technological University, MIT University of Canberra (to 10/04/2020)
	A. Rummery, Cert III CIT (x3)
	D. Scott, AssocDipMechEng CIT (to 01/08/2020)
	J. Tatapudi, BEng Jawaharlal Nehru Technological University, GradDip in Business Information Systems Federation University Melbourne, AdvDip Leadership & Management Mercury Institute of Victoria
	D. Thomson, Cert-Fitting and Machining Trade (to 31/07/2020)
	U. Troitzsch, Diplom Technische Universität Darmstadt, PhD ANU
	D. Vasegh, AssocDeg Khajeh Nasireddin Toosi University of Technology (Iran)
	X. Zhang, PhD LaTrobe (to 31/07/2020)
	X. Zhao, BSc Jilin University, PhD Southampton
	S. Zink, BSc Hanover, Diploma (MSc) Hanover

Laboratory Assistant	D.T. Jayarathne (from 03/02/2020)
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POST-GRADUATE STUDENTS

PhD Candidates

Agrawal, Shubham	Gai, Congcong	Shannon
Amarathunga, Udara	Gao, Yajie	McGirr, Rebecca
Baeza, Leonardo	Goodarzi, Patrick	Misztela, Monika
Baile, Riley	Gray, Sharon	Naina
Bean, Lynne	Grun, Robin	Nakrong, Nipaporn
Bhagtani, Dhruv	Harazin, Katie	Nash, Graeme
Bishop, Caleb	Hargreaves, Jessica	Nugroho, Hendro
Bonning, Geoffrey	Hayward, Kathryn	Ogunsami, Abdulwaheed
Cajal Contreras, Yamila	Hu, Jinyin	O'Neill, Cameron
Carrasco Godoy, Carlos	Huang, Zhijie	Owens, Ryan
Chandler, Ross	Jackson, Sarah	Pandey, Abhay
Chen, Bei	James, Hannah	Pasic, Bozana
Chen, Fangqin	Ji, Xuan	Patkar, Aditya
Chen, Mimi	Kinsley, Jordan	Piedrahita Velez, Victor
Chopping, Richard	Kirby, Rachel	Qian, Yao
Connolly, Clare	Kou, Yingxin	Qu, Tongzhang
Costa de Lima, Thuany	Krestianinov, Evgenii	Rama, Jemima
Crisp, Laura	Lawler, Kelly-Anne	Ray, Srijita
Devi, Riteshma	Li, Yuwei	Roosmawati, Nova
Di, Yankun	Liyanage, Tharika	Ry, Rexha
D'Andres, Joelle	Loiselle, Liane	Sakti, Artadi
Durgalakshmi	Lowczak, Jessica	Scheiter, Matthias
Duvernay, Thomas	Maharaj, Prayna	Sebastian, Nita
Eggins, Sam	Makushkina, Anna	Sommer, Johanna
Ellis, Bethany	Manceau, Rose	Stephenson, Joanne
Fang, Bowen	Martin, Stacey	Sudholz, Zachary
Farmer, Nicholas	Martinez Moreno, Josue	Sun, Yaojia
Fouladi Moghaddam, Negin	Mathews, Christopher	Tambiah, Charles
	McConachie,	Turunctur, Buse

PhD Candidates cont.

Velzeboer, Nick	Wilsbacher, Catherine	Zhao, Siyuan
Vinnichenko, Galina	Wu, Jaide	Zhao, Song
Wang, Sheng	Wu, Yang	Zheng, Siru
Ward, Josephine	Yeung, HoSonia	Zhu, Ziyi
Wenham, Lana	Zhang, Ping	

MPhil Candidates

Alvarez Rodriguez, Guadalupe
Moller, Bruno

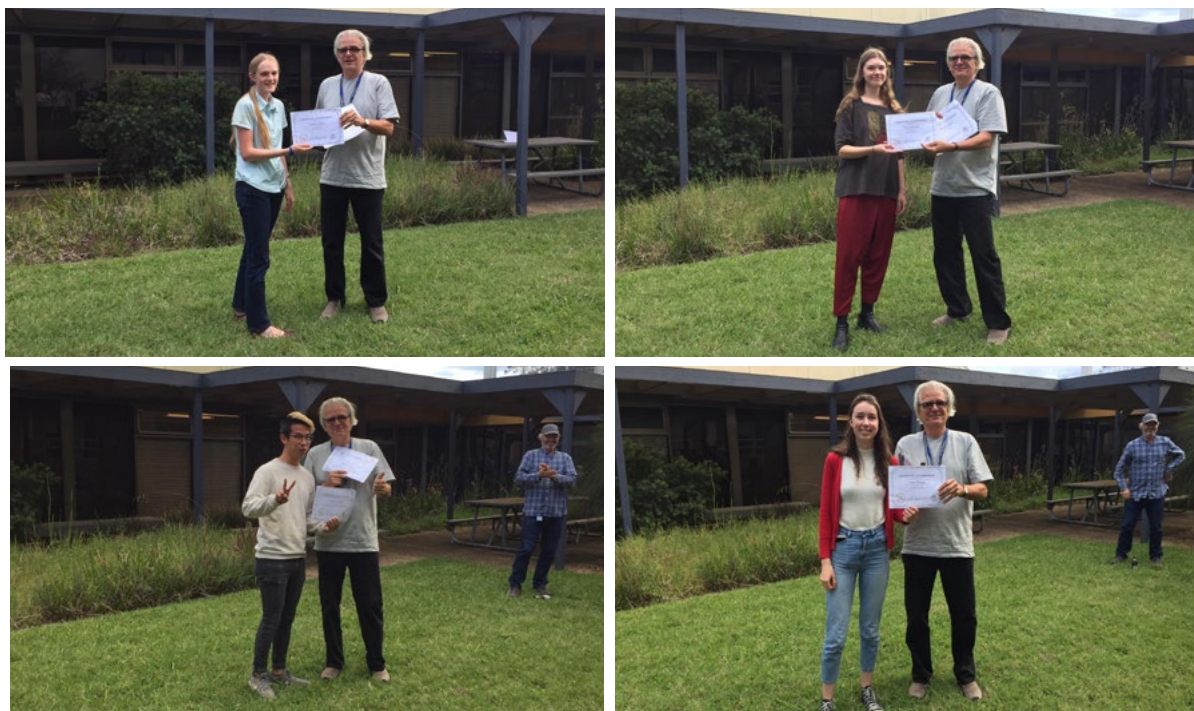
Undergraduate and postgraduate courses

Earth & Marine Science Programme

Semester 1	Course	Convenor/teaching staff	Students
EMSC1006/4006/6107	Blue Planet	J. Mavrogenes, S. Eggins	157
EMSC2022/6122	Introduction to Global Geophysics	M. Miller, D. Heslop, L. Moresi	29
EMSC2023/6123	Fundamentals of Geology	G. Yaxley	53
EMSC3014/6014	Global Stratigraphy	B. Opdyke	
EMSC3020/6019	Geobiology & Evolution of Life on Earth	J. Brocks, L. van Maldegem, B. Opdyke	21
EMSC3023/6023	Marine Biogeochemistry	M. Ellwood, S. Fallon	20
EMSC3024/4024/ 6024	Magmatism & Metamorphism	A. Burnham, H. O'Neill, R. Arculus	15
EMSC3032/4032/ 6032	Melting Polar Ice Sheets	P. Tregoning	17
EMSC3033	Applied Geophysics	McClusky, S. Allgeyer	16
EMSC3034	Dynamic Earth	R. Davies	17
EMSC4017/8017	Research Methods & Proposal	A. Roberts, P. Tregoning	13
EMSC4033/8033	Computational Geosciences: Problem-solving, Logical Thinking and Programming.	A. Valentine, M. Klöcking	5
EMSC4121/8021	Advanced Geochemistry and Petrology	A. Burnham, H. O'Neill, Y. Amelin, V. Bennett	4
EMSC4122/8022	Analytical Techniques	G. Yaxley, Y. Amelin, H. O'Neill	11
EMSC4706/8706	Natural Hazards	P. Cummins	19
EMSC8032	Research Proposal & Presentation	R. Davies	4

Semester 2	Course	Convenor/teaching staff	Students
EMSC1008/6008	Earth	A. Berry, C. Eakin	72
EMSC2024/6124	Geochemistry T. Ireland,	Y. Amelin, G. Yaxley	30
EMSC2021/4021/ 6021	Climate System Science	C. Shakespeare, A. Hogg, Annette Hirsch (Visitor)	55
EMSC3002/4002/ 6030	Structural Geology & Tectonics	G. Lister, S. McClusky, M. Forster	18
EMSC3007/6007	Economic Geology	J. Mavrogenes	8
EMSC3022/6022	Planetary Science	P. King, C. Lineweaver	38
EMSC3025/4025/ 6025	Groundwater	L. Moore	40
EMSC3027/4027/ 6027	Palaeoclimatology & Climate Change	E. Rohling, K. Grant J. Yu,	21
EMSC4017/8017	Research Methods & Proposal	A. Roberts, P. Tregoning	3
EMSC4123/8023	Data Analysis	M. Sambridge	6
Special Topics			
EMSC3050	Research project (6 Units)	A. Burnham, S. Fallon, J. Mavrogenes (x2), B. Opdyke (x3), M. Sambridge, M. Annenburg, P. Tregoning (x2), H. O'Neill, J. Brocks (x2)	9
EMSC8014	Research project (6 Units)	S. Allgeyer, P. Cummins, G. Lister, B. Opdyke	4
Archaeology Programme (Research School of Humanities & the Arts, School of Archaeology and Anthropology)			
RCH8032	Introduction to Archaeological Science	R. Wood	20
Environmental Science Programme (Fenner School of Environment & Society)			
ENVS3013	Climate Change: past, present and future	N. Abram	49

Thesis and awards



PhD theses completed (Supervisor in parentheses)

Fang, Fang “Methodological Developments in Electron Spin Resonance (ESR) Low-Temperature Thermochronometry” (Ian Williams)

Martin, Hayden “Investigating the Role of Dimethyl-Arsenic in Inducting Straighthead Disease in Rice” (Michael Ellwood)

Miller, Laura “An X-ray Absorption Spectroscopy Study of Redox Variable Elements in Silicate Melts” (Hugh O’Neill)

Pranantyo, Ignatius “Tsunami Hazard in Eastern Indonesia: Source Identification and Reconstruction for Historical Case Studies” (Phil Cummins)

Pritchard, Jennifer “Geochemical Modelling of Shallow Fractionation and Deep Mantle Melting Below Mauna Loa Volcano, Hawaii” (Victoria Bennett)

Sohail, Taimoor “Turbulence and Convection in Southern Ocean Circulation” (Andy Hogg)

Tyler, Perinne “Archean Sulfur Reservoirs of the Kaapvaal Craton” (Trevor Ireland)

Valetich, Matthew “Chalcophile Evolution in Arc Magmas: The Story of Boninites” (John Mavrogenes)

MPhil thesis completed (Supervisor in parentheses)

Carrasco Godoy, Carlos “Magmatic Evolution of the Southern Centinela District, Northern Chile: Insights from PGE Geochemistry and Zircon Fertility Tools” (Ian Campbell)

Creighton, Reuben “Using 3D Geodynamic Slab Models in Tectonic Reconstruction” (Gordon Lister)

Muston, Jack “Volcanoes, Ore Deposits, and the 3D Slab Geometry Along the Andaman-Sumatran Subduction System” (Gordon Lister)

Honours Completions

Semester 1

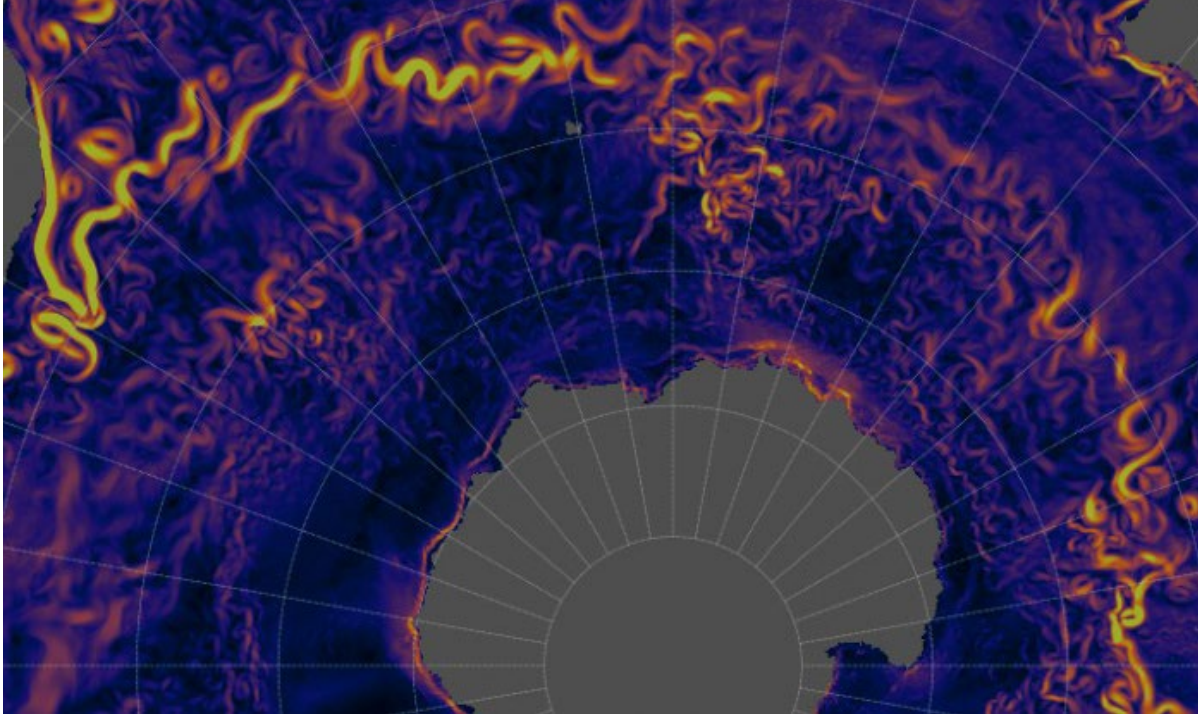
Claire Patterson
Leon Bilton

Semester 2

Claire Flashman
Elizabeth Thomas
James Sweetman
Yihang Huang

Student Honours and Awards

DA Brown Travel Fellowship	Not awarded due to COVID-19 travel restrictions
Mervyn & Katalin Paterson Fellowship	Not awarded due to COVID-19 travel restrictions
Robert Hill Memorial Prize	TBA
Sue Kesson Experimental Petrology Student Travel Grant	Not awarded due to COVID-19 travel restrictions
ASEG prize	Jemma Jeffree
Irene Crespín Prize	Chitrangada Datta
Edward Irving Prize for Geophysics	Darby Liersch
GSA Ken Campbell Prize	Lachlan Anderson
GSA Mike Rickard 3rd Year Prize	Chitrangada Datta
WB Clarke 2nd Year Prize	Imogen McDermott



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 convection, internal waves, ice-ocean interactions, the energy balance of the land surface and the large-scale circulation of the ocean. Our research profile includes funded contributions from the ARC Centre of Excellence for Climate Extremes and the Consortium for Ocean-Sea Ice Modelling in Australia (COSIMA; see cosima.org.au).

This year saw a major milestone reached with the publication of a manuscript describing the development of the ACCESS-OM2 ocean-sea ice model (Kiss et al. 2020). This is the culmination of a 4-year model development project led by this group to create Australia's leading ocean-sea ice model. The new model has a superior representation of Antarctic ocean circulation, compared with other global ocean-sea ice models which has allowed us to use it to better understand the warm ocean currents driving the recent melt of Antarctic ice shelves. In Morrison et al. (2020), we

investigated how the southward transport of warm water varies spatially around Antarctica and found a surprising result. Contrary to previous assumptions, we found that warm regions of the Antarctic continental shelf actually have very limited warm water flow onto the shelf, compared with cool regions where dense water is formed. These new results are forcing oceanographers to re-examine their understanding of the mechanisms that warm the Antarctic oceans. Further work using this model (Stewart et al., 2020) found that when the winds contracted towards Antarctica due to changes in the Southern Annular Mode (SAM), they warmed oceans north of the peak wind speed and cooled them to the south. The reverse occurred when the SAM shifted northwards towards Australia. These changes had a rapid short-term impact on overturning circulation in the Southern Ocean. However, the long impacts were very dependent on ocean eddies, adding a level of complexity to understanding how circulation in the Southern Ocean may change over extended periods.

Another piece of research by the group led to a profound change to our understanding of one of the most fundamental aspects of the ocean's circulation, ocean gyres, large-scale circulation features that give rise to important ocean currents such as the Gulf Stream in the North Atlantic and the Kuroshio current off the east coast of Japan. These gyres are critical in transporting heat from the tropics to the poles. Standard oceanographic theory suggests that these gyres are driven by wind stress, however, the simple theory that predicts the strength of these gyres fails in many parts of the ocean. Hogg and Gayen (2020) show that ocean gyres (complete with a rich eddy field and strong western boundary current) occur even in the absence of wind forcing due to temperature-driven buoyancy fluxes, a perspective that transforms our understanding of large scale circulation.

In related research (Rocha et al., 2020), together with collaborators from the USA, we developed a better way to quantify the excess heat flux that occurs due to the ocean's circulation compared to the heat flux due to thermal conduction alone, something that the fluid mechanics community refers to as the "Nusselt" number. Using analytic calculations, the team derived two alternative mathematical expressions for computing the Nusselt number and then, by performing direct numerical simulations of a fluid on which a non-uniform surface temperature was imposed, the team was able to show that with this new definition one can more rapidly obtain equilibrated values of the Nusselt number, making it practicable to run bigger computations to understand new flow regimes.

The group also continued its work on understanding some of the smallest and fastest ocean processes, including internal waves. Collaborative work with the USA National Center for Atmospheric Research investigated the role of internal waves generated by ocean tides in periodically cooling coral reefs and thus reducing coral heat stress as the global ocean warms. Bachman et al (2020) formulated a methodology for identifying such coral refugia, which allows conservation efforts to be better targeted, and may be crucial in preventing extinction of at-risk coral species. The methodology was applied to ultra-high resolution simulations of the Indonesian Seas, directly to the north of Australia. The group also led work to improve the representation of ocean tides in such simulations, by developing a new understanding for the forces exerted when internal waves are generated (Shakespeare, Arbic and Hogg, 2020).

Continuing on the topic of internal waves, we developed novel theory (Shakespeare, 2020) to describe the complex interplay of tidal and lower frequency ocean flows involved in the generation of internal waves, challenging nearly a decade of prior work that ignored this coupling. Experiments in our 5 m long wave tank in the Geophysical Fluid Dynamics Laboratory were conducted to verify the predictions of this theory (Dossman et al., 2020). Among other results, these experiments showed that internal waves can be generated at frequencies exceeding the buoyancy frequency (contrary to what you may read in a fluid dynamics textbook!) due to the impact of a geostrophic flow. This result has consequences for the existence of such waves in the deep ocean, which may contribute to ocean mixing.

The group also continued our long-running work to understand patterns of drought and rainfall in Australia, in association with external collaborators in the ARC Centre of Excellence for Climate Extremes. We used the latest climate projections from CMIP6 models to investigate future changes in droughts. Despite continuing uncertainty in mean precipitation in many regions, we found robust trends in droughts over half of the global land surface. These more robust projections provide clearer direction for water resource planning (Ukkola et al. 2020). We also investigated why, despite several high impact drought events in South Eastern Australia in the last few decades, there has not emerged significant evidence of large-scale tree dieback. In De Kauwe et al. 2020, we used a novel modelling framework to show that trees in South Eastern Australia are incredibly resilient to drought-induced tree mortality. We also identified those areas most at risk in future droughts.

Staff news

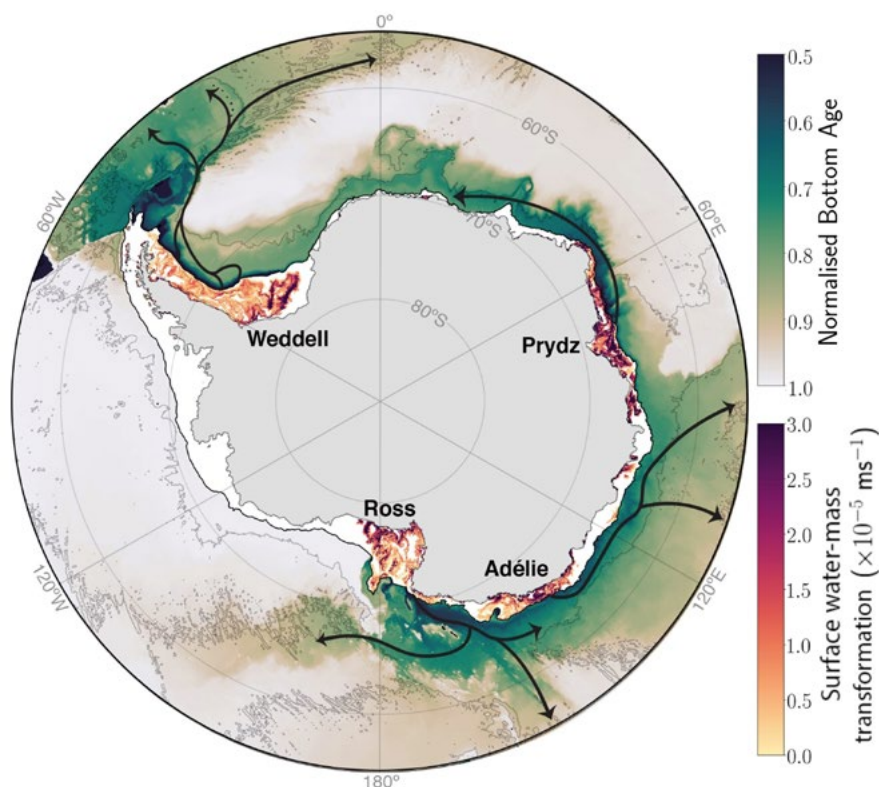
- Michael Roderick retired on 31 July, and remains as an Emeritus member of the group.
- Wilma Huneke joined the group on a 2-year postdoctoral fellowship.
- Adele Morrison was one of five winners of the \$25,000 2020 L'Oreal-UNESCO For Women in Science Fellowship.
- Navid Constantinou was awarded a DECRA fellowship.
- Andrew Hogg, Adele Morrison and Callum Shakespeare were led a funded grant to build Australia's next-generation ocean-sea ice model as part of the COSIMA consortium.
- Adele Morrison was a part of the successful Australian Centre for Excellence in Antarctic Science.
- Adele Morrison and Andy Hogg were part of a team which was funded to work on the vulnerability of Antarctic coasts to colonization through New Zealand's Marsden program.
- Anna Ukkola left the group to take up her DECRA at UNSW.
- Callum Shakespeare was promoted to Level C.

Student news

- Nick Velzeboer joined the group to start his doctoral studies Dhruv Baghtani joined the group to start his doctoral studies, supervised by Andy Hogg.
- Jingwei Zhou, supervised by Michael Roderick and Annette Hirsch, successfully submitted his Master's Thesis titled 'Diagnosing the spatial contrasts in land surface influences on heatwaves'. He was awarded a High Distinction, an impressive achievement for completing his Master's degree remotely from Wuhan, China.

Emeritus, Honorary staff and Visitors

- Prof Ross Griffiths and Dr Ross Kerr remains as active Emeritus members of the group.
- Dr Claire Carouge remains as a long-term visitor from UNSW, heading the Computational Modelling Support team for the ARC Centre of Excellence for Climate Extremes. Dr Annette Hirsch (UNSW) also sits in the group as a long-term visitor, working in the Drought Research Programs of the ARC Centre of Excellence for Climate Extremes. Dr Paige Martin visited the group from University of Michigan, and will join the group on a short-term contract in 2021.



Antarctic dense water formation (red) and circulation (green) in ACCESS-OM2-01. Figure from Moorman et al. (2020), in which we conducted freshwater perturbation simulations to investigate ocean feedbacks on Antarctic ice melt.



EARTH DYNAMICS

Group leader

Paul Tregoning

Academic members

Sebastien Allgeyer, Stephen Cox, Marnie Forster, B. Gayen, Gordon Lister (to 16/12/2020), Simon McClusky (to 28/11/2020), Julia Pfeffer (to 13/07/2020)

Emeritus, Honorary staff and Visitors

Emeritus Professor Stephen Cox is continuing work on 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. Particular focus is on injection-driven swarms in the Czech Republic, Japan and California. Results are being applied to attain a 4D understanding of fluid pathways and also to constrain fluid budgets associated with the formation of orogenic gold deposits. Cox is also working on the dynamics of deformation processes and fluid flow associated with the formation of the very rich, fault-related gold system at the Fosterville gold mine in Victoria.

Outreach activities & Service roles external to ANU

At the invitation of Newmont Cororation, Stephen Cox contributed to a 3-day, online symposium on Orogenic Gold Systems for Newmont geoscientists in Australia, the USA and Canada. He also

presented a half-day training workshop on “The dynamics of permeability enhancement and fluid flow in overpressured, fracture-controlled, hydrothermal systems” to mining and exploration geologists in central Victoria. Cox also provided an online workshop on “Fluid involvement in fault mechanics” to graduate students in the Earth and Environmental Sciences program at Tohoku University (Japan).

Student news

PhD student, Kathryn Hayward has continued experimental studies on the role frictional melting in influencing fault mechanics. Using new, custom built technology we are exploring fault rupture using an optical sensor and strain gauges located close to the fault surface. Together these instruments are allowing us to capture, at microsecond resolution, the complex interplay between fault movement and stress release under pressure conditions approximating that of seismogenic depths in the crust.



EXPERIMENTAL PETROLOGY

Group leader

Andrew Berry

Academic members

Michael Anenburg (from 16/11/2020) Antony Burnham, Ian Campbell, Corinne Frigo, Dorrit Jaccob, John Mavrogenes, Hugh O'Neill, Greg Yaxley

Overview

In 2020 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 (Michael Anenburg, Antony Burnham, and Corinne Frigo), 16 PhD students, one MRes student, and two technical staff.

2020 was clearly a difficult year. It started badly when a hailstorm destroyed a lot of the infrastructure on the roof of the building, which put the labs out of action for over a month. This was followed by the covid shutdown and then a gradual return of workers as restrictions were relaxed. We maintained our regular Friday Group Meetings throughout this period and had many excellent talks from both local and international speakers. Our meeting convenor, Zach Sudholz, was able to find people from all sorts of time zones who were willing to give talks at a time that was convenient for us but not always for them. We thank all these speakers.

Research highlights

Research highlights include a paper in Science Advances entitled "Redox state of Earth's magma ocean and its Venus-like early atmosphere" (doi:10.1126/sciadv.abd1387), a paper in Geology on

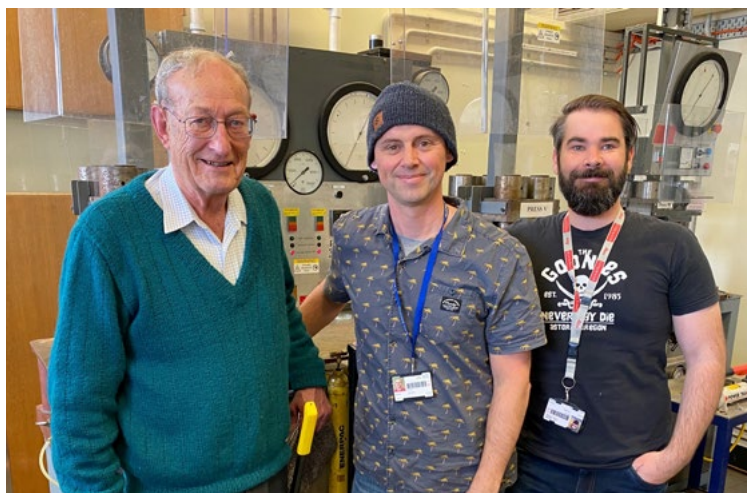
“Noble metal nanonugget insolubility in geological sulfide liquids” (doi.org/10.1130/G47579.1) and another paper in *Science Advances*, entitled “Rare earth element mobility in and around carbonatites controlled by sodium, potassium, and silica” ([doi:10.1126/sciadv.abb6570](https://doi.org/10.1126/sciadv.abb6570)). Hugh O'Neill and Ian Campbell were awarded an ARC Discovery Project on the geochemical properties of precious metals and John Mavrogenes was awarded grants from ARC Linkage and the Geological Survey of Queensland for various projects on critical metals.

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. We were awarded synchrotron beamtime at the Australian Synchrotron (AS) and Advanced Photon Source (USA) and Andrew Berry continued to serve on the advisory panel of one of the new beamlines (MEX) being built at the AS/

Staff news

We sadly said goodbye to Dean Scott after 24 years of service as a technical officer in our labs. Dean was a valued member of the group who maintained the Experimental Petrology labs, firstly with Bill Hibberson and then with David Clark. During Dean's time in the Group we undertook 10,000 piston-cylinder experiments! This enormous amount of work would not have been possible without Dean's efforts.



L-R: Bill Hibberson, Dean Scott, and Dave Clark, taken on Dean's last day at RSES. Between them Bill, Dean and Dave provided technical support to Experimental Petrology over the last four decades.

The Group benefited from the contributions of Richard Arculus (Emeritus), Lynton Jaques and Terry Mernagh (Visiting Fellows) and Andrea Gerson (Adjunct Professor).

Student news

We welcomed new PhD students Srijita Ray (Kolkata) and Catherine Wilsbacher (Purdue and Kent State) who are both working on REE geochemistry. We also look forward to welcoming Oliver Hsu (NTU Taiwan) and Rosmalia Nugraheni (Universiti Teknologi Petronas, Malaysia) who are both currently waiting for border restrictions to relax so they can enter Australia to start their studies. A number of PhD students finished and moved on to new positions including Matt Valetich (Geological Survey of Queensland), Laura Miller (Monash University), and Nick Farmer (Australian Synchrotron).



GEOCHEMISTRY AND COSMOCHEMISTRY

Group leader

Trevor Ireland

Academic members

Yuri Amelin, Janaina Avila, Vickie Bennett, Bin Fu, Penny King.

Professional staff

Peter Holden, Peter Lanc, Shane Paxton, Dave Thomson, Sonja Zink

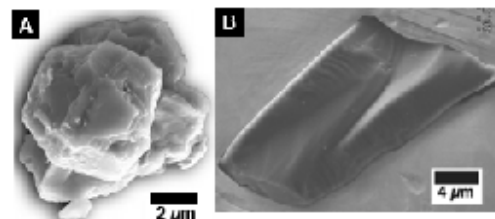
Overview

Geochemistry and Cosmochemistry includes mass spectrometry (SHRIMP, TIMS, noble gases), infrared spectroscopy and gas-solid reaction experimental facilities. With the lab-based work on hold due to ANU COVID restrictions, this year accelerated developments in remote instrument operation.

Research highlights

Associate Professor Yuri Amelin developed a novel method for isotope analysis of manganese by thermal ionization mass spectrometry and carried out Mn isotope analyses for determination of the half-life of Mn-53 in a joint project with researchers from Paul Scherrer Institute.

Dr. Janaina Ávila continued her work on the application of multiple sulfur isotopes to constrain early microbial activity in the geological record as well as a record of



Scanning electron microscope images (secondary electrons) of two types of presolar SiC grains.
(A) Grain with a euhedral shape indicating it everted shattering
(B) Grain with a shard-like appearance with fractures.

temporal changes in atmospheric chemistry of the Archean and Paleoproterozoic. In collaboration with Professor Penny King, Dr Ávila started working on in situ measurements of sulfur isotopic abundances and volatile content of basaltic glasses. Also, findings made by an international research team involving Dr Ávila and published in PNAS in 2020 made headlines. The study, presenting interstellar ages of individual stardust SiC grains, was featured by National Geographic as the top story in “the top 10 awesome science discoveries you may have missed in 2020”, by Yahoo! News as the top story in “The biggest and most important scientific breakthroughs of 2020”, by Live Science among the “10 science records broken in 2020”, by CNN among “Science’s most fascinating and awe-inspiring discoveries in 2020”, and by BBC Science among the “20 moments in science to make you feel better about 2020”.

Professor Vickie Bennett made substantial progress on her ARC funded investigation of the development of ancient tectonic processes and their contributions to generating habitable early Earth environments. A highlight was the development of a new chemical extraction method by Prof Bennett and Sonja Zink for the element Nd from rock matrices to enable high precision, low blank isotopic determinations of ^{142}Nd , which is the daughter product of the now extinct, short half-life isotope ^{146}Sm using thermal ionization mass spectrometry. Variations in ^{142}Nd compositions preserved in ancient rocks can be directly linked early chemical and tectonic processes.

Dr. Bin Fu worked on both U-Pb geochronology, trace element and isotope geochemistry of igneous and metamorphic rocks and ore deposits from China and India as well as archaeological materials by using ion microprobe (SHRIMP) and LA-(MC)-ICPMS. He established and improved analytical protocols for U-Pb-P analyses of zircon, and Ti in quartz.



Sample of asteroid Ryugu recovered from the Hayabusa2 return capsule.

Professor Trevor Ireland and student Geoff Bonning participated in the Hayabusa2 sample capsule recovery in early December. Geoff participated in the optical observation program with our colleagues from the Desert Fireball Network from Curtin University. Trevor was the official international observer for the JAXA mission with responsibility for ensuring the integrity of the sample was maintained during the recovery and shipment back to Japan. The recovery was a great success with a nominal landing and the exciting observation of solar wind He from the sample container the day after the recovery. The container has since been opened revealing a wealth of material (over 5g was recovered). Sample curation is now taking place in Tokyo with Preliminary Examination scheduled to commence in mid-2021.

Professor Penny King investigated how gas-solid reactions occur in three-dimensions and the resulting chemical and mineralogical features. The results of experiments and analyses were applied to ore deposits and smelting processes.

Emeritus, Honorary and Visiting Staff

Dr. George Gibson, Honorary Associate Professor continued collaborations with group members on mineralization processes in northern Australia.

Dr. Marc Norman, ANU Emeritus Fellow, continued independent research activities and collaborations with group members on ore deposit geochronology, granite genesis, and planetary science.

Emeritus Professor Ian Williams in collaboration with Kelsie Long (ARC Centre of Excellence for Australian Biodiversity and Heritage) have made the first combined C-O micro-isotopic analyses of freshwater gastropod shells by SHRIMP.

Dr. Lesley Wyborn received Honorary Professor status in the group and continued her work on geological “big” data storage and use.

Staff news

This year we bid sad farewells to long time staff members Dr Peter Holden and David Thomson (SHRIMP group), Shane Paxton (Lapidary workshop) and Xiaodong Zhang (Noble Gas group). The four of them represent more than 100 years of combined expertise that will be greatly missed. We thank them for their valued help and support to generations of students and staff over the years and for making RSES a great place to work. It will just not be the same without them. We wish them health and happiness in retirement.

Student news

Degree completions

Joëlle D'Andres (supervisors Mark Kendrick and Vickie Bennett) submitted her Ph.D. thesis “Halogens and noble gases in modern and ancient oceanic lithosphere: Implications for subduction budgets and evolution of Earth’s surface reservoirs”.

Emily Oborski completed her “Masters in Earth Sciences Advanced” degree with P King on “Tracking the Processes Forming Glass and Minerals in the 2018 Kilauea Ash Eruptions”.

Jennifer Prichard completed her Ph.D. (Supervisors- Marc Norman and Vickie Bennett) on Geochemical Modelling of Shallow Fractionation and Deep Mantle Melting Below Mauna Loa Volcano, Hawaii’

Commencing students

Riley Baile commenced a Ph.D. with Penny King on “Volatile Evolution of the Terrestrial Planets”.

Yankun Di (PhD project “Chronology and nucleosynthetic anomalies of calcium-aluminium-rich inclusions”, primary supervisor Yuri Amelin, members of supervisory panel Trevor Ireland, Alexander Krot and Francois Tissot) presented his mid-term report, which was approved by the panel. The results were presented at the Lunar and Planetary Science Conference and Goldschmidt Conference. Two manuscripts have been written and are being finalized for submission.

Tim Hunt commenced an Honours degree with Penny King on “Mineralogical, Geochemical and Thermodynamic Analysis of Calcium Sulfates Applied to the Regolith of Mars”.

Rachel Kirby returned to her PhD with Penny King after maternity leave.

Evgenii Krestianinov (PhD project “U-Pb and Rb-Sr systematics of the ungrouped achondrites – insights into the early history of asteroids”, primary supervisor Yuri Amelin, members of supervisory panel Trevor Ireland, Vickie Bennett and Qingzhu Yin) presented his mid-term report, which was approved by the panel after additional revision. The results were presented at the Lunar and

Planetary Science Conference and Goldschmidt Conference. One manuscript is submitted to Chemical Geology, another is written and is being finalized for submission.

Undergraduate student Chitrangada (Chini) Datta completed a special topics project “Pb-Pb Dating and Cooling Rate Estimation of the Angrite NWA 12320” (supervisor Yuri Amelin). The results are being presented at the Lunar and Planetary Science Conference.

Visitors

Dr. Bin Fu hosted Assoc. Prof. Shuiyuan Yang for 12 months and three students: Miss Ruoxi Zhang (12 months), Mr. Yang Chen (12 months), and Mr. Faqiao Li (16 months).

Outreach activities

Prof. Vickie Bennett served as President of the Geochemical Society; she is the first scientist outside of North America or Europe to lead this distinguished professional society. Highlights of the activities during her first year included turning the scheduled June 2020 Goldschmidt Conference, planned for Hawaii into a successful virtual conference in response to pandemic restrictions. This was one of the first Earth science conferences to be held in a virtual format. In June, the Geochemical Society organized a well-attended (>500 participants) international town hall: Black Lives Matter-Promoting Diversity, Equity, and Inclusion in Geochemistry

Prof. Penny King visited several schools and gave a public talk for National Science Week and a talk to the National Youth Science Forum. She was a panel speaker for the international Geochemical Society town hall Black Lives Matter-Promoting Diversity, Equity, and Inclusion in Geochemistry.

Em. Prof. Ian Williams gave a talk to the National Youth Science Forum.

Dr. Marc Norman was session convener at the Goldschmidt Virtual Conference.

Research grants awarded during 2020

Chen, Y.J., Lai, Y, Fu, B. and 7 others. Study of Genesis of Giant Porphyry Mo Deposits in the Qinling-Dabie Mo Belt, Central China, NNSF of China, Grant No. 41630313, ~\$638k, 1/2017-12/2021.

Doran B, Stevenson, J, Johnston D, Jones T, Moritz C, Haberle S, King P, Denham T, Backwell P, Sutherland S, Mathews D, Wallace R, O'Connor S, Provost S, and Weir J, Mapping a New Path - Strengthening social and emotional wellbeing through community-led research and knowledge sharing, ANU Grand Challenge project \$1.2 million, 2020-2025

Doran B, Stevenson, J, Johnston D, Jones T, Moritz C, Haberle S, King P, Denham T, Backwell P, Sutherland S, Mathews D, Wallace R, O'Connor S, Provost S, and Weir J, Ubirr Site Complex Conservation Management Plan, Kakadu National Park, National Heritage Grant, \$308k, 2020-2022

Ireland T, and Zolensky M., Analysis of asteroid samples returned by Hayabusa 2 and Osiris-REx, ARC Discovery Project, \$450k, 2021-2023.

King PL, Arculus RJ, Ávila J and Ireland TR, Identifying submarine volcanism in the Izu-Bonin-Marianas Forearc, Australia NZ IODP Consortium Legacy Analytical Support Scheme, \$20k, 2020-21.

Liu, X.C., Qu, W., 5 others, Fu, B., Petrological Constraints on Mesozoic Tectonic Evolution of the South Qinling Orogen, Central China, NNSF of China, Grant No. 41872059, ~\$136k, 1/2019-12/2022.

Phillips D., Jourdan F, Matchan E., Gleadow A, Li Z-X, Bland P, Norman M, Honda M, Cawood P, Weinberg R, Vasconcelos P, Herries P, Fiorentini M, and Wingate M, Ultra-precise dating in Earth, planetary, and archaeological sciences. ARC LIEF, \$905,654, 2021.

Smith, T, Green, D., Williams, I.S., Constructing robust climate proxies to explore human and primate evolution, ARC Discovery Proposal, \$343k, 2021-2.

Staff Honours & Awards

Staff Member

Yuri Amelin

Trevor Ireland	Award	Awarding Body
Penny King	Colleges of Science Deans' Commendation for Student Supervision	Colleges of Science, ANU
Marc Norman	Geochemistry Fellow	Geochemical Society
	Colleges of Science Deans' Commendation for Student Supervision	Colleges of Science, ANU
	Fellow	Mineralogical Society of America

External Committees and Editorial Boards

Name	Position	Committee / Board
Y. Amelin	Associate Editor	Geochimica et Cosmochimica Acta
V. Bennett	President	Geochemical Society
	Chair	Geochemical Society, Board of Directors
	Chair	Biogeochemistry award committee, Geochemical Society
	Member	Geological Society of Australia, Ringwood medal committee,
	Member	Joint Publication Committee of the Geochemical and Meteoritical Societies
G. Gibson	Editorial Board	Journal, MINERALS
M. Honda	Editorial Board	Geochemical Journal,
T. Ireland	Past President	The Meteoritical Society
	Member	JAXA Hayabusa2 Joint Science Team
	Member	NASA Osiris REx science team
P.L. King	Member	Australian Academy of Science, Decadal Review of Space Sciences, Planetary Science Working Group
	Member	American Geophysical Union Volcanology, Geochemistry & Petrology Fellows Committee
	Member	Mineralogical Society of America –MSA Medal Committee
	Advisory Board Member	Australasian University Geoscience Educators' Network
M. Norman	Associate Editor	Geochimica et Cosmochimica Acta
I.S. Williams	Editorial Board	Journal of Analytical Science and Technology



PALAEOENVIRONMENTS

Group leader

Katharine Grant

Academic members

Nerilie Abram, David Heslop, Brad Opdyke, Brad Pillans, Andrew Roberts, Eelco Rohling, Nicky Wright, Jimin Yu, Jia Liu and Xiang Zhao

The Palaeoenvironments Group is a collection of research scientists that specialise in environmental reconstruction on times scales that range from thousands to millions of years for both marine and terrestrial environments. We investigate cave precipitates, lake sediments, corals and reef sediments, marine sediments and ice cores to construct records of past environmental change. These reconstructions extend the record of climate behaviour and variability beyond those observed in the modern. They provide insights on processes (e.g., the response of ice-sheets) that act on long timescales, provide invaluable context for recent environmental change, and provide crucial data for ground-truthing climate models.

2020 was a challenging year, with the COVID-19 pandemic forcing rapid closure of the laboratories and a move to remote working early in the year. From mid-year we began the process of re-opening the laboratories and a staged return of students and staff. Our sincere thanks go to Joe Cali for his leadership in guiding our group and others in the school smoothly through this process so that our scientific work could re-commence.

Research highlights

Jimin Yu led a study published in Nature Geoscience which looked at past ocean circulation changes and their impacts on carbon cycle and atmospheric CO₂. Ocean circulation critically affects the global climate and atmospheric carbon dioxide through redistribution of heat and carbon in the Earth system. Despite intensive research, the nature of past ocean circulation changes remains elusive. Based on deep-

water carbonate ion concentration reconstructions for widely distributed locations in the Atlantic Ocean, this work presented the first meridional carbonate ion transect for the Atlantic during the Last Glacial Maximum around 20,000 years ago. This transect reveals a new glacial deep Atlantic circulation scheme different than commonly considered. The research finds that carbon-rich Pacific Deep Water extended northward up to about 20° S in the South Atlantic at 3–4 km depth during the Last Glacial Maximum. This may have contributed critically to the contemporaneous decline in atmospheric carbon dioxide, thereby helping to initiate the glacial maximum.

Eelco Rohling was part of a team that published a major review into the equilibrium sensitivity of Earth's climate. The team was able to make substantial progress in reducing the range of estimated climate sensitivity by looking at many lines of evidence, including the information from key time intervals in Earth's past. The overarching outcomes that future climate won't warm as much as we feared –but it will warm more than we hoped –were described in an article for *The Conversation*.

Nerilie Abram, Nicky Wright and Bethany Ellis led a publication in *Nature* that used coral records to reconstruct 500 years of variability of the Indian Ocean Dipole. The work also involved past students of the group, Bronwyn Dixon and Jennifer Wurtzel. The work found that climate variability is tightly linked between the tropical Indian and Pacific oceans, and showed that the positive Indian Ocean Dipole events that bring drought to southeast Australia and increase our bushfire risk are becoming more common because of climate change. The work is also described in an article published in *The Conversation*.

Andrew Roberts and Prof. Jinhua Li (Chinese Academy of Sciences, Beijing) made exciting advances in understanding the microbiology associated with magnetotactic bacteria. Their work is funded by a Chinese \$478,000 National Natural Science Foundation grant. Phylogenetic analysis is indicating a multi-phyletic origin (13 phyla identified so far –not long ago, it was thought to be only one) for the ability of these bacteria to navigate using Earth's magnetic field. Their origins appear to go back to the Archaean, which provides independent evidence for the longevity of Earth's magnetic field. Their work is also demonstrating that bacteria from each phylum produce magnetic particles with distinct morphologies, and that each species within each phylum produces magnetic particles with unique size/shape distributions. This gives hope for the eventual development of environmental proxies using the fossil remains of magnetotactic bacteria. Their work has also demonstrated that these bacteria play an active role in the biogeochemical cycling of C, N, Fe, and S in aquatic environments.

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.

Funding

In 2020 the Paleoenvironments group was involved in the award of funding for two large research centres. The Australian Centre for Excellence in Antarctic Science was awarded \$20M in funding over 4 years. The Centre is led by the University of Tasmania, and ANU is a major node that involves six chief investigators from RSES, including Nerilie Abram and Eelco Rohling from the Paleoenvironments group. It is planned that the Centre will formally commence in mid to late 2021. Funding for the National Environmental Science Program 2 was also announced in late 2020, with the RSES part of the \$38M Climate System Hub that will be led by CSIRO from mid-2021 for 7 years.

Awards

Congratulations to Andrew Roberts who was the 2020 Edward Bullard Lecturer of the American Geophysical Union. He gave his lecture Mineral Magnetism: Some Surprises and Future Challenges at the online Fall Meeting in December.

Congratulations also to Nerilie Abram who was the 2020 Priestley Medal recipient of the Australian Meteorological and Oceanographic Society. She gave her medal lecture at the AMOS conference in Fremantle in February of 2020.

Student completions

Congratulations to Congcong Gai who completed a PhD with Andrew Roberts. Congcong's research looked at the East Asian monsoon evolution since the late Miocene from the South China Sea.

Welcomes and Farewells

Dr Jia Liu joined the Paleoenvironments groups to work as a postdoctoral research fellow with Dave Heslop and Andrew Roberts on the ARC Discovery Project: A new generation of paleomagnetic statistics. We also welcomed Chen Xu who joined the group as an Honours student working with Jimin Yu.

In 2020 we also farewelled Joe Cali from the group. We wish him all the best and clear night skies for his retirement.



SEISMOLOGY AND MATHEMATICAL GEOPHYSICS

Group leader

Hrvoje Tkalčić

Academic members

Phil Cummins, Rhodrie Davies, Caroline Eakin, Sia Ghelichkhan, Babak Hejrani, Voon Hui Lai, Chengxin Jiang, Marthe Kloecking, Meghan Miller, Robert Pickle, Malcolm Sambridge, Benoît Tauzin, Andrew Valentine, Lauren Waszek

Overview

Notable achievements of the Seismology & Mathematical Geophysics (S&MG) Group's members this year include the accomplishment of the first stage of the Macquarie Ridge Complex (MRC) in the Southern Ocean, the project supported by ARC, CSIRO and NERC, exceeding 10M in value. Nine group members led by Tkalčić and Eakin participated in the voyage in September/October, after quarantining in Hobart for two weeks. 27 ocean-bottom seismometers were deployed, and a large portion of the MRC was mapped. The project aims to investigate the subsurface of the MRC and large earthquakes occurring in that region, it is led by RSES/ANU and joined by UTAS, Caltech and Cambridge. The recovery voyage will take place in November of 2021.

Despite the challenges of 2020 lockdowns and border closures, the Lake Eyre Basin seismic array (https://doi.org/10.7914/SN/5G_2018) was fully serviced by the field support team in Nov 2020 via

4WD and helicopter (led by Eakin and assisted by Salmon). This was our last trip with Armando Arcidiaco, who after 31 years of service, will be leaving us next year. The acquisition of a Distributed Acoustic Sensor (DAS) integrator unit through AuScope funding took place during 2020. This instrument transforms fibre optic cables into densely spaced sensors for large-N seismology. There were three successful deployments of nodal seismometer arrays of 100 3-component nodes including Mt Stromlo and Lake George regions (led by Miller and Jiang). These densely spaced autonomous sensors are part of the large-N seismology capability at RSES. Miller and Kennett's ARC Linkage Project began with the deployment of 25 seismometers in southwest WA.

Research news

S&MG group researchers published about 50 papers in international peer-review journals, many of which are impossible to mention in this summary. Research highlights start with a research on the Covid-19 pandemic published in Nature Communications by Sambridge and co-authored by A. Jackson, ETH-Zurich. It is a novel study on use of Benford's Law of 1st digits to detect fraud in national reports of infections and fatalities but follows on from the group's initial exploration of the 1st digit phenomenon in seismic signal detection a decade ago. On a similar topic, Miller and Moresi contributed to a global study published in Science that detected the change in seismic noise during COVID-19 lockdown. Another study published in Nature Geoscience (Ghelichkhan, Davies' group member as a co-author), described a relationship between the locations of large sediment-hosted mineral systems and the thickness of tectonic plates. In a study of historical earthquakes and tsunamis in the Banda Sea published in Nature Geoscience, Cummins's group was able to attribute the source of the most destructive events to an immense submarine normal fault recently discovered by RSES geologists. Tauzin co-authored a paper on Mars shallow structure published in Nature Geoscience and started a collaboration with Waszek on the mid-mantle structure. Eakin's group significant publication topics include mantle and slab deformation in subduction zones (e.g. Agrawal et al., Geophys. Res. Lett.) and subduction zone initiation (Crameri et al., Nature Communications). Valentine and Davies developed a statistics-based model for Earth's present-day dynamic topography and its spectral properties, enabling better models and opening new possibilities (G-cubed). The group continued publishing leading-edge papers on the Earth's correlation wavefield (e.g. Wang and Tkalčić, J. Geophys. Res., highlighted by the Editor of Eos). Other research topics included work on the nature of seismic sources (e.g. Hejrani and Tkalčić, J. Geophys. Res.), development of new methods, forensic seismology, and deep Earth structure (e.g. Stephenson et al., J. Geophys. Res.). Last but not least, Professor Emeritus Brian L.N. Kennett published a new book: "Exploiting Seismic Waveforms" (Cambridge University Press) with A. Fichtner, ETH-Zurich.

Awards

Malcolm Sambridge was awarded the Beno Gutenberg Lecture by the American Geophysical Union and he is also a recipient of the 2021 Beno Gutenberg Medal by the European Geosciences Union.

He delivered the AGU Gutenberg Lecture successfully at the Australian Academy of Sciences' Shine Dome in December.

Hrvoje Tkalčić was elected a Fellow of the American Geophysical Union.

Arrivals, departures and promotions

Arrivals

Post Docs – Dr Voon Hui Lai; Dr Chengxin Jiang

Promotions

Dr Caroline Eakin was promoted to academic level C.

Professor Meghan Miller was promoted to academic level E.

Departures

Dr Lauren Waszek moved to a tenure-track faculty position at the James Cook University in Townsville, Australia.

Dr Andrew Valentine moved to a tenure-track faculty position at Durham University in Durham, UK.

Dr Benoit Tauzin returned to a continuing position at the Lyon University, France.

Two Honours students, Leon Bilton and Claire Flashman, graduated this year.



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.

2020 was an unusual year for ANZIC as we pivoted our activities and efforts around bushfires, hail and the pandemic, each event leaving their mark on our operations and engagement nationally and internationally. Somewhat surprisingly we did have ANZIC scientists participate in an IODP

expedition within the southwest Pacific region in 2020, whereas other Expeditions planned, including 387, 388 and 390, with ANZIC scientists selected to participate, were postponed as the pandemic took hold of the world and all our international activities.

Focusing on our one successful expedition, Exp 378 South Pacific Paleogene Climate, sailed out on 3 January from Lautoka, Fiji, and after returned to port on the 6th February in Papeete, Tahiti. On board, ANZIC had two scientists, Prof. Simon George (Macquarie University) as one of the sedimentologists, and Dr Chris Hollis (GNS-Science) as the micropaleontologist focused on radiolaria. In addition, a New Zealand-based Outreach officer, Ms Claire Concannon from Otago Museum, was also on board. The preliminary report outlines the results from the expedition; “Expedition 378 recovered the first continuously cored, multiple-hole Paleogene sedimentary section from the southern Campbell Plateau at Site U1553. This high-southern latitude site builds on the legacy of Deep Sea Drilling Project (DSDP) Site 277, a single, partially spot cored hole, providing a unique opportunity to refine and augment existing reconstructions of the past ~66 My of climate history. This also included the discovery of a new siliciclastic unit that had never been drilled before” (Thomas, Rohl, Childress & Exp 378 Scientists, Apr. 2020, <https://doi.org/10.14379/iodp.pr.378.2020>).

ANZIC’s national activities were heavily focused on the delivery of Australian and New Zealand-focused science expertise, questions and future scientific drilling research aims encapsulated through the Ocean Planet Decadal Science Plan report. The report forms part of the future international Science Strategic Plan beyond 2023, and can be downloaded from: <https://doi.org/10.25911/5e1c39629af61>.

As a result of our enthusiastic decadal report, eight ANZIC members were selected to be included on the writing team and working group for the development of the future IODP Science Strategic Framework. ANZIC’s major thematic contribution to the strategic science plan was centred on the inclusion of our Ocean Health through Time theme under one of the new Flagship Initiatives of the Framework. The ANZIC Science Committee, members of the Governing Council and the ANZIC community also provided significant feedback to the two international community input requests as the Framework was developed and finalised. The document was completed and released in October 2020. The new Strategic Framework’s Mission and Vision are detailed below:

- **MISSION:** The 2050 Science Framework for Scientific Ocean Drilling guides multidisciplinary subseafloor research into the interconnected processes that characterize the complex Earth system and shape our planet’s future.
- **VISION:** To be globally recognized as the source of authoritative information about ocean and Earth system history and its links to society.

The Framework guides scientists on important research frontiers that scientific ocean drilling should pursue, as outlined by seven Strategic Objectives, five Flagship Initiatives and a backbone of Enabling Elements to advance the aims of scientific ocean drilling. Three versions of the framework have been produced to suit various audiences, including a 2 pg general summary flyer, a 12 pg general summary brochure and the complete 126 pg Science Framework. All are available for download directly from IODP: <http://www.iodp.org/2050-science-framework>.

In July 2020, ANZIC sought applications for Analytical Funding from our Australian and New Zealand members to support studies of legacy scientific ocean drilling material and/or data. We had a record high of 32 applications, double our normal number of applications (including a record eight applications from RSES), seeking total support of just over \$583,000. Submissions were received

from 28 Australian and 4 New Zealand applicant teams across 13 ANZIC member institutions. 43% of all applications were led by women Chief Investigators. In total, a maximum of 14 out of 28 Australian applications were successful (with four from RSES) and an additional three out of four NZ applications also successful, representing consortium support of just under A\$250K and NZ\$40K, respectively.

ANZIC's future remains tied to the outcome of Government funding. Having applied for NCRIS 2020 funding, ANZIC was advised by the Dept. of Education, Skills and Employment (DESE) in October, that our bid was not successful due to a focus on completing the funding of Government priorities that remained outstanding from the 2016 Roadmap. DESE, nonetheless, have encouraged ANZIC to participate in the future 2021 National Research Infrastructure Roadmap process and the subsequent 2022 Investment Plan, from which our future support through NCRIS can be assessed in the future.

Fortunately, ANZIC's additional funding request to the Australian Research Council LIEF scheme, led through RSES by Prof. Eelco Rohling was successful. Announced by the Hon. Minister Dan Tehan on the 23rd Dec, 2020, ANZIC's proposal received \$3M over 18 months. The next stage of ANZIC's subscription to IODP should commence in the second half of 2021, and enables us to maintain our subscription for an additional year in IODP.

ANZIC also submitted a request to AuScope under their Opportunity Fund to a 2 year pilot Land-to-Sea proposal that involves the International Continental Drilling Program (ICDP) and drilling with a NZ-led international consortium to the Antarctic. Due to COVID-impacts on our proposal implementation timeline under this proposal, AuScope have asked us to resubmit this very interesting proposal again in the 2021 round.

Locally, the ANZIC Office was located off campus for seven months of 2020, however, we are now all back on board and look forward to seeing ANU and other ANZIC member's pass by from time to time. We also said farewell to Prof. Richard Arculus as the ANU representative after decades of service to the running and enthusiasm behind holding the ANZIC Office here at RSES. We also said farewell to Prof. Stephen Eggins as the ANU Host representative and welcomed to Prof. Dorrit Jacobs as his replacement as she took up the role of RSES School Director in September 2020.



MeriSTEM

Project Officer

Alisha Duncan

The primary aims of the MeriSTEM project are to enable high quality teaching of Earth and environmental science, and to attract students to ANU from around Australia. Using content created by researchers allows teachers to focus on experiments and practical experiences in the classroom. By matching the content to the Australian curriculum, it ensures the resources can be effective and valuable across Australia.

In aligning the student experience to the strategic aims for RSES, the videos have naturally fallen into three categories:

- Introduction to the concept: An explanation of the current understanding on the curriculum topic
- Applied example: Often this is a research example, but presenters have also referenced industry and social examples
- Profile of the scientist: Some personal points aligned to the 'Science as a Human Endeavour' curriculum descriptions

In early 2020, the focus shifted to supporting undergraduate education, in the way of filming and editing content for the transition to online learning amid the emerging pandemic. Once the meriSTEM video series concludes, it would be a nice addition to rework this undergraduate content to suit the year 11 and 12 audience.

Once the undergraduate video component was complete, the project refocussed back to planning. Careful consideration and investigation of the Australian education system went into this phase to ensure the projects efficacy in line with the RSES's primary aims for the project.

This led to two main outcomes:

1. A distinctly modular approach to the video sequences, and
2. A focus on building instant credibility with the viewer through use of the ANU brand and high quality audio-visual experience

The planning has been designed to match the learning to the Australian senior science curriculum. Each state has different interpretations of the Australian curriculum, and these are outlined in each state syllabi. During the planning, state syllabi were carefully mapped and broken down so that the videos are segmented into discreet modules. Each module includes between 4 and 12 videos which can be moved around in the school year, to allow for the different flow of learning in each state. Within the module, the videos can remain in order no matter where they are being used across Australia, allowing for easy implementation for teachers.

One such flow is outlined below:

- Video 1: Introduction to the rock cycle
- Video 2: Sediments: compaction and cementation
- Video 3: Sediments: reading the rocks
- Video 4: Igneous rocks: composition
- Video 5: Igneous rocks: texture
- Video 6: Metamorphic rocks

The planning phase also included seeking feedback from teachers to inform the project as a whole. Feedback was sought individually with teachers within the current meriSTEM network, as well as more broadly across social media platforms. These interactions led to placing an emphasis on literacy and collecting ideas for classroom experiments wherever it was practicable.

Educational outcomes for this age group vary across classrooms in Australia. While some students will be advanced and ready to learn at the first year undergraduate level, others struggle with the reading and writing associated with schooling. The meriSTEM videos cater for both ends of the spectrum. The audience will see the literacy emphasis implemented as on-screen pop ups, outlining key information, questions and definitions in writing. The spoken explanations lend themselves to both the advanced group and the reading-impaired group, allowing for non-discriminate understanding across the range. The depth of each video naturally flows from introductory information, to more detailed information. Some of the more technical descriptions will cater to the advanced learners, where the initial 'introduction to the concept' videos cover the curriculum described learning in plain English for the majority of the cohort.

During conversations with teachers it became clear that implementing a flipped classroom, using meriSTEM video resources would allow for much more time to experiment in class, and this can be a daunting prospect at the outset. As videos have been filmed, any information about classroom experiments in use at the undergraduate level has also been collected and stored. In future this may lead to a more comprehensive learning guide, but is outside the scope of the current project.

The planning phase included seeking advice from on-campus visual storytellers, both at the college and central levels at ANU. This led to the purchase of equipment that's fit for the purpose of the project, allowing for high quality videos and ongoing mentorship from senior members of ANU staff.

Filming with RSES researchers commenced after the work from home directive was lifted. A total of 116

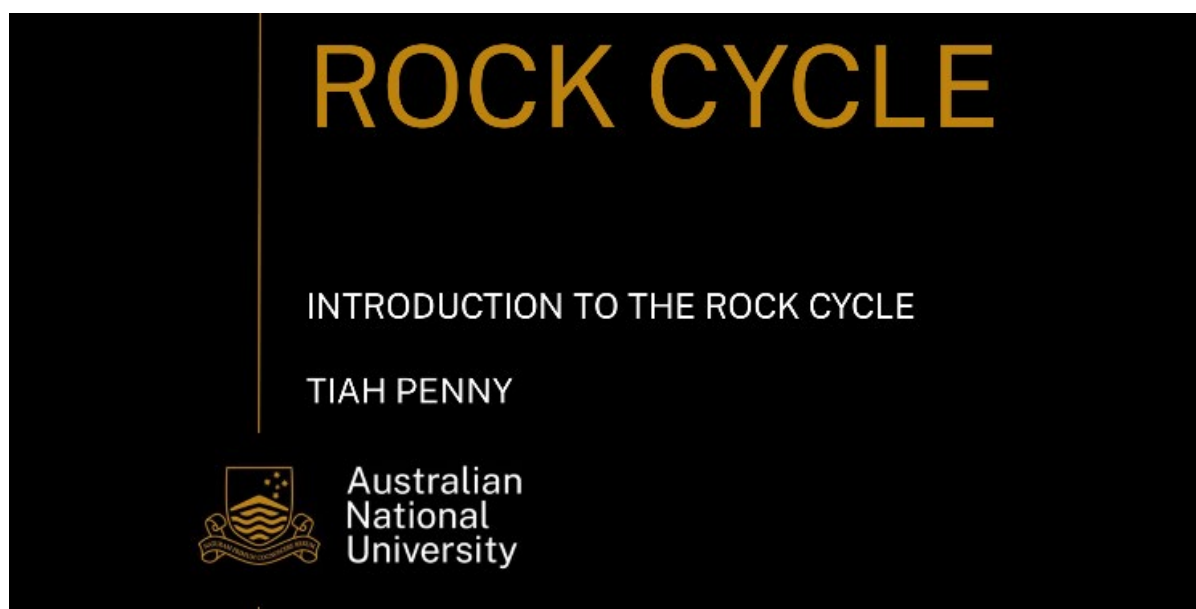
educational videos were filmed in 2020, with topics as diverse as the impact of natural hazards, to rare Earth elements, to ocean circulation patterns. Editing was delayed due to the top down implementation of a new ANU visual brand commencing late in 2020.

Partnerships

During the course of the year, key groups were identified as valuable partner organisations. Connections were made with these groups initially and progress was made to providing value to the organisations. In future it is intended that these partnerships are able to provide avenues for further development of the project, or avenue for attracting teachers to the resources created within RSES. Those key organisations were:

- Questacon
- CSIRO
- Australian Association for Environmental Education, ACT Chapter Branding

At the end of 2020, the draft style guide for the new ANU brand has been released and the final look and feel of the RSES meriSTEM videos is being finalised in concert with ANU Marketing. This is set to include a range of bespoke items including an educational introduction slide, pictured.



At the end of 2020, two complete modules were released to a small number of testing teachers. One comment provided is as follows:

“I liked how strongly the videos linked to real research. Overall very happy with these videos -thank you!”

Work on the project for 2021 is scheduled to include editing the raw footage already filmed, filming for the remaining topics, and branding everything in line with the new ANU brand, ahead of release to teachers.



Photos & socials







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