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Quaternary AUSTRALASIA

Defining the Anthropocene

Policy-making in focus

Making the most of INQUA 2015

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FRONT COVER PHOTO:

Coring at Warneet, Victoria, Australia. The core was taken as part of a 'blue carbon' stock assessment commissioned by the Port Phillip and Westernport Catchment Management Authority. At this particular site we sampled saltmarsh, mangrove, and freshwater drains. The site had some of the highest carbon stocks across the entire state of Victoria (see report by Paul Carnell *et al*. "The Distribution and Abundance of 'Blue Carbon' within Port Phillip and Westernport", available from Peter Macreadie: Peter.Macreadie@uts.edu.au). Photo: Peter Macreadie.

INSIDE FRONT COVER PHOTO:

Ground Swell by Matthew Harding, on display at Sydney Airport.

This work explores the geological history of the Botany region. The zoomorphic forms are made from 9000 year old Forest Red Gum and Angophora wood dredged during the construction of the parallel runway. These forms move across the ancient river systems that existed during the last ice age, which has since flooded to create Botany Bay. The presence of earth, air, fire and water speak of the essential forces that shape and sustain life. Photo: Patrick De Deckker.

EDITORIAL

Dear Fellow Quaternarists,

As you receive this issue of QA, most likely many of you will be gearing up for (or just returning from) the INQUA Congress in Nagoya. Not only is this quadrennial meeting an excellent opportunity to get really up-to-date on recent Quaternary research developments and to catch up – both scientifically and socially – with Quaternarists from across the world, it also presents prospects for networking and career building. This may take the form of establishing new scientific collaborations and partnerships, but also to learn of new employment possibilities and to meet with potential new supervisors. The latter is particularly relevant for early and mid-career researchers who have yet to attain a permanent position in research.

On this note, then, it is timely that we include a number of reports relevant to career building in this issue. Particularly thematic is Patrick Moss and Lydia Mackenzie's piece discussing how to make the most of international conferences – and for many of our student and early postdoc members, INQUA will probably be among their first major international meetings. Helen Bostock and Claire Krause introduce ideas for a mentor scheme under the AQUA banner in this news section, and Claire also describes her experiences in learning about the relevance of her research to policy makers at the annual Science meets Parliament event in Canberra.

Participation in research networks is another important way for young researchers to establish themselves in their scientific careers. In this issue, Drew Lorrey updates us on recent activities within the SHAPE initiative.

We also publish two white papers by the scientific community in this issue, introduced to us by our Treasurer, Steven Phipps. The first discusses the critical role of palaeoclimate research in dealing with climate change in the future, and the kind of support and investment which is required by governing bodies to facilitate continued research in this field. The second white paper argues for continued investment in tropical zone palaeoclimate research, particularly in order to better understand the Indo-Pacific climate modes such as the El Nino-Southern Oscillation and Indian Ocean Dipole, which have a significant influence on global temperature and precipitation regimes – even within timeframes typical of electoral terms. Collective efforts such as these are particularly important for gaining the attention of policy makers and governments who control research funding. An important recent case in point is the last-minute response of the Australian government to continue funding for the National Collaborative Research and Infrastructure Strategy, under pressure from the National Research Alliance. Although this reprieve is presently only valid for 12 months, it nevertheless places some confidence in the influence of the collective scientific community on critical governmental decisions such as these.

We look forward to catching up with you in Nagoya!

Yours Quaternarily,
Kat Fitzsimmons and Pia Atahan *Editors*

PRESIDENT'S PEN

I hope you are all limbering up for the upcoming Quaternary Olympics – the XIX INQUA congress in Nagoya, Japan. It is great to see that there are several dedicated Southern Hemisphere sessions which have had lots of submissions. The SHAPE session has had over 47 abstracts and the oral session stretches over a whole day. I'm sure that Australasia will also be represented in many of the other specialist sessions throughout the congress. The meeting will also be a great opportunity to catch up with other Australasian and international colleagues as well as develop new collaborations over a sake or two! For Early Career Researchers – there is a special session and opportunities to network – check out the conference programme.

This year AQUA offered four grants of A$2250 each to cover the costs of travel to the INQUA Congress. We had a total of 36 applications from students at all stages of their studies, covering a wide range of topics, but after some debate four of the applicants emerged as the clear winners. We are therefore pleased to announce that the recipients of the 2015 AQUA Travel Award are, in alphabetical order:

- Shaun Eaves, Victoria University of Wellington: Uniform summertime cooling drove glacier advances across New Zealand during the Antarctic Cold Reversal
- Jessica Hinojosa, University of Otago: Holocene evolution of marine radiocarbon reservoir ages offshore southwest New Zealand: Implications for water mass migration and radiocarbon dating accuracy
- Claire Krause, Australian National University: New insights on tropical vegetation productivity and atmospheric methane over the last 40,000 years from speleothems in Sulawesi, Indonesia
- Jennifer Wurtzel, Australian National University: Holocene climate variability recorded in a speleothem from Sumatra, Indonesia

We know that these students will do an excellent job as ambassadors for AQUA. For those of you who haven't been to INQUA before I suggest you check out the article by Patrick Moss and Lydia Mackenzie on "Making the most of big international conferences". To aid AQUA members to meet each other we will be holding an informal social function early on in the week at INQUA so keep an eye on your e-mail, facebook or other social media to find out where and when. Unfortunately I will not be able to attend INQUA this year, but I look forward to reading all about it in the next QA.

Over the last few months we have had several AQUA members attend Science meets Parliament; Duanne White and Claire Krause (see QA article). Meanwhile, Stephen Phipps attended the inaugural Science meets Policymakers event. With increasing pressure on research funding it is important that Quaternary Scientists are represented at these kinds of events and that the relevance of our science is highlighted to representatives that make the decisions on funding.

It has been a disappointing few months for research funding – especially in Australia where the government has threatened to scrap the Future Fellowships funding for mid-career scientists, following in the footsteps of the recently scrapped ARC Australian Research Fellowship (ARF) and ARC Queen Elizabeth II Fellowship (QEII). The government also held the funding for research infrastructure hostage until the budget savings from the higher education reforms were passed. Just as 27 research facilities were preparing to close down, there was a one year reprieve on the $150 million needed to keep these research facilities up and running. However, the long term future of these facilities, that support the science of 35,000 researchers, is unclear. This is on top of recent funding cuts to CSIRO and other research agencies. All of this has significantly affected climate change research.

In New Zealand there is still ongoing frustration over the very low success rates of Marsden funding (5-10%) and the lack of funding for early career researchers following the removal of the postdoctoral scheme several years ago that funded ~90 post docs per year, leaving only a few independent postdoc fellowships available. This Foundation of Research Science and Technology (FRST) postdoc scheme has been replaced with the prestigious Rutherford Discovery Fellowships that fund 10 early to mid-career researchers across all disciplines, with 3-8 years post PhD experience, for 5 years. So far two Quaternary Scientists have been successful. After the great launch of the New Zealand 10 year National Science Challenges 2 years ago via a national TV and web campaign (and articles in high impact journals), with the promise of "new money" for research in strategic areas, we are still waiting! New science projects have still not been initiated and "the best teams" of researchers are still waiting for calls for proposals as the challenges undergo some teething issues in setting up the structure, science plans, funding and governance.

The lack of stability in research funding and the risk-averse nature of current funding bodies is not conducive to innovative science, and is especially difficult for young scientists starting out in their careers. For this reason I hope that many of the more experienced Quaternary researchers will be prepared to put your names down to act as mentors for our future Quaternarists in training.

Helen Bostock *AQUA President*

NEWS

MENTORING FOR QUATERNARY POSTGRADUATE STUDENTS AND EARLY CAREER RESEARCHERS

Helen Bostock, *NIWA, Wellington, New Zealand*

Claire Krause, *Research School of Earth Sciences, Australian National University, Australia*

AQUA has always been a strong supporter of students and early career researchers (ECRs). As stated in our constitution:

"The Association is an organisation that promotes the discussion and dissemination of information and ideas within the various disciplines and interests relating to Quaternary Studies. The primary emphasis is on the promotion of research and training activities, particularly of new researchers in all areas of Quaternary Studies."

This has primarily occurred through the provision of travel awards to allow students to attend local and international meetings and present their research results. The local biennial AQUA meetings have always been a relatively relaxed forum to allow the students to build their confidence in giving talks, or presenting their posters, to a friendly and supportive audience. We have also encouraged students and ECRs to get involved in the running of AQUA, with several ECRs on the AQUA committee providing a voice for the younger researchers.

But is there more that we could be doing for the next generation of Quaternary researchers?

One suggestion that has recently come up during committee discussions is the idea of setting up a mentoring scheme. Many universities have mentoring networks, but international professional organisations are also increasingly establishing mentoring programs, such as the Earth Science Women's Network (http://eswnonline.org/). In the modern era of increasing telecommunications there are now no restrictions as to the location of mentors and students – I regularly skype with colleagues and students in different locations and timezones.

Many of us have had mentors – whether formally or informally during our careers – or researchers that have inspired us, or allowed us to brainstorm our sometimes crazy ideas without laughing too hard! While for some of us our supervisors and advisors are great mentors, it is often useful to have a mentor that is removed from the immediate project and has a different but related background, as these people may approach the problem from a different angle, or use a different technique. Some students are confident enough to approach researchers and ask for advice – and they should be encouraged to do this, but others may not know where to start as they have not yet developed a network.

All mentor relationships will work differently and while some may be a one-off conversation, others will be an ongoing relationship. Some will be a relationship where the mentor is providing technical help or editing manuscripts, while others will be more about providing career advice, building general confidence. Therefore it is unclear exactly how to set a mentoring scheme up. We suggest that if you are happy to mentor or offer advice on a particular subject that you send in your details and AQUA will keep a database of potential mentors that are happy to help students and ECRs (see following example).

Name: Dr Q. Researcher

Address: University of life, Australasia, Southern Hemisphere

Phone #: +61 1234567

Skype: I_love_mud

Expertise: Sediments, Geochemistry, Radiocarbon. Also happy to help with editing or reviewing manuscripts.

The profiles will not be made available online, but students should contact AQUA to find someone with specific expertise that they would like to tap in to. In the meantime we would like to encourage students to have the confidence to contact researchers that they would like help from – or approach them at conferences. Most researchers will be flattered to have a student ask for constructive help and advice.

If you have any feedback on setting up the mentoring network, or other suggestions of what AQUA can do for students and ECRs then please get in touch. Please also email your brief profiles to: president@aqua.org.au.

NEW ARRIVALS FOR AQUA MEMBERS

We would like to congratulate several members of the committee on their new babies:

Scott Mooney and his partner had a little boy Arthur George Mooney-Fitzgerald on the 30 December

Duanne White and his partner had a little boy Felix White on the 2 January

Our AQUA President Helen Bostock and her partner had a little girl, Freya, on May 10. Congratulations, Helen!

MEET A MEMBER OF THE AQUA EXECUTIVE COMMITTEE

STEVEN PHIPPS: TREASURER, AQUA

Steven grew up in the wilds of the UK, before being lured to Gondwanaland by the ancient mountains and forests of New Zealand. After experimenting with a few different career options, and discovering a love of fine wine along the way, he eventually completed a PhD in climate modelling at the University of Tasmania in 2006. Subsequently, he came to realise that simulating past climates is only a worthwhile exercise if your model is constrained by real-world data. Thus he embarked on a weird and wonderful journey with all the weird and wonderful members of the Australasian Quaternary research community. In 2010, that journey took him to Stradbroke Island and his first AQUA Biennial Meeting. There was a vacancy for Treasurer and, as he has always embraced quantitative approaches, he thought that he should put his hand up. Thus began an equally weird and wonderful journey through AQUA's finances. However, after five years in the job, he is finding it increasingly hard to find the time to count all of AQUA's accumulated wealth. At the upcoming AGM, he will therefore be handing over his responsibilities to whomever is sufficiently gullible and enthusiastic to accept this critical role. He is looking forward to continuing to get his hands dirty with the proxy data, and notes that he is available for fieldwork.

The advent of the Anthropocene in Australasia

Helen C. Bostock[1], David J. Lowe[2], Richard Gillespie[3], Rebecca Priestley[4], Rewi M. Newnham[5], Scott D. Mooney[6]

1. *National Institute of Water and Atmospheric Research, Private Bag 14901, Wellington 6021, New Zealand*

2. *Earth Sciences, School of Science, Faculty of Science and Engineering, University of Waikato, Private Bag 3105, Hamilton 3240, New Zealand*

3. *Centre for Archaeological Science, School of Earth and Environmental Sciences, University of Wollongong, Northfields Avenue, Wollongong NSW 2522, Australia, and Department of Archaeology and Natural History, School of Culture, History and Language, Australian National University, Acton 2601, Australia*

4. *Science in Society group, Victoria University of Wellington, P.O. Box 600, Wellington 6140, New Zealand*

5. *School of Geography, Earth and Environmental Sciences, Victoria University of Wellington, P.O. Box 600, Wellington 6140, New Zealand*

6. *School of Biological and Earth and Environmental Sciences, UNSW, Kensington, Sydney, NSW 2052, Australia*

INTRODUCTION

As early as the late 19th Century, several scientists had suggested that humans were starting to influence the physical environment of planet Earth (e.g. Marsh, 1864; Stoppani, 1873; Arrhenius, 1896; Chamberlain, 1897). This idea was resurrected and expanded in 2000 by Paul Crutzen, a Nobel Prize-winning chemist, and the late Eugene Stoermer, a professor of biology specialising in diatoms, who suggested that we had left the Holocene and entered the "Anthropocene" (Crutzen and Stoermer, 2000). As summarised by Steffen et al. (2011) and Wolfe *et al.* (2013), these iconoclastic scientists were referring to the Anthropocene as the interval of demonstrable human alteration of global biogeochemical cycles, beginning subtly in the late 18th Century following James Watt's invention of the coal-fired steam engine, and accelerating markedly in the mid-20th Century (termed "The Great Acceleration"). Thus Crutzen and Stoermer (2000) argued that the Anthropocene should be an epoch, and for a starting date at the beginning of the Industrial Revolution (Monastersky, 2015).

The term Anthropocene is now regularly used in the geological/environmental literature, appearing in nearly 200 peer-reviewed articles in 2012, and three new journals have been launched over the last few years specifically focussed on this topic, namely The *Anthropocene Review*, *Anthropocene*, and *Elementa: Science of the Anthropocene*. In 2014, the Geological Society, London, published A Stratigraphical Basis for the Anthropocene (Waters et al., 2014), a 321-page volume devoted to the subject. The problem is that the Anthropocene has not yet been formally defined and different disciplines (and even scientists within the same discipline) have different viewpoints as to when the Anthropocene began, if at all (Table 1). In addition, most perspectives on this issue are derived from the Northern Hemisphere, although Brown *et al.* (2013) and Ellis *et al.* (2013) and some others have taken a more global viewpoint.

Table 1: Dates or ages proposed in the literature for the start of the Anthropocene, arranged in chronological order. Adapted from Lewis & Maslin (2015)

	EVENT	AGE OR DATE	GEOGRAPHICAL EXTENT	REFERENCE
1	Use of fire	Early Pleistocene	Global but highly localised and diachronous	Roebroeks and Villa (2011); Glikson (2013)
2	Megafaunal extinction	50,000-600 yrs BP	Global but diachronous	Barnosky (2014)
3	Origin of agriculture	~11,000 yrs BP to present	SW Asia then global	Smith and Zeder (2013)
4	Intensification of agriculture	~8,000 yrs BP to present	Eurasia then global	Ruddiman (2013) (see also Monastersky, 2015)
5	New-Old World collision	AD 1492-1800	Eurasia – Americas	Lewis and Maslin (2015)
6	Industrial Revolution	AD 1760 to present	NW Europe then global	Crutzen and Stoermer (2000)
7	Tambora eruption (Indonesia)	AD 1815 (April)	Global: synchronous sulphate fallout at both poles	Smith (2014)
8	Great Acceleration	AD 1950	Many local events, global influence	Waters *et al.* (2014); Steffen *et al.* (2015)
9	Nuclear weapon detonation	AD 1945 to present (peak AD 1964)	Global	Steffen *et al.* (2007); Zalasiewicz *et al.* (2011; 2015); Wolfe *et al.* (2013)

HOW TO DEFINE THE ANTHROPOCENE AND WHEN IT SHOULD START

In 2016, members of the International Commission of Stratigraphy (ICS), as custodians of the formal Geologic Time Scale, will decide whether the Holocene epoch has given way to the Anthropocene and, if so, where the boundary between the two should be placed. As well as the issue of timing, the Anthropocene Working Group (AWG, chaired by Jan Zalasiewicz) of the Subcommission on Quaternary Stratigraphy, which advises ICS, is to recommend which hierarchical status the Anthropocene should attain if adopted. If it is to be a geological "epoch" (i.e. at the same hierarchical level as the Pleistocene and Holocene epochs) then it would lie within the Quaternary Period and follow the (terminated) Holocene Epoch. Alternatively, it could be considered at a lower hierarchical level such as "age", implying it is a subdivision of the ongoing Holocene Epoch (Monastersky, 2015; see also http://quaternary.stratigraphy.org/workinggroups/anthropocene/).

At the same time the ICS will decide whether to formally adopt a proposal to subdivide the Holocene into three sub-epochs (Walker *et al.*, 2012; Gibbard, 2015). This parallel effort to subdivide the Holocene is relevant to the Anthropocene question because it clearly characterises the Holocene as being based on natural climatic/environmental events, thus leaving open the possibility of a subsequent epoch defined entirely by the global signature of significant human impact on the environment.

The Holocene was formally ratified by the ICS in 2006. It is defined as the most recent epoch of the Quaternary Period, being broadly the time since the first signs of climatic warming at the end of the Younger Dryas/Greenland Stadial 1 cold phase (11,700 calendar years before the year AD 2000) through to the present day (Walker *et al.*, 2009). The official boundary of the Holocene is defined in the Greenland NGRIP ice core at 1492.45 m depth (marked by an abrupt shift in deuterium excess values), and selected auxiliary lacustrine and marine records, including sediments in Lake Maratoto in northern New Zealand representing the Australasian parastratotype. Holocene stratigraphic records, as well as providing evidence of climate and sea-level change, geomorphological and hydrological processes, vegetational changes, and faunal migrations, also contain archaeological data that attest to the development of society, and the evolving relationships between people and the environment (e.g. Walker *et al.*, 2012; Roberts, 2014). A key problem in attempting to define the

Anthropocene is to distinguish between the detection of human impacts and their distribution in time and space, and the point at which the magnitude of human impacts on the Earth system (key biogeochemical cycles) exceeds the influence of the natural systems and which can be recognised in the context of geological time (Steffen *et al.*, 2011; Wolfe *et al.*, 2013). In a nutshell, the Holocene might be seen as totally adequate to cover the former, and the Anthropocene should perhaps be used to cover the latter.

AUSTRALASIAN PERSPECTIVE

In this article we present an Australasian perspective, and invite your feedback and comments, which will be compiled and sent to AWG to help advise the ICS. We do not suggest that Australasian evidence should necessarily be at the forefront of defining the onset or formal stratigraphic status of the Anthropocene, but that the evidence from our region should be compatible with, and should inform, any globally applicable definitions. Because Australia (and Papua New Guinea) and New Zealand (and other Pacific islands of Polynesia) have very different Quaternary histories, they are treated separately in the brief overviews below.

AUSTRALIA AND PAPUA NEW GUINEA

Based on the dating of occupation and burial sites, humans arrived in Australia and Papua New Guinea around 45,000—50,000 years ago (e.g. Roberts and Jones, 2000; Turney *et al.*, 2001a; Bowler *et al.*, 2003; Allen and O'Connell 2014). Around this time there is also considerable evidence for significant changes in fluvial hydrology and lake levels (Magee *et al.*, 2004; Cohen *et al.*, 2015), evidence for charcoal and biological turnover (Turney *et al.*, 2001b; Mooney *et al.*, 2011), and for the extinction of the megafauna (Roberts *et al.*, 2001; Gillespie, 2008). There is still considerable debate in Australia, partly due to the sparse distribution and often poor quality dating of megafaunal sites, whether human hunting and associated practices, including use of fire, or climate change, or some combination of both, caused the demise of the megafauna (e.g. Miller *et al.*, 2005; Gillespie *et al.*, 2006; Brook *et al.*, 2007, 2013; Prideaux *et al.*, 2010; Rule *et al.*, 2012; Murphy *et al.*, 2012; Price, 2012; Wroe *et al.*, 2013; Cohen *et al.*, 2015). During the early to mid-Holocene period there is evidence for plant domestication in the highlands of Papua New Guinea (Denham *et al.*, 2003; Haberle, 2007), but Aboriginals on mainland Australia primarily remained hunter-gatherers.

The first Europeans landed on Australia in the 17th Century, but large-scale European colonisation did not occur until 1788 with the development of the penal colonies around Sydney and the satellite convict settlements on Norfolk Island (from 1789) and Hobart (1803) (e.g. King, 2003). For the next ~100 years there is considerable evidence from historical and palaeoenvironmental archives that the European settlers had a considerable impact on the landscape, with massive deforestation of the east coast forests especially, leading to changes in the vegetation, increased charcoal in the archives, and large increases in sedimentation in lakes, estuaries, and near-shore environments (Haberle *et al.*, 2006). A significant acceleration of the impact of these and other land-use activities occurred in the 1950s (e.g. Douglas *et al.*, 2010; Gehrels *et al.*, 2012; Macreadie *et al.*, 2012).

PACIFIC ISLANDS AND NEW ZEALAND

In comparison with the early arrival of humans in Australia, many of the Pacific islands were only discovered and populated by seafaring Polynesians in the Late Holocene, with colonisation of West Polynesia from around 200 BC, central East Polynesia from around AD 900-1100, and Hawaii, Easter Island (Rapanui), and South Polynesia, from around AD 1200-1300 (Anderson, 2015a). The earliest arrival in New Zealand (part of South Polynesia) was not until the 13th Century, possibly around AD 1280 (Lowe and Pittari, 2014). Why New Zealand was settled so late in prehistory is debated, but, as well as being a remote archipelago, its discovery has been linked to the requirement of sophisticated sea craft and navigation and was possibly associated with a peak in El Nino frequencies (e.g. Anderson *et al.*, 2006; Anderson, 2015a, 2015b), or just general changes in the wind systems during this period (Goodwin *et al.*, 2014). The early Polynesians (who culturally became Maori in New Zealand) brought with them domesticated plants and animals (dogs and rats), although some of the tropical plants were not suitable for the New Zealand climate. Evidence from peat, lake, and marine-derived pollen records, lacustrine sedimentation records, and bones of the commensal Pacific rat Rattus exulans, rat-nibbled seed cases and snail-shells, fire records, ancient DNA, and archaeological studies show that Polynesians had a substantial impact on the landscape from around 700 years ago (e.g. Higham and Hogg, 1997; Wilmshurst, 1997; Ogden *et al.*, 1998; Schmidt and Higham, 1998; Higham *et al.*, 1999; McGlone and Wilmshurst, 1999; Brook, 2000; Anderson, 2002, 2005, 2013; Wilmshurst *et al.*, 2008, 2011, 2014; Lowe, 2011; Perry *et al.*, 2012; Jacomb *et al.*, 2014; Anderson, 2015c). There is also considerable evidence that hunting of the local wildlife in New Zealand lead to the extinction of a species of sea lion and many birds (~ 40 species) (Collins *et al.*, 2014), including several megafauna: all nine species of moa (extinct from AD 1440 ± 20; Perry *et al.*, 2014) and Haast's Eagle (extinct around AD 1400; Tennyson and Martinson, 2006).

Abel Tasman was the first known European to reach New Zealand in AD 1642 with evidence of possible contact by further Dutch explorers after AD 1705 ± 5 (Palmer *et al.*, 2013). Following the arrival of Cook in 1769, there is ample evidence for explorers, missionaries, whalers, sailors and traders, with small whaling and sealing stations around the country from the early 19th Century (e.g. King, 2003). The Treaty of Waitangi was signed in 1840 and large pakeha (primarily British) settlements continued to develop during the 19th Century. Further dramatic changes in the vegetation occurred during this European era, as observed from historical as well as geological and palaeoenvironmental archives. Pollen records in particular indicate resurgence in forest clearances by early pakeha settlers and accompanying introduction of a wide range of exotic plants. The large-scale development of grasslands occurred in the late 19th and early 20th centuries with the so-called "grasslands revolution", which lead to forest clearance on lowlands through to steeplands, and the widespread and efficacious drainage of wetlands (e.g. King, 2003; Brooking and Pawson, 2011; Cushman, 2013; Brooking and Wood, 2013; Park, 2013). Accelerating soil erosion and measurable environmental geochemical influences are recorded in landscapes and in lake and marine sediments from the 1920s onwards (e.g. Rawlence, 1984; Hume *et al.*, 1989; Page *et al.*, 2004; Augustinus *et al.*, 2006; Gomez *et al.*, 2007; Gehrels *et al.*, 2012; Basher, 2013), with a markedly increased intensification of land use from the 1950s, including the advent of aerial topdressing (from 1948-49), leading eventually to widespread changes (degradation) in water quality (e.g. Pawson and Brooking, 2013).

THE GREAT ACCELERATION

It is clear that the 1950s was an important decade for both New Zealand and Australia, and it is also an important time globally, with a major expansion of human population after World War II, intensification of land use, and the development of many new technologies and materials (plastic, artificial fertilizers, advent of new breeds of crops such as rice, etc.). This period, as noted earlier, has been called the "Great Acceleration" (e.g. Wolfe *et al.*, 2013; Monastersky, 2015; Steffen *et al.*, 2015). These changes have had a major impact on our atmosphere and climate with atmospheric CO_2 and methane rapidly increasing after the 1950s. It is now estimated that nearly half of the nitrogen in our bodies was produced in a factory using the Haber-Bosch process. In addition, ever-enduring plastic can now be found in all parts of the Earth – the current estimates suggest the ratio of plastic to marine life in the world's major marine gyres is 6 to 1 by weight (Vince, 2014; Kidwell, 2015; Young, 2015). Steffen *et al.* (2015) emphasise that only beyond the mid-20th Century acceleration is there unequivocal evidence for fundamental shifts in the state and functioning of the Earth system that exceed the range of variability of the Holocene, and which are driven by human activities. Thus these authors consider that the beginning of the Great Acceleration is "by far the most convincing for a start date for the Anthropocene".

THE ATOM BOMB EFFECT

The mid-20th Century was also the start of the nuclear age. The first nuclear bomb was detonated by the United States of America (USA) on 16 July 1945. In the subsequent nuclear arms race, first the USA and Soviet Union, and then the United Kingdom, France, and China, began developing and testing nuclear weapons of ever-increasing size. The first thermonuclear bomb (or hydrogen bomb) was detonated by the USA in 1952, this new type of bomb, which the Soviet Union first tested in 1953, produced much larger yields of fission products and blasted radioactive isotopes high into the stratosphere where they spread around the world and were deposited as nuclear (radioactive) fallout.

It was a New Zealand scientist, Athol Rafter, who first observed that nuclear weapon detonations – particularly the hydrogen bomb tests – were significantly increasing levels of radiocarbon in the atmosphere. In a 1957 paper he coined the phrase "the atom bomb effect" (Rafter and Fergusson, 1957) and outlined how nuclear weapons tests had doubled atmospheric radiocarbon in the Northern Hemisphere and increased Southern Hemisphere levels by 60%. These increases produced a sudden spike of "bomb carbon" in the 1960s (Figure 1).

During 1961-62, many high-yield weapons were tested by the USA and Soviet Union, after which both countries signed the 1963 Limited Test Ban Treaty (tests by France, and then China, continued). In both northern and southern hemispheres, peak strontium-90 (^{90}Sr) and caesium-137 (^{137}Cs) levels were reached in 1964. The two-year delay between peak testing and peak deposition was due to the long residence time of fallout in the stratosphere. In the Southern Hemisphere, peak ^{90}Sr and ^{137}Cs deposition averaged 40% of Northern Hemisphere levels, with higher levels of deposition in areas with higher rainfall (Matthews, 1993).

GOLDEN SPIKE (GLOBAL STRATOTYPE SECTION AND POINT: GSSP) OR GLOBAL AGE (GLOBAL STANDARD STRATIGRAPHIC AGE: GSSA), OR BOTH, FOR THE ANTHROPOCENE?

For the Anthropocene to become a formal geological unit it needs to be recorded in the geological, sediment, or ice records (preferably all of these archives) as a stratigraphically significant single global event (or at least covering a significant proportion of the globe), and

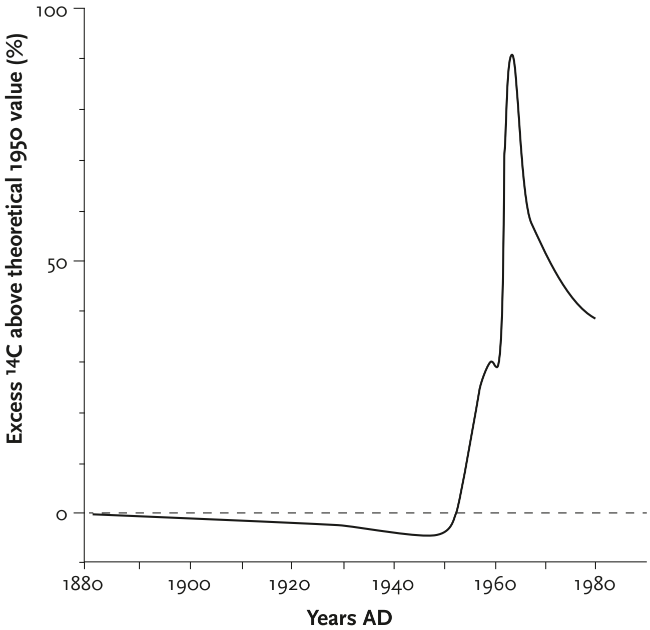

Figure 1: Atmospheric radiocarbon abundance, showing the fossil fuel effect and nuclear bomb effect (Gillespie, 1984).

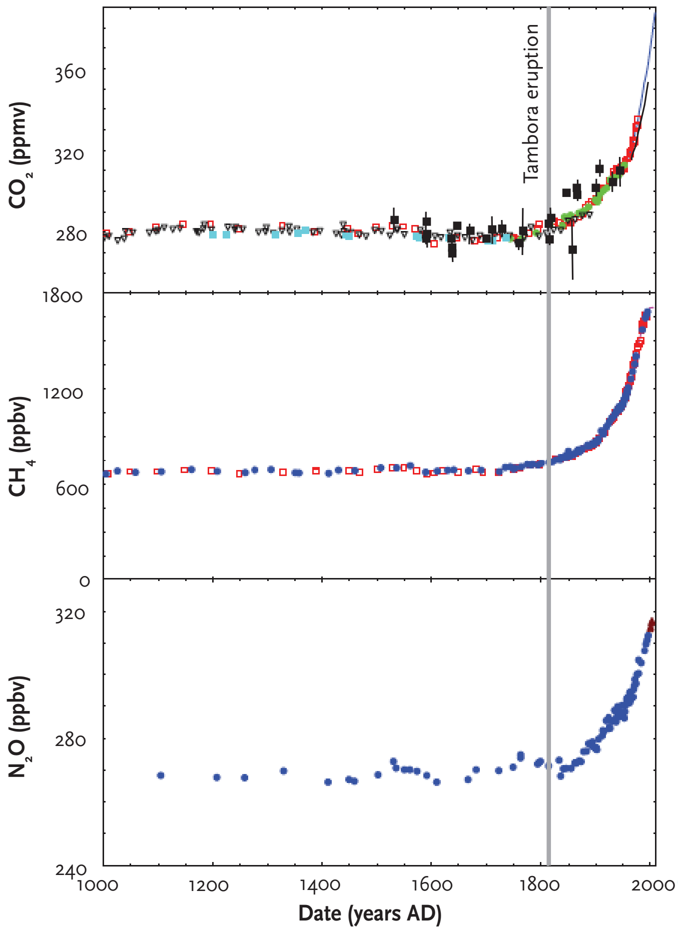

Figure 2: Changes in greenhouse gases recorded in ice cores in the last 1000 years with the date of the Tambora eruption (1815) indicated (vertical line). Coloured symbols represent data from Antarctic ice cores: red boxes = Law Dome, green circles = Siple, purple triangles = EPICA DML, blue boxes = South Pole; black boxes are data from GISP2, Greenland. Atmospheric CO2 measurements from Mauna Loa are also plotted (solid blue line) for the last ~50 years. Figure from Smith (2014), after Wolff (2011). Reproduced with acknowledgement and thanks to The Geological Society, London, and to Victoria C. Smith. (Please see the electronic issue for a colour version of this figure. Electronic issues are available on the AQUA website and through our ePublisher, Informit).

preferably not time-transgressive (i.e. not diachronous). If we accept that the Anthropocene onset must be (largely) globally discernible, the Australasian evidence outlined above precludes definitions 1-5 (Table 1). If we take definition 6 then the rise in CO_2 in the ice cores is clear, but it is difficult to define precisely. The initial change in concentrations is gradual, reflecting the sluggish and variable spread in the use of coal, starting in northwest Europe and slowly spreading to North America and then globally. So there is no abrupt change in CO_2 or other products associated with the burning of fossil fuels (Lewis and Maslin, 2015), but the marked rise in greenhouse gases nevertheless is evident from the early 1800s (Figure 2). One other suggestion for a golden spike (GSSP) for the early 19th Century (definition 7), relating chronostratigraphically to this greenhouse rise, has been fallout from the Tambora volcanic eruption (Indonesia), which occurred in April 1815, and resulted in a global cooling and "the year without a summer" in the Northern Hemisphere (e.g. Fischer *et al.*, 2007; Smith, 2014). More importantly for generating a global marker, the eruption produced an instantaneous, synchronous, and recognisable aerosol-derived sulphate spike in the ice cores of both Greenland and Antarctica and in glacier ice in North and South America, and a distinct signal in dendrochronological records (Briffa *et al.*, 1998; Oppenheimer, 2003; Smith, 2014). Probable fallout from Tambora in New Zealand was identified by Gehrels *et al.* (2008) from measurements of lead (Pb) concentrations and isotope values in salt-marsh sediments in southeast South Island. It is likely, on the basis of recent discoveries of cryptotephra deposits (sparse glass-shard concentrations not visible as layers: Lowe, 2011; Davies, 2015) at distances >7000 km from the eruption source (e.g. Lane *et al.*, 2013; Jensen *et al.*, 2014), that glass shards from the Tambora eruption are identifiable as cryptotephras in terrestrial and marine sediments over wide areas of the Earth's surface, hence potentially providing a definitive isochron or marker 'bed' on a hemispheric scale. Thus it could be argued that the Tambora eruption deserves serious consideration as the golden spike because it is a demonstrably globally synchronous signal that ties in with associated evidence of increasing human impact, namely the atmospheric greenhouse gas rise from the early 1800s (Figure 2) (Smith, 2014). Another idea is that this eruption event could simply be seen as a global marker for the start of the ~150 year transition from the Holocene to Anthropocene.

We would argue, however, that the definition(s) that relate best overall to the evidence in the Australasian region are definitions 8 and 9, respectively the "Great Acceleration" combined with the "Nuclear Age" at around AD 1950 (i.e. between AD 1945 and 1965). It is clear that globally there have been many changes in land use and technology and other developments from the mid-20th Century that have led to fundamental shifts in the functioning of the Earth system to a point where many biophysical indicators now exceed limits of Holocene variability. There is now an unprecedented "emergent, planet-scale coupling, via globalisation, between the socio-economic system and the biophysical Earth System", according to Steffen *et al.* (2015). The global fallout of bomb-test radioisotopes has the potential to create a truly global marker horizon for the Anthropocene (Zalasiewicz *et al.*, 2011; 2015). The nuclear weapon detonations introduced a range of radioactive isotopes that can be traced in soil, sediment, ice, tree-ring, and coral archives. Caesium-137 and strontium-90 were first detected in soils in 1952, while there is evidence that bomb radiocarbon in geological archives peaked in 1965 in the Southern Hemisphere, slightly offset by a couple of years from the Northern Hemisphere peak in 1963 and that of the tropics in 1964 (Hua *et al.*, 2013; Zalasiewicz *et al.*, 2015). Unfortunately, not all of these bomb isotopes will be useful for the tracing of this event in the geological future because ^{90}Sr and ^{137}Cs have very short half-lives (28 years and 30 years, respectively), while radiocarbon is slightly longer with a half-life of 5,730 years. However, several other isotopes, such as plutonium-239 and iodine-129, have longer half-lives of 24,110 years and 15.7 million years, respectively, and hence the latter should therefore be evident in the geological record effectively indefinitely (Hancock *et al.*, 2014).

Others have argued that the date of around AD 1950 postdates the upward inflection of atmospheric CO_2 from fossil fuel combustion in ice cores by more than a century (Fig. 2). However, it is clear from the records that there is also an acceleration in the increase of atmospheric CO_2 at this time (Steffen *et al.*, 2015), with evidence that this is the first interval when anthropogenic greenhouse gas forcings dominated over natural climate forcings (Hansen *et al.*, 2008). Thus this ~AD 1950 date fits with the postulated definition of the advent of the Anthropocene as being the point at which the magnitude of human impacts on Earth system (key biogeochemical cycles) exceeds the influence of the natural systems (Wolfe *et al.*, 2013). Taking a rather different, namely microbiological, viewpoint, Gillings and Paulsen (2014) suggested that the 'Great Acceleration' be assigned a formal starting date of 1953 (when the structure of DNA was first published) on the grounds that human manipulation of the biological information flows from DNA, to RNA, to protein, and thence to phenotype (a process known as the 'Central Dogma' of cell biology), is a major development in the course of evolutionary history. Because such manipulation "has the potential to expand the power of gene technology to whole-Earth scales", Gillings and Paulsen (2014) concluded that "DNA technology will be a powerful force in our future, and for dealing with the Anthropocene."

Finally, some have proposed that a GSSA alone may be more appropriate at this time to define the start of the Anthropocene because the community is still fleshing out the full range of physical, chemical, and biological phenomena associated with the postulated Holocene-Anthropocene transition (Zalasiewicz *et al.*, 2011; 2015; Wolfe *et al.*, 2013), and hence a GSSP can wait. However, other scientists completely disagree with all these proposals and believe that we are still in the Holocene and that the "anthropocene" should remain an informal unit (e.g. Autin and Holbrook, 2012; Gale and Hoare, 2012; Smith and Zeder, 2013; Gibbard and Walker, 2014; Ruddiman *et al.*, 2015). In this case, the name would continue to be used in the same way as such archaeological terms as Neolithic and Bronze Age (Monastersky, 2015). Another view is that we are in the transition towards the Anthropocene and need a much longer perspective to assess "the character of the fully developed Anthropocene" and it should be left to future generations to decide (with hindsight) when the Anthropocene began (Wolff, 2014). For example, Ruddiman *et al.* (2105) suggested that future changes – such as species extinctions and ocean acidification (e.g. Drake *et al.*, 2014) – are projected to be much larger than those already seen but are difficult to predict.

Please send your thoughts and feedback to Helen Bostock (Helen.Bostock@niwa.co.nz) by **1 September 2015**.

Issues to address include:

1. Should the Anthropocene be formalised as part of the Geological Time Scale?
2. If adopted, when should it start?
3. If adopted, what status should a formally defined Anthropocene have in the hierarchy of the Geological Time Scale: epoch, age, or something else?

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A Quaternarist's guide to attending INQUA

Patrick Moss[1] and Lydia Mackenzie[1]

1 School of Geography, Planning and Environmental Management, University of Queensland, Australia

With INQUA 2016 in Nagoya rapidly approaching we thought it would be a good idea to provide a guide to fellow AQUA members (particularly first-time INQUA attendees), outlining what to expect at the INQUA congress, as well as some general tricks and tips for ECRs attending and presenting at conferences. This report may also contain something that more experienced conference attendees should take note of as well.

WHAT IS AN INQUA

An INQUA Congress is the Quaternarists' version of the Olympics: they are held every four years, bidding for them is highly competitive, and they highlight the work of leading Quaternary scientists. In fact you will be overwhelmed by the volume of interesting talks and posters, often over four or five concurrent sessions, and by the mass movement of people between sessions. This will be Lydia's second INQUA conference and Patrick's fourth, and both of us agree that INQUA is an extremely valuable experience, not only in terms of highlighting our research, but also to catch up on the newest ideas in Quaternary Science, and to meet with old friends and colleagues (often not having seen them since the last INQUA!).

The INQUA Congress runs over eight days. The first day begins with an Icebreaker in the evening (in INQUA 2015's case, a Sunday), which is a great opportunity to meet fellow Quaternarists in an informal setting and is followed by three days of conference sessions (including the conference opening, plenary sessions and INQUA Commission meetings). A day is then devoted to the Mid-Conference excursions (if you have had the foresight to join), to self-guided excursions (for Reno 2003, Patrick and colleagues hired a car and drove around Lake Tahoe) or simply to recover. The final three days return to the conference sessions. There are also a range of pre– and post-conference field trips that can be undertaken. Also, all of the INQUA Commissions are open to interested people and there are a range of formal and informal events occurring every night of the conference.

Our key piece of advice is to enjoy all that is on offer with this smorgasbord of Quaternary Science – but it is also important to pace yourself, since at some stage your head may explode from all the information flying past! Another key suggestion is to go through the conference program and highlight the key presentations/posters you want to see. You will be overwhelmed by some very interesting presentations that will often conflict – so identify the key ones you want to see, check out the room size (often popular talks will have an audience lining up outside the room) and estimate the time it will take to move to another room. The size of the INQUA Congress (often 1000+) can make this a bit daunting, particularly for participants new to the wonderful world of the Quaternary so we have included some general tips and tricks (which also apply to other conferences).

KNOW YOUR HEROES

Do you want to work with a particular lab group in Europe? Is there an author who keeps popping up in your reference collection? The INQUA Congress is the perfect place for some serious stalking (aka 'networking'). Do your research so you can pick your personal hero from the crowds. What are they working on at the moment? Any new and exciting grants they might just need a post-doc for? Just don't be creepy about it and you might be able to share a drink with them at the Icebreaker or share a table at the conference dinner!

THE THREE P'S OF PRESENTING: PREPARE, PREPARE, PREPARE

Don't be 'that guy' who can't go hiking/drinking/exploring because you haven't prepared your presentation. Quaternary Scientists *like* the outdoors and chances are you're going to want to make the most of the location and colleagues. Don't make the mistake of trying to write your talk while on the train to the conference venue, don't analyse your data in the hotel late at night or memorise your speech the morning of your talk. Enjoy your partially-funded trip and feel smug when drinking that cold Sapporo Beer the night before your presentation rather than panicking. This year the INQUA ECR team are running a practice seminar early in the conference. Make the most of it: come along to meet other ECR's and get helpful advice on your presentation. You could also seek out your advisor or peers (if they are attending) for a practice seminar as well.

ORAL PRESENTATION

Most conferences outline a time for oral presentations – stick to it. The audience will appreciate it! Rather than presenting your entire PhD in 12 minutes, pick a particular question/section that you think will be appropriate for the audience. Too much information crammed into one talk can confuse your audience and end in a tangled heap of facts, figures and frustration. Even the most experienced presenters still get nervous. Make sure that you have water present if you suffer from 'dry mouth syndrome', and that you pace your presentation (not too fast or slow – the Goldilocks principle of 'just write').

Rather than simply saying 'thank you' on your final slide, why not have a summary of your talk and your contact details? The final slide lingers on the screen during question time, allowing people to reflect on your key points and (possibly) to write down your details.

Be prepared for questions at the end of the talk. Come up with a few that you may be asked and plan a response. Thanking your ~~interrogator~~ audience for their thoughtful questions is a good way to buy time to formulate a concise answer. And be honest if you don't know the answer. In general the audience is very interested in what you are presenting and several new collaborations (or postdocs) have emerged after a good INQUA talk.

And finally...make sure your format WILL work on the computers provided BEFORE it's your turn.

POSTERS

Poster sessions can be a great way to talk to people who are interested in your work. The best part – they come to you! So make it easy for your potential viewers to find you, to take away the key points and to contact you later. The other key advantage over a seminar is that you have to finalise your poster prior to arriving at the conference and you won't experience the last minute preparation that is often a feature of oral presentations.

Lydia's favourite 'what not to do' poster example comes from INQUA 2011 where she spotted a presenter feverishly scribbling information onto their crowded poster while it was hung on the wall. A clear and concise poster is the way to go – keep the text to a minimum. Every year the School of Geography, Planning and Environmental Management at The University of Queensland runs a poster competition; it's always the simple, uncluttered and eye-catching ones that win the prize (check out the GPEM website for last year's winners). The idea is not to data-dump your entire PhD onto a poster but to entice your readers to learn more.

How will viewers remember YOUR poster at the end of the day? Try having business cards, printouts or a QR code that can be downloaded. This makes it easy for people to access the information and come back to it after the conference hangover has lifted.

Also take the time to stand at your poster during the session. Maybe you won't have as many visitors as the Megafauna Extinction poster but every person you get to talk to makes the difference. Have a quick 3 minute spiel pre-planned in case your audience wants to know more.

ASSOCIATION

Finding people at an international conference can be tricky. Luckily the AQUA community will be well represented like they were at the last INQUA in Bern (Fig 1). So make sure you find out if there are any events happening after hours. There is also a range of Commission Meetings, including the INQUA ECR Commission who will be arranging a number of social events and practice sessions. These will be posted on the facebook site. Also each INQUA commission has a social media page with updates leading up to the conference. Make sure you join so you don't miss out.

Figure 1. The Australasian contingent at the Bern 2011 INQUA Congress

Dealing with Climate Change: Palaeoclimate Research in Australia

Katrin Meissner, *Climate Change Research Centre, University of New South Wales, Sydney, Australia*

Nerilie Abram, *Research School of Earth Sciences, The Australian National University, Canberra, Australia*

Leanne Armand, *Department of Biological Sciences, Macquarie University, Sydney, Australia*

Zanna Chase, *Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, Australia*

Patrick De Deckker, *Research School of Earth Sciences, The Australian National University, Canberra, Australia*

Michael Ellwood, *Research School of Earth Sciences, The Australian National University, Canberra, Australia*

Neville Exon, *Australian IODP Office, Research School of Earth Sciences, The Australian National University, Canberra, Australia*

Michael Gagan, *Research School of Earth Sciences, The Australian National University, Canberra, Australia*

Ian Goodwin, *Marine Climate Risk Group, Macquarie University, Sydney, Australia*

Will Howard, *School of Earth Sciences, University of Melbourne, Melbourne, Australia*

Janice Lough, *Australian Institute of Marine Science, ARC CoE Coral Reef Studies, Townsville, Australia*

Malcolm McCulloch, *ARC CoE Coral Reef Studies, University of Western Australia, Perth, Australia*

Helen McGregor, *School of Earth and Environmental Sciences, University of Wollongong, Wollongong, Australia*

Andrew Moy, *Australian Antarctic Division, Australian Government, Hobart, Australia*

Mick O'Leary, *Department of Environment and Agriculture, Curtin University, Perth, Australia*

Steven Phipps, *Climate Change Research Centre, University of New South Wales, Sydney, Australia*

Greg Skilbeck, *University of Technology, Sydney, Australia*

Jody Webster, *Geocoastal Research Group, School of Geosciences, University of Sydney, Sydney, Australia*

Kevin Welsh, *School of Earth Sciences, University of Queensland, Brisbane, Australia*

Jens Zinke, *Department of Environment and Agriculture, Curtin University, Bentley, WA 6845, Australia; School of Earth and Environment, The University of Western Australia Oceans Institute and Australian Institute of Marine Science, 39 Fairway, Perth, WA 6009, Australia.*

Corresponding author: Katrin Meissner (k.meissner@unsw.edu.au)

PREFACE:

"Dealing with Climate Change: Palaeoclimate Research in Australia" was written as a contribution to the National Marine Science Plan White Paper "Dealing with Climate Variability and Climate Change". It identifies Australian palaeoclimate research and funding priorities for the next decade and beyond and was compiled from multiple submissions from the community. The paper was presented at the National Marine Science Symposium, held in Canberra from 25-26 November 2014, and is reproduced here for the benefit of the broader community.

ABSTRACT

Palaeoclimate research relevant to marine systems in Australia includes the collection and analysis of: (a) shallow-water and deep-sea corals, which provide high-resolution archives, (b) deep-sea sediment and ice cores, which span longer time scales, and (c) palaeoclimate modelling, which gives us insights into mechanisms, dynamics and thresholds underlying past climate states. Palaeoclimate research in Australia is mature and well recognised internationally. To further advance Australian palaeoclimate research, we must address major challenges that include insufficient research vessel access, insufficient targeted research funding, as well as the lack of a well funded national centre to coordinate research efforts (e.g. academic institution or ARC Centre of Excellence for Palaeoclimate Research).

BACKGROUND

The main palaeoclimate data/proxy group is located at the Australian National University (Research School of Earth Sciences, 15+ researchers and their groups). Smaller groups also exist at the University of Western Australia, the Australian Institute of Marine Science (AIMS), James Cook University, University of Queensland, University of Wollongong, Curtin University, University of Sydney, Macquarie University, Melbourne University, the University of Tasmania, ANSTO Environment, Geoscience Australia and the Australian Antarctic Division. The main palaeoclimate modelling group is located at the University of New South Wales (Climate Change Research Centre) with smaller groups at CSIRO, Monash University and the University of Western Australia.

Australia is a member of the International Ocean Discovery Program (IODP), through the Australian and New Zealand International Ocean Discovery program Consortium (ANZIC), hosted at ANU and with 22 member organisations in Australia and New Zealand. IODP is the world's largest multinational geoscience program and includes almost all OECD countries. IODP carries out deep scientific coring in all of the world's oceans using a variety of platforms, and provides 'ground truthing' of scientific theories that are often based largely on remote sensing techniques. 'Environmental changes, processes and effects' is one of three key research themes within IODP.

ANZIC is funded jointly by Australia and New Zealand, with Australia being the major partner. Australia's funds are provided under an ARC/LIEF grant, with the ARC funds amounting to $1.8 million p.a. and the 18 Australian partners providing $855,000 p.a. toward Australian membership of IODP. ANZIC actively supports Australian scientists to participate in IODP palaeoclimate research. Between 2009-2014, 16 Australian scientists participated in palaeoclimate-focused IODP expeditions as members of the Science Party. Through ANZIC, from 2010-2014, 12 Australian scientists have been granted up to $40,000 of post-cruise funding, and in 2012 and 2014 ANZIC supported a total of 24 Australian scientists in groups through analytical funding of up to $25,000 to work on legacy material.

Australian palaeoclimate science is also funded through the Australian Research Council (ARC, Discovery Grants, Future and Laureate fellowships), the ARC Centre of Excellence for Coral Reef Studies, the Australian Institute of Marine Science (AIMS), the Australian Antarctic Division (AAD), university fellowships and joint international programs (e.g. Australian Academy of Science administered programs, French and U.S. science programs). Ship time is supported through the Australian Antarctic Science Program, the Marine National Facility, significantly through international research vessels, and the Integrated Ocean Discovery Program (IODP). Other funding sources include AINSE and ABRS grants.

Australia's palaeoclimate research contributes to several international working groups of IGBP-Past Global Changes (PAGES; e.g. Ocean2k, Aus2k, 2k-Network, Sea-Ice Proxy and IMPRESS), of the International Union for Quaternary Research (INQUA; e.g. SHAPE), PALSEA2 (PALeo constraints on Sea Level rise), PLIOMAX (Pliocene Maximum Sea Level) and PMIP (the Palaeoclimate Modelling Intercomparison Project). It has also contributed to the Intergovernmental Panel for Climate Change (IPCC) assessment reports (e.g. AR5 working group 1, Chapter 14: *Climate Phenomena and their Relevance for Future Regional Climate Change*). Australian palaeoclimatologists are representatives on many international governing, scientific and technical boards related to IODP and international collaborative science programs (e.g. BIOTRACERS, ECORD, IMPRESS, PAGES, SCAR).

The research is mature and rates internationally. Some examples of high-impact contributions by Australian scientists over the past 5 years include (but are not limited to): Climate sensitivity (Rohling *et al.*, 2012), sea-level history (O'Leary *et al.*, 2013; Rohling *et al.*, 2014; Zinke *et al.*, 2014), ocean acidification (McCulloch *et al.*, 2012), ENSO, Indian Ocean and Southern Hemisphere climate modes (Abram *et al.*, 2008; Maina *et al.*, 2013; McGregor *et al.*, 2013; Abram *et al.*, 2014; Zinke *et al.*, 2014), ocean carbon cycle (Yu *et al.*, 2010), Antarctic melting rates (Mulvaney *et al.*, 2012; Abram *et al.*, 2013), past behaviour of oceanic currents (De Deckker *et al.*, 2013).

RELEVANCE

Palaeoclimate reconstructions can be used to estimate the sensitivity of the climate to CO_2 and other boundary conditions (e.g. Rohling *et al.*, 2012), an important parameter needed to understand the possible extent of future warming of the planet. Some periods in the past may provide analogues that can constrain important aspects of the climate system (e.g. the cryosphere) under future scenarios (e.g. Cook *et al.*, 2013). Furthermore, palaeoceanographic data are used to calibrate climate models. Indeed, the most recent assessment by the IPCC (AR5) has for the first time included palaeoclimate information in its evaluation of climate model performance (Braconnot *et al.*, 2012). Palaeoceanographic data and palaeoclimate modelling provide a benchmark against which to assess current and future changes in climate, the carbon cycle and marine ecosystems, for example in response to ocean acidification (e.g. Moy *et al.*, 2009) and the role of seasonal sea ice (e.g. Houben *et al.*, 2013). High-resolution coral data can give us a better understanding of the characteristics of natural climate variability including societally-relevant interannual to decadal oscillations (such as the ENSO and the IOD; e.g. Abram *et al.*, 2008; McGregor *et al.*, 2013; Zinke *et al.*, 2014) and therefore improve the forecast of such events, including Australian rainfall impacts. Finally, palaeoclimate modelling can provide for additional interpretation of the proxy data (e.g. Huiskamp and Meissner, 2012; Phipps *et al.*, 2013). Examples include the exploration of the dynamical mechanisms underlying past changes (e.g. Brennan *et al.*, 2013), and the formal detection and attribution of anthropogenic influences on the ocean (e.g. Bindoff *et al.*, 2013).

End-users for this research range from state and national governments to environmental and resource agencies in Australia (and internationally) who have to develop long-term planning strategies for 'living in a changing environment' (ARC National Research Priorities) or global research priorities (Kennicutt *et al.*, 2014) over the coming decades and centuries.

SCIENCE NEEDS

KEY CHALLENGES

The most important challenges our community is facing include insufficient research vessel access, insufficient targeted research funding and the lack of a well-funded national centre to coordinate research efforts. For example, funding for RV *Investigator* has been reduced from the original plan of 300 to just 180 days per year, and university-based research needs to seek, independently, both ship and project support to guarantee the achievement of scientific objectives. Other marine nations (e.g. Japan, Germany, France, US), which have several national research vessels each, support ~300 days ship time and link funding for ship time and research to ensure success. Palaeoclimate research is largely a university-driven research field with heavily restricted opportunities for collaborative support from government research institutions (such as the CSIRO, Geoscience Australia, or the AAD) where this science is no longer specifically supported or a research priority. In contrast, the IODP programme is key to research programmes and should receive longer term funding. Again, Australia is unusual among IODP member countries in having funding for only 2 years (renewal necessary for 2016 and beyond). ARC funding should be targeted for the areas of oceanography, earth sciences and climate modelling. A key challenge is also to retain the necessary scientific expertise and leadership to undertake this research effort within Australia.

KEY SCIENCE GAPS

- Understanding of the climate history for the Australasian region
  - Sea level: Impact of natural variability (including Antarctic Ice Sheet variability) on sea level and rates of change. Sea level benchmarks from past periods of warming and higher CO_2 (i.e. MIS5e, MIS11, the Pliocene, etc.).
  - Climate sensitivity of the Australasian region: develop a history of wet and dry phases for Australia, and define leads and lags between oceans and land.
  - Develop a history of continental run-off (weathering history).
- Subtropical/tropical marine variability and change
  - History of the East Australian Current and Leeuwin Current, plus the dynamics of the Indo Pacific Warm Pool.
  - Spatially and temporally comprehensive marine climate history for Indo-Pacific waters, decadal climate variability within different background climate states, which are part analogues for future climate (i.e. MIS5e, MIS11, the Pliocene, etc.). The climate of the past 2000 years is of particular interest (international research priority).
  - The role of external forcings (orbital, solar, volcanic, greenhouse gases) in driving past changes.
- Southern Hemisphere ocean modes and linkages
  - Better understanding of the dominant modes of variability in the Southern Hemisphere Oceans, on timescales ranging from annual to orbital.
  - Better constraints on the timing of past changes, particularly during glacial/interglacial transitions.
  - Linkages between the Northern and Southern Hemisphere oceans, including any leads or lags.
- Ocean control of atmospheric carbon dioxide (CO_2) during past warming events
  - Identification of the main sources of CO_2 during past key warming events.
  - Identification of mechanisms, triggers and thresholds involved during these past periods of abrupt warming.
  - Adequate representation of these processes and feedbacks in climate models used for future projections.
  - Adaptability of marine organisms to climate variations.
  - Better understanding of organism changes through time via fossil assemblages.

- Better understanding of reef ecosystem responses to past disturbance (climate, ocean acidification, land-derived, etc.) and identification of refugia.
- Effects of fisheries on deep-sea corals.

- Global climate – carbon cycle – ecological dynamics and feedbacks
  - Ocean-atmosphere-cryosphere linkages and feedbacks.
  - The lack of an Australian palaeoclimate model able to simulate long timescales and including prognostic palaeoproxies.

KEY OUTCOMES

- High-resolution reconstruction of past sea levels and understanding of driving mechanisms.
- High-resolution reconstructions of past sea surface temperatures.
- Improved understanding of changes in climate variability in the Australasian region leading to improved forecasts for rainfall and weather extremes.
- The development of an Australian climate model able to simulate long timescales and including prognostic palaeo climate proxies (e.g. oxygen and carbon isotopes), as well as a fully coupled carbon, nitrogen and phosphorus cycle.
- Improved proxies for ecosystem composition and carbon cycle parameters such as productivity, nutrient availability and oxygen, including development and utilisation of chemical composition of fossil organisms as climate proxies.
- Understanding of the climatic events leading to, and resulting from, Antarctic ice sheet deglaciation and collapse and the subsequent impact on oceanic ecosystems (tropical to polar).

PERSPECTIVE

SPECIFIC SCIENCE PRIORITIES

- Establishment of a coordinated palaeoclimate national agenda (defining national priorities in terms of locations, time spans, tools, techniques, supplementary data, and ensuring an appropriate division of resources).
- Establishment of a well funded national centre to coordinate research efforts. This can be either an academic institution or an ARC Centre of Excellence for Palaeoclimate Research. While Australia's palaeoclimate researchers are international leaders in their respective fields, there is at present insufficient funding to coordinate this world-class research between groups that are scattered all over the continent. Such a centre would also allow for the training and retention of necessary scientific expertise in Australia.
- Strengthen and maintain Australia's capacity as world leaders in developing high-resolution palaeo-environmental reconstructions from the tropical oceans. Need for clear understanding of tropical climate variability influencing the Indo-Australian region over priority and relevant time intervals. Provide a better understanding of the range of climate variability in regional areas across Australia, and understand how the natural environment has responded.
- Need for a systematic effort to develop/maintain palaeoclimate modelling research capacity. Palaeoclimate modelling requires models that are computationally efficient and that include representations of key elements of the Earth system (such as the carbon cycle, stable isotopes and ice sheets). These requirements are very different to the requirements for modelling 21st century climatic change, where the emphasis is generally on maximising the spatial resolution of the models. As such, palaeoclimate modelling requires dedicated modelling frameworks or, at the very least, dedicated versions of existing models.
- Australian community works towards taking a leading role in the reconstruction of the deglacial history of the poorly constrained (Mackintosh *et al.*, 2014) East Antarctic Ice Sheet (EAIS) using marine-based records proximal to the ice shelf to interpret current changes in the mass of the ice sheet, and potential contribution to sea-level rise. Given the presence of Australian bases in East Antarctica, the existing expertise in the region, and the impact of EAIS melt on Australian sea level, investment in this area is needed. With the new vessel RV *Investigator*, and a new icebreaker coming in the next decade, there is potential to make significant advances. There is also an opportunity for Australian scientists to participate in international efforts in this field, through the IODP and ANDRILL programs.
- Strengthening Australia's involvement in Southern Ocean and Antarctic Circumpolar Current (ACC) palaeoclimate science. Link with ISOLAT (Integrated Southern Ocean Latitudinal Transects), an international program to advance Southern Ocean palaeoceanography through a coordinated series of sections through the different regions of the Southern Ocean (Dr Leanne Armand, Macquarie University, is a member). These priorities relating to high latitude palaeoceanography were identified in the recent SCAR Antarctic and Southern Ocean Science Horizon Scan (Kennicutt *et al.*, 2014). Indeed, one of the proposed focus regions is a transect south of Tasmania to the ice-edge, capturing the important transition zone between the western Pacific and eastern Indian oceans. Australian scientists are particularly well-placed to

address this transect, as well as the overall sub-goals of reconstructing:

- Variability of latitudinal sea-ice extents, westerly wind strength and dust deposition, and the biological pump and their implications for air-sea gas exchange and atmospheric chemistry (CO_2); and
- Variability of surface ocean fronts and their relation to ACC activity and changes in westerly winds.

- Strengthening Australia's research capacity in sea-level reconstructions to develop critical benchmarks for a warmer, high CO_2 world.

REALISATION

- A large (and well-funded) academically based institution that acts as a coordinating centre (comparable to University of Southampton in the UK, or Scripps /Woods Hole in the US).
- An ARC Centre of Excellence for palaeoclimate research (integration of palaeoclimate proxy and modelling communities).
- Longer-term and increased ARC funding options (5 years, 30% success rate).
- Long-term funding of the RV *Investigator* at 300 days per year.
- Two additional small research vessels to carry out work in the coastal zone, and for short-term voyages.
- Australia must remain a member of IODP. Australian scientists will gain through shipboard and post-cruise participation in cutting edge science, by building partnerships with overseas scientists, by having research proponents and co-chief scientists who can steer programs and outputs, and by early access to key samples and data. They will also have the opportunity of science training for postdoctoral fellows and doctoral students in marine science that could not be obtained in any other way. Our region is unique to address various global science problems. Being a member of IODP will help us maintain our leadership in Southern Hemisphere marine geoscience research.
- In order for Australian scientists to put forward strong drilling proposals to IODP, there must be funding mechanisms in place to support pre-drilling geophysical site surveys. For example, the UK supports membership in IODP through a Site Survey Investigations scheme (http://www.nerc.ac.uk/research/funded/programmes/ukiodp/news/ao-ssi/).
- A challenge common to many facets of ship-based marine science is the lack of coordination between funding for ship-time through an application to the MNF and funding for the research (e.g. salary, travel, equipment and analysis costs), which typically comes from applications to the ARC or the AAS. Better coordination of these funding rounds would maximize use of resources and ensure the best science is properly supported.
- National effort in palaeoclimate modelling (development of a palaeo-version of the ACCESS model). We must ensure that Australia maintains access to world-class palaeoclimate modelling capacity – including not just the development of the tools themselves, but also ongoing maintenance, training and investment in personnel.
- The Australian marine geoscience community needs to strengthen their involvement in international efforts in terms of infrastructure and human resources. For example, being proactive about bringing international researchers on the RV *Investigator* (if funding exceeds 180 days per year) and also trying to attract foreign research vessels in our waters (i.e. have some financial attraction/incentives to do this (e.g. pay ship time, joint scholarships). Re-institute the MST (Marine Science Technology) grant system or something similar.
- Closer coordination through funding of working groups, for example through renewal of national program of activity (i.e. AUSCORE – Australian Coral Records) to link the Australian palaeoclimate community. This will allow an integration of research expertise/measurement and modelling facilities across organizations, and provide a coordinated coral and sediment core material sharing and sample effort.
- Archiving of physical coral and core material and material exchange to ensure maximum use of material collected to date. AIMS, for example, currently houses the AIMS Coral Core Archive, a national facility which, at present, contains coral material from the Great Barrier Reef and eastern Indian Ocean reefs. There is scope to curate additional material within this archive and thus make it a truly national facility of international significance. There is a sediment core repository at Geoscience Australia but it needs resources to bring it to international standards.
- The development of a national training curriculum for universities and an ability/access to the RV *Investigator* to train future Australian marine palaeoclimate scientists. A small training marine geoscience program has been supported by ANZIC since 2013, and a larger Master's at sea marine training program is under development through a consortium of universities headed by Macquarie University.

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Dealing with climate change through understanding past tropical ocean-atmosphere climate interactions and their impacts on marine ecosystems

*,[1]Jens Zinke, *Department of Environment and Agriculture, Curtin University, Bentley, WA 6845, Australia; School of Earth and Environment, The University of Western Australia Oceans Institute and Australian Institute of Marine Science, 39 Fairway, Perth, WA 6009, Australia.*

Helen V. McGregor, *School of Earth and Environmental Sciences, University of Wollongong, Wollongong, NSW 2522, Australia.*

Nerilie J. Abram, *Research School of Earth Sciences, The Australian National University, Canberra, A.C.T. 0200 Australia.*

Janice M. Lough, *Australian Institute of Marine Science, ARC Centre of Excellence for Coral Reef Studies, PMB 3, Townsville MC, Queensland 4810, Australia.*

Michael Gagan, *Research School of Earth Sciences, The Australian National University, Canberra, A.C.T. 0200 Australia.*

Mick O'Leary, *Department of Environment and Agriculture, Curtin University of Technology, Kent Street, Perth, WA 6845, Western Australia.*

Malcolm McCulloch, *ARC Centre of Excellence for Coral Reef Studies, School of Earth and Environment, The University of Western Australia, 35 Stirling Hwy, Crawley, WA 6009, Australia.*

Jody Webster, *Geocoastal Research Group, School of Geosciences, University of Sydney, University of Sydney NSW 2006 Australia.*

Colin Woodroffe, *School of Earth and Environment, University of Wollongong, Wollongong, NSW 2522, Australia.*

**Correspondence to: jens.zinke@gmail.com.*

[1] Now at Department of Environment and Agriculture, Curtin University of Technology, Perth, WA 6845, Australia.

PREFACE:

"Dealing with Climate Change through understanding past tropical ocean-atmosphere climate interactions and their impacts on marine ecosystems" was written as a contribution to the National Marine Science Plan White Paper "Dealing with Climate Variability and Climate Change". The White Paper was compiled from multiple submissions from the community and was presented at the National Marine Science Symposium, held in Canberra from 25-26 November 2014. This contribution highlights Australia's strong history in tropical coral reef-based paleoclimate research and identifies science and funding priorities for the next decade and beyond. It goes into more detail on tropical paleoclimate than the paleoclimate White Paper and is reproduced here for the benefit of the broader community.

ABSTRACT

Australian scientists are world leaders in developing robust palaeo-environmental reconstructions from coral archives, relevant for understanding Australian climate extremes. The key issues for advancing this field are the need for high-resolution marine paleoclimate records to place the present in the context of past natural climate and sea level change, and to understand the impact of those changes on marine ecosystems. We call for sustained investment in paleoclimate science, infrastructure, and personnel to advance these critical areas of research.

INTRODUCTION

The tropical Indo-Pacific is crucial for global climate. This area comprises the warmest body of surface ocean water on the planet, and the deep atmospheric convection over this warm water acts as the heat engine of the global climate system. Many of the most significant sources of climate variability are generated in the Indo-Pacific; climate modes such as the El Niño-Southern Oscillation (ENSO), Indian Ocean Dipole (IOD), Indian Ocean Basin Mode (IOBM) and the Pacific Decadal Oscillation (PDO), impact global temperatures and cause rainfall extremes over Australia and beyond (England *et al.*, 2014). Observational records are too short to provide perspectives on the natural range of marine climate variability and long-term change, but this information is critical since recent climate simulations suggest that the impacts of ENSO and IDO variability may intensify over the coming century (Cai *et al.*, 2014a, b).

Tropical corals and other carbonate secreting organisms contain annual growth bands (similar to tree rings) that provide high-fidelity reconstructions of past marine climate and environments with valuable information on climates prior to historical observations (Figure 1). Additionally, the annual density bands give long histories of coral growth, from which to assess the impacts of climate on the backbone of coral reef ecosystems, sustained calcification. Reef and sediment cores from extensive fringing and barrier reef or continental slope environments provide invaluable insights into long-term (thousands of years) reef ecosystem responses and sea level histories.

Australian scientists are world leaders in developing robust climate and coral growth reconstructions from massive coral skeletons in Indo-Pacific coral reefs. Primary research activities are undertaken at The Australian National University (Abram, Fallon, Gagan, McGregor*, Mallela), University of Western Australia (McCulloch, D'Olivo), Australian Institute of Marine Science (Cantin, Lough, Zinke), James Cook University (Lewis, Smithers), University of Queensland (Zhao, Pandolfi, Rodrigues), University of Wollongong (Woodroffe), Curtin University (O'Leary, Zinke), Sydney University (Webster), ANSTO (Hua) and Macquarie University (Goodwin). The work to date has been funded through the Australian Research Council (ARC), Australian Institute of Marine Science (AIMS), the ARC Centre of Excellence for Coral Reef Studies, university fellowships and international research agencies including the Integrated Ocean Discovery Program (IODP). High-impact contributions by Australian scientists to the field over the past 10 years include (but are not limited to) those shown in Table 1.

This field of research actively contributes to the Past Global Changes Ocean2k and Australasia2k initiatives reconstructing natural climate variations of the past 2000 years (e.g. PAGES Consortium 2013 *Nature Geoscience;* Neukom *et al.* 2014 *Nature Climate Change*), and to the Intergovernmental Panel for Climate Change (IPCC) assessment reports (e.g. AR5 working group 1, Chapter 14: *Climate Phenomena and their Relevance for Future Regional Climate Change*).

RELEVANCE

Much of Australia's climate is influenced by interannual to decadal oscillations that originate in the tropical Indian and Pacific Oceans. Well-known oscillatory events such as the ENSO and the IOD are now forecast with some degree of certainty once events begin, allowing the Bureau of Meteorology to give around 6-months' warning of the likely Australian rainfall impacts. Longer-term projections remain elusive, however recent climate simulations suggest frequency of extreme El Niño and positive IOD events may double or triple over the coming century.

Robust, highly resolved climate reconstructions place current marine environmental and climatic variability in a longer context than possible with observational records. Such records contribute to understanding the nature and causes of tropical climate variability and hence, ultimately, help refine the global climate models used to project future climates in a rapidly warming world. Importantly, massive coral records provide the high-resolution (annual to seasonal) link for the past several centuries between recent, short observational records and longer-term, but much lower resolution, paleoclimate records (e.g. marine sediment records) for the region. In addition, fossil corals allow us to generate climate histories for well-dated windows further back in time, and are one of the only ways of reconstructing interannual climate behaviour (such as ENSO and the IOD) in different background climate states of Earth's past.

End-users for this research, therefore, range from state and national governments and environmental and resource agencies in Australia (and beyond) who develop long-term planning strategies for "living in a changing environment" (an ARC National Research Priority) over the coming decades and centuries. Australian scientists also play a lead international role in this field, where their work has far-reaching impacts for the international science community (see Table 1). Coral palaeoclimate record development is a cost-effective tool for generating solid environmental baselines that add significant value to the often short-term and high-cost instrumented monitoring activities in remote marine locations.

* Now based at the University of Wollongong.

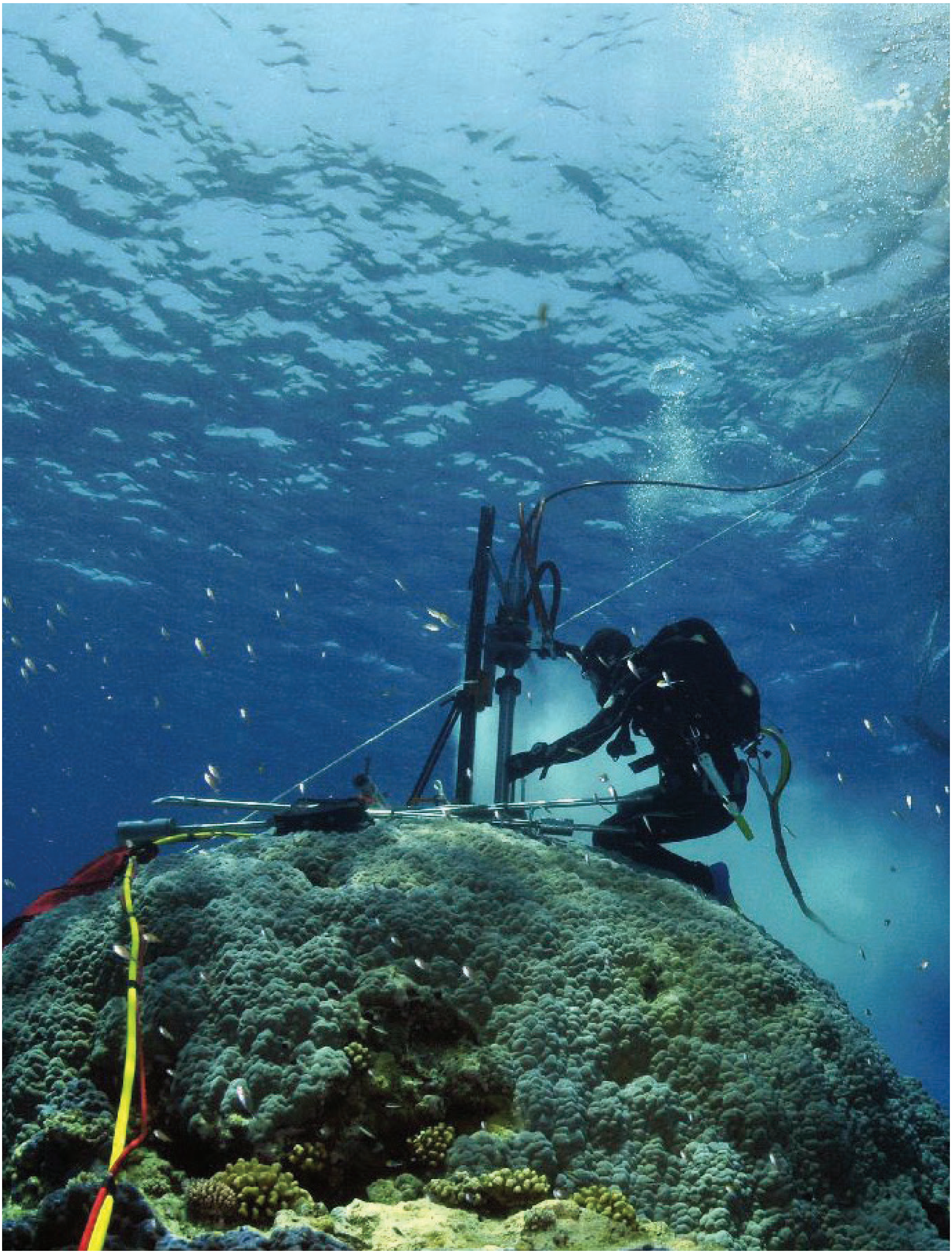

Figure 1: AIMS scientist coring large Porites bommie at Rowley Shoals, northwestern Australian shelf in 2009. Photo credit: Eric Matson, Australian Institute of Marine Science.

Table 1. Research themes, some of the Australian scientists involved, and key publications addressing each theme. For an extended list of references on tropical palaeoclimatology see References.

RESEARCH THEME	AUSTRALIAN SCIENTISTS	KEY PUBLICATIONS
El Niño-Southern Oscillation	McGregor, Gagan, Lough, Zinke	*McGregor et al., 2013 Nature Geoscience;* *Lough et al., 2014 Paleoceanography*
Indo-Pacific Warm Pool interactions; Indian Ocean climate modes	Gagan, McGregor, Abram, Zinke, McCulloch, Fallon	*Abram et al., 2008 Nature Geoscience;* *Abram et al. 2009 Quaternary Science Reviews;* *Zinke et al., 2014 Nature Communications;* *Zinke et al., 2014 Scientific Reports;* *Zinke et al., 2008 Geophysical Research Letters;*
North Queensland rainfall & Great Barrier Reef teleconnections	Lough, Gagan, Lewis, McGregor, Webster, Fallon	*Felis et al., 2014 Nature Communications;* *Lough et al., 2014 Paleoceanography;* *Rodrigues et al., 2014 PLoS One*
Coral reef environmental health and calcification	Lough, Cantin, McCulloch, Mallela, D'Olivo, Lewis	*Mallela et al., 2013, PLoS One;* *Cooper et al., 2012 Science;* *Cantin and Lough, 2014, PLoS One;* *Lough & Cantin, 2014 Biological Bulletin;* *D'Olivo et al., 2013 Coral Reefs*
Sedimentation and river runoff history	Lough, McCulloch, Zinke, D'Olivo, Cantin, Lewis, Fallon	*Lough 2011 Coral Reefs;* *D'Olivo et al., 2013 Coral Reefs;* *Grove et al., 2013 Climate of the Past;* *Grove et al., 2012 Biogeosciences;* *Maina et al., 2013 Nature Communications*
Sea-level history	Woodroffe, Smithers, Webster, O'Leary, Zinke, Goodwin	*Woodroffe et al., 2012 Geology;* *Zinke et al., 2014 Nature Communications;* *O'Leary et al., 2013 Nature Geoscience*
Ocean acidification	McCulloch, Trotter, Holcomb, D'Olivo, Fabricius, Lough, Fallon	*McCulloch et al., 2012 Nature Climate Change;* *Holcomb et al., 2014 Scientific Reports*
Reef response	Woodroffe, Webster, Smithers, Pandolfi, Zhao	*Woodroffe & Webster 2014 Marine Geology;* *Abbey et al. 2014 Palaeogeography, Palaeoclimatology, Palaeoecology;* *Camoin et al., 2012 Geology;* *Perry et al. 2012 Geology*

SCIENCE NEEDS

Key science gaps are:

- The need is for spatially and temporally comprehensive marine climate history for Indo-Pacific waters. This includes well dated windows of societally-relevant interannual and decadal climate variability within different background climate states, which are part analogues for future climate (i.e. MIS5e, MIS11, the Pliocene etc). Climate of the past 2000 years is of particular interest (international research priority).
- The need for a better understanding of reef ecosystem responses to past disturbance (climate, ocean acidification, land-derived etc.) and identification of refugia.
- The need for sea level benchmarks from past periods of warming and higher CO_2 (i.e. MIS5e, MIS11 the Pliocene etc).

Key challenges/needs for addressing the science gaps:

- Funding support for existing key infrastructures in Australia's high resolution paleoclimate centres of Australia (e.g. ARC Discovery; ARC Centre of Excellence for Paleoclimate Research).
- Closer coordination through working group meetings, for example through renewal of the national program of activity (i.e. AUSCORE – Australian Coral Records) to link the Australian coral paleoclimate community. This will allow an integration of research expertise/ measurement facilities across organizations, and provide a coordinated coral core material sharing and sample effort (expensive component of research).
- Archiving of physical coral material and material exchange to ensure maximum use of material collected to date. AIMS, for example, currently houses the AIMS Coral Core Archive, a national facility which, at present, contains coral material from the Great Barrier Reef and eastern Indian Ocean reefs. There is scope to curate additional material within this archive and thus make it a truly national facility of international significance.
- Research vessels access through ARC LIEF funding to collect modern tropical coral material, older coral or reef cores, deep sea corals and sediment cores from ocean drilling campaigns (link with IODP, for instance IODP Exp. 325) from remote locations and to collect a wealth of site survey data needed to stimulate new IODP expeditions.

CONCLUSIONS

There is no doubt that the Australian coral palaeoclimate and palaeoenvironment community have made globally significant contributions to understanding the tropical ocean-atmosphere interactions and impacts that directly mediate Australian climate and rainfall and ecosystems. Australian scientists are world leaders in this field, but the time is ripe to provide a more focussed and integrated approach that capitalises on our location, our significant coral reef ecosystems and Australia's scientific expertise. Outputs are relevant both nationally and internationally.

There is a dire need to develop new records that cover past several centuries and well dated windows of the more distant past from key locations of tropical Indo-Pacific climate variability. This will provide an integrated, high-resolution Indo-Pacific climate history allowing current environmental changes and their impacts to be placed in an historical context. The research links to international efforts to provide critical baseline data (e.g. PAGES2k) to constrain climate model uncertainty (e.g. PMIP3).

To support these scientific priorities there is a need for a national, well-funded initiative to close the huge gap in the number of high-resolution marine paleoclimate records in Australian and Commonwealth waters and for the wider Indo-Pacific. Infrastructure and analytical facilities are already in place. The key challenge over the next 5 to 20 years is to focus the research effort and obtain the necessary funding for the essential sample collection, geochemical analyses and maintenance of facilities needed to produce ground-breaking past climate, sea-level, ocean acidification and environmental change information that is required to understand the context and impacts of future changes in Australia's marine environment. A key challenge is also to retain within Australia the necessary scientific expertise and leadership to undertake this research effort.

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SHAPE update: from Mildura to Nagoya

Andrew Lorrey[1], Steven J. Phipps[2] and Helen Bostock[1]

1 National Institute of Water and Atmospheric Research, New Zealand

2 Climate Change Research Centre and ARC Centre of Excellence for Climate System Science, University of New South Wales, Sydney, Australia

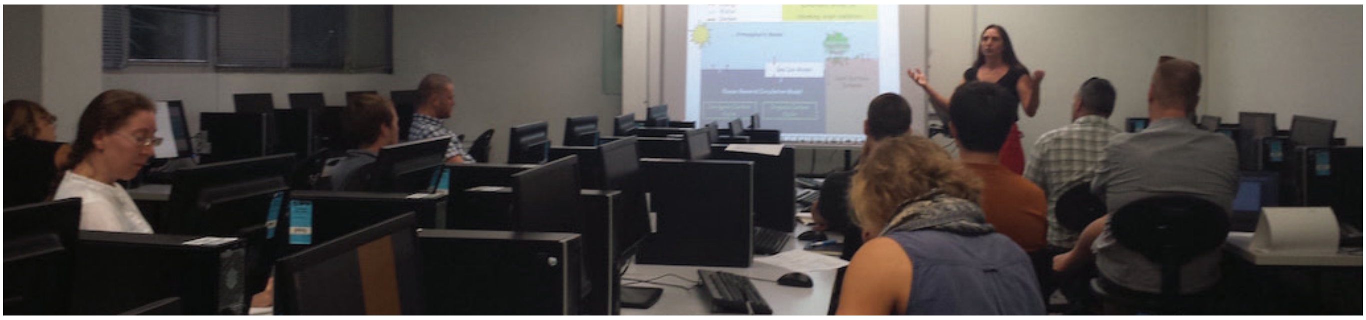
The middle of 2014 saw the beginning of a very active period for the SHAPE (Southern Hemisphere Assessment of PalaeoEnvironments) project.

This activity began with a successful session at the biennial AQUA meeting held in Mildura, Australia from 29 June to 4 July 2014. This conference marked the end of the initial data synthesis stage of SHAPE. One of the main efforts of the project participants was to produce posters summarising the published data that is available for subsequent research focused on sub-regions or key time periods of interest. In total, four of the main SHAPE regions were covered: Australia and the tropics, New Zealand, Antarctica and the Southern Hemisphere oceans. Notable additions to many of the regional data compilations for SHAPE included coverage of Oxygen Isotope Stage 3 (24 to 60 ka), new age models for sedimentary data, and an abundance of cosmogenic radionuclide dates on moraines that have not been produced since INTIMATE-II came to a conclusion. There were a wide variety of presentations in the SHAPE oral session, ranging from development of new hydroclimate proxies to palaeoclimate model interrogation. Of significance, presentations included high-quality work from emerging researchers focusing on Australasia, Antarctica and South America, indicate that the Southern Hemisphere Quaternary research community is healthy and growing.

There were also several presentations related to the SHAPE project goals at the Geoscience Society of NZ annual conference in late November 2014 in New Plymouth, New Zealand. One presentation in particular that was led by Dr. Kat Holt (Massey University) reviewed tephrochronology and tephrostratigraphy of New Zealand for the last 60ka. Many of the tephra are widespread and provide critical marker ties between terrestrial and marine proxy records.

The final activity for this phase of SHAPE took place in Sydney, Australia in February 2015. A two-day training workshop was held for early career researchers, with a primary focus on state-of-the-art tools for climate modelling and palaeoclimate synthesis. The training was delivered by up-and-coming researchers within the SHAPE community, and demonstrated how a wide range of models and techniques are being used to investigate late Quaternary environmental and climate change. From the proxy side, Shaun Eaves covered cosmogenic radionuclide dating and the use of mountain glaciers to reconstruct past climatic change, while Michael-Shawn Fletcher covered the use of radioisotopes, charcoal and pollen to reconstruct past environmental changes. Duncan Ackerley demonstrated climate field reconstructions of geopotential height and other variables using the Past Interpretation of Climate Tool (pict.niwa.co.nz). From the modelling side, Laurie Menviel showed us how to simulate millennial-scale changes using the LOVECLIM model. Steven Phipps also gave some hands-on training in the CSIRO Mk3L climate system model, giving some of the participants their first taste of modelling! Finally, in an inspirational presentation, Stuart Browning demonstrated the potential of data assimilation to bring the data and the modelling together.

The next activity of SHAPE will be a session at the 19th INQUA Congress in Nagoya, Japan. Join us for a full day of talks on Saturday 1 August 2015, and view the accompanying posters. Thus far, more than 45 abstracts have been submitted to the SHAPE session, with presentations covering a range of topics from every geographical region of the Southern Hemisphere. There is clear interest from within the SHAPE community to carry on the large-scale collaboration, and discussions of our future direction will take place in Nagoya. A meeting of everyone who is interested in the SHAPE project will be held during the Congress, and will be advertised closer to the event.



Science Meets Parliament 2015

Claire Krause

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

On the 24th and 25th March 2015, I was fortunate enough to attend the annual "Science Meets Parliament" forum, hosted by Science and Technology Australia, as the official representative for AQUA. This annual event aims to introduce scientists to the world of politics and policy-making, providing them with information and skills required to move their science from the lab into the public domain. The event culminated in a meeting with a member of parliament, where we got to put our new-found skills into practice.

The two-day event began on Tuesday at the National Convention Centre in Canberra, where we spent one day learning how news and policy are made, and how we can best engage the people at the frontline of these processes. We heard from Alison Carabine from ABC Radio National Breakfast and James Massola from Fairfax Media about a typical day in the life of a political journalist. It certainly made me appreciate the relative calmness of writing up a PhD! They brought home the importance of a unique and engaging story that will catch the attention of the public, something not always associated with the scientific process. They encouraged us contact journalists directly if we had a story we believed was newsworthy, but highlighted the importance of targeting a journalist who will be interested in the story and who speaks to the audience your research hopes to reach.

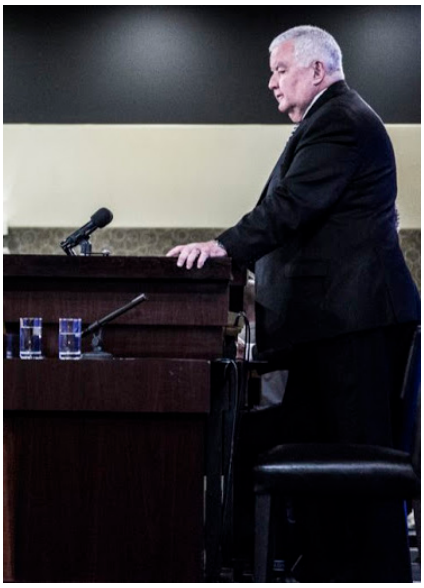
We also heard from political lobbyists Jeanette Cotterell and Simon Banks on how to speak to politicians, and more importantly, how to get them to listen. Mr Martin Hoffman,

Top to Bottom:

1. Practising our "science blurb" in preparation for meeting with MPs. Photo: Lorna Sim.

2. Professor Ian Chubb addressing the National Press Club. Photo: Lorna Sim

3. Professor Hugh White and Professor Brian Schmidt sharing their words of wisdom. Photo: Lorna Sim.



Clockwise from top left:

1. AQUA ladies all frocked up for dinner at Parliament House. Helen McGregor, Monika Markowska and myself.

2. The Honourable Ian Macfarlane speaking at the Gala Ball at Parliament House. Photo: Lorna Sim.

3. Selfie with Bill Shorten.

4. Off to Parliament House to practise my lobbying.

the Deputy Secretary for the Science Group at the Department of Industry and Science, highlighted the "messy nature" of the policymaking process.

One of my personal highlights of the day was hearing from Professors Brian Schmidt and Hugh White, who provided their insider tips on how to influence policy. I managed to fill four pages of my notebook with their words of wisdom, but I think one of the best pieces of advice they gave was not to speak "science" to a policymaker – they won't necessarily understand you or the message you're presenting and you may miss your opportunity. We must translate our scientific message into policy terms, speaking in terms of "objectives", "decisions" and "outcomes". Professor Schmidt highlighted the importance of creating relationships with both side of parliament to ensure that you don't lose your influence when the government changes.

The last task of the day was a workshop lead by Dr Rod Lamberts and Dr Will Grant from the Centre for the Public Awareness of Science at ANU on how to actually go about implementing some of the advice given throughout the day. We each wrote a one minute blurb about our work, which we presented to the people around us. This was all done in preparation for the following day, when we were scheduled to meet with members of parliament to speak about our work as scientists.

That night, delegates and MPs frocked up and descended on the Great Hall at Parliament House for the Gala Dinner. Members of Parliament were invited along, and sat amongst us, giving us our first chance to practice our newly developed communication skills. Adam Spencer was the MC for the night, regaling us with fun facts about numbers (three is the most popular number of members for a girl group and it takes eight minutes for light to reach Earth from the Sun), while highlighting the importance of maths and science education. Guest speakers for the night included Catherine Livingstone, President of the Business Council of Australia, The Honourable Ian Macfarlane, Minister for Industry and Science and The Honourable Bill Shorten, Leader of the Opposition. We had an excellent night speaking to other delegates, as well as the politicians who joined us for the night. I managed to catch Bill Shorten and ask him about the best thing, I as a scientist, could do to help him out. His answer was something along the lines of, "In your working life, try to commit just 1% of your time to politics, to speaking to politicians and speaking out about issues that you're involved in – it would make my job much easier. Oh, and join the labour party."

Day two began at Parliament House, with meetings scheduled between delegates and MPs throughout the day. My meeting was with Mr Jason Wood, the Liberal MP for La Trobe, who I got to speak to about palaeoclimate. He was particularly interested in the caving I do to collect stalagmite samples and wanted to hear all my horror stories about the strange creatures we encountered in the caves (like giant crickets with feelers the length of their bodies!).

Following our meetings, we were bussed over to the National Press Club, where we had lunch and listened to Professor Ian Chubb, Chief Scientist for Australia, address the press on the importance of science for Australia's future. A report titled, "The importance of advanced physical and mathematical sciences to the Australian economy" had been released earlier that day, which quantified the economic benefits of science to Australia. Professor Chubb highlighted the need to recognise the importance of science and the economic contribution it makes. The address was televised live on ABC, and a quick text to my mum meant she was watching along from home.

The remainder of the day was spent at question time in the House of Representatives (one of the more fascinating aspects of SmP. I found myself almost David Attenborough-esque, trying to make sense of the rabble, heckling and, well, politics that is federal parliament) and at a forum of MPs and ARC representatives on the ability of science and politics to get along. Science meets Parliament was rounded off with a cocktail function, hosted by the Parliamentary Friends of Science – a collection of science lobbyists, MPs with environmental portfolios, and Adam Bandt, the Deputy Leader of the Australian Greens. At this event I got to put my new-found skills and confidence in speaking to MPs to use, to chat to Dr Bandt about ways I, as a scientist, could be involved in influencing politics. Dr Bandt was very welcoming and engaged when I spoke to him, and offered for me to visit his office for the day to get a better understanding of the life of an MP "behind-the-scenes", which I gratefully accepted.

Science Meets Parliament was hands down one of the best conferences I have been to. The atmosphere was one of positivity and encouragement, and I certainly walked away feeling more confident in my ability to positively influence Australian politics. The MPs were very welcoming, particularly during our day at Parliament House, and willing to engage with us scientists at every opportunity. I want to thank AQUA for the opportunity to attend this event, and encourage anyone who is given to change to head along – it will be one of the more enduring experiences of your career.

ARC results

DECRA AWARDS

ANU

WOOD, DR RACHEL E

ARCHAEOLOGY

This project aims to develop techniques to radiocarbon date archaeological tooth enamel. In warm environments, it is rarely possible to date bone, as the protein targeted degrades rapidly. Without direct dates on skeletal material, chronologies underpinning archaeological studies across much of Australia and South East Asia (SEA) are insecure, hindering the study of numerous archaeological questions. Enamel is relatively stable, but it does degrade during burial. The effect of degradation on the radiocarbon age of archaeological teeth will be studied to identify the least altered areas for dating. Using these outcomes, a chronology for the spread of pigs through SEA will then be developed, testing models that explain how early farming practices developed.

LA TROBE UNIVERSITY

HAYES, DR SARAH C

ARCHAEOLOGY

Victoria's 19th century gold rush triggered a major social and economic transformation with far ranging consequences. This project aims to investigate how individuals responded and contributed to this transformation over their life course, and how this moulded current values around quality of life in Australia. The project also aims to develop a pioneering approach that will integrate historical and archaeological evidence on individual, site, neighbourhood, city and global levels in new ways. Fresh social histories of Melbourne and Bendigo will be generated, which reinforce national identity and have implications for understanding the impact of the current mining boom on individuals.

THE UNIVERSITY OF QUEENSLAND

MANNE, DR TIINA

ARCHAEOLOGY

For over 40 years, archaeologists have debated the nature of the initial colonisation of Australia and how people subsequently coped with large-scale climate change. This is the first study to examine systematically variation in human subsistence behaviour and animal community structure across northern Australia. Through analyses of archaeofaunas from key archaeological sites, this project aims to test assumptions about why and how northern Australia was first occupied and the manner in which people responded to dramatic environmental shifts. An additional outcome of this project, it is hoped, will be insight into the causes of fragmentation in Australian fauna assemblages and in particular, the recognition of carnivore damage.

THOMPSON, DR JESSICA C

ARCHAEOLOGY

This project will test novel hypotheses about human behavioural strategies and responses to resource stress in central Africa at the time of early human dispersals out of Africa. It aims to examine how behavioural complexity observed in the stone artefact records of southern and eastern Africa relate to those in northern Malawi, which lies at a key crossroads for these dispersals. The study area contains rare archaeological deposits that offer a unique opportunity to address problems of early human resource use at all scales: site, landscape, and region. This project aims to contribute to human origins research through investigation of why and how local geophysical and climatic constraints shaped past human behaviour relative to other regions.

THE UNIVERSITY OF SYDNEY

POLKINGHORNE, DR MARTIN

ARCHAEOLOGY

This project aims to conduct the first systematic archaeological investigations of Cambodian Middle Period capitals on the banks of the Mekong and Tonle Sap arterial rivers between 1350 and 1750. Whilst the decline of Angkor is one of the most significant events in the history of Southeast Asia, we do not have a precise date for the event that involved the relocation of many hundreds of thousands of people. By determining when the Kings of Angkor moved to the southern capitals we will clarify the end of Angkor, retrieve Cambodian history from a perceived Dark Age, and reveal critical linkages between the celebrated Angkorian past and modern and contemporary Cambodia.

THE UNIVERSITY OF NEW SOUTH WALES

MENVIEL, DR LAURIE

PHYSICAL GEOGRAPHY AND ENVIRONMENTAL GEOSCIENCE

In the past 50 000 years there were several episodes of abrupt climate change during which atmospheric carbon dioxide rose significantly. This project aims to determine the causes of past abrupt changes in atmospheric carbon dioxide. The project is significant because understanding changes in the global carbon cycle is essential to estimate future climate trajectories. Innovatively, it will highlight the relationship between Southern Hemisphere water masses and the marine carbon cycle during abrupt climate change. The expected outcomes include a better understanding of the interplay between Southern Ocean processes and the carbon cycle.

DISCOVERY PROJECTS

THE AUSTRALIAN NATIONAL UNIVERSITY

HUNG, DR HSIAO-CHUN; CARSON, DR MICHAEL T

ARCHAEOLOGY

Over several centuries since 4000 BC, the social-ecological setting of Taiwan transformed from low-impact hunting – foraging to high-density village residence and intensive farming. Meanwhile, it was reshaped by new strategic relations with the outside world through migration and trade networks. New research aims to investigate how these long-term developments inter-related and transcended changing climate, natural habitats, population size, and other factors. The research is designed to address how a complex economic landscape system developed and sustained itself through ongoing challenges, by concentrating on Taiwan as a uniquely informative example of combined intensive internal land – use and external partnerships.

O'REILLY, DR DOUGALD J; SHEWAN, DR LOUISE G; ARMSTRONG, DR RICHARD A; LIM, A/ PROF SAMSUNG; CHANG, DR NIGEL J; DOMETT, DR KATHRYN M; HALCROW, DR SIAN E

ARCHAEOLOGY

Since their discovery in the 1930s, the mysterious collections of giant stone jars scattered throughout central Laos have remained one of the great prehistoric puzzles of south-east (SE) Asia. It is thought that the jars represent the mortuary remains of an extensive and powerful Iron Age culture. This project seeks to determine the true nature of these sites, which date to a dynamic period of increasing complexity in SE Asia (c.500BCE-500CE). The project entails extensive reconnaissance, precision mapping, archaeological excavation and analysis of associated burial material. Using a suite of cutting-edge archaeological technologies, it is expected to have far-reaching benefits for archaeology, science, Laos and World Heritage.

LAMBECK, PROF KURT

PHYSICAL GEOGRAPHY AND ENVIRONMENTAL GEOSCIENCE

Glacio-isostatic (GI) effects are recorded in geological and geodetic data sets and mask other deformational processes. This project builds on past work using geological data with a focus on combining geodetic and geological evidence to improve knowledge of the past ice sheets, separate out effects of past and present deglaciation and develop improved models for the mantle rheology to include time-dependencies in mantle response (transient creep in the first instance). The project aims to provide a complete and predictive description of the GI effects on geodetic data, consistent with geological evidence, such that other tectonic, hydrologic and sea-level signals can be estimated free of these effects.

KING, DR PENELOPE L

GEOLOGY

High temperature gases circulate through Earth's interior and atmosphere, but little is known about how they react. Recent work shows that exceptionally rapid reactions occur between gases and solids at surfaces. These reactions are instrumental in forming ore deposits and transporting gases and salts to Earth's surface, atmosphere and oceans – affecting climate and biological productivity. This project aims to examine natural samples and investigate gas-solid reactions experimentally to constrain reaction mechanisms. It is expected that the project outcomes will open up a new field of geochemistry with novel experiments, state-of-the-art analysis and the development of innovative models that account for the role of gas-solid reactions in Earth and planetary processes.

THE UNIVERSITY OF NEW SOUTH WALES

FIELD, DR JUDITH H; SUMMERHAYES, PROF GLENN R

ARCHAEOLOGY

Around 50 000 years ago, people crossed the Wallace Line and set foot on Sahul (Pleistocene Australia-New Guinea) for the first time. Rapid dispersal across the Sahul continent followed during a period of climatic deterioration. Subsequent human impacts on the landscape are well preserved in the fossil record, particularly plants. This project aims to implement an archaeological and palaeobotanical approach to investigate the temporal and spatial patterning of landscape use through a period of climatic change in the Late Quaternary. The results are expected to provide a fuller understanding of the subsistence strategies and dynamics of human responses to climate change over long time periods.

ENGLAND, PROF MATTHEW H; SEN GUPTA, DR ALEXANDER R; SANTOSO, DR AGUS; MCGREGOR, DR SHAYNE; UMMENHOFER, DR CAROLINE C; CAI, DR WENJU; TIMMERMANN, PROF AXEL

OCEANOGRAPHY

Variability in the Pacific Ocean has a profound impact on global climate. Recent unprecedented decadal variability in the Pacific has been linked to global temperature trends and extremes, yet little is known about what drives this variability or its impact on regional climate. This project will combine observations, advanced coupled climate models and ocean – atmosphere dynamical theory to quantify remote drivers of Pacific Ocean variability on interannual-decadal time-scales. This project aims to enhance our understanding of the modes of variability operating in this region and their impact on global and Australian climate. This will have significant benefits for the many sectors of society reliant on interseasonal – decadal climate prediction.

THE UNIVERSITY OF SYDNEY

BETTS, PROF ALISON V; VICZIANY, PROF MARIKA A; DI CASTRO, DR ANGELO ANDREA; DODSON, PROF JOHN R; CONG, A/PROF DEXIN; LI, PROF XIAO QIANG; SALZMAN, PROF PHILIP

ARCHAEOLOGY

The early rise of China's great civilization owed its rapid momentum to important technological innovations that were brought in from the far distant Eurasian steppes, but almost nothing is known of how or why this process took place. The project aims to explore these questions through excavations at one of China's most important Bronze Age archaeological sites in western Xinjiang. The innovations include the cultivation of wheat and barley, complex metallurgical techniques in bronze, silver and gold, the domesticated horse and the spoke-wheeled chariot, which became a universal weapon of war across the ancient world. The project aims to test theories of cultural transmission through interactive GIS modelling of environment and land use potential.

CLARKE, DR ANNE F; PHILP, DR JUDE P; TORRENCE, DR ROBIN; KNOWLES, MS CHANTAL M

ARCHAEOLOGY

Sensing the impacts of colonisation, the first Administrator of British New Guinea William MacGregor made a significant collection of objects specifically for its future citizens. This comprehensive legacy of 13 000 objects did not remain in the country but was dispersed to three Australian and six overseas museums. Our aim is to re-assemble and re-connect this material by 'excavating' its private and official components. This research aims to focus on the makers and traders to disentangle the social relationships embedded in the objects. Using material-centred, assemblage-based archaeological approaches, we aim to investigate how indigenous groups used objects to negotiate with the new colonial government

SOUTHERN CROSS UNIVERSITY

EYRE, PROF BRADLEY D; SCHULZ, A/PROF KAI G; ANDERSSON, ASST PROF ANDREAS

GEOCHEMISTRY

Dissolution of calcium carbonate ($CaCO_3$) in sediments in the context of ocean acidification is poorly understood. This project will use in situ advective benthic chamber incubations and experimental manipulations under future ocean acidification scenarios to determine the controls on the dissolution of $CaCO_3$ in sediments. This project is significant because changes in the dissolution of $CaCO_3$ in sediments in an acidifying ocean are at least as important, and potentially more important, than calcification to the future accretion and survival of carbonate ecosystems. It is expected that outcomes of this project will significantly advance our understanding of the drivers of the dissolution of $CaCO_3$ in sediments and the functioning of globally important carbonate ecosystems

SANDERS, DR CHRISTIAN J; SANTOS, A/PROF ISAAC R; SACHS, PROF JULIAN P

SOIL SCIENCES

The aim of this project is to investigate carbon burial in mangroves during current and historical climatic conditions through in depth dating methods and paleoclimate reconstructions. The project intends to use state-of-the-art radionuclide tracer technologies to determine system scale aspects of the mangrove carbon budget, i.e. burial, tidal export and respiration. This project is significant because it aims to delineate how climatic conditions are directly related to the mangrove carbon budget. Further, the site specific data on historical mangrove carbon burial could allow adaptation strategies for use of coastal wetland habitats that sequester CO_2, a natural means to help ameliorate greenhouse gas, as support for mangrove forest protection and restoration.

UNIVERSITY OF WOLLONGONG

WOODROFFE, PROF COLIN D; MURRAY-WALLACE, PROF COLIN V; KENNEDY, DR DAVID M; TAMURA, DR TORU; NICHOL, DR SCOTT L; MCBRIDE, DR RANDOLPH A

PHYSICAL GEOGRAPHY AND ENVIRONMENTAL GEOSCIENCE

This project aims to reconstruct sedimentary processes and evolution of key coastal plains in southern Australia. These low-lying coasts, and the settlements and infrastructure on them, are vulnerable to inundation and shoreline erosion. Past behaviour of different types of coasts will be determined by combining innovative geospatial techniques to map morphology and past changes, geophysical imaging of stratigraphy and geochronology. The outcome will be models that explain responses to sediment availability, past storm history and sea-level changes. This will benefit sustainable coastal planning and management, providing geomorphological evidence to support erosion hazard assessments of these and adjacent coasts.

LA TROBE UNIVERSITY

COSGROVE, A/PROF RICHARD F; GARVEY, DR JILLIAN M; WEBB, DR JOHN A

ARCHAEOLOGY

This project examines the archaeology of Aboriginal people in eastern Tasmania. Its major aim is to test two models of Holocene and late Pleistocene land use. It investigates the earliest traces of human occupation in eastern Tasmania and subsequent cultural developments after the apparent abandonment of southwest Tasmanian caves at the end of the ice age. The study aims to strengthen understanding of the impact of geographic connectedness and isolation on Aboriginal populations and the development of Tasmanian Aboriginal society recorded at European contact. Its potential significance lies in contributing to debates on Aboriginal social/economic change and stasis.

STERN, DR NICOLA; JACOBS, DR ZENOBIA; MCCLUSKY, DR SIMON ; WILLIAMS, PROF IAN S; MURRAY-WALLACE, PROF COLIN V; GRUN, PROF DR RAINER; DENHAM, DR TIMOTHY P

ARCHAEOLOGY

The southern tip of the Mungo lunette is an icon of Australia's Indigenous past. Despite its international significance, the archaeological traces have disintegrated as the lunette has eroded over the past 30 years. In this interdisciplinary project, collaboration with Elders from the Willandra Lakes Region World Heritage Area is expected to reconstruct the history of environmental changes and the life-ways of the first humans to settle this region. The focus will be on stitching together the archaeological traces scattered through space and time, and on measuring processes of modern sediment erosion and deposition so as to develop management strategies for the future protection of this unique archive of Australia's past.

MONASH UNIVERSITY

HOPE, A/PROF COLIN A; BOWEN, DR GILLIAN E; GARDNER, PROF IAIN

ARCHAEOLOGY

This project aims to examine the growth and survival of the cult of Seth in Egypt's Western Desert against the background of the cult's suggested proscription elsewhere in the ancient state. Through detailed excavation and radiometric dating of the cult centre in Dakhleh Oasis, it aims to explore the proposition that the continued veneration of Seth can be read as a sign of regional independence. This is intended to challenge the orthodox view that Egypt operated as a monolithic state; reshaping how we approach ancient Egyptian religion and administration. In doing so, the study is expected to position an Australian research team at the forefront of contemporary scholarship on Egypt, enhancing our national reputation in the promotion and preservation of global heritage.

THE UNIVERSITY OF ADELAIDE

TIBBY, DR JOHN; MOSS, DR PATRICK T; LENG, PROF MELANIE; SHAKUN, DR JEREMY; SPOONER, ADJ/PROF NIGEL A

ARCHAEOLOGY

Before the arrival of Europeans, two events shaped Australia's current landscapes and biota more than any others: climate change during the glacial cycle and the arrival of humans on the continent. However, the full scale of these events is not well understood. High resolution analyses of two continuous 140 000 year old sediment deposits will be used in this project to fill this void and answer fundamental questions about how current Australian environments came to be.

THE FLINDERS UNIVERSITY OF SOUTH AUSTRALIA

PRIDEAUX, A/PROF GAVIN J; HUTCHINSON, DR MARK N

EVOLUTIONARY BIOLOGY

The Wellington Caves in central eastern New South Wales are Australia's most historically significant fossil locality and preserve one of the world's most complete records of vertebrate life spanning the past 4 million years. To date this unique archive has been vastly under-exploited as a source of information on how faunas respond to increased aridity and climatic variability, as well as human activities over the past 50 000 years. This project aims to elucidate how climate change drove the evolution of the modern fauna of eastern Australia by analysing changes in diversity, diet and community structure over time. It may also help break the 130-year climate-versus-humans deadlock over what drove the Pleistocene megafaunal extinctions.

THE UNIVERSITY OF QUEENSLAND

SHULMEISTER, PROF JAMES P; HESP, PROF PATRICK A; MIOT DA SILVA, DR GRAZIELA; WELSH, DR KEVIN J; SANTINI, DR TALITHA; LARSEN, DR JOSHUA; GONTZ, A/PROF ALLEN M; RITTENOUR, DR TAMMY

PHYSICAL GEOGRAPHY AND ENVIRONMENTAL GEOSCIENCE

This project aims to generate fundamental information about the timing and mode of formation of sand dunes in the world's largest downdrift sand system, Cooloola and Fraser Island, Queensland. The project aims to provide a world class record of climate variability, sea-level change and long term climate change from the sub-tropics of Australia, an area critical to understanding global climate links and sea-level change but where high quality long-term records are sparse and little investigated. This project will also underpin the outstanding universal value of the Fraser Island World Heritage Area which is based on the area being the world's largest sand island, but for which scientific understanding of the sand dunes is remarkably poor.

CURTIN UNIVERSITY OF TECHNOLOGY

GRICE, PROF KLITI; BUSH, PROF RICHARD T; VISSCHER, PROF DR PIETER T; SESSIONS, PROF ALEX; SCHWARK, PROF DR LORENZ

GEOCHEMISTRY

This project will apply compound specific sulfur isotope analyses to sulfur-rich deposits from extreme environments including sulfidic black oozes (Peel-Harvey estuary); modern microbialites (for example, Shark Bay) and oils/source rocks (established and frontier oil fields). Sulfur isotopic data, integrated with other stable isotopic and molecular data, will greatly assist the study of sulfur biogeochemical cycles and mechanisms of organic sulfurisation at different diagenetic stages or geological ages. The project aims to address national concerns through measuring the respective impact of anthropogenic and natural changes on environments, helping to understand the evolution of life on Earth and contributing to efficient discovery of our natural petroleum systems.

Geoarchaeology of Aboriginal landscapes in semi-arid Australia

Simon J Holdaway and Patricia C Fanning

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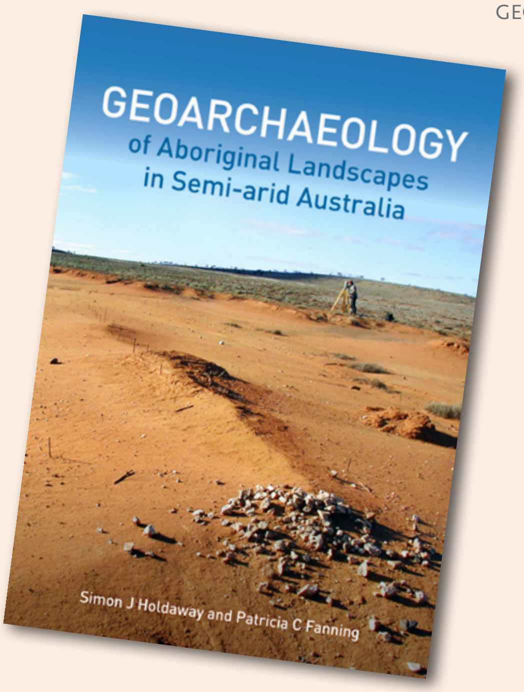
Review by Kathryn Fitzsimmons

Department of Human Evolution, Max Planck Institute for Evolutionary Anthropology, Leipzig, Germany

Fowlers Gap Arid Zone Research Station lies in remote western New South Wales, where the tarmac of the Silver City Highway meets the interminable gravel which heralds the outback. Since taking on the Station lease since 1966, the University of New South Wales has overseen and supported innumerable research projects spanning the sciences from ecology to geomorphology, earning the site a place on the Register of the National Estate. Quaternary geomorphology has not been overlooked in this slew of research (e.g. Dunkerley and Brown, 1999; Mabbutt, 1973; Wakelin-King and Webb, 2007). However, up until recently, the role of people in the landscape has received comparatively little attention. This 224-page volume by archaeologist Simon Holdaway and geoarchaeologist Trish Fanning represents the first truly systematic and interdisciplinary approach to understanding archaeological traces from a landscape perspective.

Holdaway and Fanning's task is a formidable one. The landscape of this part of arid western New South Wales is relatively sediment-poor, and the reconstruction of past land surfaces across which people left traces of their occupation is correspondingly difficult. The authors were well aware of this challenge – one which confronts geoarchaeologists working across many parts of arid Australia – and consequently invested a great deal of time into developing a systematic and integrated methodology for conducting geoarchaeological surveys in comparable landscapes.

The result is a book which unfolds over six chapters, but which can nevertheless be read independently depending on one's main field of interest. It is clearly and concisely written, and aimed at a level accessible not only to specialists but also to undergraduates and professionals working in cultural heritage and environmental management. Since archaeological and geological specialists often suffer from a lack of communication across the disciplines, the accessibility of the text is no mean feat, and a great credit to the effective synergy between the two authors.



The first two chapters focus on providing the reader with the requisite understanding of the local environment and state-of-the-art research (Chapter 1), and the methodological framework which underpins geoarchaeological research in this sort of landscape (Chapter 2). The regional description, assisted by a swath of colour plates at the beginning of the book, leaves the reader in no doubt as to the scale of the challenge involved in developing a systematic framework for geoarchaeological survey in the Fowlers Gap area. It quickly becomes evident that the conventional approach to an archaeological survey – combining excavation and analysis of stratified sedimentary deposits with surface surveys using grids or transects – is ineffective in this kind of landscape. The second chapter systematically presents and pragmatically discusses the challenges involved, and proposes a carefully considered framework based on the integration of 1) an assessment of artefact assemblage formation, and 2) landscape mapping as a foundation for artefact surveys. This is an elegant approach which can theoretically be applied across comparable landscapes.

The applicability of the proposed methodology is then demonstrated using the case study of Fowlers Gap in the subsequent chapters. These focus on the specific fields of surface artefact preservation (Chapter 3), chronology (Chapter 4), and lithic assemblages (Chapter 5), respectively. At the beginning of each chapter, the authors describe the theory and methodology of the approach in greater detail than provided in the preceding overview. These chapters afford a more specialist viewpoint and can be read in isolation, although arguably the purpose of the book is to take an holistic standpoint, one which is synthesised in the final Chapter 6. The systematic approach adopted by the authors is clearly evident from these chapters: the data are thoroughly interrogated by means of multiple figures, graphs and tables throughout. From my point of view, the chronology data in Chapter 4 provides an interesting case where novel luminescence dating of heat-retainer hearth sediments is combined with radiocarbon dating to produce a surface network rather than a stratigraphic sequence of age estimates. Temporal and spatial patterns of hearth construction phases are therefore extracted from the palimpsest and synthesised across the multiple survey nodes. This presents a highly innovative approach to reconstructing the past from a formidably sediment-poor landscape. More space is allocated to the analysis of artefact assemblage preservation and variability in lithic core technology, distribution, and raw material types than to the geochronology; I would have liked to have seen more discussion regarding the quality of the geochronological data. However this may have been because Chapters 3 and 5, by comparison, simply require more tables and figures to demonstrate their point.

The final synthesis, drawing together the data discussed in the preceding chapters, paints a powerful picture of spatial and temporal patterns of landscape use in the Fowlers Gap region – all the more so given what the reader by now understands to be a challenging landscape – and provides compelling evidence to support the systematic framework proposed earlier in the book. The authors engage in a thorough discussion of important issues and common traps for archaeologists – in particular, the matter of occupation vs. visitation – which will hopefully provoke further discussion on these topics amongst specialists and undergraduates alike. While the book focusses on the Fowlers Gap region, it is clear that the proposed framework is highly applicable to vast tracts of semi/arid Australia, not to mention comparable landscapes across the world. As such, it is a highly useful and timely book for researchers, teachers and students alike.

Paper copies may be purchased online from CSIRO's publications website and as an ebook from E Books, Google and Amazon for a smaller fee.

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THESIS ABSTRACTS

Replicate Palaeoclimate Multi-proxy Data Series from Different Speleothems from N-Italy: Reproducibility of the Data and New Methodology

Romina Belli (PhD)

School of Environmental and Life Sciences, University of Newcastle, NSW, Australia (now University of Trento, Italy)

Changes in geochemical and physical properties of speleothems are considered to be accurate proxies of climate variability. However, the climate signal is modified by the internal dynamics of the whole karst system. The aim of the PhD research was to obtain reproducible data extracted by established and non-conventional techniques from two coeval speleothems removed at Grotta Savi cave (Italy), to gain information about regional climate responses across the Late Glacial to Holocene transition (15 to 9 kyr BP). Different past hydrological regimes for the two drips were reconstructed on the basis of stalagmites physical characteristics and this helped to disentangle the global, from the local phenomena. This non-conventional approach, was applied here for the first time on fossil samples resulting in a benchmark for the interpretation of chemical proxies and, thus, enabling an assessment of the calcite formation environment, hitherto not possible. The interpretation of $\delta^{18}O$ values (which vary from – 5 to – 7.4‰) as reflecting past hydrology was then validated by using an independent palaeohydrological proxy, developed in this study.

At Grotta Savi, hydrology, and in particular flow-regime, had a strong control on Mg incorporation in the stalagmite, as determined by coupling petrographic observations and trace element time series. Thus, it was found that under low-moderate flow regimes, Mg derived almost exclusively from dissolution of carbonate host-rock, as a result of incongruent carbonate dissolution through prolonged rock water interaction. Mg associated with tracers typical of silicate minerals and coinciding with impurity-rich layers, was ascribed to particulate matter, which were incorporated in the stalagmite during high flow regimes. Hydrological variability controlled also the incorporation of Sr whose concentration variability is commonly related to speleothem growth rate. The $^{87}Sr/^{86}Sr$ ratios, which ranges from 0.7077 to 0.7082, were used to identify the source of Sr. Increases in the $^{87}Sr/^{86}Sr$ ratios suggest a higher contribution of radiogenic Sr from aeolian dust originated from proximal subalpine periglacial regions and transported onto the catchment of Savi cave. It is worth noting that the Sr isotope ratio is here interpreted as increase in wind strength, which likely enhanced evaporation in the soil zone and thus contributed toward the amplification of a "dry climate" signal recorded by the stalagmites. After removing the growth rate component to Sr concentration, taking into account the source of Sr and minimising the Mg component associated with particulate transport, it has been possible to use Sr and Mg time series to reconstruct palaeohydrological and hydroclimatological variability across the deglaciation. The non-hydrological component to the $\delta^{18}O$ values was then extracted and could be interpreted as changes in air-mass provenance and rainfall seasonality (hydroclimatological component).

The $\delta^{13}C$ time series, whose values at Savi varies from – 9 to – 11.2‰, are commonly interpreted as temperature-dependent soil respiration rate, but, at Grotta Savi, they also show a hydrological component (associated with the more positive values) which was detected by combining dead-carbon proportion (dcp) and $^{87}Sr/^{86}Sr$ ratios. Episodes of great $^{87}Sr/^{86}Sr$ ratios suggested drier conditions, whereas episodes of high dcp values (~15%) have been interpreted as a result of enhanced host-rock dissolution during wetter conditions. The combination of palaeohydrological indicators and $\delta^{13}C$ signal allowed recognising that wet climate conditions occurred during phases of Northern Hemisphere climate cooling, which adds a new perspective to the common interpretation of wet/warm or cold/dry climate extracted from speleothem geochemical proxies when a multi-proxy approach is not taken.

The comparison of the Late Glacial $\delta^{13}C$ time series of Savi speleothems with a stalagmite showing similar fabrics from Sofular cave in Turkey revealed a common trend. This similarity suggests the possibility that speleothems may encode information on the global C cycle, similar to soil carbonates, which needs future testing.

The conclusive palaeoclimate interpretation for the Late Glacial in the region is that, the Younger Dryas was characterised in the Northern Mediterranean by high hydrological variability, possibly related to changes in air masses trajectories and wind strength. The stalagmite proxies further suggest that the wind regime was orographically induced, with the Alps acting as a barrier, deviating westerly winds and causing increased wind strength in the northern Adriatic region.

The greatest contribution of the research to the speleothem science community is, however, the use of a multi-proxy approach on two stalagmites from the same cave to disentangle hydro-climatologic from hydrological processes, and the recognition of different sources for key trace elements provenance, which were eventually related to climate parameters (wind strength and precipitation).

Distribution and dispersal of legacy sediment and contamination from historical gold mining at Hill End, New South Wales, Australia

Nathan Nagle (MRes)

Department of Environmental Sciences, Macquarie University, NSW, Australia
Supervisor: Dr Tim Ralph

Gold rushes in the 19th century impacted landscapes throughout the world through vegetation clearance, disturbance of soil and sediment and the release of metals (e.g. mercury and arsenic) into the environment. Legacy sediment episodically produced from anthropogenic activities such as gold mining is now stored in modern landscapes and can contain high concentrations of metals. In Australia, the limited research into the environmental impacts of historical gold mining has generally focused on metal contamination and there has been limited research into long-term geomorphological changes in landscapes associated with gold mining processes such as the impact of large scale legacy sediment production. This study explored the long-term environmental impacts of historical gold mining at Hill End, New South Wales, Australia, by investigating the dispersal of legacy sediment as well as spatial patterns and temporal trends of mercury, arsenic, lead, copper and zinc contamination. Soil and sediment metal contamination was analysed using X-ray fluorescence (XRF) and a direct mercury analyser, and optically stimulated luminescence (OSL) and excess ^{210}Pb were used to constrain temporal patterns of contamination and sedimentation. Hill End has high hillslope-channel and longitudinal connectivity and there are few places where legacy sediment storage occurs within the catchment. In the uplands of Hill End, legacy sediment is stored in finely laminated sequences in tailings dams. There was no sediment stored in the steep gorges of Hill End and sediment was stored with cobbles and gravel in occasional mid-channel and bank attached bars in the lower reaches of the system. The majority of samples contained little to no metal enrichment and high levels of metal contamination were mainly restricted to artificial depocentres such as tailings dams and in spoil adjacent to stamper batteries and cyanide tanks. Chemostratigraphy and OSL dating in Chappell's Dam revealed that metal contamination peaked during the height of gold mining (c. 1871-1880) and declined shortly after the cessation of ore processing in the adjacent stamper battery, coinciding with the decline of gold mining in the region. Peak metal concentrations of mercury (44.58 mg kg^{-1}) and arsenic (221.0 mg kg^{-1}) found in Chappell's Dam are well above ANZECC sediment quality guidelines and could pose a risk to local aquatic ecosystems. Understanding the fate of legacy sediment and metal contaminated sediment in a highly connected system such as Hill End will shed light on the larger scale impacts of historical gold mining in Australia and can be used to inform management strategies for derelict and active mines.

Geomorphic analysis of channel change and erosion processes contributing to avulsion in the Macquarie Marshes, Australia

Samantha Oyston (MRes)

Department of Environmental Sciences, Macquarie University, NSW, Australia
Supervisor: Dr Tim Ralph

Geomorphic processes such as erosion play a critical role in the development of existing river channels, as well as the formation of new channels by avulsion in multi-channelled systems. The Macquarie Marshes is an anastomosing and distributary system that supports extensive floodplain wetlands through overbank flooding and channel erosion poses a threat to these sensitive ecosystems.

Four sites within the Southern Macquarie Marshes were investigated to identify the dominant patterns, processes and rates of erosion that contribute to channel change and to establish an evolutionary sequence of channel development. Channel incision and narrowing were the dominant processes measured together with knickpoint retreat at the three less mature sites, while channel widening and stabilisation were characteristic of the most mature site.

Significant differences in channel morphometrics including width, depth and cross sectional area were found at the four sites using data from 2008 and 2014. The sites and their erosion processes fit into a geomorphic and evolutionary sequence: (1) knickpoint retreat and incision in a small swamp outflow channel (Buckiinguy); (2) incision and widening in a large swamp outflow channel (Willancorah); (3) minor incision and widening in the upper and lower reaches of a shallow, continuous marsh channel (Pillicawarrina); and (4) minimal erosion and channel stabilisation in a well-established, continuous marsh channel (The Breakaway). Bank strength is a key factor that contributes to erosion potential in the system, and sediment moisture content affects bank strength. Other factors (organic content, sand, silt and clay content, dry bulk density) have very weak relationships with bank strength.

A trend was found where more mature sites have higher bank strength, probably related to the extent of past erosion. A conceptual geomorphic model shows how erosion affects the development and formation of new channels during avulsion, and the effects on longitudinal and lateral connectivity in systems like the Macquarie Marshes, by redistributing water and sediment within the wetlands. The formation of channels by erosion plays a critical role in the evolution of anastomosing and distributary systems.

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Dr Steven Phipps
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Faculty of Science,
University of New South Wales
Sydney, NSW 2052, Australia

PH: +61 (0)2 9385 8957
treasurer@aqua.org.au

SHADOW TREASURER

Lydia Mackenzie
School of Geography, Planning and Environmental Management
University of Queensland, QLD 4071, Australia

lydia.mackenzie@uqconnect.edu.au

COMMUNICATIONS & IT COORDINATOR

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QUATERNARY AUSTRALASIA EDITORS

Dr Kathryn Fitzsimmons
Department of Human Evolution
Max Planck Institute for Evolutionary Anthropology
Deutscher Platz 6, D-04103
Leipzig, Germany

PH: +49 (0)341 3550 344
FAX: +49 (0)341 3550 399
editor@aqua.org.au

Dr Pia Atahan

editor@aqua.org.au