VOLUME 35 | NUMBER 1 | JULY 2018

Quaternary AUSTRALASIA

Mungo Man: return to country

Anthropocene update

Quaternary science in New Zealand

Australasian Quaternary Association Inc.

AQUA

2018 AQUA Biennial Conference

10-14 December
Acton Peninsula
Canberra

Pre-conference Field Trip:	High altitude environments of eastern Australia - 5 to 8 December
Icebreaker:	Sunday 9 December
Conference sessions:	Monday 10 to Friday 14 December Crawford Precinct, Acton Peninsula

See **http://aqua.org.au/conference/aqua2018** for more details and deadlines.

VOLUME 35 | NUMBER 1 | JULY 2018

Quaternary AUSTRALASIA

ISSN 0811-0433

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The beautiful Mildura landscape: south of the walls of China. See Article by Jessica Reeves. (Photo Credit: Jessica Reeves).

Below:

Fire pit from the return of Mungo Man to Mildura. See Article by Jessica Reeves. (Photo Credit: Jessica Reeves).

EDITORIAL

Dear Quaternarists,

Welcome to the July 2018 issue of Quaternary Australasia. As one of the editors it is a sneaky pleasure to read the contributions before anyone else, and this edition is no exception.

The highlight for me is Jess Reeves account on the return of Mungo Man to his place of burial. Jess describes the day and captures the emotion, dignity and reverence of this poignant event. A number of other AQUA colleagues were present on the day, but we thank Jess for sharing her personal experience with us.

Helen Bostock has provided an update on the formalisation of the Anthropocene. The Global Boundary Stratotype Section Age has been proposed; but the 'search' is still on for a supportive Global Boundary Stratotype Section and Point. AQUA members may have some excellent ideas of their own to suggest to the Anthropocene Working Group.

(Editors Comment: If Quaternary researchers are known as Quaternarists; are Anthropocene researchers to be known as Anthroparists?)

David Lowe has contributed a number of articles on 'Quaternary Science in New Zealand – Report to the Catalyst Fund'. David's contributions are comprehensive, and a number of sections are included as hyperlinks.

We have two book reviews: a 'Sunburnt Country' by Jöelle Gergis and the 'Prehistory and Archaeology of Northeast India' by Manjil Hazarika.

We have our usual latest publications and thesis abstracts (congratulations to those students who completed their studies).

In the President's Pen, Scott Mooney signs off as AQUA President. The AQUA Committee would like to thank Scott for his role as President over the last 2 years and welcomes new president Tim Cohen to the position. Scott has now taken over the position of Shadow Secretary for AQUA.

Welcome also to the new and returning members of the AQUA Committee.

Finally, don't forget about the AQUA Biennial Conference in Canberra, 10-14 December. It is a good time to start considering your contributions to this popular event. See the conference website for more info. http://aqua.org.au/conference/aqua2018

Yours Quaternarily,

Carol Smith and Sanja van Huet

Co Editors

WARNING: Aboriginal and Torres Strait Islander readers are warned that this edition contains images of deceased persons.

PRESIDENT'S PEN

Fellow Quaternarians, if you are reading this now it means I have been murdered. Well, actually, like Pauline Hanson, this is a slight exaggeration: this is my last Presidents' Pen, as constitutionally the reins of AQUA are handed over to a new President at the May 2018 AQUA AGM. (Editors note: Welcome to the new AQUA President Tim Cohen). I'd like to thank the AQUA community, and particularly the AQUA Committee for their support over the last few years and I wish the incoming Committee the best of luck.

I am definitely getting old: dragging my sorry arse through shrubby and prickly (Hakea) swamps of the Sydney region is increasingly tiring. Recently I (re) read an old paper (Tony Martin's palynology from Kosciuszko National Park, in Rev. Palaeobot. & Palynol. 1986) and found myself grumpy and lamenting the old days: another sure sign of masculine old age! The lament was for the past when academics could spend time on demanding analyses (palynology!) and write long, carefully crafted papers (Martin 1986 is 42 pages). The grumpy bit results from my own stupidity: I have been trying to get a handle on Holocene variability in our region for some time, but it is (arguably) best characterised in research that is increasingly slipping from my memory (or even perhaps from our collective consciousness in the pre-pdf age). Martin (1986), just as an example, again, he details a 'Pomaderris interval' that any Australian palynologist of a certain age is likely to recall as worthy of consideration (e.g. as a period of enhanced moisture availability)... and I'd forgotten all about it.

Don't forget to start planning for the December 2018 AQUA Biennial Meeting in Canberra. This will be a great chance to all come together and remind ourselves of the fantastic work that has been achieved and continues in the Australasian Quaternary community. I look forward to catching up with you all in Canberra.

Best wishes

Scott Mooney *AQUA President*

NEWS

PALAEO SESSION AT THE NEXT ECOLOGICAL SOCIETY OF AUSTRALIA

Patrick Moss (School of Earth and Environmental Science, University of Queensland) is giving a palaeo session at the next Ecological Society of Australia meeting in Brisbane, 25-29 November, 2018.

Palaeo Session: University of Queensland, Queensland, Australia. Lessons from the Past: The application of palaeoecology and archaeobotany to ecological science.
28 November 2018, 11am – 1:00 pm
Symposium Convenors: A/Prof Patrick Moss, A/Prof Andrew Fairbairn, Prof Jamie Shulmeister

Modern ecological landscapes are the product of a range of environmental processes that have operated over annual, decadal, centennial and millennial scales (and beyond). These processes can be linked to natural climatic variability and/or anthropogenic impacts that occur over a variety of temporal and spatial scales. In particular, the Holocene (~last 12,000 years) has played an important role in shaping modern landscapes through the development of the current warm, ice free high sea-level environments that characterise this interglacial period, as well as observing the development of agriculture, urban regions and subsequent rapid human population growth. Furthermore, an understanding of previous ecosystem response to dramatic climate change and/or human impacts can also provide important context for how these systems may respond to further environmental change, particularly anthropogenic global warming. This symposium will examine how palaeoecological and/or archaeobotanical data can be utilised to provide context to ecological science, particularly how Holocene environments and/or human impacts have shaped the ecological composition of modern landscapes, as well as how this data can be used in the conservation and management of these landscapes into the future. Particular emphasis will be given to presentations that integrate palaeoecological/archaeobotanical data with the management of contemporary landscapes.

Abstracts are due July 20.

Information about the conference can be found at http://esa2018.org.au

MUNGO MAN: RETURN TO COUNTRY

Jessica Reeves

Environment and Geoscience, Federation University Australia – Gippsland, Victoria, Australia

WARNING: Aboriginal and Torres Strait Islander readers are warned that this article contains images of deceased persons.

These days at any public gathering in Australia you can expect to hear (or be obliged to give) an acknowledgement of country. Typically this involves naming the Indigenous custodians of the land where the meeting occurs and a statement of respect to the past and present Elders of that country. Sometime this can be delivered in a nuanced way, with true sincerity – often it is read off a sheet in a cursory manner. For the millions of migrants to Australia, it can be challenging to truly appreciate this connection to land, as part of self, and acknowledging people and country as one; particularly if this connection goes back millennia. Perhaps this connection is something that is best felt.

On the 17th November, 2017 the bones of Mungo Man and over 100 other ancestors were returned to the Willandra Lakes World Heritage Area. The bones had been removed from the site in a series of archaeological excavations, commencing over 40 years ago. Mungo Man – and also Mungo Lady – revealed themselves to Jim Bowler when he was surveying the shorelines of the palaeolakes of the Willandra system. As was the 'done thing' at the time, the bones were carefully excavated by archaeologists John Mulvaney and Rhys Jones, who determined that the bodies had been very carefully interred, covered in ochre. The bones were removed from the Joulni region of the Lake Mungo lunette and sent to the ANU for extensive analysis, primarily by physical anthropologist, Allan Thorne. The key findings include both the antiquity of these individuals, both eventually being dated at over 40,000 years old, and that they were clearly modern humans with sophisticated cultural practice. These two facts completely turned around global ideas of migration and sophistication of early humans, as reaching Australia would have required highly advanced communication and technology to make the water crossing from the Indonesian archipelago to the Australian continent.

It should never be forgotten that these bones belong to people – the ancestors of the Traditional Owners of the Willandra region; the Mutthi Mutthi, Barkanji and Ngiyampaa people, who have been negotiating for many years to have the bones returned to country. Mungo Lady was returned in a ceremony in 1991, however the rest of the remains stayed in Canberra...until this journey.

The journey commenced on 15th November, 2017 from the National Museum of Australia, where the bones had been kept securely since 2015. Elders from each of the Traditional Owner groups of the Willandra met with the Ngunnuwal people of the Canberra region and representatives of Aboriginal groups from all around the country, where a smoking ceremony and presentations from dignitaries wished Mungo Man and his people well on the long journey home. The remains of Mungo Man were placed in an ancient river red gum 'coffin', crafted especially for this purpose. He, along with the other remains, were carefully stowed into the hearse: a Chrysler Valiant station wagon that had been used in the 1970s and 80s to return countless Aboriginal people to their final resting places on country. The hearse and procession then passed through the towns of Hay and Balranald, where ceremonies were also held to welcome the party and wish them safe passage.

I caught up with the procession on the turn off to the Willandra from Balranald. A long caravan of cars mustered on the side of the road awaiting the hearse. Even here, there was an air of nervous anticipation for this momentous occasion. The word was then given for cars to move on and meet with the others at the rise near Joulni. The air was calm as we made our way through the welcoming smoke, across to where the main ceremony was to take place (Figure 1). The gathering crowd was quiet and respectful – extended family and long-time friends and colleagues warmly greeting each other with a shared energy gently moving between us all. AQUA was well represented by members and friends including Jim Bowler, John Magee, Jeanette Hope, Steve Webb, Tim Denham, Harvey Johnston, Dan Rosendahl, Nikki Stern and several of her students (Figure 2).

Steve Meredith, deftly performing the role of MC for the event, welcomed us all and set the tone for the day. A day of respect, celebration, sorrow, joy and healing – for this long-awaited return. Elders from each of the Traditional Owner groups sat facing the audience, with the Aboriginal flag flying proudly behind them (Figure 3). After a nervous wait, the hearse arrived with Daryl Pappin at the wheel (Figure 4). Strapping young men representing each of the Willandra groups (and looking very cool in dark shades), reverently removed the precious cargo and placed it before the audience; shrouded in smoke from the gum leaves (Figure 5). A wind whipped up through the congregation and fluttered the flag. Mungo Man was home.

Elders from each of the Traditional Owner Groups (Lottie Williams and Michael Young – Barkandji; Mary Papping – Mutthi Mutthi; Roy Kennedy – Ngiyampaa) spoke of their journey over the long and at times challenging struggle to bring home their ancestors. They each expressed immense joy that this day had come, but also sadness that many of the Old People who began this process were no longer there to be able to see this day. Each spoke of a shared journey forward – what the science had contributed to their story, but the need for respect of culture and country. They spoke of forgiveness and healing, memories of the past and vision for both their communities' future and the Willandra. The generosity in their words and stories – and ability to communicate this to a broad audience – was remarkable.

Top to Bottom:

Figure 1. Location for main ceremony. (All photo credits Jessica Reeves)

Figure 2. John Magee and Jim Bowler.

Figure 3. Elders awaiting the arrival of Mungo Man.

Figure 4. Mungo Man arrives.

Figure 5. Mungo Man in an ancient river red gum 'coffin', surrounded by other returned remains.

Other speakers included the NSW Minister for the Environment and Heritage, the Office of Environment and Heritage CEO, the Barkandji Native Title Group Aboriginal Corporation and Jim Bowler – a man whose life has become intertwined with that of Mungo Man's. The ceremony continued with dance performances from local school students and heartfelt songs from Ernie Mitchell, Dane Kennedy, Shane Howard and Roy Kennedy. The boxes were then returned to the hearse which drove off for a private gathering of the Elders (and a few dozen photographers!) (Figure 6).

The gathering hugged, cried, smiled, shared stories and sandwiches and felt the immense power of this place. This was connection to country. This was respect to Elders – past and present. Eventually we all dispersed to our cars in the knowledge that a very small part of the puzzle had been put right. The celebrations continued in Mildura on the Friday night with a free all-of-community festival of song and dance. By all accounts, this was a monumental success and truly joyous occasion. The organisers of the formal repatriation and the celebration: Steve Meredith, Harvey Johnston, Dan Rosendahl, the 3TTG Elders Group, Ben Bowler and all others involved should be truly proud of their efforts in pulling this off – no small task.

I am immensely grateful for the opportunity to bear witness to this truly extraordinary day. My heart wells over as I type these words. Whilst Mungo Man is now home, all of Australia – and in fact the world – has much to learn from this place and its people. Many AQUA and AAA members share an intimate connection to this place. We have the privileged opportunity to tell part of this story – complementary to and in support of the cultural stories that are a fundamental part of the fabric of this unique landscape and its people. (Continued on page 34)

Figure 6. Below: Mungo Man is driven off to a private gathering of the Elders.

DATING WASSON'S DERWENT VALLEY FANS

Peter D. McIntosh

Forest Practices Authority, Hobart

Gravelly alluvial fan deposits at Granton on the south bank of the Derwent River north of Hobart were first mapped by Wasson (1977). Wasson was hampered in his interpretation of the fan deposits of the lower Derwent Valley by the absence of datable material. Only charcoal in recent infill could be dated and proved to be Holocene. Wasson did however identify two phases of fan formation separated by thin aeolian deposits and concluded that all deposits originated in the Last Glacial period.

Thermoluminescent ages of c. 74 ka were obtained from weathered dune sands underlying fan deposits on the north bank of the Derwent at New Norfolk (McIntosh *et al.*, 2012). These indicate fan deposition in oxygen isotope stage 4 or later.

However recent TL dating of an aeolian lens in the Granton fan on the south bank of the Derwent River (illustrated above) by D.M. Price produced an age of >/=134±21 ka (W4784). Price's date suggests that the fan deposits at Granton span the Last Glacial and Penultimate Glacial periods, a proposition also supported by the colour change of the gravels' matrix from yellow-brown (below the aeolian lens) to grey (above the aeolian lens) Figure 2.

Price remarked that "the TL age determined for sample W4784 may well be in excess of the true depositional age due to poor resetting of the previously acquired TL signal during the final transport phase". So, the aeolian lens may have accumulated during the transition to a rapidly cooling (and drier?) climate that at the beginning of oxygen isotope stage 5d.

Figure 1. General view of the Granton Fan. The road cutting is about 7 m high (All photo credits Peter McIntosh).

Figure 2. Detail of sampled aeolian lens.

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QUATERNARY SCIENCE IN NEW ZEALAND: REPORT TO THE CATALYST FUND

David J. Lowe

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Editors note: The following report, (including Appendix A) was prepared by David Lowe for the New Zealand Royal Society (Te Apārangi) Catalyst Fund. It is an annual report on behalf of the Quaternary research community in New Zealand with regard to international membership of the International Union for Quaternary Research (INQUA) to the Royal Society (Te Apārangi) Catalyst Fund. *Full report http://aqua.org.au/quaternary-australasia/qa-vol-35-july-2018*

David Lowe writes: "*I have discussed the report with some of the leading New Zealand Quaternarists and/or leaders of several INQUA-funded projects/IFGs (names are listed on p. 7). I attach a 17-page document* (Appendix A) *that summarises Quaternary-related research in New Zealand and the relationship of research to the International Union for Quaternary Research (INQUA) and the associated focus groups and projects. It is referred to in the report below*".

SUPPORTED INTERNATIONAL UNION MEMBERSHIP:	INTERNATIONAL UNION FOR QUATERNARY RESEARCH (INQUA)
New Zealand national delegate:	Professor David J. Lowe, University of Waikato FRSNZ, FNZSSS, Hon Fellow INQUA
Affiliated New Zealand organisation/national committee:	Ad hoc group of New Zealand Quaternary researchers, some in leadership roles associated with INQUA-funded projects and/or international focus groups (IFGs) as noted in the report below. Most are members of the active Australasian Quaternary Association (AQUA), which is affiliated with INQUA, and various other science associations/societies in NZ.
President/Chair of New Zealand organisation or national committee:	Dr Helen Bostock (NIWA) – Immediate Past-President, Australasian Quaternary Association (AQUA)
Reporting year:	1 December 2016 – 31 December 2017
Report due date:	10 March 2018

Citation: Lowe, D.J. 2018. Quaternary research in New Zealand and relationship to the International Union for Quaternary Research (INQUA). *Annual Report for 'Catalyst Fund: Influence' for 2017 (with Appendix)*. School of Science, University of Waikato, Hamilton, 24 pp.

1. CATALYST: INFLUENCE ASSESSMENT CRITERIA

1.1 Please comment on how the supported union membership involves recognised global science and innovation leaders, the connection with whom could benefit New Zealand in a substantive manner.

Many of the top Quaternary science specialists globally are members of the *International Union for Quaternary Research* (INQUA), and a number of New Zealand Quaternary scientists arguably are in that elite category. Membership of INQUA provides access to this international knowledge base and the latest developments in the discipline, as described below and in Appendix A, which includes examples of the international recognition of New Zealand Quaternary geological archives as globally important or unique, and of New Zealand participation and leadership in (a) globally-significant research and (b) in decision making at the international level through INQUA and through associated activities/outlets involving Quaternary research and its dissemination.

Most of New Zealand's Quaternary researchers have been involved with INQUA-led projects or research groups, referred to as international focus groups (IFGs), that enable them to tackle globally-relevant research questions in the disciplines encompassed by the Quaternary (see Appendix A). Key questions about climate change in the past are a main focus because understanding the causes and timing spatially and through time requires a global and multi-disciplinary approach, with a Southern Hemisphere perspective especially important because of the general paucity of data in much of the hemisphere to compare with that from the Northern Hemisphere. Future models of changing climate are largely contingent upon robust paleoenvironmental data, dated at high precision, being obtained from a range of archives throughout New Zealand and surrounding marine sediments by Quaternary scientists. Increasingly, high-resolution past-environmental data are needed as are improved chronologies, to enable questions of leads and lags in past climate systems to be answered at a range of scales (both regionally and globally).

INQUA's five broad *commissions* (Appendix A) provide seed funding to IFGs and projects annually to enable new and especially collaborative research to be undertaken on important topics that may incorporate revised or new methodologies. Many early career researchers (ECRs) especially have benefitted from the funding provided by INQUA through support to attend and participate in meetings and conferences through travel grants. In addition, the New Zealand and Australian Quaternary research communities have forged closer relationships over the past decade under the umbrella of the *Australasian Quaternary Association* (AQUA), which is affiliated with INQUA. AQUA members have been very active with biennial conferences hosted in New Zealand and Australia, the publication of biannual newsletters, and financial and in-kind support for the INQUA-led IFGs and projects.

1.2 Please comment on how the International Union membership has advanced New Zealand's research, science and technology reputation over the last year and/or presented new opportunities for collaboration in research fields of strategic importance to New Zealand.

From 1 December 2016 to 31 December 2017, the New Zealand Quaternary research community, with strong support from Australian counterparts, made significant advances in three main ways, in part catalyzed through membership of INQUA:

a. by showcasing completed research important both to New Zealand and globally in key disciplines of (i) paleoclimatic studies and (ii) the use of volcanic-ash (tephra) layers as correlating and dating tools (tephrochronology) via publication of **three 'special issues' of three international journals** *Climate of the Past, Journal of Quaternary Science*, and *Quaternary Geochronology* (Lorrey and Newnham 2017b; Lane *et al*. 2017b; Lorrey *et al*. 2017) (references are given at the end of Appendix A);
b. by continuing and maintaining collaborative national and international opportunities for presenting and discussing new research and networking at four conferences/workshops held in this period by leaders of INQUA-funded IFGs and project – the key IFGs and projects in New Zealand currently supported by INQUA include SHAPE (ongoing IFG), INTAV (ongoing IFG), EXTRAS (project), and SHeMax (project) (defined in Appendix A); and
c. by mentoring and developing ECRs through provision of opportunity for them to participate in conferences or workshops using funds provided by INQUA and AQUA to support travel or to offset registration costs.

The development of several key IFGs and projects, led in part by New Zealand Quaternary researchers, has been critical in improving and bringing together researchers with widely varying interests to tackle difficult problems and 'big' topics such as climate change that are essential to help obtain a global understanding of environmental change past, present, and future. Further details are given below in section 2 and Appendix A.

1.3 Please comment on what the New Zealand research sector, aligned with the International Union membership, can offer to international researchers, with a view to creating potential partnership, or cement New Zealand's involvement, in the activity over the long-term.

Very strong partnerships have been developed by New Zealand and Australian researchers through the IFGs and projects that are supported by INQUA. As noted elsewhere, the advent of the Australasian INTIMATE project led to the more-or-less entire Quaternary communities of New Zealand and Australia becoming involved to develop new ideas and to publish benchmark papers and interpretations and a new template for interpreting climate change from c. 30,000 years ago through to c. 8000 years ago. Although centered on Australasia, the myriad of connections between New Zealand and Australian researchers and counterparts all around the world means that international partnerships are strong and durable. For example, the INTAV executive comprises representatives from New Zealand, Canada, UK, Japan, and Switzerland. And every four years the global Quaternary research community assembles for the full INQUA congress (held in Japan in 2015 and to be held in Eire (Republic of Ireland) in 2019), with New Zealand an important voice on the International Council and with numerous scientific sessions being convened by New Zealand and other scientists, i.e. the INQUA community provides one of the best examples of strongly connected and productive relationships in science that is tackling globally-relevant problems. New Zealand Quaternary scientists are extremely productive and effective given the small size of our community.

1.4 Please comment on what has been planned for New Zealand to leverage off the opportunities identified in 1.2 or 1.3. If these are ongoing activities, please comment on the progress since last year's report.

As evident below and in Appendix A, the current IFGs and projects being undertaken currently in New Zealand are set to run until the INQUA congress in Dublin in 2019. Consequently, conferences and other activities for these are being planned for 2018. For example, SHAPE members held a workshop at Wollongong in February 2018, INTAV members are holding an international tephra conference in Romania in June 2018, and

SHeMax members are running a workshop in Australia in June 2018. AQUA is holding its biennial meeting in Canberra in December 2018. Each of these meetings/workshops provides further opportunity for new research and collaborations and for ECRs to engage with the Quaternary community.

2. INFORMATION RELEVANT TO THE RESEARCH COMMUNITY IN THE PREVIOUS YEAR

2.1 Please list any New Zealander(s) participating in International Union work programmes and/or the Union council(s), and several notable achievements of 2017 pertaining to Quaternary research in New Zealand

Prof David Lowe (University of Waikato):

iv. New Zealand representative of RSNZ (and the New Zealand Quaternary science community) on the International Council of INQUA

v. One of only four New Zealanders to be awarded an honorary life fellowship of INQUA (in July 2015)

vi. Formal advisor to SACCOM, INQUA

vii. Immediate Past-President on the executive of INTAV, under the aegis of which the executive has proposed three tephra-focussed sessions for the full INQUA congress in Dublin, 2019

viii. Leader of the ongoing EXTRAS project of INTAV

ix. Co-editor of INTAV special issue of *Quaternary Geochronology* (Lane *et al.* 2017b)

x. Co-organiser of the "Crossing New Frontiers" tephra meeting planned for Romania, June 2018

xi. (viii) Member of advisory editorial boards of *Quaternary International, Journal of Quaternary Science, Quaternary, Quaternary Geochronology*

Dr Andrew Lorrey (NIWA):

i. New Zealand early career researcher representative on SACCOM, INQUA

ii. Co-leader of SHAPE, under the aegis of which the executive has proposed a SHAPE session for the full INQUA congress in Dublin, 2019

iii. Co-editor of two SHAPE special issues in *Climate of the Past* (Lorrey *et al.* 2017) and *Journal of Quaternary Science* (Lorrey and Newnham 2017b)

Dr Lynda Petherick (Victoria University of Wellington):

i. Leader of SHeMax

Prof Rewi Newnham (Victoria University of Wellington):

i. New Zealand representative on formal subdivision of the Holocene series/epoch

ii. Regional Editor (Asia and Australasia), Journal of Quaternary Science

iii. Member of advisory editorial board of The Holocene

iv. Co-editor of SHAPE special issue of *Journal of Quaternary Science* (Lorrey and Newnham 2017b)

Prof Andrew Mackintosh (Victoria University of Wellington):

i. Lead Author, Intergovernmental Panel on Climate Change (IPCC) "Special report on the ocean and cryosphere in a changing climate" (in preparation)

ii. Review Editor and member of advisory editorial board of *Frontiers in Cryospheric Sciences*

Dr Helen Bostock (NIWA):

i. Immediate Past-President (New Zealand) of the Australasian Quaternary Association (AQUA) and member ex officio of AQUA committee (2012-2018)

ii. Co-editor of the SHAPE special issue of *Climate of the Past* (Lorrey *et al.* 2017)

Dr Carol Smith (Lincoln Univ.):

i. Co-editor of *Quaternary Australasia* (newsletter of AQUA)

Dr Andrew Rees (Victoria University of Wellington):

i. Member of AQUA committee (2016-2018)

Associate Prof Alan Hogg (Radiocarbon Dating Laboratory, University of Waikato):

i. Member of editorial advisory board of *Quaternary Geochronology*

Prof Jamie Shulmeister (University of Queensland, Brisbane):

i. Editor of book on the New Zealand Quaternary (published by Springer/Atlantis Press) in 2017: "Landscape and Quaternary Environmental Change in New Zealand"

Emeritus Prof Paul Williams (University of Auckland):

i. Author of textbook on the geomorphology of New Zealand including its Quaternary record (published by Elsevier) in 2017: "New Zealand Landscape: Behind the Scene".

2.2 Please list International Union activities over the last year of relevance to your research community and describe how these have been communicated.

INTAV

a. A skill enhancement grant to INTAV of €5000 (~$8500), awarded by SACCOM, INQUA, in 2017 enabled 10 early career researchers, and Prof David Lowe (University of Waikato) (awarded a separate grant of $3000 from the State University of New York at Buffalo, USA), to attend a specialist tephra workshop "Best practices in tephra collection, analysis, and reporting: leading toward better tephra databases" on 19 August 2017 in Portland, Oregon, USA. That workshop involved around 10 New Zealand participants out of a total of 50

b. EXTRAS project: a special volume of tephra-focussed papers relating to the EXTRAS project was published in the international journal *Quaternary Geochronology* by Lane *et al.* (2017b) and comprised 12 papers and 2 editorials including Lane *et al.* (2017a). Also, a substantial invited review paper on tephra correlation and statistical methods was published in the international journal *Quaternary Science Reviews* as an output of both EXTRAS and SHAPE (Lowe *et al.* 2017)

c. A number of INTAV members including David Lowe were involved in the New Zealand three-group paleoclimates workshop in Wellington 27-28 August 2017 (noted also for SHAPE and SHeMax below)

d. INTAV executive including David Lowe are organizing an international tephra meeting "Crossing New Frontiers: Tephra Hunt in Transylvania", 24-29 June, 2018, to be held near Brasov, Transylvania, Romania

SHAPE

SHAPE was awarded €6000 (~$10,200) by PALCOM, INQUA, to enable the leaders including Dr Drew Lorrey (NIWA) to build networks across the Southern Hemisphere to undertake new paleoclimate research in the hemisphere as described in Appendix A. The funding supported two workshops of SHAPE as follows:

a. New Zealand paleoclimates workshop held in Wellington from 27-28 Aug 2017 with around 40 participants, mainly from New Zealand but with several from Australia. The workshop, as well as showcasing current research, led to the proposal for two review articles (on past climate proxies and geochronologies) to be developed over the next few years, these reviews being led by Dr Shaun Eaves (VUW) and Dr Andrew Rees (VUW)

b. An Australian paleoclimates workshop was held in Wollongong 2-3 February 2018 with around 30 participants from both New Zealand and Australia

c. SHAPE members in 2017 also produced two special volumes, one in the international journal *Journal of Quaternary Science* edited by Lorrey and Newnham (2017b) (15 papers and an editorial) and a second in the international journal *Climate of the Past* (Lorrey *et al.* 2017).

SHeMax

SHeMax leaders were awarded €4000 per year for 2016 and 2017 (i.e. €8000 total, about $13,600) to undertake new collaborative research on the Last Glacial Maximum in the Southern Hemisphere. SHeMax leaders organized

a. a two-day workshop in Auckland 3-4 December 2016 and then took part in the New Zealand paleoclimates workshop in Wellington 27-28 August 2017

b. Another SHeMax workshop, led by Dr Lynda Petherick, is to be held 28-29 June 2018 at the Moreton Bay Research Station of the University of Queensland on North Stradbroke Island.

Communication in all of these programmes has been made via published papers in the international literature as well as via notices and reports in newsletters including *Quaternary Australasia* (AQUA) and *Quaternary Perspectives* (INQUA), multiple Facebook sites, and individual organisational (focus group or project) webmail services. David Lowe also reported to the New Zealand Quaternary community several times in 2016 and 2017 (also once so far in 2018) with brief updates on activities and issues via an email list (~60 names) of the main active Quaternary researchers. These emails are also copied to Australian INQUA representative Dr Jessica Reeves (Federation University Australia).

3. ADDITIONAL COMMENTS

3.1 Additional comments relevant to the International Union membership that you would like to share with the Society, MBIE, and/or the research community.

The fee paid annually to INQUA, CHF2370 (~$3500 NZD) represents very good 'value for money' in the sense that (a) New Zealand is paying the second lowest membership rate to INQUA, and (b) the New Zealand and (in part) Australia Quaternary research communities received considerably more in return from INQUA in the form of grants to the focus groups and projects of ~$35,300 for the year Dec 2016 to Dec 2017, approximately a ten-fold difference.

Signature: 

Delegate: (David J. Lowe)
Date submitted to the Society: 10 March 2018

ACKNOWLEDGEMENT:
I am very grateful to the following colleagues for information or insightful comments that improved the report:

Associate Prof Peter Almond (Lincoln Univ., Lincoln)

Dr Helen Bostock (NIWA, Wellington)

Dr Andrew Lorrey (NIWA, Auckland)

Prof Rewi Newnham (VUW, Wellington)

Dr Lynda Petherick (VUW, Wellington)

Dr Marcus Vandergoes (GNS Science, Lower Hutt)

Full report http://aqua.org.au/quaternary-australasia/qa-vol-35-july-2018

UPDATE ON THE FORMALISATION OF THE ANTHROPOCENE

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We follow up the report and survey undertaken through this newsletter several years ago (Bostock 2015; Bostock *et al.*, 2015) with an update on the current situation regarding the status of the 'Anthropocene'. After several years of presentations and debate, the Anthropocene Working Group (AWG) finally took a series of votes at the 35th International Congress in Cape Town in August 2016. The AWG members overwhelming supported the idea that the Anthropocene is functionally and stratigraphically different from the Holocene, recommending that it started about 1950 (coincident with the 'Great Acceleration'). They voted in favour of the formalisation of the Anthropocene at the level of epoch. This means that, following ratification from several other organisations, the Holocene Epoch is to be terminated, but we are still within the Quaternary Period and Cenozoic Era (Fig. 1; Zalasiewicz *et al.*, 2017).

Although a Global boundary Stratotype Section Age (GSSA) has been suggested based on the detonation of the first atomic bomb on July 16 1945, there is strong support to designate a GSSP (Global Boundary Stratotype Section and Point) and auxiliary stratotype sections. Traditionally, GSSPs have been in marine sediments, but the Holocene GSSP (the boundary between the Pleistocene and Holocene) is in the Greenland NGRIP ice core, with

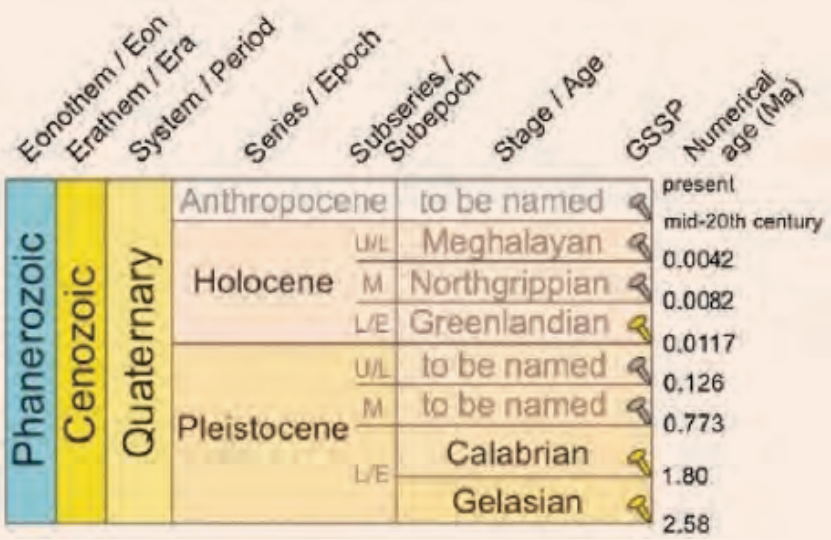

Figure 1. Preferred Quaternary time scale of the AWG, 2017, with the Anthropocene shown at the rank of series/epoch. Black type indicates names officially approved and ratified by the International Commission on Stratigraphy (ICS)/Executive Committee of the International Union of Geological Sciences (IUGS EC). Names for Global Boundary Stratotype Section and Point (GSSP) designations in grey type or as grey 'spikes' have yet to be officially sanctioned by ICS/IUGS EC, but stage names and subseries for the Holocene were approved by the Subcommission on Quaternary Stratigraphy (from Zalasiewicz et al., 2017).

auxiliary sections in four lakes around the world (including Lake Maratoto, Waikato, New Zealand, representing Australasia) and one deep marine anoxic basin off the coast of Venezuela, the Cariaco Basin (Walker *et al.*, 2009). Potential GSSP sites for the Anthropocene Epoch from a wide range of different (paleo)environments from around the globe are currently being reviewed ranging from settings associated with accumulations of anthropogenic material (rubbish tips and dumps), marine anoxic basins, coral reefs, estuaries and deltas, lakes at various latitudes, peat bogs, snow/ice layers, speleothems and trees (e.g., Gałuszka *et al.*, 2017; Malhi, 2017; Waters *et al.*, 2018). There is also some debate about the primary and secondary markers that could be used to mark the base of the Anthropocene. Radionuclides (^{239}Pu: peak in 1952; ^{14}C: peak in 1954) and stable carbon isotopes are applicable in most paleoenvironments, whereas fossil markers, nitrogen isotopes, fly ash, microplastics, heavy metals, and various specific organic compounds may be applicable as secondary markers in other environments. Sites with annual varves or layers are preferred targets for a GSSP or auxiliary stratotype, where the use of annual layer counting can be corroborated with radionuclide/radiometric dating. Thus, peat bogs, estuaries and deltas (which tend to have missing layers) are precluded. Some deep-marine records (anoxic basins, deep-sea corals) are also deemed less suitable because of the delay in some of these signals being incorporated into the archive due to time lags associated with ocean circulation. It is likely that there will also be time lags in speleothems and ice cores, except in regions of rapid snow accumulation, such as coastal Antarctica. Rubbish tips and dumps are also unlikely to be suitable as they accrete laterally as well as vertically and are sometimes overturned or redistributed. The strongest candidates for paleoenvironments for the GSSP and auxiliary sites for the Anthropocene currently include tropical long-lived coral bioherms, high-resolution hypoxic lakes, high-resolution coastal ice cores, and tree rings (Waters *et al.*, 2018).

Recently, Turney *et al.* (2018) have suggested that tree rings from an exotic Sitka spruce (*Picea sitchensis*) on remote Campbell Island (Fig. 2) should be considered as an Anthropocene GSSP as they show a clear radionuclide bomb signal ('bomb carbon') initially rising in 1954 and peaking in late 1965, a record that matches the direct monitoring of the ^{14}C bomb signal in Lower Hutt, Wellington (Fig. 3). These results are supported by measurements on cores from an adjacent peat bog on Campbell Island. There is also a steady long-term decline in the δ^{13}C in the tree representing the Suess Effect (the decline in carbon isotopes due to the burning of ^{12}C-rich fossil fuels) (Turney *et al.*, 2018). In support of their proposal, Turney *et al.* (2018) argued that it satisfies the requirements for a GSSP (Lewis and Maslim, 2015; Waters *et al.*, 2018), namely that it is represented by a principal correlation event (the marker); other primary and secondary markers are evident; it has a demonstrable regional and global correlation; there is complete continuous sedimentation with adequate thickness above and below the marker; it has an exact location, latitude, longitude and height/depth (a GSSP is placed at only one place on Earth); it is accessible; and it has provisions for protection and conservation.

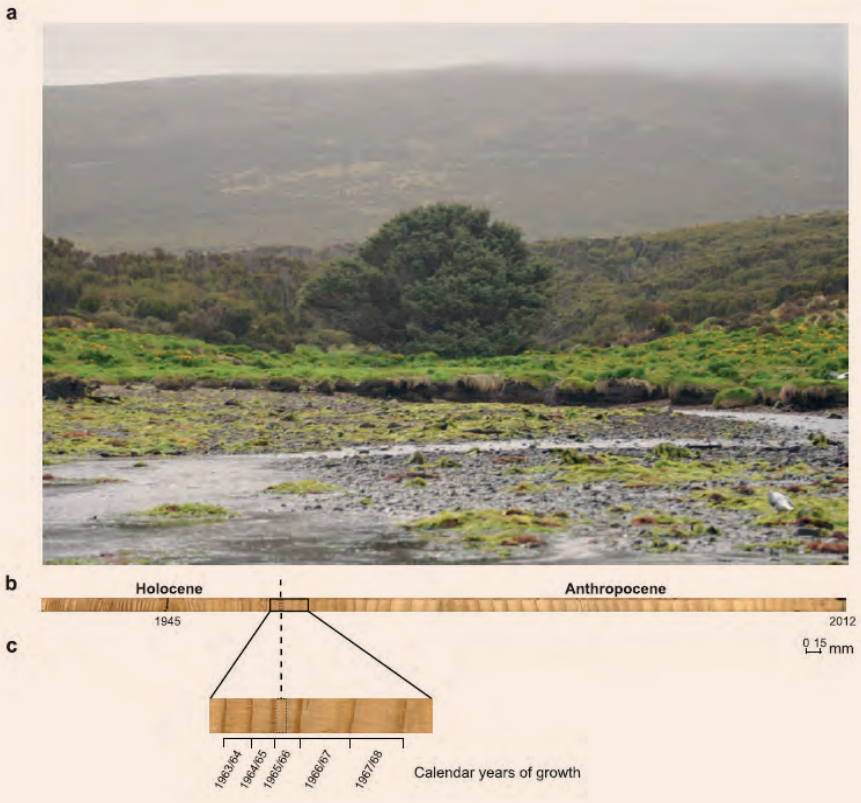

Figure 2. The solitary subantarctic Campbell Island Sitka spruce (*Picea sitchensis*) surrounded by open *Dracophyllum* sp. scrub (image a) with visual image of tree-ring growth (image b) and enlargement of the proposed transition between the Holocene and Anthropocene (image c) (from Turney et al., 2018).

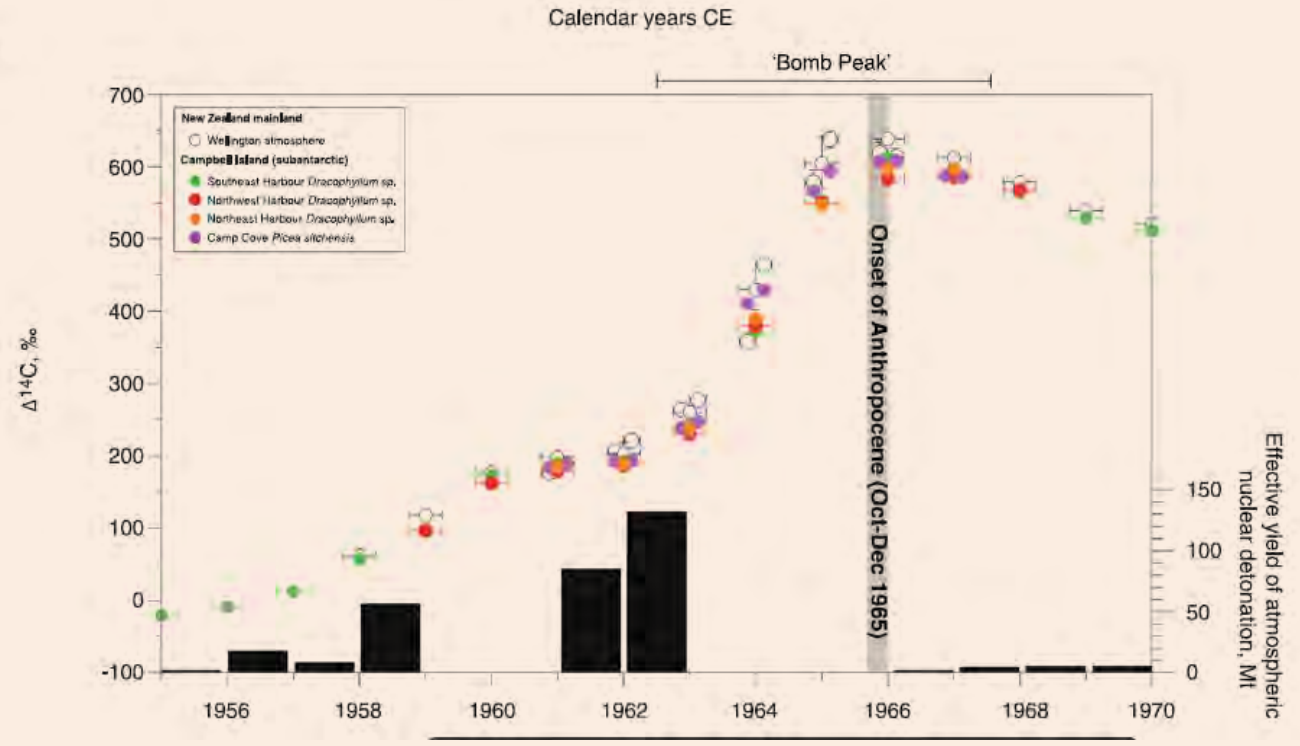

Figure 3. Bomb carbon measured for the period 1955–1970. The peak in the Campbell Island Sitka spruce ^{14}C (filled purple circles) during the austral spring (October-December) of 1965 matches the signal measured at Lower Hutt (open circles) and demonstrates a regionally-representative signal that falls within the period of the Northern Hemisphere bomb peak (from Turney et al., 2018).

The next step in this process is to select a few sites and analyse them thoroughly to determine their suitability. If any AQUA members or their colleagues have a site that could be suitable, please get in touch with the AWG. In the next couple of years the AWG will submit a final proposal to the International Commission of Stratigraphy, in order for the Anthropocene Epoch to be formally included in the Geological Time Scale.

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NCES REPORT - THE DECADE AHEAD

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The Australian membership of AQUA is represented at the Australian Academy of Science by the National Committee for Earth Sciences (NCES). The NCES is one of 22 committees that report to the Academy. The NCES acts as a peak body for scientific research planning, international representation, education and industry liaison for Earth Sciences. It provides guidance on the research priorities, can act as an advocate body for lobbying parliament and importantly, pays Australia's subscription to INQUA.

AQUA has been a member of the NCES since 2013. We briefly had our own National Committee for Quaternary Research in the early 2000s. However, due to the proportionally small membership, we were merged back in with other earth sciences. The NCES committee currently comprises 12 members from the disciplines of computational geophysics and geodynamics, geochemistry, biogeochemistry, digital modelling for exploration, glaciology, planetary research – and of course, Quaternary research. There are also representatives from Geosciences Australia and industry and close links with the National Committee for Earth Systems Sciences.

One of the key purposes of all the National Committees is to provide strategic direction for the communities they represent, through the publication of Decadal Plans. The first of such plans was the National Strategic Plan for Geosciences (Geoscience – Unearthing our future (2003)). This was a powerful document aimed to lobby support for key research priorities. Of interest to the Quaternary community, these included: membership of the IODP program, increased support for climate research and prioritisation of major infrastructure, such as the *Investigator* and the Sirius AMS facility. One of the intentions of the Decadal Plans is to include items that can very conveniently be cut and pasted into grant applications, with the statement...."as determined by the geoscience community to be a key priority."

The NCES is about to launch the Decadal Plan for Earth Sciences 2018-2027: Our Planet, Australia's Future – A decade of transition in the Earth Sciences. The committee has spent the last three years brainstorming what the future might look like – what the research priorities are likely to be and the areas where extra resources would be very welcome. This was an extensive and exhausting process, which included stakeholder consultation within industry, academia and the Academy; presentation at key conferences and public comment through various mailing lists. The result has been two documents: one snappy little coffee table number and a more expansive report, which gives a more nuanced approach to the needs of the earth sciences community. I recommend you read (or at least scan through) both.

The mission statement reads as follows:

> *To forge a new, predictive framework for understanding our complex planet, the Earth Science community will:*
>
> - *develop and deploy advanced technology to understand Earth processes and to reveal our planet's past, present and future;*
> - *harness greater access and knowledge of the Earth to address whole-of-Earth challenges;*
> - *drive a strongly collaborative and integrated approach to Earth Science research and its applications; and*
> - *foster well-informed decision-making and management of Australia's natural resources.*

Lofty ambitions indeed. The Plan identifies this as a decade of transition – and one of mind-set as well as practice. For perhaps the first time we have become truly aware of the carrying capacity of our planet – and that our current practices are clearly exceeding this in an unsustainable way. So how do Earth Sciences contribute to making a change and what do we need to achieve this transition? Only through a systems approach and evidenced-based decision making do we have a chance.

One of the most fundamental areas of improvement was greater collaboration both within and between disciplines, but most importantly, between academia, industry, policy and the broader community. This needs to start at an early level. More students need to be encouraged to pursue higher education in earth sciences and understand that this discipline is not just about extractive resources, but the whole of landscape management. Students must be encouraged to see earth sciences as an integrative

science with very strong cross-overs into maths, chemistry, biology, physics, economics and an increasing emphasis on big data – depending on your bent – to be a truly integrative science. Earth Science plays a critical role in agriculture, climate change adaptation, urban development, natural hazards – as well as resources. One thing we were all clear about is that we have not sold our story well.

Other areas included the gathering, storing and interrogation of big data sets. As Quaternary scientists, we have an ever expanding capacity in sensor technology, tracing everything from water availability to earthquakes – but having the computational capability to make sense of all of this is challenging. The scale of Earth Sciences is vast – spanning not only all of the globe (terrestrial and marine), but also deep into the Earth and back through time. It also includes the human access of resource use and human impact on the Earth, both in the past and going forward. It's a big shopping list!

The extended plan is broken into four key areas of: Earth Resources (food and water; minerals and energy); Cultural Resources; Risk, Responsibility and Accountability (geohazards; climate change) and the Global Economy. These are underpinned by grand science challenges in the areas of:

- Australia's evolution: deep interior and deep time
- Real-time dynamism of Earth's crust
- Interpreting change through the geological record

The plan also speaks to how we address these challenges, which includes a bigger picture view, investing in education and training and greater advocacy: engaging the community at all levels.

The plan then goes on to make a series of key recommendations. Of particular interest to Quaternary community are:

- A new-generation collaborative geochemical analytical and experimental national capability
- Extending the reach of Australia's marine Geoscience
- Enhance the analytical capabilities of Earth Science with expansive and accessible data and information
- Massively expand Australia's national computational capability
- Improve the understanding of Earth processes and climate systems
- Understand biogeochemical and geobiological interactions

In addition to the things we can all relate to:

- Invest in and support all levels of Earth Science education
- Professional development and retraining opportunities
- Outreach: celebrating the success and value of Earth Science
- Support and nurture collaborative projects and interaction

I am the first to admit that the abridged version, which will see a soft launch at the Australian Earth Sciences Convention, is heavily biased toward the extractive resource industry. However, the committee has had assurance that the full document will be readily available through the NCES website: (https://www.science.org.au/support/analysis/decadal-plans-science/decadal-plan-australian-geoscience). I suggest you refer to this one on your next grant application!

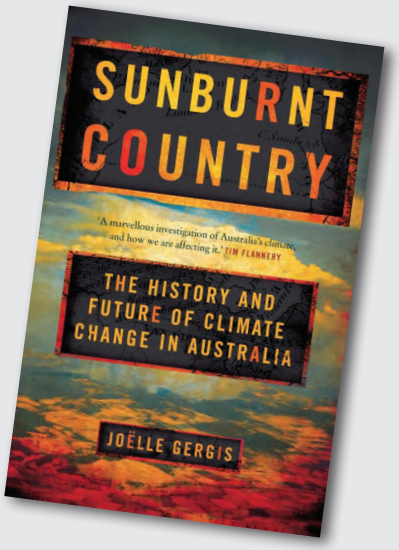
Sunburnt Country: The history and future of climate change in Australia

Dr. Joëlle Gergis

Melbourne University Publishing, April 2018.

Reviewed by: Lydia Mackenzie

Nanjing Institute of Geography and Limnology, Chinese Academy of Sciences, Nanjing, China



The Sunburnt Country spans the past, present and future of climate change in Australia – an ambitious endeavour! However, if anyone is up to this immense task it is Dr Joëlle Gergis, who is based at the University of Melbourne, Australia. Since completing her PhD in high-resolution palaeoclimatology she has lead the international Past Global Changes (PAGES) working group on Australasian climate variability of the past 2,000 years (Aus2K), building a 1,000-year regional temperature reconstruction for the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report. Gergis is also comfortable working across disciplines, leading the South-Eastern Australian Recent Climate History (SEARCH) project which combined science and humanities to reconstruct climate variability from Australia's first European settlers in 1788. This book is a product of the authors varied research past, following her career path from piecing together high resolution climatic reconstructions to investigating historical records. The reader could not be in better hands as the author leads us on a journey of scientific discovery and the implications of past, present and future climate change in our own back yards.

Part 1 (Colonial Calamities) of the Sunburnt Country gathers together the rich historical climate records stretching back to European Settlers 1788 arrival in Australia. This section is the product of the SEARCH project lead by Gergis which collated over 3,400 pages of historical weather records from newspapers, ship logs, government reports and early setter diaries from the southern states from 1788-1900. It quickly became clear that Australia was a place of climatic extremes, with drought, fires and floods occupying the minds of the early settlers. For example, one of the earliest descriptions of bushfire conditions in Australia in 1798 reports: "The heat of the sun was so intense that every substance became combustible, and a single spark, if exposed to the air, in a moment became a flame, much evil was to be dreaded from fire. (pg. 34)"

The author is honest about the limitations of such records, but despite this the reader is swept up in the breadth and depth of the observations available from this early chapter of European settlement in Australia. What the settlers didn't know was that the erratic weather they encountered was driven by Australia's competing seasonal weather patterns and longer climatic fluctuations including the El Niño-Southern Oscillation (ENSO), the Indian Ocean Dipole (IOD), and the Southern Annular Mode (SAM). The book's coverage of these climate modes is comprehensive, concise and accessible to a wide audience. This chapter captures the essence of what it was like to encounter an unfamiliar country and climate, with the author weaving personal observations and scientific knowledge into a captivating narrative. I found this chapter engaging and dense with historical data – a useful research tool for anyone embarking on palaeoenvironmental reconstructions within an Australian context.

Section 2 (Weather Watchers) combines historical accounts and early instrumental records to place recent climate extremes into a historical context. The birth of the Bureau of Meteorology (BOM) in 1908 standardised the method of collecting meteorological data and initiated monitoring of the nation's weather. This reduced the wide uncertainty in previous records from the colonial period where "thermometers were sometimes housed in beer crates on outback

veranda's (pg. 55)". Australia's earliest formal weather records can extend available instrumental data, allowing Gergis and her team to validate historical accounts against weather observations; testing if people who wrote about weather extremes were "just spinning us a colourful yarn!" (pg. 68). However, the author notes that even 110 years of instrumental observations is insufficient to capture the complete picture of Australia's natural climate variability – as Quaternary Scientists can well understand. This chapter highlight's the value of historical records, and how under-utilised this data is. Gergis also includes us on her own scientific journey as she rediscovers Australia's first handwritten meteorological record spanning 1788-1791 by William Dawes.

The SEARCH team's comparison of historical accounts and early meteorological records found settlers arrived during a mild period in Australia's climate. It wasn't until the summer of 1790-91 that temperatures reached the thirties and low forties °C in Sydney Cove, causing birds and bats to fall from the skies. Historical observations also revealed information about past extreme events including bushfires, floods and drought. Section two covers key events in Australia's recent past including the catastrophic Black Friday bushfires which directly or indirectly affected three quarters of Victoria in 1939. This section also begins to explore the role of current global warming on Australia's extreme events. While droughts are part of Australia's natural variability, the Millennium Drought occurred under different seasonal patterns of rainfall, with global warming already thought to be changing the nature of Australia's droughts.

Section three (Time Travellers) launches us further back in time to explore the natural climate archives available within the Australasian region. The reader is lead from the invaluable dendrochronology records of the ancient Kauri forests of New Zealand to the coral archives of temperature and flooding events from tropical northern Australia. Longer records of climatic variability are also explored, although briefly, including the Law Dome ice core records and lake archives. This section details the immense work of the PAGES 2k group in piecing the climate jigsaw together to produce a 1,000-year long record of climate change in the Southern Hemisphere. The landmark study highlighted the differences and similarities between the hemispheres past climates and found the post 1974 anthropogenically-driven warming was a global phenomenon, confirming that the entire globe is now warmer than at any other time in the past 1,000 years. As an Early Career Scientist I found this section very interesting as the book goes 'behind the scenes' and reveals the personal toll sometimes associated with producing a politically charged scientific breakthrough. The author recounts her personal experience of being caught up in the politics of the *Clean Energy Act* and climate debate of 2011, receiving hate mail and Freedom of Information requests, and struggling to correct a manuscript which ended with seven reviewers and nine rounds of reviews. The negative response to the hard work by a large group of scientists highlights the personal cost sometimes associated with working in the climate sciences – even within the Australian arena.

Part 4 (History Repeating) addresses common climate misconceptions, with the author giving a crash course in the causes of natural variability (astronomical variations, volcanic eruptions, sunspot activity etc). This section explores what the current combination of natural climatic variability and human-caused climate change means within an Australian context and is comprehensive and accessible to the public. The take home message of this section is that the world has entered a non-analogue state with the pace of global environmental change far beyond that of any historical counterpart in the geological past. The effects of current and future climate change is explored, including the increasing risk of bushfires, floods and rising sea levels. This chapter draws together supporting research from a wide range of exemplary Australian and international scientists and is both convincing and compelling.

Finally, section 5 (The Age of Consequences) of the Sunburnt Country looks at what life in Australia during the 21st century might be like if there is no reduction in global greenhouse gas emissions. This section ties together the preceding chapters, predicting the future impact of climate change on Australia's society and environment. The author covers a range of topics including the human health risks of climate change, and how the increasingly erratic Australian climate may require us to 'redraw the map'. The loss of unique and iconic Australian ecosystems such as the Great Barrier Reef and the Queensland tropics are used as emotive examples of what Australia has to lose with increasing global temperatures. The book ends with a call for the global community to reduce carbon emissions, vote wisely, and choose governments

that will take strong policy action on climate change, concluding with 'Together, we've got this'.

The Sunburnt Country weaves together historical accounts, scientific evidence and personal narrative to produce an engaging and informative read that highlights the extremely variable climate of Australia's past, present, and future. Gergis has taken a huge range of scientific literature and distilled it into something that the reader can relate to and is undeniably already occurring in Australia. This book is not a text book, nor is it a personal story of a scientist's career, but something in between. The scientific research cited throughout the text is up to date and the overview of complex climatic drivers sufficiently in depth for the purposes of this text. At times I found the structure of the book difficult to follow, with some repetition and disconnection between data heavy chapters and more personal stories. I found the first two chapters incorporating extensive historical data could have almost stood alone as a valuable collection of early weather records. However, the result is an engaging and emotive book.

I recommend the Sunburnt Country and believe it will appeal to a wide audience. For example, this book would be a good text for undergraduate students aiming to understand climate change within an Australian context. It is also useful to those of us working in reconstructing Australia's extremely variable past, and to anyone who is interested in how climate change will affect our 'own backyards' in the future.

Prehistory and Archaeology of Northeast India: Multidisciplinary Investigation in an Archaeological Terra Incognita

Manjil Hazarika

New Delhi; Oxford University Press, 2017. xxii + 325 pages. 978-0-19947-466-0 hardback ₹995.

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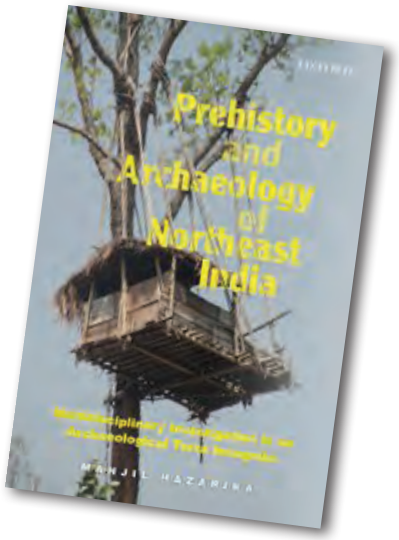

Northeast India is a region that has undeniably been archaeologically understudied, indeed it was entirely absent from Coningham and Young's otherwise excellent 2015 volume, *The Archaeology of South Asia*, while Chakrabarti's exhaustive *Oxford Companion to Indian Archaeology* (2006) makes only brief references to the region. Hazarika sets out many of the reasons for this archaeological marginalisation in his introduction; high levels of seismic activity, heavy alluvial deposition, thick vegetation, an extremely wet climate which both hinders fieldwork and results in significant groundwater, very poor preservation of organic materials due to the humid climate, and of course the significant political instability which has afflicted this area of South Asia for much of the last century.

However, despite these challenges, Hazarika argues that the region is critical not only to understanding the prehistory of northeast India, but more importantly to understanding key questions such as the domestication(s) of rice in Asia – lying as it does on the periphery of the accepted primary centre of domestication (the Yangtze Corridor), the "secondary" centre of mainland Southeast Asia, and the Gangetic plains of India – often propounded as an independent primary centre of domestication. Similarly, the author occasionally hints at the key role that this region *might* have played in the migration of anatomically modern humans out of Africa, and into Southeast Asia, and from there on to Australasia. In order to build this argument, and to explore these issues, the author attempts what he labels as a "multidisciplinary" approach – combining ethnographic, linguistic, and archaeological surveys of the region in order to examine the prehistory (in its widest sense) of the region.

It is fair to say that the books' origin as a doctoral thesis shines through in its structure, presentation and style – and this does not always make for the most entertaining read, but it does make for a very clear and easy to follow read. Hazarika begins by setting out detailed aims and objectives for the volume, focussing on the causes and mechanisms of cultural change in prehistoric

Northeast India, and specifically whether these changes were the result of indigenous invention, cultural diffusion, or population migration. Following the earlier "multidisciplinary framing", the author then kicks off with an ethnoarchaeological examination of the relationship between "man" (as Hazarika terms it) and environment in current day Northeast India. Hazarika's survey of the region's environment is detailed, but there is unfortunately no explanation or description of where his ethnographic data comes from, or how it was obtained – human behaviour is typically presented as fact, and is typically presented as universal throughout the region, with little distinction made between the different environments, ethnic or linguistic groups within the study area.

Hazarika then goes on to examine the different linguistic groups of these populations. First, by providing a detailed synthesis of historical linguistic studies within the region. Before introducing more recent genetic studies on eastern-Himalayan tribes in order to try and disentangle the waves of human migration, diffusion and interaction that passed through Northeast India – seemingly a critical corridor of movement during repeated multidirectional dispersal events during the late Pleistocene and early Holocene. The author then attempts to integrate "trade links" into this examination, leading neatly on to the main body of the book, two chapters examining the archaeological record of the region. The first of these two chapters (numbered Four and Five respectively) synthesises what little existing archaeological data there is, including a brief summary of the absence, to date, of any artefacts or sites associated with early hominin dispersals in Northeast India, and the continuing debate over possible later Palaeolithic lithics recovered from Neolithic sites in the region. We are then presented with a detailed synthesis of Neolithic sites in the region, broken down geographically, and covering more than 50 years of research.

Unfortunately, the majority of these sites lack any scientific dates, and Hazarika's summaries appear to be limited by the quality and quantity of data published for each site. However, tables characterising and summarising the lithics, ceramics, structures and economies of each region (by site) assist hugely in presenting this data, as does a table of all available scientific dates for Neolithic sites in Northeast India. Finally, closing the synthesis of existing archaeological data, Hazarika attempts to place the prehistoric archaeology of Northeast India within a regional context – contrasting and comparing the region's Neolithic with the surrounding regions – the Indian subcontinent to the west, and Southeast Asia to the east.

After some 154 pages of contextualisation, framing, and synthesis the volume finally presents new data, in the form of an "area approach" archaeological and ethnographic survey of the Garbhanga Reserve Forest, a National Park immediately south of the Brahmaputra river, and straddling the border of Assam and Meghalaya. This survey appears to follow the traditional South Asian "village-to-village" methodology (see Coningham *et al.* 2013 for a critique) and this non-probabilistic methodology, coupled with a shortage of detailed maps or figures presenting or illustrating the study area, render the data that follows somewhat descriptive and gazetteer-like. However, the ethnographic survey that follows, while similarly gazetteer-like in its presentation is detailed in its description of the local indigenous people, the Karbi.

This ethnographic study of the Karbi is followed by a discussion of the possibility of primary domestication of key cultigens species such as rice within Northeast India. Bringing together the ethnographic, archaeological and linguistic datasets, Hazarika reviews the *potential* the region has for early (or even primary) domestication. However, despite this comprehensive review there is no clear evidence at this point for either significantly early or primary domestication of any species within Northeast India. That said, Hazarika does present a persuasive argument for the rich potential of the region, both for early agriculture and for future archaeological research, concluding with a substantial list of avenues for future research in the region.

For anyone interested in the prehistory of South Asia, in prehistoric tropical forest societies, or in the development of farming in Asia, this volume represents an excellent addition to the fields' literature, and a long overdue coverage of an area that has long been overlooked and understudied. There are undoubtedly flaws in this study. Its repeated presentation of the Neolithic as a "revolutionary" period appears dated and at odds with more recent examinations of the development and adoption of agriculture, sedantism, and technologies such as ceramics (such Greene 1999 or Svizzero 2017 for discussion). In particular, it would have been good to have seen greater consideration of more nuanced long-term prehistoric anthropogenic impacts upon the tropical forests of Northeast India,

rather than focussing upon the establishment of agriculture. The recent *Nature Plants* paper by Roberts *et al*. (2017) provided an excellent review of human impacts upon tropical forests, and the potential that archaeology offers to better understand the relationships between hunter-gatherers and early-agriculturalists and tropical forests in Southeast Asia and South America, and this is one area that might be added to Hazarika's concluding list of future research for the archaeology of Northeast India.

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THESIS ABSTRACTS

Integration of wetland assessment and management into the hydrological landscape framework

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The Hydrogeological Landscape (HGL) Framework provides a landscape characterisation method to discern areas of similar physical, hydrogeological, hydrological, chemical and biological properties, referred to as HGL Units. The underlying principle of the HGL Framework is that water distribution and movement is controlled by climate, landform, geology, regolith, soil and vegetation properties. Through understanding the patterns of variability in the setting and controls of atmospheric, surface and groundwater systems for a given landscape, the developed HGL Units can be used for hazard assessment and natural resource management centred on water availability, quality, sustainability and associated ecological systems. Applications of the HGL Framework have been used to address dryland salinity, urban salinity, soil and land degradation issues across New South Wales, Tasmania and the Australian Capital Territory (ACT).

Wetland presence is determined by the water balance of a given landscape area which favours water to be stored on top of the ground, be it permanently or for temporary periods of time. The water sources and losses for a wetland, varying contributions from each and resulting spatial and temporal dynamics, can allow for a wide variety of wetland water balance equations and hydrological types to be determined. Existing wetland frameworks demonstrate it is the hydrogeomorphological or hydrogeological characteristics of the landscape that will determine the variability in water inputs and outputs for a wetland water balance, a principle shared with the HGL Framework. It is therefore logical that HGL Units and Management Areas can be used as planning units for wetland hazard assessment and management.

There are 3 parts to this research: the expansion of the HGL Framework method; using the HGL Framework for wetland hazard assessment and; using the HGL Framework for wetland management. The parts of the thesis are addressed through 5 research aims. The first aim of this research is to trial the use of the Self-Organising Maps (SOM) algorithm to assist in the validation of HGL Units. The second aim is to trial the use of landform modelling to delineate Management Areas within HGL Units. The third and fourth aims are to develop both rapid and detailed wetland hazard assessments where indicators and risk matrices are used to rate and prioritise HGL Units, Management Areas and individual wetlands for further investment and undertaking on-ground Management Actions. The fifth aim is to use the concepts developed in this research to construct a Wetland Module within the HGL Framework to enable wetland managers to identify and prioritise Wetland Functions, effectively select Management Strategies and appropriate on-ground Management Actions to improve current or mitigate future identified hazards. That provides a HGL Framework hazard assessment and natural resource management context that has not previously been explored.

Application of the HGL Framework developed 74 regional scale HGL Units for the South East Local Land Services region study area and 25 local scale HGL Units for the ACT study area. Inclusion of the SOM algorithm in the HGL Framework methodology complements the existing expert interpretation and field based validation and testing techniques. The SOM analysis is particularly useful in study areas that the HGL team is less familiar with or where it is financially and logistically challenging to undertake comprehensive targeted testing. The landform modelling approach effectively delineated landscape categories across the ACT, with attribution of Management Areas successfully discerning internal HGL Unit complexity. The modelling outputs and Management Area attribution was able to spatially map both simple topographic sequences in the Werriwa Tablelands and more complex sequences in the Australian Alps (with minor modification), therefore providing a very dynamic landscape characterisation technique to integrate into the HGL Framework methodology. The combined use of SOM and landform modelling techniques ensures greater rigor in determination of landscape patterns, thereby creating a more refined HGL Framework landscape characterisation, hazard assessment and natural resource management tool. Because this approach recognises areas in the landscape that have a discrete set of landscape properties, comparisons can be made within a landscape, across a region, and between regions, nationally and internationally.

The HGL Units and Management Areas developed in the earlier part of the research were effectively used as planning units for both rapid and detailed wetland assessments. Regional scale SE-LLS HGL Units were used for a rapid hazard assessment for 11799 wetlands across the Southern Tablelands, to identify broad locations with lower risk to investment and therefore higher potential for successful management. The ACT Management Areas were effectively used as planning units to attribute data to 1296 wetlands and undertake a detailed wetland assessment. The Management Areas identified the internal complexity and topographic sequences within the local scale ACT HGL Units, therefore facilitating a refined hazard assessment which would not have been possible previously, and linked the specific landscape setting to each individual wetland. Variables used in the wetland assessments represented indicators of current anthropogenic pressure, future hydrological change in water sources and losses and future ecological change in vascular plant and amphibian communities. The detailed assessment also assessed multiple climate futures (consensus, wet-cool extreme and dry-hot extreme scenarios) allowing wetland managers to consider a range of likely futures and possible desired outcomes.

The developed HGL Framework Wetland Module is consistent in approach with the Ramsar Convention wetland vulnerability to climate change assessment framework, and further integrates leading Australian and international conceptual literature. It provides a trade-off analysis for wetland managers to allocate and prioritise Wetland Functions, Management Strategies and Management Actions, to improve or mitigate the currently occurring or identified future hazards. An applied example of the Wetland Module is illustrated using the Ginini Flats Wetland Complex case study.

Unlocking the Kimberley's past: The applicability of organic spring deposits for reconstructing late Quaternary climatic and environmental change

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There are limited high-resolution records of climatic and environmental change from the Kimberley region of northwest Australia. This has hindered the development of knowledge of climate and environmental change in Australia's monsoonal tropics, and the ability to provide context for the area's rich archaeological record and globally renowned rock art. The lack of high-resolution records from this region is primarily a result of the monsoonal climate which limits the presence of "classic" palaeoenvironmental archives such as perennial lakes and wetlands. Organic spring deposits are unconventional archives of past environmental change yet offer potential to provide outstanding records in arid and semi-arid regions such as the Kimberley. Despite this, the majority of existing research demonstrates complications with their use, in particular the application of standard radiocarbon (^{14}C) techniques to build robust chronologies of their development. Because of the importance of springs as critical palaeoenvironmental archives, and the pressing need for high-resolution records from

northwest Australia, this thesis utilised three organic spring deposits to develop new, high-resolution records of climate and environmental change for the Kimberley. These records span the last ~14,500 years, and were underpinned by a new protocol for establishing robust chronologies from these settings which was developed via a rigorous geochronological investigation.

Initial ^{14}C results from a core collected from Black Springs in 2005 were confusing, with convoluted ages below 94.5 cm limiting the reliability of an initial palaeoenvironmental reconstruction >9070 cal. yr BP. A new protocol for obtaining robust chronologies from organic spring deposits was therefore developed for cores collected from the three sites in 2015, utilising multiple geochronological methodologies including ^{14}C dating of different carbon fractions (stable polycyclic aromatic carbon (SPAC), macro-charcoal, pollen concentrate, bulk sediment and roots), ^{210}Pb dating, the application of $^{239+240}$Pu, and high-spatial resolution, luminescence techniques (natural sensitivity-corrected luminescence (L_n/T_n)). Whilst L_n/T_n demonstrated that the organic spring deposits contained a relatively uncompromised stratigraphic record, ^{14}C dates were contaminated by roots, groundwater fluctuations, and incorporation of allochthonous "old" carbon. SPAC isolated by the hydrogen pyrolysis (HyPy) pre-treatment appeared to remove post-depositional sources of alteration, and therefore provided a viable approach for constructing chronologies in these settings. Developing more recent chronologies (i.e. the past 100 years) using ^{210}Pb was found to be problematic due to the behaviour of the springs as an open system with regards to uranium, suggesting this may not be possible in many spring environments. Whilst this investigation was made with respect to springs, the contamination pathways are not unique to these settings and therefore the chronological developments are more widely applicable (e.g. for constructing chronologies in archives subject to deep root growth and/or significant changes in hydrology).

This new dating protocol enabled the climatic and environmental reconstructions from the three new records presented in this thesis to be placed on secure timescales. These new records utilised pollen, micro-charcoal, non-pollen palynomorphs (NPPs) and elemental geochemistry (Itrax micro X-ray fluorescence (◂XRF) core scanning). Principal Components Analysis (PCA) axis 1 scores demonstrated similarity between inter-site elemental geochemistry and non-pollen palynomorph datasets, although there were significant discrepancies between the pollen records which reflected predominantly local conditions. In order to isolate dominant modes of regional variability, Monte Carlo Empirical Orthogonal Function (MCEOF) analysis was applied to proxies from the geochemistry and NPP datasets, providing a regional reconstruction of climatic variability in the Kimberley for the last 14,500 years. The results of this reconstruction show increasing monsoon activity from 14,500 cal. yr BP consistent with the deglaciation, followed by peak monsoon activity during the early-Holocene (between ~11,000 – 7500 cal. yr BP). There is a trend of decreasing monsoon activity throughout the remainder of the Holocene, interrupted by a short period of wetter conditions at ~4200 cal. yr BP, and peak aridity spanning ~2600 – 1000 cal. yr BP.

This thesis makes a significant contribution to understanding of climatic change in Australia's monsoonal tropics, in particular long-term changes in monsoon activity in northwest Australia since the Last Glacial-Interglacial Transition (LGIT). It also provides a method for building reliable chronologies in organic spring deposits which are critical palaeoenvironmental archives in arid and semi-arid environments. In light of the Kimberley's rich archaeological record, requirements have been highlighted for the need to extend high-resolution palaeoclimate reconstructions in the region to ~50,000 cal. yr BP to encompass the entire known history of likely human occupation in the region.

The Application of Dendroclimatology to Reconstruct Long-Term Rainfall Records for Subtropical Southeast Queensland, Australia

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In the tropical and subtropical regions of eastern Australia multidecadal periods of floods and droughts have major economic and environmental consequences. Due to the short duration of instrumental rainfall records in this region the temporal pattern of these extreme events is poorly understood. Subtropical Southeast Queensland (SEQ) is one area that frequently experiences floods and droughts and is lacking in both instrumental rainfall records and sources of proxy data. There are old growth forest stands found in National Parks where dendroclimatology, the reconstruction of climate using tree-rings, can be applied. Tree rings have been widely utilized in temperate environments to provide annually-resolved centennial-scale climate information. However, in tropical and subtropical regions dendroclimatology has been underutilized, as many species in these regions are difficult to analyse. These species have short life-spans, poorly preserved timber, and are believed to exhibit numerous ring anomalies making dating of ring series difficult. Due to this, few species have been analysed for relationships between tree growth and climate. Recent reviews of both tropical and Australian dendrochronology have suggested that if a multi-technique approach is applied more species could be found suitable for use in reconstructing climate.

This thesis first reviews the dendroclimatological history of Australia evaluating 36 studies across the continent that examined tree and shrub species for growth-climate relationships. This review showed that all four climate zones of Australia; temperate, arid, tropical, and subtropical, contained species that had the potential to provide high-quality, long-term climate reconstructions in areas under represented by instrumental data. Only four climate reconstructions have been developed in Australia. In all of these studies a combination of traditional ring-width measurements and modern analysis techniques allowed for the reconstructions to be developed. Several species located in SEQ had been assessed for growth-climate relationships and were found to grow as a result of rainfall conditions, with trees in the *Araucariaceae* family demonstrating the most potential. These trees are longer-lived than most tropical/subtropical species, are known to put on annual rings, and grow as a result of environmental conditions which led them to be targeted in this thesis.

Secondly, to test the spatial patterns of SEQ rainfall the instrumental data network was evaluated with Pearson correlation analysis undertaken on 140 rainfall stations active during 1908 to 2007. Stations are clustered into groups that correlate at r = 0.80, 0.85, and 0.90 levels. The pattern produced indicates that rainfall across SEQ is not uniform with correlated groups being separated by the Great Dividing Range with both coast-inland and north-south separations. To determine the effect this spatial variability has on the spatial applicability of rainfall reconstruction, the 140-year *Toona ciliata* tree-ring width record developed by Heinrich *et al.* (2009) is compared with the different rainfall groups and subgroups observed across SEQ. The rainfall reconstruction is found to best represent the spatial subgroups within which it is contained rather than representing the entire regional rainfall network. This suggests that several sites within SEQ need to be targeted to develop rainfall reconstructions for the region.

Consequently three spatial distributed sites are targeted within SEQ with cores collected from *Araucaria cunninghamii* trees in D'Aguilar and Lamington National Parks and *Araucaria bidwillii* trees in Bunya Mountains National Park. These *Araucariaceae* cores are assessed for ring anomalies though the application of visual ring dating with false, faint, locally absent, and pinching rings found to be present in both species. However, through the use of bomb-pulse radiocarbon dating of *A. cunninghamii* samples anomalous rings are identified and annual growth patterns determined. Dendrometers are installed at the Lamington and Bunya Mountains sites to determine the exact growth-climate relationships for these species in SEQ. The amount of growth experienced by these trees is driven by annual rainfall while minimum temperatures are shown to be influencing the start and conclusion of the growth seasons. These results suggest that annual rainfall can be reconstructed from *Araucariaceae* trees when dating is verified using radiocarbon dating to account for ring anomalies.

Two statistically significant rainfall reconstructions developed from *A. cunninghamii* trees are then presented. The first is a 69-year rainfall reconstruction for Brisbane developed from the D'Aguilar site. The trees at this location are all found to exhibit faint, indeterminate ring boundaries making them unsuitable for traditional

visual ring-dating. A new method is presented using x-radiographs and density patterns scanned using an Itrax core scanner to build this reconstruction. Thirty-nine 12mm cores from twenty trees have their ring boundaries identified on the Itrax produced images based on features visible in the radiographs and the density patterns. Bomb-pulse radiocarbon dating is performed to verify the chronology. Climate response function analysis demonstrates that growth in driven by Austral annual (June-May) rainfall. The second reconstruction is a 164-year record developed from eighteen trees located in Lamington National Park. A field sampling strategy is applied where multiple cores are collected from the upslope, downslope, and across-slope sides of the study trees to help eliminate anomalous ring issues identified as being prevalent in these species. This chronology is then developed using traditional visual ring identification complemented by bomb-pulse radiocarbon dating to verify and correct the ring counts. Climate response function analysis indicates that Austral annual (June-May) rainfall is driving growth in these trees. Comparisons to both a Brisbane rainfall station (located about 100km from the Lamington site) and a station local to Lamington are undertaken with the rainfall signal at the local site more closely related to tree growth. Drought conditions are well represented by this chronology. The El Niño Southern Oscillation is found to be driving rainfall for the Lamington area but only since the 1940s.

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Astronomical Forcing of Sub-Milankovitch Climate Oscillations during the Late Quaternary

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A climate signal of ~1500-yr quasi-periodicity (e.g., Bond events) has been found from the Arctic to Antarctica, in palaeoclimatic data derived from a range of environmental proxy records. Solar and lunar forcing have individually been suggested as the cause of this millennial-scale signal, although some contend that it is little more than stochastic resonance within the climate system. Also debated is whether this climate signal is forced by the ocean-atmosphere dynamics of the North Atlantic or the tropical Pacific, as well as relevant climatic teleconnections. The cause of this cycle is elusive as no known solar cycle of this length exists, whilst forcing due to lunar gravitation has been dismissed as being too weak.

The most likely cause of any periodic climate signal is an astronomical one, as demonstrated in Milankovitch cycles. This thesis explores a potential astronomical cause of millennial – and centennial – scale periodicities and variability, based on a combination of solar and lunar forcing. Conceptual and trigonometric models, physical models of insolation, solar irradiance, and gravitation, and astronomical data were used in this exploration. Identified as a possible cause of the ~1500-yr climate cycle is precession. Precession changes the timing of Earth's seasons relative to our calendar and external reference points, such as the fixed stars and the closest point in Earth's orbit to the Sun (the perihelion).

The primary actors in precession are the Sun and Moon through their gravitational influence on the rotating Earth. Significant climatic impacts of precession are seen in the ~21-ky Milankovitch precessional cycle, the result of two interacting precessional cycles: equinoctial (associated with the seasonal/tropical year) and apsidal (associated the perihelion and anomalistic year). This thesis investigates precession at a high-frequency scale, enabling a more detailed tracking of the moving seasons relative to the moving perihelion at sub-Milankovitch scales through-out the last 5,500 yrs.

This research found a statistically-significant, strong positive correlation between solar irradiance reconstruction derived from Antarctic ^{10}Be ice-core data and a normalised, chronologically-anchored model of superimposed astronomical cycles that emulates the ~1500-yr climate cycle. Pronounced millennial-scale signals were observed in Earth-Moon distances and gravitation data. Maximum forcing occurs at perihelion, close to lunar perigee and Bond events occur at these points during the range of the astronomical data. Previously identified potential components of the ~1500-yr climate signal, *viz* the 209-yr Suess de Vries cycle and a 133-yr cycle, can be clearly seen in the astronomical and physical data. Modelled, high-frequency, perigee-perihelion interaction by this research reinforces these results, reproducing and explaining the variability of millennial-scale

climate signals. Such variability is also supported through the movement relative to the tropical year, in conjunction with mapping of Metonic lunation and perihelion positions.

Supported by multiple lines of evidence, the results of this thesis suggest that the Sun and Moon act together through gravitation and insolation to produce millennial-, centennial-and decadal – scale climate signals through tidal forcing of Earth's atmosphere and ocean. Key mechanisms and components are precession, perihelion, perigee, lunation, and nutation (wobble of Earth's axis). Key inferences from these results are that astronomical forcing influences radiocarbon chronological variability, such as marine reservoir values, variability and time lag in radiocarbon data, and also suggest that the 209-yr SdV cycle is caused by combined solar and lunar forcing rather than previously inferred solar variability.

Palaeofire activity in western Tasmania: climate drivers and land coverage changes

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Under the current changing climatic regime, in which wildfires are predicted to increase in frequency and magnitude, it is important we gain a better understanding on past climatic trends and fire activity to properly manage fires and landscapes, preserve valuable natural ecosystems and protect human lives and properties.

Fire activity is especially projected to increase in temperate regions, such as Australia's southeast. In this context, western Tasmania represents a key region where the environmental impacts of wildfires can be disastrous for the remnant pockets of fire-sensitive vegetation.

Climate influence on fire activity and vegetation dynamics operates at multiple timescales, from inter-annual to multi-millennial. Given the time limitation of historical records, we need to look at long-term records to gain a better understanding on what modulates fire activity and how changes in fire regimes influence ecosystem dynamics. This PhD project aimed to a) identify the climate drivers of short – and long-term fire variability in western Tasmania and b) quantify climate – and fire-driven vegetation changes in this region throughout the Holocene.

To understand the short-term drivers of fire activity in western Tasmania, I explored the relationship between the main climate modes of the Southern Hemisphere and a documentary record of fire occurrence from this region. This analysis suggested that the Southern Annual Mode (SAM) – an index for the position and strength of SWWis strongly correlated with inter-annual fire activity across western Tasmania during the last 25 years. Moreover, the persistent positive trend in SAM recorded during the last 500 years was found to be tightly coupled to increased biomass burning within the same region.

To understand the long-term landscape changes in western Tasmania, I combined high resolution pollen and charcoal analyses, coupled with recently developed mathematical modelling of pollen dispersal and productivity. Within this Thesis, I applied pollen dispersal models to calibrate the pollen-vegetation relationship for the first time in Australia. This method involves two steps: (1) a modern pollen analysis coupled with distance-weighted vegetation data to calibrate the present-day pollen-vegetation relationships and (2) an application of these relationships to a fossil pollen record to produce past vegetation cover estimates. The application of pollen dispersal models proved the biases inherent in previous interpretations of pollen spectra from western Tasmania. Specifically, the results from these analyses showed that this region was mostly dominated by treeless moorland vegetation, supporting the identification of western Tasmania as a cultural landscape. Moreover, my results showed that land-cover changes throughout the Holocene occurred in response to climatic change and a shift in fire regimes due to ENSO/SWW interactions.

Controls on salt mobility and storage in the weathered Jurassic dolerites of North-Eastern Tasmania

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In Tasmania most salts in the landscape originate from precipitation and accumulate in landscapes after evaporation occurs. Changes in land use and vegetation due to agriculture, forestry practices and urbanisation can accelerate salinity effects leading to land degradation and potentially threatening infrastructure and ecosystems. Researchers of salinity hazards (Moore *et al.*, 2014) identified that salinisation was associated with deeply weathered dolerite in some regions around Launceston. Previous studies did not consider dolerite to be a significant salt store, meaning that the volume of salt stored in the landscapes may have been underestimated. There also has not been research into the geomorphic and structural controls on salinity and the flux of salt into the region.

The chemical composition of rainwater from an array of bulk deposition collectors was studied from Spring 2013 to Winter 2014. The average salt flux was 79 ± 10 kg/ha/yr in the study region, ranging from 170 ± 12 kg/ha/yr in the north to 42 ± 6 kg/ha/yr inland. The sites closer to the north and east coast were more influenced by marine sources compared to samples collected inland and during drier months, that had a stronger terrestrial influence. The geomorphic factors affect the chemical composition, volume of rainfall and flux of salt from windblown dust and oceanic aerosols.

The geochemical composition and mineralogy of dolerite-derived regolith has been examined in order to understand the association between salinity and weathered dolerite. Dolerite breaks down to form smectite (mostly montmorillonite), kaolinite and Fe-bearing sesquioxides. Salt can be stored in the pore spaces between these minerals, by adsorption and in their interlayer spaces (smectite). The electrical conductivity of 1:5 soil/waters suspensions is higher in the more weathered dolerite material (maximum 4.9 dS/m). The clay content and salinity of the dolerite regolith profiles varies, depending on the local geomorphic context. There are fault-bounded pockets of colluvium and highly-weathered, *in-situ* dolerite material, where 2:1 montmorillonite clays dominate. These regions have the capacity to store large volumes of salts.

By exploring the complex interactions of geomorphology and other biophysical parameters the study area has been divided into Hydrogeological Landscape (HGL) units. The HGL units have a range of structural and geomorphic controls which affect the configuration of the regolith (salt store) and where there are impediments to flow. Associated conceptual models describe the regolith distribution, how and where salt is stored and how water moves through the landscapes.

The amount of salt moving through the surface catchments has been examined using the bulk deposition model as inputs, and loads calculated from flow and electrical conductivity data from stream gauging sites as outputs. Sub-catchments importing more salt than exporting, have high salt stores, and geomorphic features that impede the flow of water leading to higher rates of evaporation. Sub-catchments with greater outputs than inputs are characterised by high rainfall and steep slopes combined with either low salt stores (well – or moderately well-drained soils and thin regolith cover) or moderate to high salt availability or both.

By examining climate change models, it is predicted that there will be an increase in salt deposition and a larger volume of salt stored in the regolith in regions that are low-lying and have geomorphic impediments to flow (very high risk HGLs). This will impact most upon those regions that are currently close to equilibrium (i.e. those that currently fluctuate between exporting and storing salt). Unless the land susceptible to salinisation is managed carefully, a greater area will be impacted by land and water salinisation.

The use of speleothem palynology to elucidate late-Holocene vegetation change on the Nullarbor Plain, Southwestern Australia

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Fossil pollen from two stalagmites is examined to reconstruct the vegetation of the Nullarbor Plain over the past 2000 years. This novel approach to palynology takes advantage of the ability to date calcite with high precision using U-Th techniques, and avoids the issue of poor preservation of pollen that is sometimes associated with arid-zone lacustrine deposits.

Environmental changes over the past 2000 years are most commonly reflected in intra-family variation in chenopod species abundance, though a peak in woody taxa between 1.0 and 0.8ka is interpreted as evidence of increased moisture conditions around the proposed time of the Medieval Climate Anomaly (MCA). Whilst no strong palynological signal is observed at the time of European colonisation of Australia, a significant change occurs in the past 40 years, which is interpreted as a vegetation response to fire.

As speleothems rarely contain enough fossil pollen for analysis, the taphonomic biases of speleothem archives remain poorly understood. This study, as well as being a high-resolution record of environmental change, presents an opportunity to examine these taphonomic filters. The record is shown to be sensitive to episodic deposition of presumably insect-borne pollen, but despite this, appears to provide a faithful representation of local and regional vegetation change. The study demonstrates the need for greater research into taphonomic processes, if speleothem palynology is to be developed as a viable alternative to lacustrine sediments in the investigation of past environments.

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UPCOMING MEETINGS

JUNE 2018

POLAR2018
(ASCAR and IASC Conference)

Venue: Switzerland

Date: 15-26 June 2018

www.polar2018.org

INQUA INTAV
(Including TEPHRA HUNT in Transylvania – Crossing New Frontiers)

Venue: Brasov, Romania

Date: 25-29 June 2018

www.comp.tmu.ac.jp/tephra/intavtmu/pg772.html

www.facebook.com/groups/INTAV/

ICAR – International Conference on Aeolian Research

Venue: Bordeaux, France

Date: 25-29 June 2018

https://colloque.inra.fr/icar2018

JULY 2018

5th International Palaeontological Congress (IPC)

Venue: Pierre and Marie Curie University, Paris, France

Date 9-13 July 2018

https://ipc5.sciencesconf.orgresource/page/id/38

AUGUST 2018

20th International Sedimentological Congress

Venue: Quebec City, Canada

Date: 13-17 August 2018

www.isc2018.org

SEPTEMBER 2018

EXAQUA2018 Hungary
Paleohydrological extreme events: evidences, archives, models, future perspectives

Venue: Kis-Tisza Ecocenter, Tiszalök, Hungary

Date: 9-14 September 2018

Contact: exaqua2018@gmail.com

http://kistisza.hu/en/exaqua-2/

LOESSFEST 2018

Venue: Volgograd, Russia

Date: 23-29 September 2018

http://loessfest2018.ru

NOVEMBER 2018

Ecological Society of Australia Meeting

Venue: Brisbane, Australia

Date: 25-29 November

http://esa2018.org.au/

DECEMBER 2018

2018 AQUA Biennial Conference

Venue: Acton Peninsula, Canberra, Australia

Date: 10-14 December 2018

www.aqua.org.au/conference/aqua2018

ADVANCED NOTICE

JULY 2019

XX INQUA Congress

Venue: Dublin, Ireland

Date: 25-31 July 2019

www.inqua2019.org

SEPTEMBER 2019

13th International Conference on Paleoceanography (ICP13)

Venue: University of New South Wales, Sydney, Australia

Date: 1-6 September 2019

www.icp13.com.au

DETAILS TO BE CONFIRMED

2019

Society of Vertebrate Palaeontology

Venue: Brisbane

Date: 9-12 October 2019

2020

Palaeo Down Under 3

Venue: Brisbane

Above: Figure 1. Mungo man returns to country (Photo credit: Jessica Reeves) See article page 6

Below: Figure 2. Jim Bowler (Photo credit: Jessica Reeves)

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