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Quaternary AUSTRALASIA

Maria Island blockfields

The potential of ground penetrating radar

Focus on AQUA 2014 Mildura

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FRONT COVER PHOTO:
Biological anthropologist, Dr Colin Pardoe, examines the remains of Kiacatoo Man in central New South Wales.
Photo courtesy of Justine Kemp.

EDITORIAL

Dear Fellow Quaternarists,

As 2014 draws to a close, so too does a busy year for the Australasian Quaternary science community! Doubtless the highlight for many AQUA members was the Mildura meeting, which celebrated our organisation's 30-year anniversary and brought us back to where it all began. As a reflection on this big event, each of the students awarded at the meeting report on different aspects of the conference. Kelsie Long and Dorcas Vannieuwenhuyse provide palaeoclimatologist's and archaeologist's perspectives of the presentations respectively; Daniela Mueller and Dierdre Ryan describe the pre – and mid-conference field trips and Ignacio Jara chronicles the Willandra excursion; Suman Asadusjjaman covers the Public Lecture; and Bronwyn Dixon delights in the lighter side of the meeting, the traditional trivia night. Furthermore, John Magee thanks the AQUA community for his award of the Lifetime Membership to AQUA, bestowed at the Mildura meeting. Congratulations to the students on their excellent presentations and we're glad to see you contributing to Quaternary Australasia!

AQUA Mildura was not the only meeting at which Australasian Quaternarists have been active this year. We have several additional workshop reports, including one for the European INTIMATE brainstorming session in Zaragoza thanks to Helen Bostock, and Joelle Gergis' discussion of the recent PAGES Aus2K workshop.

Our news section is somewhat larger than in previous issues. Among other items, our newly instated communications coordinator, Claire Krause, discusses the merits of new forms of providing information to our community, through means such as shared online teaching resources and Wikipedia. Please get in touch with her if you would like to get involved!

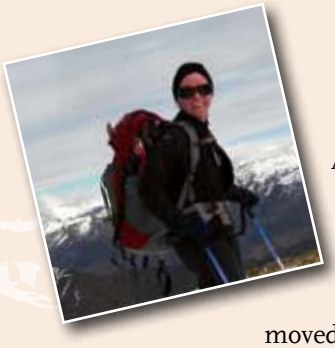
We also publish two research articles in this issue. Justine Kemp discusses some advances in ground-penetrating radar technology, and describes its application in a survey near the Kiacatoo Man burial site in central New South Wales. Periglacial geomorphology forms the focus of Adrian Slee and Kevin Kiernan's short research note on the low elevation blockfields of Maria Island in Tasmania.

Finally, Esmee Webb offers her perspective on what constitute icons and significant sites in Western Australia, in response to recent reports in QA describing "iconic" sites across Australasia (Fitzsimmons 2012: 29(2), 14-27 and Ward 2013: 30(2), 24-31). Hopefully her opinion piece will spark further discussion not only with respect to the perception of site significance, but also regarding the future of interdisciplinary communication across Quaternary science and archaeology.

QA's existence and persistence is based on your contributions, so please keep them coming!

Yours Quaternarily,
Kat Fitzsimmons and Pia Atahan *Editors*

PRESIDENT'S PEN



It has been a big year for AQUA with the biennial conference held in Mildura in July to mark the organisation's 30-year anniversary. I am sure all of you who were able to attend the conference would agree that AQUA 2014 was a great success. I would like to pass on our thanks to Jessica Reeves and her team who planned and coordinated all the different activities during the conference. There were a large number of highlights from the conference, many of which are covered by articles in this issue from the students who received awards to attend. The highlights for me were to see the overlap and integration of the Quaternary and archaeological records, that some of the accepted dogma on the Australian climate at the last glacial maximum is being challenged by new work, the use of Quaternary science to develop management strategies, and there were some excellent talks in the SHAPE session. But undoubtedly the stand out was the Lake Mungo field trip. I have never seen such a huge convoy of vehicles and large number of people on one field trip, shepherded by Harvey Johnston. It was great to hear from so many experts about the past and ongoing work that is being undertaken in the Willandra Lakes region. I am sure that over the next few years many more important secrets of the Mungo region will be revealed. AQUA will endeavour to support proposals to include Joulni into the heritage area and provide a suitable location for the return of Mungo Girl and Mungo Man.

As well as revelling in the past glory of AQUA we have also been moving forward into the 21st century. Over the past couple of years we have updated our website, put all of the QA online, moved our membership registration online, had a blogger writing regular articles, and now have almost 150 members on facebook. We have even been active on twitter... After the special general meeting at AQUA we have also recently ratified our constitution in line with new law changes. A copy of the constitution is up on our website. Please read the short article by our Treasurer Steven Phipps which outlines the key changes.

Over the next couple of years one of our aims is to improve our outreach and we have recently created a new communications role on the AQUA committee, which has been taken on by Claire Krause (in addition to her IT role). She has introduced herself and discusses some new ideas in a short article in this issue. If you have any other ideas then please do not hesitate to get in touch with her.

With 2015 just around the corner we hope that many of you will be planning to attend the XIX INQUA congress in Nagoya, Japan in July, showcasing the wide range of Quaternary activities being undertaken in the Australasian region. Then in 2016 we invite you to the next AQUA, in Auckland, New Zealand (as voted for by the participants of AQUA 2014).

Helen Bostock *AQUA President 2014*

MEET A MEMBER OF THE AQUA EXECUTIVE COMMITTEE

SCOTT MOONEY: VICE PRESIDENT, AQUA

Scott grew up on the northern beaches of Sydney, which explains why he gets grumpy if he isn't immersed in salt water regularly. Somewhat unusually for someone from this area, he has had a long association with UNSW (on the 'wrong' side of Sydney), receiving his PhD in 1996 and teaching there (off and on) since 1988. Scott is too impatient to be a palynologist and so tends to use multi-proxy methods to investigate climate variability and human impacts, especially in the late Holocene, although this temporal focus has been slowly extending into the post-glacial period. Like most academics he has no off-button: when not officially working he can be found in mountains considering tree-lines, mires and what he should have for dinner that night. He is currently obsessed with Monte Bianco and is trying to work out how his next research grant can include significant time in the Italian alps.

NEWS

NEW FOCUS ON AQUA COMMUNICATIONS

The outreach activities of AQUA are getting a makeover! A new committee position has been established to oversee the outreach and communications activities of AQUA. In the first instance, Claire Krause will be taking on the role of "communications coordinator", aimed at promoting our organisation, research and members to a wider audience. Alongside this new initiative, she will also be taking over the role of IT coordinator, and will be giving the AQUA website a facelift.

Communications activities will be initially targeted towards two key initiatives:

Developing online teaching resources to be made available via our website

We would like to start to harness the expansive knowledge of the AQUA community through the development of a series of online teaching resources. These will be made publically available via the website and can be targeted at a range of audiences, from high school through to post-graduate and beyond.

The material should be on topics relating to the Quaternary, and should be self-contained and suitable for general use.

If you have PowerPoint presentations or slides, self-contained practical lessons, PDF notes or any resources you'd like to provide, please contact Claire Krause (claire.krause@anu.edu.au), to organise putting this material online.

Wikipedia – Increased Australasian Quaternary content needed!

Learning about completely new topics usually begins with Wikipedia. Wikipedia is the largest encyclopaedia in the world and the great thing about it is that it is constantly updated and changing and anyone can contribute. Here is your chance to make sure Wikipedia has lots of information about the Quaternary in the Australasian region. At the moment, a number of our key Quaternary sites do not have a Wikipedia page or presence, making it difficult for the general public to access and learn about them without digging through peer-reviewed literature (the latter is usually not available or too technical for the public).

Therefore we would like to encourage everyone to produce Wikipedia articles on your favourite Quaternary sites (or proxies) such as: Wanganui Basin, Lake Keilambete, or the Kosciuszko massif in NSW? Or maybe you'd be able to help fill out or correct existing Wikipedia articles on Liang Bua in Indonesia, Lake Frome in South Australia or add some information on the paleohydrology of Lake Eyre? All you need to do is follow the online template and provide some references. These will be fact checked by someone before the Wiki page goes live.

We'd also like to lift the profile of successful scientists within our field, assisting people to find and connect with researchers working within the Quaternary. If Elmo has a Wikipedia page, then surely the likes of Jim Bowler, Jeanette Hope and Jessica Reeves should also be represented!

If you would like to put together a Wikipedia article, please contact Claire Krause (claire.krause@anu.edu.au), who is coordinating our contributions.

AQUA HAS A NEW CONSTITUTION

Our previous constitution had served us well for many years, but was becoming increasingly out-of-date. The biggest limitation was that members had to be physically present to count towards the quorum at Annual General Meetings. This was often hard to achieve, and required us to pay the travel costs of Executive members so that they could travel interstate to attend meetings in person. Also, in 2012, Victoria overhauled the laws that govern incorporated associations such as AQUA. This abolished the role of public officer and made other changes that rendered our constitution even more obsolete.

It was therefore time for an upgrade. Starting with the model constitution supplied by Consumer Affairs Victoria, we transferred all the key features from the old constitution (such as our name, scope and purposes). We also took the opportunity to add a couple of new features. Firstly, we added term limits for the President and Vice-President, who may not now serve more than two consecutive one-year terms. Secondly, we specified the process for creating life members, which was not previously defined. The new constitution states that:

"A Life member is a person who has made an outstanding contribution to Quaternary Studies over a substantial period of years or who has provided exceptional long-term service and support to the Association. A Life membership is proposed by the Committee and must be approved by a general meeting. Life members are not expected to pay fees and may choose to receive any publications produced by the Association. A Life membership cannot be proposed if

the number of Life members exceeds 5 percent of the total number of members."

Most importantly, the new constitution allows members to take part in meetings remotely and still count towards the quorum.

A Special General Meeting was held on 3 July 2014, as part of the Biennial Meeting in Mildura. The new constitution was adopted unanimously, and was subsequently approved by Consumer Affairs Victoria. As a result, AQUA now has a fully up-to-date constitution, that should serve us well for many years to come. Anyone who would like to read the 21-page epic can find it on our website.

EUREKA PRIZE WINNER – JOELLE GERGIS AND THE SEARCH TEAM

Congratulations to Joelle Gergis and the SEARCH (South-East Australian Recent Climate History) Project Team from the University of Melbourne for being awarded the 2014 University of New South Wales Eureka Prize for Excellence in Interdisciplinary Scientific Research. The Australian Museum Eureka Prizes are Australia's most comprehensive national science awards. Dr Gergis and her team were recognized for their landmark project drawing together scientists, water managers, volunteers and historians to extend our record of natural climate variability in the Australian region. Congratulations Joelle!

AQUA TRAVEL AWARD

The XIX INQUA Congress in Nagoya Japan, 27 July – 2 August 2015 is rapidly approaching. The theme of the conference is "Quaternary Perspectives on Climate Change, Natural Hazards and Civilization". The deadline for abstracts is 20 December 2014 and for early bird registration is 28 February 2015. We hope that a number of the AQUA community will attend and represent the wide range of Quaternary work that is being undertaken in the Australasian region. AQUA members are particularly encouraged to present their work in the Southern Hemisphere Assessment of Paleo-Environments (SHAPE) session, or in other relevant sessions.

AQUA is offering four very generous travel awards of A$2250 each. We invite applications from students, postdocs and other AQUA members who do not have funding to attend the INQUA conference, but who have a unique project to present and who can demonstrate that they will benefit considerably from participating in this prestigious international conference. To be eligible for one of these travel awards you need to:

1. be a current financial member of AQUA,
2. fill out an application form (available on the AQUA website's Awards page),
3. send us:
    a. a copy of the submitted INQUA abstract,
    b. a reference,
    c. a detailed budget,
    d. proof that you have registered for the INQUA conference.

The deadline for applications is 20 December 2014. Applications should be sent to the AQUA Secretary at secretary@aqua.org.au.

Links:

XIX INQUA Congress: http://inqua2015.jp/

SHAPE session: http://convention.jtbcom.co.jp/inqua2015/session/p12.html

AQUA Awards: http://aqua.org.au/?page_id=164

AQUA membership: https://www.regonline.com.au/aqua_membership

INQUA SESSIONS CONVENED BY AUSTRALASIAN RESEARCHERS

CMP (Coastal and Marine Processes)

C06: Coastal Land-Sea interactions: Understanding Land-Sea interactions on the Coastal Plain and near shore environment
Conveners: Mark Bateman, Colin-Murray-Wallace, Jonathon Nott, Toru Tamura

HaBCOM (Humans and the Biosphere)

H10: Identifying the Initial Period of Human Activity in Palaeoecological Records
Conveners: Simon Haberle, Alistair Seddon, David McWethy

H21: From the shores of the Caspian to the Tian Shan foothills: paleoenvironments and human behavioral adaptations in Central Asia
Conveners: Radu Iovita, Kathryn Fitzsimmons

H30: Domestication in eastern Asia
Conveners: John Dodson, Guanhui Dong

PALCOMM (Palaeoclimate)
P07: Advances in understanding the last glaciation maximum (LGM) in the Southern Hemisphere
Conveners: Jamie Shulmeister, Brian Chase, Tim Cohen, Patricio Moreno

P12: Southern Hemisphere Assessment of PalaeoEnvironments (SHAPE): a southern perspective on climate evolution over the past 60 kyr
Conveners: Andrew M. Lorrey, Steven J. Phipps, Brian M. Chase, Maisa Rojas, Heidi A. Roop

P14: Antarctic ice sheet variability and Southern Ocean dynamics
Conveners: Yusuke Suganuma, Duanne White, Andrew Mackintosh

P18: Seasonal palaeoenvironmental records from archaeological sites
Conveners: Amy Prendergast, Hazel Reade, Rhiannon Stevens, Alex Pryor

P19: Islands in Time: Late Quaternary reconstructions of island environments (P19)
Conveners: Patrick Moss, John Tibby, Lynda Petherick, Craig Sloss

P28: Modern calibration of palaeoenvironmental proxies from biogenic carbonate geochemistry
Conveners: Amy Prendergast, Emma Versteegh

SACCOM (Stratigraphy and Chronology)
S04: Studies on tephras and cryptotephras and their use as isochrons in palaeoenvironmental and palaeoclimatic reconstructions
Conveners: David Lowe, Victoria Smith

S05: Tephras and cryptotephras and their use in studies of natural hazards and archaeology
Conveners: Takehiko Suzuki, Christine Lane, David Lowe

S06: Eolian deposition: a clue to understanding the nature and interactions among Earth surface systems
Conveners: Shiling Yang, Slobodan Marković, Eric Oches, Paul Hesse

TERPRO (Terrestrial Processes, Deposits, and History)
T14: Beyond steady-state erosion: rethinking the spatial and temporal dynamics of Earth surface processes
Conveners: Alexandru T. Codilean, David Fink, John D. Jansen, Oliver Korup, Yuki Matsushi

T17: The legacy of mountain glaciation
Conveners: Jamie Shulmeister, Jürgen Reitner, Glenn D. Thackray, Stefan Winkler

FOCUS ON AQUA, MILDURA

Recent advances in palaeoclimate studies

Kelsie Long

PhD Student,Research School of Earth Sciences, Australian National University

The 2014 Australasian Quaternary Association (AQUA) biennial meeting, held from the 29th of June to the 4th of July, took attendees back to where it all began in 1987: The Grand Hotel, Mildura. Despite the nostalgic setting this year's conference featured a plethora of presentations on recent advancements in palaeoclimate studies. These advances include the application of new models to datasets, development of new palaeoproxies and the use of technological advances to create high resolution records of elemental fluctuations.

The conference was split up into eight main sessions, each themed around a different aspect of Quaternary research in Australasia, and including an open session for talks beyond categorization. The main sessions were titled:

- Lakes, Dust and Dunes
- Prehistoric human impact in Australia
- SHAPE Interhemispheric comparisons
- The role of the Quaternary to inform management
- New Research in Willandra
- Role of the oceans and ice
- The Last Glacial Maximum in Australia
- Lessons from Rivers

The scope of these sessions was too great for this report and so I will present only a taste of some of the brilliant research occurring within these areas.

The first session, Lakes, Dust and Dunes, included many interesting talks about the development of high resolution records from lake cores, the use of dunes and loess as palaeoclimate archives and new approaches to the dating and interpretations of these fields. One of the more recent advances in climatic research in this area is the development of new proxies for climatic information. Allan Chivas spoke about the many wonderful and useful properties of charophytes, green water plants. These plants are used in studies of lakes and river cores as broad indicators of past water depth and salinity but recent advances in elemental and isotopic research are generating a wider range and more detailed information. They have the potential to provide temperature

information on long time scales, changes in salinity of fluvial and lake systems and lead to more robust chronologies within the Quaternary.

The session on prehistoric human impact in Australia also included a number of intriguing talks. Alan Williams provided a novel approach to approximating past human populations in Australia through the use of mass radiocarbon data bases and modelling. He modelled 5,044 radiocarbon dates from 1,748 sites across Australia, looked at the spatial distributions and patterns in this dataset to determine refugium areas and shifting mobility patterns. This demonstrates how datasets can be used to generate new theories about the movement of human populations across Australia at various spatial and temporal scales.

The SHAPE interhemispheric comparisons session focused on reconstructions over the last 60ka years of climate using multiple proxies, modelling and comparisons between datasets. This session included analyses of speleothems, ice cores, palynological records and tephrochronology. One of the key advancements within this area is the development of elemental proxies for climatic changes and the modelling of these. Claire Krause presented new findings in the use of $\delta^{13}C$ records in speleothems (stalagmites). This method can be used to infer changes in atmospheric methane and the role of tropical vegetation in driving the global methane budget over the past 40,000 years. Using a combination of simulations and $\delta^{13}C$ fluctuations in speleothems she was able to directly attribute global methane emissions within her time period to tropical ecosystems. Helen Bostock, Steven Phillips and Andrew Mackintosh also spoke about the various uses of modelling to infer how climate changed in the past and to identify the mechanisms involved. This has huge implications for predicting how our current climate might be affected by various inputs and what can be done to prevent any dramatic shifts.

In the session on New Research in the Willandra presenters gave us an update on ongoing projects in this world heritage area. Emily Dillion presented on her recent honours research project at Lake Mungo looking into constructing archaeostratigraphic sequences across different scales. This has the potential to provide detailed information at specific sites of interest which can then be compared much broader macroscale stratigraphic models. Michael Westaway provided an overview of some very new and exciting research using ancient DNA, among other methods, to look at the origins of the first Australians.

The results of this are awaiting publication but are very promising for contributing to the global narrative of modern humans outside of Africa.

The ITRAX made an appearance in many talks. This multi element-function core scanner can be found at the Australian Nuclear Science and Technology Organisation (ANSTO) and is designed to measure a wide range of elements at small scale intervals along cores. The machine also provides high resolution optical and x-radiograph images and conducts magnetic susceptibility tests. It has been applied to speleothems, tree rings and lake sediments stretching throughout the Quateranary. Although the full meaning of these elemental fluctuations is still being assessed, the technique is promising for generating another set of climatic influenced data.

Australian Quaternary research is greatly benefiting from advances in technology, such as the ITRAX, the application of new modelling techniques to old datasets and the development of new palaeoproxies. By learning about the past, we can better understand the present and are more capable of securing the future.

Role of Quaternary science in archaeology

Dorcas Vannieuwenhuyse

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In the last five decades, archaeological practice has become closely associated with the use of scientific procedures. Science and more precisely Quaternary Science in archaeology provides an accurate and comprehensive framework to human studies, such as chronology, palaeoenvironmental background and site formation processes, that contribute to the global interpretation of an archaeological record. Once again the AQUA conference in Mildura has been a wonderful platform for the communities of archaeologists and scientists to exchange and connect. Several presentations illustrated the close interaction between these disciplines, with talks and posters given by specialists in archaeology, geomorphology, palaeoenvironmental science, etc....

A particular focus of Quaternary Science in archaeology is geochronology. This area of research is very important in Australian Indigenous archaeology as few cultural markers exist that can be used for relative chronology. Relative chronology in archaeology is commonly used in other parts of the world where civilizations, with strong differentiation in cultural productions have succeeded to each other and are easily identifiable in the archaeological record. Indeed, the need to develop robust absolute chronologies in Australia has led to an extensive use and development of a range of geochronological techniques. Radiocarbon and Optical Stimulated Luminescence (OSL) dating are the most commonly used to date archaeological sequences. With the improvement in pre-treatment procedures and the use of accelerator mass spectrometers (AMS), very small amounts of charcoal can now be dated. Similarly in OSL dating, individual grains of sand can be measured using a focused laser beam, increasing the reliability of the results. During the conference, some of the latest improvements and applications of geochronology in Australasian contexts were presented. Rachel Wood showed how to push the limits of radiocarbon dating of bones in warm arid environments by applying a new method based on selective sub-sampling of amino acids using the chemical ninhydrin. Justine Kemp showed her research on the validity and limitations of OSL dating applied to ancient Australian graves, with her experiments indicating that this technique does not produce accurate ages for grave infills.

Archaeological excavations are undertaken in a variety of contexts and landscapes. Caves and rock shelters are very often investigated due to their high probability of human occupation. Open air sites are also a dominant part of archaeological survey results, with the presence of artefact scatters, hearths and stone arrangements, most commonly along rivers, lakes edges and sea coasts revealing patterns in land use. Thus, understanding the landscape is key for archaeologists correctly interpreting the preserved artefactual record. Quaternary researchers are working on a range of terrestrial, alluvial, lacustrine and coastal geomorphology, as shown by the number of presentations during the conference in sessions such as Lakes, dunes, dust and soils, SHAPE, Willandra and Rivers. Examples of formation and geochronology of longitudinal dunes and coastal dunes were detailed by Paul Hesse and Adrian Fisher, Deirdre Ryan and Allen Gontz. Alluvial sequences from different Australian south-eastern river catchments were described by Éva Papp, Tony Dosseto, Paul Hesse, Timothy Ralph, Sandra Mann and Stephanie Kermode. Palaeo-lacustrine environments, in particular Willandra lakes, have been extensively covered during the conference and explained during the field trip by Jim Bowler, Timothy Barrows and John Magee. Periglacial environments were presented with examples from New Zealand with presentations from Peter Almond on a loess palaeorecord and Shaun Eaves on glacier geomorphology. Both pure geomorphological data and palaeoenvironmental information are contained in these records, from which landscape and climate changes can be inferred. When combined with human occupation, these records can provide an interesting picture of human-landscape-climate interaction.

Local records can be compared to regional or continental palaeoenvironmental reconstructions available from a number of proxies. Most of the work presented during the AQUA conference was focusing on palaeoclimate and palaeoecology reconstructions of the Late Quaternary, with sessions such as SHAPE and Oceans and Ice that provided the audience with a brand new range of datasets regarding palaeoenvironment in the Southern Hemisphere. Presentations covered a wide variety of proxies such as pollen, chironomid, foraminifera, sediment and speleothem, from cores taken in a range of

different environments (glacial, marine, coastal, fluvial, lake, peat, waterhole, etc...). Recent efforts to integrate multi-proxy data in climate models have led to more accurate past climate reconstruction, with a special focus made on the Last Glacial Maximum records during a session dedicated to this time period. All these proxies provide an increasingly defined palaeoenvironmental baseline that is used by many archaeologists to build comprehensive theories of human-climate interactions.

At the archaeological site scale, it is also primary for archaeologists to understand the site formation processes. Archaeologists often forget that a site is mainly composed of dirt and only focus on the anthropogenic signals (artefacts, combustion features, etc.) embedded within the sediment. However, study of the sediment itself is key for assessing the quality of the stratigraphic record and consequently, the archaeological record. Natural deposition and post-depositional processes vary through time – deposition can be rapid, slow, even cease. Erosion can overtake deposition creating a complex sequence with palimpsest or discontinuities. Archaeological sequences contain both palaeoenvironmental and anthropogenic signatures, often spanning several thousands of millennium, and thus are very precious records for cross-linked studies such as archaeobotany, zooarchaeology or geoarchaeology. However, geoarchaeological investigations are still not widespread in Australia. The discipline is just starting to expand with exciting research being undertaken in some areas of Australia. Several presentations during the conference focused on geoarchaeological applications. A series of shell mounds are being studied by Trish Fanning in Weipa (tropical North of Australia) to better understand their processes of formation. In the same field, shell mounds are investigated by Jillian Garvey to better understand the link between economic patterns and environmental changes. Micromorphology studies are taking off in Australia with Dorcas Vannieuwenhuyse's work on caves in the Kimberley and Emily Dillon's project on the Mungo lunette, both providing microstratigraphical insights on complex site formation processes and human-environment interactions through time.

However the main contribution of Quaternary Science to archaeology is in resolving some of the "big questions" or major Australian archaeological themes related to human colonization, mobility, impact on environment and cultural production. Several talks have addressed directly these issues during the conference. Ancient DNA analysis by Michael Westaway on some of the Willandra remains provides new insights on the origins of First Australians. Alan Williams' presentation about developing a regional framework between archaeological and palaeoclimatic data illustrates the immense efforts undertaken to synthesize decades of archaeological research in Australia and create a valuable documentation of human density and mobility through time and space. The impact of humans on their landscape has been also addressed with themes such as the distinction between natural and human controlled fires in Australia, with talks presented by Richard Cosgrove and Lydia Mackenzie (respectively on open space in tropical forests and fire regimes in Queensland). Scott Mooney conducted a statistical comparison of charcoal and archaeological records revealing a very weak relationship between intense fire regimes and human occupation, challenging the common belief in ancient aboriginal fire landscape management. Controversial analysis on the question of human causing or not the megafaunal extinction during the Pleistocene by Judith Field was a good example of how the debate on this topic is still ongoing. The antiquity of rock art production is another central theme of research in Australian indigenous archaeology. Direct dating on rock art is difficult or even impossible or sometimes forbidden, which makes the availability of dates for rock art very scarce. Most of the chronologies available are stylistic relative chronologies. Some new non-destructive approaches have been tested recently, for example OSL dating on grains extracted from mud-wasp nests sampled on top of ancient rock art in the northern Kimberley done by Kira Westaway.

Quaternary Science provides invaluable data that helps the archaeologists to understand the landscape and the environment in which humans were evolving during the Late Quaternary. On the other hand, archaeological studies reconnect pure science with a more common meaning, which is the story of people. It has to be noted that only a small number of archaeologists were attending the AQUA conference, which means that some improvements still need to be made to increase the interaction between Quaternary Science and archaeological practice.

AQUA 2014: Pre- and Mid-Conference Field Trips

Pre-conference Field Trip: Daniela Mueller

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Mid-Conference Field Trip: Deirdre Ryan

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INTRODUCTION

The AQUA Biennial Meeting this year was held in celebration of 30 years of AQUA; the inaugural meeting took place at the same venue, the Mildura Grand Hotel, on 12th July 1985. This year the congregation of Quaternary scientists focussed on Australasian geomorphology, palaeoecology, and archaeology working towards understanding landscape change, the palaeoenvironment and the impacts to and responses by both indigenous and European communities. These themes were reflected in the pre – and mid-conference field trips. The pre-conference field trip to the Murrumbidgee palaeochannels and dunes looked at palaeohydrology, previous and current study sites, whereas the mid-conference field trip to Mildura Wetlands, in contrast, illustrated the impacts on the wetlands following European settlement.

PRE-CONFERENCE FIELD TRIP: LATE QUATERNARY MURRUMBIDGEE PALAEOCHANNELS AND DUNES, 26 JUNE 2014

On route to Mildura, a group of conference attendees took the long way – coming from the NSW east coast – with scientific stopovers along the Murrumbidgee River. The Murrumbidgee riverine plains have been studied in detail since the late 1960s but it wasn't until Page *et al.* (1991, 1996) established an extensive mapping and dating campaign that assigned the near-surface former stream systems to a late Quaternary origin. Four well-preserved and easily distinguishable systems were ascertained. Each older system showing coarser sediment deposits and more massive wetted perimeters at bankfull stage, which have been inferred as carrying up to 4 to 5 times the discharge of the modern river (Page *et al.*, 1996).

The group, led by Duanne White, was privileged to have Ken Page with us. The excursion started at Eunony Bridge in Wagga Wagga with a review of source-bordering dune development and some perspectives of the modern Murrumbidgee River. Making our way west to the Coleambally system, Éva Papp from ANU provided a thorough overview of the impact this oldest dated palaeochannel system (105 to 80 ka; Page *et al.*, 1996) may have on groundwater flow and geochemical composition. Kevin Kelly, Assets and Maintenance Manager of Coleambally Irrigation Co-Operative Limited, joined in the discussion and contributed with

Figure 1: Standing on gravel in front of cross-bedded sands – Éva Papp, Ken Page, Tim Barrows and Duanne White (left to right) in the Kerarbury Pit.

Figure 2: Looking into the past – Ken Page (front) and Duanne White (back) at Yarrada Lagoon.

facts about the extensive Colleambally gravity irrigation system, the salinity issue, implications for farmers and the importance of understanding the landscape we are working with.

Making our way north, we encountered Kerarbury Pit – one of Ken's most impressive sites (Fig. 1). The approximately 9 m deep depression is still used as a sand quarry pit and offers excellent insights into the cross-bed stratigraphy and grain size changes within the Kerarbury system. Travelling in time and space we set out from this 55 to 35 ka old palaeochannel system to the next younger phase. Yarrada lagoon (Fig. 2), a nearly 3 km long and 190 m wide scar, is probably the most prominent representative of the Gum Creek phase and easily accessible from the Sturt Highway. The system is thought to have been active in between 35 to 25 ka via multi-grain thermoluminescence dating but its precise occurrence is currently under revision. Disregarding any age discrepancies, this site shows the most intact channel remains and makes it easy to imagine how much more water had been carried through these older waterways. After sharing three of his four identified palaeochannel systems as well as his fundamental expertise of the region the group had to say goodbye to Ken Page before heading off to Balranald and the last leg to the conference venue the next morning.

MID-CONFERENCE FIELD TRIP: MILDURA WETLANDS, 2 JULY 2014

The field trip to Mildura Wetlands was led by Jessica Reeves and stopped at Kings Billabong and Psyche Bend Pumping Station. The region is the traditional country of the Nyeri Nyeri people, but was used by other groups as well (Reeves *et al.*, 2014) prior to European settlement. The region was significantly altered by river regulation and the establishment of the Mildura Irrigation Scheme by the Chaffey Brothers in 1886.

Our first stop was Kings Billabong, a naturally intermittent wetland which was turned into a permanently filled water storage basin in 1896. The billabong is a pleasant site with many water birds present on the day of our visit including: black swans, ducks, sea gulls and a pelican. Although the billabong has now been established as a Wildlife Reserve (1979) and Nature Conservation Reserve (2001), the permanent inundation has had severe impacts on the pre-European ecosystem. Giri Kattel, who presented during the conference on the topic, summarised his analytical results of a continuous, long term sediment record from the billabong. The changes to the subfossil assemblages of cladocerans and diatoms, as well as the stable isotope ratios of carbon and nitrogen reflect an ecosystem transition from the historic natural cycle-based submerged macrophyte-rich clear water ecosystem to a phytoplankton dominant, less resilient ecosystem following river regulation. Giri also mentioned that the native fish species of Kings Billabong were under threat by the introduced mosquito fish and carp.

Figure 3: Psyche Bend Lagoon, which has been used as a water storage basin for the Murray River salt inception scheme since 1996. High salt concentrations and heavy metal pollution has killed the trees within and immediately surrounding the lagoon.

Following Kings Billabong, the field trip went slightly up river to visit the Psyche Bend Lagoon, also a naturally intermittent wetland which was turned into a permanently filled water storage basin. In 1996 the lagoon was selected as part of a salt inception scheme to reduce salinity in the Murray River by collecting saline groundwater before it entered the river (Murray-Darling Basin Commission, 2008). Tim Ralph presented some of the impacts of the scheme on Psyche Bend. Monitoring of the lagoon from 1996-2001 (Gell *et al.*, 2002) showed a substantial increase in salinity following the inception of influx of saline irrigation-drainage waters. By the summer of 1998/99 the lagoon had become eutrophic and remained so for the extent of monitoring. During the last major drought the pH of the lagoon dropped from 9.5 to 5.1 for several months in 2004 (Gell, 2010). The release of sulphuric acid, iron and probably aluminium resulted in a red-stain and extermination of remaining fish populations. Although the lagoon has returned to a more 'natural' colour, we were reminded by the numerous dead trees within and surrounding the lagoon that its waters are excessively saline and polluted by metals (Figure 3).

The Chaffey Brothers established the Psyche Bend Pump Station in 1891 to pump irrigation water from the Murray River to provide a major boost to agricultural production in the region. The pumps were capable of removing ~130,000 gallons (~492,000 litres) of water/minute from the river. Draw down from the river was seasonal and dependent on the needs of farmers. The pump station steam engine and pumps were in operation until 1959 when they were decommissioned and replaced by electric pumps (Discover Murray River, 2008). The replacement was largely due to the lack of firewood resources following the decimation of the River Red Gum forest in the region. The River Red Gums were also adversely affected by the permanent inundation of Kings Billabong and Psyche Bend Lagoon where waterlogging killed many of the red gums in the reserve. The steam engine and pumps were recommissioned in 1995 as a working exhibit following a seven year restoration project lead by the Sunraysia Steam Preservation Society. Members of the society were present during the field trip to provide a history of the Pumping Station and allow a viewing of the steam engine and boiler house.

The field trip ended with afternoon tea at Woodsie's Gem Shop. Woodsie's is an eclectic place with plenty of jewellery and rock buddies and the not-to-be-missed Aladdin's Cave.

ACKNOWLEDGEMENTS

We would like to express our gratitude to AQUA and AINSE for the AINSE-AQUA Travel Award which made attendance at this conference possible.

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Public Lecture: AQUA Conference – Mildura

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During 30th anniversary Australasian Quaternary Association (AQUA) Biennial Conference Professor Jim Bowler and Professor Roger Jones delivered public lectures to a full house at the Grand Ball Room, Mildura. This event was introduced by Glenn Milne, Mayor, Mildura rural city council, and conducted by Dr. Jessica Reeves, former president of AQUA.

In the first lecture Jim engaged us with his passionate talk on "Journey to Discover, Who are we", where he focussed on his lifelong research at Lake Mungo. Jim reminded us about the six decades of scientific research at Mungo, including a vivid description of the day he discovered Mungo Man's skeleton in the dunes at Joulni, which was to go on to change our understanding of Aboriginal occupation of Australia. However, his emphasis then moved onto the challenges for future research. This included the key role that the current traditional owners have in managing and facilitating science, their potential role in researching their history, and the need to establish a keeping place on-site at Mungo to repatriate the archaeological finds, both past and future. Jim finished by encouraging young researchers to engage with the site, particularly given the continued erosion of the dunes and destruction of cultural and natural heritage, especially given the world heritage listing.

In the second lecture Roger focused on our future world in the face of climate change, and how we will experience it. Roger began by highlighting the dominance of uniformitarianism over catastrophism in scientific thinking during the past few centuries. He described how this trend in thought has shaped our perspective, and narratives on trends in present and future climates, highlighting the overall gradual increases in temperature with time. Roger contended that this is only part of the story, and that we miss the importance of non-linearity in the climate system – or alternatively stochastic variation along with a gradual change. He described the importance of this variability in influencing the lived experience and response of people to climate change, with particular focus on how we feel an abrupt shift given the step changes in the nature of extreme events. I think this fact should be communicated properly to make people concerned about possible future abrupt change for proper adaptation and better management.

Along with all the conference attendees, many non-scientists, indigenous people and local electronic and print media reporters attended the public lecture. People were engaged by the lectures and posed some interesting questions. Both lecturers were happy to answer questions and share their practical and research experience. The public lecture got media attention and huge public interest. I think it was a great idea to arrange a public lecture during the AQUA conference as it is the best way to engage some of the community and let them know our scientific findings. I hope it will continue at all AQUA events in future.

A journey through Australian prehistory: The Willandra Lakes field trip chronicle

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Figure 1: The famous Joulni area – where "Mungo Man" and "Mungo Woman" were found – was visited during the first day of the field trip. We had the privilege to listen Prof. Jim Bowler talk about the scientific implications of some of his archaeological findings. Photos by Ignacio A. Jara

After the 2014 AQUA biennial conference, a group of attendees travelled c.150 km north from Mildura to visit the Mungo National Park in the Willandra Lakes region World Heritage area, New South Wales. This area comprises a series of dry lake basins surrounded by old sand dunes. From the road the region looks quite flat and deserted to eyes accustomed to lush, green, New Zealand scenery. But this initial perception was rapidly replaced by an overwhelming feeling of significance as the guided tour of the region opened our eyes to the vastness and magic of this region.

The Willandra Lakes system can be understood as a "stairway" of lake basins that are linked by one river system, the Willandra Creek. Although at present the river is not much more than a subtle depression meandering in the landscape, evidence suggests that it intermittently flowed, filling and emptying the lakes many times during the Quaternary period. The Willandra Creek is fed by the Lachlan River, which originates hundreds of kilometres away in the main range along the east coast of Australia. In past times the discharge of the river filled up the northern-most basin and then spilled over and cascaded into the basins below. Thus despite regional aridity, the northern most basins could have high lake levels if the main range to the east received abundant precipitation, whereas the lakes downstream were more susceptible to the dry environment and experienced longer dry phases. This wetting and drying activity throughout the Quaternary period was associated with the build-up of extensive shoreline rings or "barrier beaches" that captured and preserved a wide range of different sediments including sands, gravel, plant and animal remains. The final drying out of the lake beds led to the burial of these fossil-rich shorelines by a thick layer of clays derived from the basins floors, building up bordering dunes or "lunettes" on the eastern edges of the lake basins.

Lake Mungo is one of the southernmost basins in the Willandra lake system. Archaeological findings suggested that during wet phases the lake shore sustained human populations that exploited the lake's aquatic resources until around 15,000 years ago when the last evidence of a water-filled lake occurs. Since that time, the continuous erosion of the lunettes has revealed a great number of old

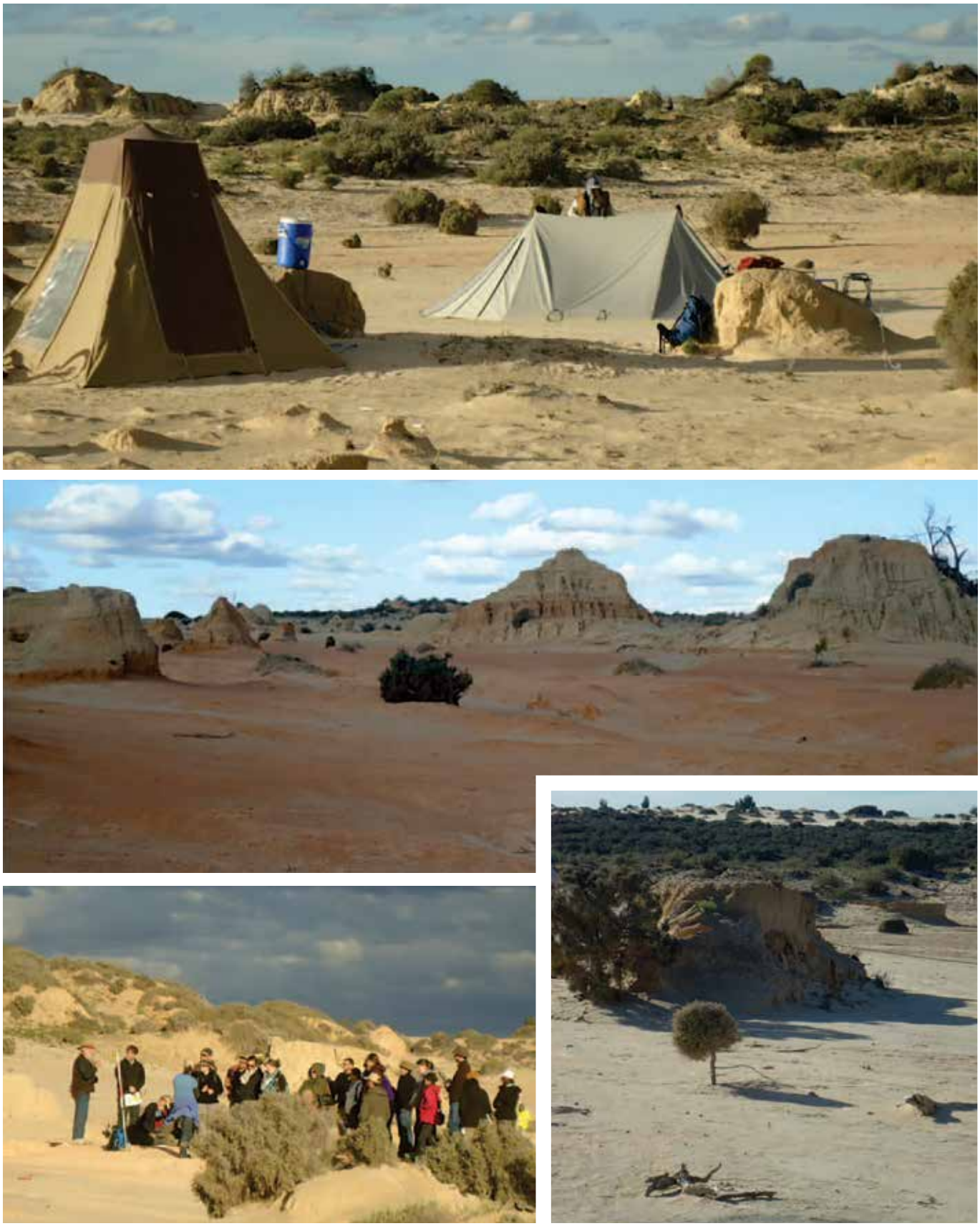

Figure 2: The afternoon of the first day included a visit to an ongoing archaeological dig on the Central Mungo Lunette. Since 2007 a multidisciplinary research group have been working in this area with the purpose of gathering new information about the extensive human occupation record of this area and to improve the understanding of the past environmental evolution of the lake. Photos by Ignacio A. Jara

animal and human remains from those early settlement times, becoming a key region for archaeological research in Australia. Early investigations of the lakes' history were focused on its complex Quaternary sedimentary sequence, however the region was finally thrown into the spotlight by a series of archaeological findings in the Joulni area on the southern edge of Lake Mungo during the late 1960's and 1980s – including the discovery of "Mungo Girl" and "Mungo Man", subsequently dated to ~40,000 years before present by Optically Stimulated Luminescene (OSL; Bowler *et al.*, 2003). Our group had the privilege to visit the Joulni area in the company of some of the leading scientists who discovered the bodies and have been working there for many decades. The aim of the field trip was to review the geological and archaeological investigations at Willandra, as well as see some of the new ongoing scientific research.

On our arrival at the Mungo Visitor centre, the group was welcomed by some elders from the traditional tribal groups of the Willandra area. After sharing a welcome morning tea that warmed our bodies on the cold desert morning, we visited the famous Joulni area at the southern edge of Lake Mungo, the place where the first human remains were found in 1969 (Figure 1). The colourful moon-like background at the eroding dunes was undoubtedly beautiful, and we had the privilege to listen not only to Prof. Jim Bowler talk about the scientific implications of some of his archaeological findings, but also to the aboriginal elders comments on the significance of Mungo for their ancestral culture and heritage. Besides the indisputable scientific importance, the attendees realized that the Willandra lakes have great value for the spiritual belief of the aboriginal communities of this region. It's not surprising that in recognition of its scientific and cultural significance, this region was listed on the UNESCO World Heritage list in 1981.

After a smoking ceremony and a quick lunch back in the visitor centre, the group visited an ongoing archaeological dig on the Central Mungo Lunette. Since 2007 a multidisciplinary research group have been working in the area with the purpose of gathering new information about the extensive human occupation record of this area and to improve the understanding of the past environmental evolution of the lake (Figure 2). Walking through the colourful dusk landscape of the lunette with the vastness of the desert as a background, watching the archaeological excavation, and listening to the archaeologists describe some of the findings, was undoubtedly an inspiring experience that made us – geologists, biologists and climate scientists/modellers – appreciate the overall relevance of archaeological investigation. Bearing in mind the significance of the Willandra Lakes as an area of World Heritage did nothing but boost this "sacred" feeling of visiting this venerated site.

On the second day of the field trip we visited the Chibnalwood Dune and the outer Lake Arumpo sand dunes south from Lake Mungo. The Arumpo dunes – on the eastern flank of a lake basin with the same name – were packed with fossil bones and human-made stone artefacts, and the group enjoyed the constant company or surveillance of a 4-helixed drone (not kidding!). We also visited the location where these stone artefacts are thought to have originated on the western shoreline of Lake Mungo, where Pliocene silcrete rock is found. The final stop for the field trip occurred in the afternoon of the second day, when the group visited the Garnpang area to the east of Lake Mungo. A series of ancient footprints were discovered here in 2003. Detailed studies of the foot tracks have revealed intimate insights into the transportation of the family groups that inhabited Lake Mungo 20,000 years ago, including children's escapades and even evidence of a one-legged individual. However, the paradox here is that erosion is working against the archaeologists, slowly erasing the ancient steps of ancestral Australians and hence this priceless cultural heritage. For this reason the site is now completely covered and the group did not have the chance to actually see the footprints. During the travel back I was pleased to have the chance to spot a great number of wild kangaroos and emus.

Overall this field trip presented a unique opportunity to visit an important region for Australian science and history. The presence of some of the scientists who discovered and studied this area made the trip even more informative and special. Covering more than 40 years of outstanding research in two days was a major challenge and of course many pieces and details of this history were not covered, left for another occasion. As the dunes around the Willandra Lakes keep eroding, the potential for future findings is undoubtedly huge and exciting. Perhaps the biggest challenge for the Australian community will be to balance the scientific curiosity with the aboriginal claims for ownership and preservation of their heritage.

Friendly Competition: the 2014 AQUA meeting trivia night

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The Australasian Quaternary Association (AQUA) celebrated the 50th anniversary of its biennial meeting in Mildura this past July. The week was filled with a blend of informative sessions, field trips, and social events. One of the beloved evening traditions of the conference is the trivia night, which presents the opportunity for members and attendees to interact with their fellow Quaternarists in a casual, yet competitive, evening. This year's event was no exception.

The 2014 trivia night was held on the final evening of the AQUA conference at the Mildura tennis club. The first order of business for the evening was the formation of teams. Some groups of old friends and colleagues naturally gravitated towards each other, while other teams were more strategic in the combination of experience and specialties. Even this process became heated, with offers of radiocarbon dates and other scientific bribes jokingly offered for some of the more experienced AQUA attendees. The local Lions club provided a BBQ feast, in front of a backdrop of scenic and humourous pictures of past AQUA events. Tim Barrows and Jessica Reeves were the emcees for the evening.

Round one left some of the younger teams baffled, when the questions centred on pictures of past AQUA meeting venues. Leaving the game behind for a moment, everyone could enjoy the beautiful places where AQUA had gathered in the past. Following rounds consisted of questions derived from the week's presentations. Topics included particular proxies and species of organisms used in studies, as well as dating methods, specific study sites and new interpretations of old data sets. The isotope-specific round brought some members back to school days, with questions about notation and specific applications. The theme of model integration into proxy-based methods – a theme that had been explored throughout the week – was also continued through a set of modeling questions, which were sufficiently non-threatening to make proxy-oriented participants more comfortable with modeling tools.

Lighter questions, which focused on humorous or memorable remarks made by presenters, were interspersed with the more serious questions. Questions covered a large range of topics, with participants having to remember that Allan Chivas encouraged correct naming of charophyte parts, while Jeannette Hope introduced the 'demon duck of doom', properly known as Dromornithidae, and Len Martin compared burning sphagnum moss to burning a head of lettuce. In a change of direction, one of the later rounds focused on Quaternary-themed songs. The answered ranged in genre from country-western to rock n' roll, but the song that had the most favourable response was 'I am a Paleontologist' by They Might Be Giants. Keep an eye out for this song reappearing in future AQUA events.

When the final scores were tallied, the group named 'Cool Chicks' came out on top, and prizes were awarded to both the first and final places. In all, the evening was a success, concluding with wild applause to thank the emcees for assembling the questions and guiding everyone through the highlights of the week.

Teams assemble before the start of the 2014 AQUA trivia night. Photo courtesy of Lynley Wallis.

Lifetime membership: Letter of thanks from John Magee

Dr Jessica Reeves, Dr Helen Bostok, AQUA Presidents, past and current AQUA Committee members and the wider AQUA community.

Dear Colleagues,

I am writing to express my gratitude to all those who played a role in my nomination followed by approval of the award of Life Membership of AQUA as conferred at the recent Mildura AQUA meeting. Also I thank the committee for facilitating my attendance at that meeting to receive that award.

It is a very humbling experience to receive such recognition from one's peers and I feel honoured and privileged. My 40+ years of involvement in Quaternary science has not been a typical journey and has sometimes not gone smoothly, but it has always been exciting, rewarding and mostly a lot of fun. That was really brought home to me when I saw the small array of photos attached to the citation in Quaternary Australasia. In those pictures, I seemed often to be deep in a hole; writing notes or taking samples. I think that is how I liked it best, face to face with a section detailing evidence of Quaternary events, interviewing the sediments to unravel their story. But also memorable are the people I have met and/or worked with throughout that 40 odd years; including those who mentored me, research colleagues, students, traditional owners and pastoral station landholders – many life-long friends made – far too many to individualise or to risk offending by omissions.

Since leaving direct Quaternary research my opportunities for interaction with the Quaternary research community have been regrettably limited. I hope that the award of Life Membership will provide me better opportunities in the future, especially when I am retired and attempt to undertake the task of reducing an embarrassing backlog of unpublished data.

Once again, I thank one and all for an honour which I will always treasure.

Yours sincerely,

John Magee

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7 July,2014

AUS2K Meeting

Australasia's past climate variability

STRENGTHS DRAWN FROM PALAEOCLIMATE AND MODEL DATA OVER THE LAST 2000 YEARS. AN OPEN WORKSHOP INCORPORATING THE PAGES AUS2K WORKING GROUP AND AUSTRALIAN CLIMATE CHANGE SCIENCE PROGRAM (ACCSP) PALAEOCLIMATE DATA–CLIMATE MODEL COMPARISON PROJECT VARIABILITY OF AUSTRALIAN CLIMATE OVER THE LAST 1000 YEARS IN COUPLED MODEL SIMULATIONS AND PROXY DATA

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The aim of the 3rd Aus2k workshop was to review progress made by the Aus2k community to date, and to develop specific plans to contribute Australasian science towards Phase 2 of the PAGES 2k Network. Around 40 palaeoclimatologists, meteorologists, hydrologists, and oceanographers attended the workshop, resulting in a very constructive and stimulating cross-disciplinary meeting.

The Aus2k working group took the opportunity to hold the workshop jointly with the Australian Climate Change Science Program (ACCSP), with participants presenting results of a palaeoclimate data–climate model comparison project *Variability of Australian climate over the last 1000 years in coupled model simulations and proxy data*. The intention was to engage the wider meteorological community with expertise in climate data–model comparison and diagnostic analyses, with the ultimate goal of understanding the mechanisms driving Australasian climate variability over the last 2000 years.

The specific goals of the 3rd Aus2k workshop are listed below in plain text. Sub-projects around each aim were agreed upon and coordinators are listed in italics.

1. Expand the Aus2k database to incorporate low-resolution material for the development of a common dataset for Australasian climate reconstructions;

   Database to be frozen December 31 2014. Contacts: Bronwyn Dixon, Jonathan Tyler and Ben Henley

2. Develop guidelines for the future collection of climate proxy records based on spatial and temporal gaps in the Australasian palaeoclimate record;

   Nerilie Abram and Russell Drysdale will lead the testing of the number and location of records required to reconstruct specific features of Australian climate and to deal with potential biases caused by non-stationarities.

3. Discuss existing multivariate data synthesis techniques being used by Aus2k and the global community, with a post-meeting goal of running a comparison exercise using different reconstruction methods;

   An inter-comparison project with Australian and New Zealand data will be coordinated by Ben Henley, Mandy Freund and Andrew Lorrey.

4. Assess the feasibility of developing Australasian climate field reconstructions (temperature, precipitation, and geopotential height) to contribute towards the global PAGES 2k Network;

   To be led by Joelle Gergis, Andrew Lorrey and Steven Phipps, and;

5. Foster linkages between the palaeoclimate and climate modeling communities, with the aim of closing the loop between proxy development, data synthesis and climate modeling.

   Modelling contacts: Steven Phipps and Duncan Ackerley; Modern climate: Pandora Hope

Day 1 showcased recent research developments in regional data synthesis; opportunities for the future collection of new palaeoclimate records from the region; the reconstruction of climate drivers such as El Niño–Southern Oscillation (ENSO) and the Southern Annular Mode (SAM); and climate modelling being undertaken by the *Palaeoclimate Modelling Intercomparison Project* (PMIP), the Centre for Australian Weather and Climate Research (CAWCR) and university groups.

Co-manager of the ACCSP, Robert Colman, opened the workshop highlighting the importance of palaeoclimate data in understanding natural climate variability. He noted the untapped potential of using long-term palaeoclimate data, which extends centuries before instrumental weather observations become available in 1900, to evaluate regional climate model simulations and constrain the latest generation of Australian climate change projections.

During session 1, Joelle Gergis provided an overview of results achieved using the consolidated high-resolution dataset during Phase 1 of the PAGES 2k Network and outlined the global goals of Phase 2 (e.g. Neukom and Gergis, 2012). Jonathan Tyler presented progress and challenges for consolidating Australian multi-decadal sedimentary records and their importance for understanding past hydroclimate variability in the region.

Helen McGregor shared insights from consolidating low-resolution marine records as part of the Ocean2k working group. She emphasized the need to establish sensible selection criteria for the inclusion of records in regional synthesis efforts, the need to consider spatial biases present in the dataset and the value of withholding independent (in that case terrestrial) data for verification of the sea surface temperature reconstruction results.

In session 2, Karl Braganza reviewed the main climate drivers influencing Australian climate: the El Niño–Southern Oscillation, Indian Ocean Dipole and the Southern Annular Mode, calling for caution when representing coupled dynamical circulation features using simple climate indices. Pandora Hope then presented results of the ACCSP project *Variability of Australian climate over the last 1000 years in coupled model simulations and proxy data*, focusing on ENSO and its interactions with Australian climate. She showed that the ENSO–Eastern Australian teleconnection pattern is reasonably well captured by the model simulations, and noted fluctuations in the dominance of biennial and decadal variability of ENSO over the past millennium.

Nerilie Abram presented a recently published SAM reconstruction–climate model comparison study (Abram *et al.* 2014) using data consolidated by the LOTRED and Antartica2k working groups, as well as a new ice core record from the Antarctic Peninsula. She noted that mean state of the SAM is now in its most positive phase for at least the last 1000 years.

Ailie Gallant's presentation on the issue of non-stationarity of climate teleconnection patterns (Gallant *et al.* 2013) generated much discussion, highlighting the need for critical thinking around estimating uncertainty associated with palaeoclimate reconstructions. She emphasized the need to develop spatially explicit climate reconstructions to allow for the evaluation of mean state changes and their expression in regional teleconnection patterns during the pre-instrumental period.

Session 3 was dedicated to discussing the role of climate modeling of the last 2000 years. Sandy Harrison highlighted recent progress with model evaluation of mid-Holocene and Last Glacial Maximum data, noting that the magnitude of future rainfall projections may be underestimated by up to 50% (Harrison *et al.* 2013). She noted that no model is good for all variables, but some are better or worse across a suite of evaluation metrics, and that multi-model ensembles incorporating different forcing are needed to account for forcing uncertainty over the last millennium.

Steven Phipps covered the key roles that climate models can play in studying the climate of the last 2000 years, including studying the roles of forced and unforced climate variability and testing dynamical hypotheses (Phipps *et al.* 2013). He also highlighted some of the current limitations, particularly uncertainties in our knowledge of past climate forcings. Sophie Lewis then spoke about the potential of using long-term palaeoclimate records for climate change and attribution studies. Tony Hirst gave the final talk of the session, highlighting the capabilities of the ACCESS (Australian Community Climate and Earth System Simulator) model and its potential use for palaeoclimate studies. He noted that ACCESS1.4 can run at 10 years per day on 384 cores suggesting that a last millennium run is feasible in under four months.

The rest of day 1 was spent discussing potential opportunities for collaboration between the Australasian palaeoclimate, climate modelling and meteorology communities. A range of projects, including testing the assumption of teleconnection stationarity, palaeoclimate runs with CAWCR's ACCESS model and pseudo-proxy model exercises to test the fidelity of palaeoclimate reconstructions, were discussed and collaborative contacts were made.

Day 2 of the workshop focused on the themes of i) Developing the database of Australasian low-resolution records: data consolidation and directions for future data

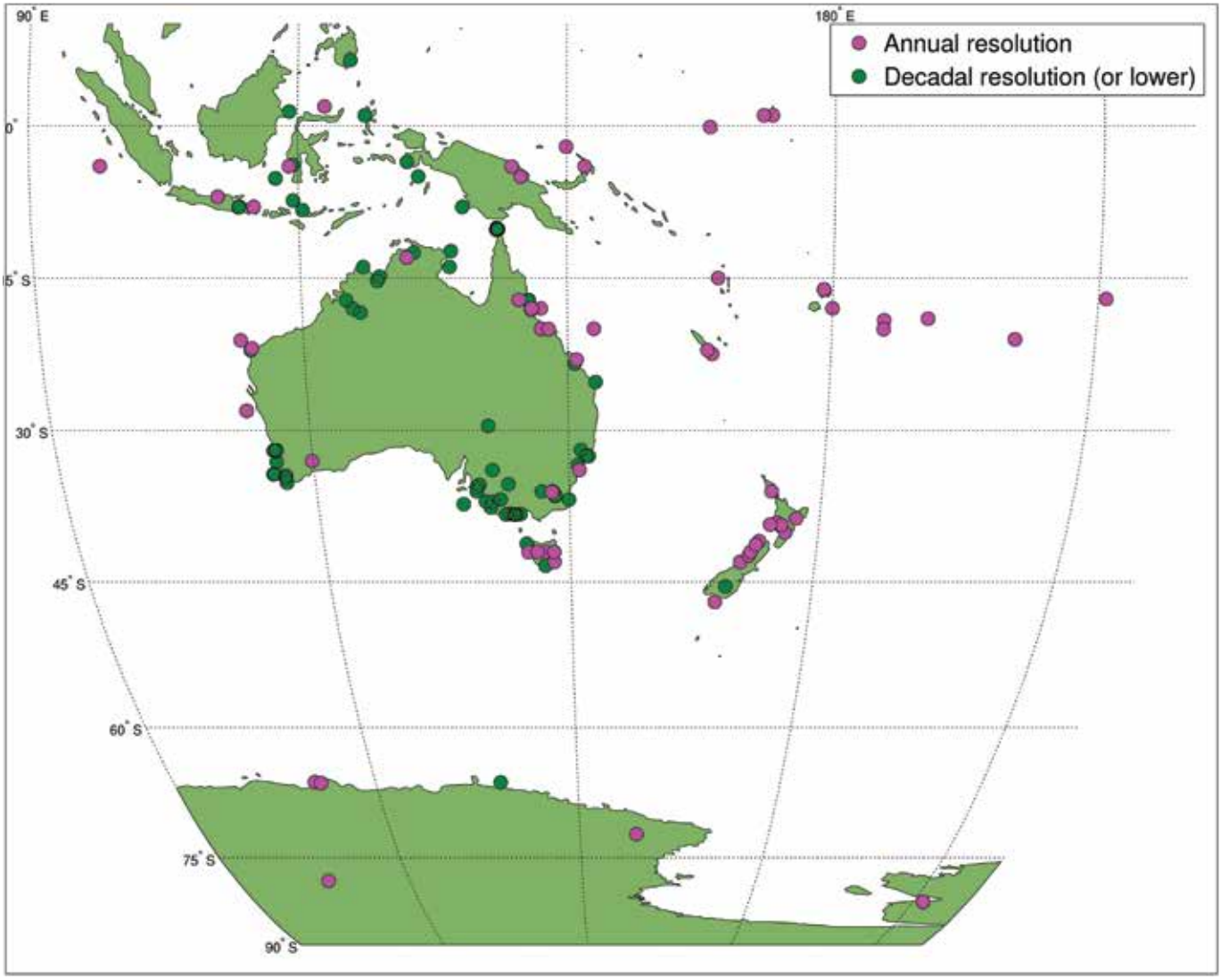

Figure 1: Locations of annually resolved and lower resolution palaeoclimate archives in the Australasian region.

collection; ii) Multi-archive data synthesis techniques being used by Aus2k and the PAGES 2k Network and iii) Climate field reconstructions and climate modeling.

In session 1, Jonathan Tyler outlined recent progress in systematically screening records using PAGES guidelines and recalibrating age models for a range of 'high quality' sedimentary records from Australia and Indonesia. A plan to incorporate material from New Zealand was discussed with Andrew Lorrey to consolidate the Australasian region's 'low resolution' database for Phase 2 activities. It was agreed that the dataset would be frozen on 31 December 2014 to allow for consistency in subsequent climate analyses undertaken by the group.

Finally, Tas van Ommen shared his experience of working in the Antarctica 2k working group and IPICS initiatives, highlighting the utility of using spectral analysis to classify records for high or low frequency climate analysis.

Plans to develop guidelines for future data collection in Australasia were also discussed, including ideas around testing the number and location of records required to reconstruct specific features of the Australasian climate and to deal with potential biases caused by non-stationarites. The white papers produced by the PAGES Trieste meeting were also discussed (http://www.ncdc.noaa.gov/paleo/reports/trieste2008/trieste2008final.pdf). Nerilie Abram and Russell Drysdale agreed to take the lead on developing this initiative.

Session 2 focused on multi-archive data synthesis techniques being used by Aus2k and the global PAGES 2k Network. Andrew Lorrey demonstrated a synoptic type and geopotential height reconstruction technique based on modern analogs using the Past Interpretation of Climate Tool (PICT) (http://content.niwa.co.nz/pict, e.g. Lorrey *et al.* 2013). Ben Henley then provided

a summary of the material presented at the recent PAGES 2k Advances in Climate Field Reconstructions (CFRs) workshop held in Woods Hole in April 2014, and an Inter-decadal Pacific Oscillation (IPO) reconstruction that is currently under development.

The issue of incorporating records with higher time uncertainty into CFRs was discussed, and it was agreed that reconstructions based on this material should form an independent way to verify low frequency trends and variability identified from the more chronologically precise high-resolution material (Figure 1 shows the current spatial distribution of these two datasets). The group agreed to perform a comparison of all methods being used by the group on the regional Australasian dataset. A plan to undertake an inter-comparison project with Australian and New Zealand data was proposed and will be coordinated by Ben Henley and Andrew Lorrey.

Session 3 was dedicated to the discussion of climate field reconstructions and climate modelling. Joelle Gergis discussed proxy selection considerations and recent progress in developing a temperature CFR for Australia within the Phase 2 timeframe. This was followed by a presentation by Steven Phipps who considered how climate modelling can contribute towards efforts to develop CFRs for the Australasian region. He stressed that the models can be used to test the assumptions underlying palaeoclimate reconstruction techniques. He also presented results of a proof-of-concept data assimilation analysis using proxies from the Aus2k, LOTRED and Antarctica2k temperature reconstructions, highlighting the potential role of palaeoclimate data assimilation in developing and assessing CFRs. He also allowed a few participants to experience the issues that modellers can face due to natural variability and biases in their climate model (in this case, a cup of ten dice).

The workshop wrapped up with the development of sub-groups based around the five objectives of the workshop, and a clear direction forward that will help deliver Australasia's best available science for the Phase 2 of the global PAGES 2k Network. The next Aus2k workshop will be held in Auckland, New Zealand in the austral spring of 2015.

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European INTIMATE (Integrating ice core, marine and terrestrial records) Meeting

ZARAGOZA, SPAIN, JUNE 2014

Helen Bostock

National Institute of Water and Atmosphere

In June 2014 I was funded by the Royal Society of New Zealand to attend the European INTIMATE meeting in Zaragoza, Spain, as a representative of the NZ/Aus Quaternary Community. My participation in this meeting was to present the aims of SHAPE (Southern Hemisphere Assessment of Palaeo-Environments – see previous articles in QA) and all the projects that have been proposed by the Aus/NZ community under this informal, collaborative group. We hoped to get some feedback on these projects, as SHAPE sits under the INQUA international focus group (IFG) umbrella of CELL 50 K (Calibrating Environmental Leads and Lags over the last 50 ka), which is aligned and led by the same people involved in the European INTIMATE project.

For those of you unfamiliar with INTIMATE here is a little bit of background. The European INTIMATE group was originally self-funded when it started back in 1995. This was followed by recognition and a small amount of money from INQUA. It inspired the formation of the Australasian INTIMATE group (OZ-INTIMATE and NZ-INTIMATE) which started in 2003. In 2010 the European INTIMATE group, led by Chris Turney, applied for funding from the European Cooperation in Science and Technology (E-COST) – a fund to aid the coordination of nationally funded research at a European level. Funding from E-COST over the last 4 years has greatly aided their ability to meet regularly, to bring in Eastern European scientists, and to run summer training schools for students. It is worth briefly restating the aims and objectives of INTIMATE, many of which will be very familiar to those who have been involved in AUS-INTIMATE and SHAPE.

The primary objective of INTIMATE is: "to reconstruct past abrupt and extreme climate changes over the period 60,000 to 0 years ago, by facilitating INTegration of Ice core, MArine, and TErrestrial palaeoclimate records and using the combined data in climate models to better understand the mechanisms and impact of change."

INTIMATE is split into 4 working groups:

- Dating and chronological modelling – a reliable chronological framework is the basis of all studies of past climate. WG 1 is dedicated to developing and improving dating methods over the last 60,000 years and bringing scientists together to develop a coherent dating framework in which records can be compared at unprecedented detail.
- Quantification of past climate – collect and quantify information of past climate in order to draw a detailed picture of the highly variable climate evolution in the North Atlantic and European region.
- Modelling mechanisms of past change – our ability to forecast the rates and magnitudes of future change depends on numerical models. By using combined ice, terrestrial and marine data sets as targets this working group will optimize methodologies to evaluate model simulations and make data-model comparisons.
- Climate impacts – gain insights into the impacts of past climatic changes on animal and human populations and the ecosystems of which they are a part. Quantify the magnitudes and the rates of population, species and ecosystem responses in space and through time.

With the E-COST funding finishing in June 2014, this was the final chance to hold a subsidised INTIMATE meeting supported by this funding. Around 90 people from across Europe (and one interloper – myself) attended the meeting held in the salubrious Hiberus Hotel. The primary aim of the meeting was to present the results from each of these working groups prior to publication of a range of papers in several journal special issues (Quaternary Science Reviews and Quaternary International) that will come out at the end of this year. It was also a chance to interrogate and compare the results between the working groups. Below I will summarise some science highlights from the talks that were given during the meeting and a summary of the 3 days field trip that followed.

The first day of the meeting was based around the results from WG1, developing detailed chronologies for the region. Initial work developing a climate event stratigraphy (CES) on the Greenland ice cores for the original INTIMATE timescale of 30-8 ka has now been

extend back to 48 ka b2k[1] (Blockley *et al.,* 2012). It has been hard to extend it beyond this to 60 ka as the peaks and troughs are small and hard to correlate between ice cores. As the CES extends back there are increasing errors on the age control of the ice cores (up to +/ – 1500 yrs), so some effort has been made to compare to speleothems from 30-60 ka (Marine Isotope Stage 3) with precise age control from U/Th ages. There has also been a lot of work on tephrochronology over the last few years to improve age control – at least between sites. Previously only a dozen macro-tephra layers (i.e. visible tephra layers) were evident in the ice cores, now hundreds of crypto-tephra deposits (glass-shard concentrations not visible as layers) have been found. The source and age of many of these tephras or cryptotephras are unknown, but likely from Iceland, but some may be far-field tephras from Japan. However, these tephras/cryptotephras need to be used with other chronological constraints such as radiocarbon dating. There have been several large projects looking at and developing tephrochronology. TRACE (Tephra constraints on Rapid Climate Events) aims to utilise isochronous tephra/cryptotephra horizons to correlate North Atlantic marine sequences and the Greenland ice-cores and determine the relative timing of oceanic and atmospheric changes associated with the rapid climate events that dominated the last glacial period. The RESET (Response of Humans to Abrupt Environmental Transitions) project aims to construct a new improved chronological framework for Europe using tephra/cryptotephra horizons which represent time-parallel signatures allowing archaeological and geological and paleoclimatological records to be linked. There was also an INTIMATE tephra workshop held in Pisa earlier in the year to try to compile a database of tephras from both the north of Europe and the south of Europe (around Italy), including those that are found across the entire region that could provide good stratigraphic markers. Some impressive "lattice diagrams" have been developed to show the tephra distribution and correlations across the region.

Radiocarbon has also been used liberally and extensively, especially in lakes, bogs and archaeological sites, along with Bayesian modelling using a variety of programs (e.g. Oxcal, Bacon). Chris Bronk-Ramsay has been developing an online database that will allow well dated records to be put on a single timescale, either INTCAL13 or the Greenland Ice Core (GICC05), thus allowing the timing of events to be compared. This details of this database will be published in an upcoming paper. In comparison to Australia there has only been a limited use of optically stimulated luminescence (OSL) for chronologies. There was a suggestion that while this technique was previously overlooked by many researchers due to the issues with precision and accuracy, there have been significant improvements over the last few years and OSL may be a good technique to try, especially in environments where other dating techniques are not appropriate, or give strange results.

Day two looked at the magnitude of change and also identifying the leads and lags. Several new proxies, especially biomarkers and the isotopes of these biomarkers, have been developed and were used in a couple of talks. These were accompanied by more well-known proxies such as foraminiferal assemblages in marine cores. Some of these talks focussed on a single high-resolution core from a lake or the ocean looking at the leads and lags of changes in a range of proxies. While others looked across regions that today have large gradients to look for spatial changes in the magnitude and timing of climatic change. With the recent inclusion of Central and Eastern Europe in 2010 the first compilation of all the data (fluvial, loess, lakes, pollen) from this more continental region has been produced and will be published in one of the INTIMATE special issues (Feurdean *et al.,* Quaternary Science Reviews, in press).

This was followed by a short Southern Hemisphere session where the SHAPE project was presented. The feedback on the SHAPE projects was very positive. Many of the European researchers also have projects in the Southern Hemisphere and there were several scientists that were keen to be involved, especially in the marine realm, while others would like to be kept in the loop about projects where they may be able to contribute. The session concluded with a talk by Joel Pedro on the data-model comparison for the Antarctic Cold Reversal across the Southern Hemisphere. This was well received with lots of questions and feedback and was a nice segue into the session on modelling.

The WG3 modelling efforts have primarily been focusing on proxy forward modelling, putting proxies like oxygen stable isotopes directly into the models. They have been primarily using intermediate complexity models like ILOVECLIM and CLIMBER3. These have a full ocean general circulation model (GCM), but simplified atmospheres. These intermediate complexity models are useful to test out a range of different forcings such as orbital forcing, greenhouse gases/CO2, changes in wind and topography due to ice sheets. The MIT General Circulation Model (MITgcm) is also being developed to look at specific time periods and issues such as the sea ice and ice bergs. This model has an automatically generated add-on which allows proxy data to be incorporated directly. The modelling session was followed with a good

1 Before the year 2000 AD

discussion on the main issues of developing models and comparing with proxy data. The biggest problem between the models and the proxy data currently is the fact that the grid size in the models is too large and therefore topography is not correct for mountainous regions, such as the European Alps, while regional downscaling of global climate models takes a lot of computer power and time. There was a suggestion that there needs to be more interaction between the modellers and the proxy community. There is financial support for the modelling work to continue through an Innovative Training Network (ITN) grant from the European Union.

The final WG4 looked at the impacts on the ecosystems, especially the vegetation, of these climate events, including the succession of flora after ice retreat or the influence of fire or extreme events. Several talks discussed the potential impact of changing climate on humans in England and Spain. There is a special issue in Quaternary International for WG4 out at the end of the year. The final talk by Mike Walker was a rather provocative overview of different definitions that have been proposed to define the Anthropocene (I will follow this up in a future QA article).

After three days of talks it was time to get outside and see a bit of the local area. We were taken to 3 areas around Zaragoza with very different Quaternary records. These field trips were expertly guided by local scientists from the University of Zaragoza that have worked on these areas. On the first day we drove north up to the Pyrenees to see the impressive U-shaped valleys in the Ordesa and Monte Perdido National Park. This was followed by visiting a series of fluvial terraces, moraines and a roche moutonnée further down the valleys which mark the extent of different Quaternary glacials. Interestingly there is no evidence of a LGM moraine, but a large moraine marks the large extent of the MIS 4 glaciers, and MIS 6.

The second field trip headed southwest to the Iberian Range to karst country to look at some Quaternary tufa deposits, which were deposited during interglacials. After a very hot morning up on the tops looking at past interglacial tufa deposits, we spent the afternoon wandering around the rather cooler and wetter Monasterio de Piedra Natural Park where tufa is currently being deposited at rapid rates of up to 2.5 cm.

The third field trip headed out west to the Bardenas Reales Natural Park, a world biosphere reserve. Here there are a series of mesas and "badlands[2]" we looked at a sequence of cut and fill Holocene alluvial deposits indicative of wet and dry periods and increasing aridity. This is also an environment that has been impacted by humans who have lived and attempted to cultivate this land. Unfortunately it had rained the night before which meant that we couldn't get down into the river beds without the risk of getting stuck in the mud!

The meeting was very well organised by our Spanish hosts and, as well as some very interesting science, they made sure that we got to see some local Spanish culture by taking us out for tapas in Zaragoza on Friday night and provided some local musical entertainment on the Tuesday night, which included some kind of frilly bagpipes – along with several other weird and wonderful musical instruments. It also involved dancing that was suspiciously like the Scottish dancing that went on at the previous INTIMATE meeting in Blair Athol (see Lynda Petherick's QA article). Unfortunately/fortunately I have no photos!

A few final impressions of the INTIMATE meeting. Initially I felt like a bit of an outsider at the European INTIMATE meeting, and it was unclear how a workshop with 90 people would allow for good discussions and debates. However, the inclusiveness and camaraderie of the group made me feel comfortable and able to contribute to the open discussions. From talking to many of the participants that there are a lot of links between Aus/NZ researchers and European colleagues, but participating in meetings like this helps improve and expand these relationships. It is clear there is support for early to mid-career researchers, with several chairing sessions and many talks and posters given by students and postdocs. Many early, mid and late career researchers have been involved in the summer training schools for the students developing some great friendships and a very cohesive community.

The meeting was a chance to reflect on the progress and the achievements of INTIMATE over the last 5-10 years and whether there was enthusiasm and drive to continue the project, and if so, what the aims should be for the next phase. The INTIMATE brand is now well recognised and has a good reputation. There are currently 270 members across Europe, 50 early career scientists have been supported to attend meetings and there have been many papers (44 are currently listed on the website – with many more coming out in the special issues in the near future), plus a few papers that have been published over the last few years in high profile journals. The general consensus amongst the community that there is still a lot of work to do to achieve the original INTIMATE objectives. At the conclusion of the meeting Dr Christine Lane (University of Manchester) was elected as the new chair of the next

2 Origin of term Badlands from dictionary.com: 1850–55, Americanism; bad1 + land + – s3 ; translation of French mauvaises terres, perhaps based on expressions in American Indian languages, alluding to the difficulty in traversing such country.

phase of INTIMATE, tasked with finding new funding and mechanisms to continue the work.

Through CELL 50 K led by Simon Blockley, there are now several INTIMATE groups set up around the world (including SHAPE). I believe these INTIMATE groups can learn from the European experience and may benefit from support from the European INTIMATE community. Officially CELL 50 K continues until the next INQUA congress in 2015 (along with SHAPE), however, many of these regional INTIMATE groups will need more time to develop their records and compilations and therefore I hope that INQUA will provide ongoing support for these activities – at least until 2019...

Clockwise from top left: Map and U-shaped valley in the Pyrenees; Badlands; Our hotel in Zaragoza; the waterfalls of Monasterio de Piedra. Photos Helen Bostock

ARC results

FUTURE FELLOWSHIPS

UNIVERSITY OF WOLLONGONG

Dr Bo Li (FT140100384)

Total: $771,504

GEOLOGY

Project Summary:
Chronology is a critical component of geological and archaeological studies. To reconstruct the evolutionary histories of Homo sapiens and other hominin species in their environmental context, we must establish reliable age estimates for key archaeological sites and Quaternary deposits. This project aims to develop new-generation sediment dating techniques using the non-fading infrared stimulated luminescence (IRSL) signal from potassium feldspars. These improved methods will be able to be applied to sites in Africa, Europe and Asia that contain important human fossils and artefacts, including the unique type localities of Denisovans and Hobbits, to answer fundamental questions about the timing of key turning points in human evolution and dispersal.

Asst Prof Benjamin Marwick (FT140100101)

Total: $654,154

ARCHAEOLOGY

Project Summary:
At a crossroads between India, Australia and the Pacific, this project recognises western mainland Southeast Asia as critical to understanding the human history of the region over the past 50 000 years. Thailand and Myanmar are strategically positioned to test competing models of initial modern human expansion, and subsequent trajectories of cultural change and interaction. This project aims to produce multiple data sets for reconstructing palaeoclimate. This data will assist in testing projections for future climate, making a significant contribution in responding to climate change and variability.

Dr Katherine Szabo (FT140100504)

Total: $812,966

ARCHAEOLOGY

Project Summary:
Shell valuables are fundamentally important in many Melanesian societies, linking people to each other, the land and their ancestors. Although shell artefacts are frequent in Melanesian archaeological sites, presently it is not possible to discriminate between types and levels of value. Through ethnoarchaeological enquiry in the Solomon Islands and intensive studies of museum ethnographic collections, this project aims to develop tools to allow archaeologists to better interpret the nature of different shell artefacts and the social contexts of their production, use and discard. In doing so, it will enhance understandings of Melanesian societies and their transformations through time.

THE UNIVERSITY OF ADELAIDE

Dr Damien A Fordham (FT140101192)

Total: $770,684

OTHER BIOLOGICAL SCIENCES

Project Summary:
Current forecasts indicate that human-driven climate change will likely cause widespread biodiversity loss. However, climatic shifts during the Quaternary (2.6 million years ago to present), similar in magnitude to those projected for the 21st century, did not apparently cause extensive extinctions (with the exception of the megafauna). This project aims to use models linked to past responses imprinted in species genes to resolve whether the disparity between observed and predicted extinction rates comes from models over-predicting species loss due to climate change. It will use this genetic – demographic approach to improve predictions of biodiversity responses to global change by establishing the biological and environmental determinants of extinction.

THE AUSTRALIAN NATIONAL UNIVERSITY

Dr Helen V McGregor (FT140100286)

Total: $771,360

PHYSICAL GEOGRAPHY AND ENVIRONMENTAL GEOSCIENCE

Project Summary:
El Niño and La Niña events have a profound influence on Australian drought conditions and rainfall. Forecasting is hampered by short climate records, which do not capture the full range of El Niño dynamics. This project aims to generate records of unprecedented length and spatial coverage from key sites across the western and central equatorial Pacific. Five hundred years of continuous, monthly-resolution climate data will be integrated with output from state-of-the-art climate model simulations to distil the key processes that cause El Niño to vary. This project aims to provide major advances in determining the full range of El Niño and La Niña behaviour, leading to improved forecasts of future changes, with consequences for Australia's water security.

Dr Jimin Yu (FT140100993)

Total: $758,724

PHYSICAL GEOGRAPHY AND ENVIRONMENTAL GEOSCIENCE

Project Summary:
The causes for past atmospheric carbon dioxide (CO_2) changes and their mechanistic links to the histories of climate and ocean carbonate chemistry remain elusive, but may hold future-relevant information. This project aims to use novel methods to quantify deep ocean carbonate ion concentrations, a critical but poorly constrained parameter of the global carbon cycle, at 10 key locations spanning the global ocean during the last 350 000 years. By feeding new data into a model, this project aims to gain critical insights into mechanisms controlling past deep-sea carbonate cycles and atmospheric CO_2 changes, thereby leading to improved understandings of the climate system.

LAUREATE FELLOWSHIPS

JAMES COOK UNIVERSITY

Prof Michael Bird

Total: $2,647,521.00

PHYSICAL GEOGRAPHY AND ENVIRONMENTAL GEOSCIENCE

What is natural? Humans, megafauna and climate in northern Australia
This project aims to produce the first long-term (100,000 year), replicated, high-resolution terrestrial records of environmental change before, during and after the arrival of humans in Australian savannas. These records will be the first in the world to extract, from the same material, independent, cutting-edge organic and isotope geochemical records of changes in water balance, vegetation type and fire activity. This will enable natural and human drivers of change in northern Australia's climate and biodiversity to be disentangled on two timescales: millennial: before, during and after Aboriginal arrival in northern Australia and centennial: before, during and after European arrival in northern Australia.

THE UNIVERSITY OF ADELAIDE

Prof Alan Cooper

Total: $2,775,898.00

ECOLOGY

Using ancient microbiomes and genomes to reconstruct human history
This project aims to generate unique insights into the processes and history that produced the current distribution of modern humans and the bacteria we carry with us (our microbiome). The project will use combined signals of bacterial, genomic and climate data to reconstruct the impacts of migrations, changes in diet, environment, and health in different parts of the world. A key aspect will be the creation of a program to map the genetic history of indigenous Australia, and the impacts of colonisation on indigenous people around the world. Research advances will be transferred to Early Career Researchers through an innovative program of workshops, and the resulting data will be used to create a new format for Australian genetic databases.

THE AUSTRALIAN NATIONAL UNIVERSITY

Prof Matthew Spriggs

Total, $2,429,568.00

ARCHAEOLOGY

The collective biography of archaeology in the Pacific: a hidden history
The project aims to establish the history of Pacific archaeology as a new sub-discipline within world archaeology, covering the period from the speculations of early explorers to the present. The often-forgotten role of Australian and New Zealand scholars will be highlighted. Pacific archaeologists, stewards of a third of the World's archaeology, have forgotten so much of that history that the discipline is in a serious conceptual crisis, with current theories about the origins of Pacific peoples mired in outmoded and often racialised assumptions. At the same time, our ideas about the Pacific past are becoming internalised among indigenous Pacific Islanders. There is a need for understanding the disciplinary history in order to move theory forward.

LINKAGE GRANTS

THE AUSTRALIAN NATIONAL UNIVERSITY

PHYSICAL GEOGRAPHY AND ENVIRONMENTAL GEOSCIENCE

Pillans, Prof Bradley J; McPhail, A/Prof D C "Bear"; Hiscock, Prof Peter D; Dosseto, Dr Anthony; Papp, Dr Eva; Opdyke, Dr Bradley N; Clark, Dr Daniel J; Osborne, Mr James D; Osborne, Mr Henry; Gregory, Mr Wayne

Total: $450,000.00

Partner Organisation(s): Geoscience Australia, Grantham Park Holdings Pty Ltd, Currandooley Pty Ltd, Tobiway Crushing Pty Ltd

Project Summary:
Lake George is an outstanding natural archive – it contains the longest continuous sedimentary record of any Australian lake and has a long, unresolved human occupation history. It also supplies 80 per cent of sand used in the Canberra region construction industry. This multidisciplinary study aims to determine the sedimentary, vegetation, climatic, hydrological, tectonic and archaeological history of the area, including application of cutting-edge dating methods. Project outcomes aim to increase knowledge of landscape evolution and human history in eastern Australia from an improved understanding of the responses of Lake George to past and future climate change and human impact, as well as optimising sustainable extraction of sand and gravel.

THE FLINDERS UNIVERSITY OF SOUTH AUSTRALIA

LP140100317 – PHYSICAL GEOGRAPHY AND ENVIRONMENTAL GEOSCIENCE

Werner, A/Prof Adrian D; Cartwright, Prof Ian; Yan, Ms Wei

Total: $294,000.00

Partner Organisation(s): SA Department of Environment, Water and Natural Resources

Project Summary:
Rivers are the main source of freshwater for many ecosystems in semi-arid zones. River water may seep into the floodplain aquifer, providing an accessible store of low-salinity water within freshwater lenses. The project aims to investigate lens dynamics using numerical groundwater models supported by extensive field data from the lower River Murray, where freshwater lenses are declining. The project aims to model lens extent, growth and decline in response to natural variations in climate and to changes in land use, river regulation and groundwater pumping. Project results intend to evaluate management options to promote freshwater lenses, with the aim of improving river salinity and floodplain vegetation health.

UNIVERSITY OF CANBERRA

LP140100521 – ENVIRONMENTAL SCIENCE AND MANAGEMENT

Unmack, Dr Peter J; Gruber, Asst Prof Bernd M; White, Dr Duanne A; Georges, Prof Arthur; Kilian, Dr Andrzej

Total: $269,692.00

Partner Organisation(s): Diversity Arrays Technology Pty Ltd

Project Summary:
Understanding factors that influence genetic spatial structure of species is essential for conserving biodiversity. Movement of freshwater organisms in riverine environments is severely constrained by dendritic structure of streams, variation in aridity, and geomorphology. The project aims to test hypotheses of how these factors impact genetic patterns across east-west climatic gradients in eastern Australia. For most aquatic species, research is limited on genetic patterns across spatial scales with varying riverine dendritic structure and rarely incorporates historical data. Uncovering genetic spatial structure in aquatic ecosystems is necessary for conservation management and predicting species movements in the current changing climate.

THE UNIVERSITY OF WESTERN AUSTRALIA

LP140100393 – ARCHAEOLOGY

McDonald, Prof Josephine J; Veth, Prof Peter M; Paterson, Prof Alistair G; Hampson, Asst Prof Jamie; Glaskin, A/Prof Katie; Whitley, Asst Prof Thomas G; Bourke, A/Prof Paul D; Mulvaney, Dr Kenneth J

Total: $720,000.00

Partner Organisation(s): Rio Tinto

Project Summary:
Despite the acknowledged National Heritage significance of the Dampier Archipelago's petroglyphs and stone features, there has been little research which assists in knowing when, why and how this art was produced. This landscape was occupied and art was produced both before and after sea level rise c.8-6,000 years ago. Developing a reliable chronology of occupation will allow a reconstruction of the role that art played in land-use systems of the Archipelago and adjacent Abydos Plain. This aims to be achieved by targeting and analysing landscapes associated with the earliest art of the Archipelago. The second aim is to explore contemporary social connections to this place back to first contact with historical seafarers and colonial settlers.

GRIFFITH UNIVERSITY

LP140100387 – ANTHROPOLOGY

Westaway, Dr Michael C; Wright, Dr Duncan J; Lambert, Prof David M; Miller, Prof Adrian; Fry, Prof Brian; Clegg, Dr Margaret; Collard, Prof Mark; Sankarasubramanian, Dr Subashchandran; Li, Dr Ruiqiang; Willerslev, Prof Eske; Hadnutt, Mr Nicholas

Total: $740,880.00

Partner Organisation(s): Novogene Bioinformatics Technology Co. Ltd, Centre for GeoGenetics, Natural History Museum of Denmark, Queensland Museum

Project Summary:
The repatriation of Aboriginal and Torres Strait Islander remains has been a focus of Commonwealth and State Governments for over two decades. It remains as a significant social and cultural issue for many Indigenous Australians. One of the main hurdles to repatriation is the fact that hundreds, and possibly thousands of human remains have very little contextual detail associated with them. A number of techniques have been developed in the field of biological anthropology to reconstruct the history of individual skeletal remains. This innovative project aims to use advances in the fields of ancient DNA, isotope analysis and craniometrics to resolve the provenance of 113 trophy skulls from the Torres Strait Islands.

JAMES COOK UNIVERSITY

LP140100536 – ANTHROPOLOGY

Foale, Dr Simon J; Wood, Dr Michael A; McIntyre-Tamwoy, Dr Susan R; Filer, Dr Colin S; Leavesley, Dr Matthew G; Kelly, Dr Matthew S; Specht, Dr Jim R; Mondiai, Mr Kenn N

Total: $228,000.00
Partner Organisation(s): Archaeological & Heritage Management Solutions, Partners with Melanesians Inc

Project Summary:
This project aims to document and integrate the natural and cultural values of the Nakanai Caves in East New Britain, Papua New Guinea, in preparation for a cultural landscape World Heritage nomination. The project's novel methodology incorporates community knowledge with archaeological and anthropological evidence to link natural and cultural values and define the landscape from local perspectives. Local input into the research will be prioritised. By emphasising local participation and management of World Heritage listing processes the project aims to address an identified gap in World Heritage methodologies. This project allows for a subtle, nuanced definition of cultural landscapes under the World Heritage Convention.

A ground penetrating radar survey near the excavated burial site of Kiacatoo Man

Justine Kemp[a]*, Allen Gontz[b], Colin Pardoe[c], Timothy Pietsch[a], Jon Olley[a]

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c Department of Archaeology and Natural History,The Australian National University,Canberra 0200
** email: j.kemp@griffith.edu.au*

ABSTRACT

Ground penetrating radar technology has advanced in the last decade to the point where it is possible to identify objects as small as a grave quickly and with great precision. This study investigates its potential for identifying possible human burials alongside the grave site of Kiacatoo Man in central New South Wales. In 2011, the weathered remains of this individual were discovered in a levee of an ancient course of the Lachlan River, and measurements taken from the reconstructed femur suggest an individual of exceptional size and rugosity. Preliminary OSL analyses of fine sandy sediment underlying the grave floor provide a maximum age for the skeleton of around 17,000 years. A GPR survey over a 200 m x 40 m grid of the levee revealed five disturbances that are consistent with the geophysical and morphological expression of grave excavations. The technique appears to be an effective tool for mapping of unmarked graves, and may be particularly useful for systematic archaeological exploration of the source-bordering dunes and levees of the Riverine Plain. These landforms may hold the key to understanding burial patterning, the distribution of people, and land-use during the late Pleistocene in Australia.

INTRODUCTION

This paper forms part of a larger project that explores the ancient river systems of inland SW Australia and how people lived along them in the past. It builds on a long tradition of collaboration in Australia between earth sciences and archaeological sciences. Geomorphological research in the Lachlan's riverine plains has identified a system of surface palaeochannels that records the evolution of the river and its highland catchment through the last glacial cycle. In February 2011, a burial unearthed at Kiacatoo on the bank of one of these ancient channels, along with other archaeological finds, presented a new opportunity for linking our two disciplines to provide a richer understanding of Australia's past. This paper reports on a Ground Penetrating Radar (GPR) survey near the initial Kiacatoo burial to investigate the nature of the levee as well as potential archaeological contents, including further burials. An overview of geomorphological research conducted in the region provides context to the survey. This is followed by a summary description of the original burial, its excavation and location, to situate Kiacatoo Man in his chronological, spatial and archaeological context. The methods and results of the GPR survey are followed by a discussion that shows its value for research in fluvial sedimentology, archaeology and land management.

GEOMORPHOLOGICAL EVOLUTION OF THE LACHLAN PLAINS AT KIACATOO

Geomorphological research using optically stimulated luminescence (OSL) dating on the middle Lachlan River has provided an environmental context for the time from when people first occupied the area, ~50,000 years ago until the present day (Bowler *et al.,* 2003). To date, there is no archaeological evidence for occupation of the SE highlands until 9,800 years ago (Aplin *et al.,* 2010), but the rugged slopes of the upper Abercrombie and the exposed tablelands of the upper Lachlan near Lake George produced runoff sufficient to sustain large sinuous channels, lagoons and lakes on the plains downstream that would have supported resources of fish, shellfish, waterfowl, large and small fauna, as well as tubers and yams (Kemp and Rhodes, 2010; Pardoe, 1995). Decreasing temperatures 34,000 years ago produced larger, actively meandering channels and greater seasonality of water resources. Flows may have declined in magnitude at the Last Glacial Maximum (LGM), but snowmelt floods were more predictable and larger than present.

The floodplain downstream from Kiacatoo features palaeochannel systems similar to those described near Condobolin and Forbes, 10 to 200 km upstream (Kemp and Spooner, 2007; Kemp and Rhodes, 2010). Older channel traces ascribed to the Gulgo Palaeochannel System are preserved, largely infilled, in the plain between the modern Lachlan River and Borapine Creek (Fig. 1A). In the vicinity of the Kiacatoo burial, these channels have been cut by sinuous channels with large meander wavelengths and scrolled, fine sandy floodplains of the Ulgutherie Palaeochannel System, dated from 20,000-35,000 years near Forbes. In this location, Ulgutherie channels are followed by the present Borapine Creek, which flows at moderate to high stages from the Lachlan River. Smaller wavelength channels south of the burial site may represent reducing flows within the Ulgutherie stage or diversion by local anabranching. The burial site of Kiacatoo Man was found in a natural levee lying north of this inset channel belt that follows its northern edge for 3 km. Locally the levee is elevated ~1.5 m above the plain with ~ 1.6 m of strong brown silty fine sand of fluvial origin overlying 2.4 m of brown fine sandy silt grading downwards into silty fine sands of the former floodplain. Six OSL samples extracted from the grave fill and from the underlying levee sediment are presently being analysed at Griffith University (Fig. 2A). The modern Lachlan trench lies 1 km north of the burial site and was formed by avulsion away from the Ulgutherie channel belt around the time that the modern flow regime was established.

KIACATOO MAN, HIS EXCAVATION, LOCATION, AND ARCHAEOLOGICAL CONTEXT

Kiacatoo is the Wiradjuri name for this region of the Lachlan Valley and survives as the name of a station property north of the river and a small settlement nearby. *Kiacatoo* is also the name of a poem by local Wiradjuri writer, Kevin Gilbert, (Gilbert, 1988: 189-90) that describes a massacre on the banks of the Lachlan in this area. Burials in such a context need to be approached with consideration and local community support (Pardoe, 2013a).

The burial at Kiacatoo was exposed by erosion from stock and an old vehicle track. Once identified as being of some antiquity (based on mineralisation, carbonate encrustation and preservation), there was considerable community interest leading to a decision to remove the remains, carry out some investigations and then rebury them near the original grave (Fig 2B).

The excavation was carried out in May 2011, when the soil was moist and suitable for such work. Summer conditions generally preclude excavation of skeletal remains as the soil is hard with soil carbonates cementing the sun-baked sediment. Members of the local Wiradjuri Aboriginal community authorised and participated in the excavation along with other interested volunteers (Fig. 2C). Only fragments of the cranium remained along with the right mandibular body (Fig. 2D). The post-cranial skeleton was complete, but fragmented with poor preservation of articular surfaces and other elements with thinner cortical bone. Very little cancellous, or spongy, bone was preserved. Preservation is a relevant, but imprecise indicator of antiquity. The bone was evenly mineralised, but with slightly darker colouration on the external surfaces. No chemical examination of the mineralisation was possible. Manganese staining was not evident.

A carbonate wash was present over exposed surfaces and appeared to be of an even thickness on upper and lower surfaces of bone in resting position. The carbonate had infiltrated the bone, assisting the destruction of cancellous bone and exacerbating or causing expansion of micro-fractures so that, while complete in situ, the bones reduced to hundreds of fragments following excavation. Limited reconstruction was possible during the time the remains were in the laboratory. Given the greater amount of carbonate on external surfaces compared to broken edges, it may be that vehicular traffic was responsible for a considerable part of the fracturing.

The preservation, with such a degree of mineralisation and carbonate encrustation, is typical of remains that are at least several thousand years old. Carbonate deposition, both type and amount, is dependent on its solution in the

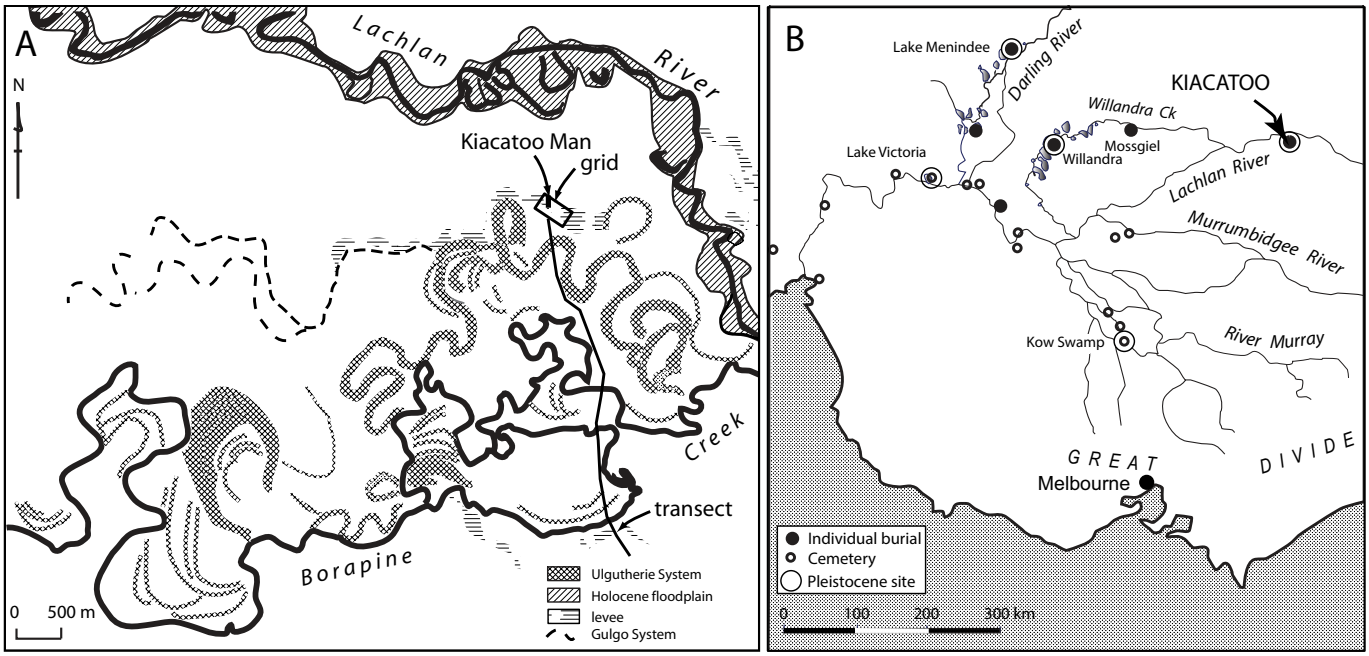

Figure 1: A. Geomorphic map of the Lachlan River at Kiacatoo. **B.** Distribution of individual burial sites and cemeteries in the riverine plains. Modified from Pardoe (1995).

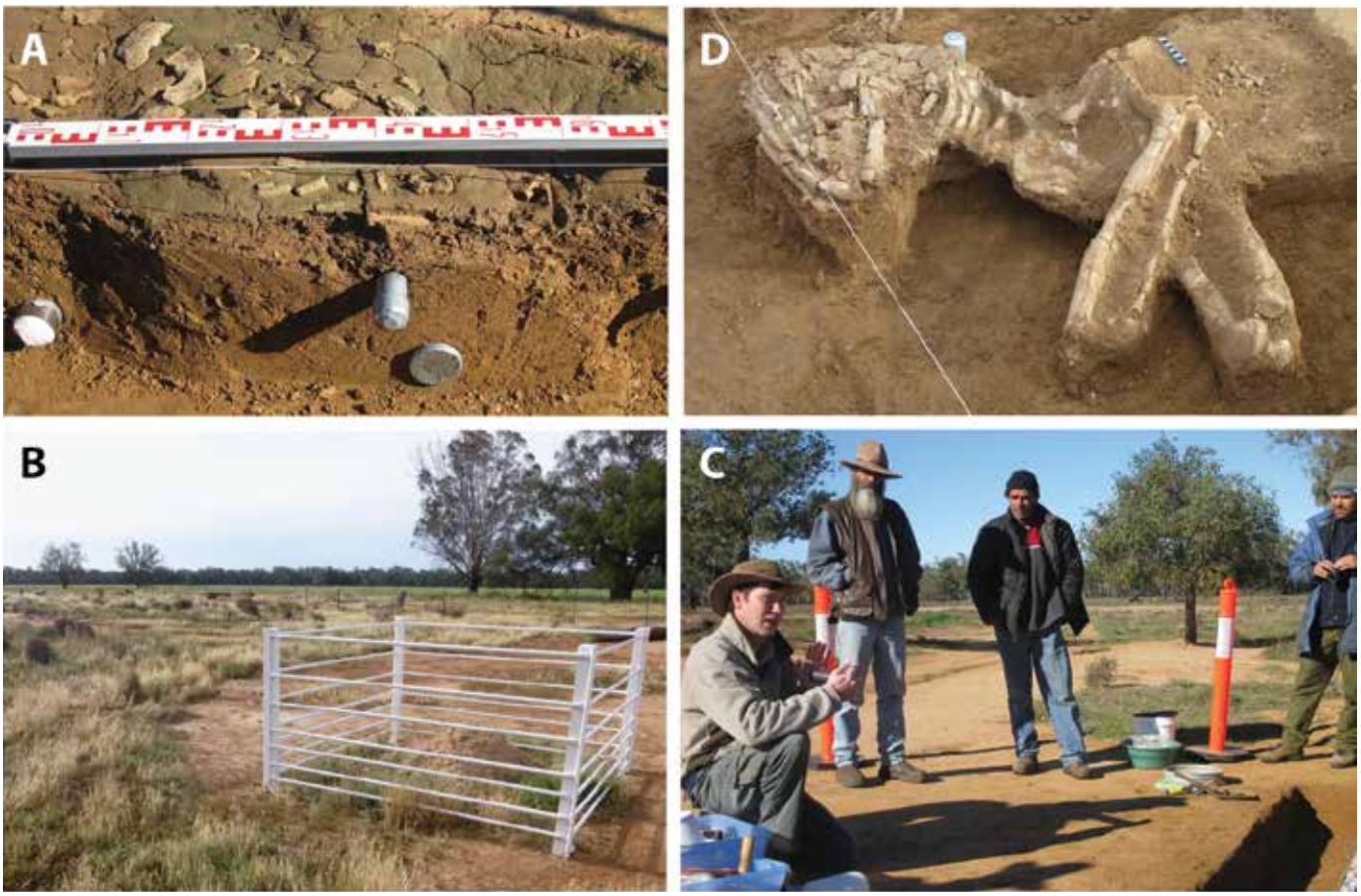

Figure 2: Photographs from the 2011 excavation of Kiacatoo Man **A.** The trench excavated adjacent to the grave revealed a clear boundary between the grave sediments and the underlying fill at 20-22 cm depth. The original depth when dug may have been around 60 cm, implying that 40 cm of the levee surface has been lost through erosion. **B.** Remains were returned to the gravesite in 2012 for reburial. **C.** Tim Pietsch explains the principles of OSL dating to community participants. **D.** The post-cranial skeleton of Kiacatoo Man was well preserved. The large, heavily-built legs have the shins folded back against the thigh in a manner only possible some time after death and rigor mortis. Although most of the cranium was fragmented, morphological features of limb bones, skull vault and face indicate an individual of great size and strength. Analysis suggests that Kiacatoo Man would have stood around six feet tall when alive, making him the largest Pleistocene individual yet discovered in Australia.

water table, degree of evapo-transpiration, depth of burial, amount of carbonate in the soil, type of soil, and no doubt many other factors. The degree of preservation, indicating great antiquity, is supported by the location of the burial in the levee of an ancient palaeochannel. Preliminary OSL analyses of one OSL sample on sediment from beneath the grave floor carried out by Griffith University has suggested a maximum age for the burial of ~17,000 years. A similar age was obtained for sediment comprising the grave fill, but an experimental study on OSL signatures in grave excavations suggests that grave fill may be indistinguishable from the age of the underlying, undisturbed sediment using OSL techniques (Kemp *et al.*, in press). Uranium-series ages on a number of teeth are currently being investigated by Rainer Grün at the Australian National University.

A more detailed description is in preparation, but in summary the remains are those of a large man, possibly the biggest individual documented in Australia. For example, the cranial fragment is as thick as any of the Willandra series, excepting the enigmatic WL 50. From in situ estimation, long bone lengths are at the upper end of the range, exceeded by no more than 2% of an Australian sampling that includes those from mid to early Holocene Rufus River as well as Kow Swamp further upstream in the Murray River corridor. This individual has the largest absolute femoral and tibial diameters of any recorded. Measurements taken from the femur, both length and circumference, place him in the top five percent of Aboriginal measurements along with exceptional rugosity. Although not necessarily the tallest of men, he would have been among the most heavily built, pushing back the contemporary Wiradjuri affinity with Rugby League by millennia. The term 'rugosity' is used instead of 'robusticity' in order to avoid the confusion this term has occasioned, particularly in related disciplines outside of biological anthropology. The former term refers to morphology related to muscle markings, including insertion of tendons, ligaments and fascia, which is itself determined by sex, body build and daily activity through life. A fuller discussion will be made in a following paper concerned mainly with the biology of Kiacatoo Man.

Their most ancient ancestor links Wiradjuri people to those further downstream, at a time when the Lachlan River had yet to jump its course west of Lake Cargelligo, and still flowed along what is now Willandra Creek, feeding the lakes and people of Willandra. During the last millennia of the Pleistocene, people would have been linked up and down the Lachlan River, preferentially marrying their neighbours in a manner required by the nature of the country (Pardoe, 2006). The size, shape and details of skeletal anatomy provide indications of the biological links between groups, and adaptation to the particular environment of rivers crossing the Riverine Plain when this was part of the Arid Zone.

Virtually all of the ancient (greater than 7,000 years) human remains in Australia have come from the Riverine Plain of the Murray-Darling Basin. People have lived throughout the region since earliest times, burying their dead close to and within residential places that are typically close to rivers, ephemeral lakes and wetlands. Most burials are considered to be in sandy deposits such as lake-edge lunettes, source bordering dunes, and other sand bodies. While burials have been noted in levees, these have tended to be associated with the large palaeochannel traces that meander across the Riverine Plain [Littleton, 1997, 1998; Pardoe and Martin, 2001].

In the Lachlan-Willandra system, source-bordering dunes and levees may hold the key to understanding the distribution of people during the coldest phase of the LGM: whether they were able to range widely or retreated to the river systems as the lakes dried. So far, apart from Kiacatoo Man, there is no direct evidence of a human presence on any of the riverine corridors upstream of Willandra Lakes before 15,000 years (Pardoe, 1995), but an extensive search has not been undertaken. The oldest and best preserved human burial sites are found in lunettes around now-dry lake systems, where high population density relative to the surrounding desert is combined with ease of excavation, high preservation potential, and in eroding sites, ease of discovery (Fig. 1B). But the subtle sandy rises on Pleistocene channels, such as that containing Kiacatoo Man, are likely to have similar favourable features. This implies that many preserved burials along ancient river corridors have yet to be recorded and this is where GPR proves useful.

METHODS

Over the past decade, improvements in GPR technology have facilitated the subsurface identification of small-scale sedimentary structures, disturbances and archaeological objects (Neal, 2004). GPR is an effective tool to identify graves because it provides a clear geological association of the skeleton with the underlying landform as well as the stratigraphic relationship between channel-floodplain-bar-levee systems. This also reduces the opportunity for uncertainty with dating methods associated with stratigraphic variations (Gontz *et al.*, 2011; Damiata *et al.*, 2013; Zhao *et al.*, 2013).

Exploratory GPR surveys were conducted using a MALA GeoScience Pro-Ex GPR system with a 500 MHz antenna to image the subsurface in a grid on both sides of the grave site. The grid was 200 m along the levee by 40 m wide, and survey lines were 0.5 m apart. A survey line

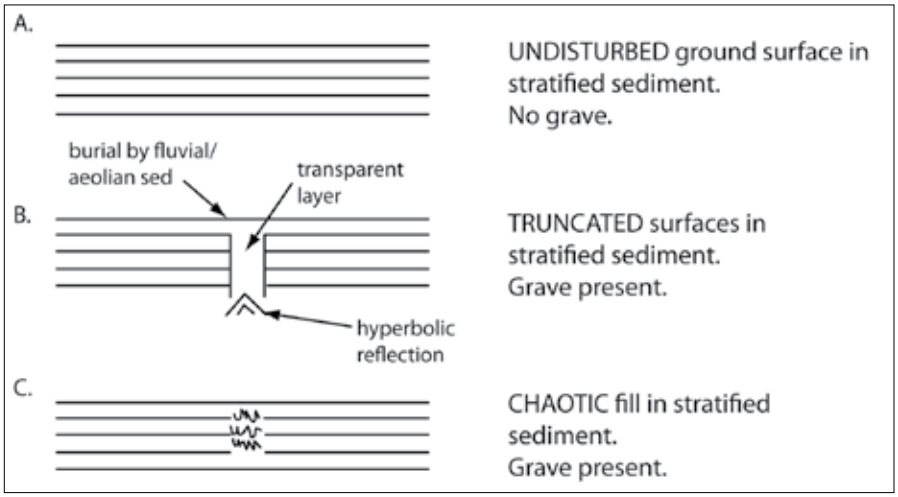

Figure 3: Typical grave signatures in stratified sediment, modified after Gontz *et al.*, 2011; Schultz and Martin 2011.

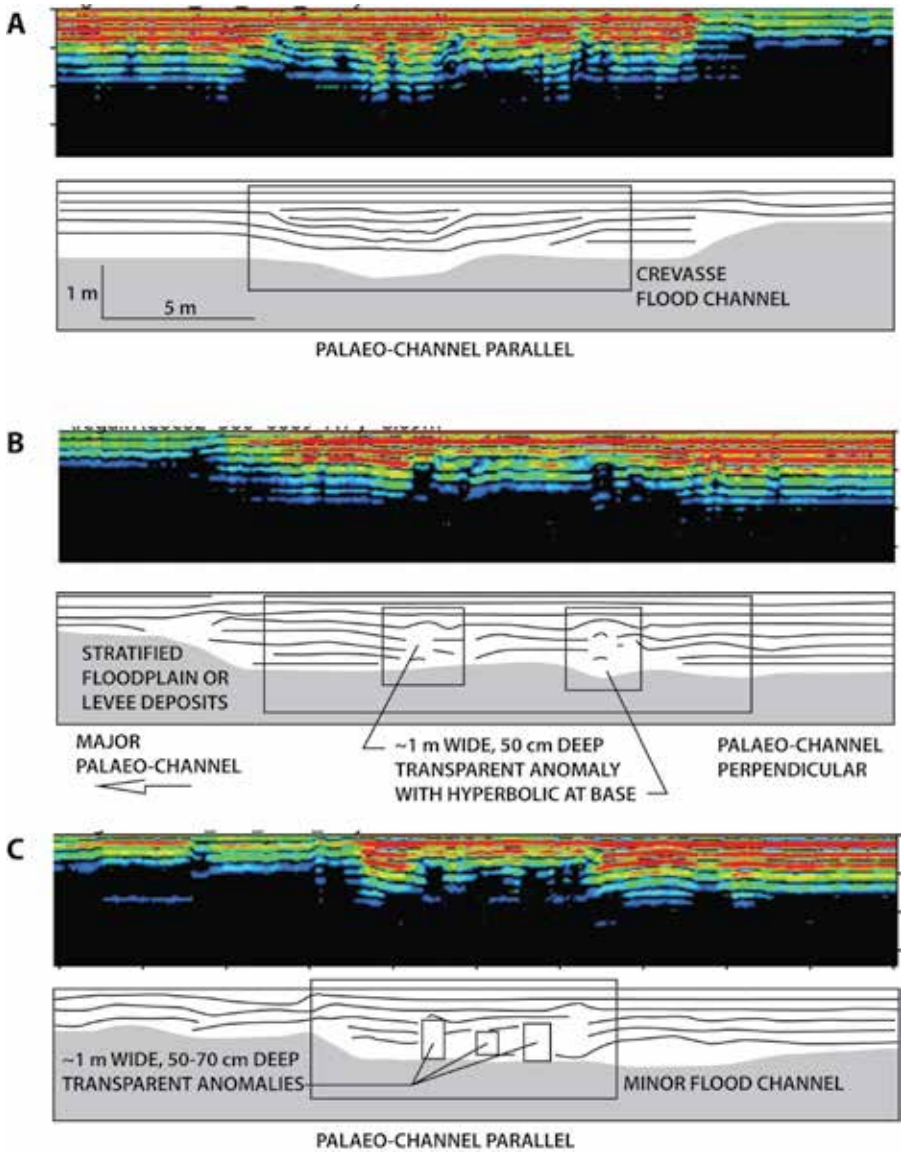

Figure 4: Ground penetrating radar lines collected and subsurface features interpreted at the site. All GPR sections are presented at the scale indicated on Panel A. Only anomalies interpreted as potential grave sites are highlighted. Other anomalies occur and could be the result of subsidence, biological processes or interference from surficial topography and/or materials.
Panel A: This line runs parallel to the major palaeochannel approximately 15 m to the south of the burial site. The radar stratigraphy indicates a small flood channel cut through the stratified sediments of the levee and floodplain deposits.
Panel B: This line was acquired approximately 5 m west of the burial site and runs perpendicular to the major palaeochannel. The radar stratigraphy shows primarily stratified sediments of the floodplain and levee system. In the centre portion of the image, three transparent anomalies are highlighted. These are consistent with the manifestation of small-scale excavations and the size (~ 1 m wide x 50/70 cm deep) is consistent with burials.
Panel C: This line is parallel to the major palaeochannel and is 5 m south of the burial site. The radar stratigraphy shows a small flood channel cut with transparent anomalies in the channel fill. The anomalies have a similar scale to those imaged in Panel B. These anomalies have a hyperbolic reflection at the base, suggesting a change in the character of the sediments above and below buried objects.

was also run from north to south for 3.5 km across levees, channels, and scroll plains of the Ulgutherie channel belt (Fig. 1A). The GPR system was coupled to a Hemisphere VS100/R100 real-time kinematic global positioning system (RTKGPS) to provide subdecimeter geospatial information, which was digitally integrated into the record at time of acquisition. A Windows XP laptop running MALA Geosciences GroundVision2 1.26 was used to log data and view real-time data during acquisition. Real-time visualization coupled with integrated RTKGPS allowed for modification of survey lines during acquisition to avoid obstructions or follow subsurface features of interest. Survey lines were acquired by dragging the antenna array along the ground towed by a survey team member or a slow-moving vehicle with radar pulses emitted at 10 Hz. Post-processing was accomplished using GPRSlice v7 developed by Geophysical Archaeometry Laboratory and consisted of DEWOW, bandpass filtering, background removal, application of user-defined gains, topographic correction, and conversion from time to depth sections. The processing increased the record quality through selectively removing noise associate with the broad-spectrum frequency emitted by the antenna, interference and signal backscattering. The resultant data has a horizontal resolution of 0.05 m and a vertical resolution of 0.075 m.

Typical GPR signatures of excavated graves are depicted in Fig. 3 (Gontz *et al.*, 2011; Novo *et al.*, 2011; Schultz and Martin, 2011; Hansen *et al.*, 2014). In stratified sediment, which includes most fluvial and aeolian sediment, undisturbed ground appears as parallel lines that depict reactivation or depositional surfaces. Dug ground usually appears in one of two ways: either as strata truncated by a transparent layer and underlain by a hyperbolic reflection caused by a side wall reflection at the base and the underlying sediment; or alternatively, as an assemblage of disturbed sediments (termed 'chaotic fill') between stratified deposits. Occasionally, depending on the frequency of the GPR antenna, the age of the burial, the orientation of the survey lines with respect to the burial and the soil type, hyperbolic reflections are observed that relate to either the chest cavity and/or the leg bones (Novo *et al.*, 2011; Schultz and Martin, 2011). The planform geometry of individual and multiples graves can be important and the scale of the disturbance is necessary to discriminate between graves and other stratigraphic disturbances. These could include crevasses and buried channels, blowouts (in the case of dunes), other anthropogenic disturbances, and tree throw (Ferguson and Brierley, 1999; Skelly, 2003; Neal, 2004; Okazaki et al., 2013).

RESULTS

The GPR penetration in this landscape was virtually zero in the black soil clays of the regularly inundated palaeochannels south of the burial site, owing to the deposition of highly conductive clay minerals during overbank events (Neal, 2004; Gomez-Ortiz *et al.*, 2010). In the sand and silty sand of levee and deposits, penetration increased to over a metre at the site and in excess of 5 m where thicker channel sand deposits were present. Line 8 (Fig. 4A) reveals ~20 cm deep strata dipping inwards towards a shallow depression 30 m wide that may represent a buried crevasse in the levee (van Overmeeren, 1998; Skelly *et al.*, 2003). The same feature produced a consistent geophysical signature over successive survey lines. Line 9 (Fig. 4B) shows evidence of a stratigraphic disturbance as a ~0.5 m wide interruption in the strata containing chaotic fill with a hyperbolic reflection at ~0.6 m depth. A transparent layer of similar dimensions within a stratigraphic interruption is apparent 20 m to the left. Line 16 (Fig. 4C) exhibits an area of disturbed stratigraphy consistent with burials, excavations or tree-throw disturbance. Five stratigraphic anomalies are revealed in an area 20 m wide. The anomalies are ~0.6 m deep by 0.5 m wide, and are preserved 0.2 m below the present levee surface. While the cause of these anomalies will not be known unless they are excavated, we can say that they are consistent with the geophysical signature and morphological expression of grave diggings. Other anomalies are visible on each of the GPR sections. These have been eliminated as potential grave sites owing to their scale; their occurrence on a single survey line; and/or their stratigraphic relationship with overlying and underlying units.

DISCUSSION

A high-resolution survey grid is ideal for exploration of cemeteries or individual burials. Survey lines in a 0.1 m grid will cross a small grave of 0.8 x 0.5 cm (the size of the Kiacatoo burial) at least 11 times and will provide a detailed delineation of the excavation. A 50 cm grid should cross a grave site at least three times, but the grave may be difficult to distinguish from tree throws of similar dimensions. Additional improvement to survey design could include the use of a higher frequency antenna. The 800 MHz antenna for the ProEx system is capable of a vertical resolution of 0.03 m, but sacrifices penetration and is generally limited to imaging to <2 m. Ideally, one would combine numerous techniques to separate anomalies. This would include a nested survey approach based on scale of investigation; for example, a large-scale geomorphic analysis using aerial photographs, followed by a geomorphic field-based study to delineate areas of interest. Once areas of interest are identified, lower resolution, deeper penetrating GPR would be employed

to locate subsurface anomalies followed by higher resolution GPR to reduce the number of anomalies based on geophysical signatures. The last survey would consist of archaeological investigation to excavate individual anomalies. Through a reiterative process of geomorphic, geophysical and archaeological investigation, a team can hone interpretations and reduce effort expended during each survey phase. The work conducted during this survey exemplifies only a portion of the complete and integrated approach required for the confident identification of human burials.

Burials reveal important information about regional cultures, while the remains themselves inform our understanding of biological variation and change. The study of biological patterning and environmental adaptation requires remains from a variety of environments and from different time periods. These conditions are met in the riverine landscapes of south eastern Australia, but we need to make a more systematic search than previously attempted. Burials in levees along abandoned channels may be more common than previously thought. Although chance discoveries of skeletons have been made in palaeochannel levees, such as Mossgiel Man south of Willandra Creek (Macintosh, 1967) and Barham near the Murray River (Daly, 1986), it may be that lack of erosion has obscured our observations. Of burials recorded on the eastern Riverine Plain, 12% (19/164) have been in levees, of which there were small groups of 7, 4, 3 and 2 as well as 2 individual inhumations (Littleton, 1997, 1998). These do not occur further west, mainly because the palaeochannels become fewer.

In 2011, 20 burials were identified during major construction work in Koondrook-Perricoota State Forest near Barham on the Murray River (Pardoe, 2012, 2013b). Of these, most were in small levees associated with small channels that form a capillary bed throughout the forest. These levees are typically 5 m wide and less than 1 m high. They consist of dark grey clay with a high organic content, partly the result of organic debris and fine sediment deposition from overbank flooding , and partly from human occupation where cooking activities were common, being distributed along the levees as well as vertically over time. These levees are important as locally high ground when the forest is flooded, but also as roads because they are generally grass-covered and offer a pathway through the riparian forest. From LiDAR (Light Detection And Ranging) mapping of the forest, it was possible to calculate the length of levees cut by construction. Just over 1,000 m of channel levee was cut by the earthworks, resulting in the discovery of 20 burials at an average of two burials per 100 m of levee, measured along the channel. The Kiacatoo GPR survey has revealed a cluster of five potential burials, in addition to the original burial, within a 200 m length of levee, giving an average of three burials per 100 m.

Linear features have advantages over point sources in these changeable landscapes, because they functioned as pathways, are easily identified and tend to be more extensive. The search for new sites may be facilitated by new-generation geophysical techniques, including Electromagnetic Induction (EMI) and Earth Resistivity Survey (ERS) in fine-textured sediments (Bersezio *et al.*, 2007; Zhao *et al.*, 2013; Hansen *et al.*, 2014) as well as new GPR technologies (c.f. http://www.malags.com/products/mala-easy-locator-hdr).

CONCLUSIONS

Ground penetrating radar technology has advanced in the last decade to the point where it is possible to identify objects as small as a grave much more quickly and with greater precision than previously. Our GPR reconnaissance survey has mapped several buried grave-like disturbances in a sandy landscape unit on the riverine plains. While fine-grained, clay-rich sediments present a potential challenge for GPR, the 500 MHz frequency range, capable of penetrating <5 m with high-resolution, is adequate for geoarchaeological surveys. While GPR surveys to identify potential burial sites are somewhat time-intensive, they are still more rapid than traditional archaeological and forensic techniques (Fielder *et al.*, 2009). The application of GPR, coupled with fluvial geomorphology and archaeology, provides the opportunity to develop palaeoenvironmental models and relate former landscapes to human settlement and land use patterns. This approach is integral to our ongoing project. In addition to the research value, it will also contribute to the development of clear and predictable assessment processes for industry, Aboriginal organisations, and local government authorities that will lead to improved results for heritage and land management.

ACKNOWLEDGEMENTS

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Research Note: A reconnaissance of low elevation block deposits on Maria Island, Tasmania

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ABSTRACT

This paper provides a description of the morphology of low elevation dolerite block deposits of periglacial and cliff topple origin. These relict deposits mantle the upper slopes of the main central mountain ridge of Maria Island; an offshore continental island that lies of south-eastern Tasmania. Observations suggest that one extensive deposit on the upper western slopes of Mt Maria displays landform characteristics indicative of periglacial processes playing a significant role in its formation. The maritime setting and moderate elevation of these deposits are of interest for palaeoclimate interpretations. The deposits indicate the potential for significant freeze-thaw activity during cold Quaternary glacial stages at elevated locations on the east coast of Tasmania.

INTRODUCTION

On the upper slopes above elevations of 500m on Mt Maria and Bishop and Clark lie a series of nine un-vegetated slopes of up to 14 hectares in extent dominated by openwork dolerite boulders up to 4m long that can be described under the loose term as 'block deposits'. Block deposits in the form of block streams (elongate downslope 'rivers' of openwork boulders), block fields (openwork boulder fields on low angle slopes) and ambiguous slope deposits colloquially described in Tasmania as 'scree' are common landforms on the upper slopes of Tasmanian Mountains (Derbyshire, 1973 Caine, 1983, Colhoun, 2002, McIntosh *et al.* 2012). Apart from occasional rock falls all of these landforms appear to be inactive under the present climate. They are therefore likely indicators of past periglacial climates during the last glacial (OIS stages 2-5) and earlier Quaternary glacial cycles (Derbyshire 1973). The Maria island block deposits are unusual in two respects first, because while dolerite boulder slopes (colluvium) are common at mid to low elevations in south eastern Tasmania (Colhoun, 2002, McIntosh *et al.* 2012) most are largely vegetated and of moderate clast size with clasts generally less than 0.5m long (a – axis). The block deposits on Maria Island are aerially extensive; occur at a moderate altitude; and are largely unvegetated. They are composed of coarse clasts up to 3-4m long. They are located on an isolated mountain massif that would have been connected to the eastern margin of Tasmania during the last glaciation.

STUDY AREA

Maria Island is a 20 kilometre long island that lies off the south eastern coast of Tasmania from which it is separated by the 5 kilometre wide Mercury Passage. The Island is composed of two mountainous landmasses connected by a 3 kilometre sand isthmus. The study focused on the larger northern section of the island where a 9 kilometre long mountain range forms the eastern backbone of the island. The range is composed of a Jurassic dolerite sill approximately 250 m thick overlying Permian siltstone, sandstone and limestone units that crop out up to an altitude of approximately 430m (Mineral Resources Tasmania, 2013). The range rises to two prominent peaks Mt Maria (711m) in the centre and Bishop and Clarke / Mt Pedder (652m) near the northern tip of the island. Surrounding these summits is a series of nine unvegetated dolerite block deposits that are clearly discernible on aerial photographs and Google Earth images. The mapped extent of the block deposits is presented in figure 1. Bushwalking tracks to the summits of both Mt Maria and Bishop and Clarke give access to the west facing block deposits three of which were inspected in the field.

OBSERVATIONS

The three inspected and named blockfields were the Bishop and Clarke NW blockfield, Mt Maria W scree and Mt Maria W blockfield. While the Google Earth images led to an initial assumption that all three block deposits were likely to have formed by the same process, field inspection revealed that the morphology of the Bishop and Clarke NW blockfield and Mt Maria W scree deposits differed to that of the Mt Maria W blockfield. The summits of both Mt Maria and Bishop and Clarke show evidence of ongoing gravitational column topple and collapse processes on the cliff edges (Figure 2). At other localities notably the northern accessible summit of Bishop and Clarke deposits of angular clasts measuring 20 – 40cm long scattered on the summit indicate that while freeze-thaw frost shatter processes are unlikely to be active under current climatic conditions frost shatter was an active process in the past.

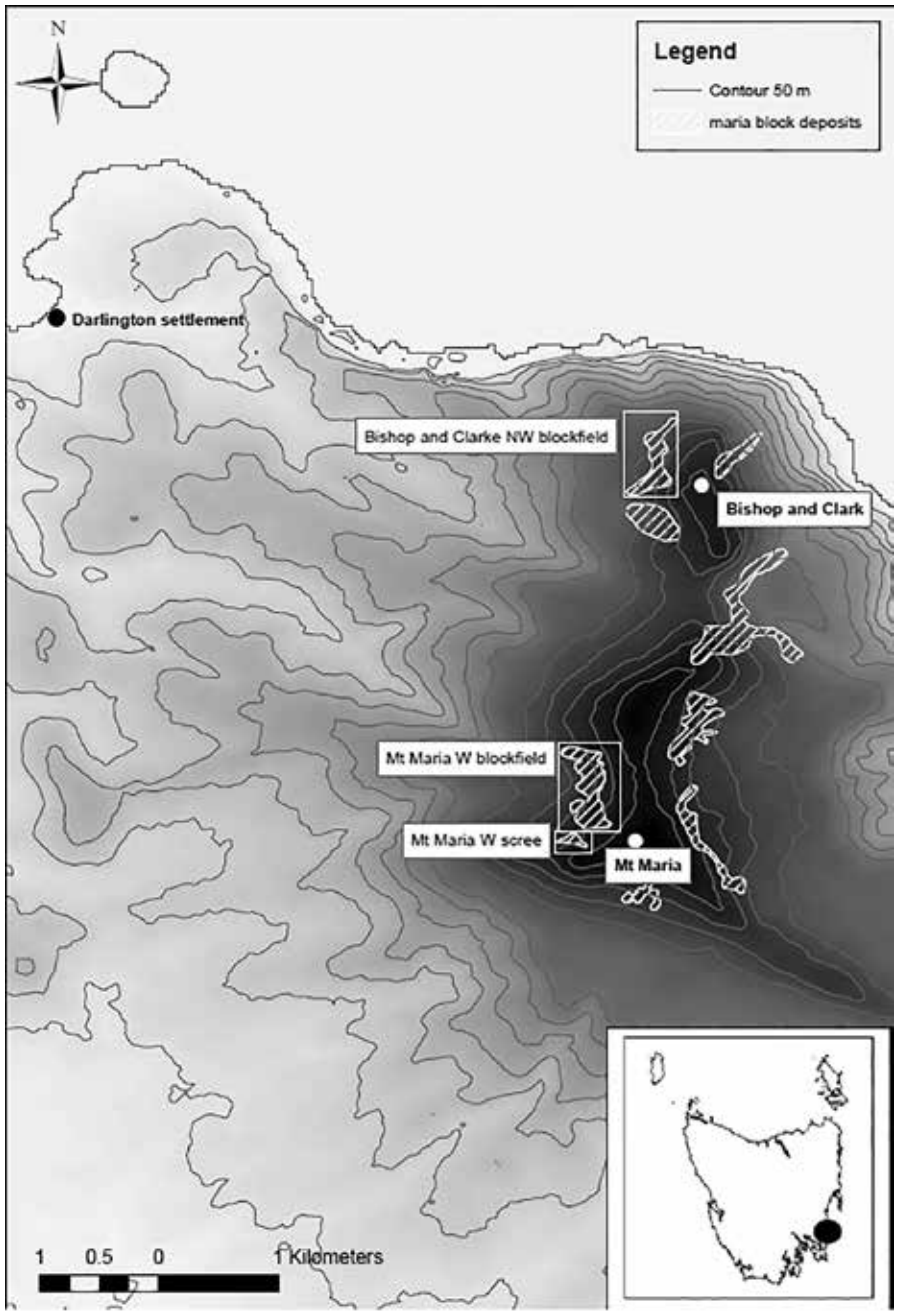


Figure 1: Map of study area on Maria Island showing the location of block deposits.

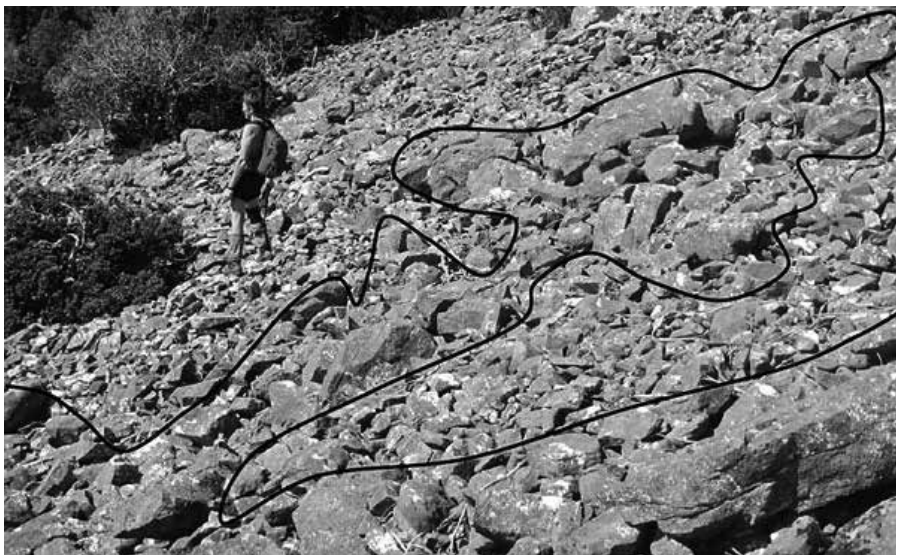


Figure 2: Patches of larger boulders alternating with finer scree on 20° slope (boundary between deposits outlined), probably related to individual column topple, Bishop and Clarke NW blockfield.

DESCRIPTION OF DEPOSITS

Bishop and Clarke NW blockfield

The Bishop and Clarke track crosses the length of this 7 hectares block deposit on the upper NW slopes of Bishop and Clarke below the summit cliffs at an altitude of 550 – 420m altitude. Angular to sub angular dolerite clasts up to 50cm long comprise around 60% of the deposit with a further 30% of smaller fragments and 10% larger boulders up to 2m long. The deposit is in the form of a cone sloping at around 20°. Relatively smooth upper slopes give way to some minor contour aligned ridging on the lower slopes. Large boulders are present throughout the deposit but no strong downslope sorting is evident. On the mid to upper slopes of the deposit lateral grainsize variations are evident with ridges formed of large boulders surrounded by zones of finer material.

Mt Maria W scree

This small block deposit covering 1 ha has a similar form to the Bishop and Clarke NW blockfield with a conical form and slopes of 20 – 22°. About 20% of the clasts are <30 cm, 70% are 30cm – 1 m and 10% large boulders up to 3m long the majority of clasts are angular to sub-angular.

Mt Maria W blockfield

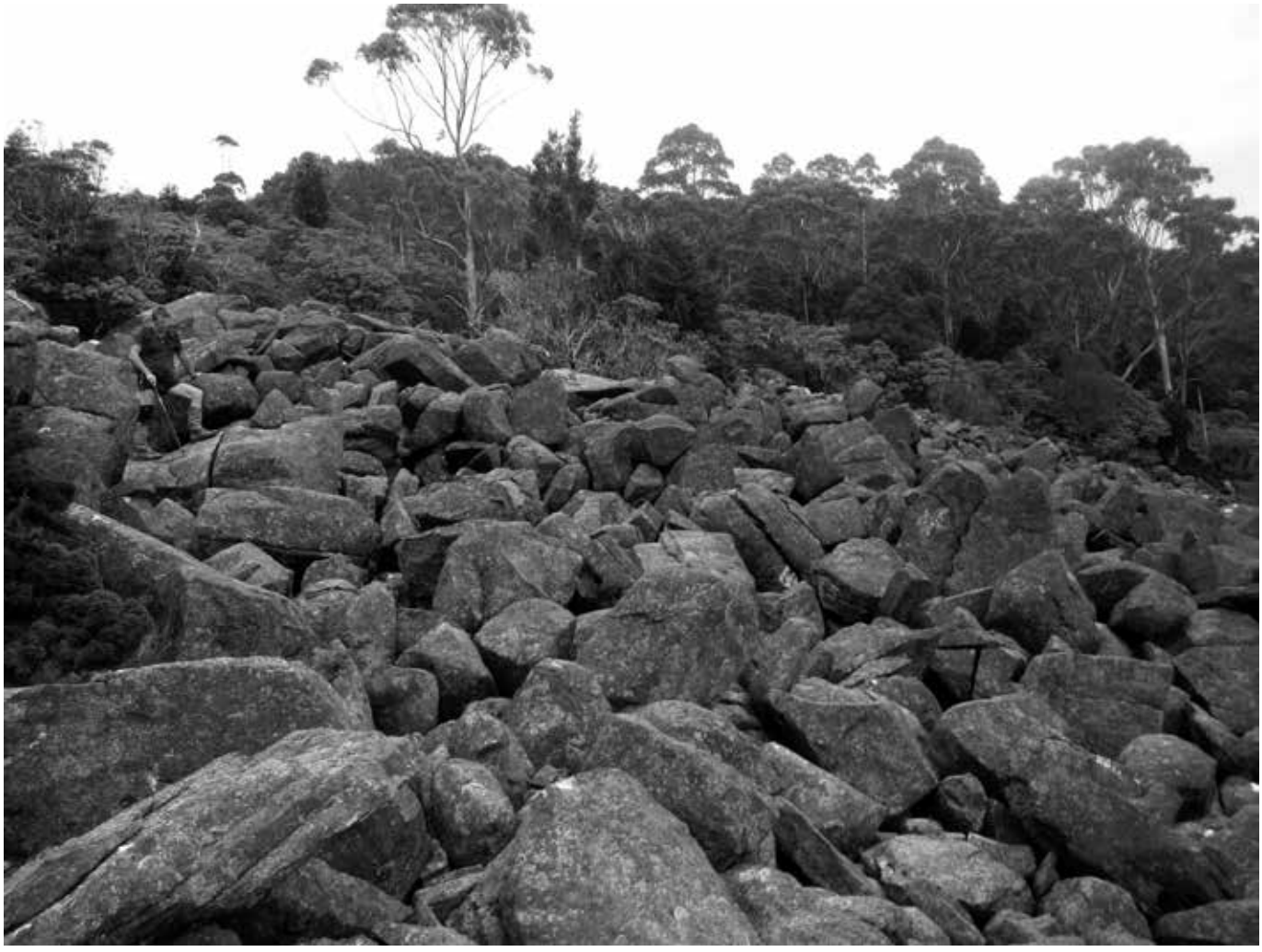
This large block deposit covers an area of approximately 11 ha on the western slopes of Mt Maria at an altitude of 530 – 630m. The morphology of this blockfield differs substantially to the other two sites investigated. The angle of slope varies but is generally in the range of 12 – 16°. The block deposit is dominated by large to very large angular to sub angular boulders with a-axis of 1 – 4m long with an estimated average length of 2m that constitute 85% of the deposit. Clasts with lengths of 20 cm – 1m comprise 13% of the deposit and there is a minimal surface exposure of any finer grained material. There is no well-defined source area in the form of a cliff immediately upslope of the deposit, but instead a low col on the summit ridge. Elongate ridges up to 2m in height extend downslope, with vague lobate forms and boulders projecting vertically on their a-axes. These characteristics suggest slow mass movement of the deposit in the past. However allochthonous block stream development appears to have been a marginal process due to the limited elongation of the block deposit down slope, as commonly observed in many other Tasmanian deposits (Caine, 1983 Barrows *et al.* 2004). At a couple of locations small boulders appear to have been sorted into well-defined patches surrounded by the much larger boulders that comprise the majority of the deposit (Figures 3 and 4). These patches take the form of circles several meters in diameter and vaguely defined stripes. The size of the features would suggest they are not related to frost produced patterned ground. Tree fall might conceivably account for the patterning however this seems unlikely due to the volume of rock displaced, the degree of sorting, the lack of characteristic root-ball depressions in the surface and the lack of any evidence for very large trees growing on the blockfield under current climatic conditions.

DISCUSSION

The morphology and location of both the Bishop and Clarke NW blockfield and Mt Maria W scree indicate that these deposits have formed largely by gravitationally induced column topple during cliff retreat. Given a lack of evidence for recent frost action, formation of this deposit was probably most active during the Last Glacial cycle, when cliff topple was probably enhanced by freeze-thaw processes and limited vegetation cover under the colder climate. In several locations ridges of large boulders are readily explained by the breakup of individual large topples during their rapid downslope movement. In contrast the Mt Maria W blockfield cannot be easily explained by gravitationally induced column topple as there is no major cliff upslope of the deposit and the very large size and chaotic distribution of the boulders, the latter contrasting with the finer mixed clast size of the neighbouring talus deposits. While there is evidence of past frost shattering of dolerite clasts on the summits of Mt Maria and Bishop and Clarke, neither the Bishop and Clarke NW blockfield nor Mt Maria W scree require periglacial conditions for their formation. In the case of the Mt Maria W2 blockfield the ridging and low slope angle and the large size of the boulders suggests that periglacial mass movement by solifluction or interstitial ice is likely to have been a factor in the vertical and downslope displacement of parts of the deposit. This process may also offer an explanation for the patches of fine material which may have risen to the surface where internal pressure forced finer material upwards. A second possibility is that this block field is largely autochthonous and formed in situ by very slow freeze-thaw processes coupled with subsidiary chemical weathering. The prominent ridges and sorted patches of finer grained material evident in the deposit may be related to the pre-existing bedrock structure and its behaviour upon sub aerial weathering. A problem with the latter theory is that if in-situ weathering of the bedrock by freeze thaw processes was the major formative process why would this process be limited to specific slopes on Maria Island given that other presumed periglacial block streams elsewhere in Tasmania exhibit signs of slow downslope movement such as large pressure ridges at the confluence of block streams on Ben Lomond (Caine, 1982). This may be

Figure 3: One of the anomalous patches of smaller size clasts surrounded by larger boulders at Mt Maria W blockfield (backpack approximately 50cm long circled). The northern section of the block deposit is visible in the background.

Figure 4: Down slope orientated boulder ridges with a vertical relief of 2m at the Mt Maria W blockfield (person for scale).



partially explained by the observations of Caine (1968) at Mt Barrow who noted that the upper parts of elongate blockfields there are autochthonous source areas dominated by randomly oriented boulder fabrics that give way to allochthonous block stream development downslope where the clasts are strongly aligned downslope. In the case of the Mt Maria W blockfield the high width to length ratio of the deposit is determined by a stratigraphic bench formed by underlying sandstone. This suggests that periglacial processes were not been sufficiently vigorous to allow significant downslope development of distinctive elongated allochthonous block streams to form. Although the sorting of fine clasts and morphologic forms of sections of the deposit suggests minor internal movement possibly associated with spring lines was likely. The sub surface sedimentology of the deposit might shed further light on the origins of this deposit however the sheer size of the surface boulders inhibits excavation and morphologic classification of this feature.

To date the only study to assess the age of Tasmanian block deposits was undertaken by Barrows *et al*. (2004) on the blockfields of Ben Lomond and Mt Wellington. The limited number of dates they obtained by cosmogenic methods revealed a wide spread of Quaternary ages spanning several glacial climatic stages with ages ranging from the late Last Glacial 22.1 ± 1.3 ka to 498 ± 43.5 ka. This spread of dates suggests that many Tasmanian blockfields have long and complex histories whereby they have undergone multiple periods of activity and have been subject to a broad range of climatic conditions.

CONCLUSIONS

The blockfields present on the upper slopes of Mt Maria and Bishop and Clark represent a suite of relict landforms that are likely to have developed under periglacial conditions. The deposits are likely to have last been active during the late Last Glacial time when transgressive scree deposits at the base of the high dolerite cliffs where reactivated and minor block stream activity may have occurred. The Mt Maria W blockfield is composed of very large boulders on moderate to low angle slopes and does not appear to have formed by cliff collapse. It is likely to be of autochthonous origin that has been affected by secondary allochthonous block stream development under a periglacial climate. The significance of this is that it the Mt Maria W blockfield is the lowest elevation well developed blockfield of likely periglacial origin in Australia, being significantly (200 – 300m) lower than similar blockfields elsewhere in Tasmania such as the blockfields and block streams of Mt Wellington . Given Maria Island lies of the south eastern Tasmanian coast and formed an isolated mountain range during the last glacial sea level lowstand. The presence of landforms likely to have developed in a periglacial environment implies freeze-thaw and possibly intermittent ground ice conditions where present in a currently maritime setting during colder Quaternary climates.

ACKNOWLEDGEMENTS

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A description of some other 'iconic' sites and a discussion of the state of Quaternary research in Western Australia

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ABSTRACT

Several places in Western Australia, not mentioned by previous authors, that merit recognition as Sites of Special Scientific Interest are described and discussed in the context of current Quaternary research in a state usually under-represented at Australasian Quaternary Association meetings.

INTRODUCTION

'Icon' entered English in the 1500s; then it meant 'simile'. The Greek root 'eikon' means 'image'; hence, its primary use in the Orthodox Church. The Oxford English Dictionary now defines 'icon', secondarily, as: 'a person or thing regarded as a representative symbol or worthy of veneration'. In my opinion, therefore, when compared with the global Quaternary record, few Australasian sites can be considered 'iconic'; an adjective that has become an over-used cliché, unfortunately. Had Fitzsimmons (2012) and/or Ward (2013) called the sites they described important and/or significant, I would not have found the time to write this response. I consider most of them are best described as Sites of Special Scientific Interest (SSSIs).

If we must have Quaternary 'icons', however, then I would argue that deep sea cores V28-238 and – 239 are 'iconic' because detailed analysis and palaeomagnetic dating of the proxy climatic data they record permitted Hays, Imbrie and Shackleton (1976) to demonstrate that Milankovich's theory of why Ice Ages occur and the periodicity of glacial-interglacial cycles was broadly correct; laying the foundation for much subsequent research into global Quaternary climate change.

Similarly, it could be argued that Olduvai Gorge, Tanzania (Leakey, 1971), and the Afar region of Ethopia (Johanson and Coppens, 1976; Johanson and Taieb, 1976) are 'iconic' because they record so many of the early stages of human evolution, albeit many of the fossils date to the Tertiary, not the Quaternary.

I would also argue that the long pollen records recovered from Grande Pile, Belgium (Woillard, 1978), and Tenaghi Philippon, Greece (Bottema, 1979), and the complex loess sequences in Central Europe studied by Kůkla (1977) are 'iconic' Quaternary sites because the data they yielded helped tie the fragmentary terrestrial environmental record to the much more detailed and continuous record of proxy climate then being identified in marine sediments; making it possible to begin to assign terrestrial sites to specific marine isotope stages (MIS). The old four-stage Penck and Brückner glacial sequence then had to be abandoned of course because, as Kůkla (1977) demonstrated, there were eight glacials during the Bruhnes Chron; although only MIS 16 and MIS 10 recorded $\delta^{18}O$ values equal to those of MIS 2 (Gibbard and van Kolfschoten, 2004).

Another Quaternary site that might be considered 'iconic' is Marks Tey, Essex, UK. The detailed pollen sequence Turner (1970, 1975) obtained there spanned the entire Hoxnian interglacial from the preceding late-glacial to the subsequent early glacial. The Hoxnian is now correlated with MIS 11 (Rowe *et al.*, 1999). By counting sample series of the laminations in the sediment, which he thought formed annually, but did not call varves, Turner (1970, 1975) estimated that the Hoxnian lasted approximately 15,000 years; which has implications for the present (Flandrian) interglacial (MIS 1).

Flandrian temperatures are well-known to have peaked 5000-7000 years ago in Britain (West, 1977: 241). Hence, if Turner's (1970, 1975) estimate of the duration of the Hoxnian is approximately correct and applicable to the Flandrian, Britain at least should be in the post-temperate, pollen zone IV (Turner and West, 1968), stage of MIS 1, but clearly is not; due to global warming (Claussen *et al.*, 2005; Ruddiman *et al.*, 2005; Ruddiman, 2013). Unless we have already tipped the climatic balance too far, I think the glaciers will return before too long to cover much of Canada, northern Europe and most mountain chains. Alternatively, if global warming increases, the polar ice caps and montane glaciers will melt and low-lying areas will flood. The global political and socio-economic consequences will be dire in either case. As I used to tell my students in London 30 years ago: people will either freeze or drown, particularly in the northern hemisphere; unless we can work out how to weather proof the planet.

I have deliberately cited the 'classic' references to these 'iconic' sites because I wanted to remind younger AQUAns how much our understanding of the Quaternary

has changed over the last 40 years and to acknowledge the quality of the original research. Many of these sites, or the data they yielded, have been reinvestigated repeatedly, but most of the initial interpretations have merely been refined, not reformulated.

Now, the 'iconic' Quaternary proxy climatic records are undoubtedly the Greenland ice cores (Svensson *et al.*, 2008); although the record from Antarctica is probably more relevant to Australasia (EPICA, 2004; Parrenin et al., 2007).

Understanding the palaeoenvironment is so fundamental to any study of the European Palaeolithic (MacDonald and Roebroeks, 2012; Pettitt and White, 2012) that the ignorance of matters Quaternary I found when I joined the Archaeology Department at the University of Western Australia (UWA) in 1988, came as quite a shock; although the perceived difficulty, then, of identifying and studying Aboriginal sites that pre-dated the Last Glacial Maximum (MIS 2) made the focus on more recent sites understandable. Also, the regolith covering much of the state comprises shallow deposits of deeply-weathered Cainozoic colluvium over Precambrian bedrock; conditions that militate against the preservation of stratified archaeological sites or Quaternary climatic events (Webb, 1993). While the integration of Quaternary studies into archaeological research in WA has improved a little since the 1990s, it is still much less well developed there than in southeastern Australia, which actually has a well-studied Quaternary record. Hence it is hardly surprising that 80% of AQUA members live 'over east'. There are other reasons for the disinterest in Quaternary studies in WA, apart from the paucity of sites. For example, cultural heritage consulting predominates over 'pure' archaeological research; while most geologists specialise in mineral resources and 'hard rocks', not the 'gardening on the surface'. Hence, that Fitzsimmons (2012) only mentioned Devil's Lair was understandable, if disappointing.

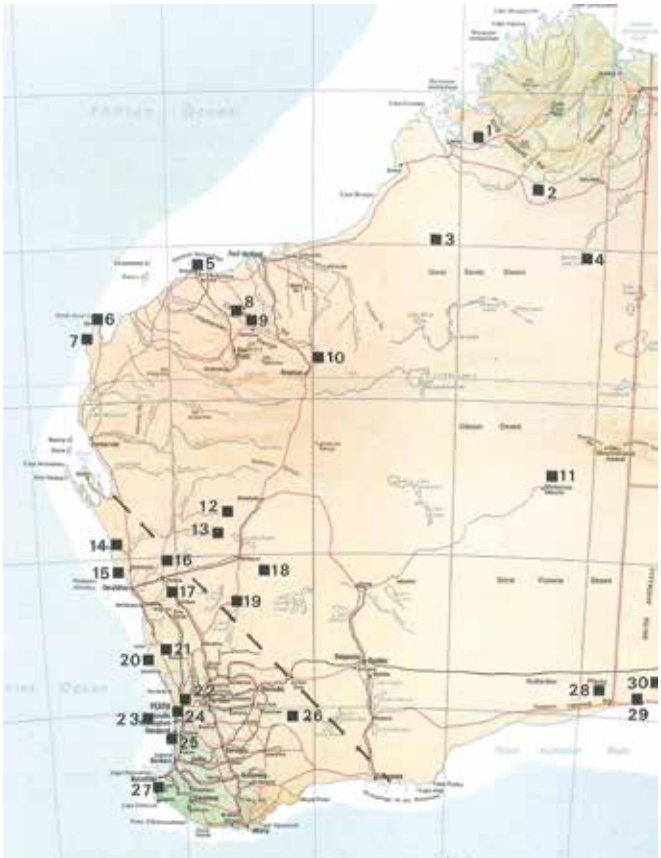
'ICONIC' WESTERN AUSTRALIAN SITES

When she received QA 29/2, Ingrid Ward contacted me about writing a response; we discussed which sites to include. I was, therefore, surprised at some of the sites she included/omitted from her paper (Ward, 2013). Her selection reflected her interest in coastal geomorphology and research undertaken at UWA, but largely ignored the southern half of the State. I consider some of the sites she included are not 'iconic'; while some she omitted are definitely SSSIs, for the reasons given here.

The Kimberley is omitted from this paper because it lies outside my areas of expertise and/or field experience. I have yet to get farther north than a brief visit to Broome, which scarcely counts; to discuss cultural heritage issues with the Port Authorities. Moreover, Ward (2013) appears to have mentioned most of the SSSIs currently being investigated in this region. The importance of the pollen diagram Pedersen (1983) derived from **Dragon Tea Soak** (Figure 1), in the heart of the Great Sandy Desert, is worth emphasising, however. It is still the only palaeoenvironmental record, albeit covering only the last 7000 years (Wyrwoll *et al.*, 1986), from the vast area between the inland Pilbara and the Kimberley; where long records are known (Fitzsimmons *et al.*, 2012). In my opinion Dragon Tea Soak is an SSSI.

The Pilbara is also barely mentioned because the sites Ward (2013) described are clearly important; although it should be said that **Murujuga**, the Burrup Peninsula,

Figure 1: Places mentioned in the text: 1. Carpenter's Gap, 2. Riwi, 3. Dragon Tea Soak, 4. Lake Gregory, 5. Murujuga, 6. C99/2, 7. Mandu Mandu Creek, 8. Juukan 2, 9. Djadjiling, 10. Hickman Crater, 11. Puntutjarpa, 12. Wilgie Mia, 13. Walga Rock, 14. Kalbarri Gorge, 15. Willigulli, 16. Tenindewa, 17. Allen's Cave, Wilroy, 18. Windimurra, 19. Mt Gibson, 20. Lake Thetis, Cervantes and the Pinnacles, 21. Yallalie, 22. Upper Swan, 23. Wadjemup, 24. Orchestra Shell, 25. Morfitt's Cave, 26. Mulka's Cave, 27. Devil's Lair, Tunnel Cave and Tight Entrance Cave, 28. Thylacoleo Caves, 29. Allen's Cave, 30. Koonalda Cave. The dashed line marks the approximate position of the boundary between the non-circumcising Noongar people of Southwestern Australia and the circumcising peoples to their east when ethnohistorians and anthropologists began to record such data in the early 1900s. The area shown in detail in Figure 4 lies between sites 12, 13 and 16.



while undoubtedly one of the most culturally significant places in Australia (Bird and Hallam, 2006; McDonald and Veth, 2009) is unlikely to be nominated to World Heritage status in the near future. Mulvaney (2011: 24) is quite right that 'the rock art cannot move; it is future industry that can and must be moved to alternate places', I doubt that will ever happen, however, because (a) if Murujuga became a World Heritage area that would severely curtail future industrial development on the Burrup, something neither Perth nor Canberra would currently contemplate, and (b) WA's *Aboriginal Heritage Act* (1972, revised) is so defective it cannot protect even such 'iconic' sites from the depredations of industry (Herriman, 2013); while some consultants are apparently complicit in this cultural vandalism (Bednarik, 2013). Recent changes to the Act have made the situation worse.

Puntutjarpa is one of the few stratified, radiometrically dated, archaeological sites in the Great Victoria Desert that has been published in detail (Gould, 1967, 1968, 1969a, 1969b, 1977, 1980, 1991, 1996). I was delighted to learn from Alan Williams (pers. comm.) in Mildura that Mike Smith and he have not only obtained copies of Gould's field notes, which need to be archived in Australia, but have been re-excavating Puntutjarpa. I await the results of their investigations with great interest. Contra Ward (2013), the socio-economic survival strategies pursued by Puntutjarpa's occupants were probably more similar to those documented by Smith (2005, 2013) and Thorley (1998, 2001) for sites in Central Australia than to those pursued at Lake Gregory, 700 km further north, because the little rain that occasionally falls around Puntutjarpa accumulates in rock holes and soaks; whereas Lake Gregory, despite being in the Tanami Desert, holds freshwater almost all year round (Veth et al., 2009).

Contra Ward (2013) again, stromatolites are not only found at Hamelin Bay and Lake Clifton, but also in **Lake Thetis** (Figure 2), just east of **Cervantes**, by the road to the **Pinnacles** in Nambung National Park. The Pinnacles formed in the Tamala Limestone, deposited along the WA coast during Quaternary high sea stands (Gozzard, 2007). Two very different hypotheses have been proposed to explain pinnacle formation: Hearty and O'Leary (2008) argued that the Pinnacles are the remains of ancient tree trunks that were buried by aggrading coastal dune sands and subsequently exposed by deflation; McNamara (2009) argued that they are remnant pillars of indurated dune sand, possibly formed around tree roots, beneath calcrete capstone. Certainly, cross-bedding can be seen in some pinnacles; while others resemble tree trunks (Figure 2). Hearty and O'Leary (2008) suggested the Pinnacles formed during MIS 11, while McNamara (2009) believed they were exposed during MIS 2; those scenarios are not necessarily mutually exclusive, of course. Whether individual pinnacles could be dated directly I do not know. Best seen at sunset, this 'iconic' site is now often over-run by tourists behaving badly (Figure 2).

Figure 2: Stromatolites in Lake Thetis (top left), the Pinnacles (top right), 'drive by' tourism (bottom).

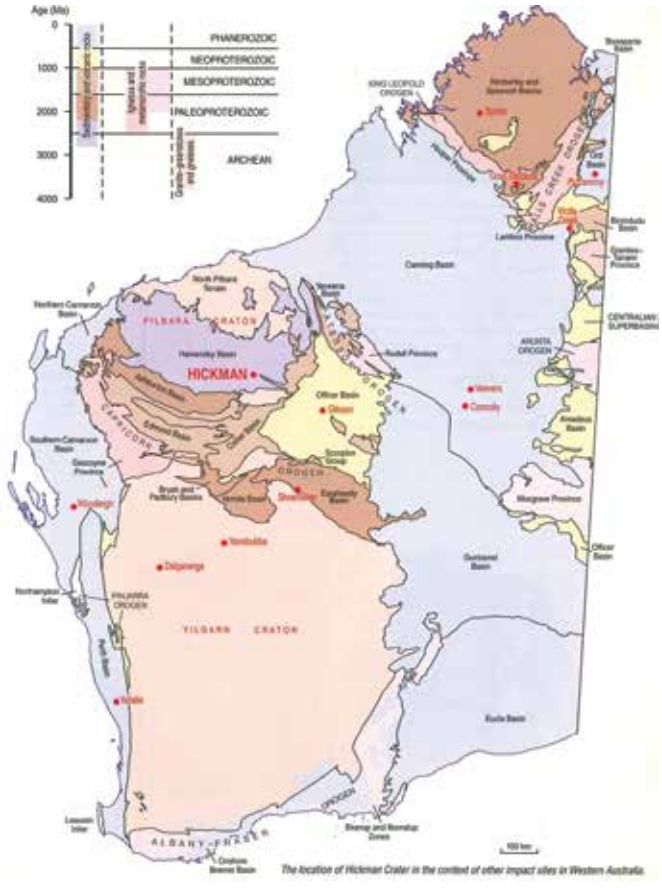
Yallalie, located 60 km inland from Cervantes, is undoubtedly an SSSI. The long, detailed, pollen sequence Dodson and his students obtained there records evidence of repeated wildfires throughout the Piacenzian (Dodson and Ramrath, 2001; Dodson *et al.*, 2002, 2005; Atahan *et al.*, 2004; Dodson and Macphail, 2004); burning occurred every few years, showing that the local flora was well-adapted to fire long before humans reached Australia. The sequence dates to 3.6-2.5 Ma, making it Upper Pliocene now that the Plio-Pleistocene boundary has been moved from the Olduvai Event (1.95-1.77 Ma) back to the Gauss-Matuyama boundary at 2.58 Ma (Gibbard and Head, 2010).

Yallallie records three pulses of aridity between 3.0 and 2.5 Ma that may be linked to the Late Pliocene inception of terrestrial glaciation. It has long been recognised that the closure of the Panamanian Isthmus coupled with the orbital forcing factors identified by Milankovich was a major driver of northern hemisphere glaciation (Coates *et al.*, 1992), because it separated the

increasingly cold waters of the North Atlantic from the warmer waters of the mid-Pacific; increasing Atlantic cooling. It is clear from the marine isotope record that the Cainozoic Ice Age began about 3.2 Ma, although the amplitude of glacial-interglacial cycles increased markedly after 1 Ma (Gibbard and van Kolfschoten, 2004); possibly partly because the periodicity of glacial cycles lengthened; from 40 kyr during the Matuyama Chron to 100 kyr during the Bruhnes Chron (Rial *et al.*, 2013), as Peter Kershaw argued at Mildura. Temperatures in glacial cycles of longer duration could obviously become colder.

Yallalie was a palaeolake that formed in a Cretaceous meteor impact crater. Twelve other such craters are known in WA (Figure 3), including the very large, and infamous, one at Wolfe Creek, in the southeast Kimberley, and a tiny one at **Dalgaranga**, in the Murchison Basin, which was probably created 25-3 ka (Hamacher and O'Neill, 2013). If so, the fall of that meteorite might have been recorded by Aboriginal artists. Pigmented rock art was well developed by 3 ka. I have not seen any motifs resembling a 'falling star' in the Murchison Basin or in the Southwest, but they might exist further north or east. The Cuballing fireball of 7 April 1930 was apparently visible throughout WA. Cuballing is 150 km southeast of Perth. Aboriginal people certainly visited Dalgaranga. Like Kelly (1961), I noted artefact scatters around the crater rim when I first visited it in 1989. Dalgaranga was apparently made a Geoheritage Reserve in the 1990s (Grey *et al.*, 2010). Clearly, it is easier to protect the geological than the Aboriginal heritage in WA.

Figure 3: Places where meteorites have created impact craters in Western Australia (© GSWA, 2013).



Palaeoenvironmental records as long as Yallalie are rarely found in WA, but several much shorter pollen records are known in the southern Perth Basin (Newsome and Pickett, 1993; Pickett *et al.*, 2004; Gouramanis *et al.*, 2012) that document important environmental changes during the later Quaternary.

One solution to the problem of finding long palaeoenvironmental records might be to investigate whether any of the other craters in Figure 3 contain polliniferous sediment. Currently, the structure and age of **Hickman Crater**, 35 km NNW of Newman in Ophthalmia Range, is being investigated by the Geological Survey of WA and WA Museum (Glikson *et al.*, 2008). Whether the infill sediment, which apparently accumulated 100-10 ka, will also be studied is unclear, but if it contains pollen, it could provide a palaeoenvironmental record for the Upper Pleistocene of the inland Pilbara; a region where such data are currently lacking.

The only sites Ward (2013: 27) mentioned in the Mid-West were **Ballinu Spring** (Figure 4), **Billibilong Spring** and **Wilgie Mia**. Fragmentary remains of *Zygomaturus trilobus* and putative artefacts have occasionally been found in the bed of the Murchison River at Ballinu and Billibilong, after flood events (Merrilees 1968). As Bordes *et al.* (1980: 40) noted 30 years ago, however, none of this material is in situ. It has all been found in 'un endroit erodé ce qui peut être un accumulation fortuite, pris dans la zone silicifiée' *(an eroded locality that could be a* **chance collection, caught in the silicified zone** [translation and emphasis mine]). This problem of stratigraphic context has still not been solved, despite Murszewski (2014) publishing an OSL date of 56 ka 'associated' with an isolated Z. trilobus bone and another 'possible artefact' found redeposited in the river bed in 2013. Not only is 'one date is no date', as Aitken (1990:95) tersely noted 25 years ago, but the degree of association between the sediment dated and the bone, and 'artefact', it allegedly dates requires confirmation. The animal obviously died elsewhere since its skeleton was disarticulated, while 'proving' the material found in the river bed is truly 'in association' is the problem that plagued previous studies of the Murchison 'cement' (Wyrwoll, 1988; Wyrwoll and Dortch, 1978). Wilgie Mia is a very important, but scarcely 'iconic', Aboriginal mine that produced a highly-prized shade of red ochre that was widely traded. The mine's cultural integrity was seriously compromised some years ago, however, when the Mines Department enclosed the

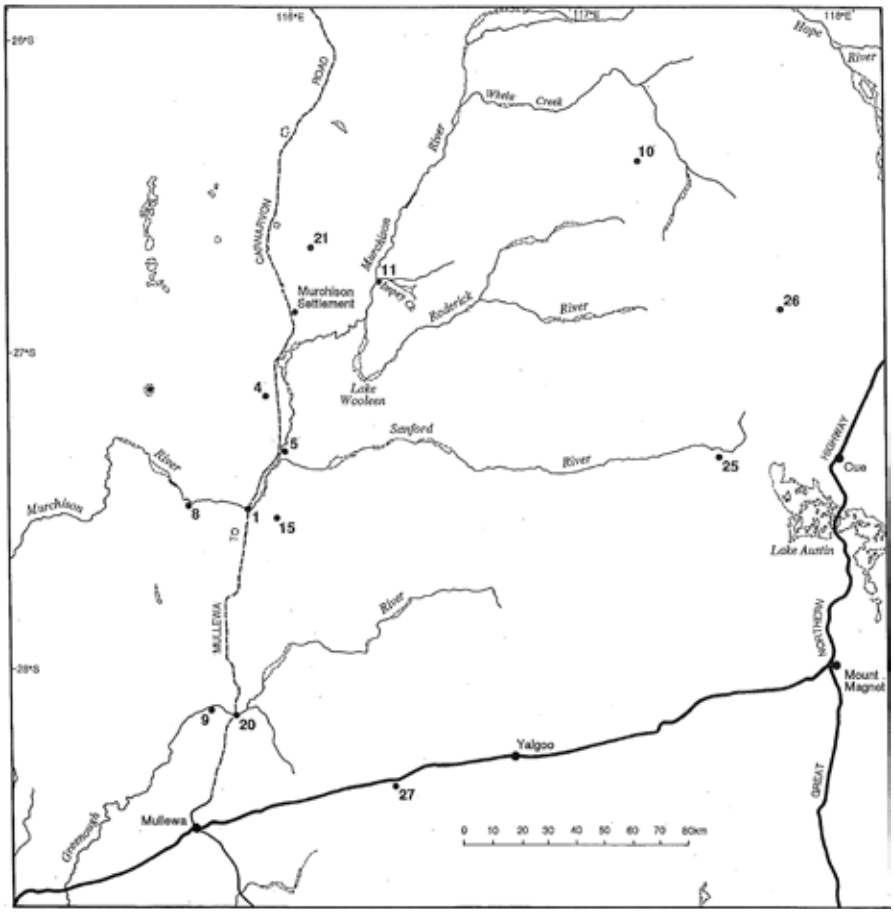


Figure 4: Sites in the Murchison Basin mentioned in the text: 1. Ballinu Spring, 5. Billibilong Spring, 10. Ejah, 20. Pindaring Rocks, 21. Quailbadoo Lunette, 25. Walga Rock, 26. Wilgie Mia.

pit in ugly cyclone fencing and plugged the European adit with cement, for safety reasons. Moreover, the very large pit seen now was probably created by internal wall collapse and European, not Aboriginal, mining activity in the early 1900s. It does not remotely match Woodward's (1914: 74-89) description of the pit he saw in the 1890s.

I consider **Walga Rock** is a better candidate for SSSI, perhaps even 'iconic', regional status, than any of those sites; although its environs are deteriorating badly, through neglect. A 'flared slope' >100 m long has developed in this bornhardt of Late Archaean granite. The main alcove is 23 m long, 6 m deep and about 12 m high (Figure 5) its back wall is densely covered with >1000 pictograms, mostly paintings, not stencils, in a wide range of colours and often of considerable size, making Walga the most profusely decorated Aboriginal site in the southern half of WA (Davidson, 1952; Gunn *et al.*, 1997; Webb and Gunn, 2004). The motifs were almost certainly made by men to explain the site's significance to boys going through initiation, although the details of their meaning and the site's Dreaming story have been lost due to the catastrophically rapid collapse of traditional culture that followed the introduction of pastoralism in the 1860s. Fink (1960: 271-272), who conducted anthropological fieldwork in the Murchison region in the 1950s, was told that the last '*proper old men of the Murchison*' died before World War I and did not pass on most of their ritual knowledge; partly explaining why no law ceremonies have been held in the region since the 1920s (Kingsford, 1982; Gunn and Webb, 2002: 59).

Figure 5: The profusely decorated main alcove at Walga Rock (photo RG Gunn 1996).

Bordes *et al.* (1983) excavated six metre squares in the main alcove at **Walga Rock**, but only published a preliminary analysis of the artefacts they recovered from five horizons in two squares: U 14-15. They divided this sequence into an upper archaeological unit containing 5565 microlithic artefacts deposited <4 ka (Layers 1-5); an important erosional phase, including roof-fall (Layers 6-9); a lower archaeological unit containing 1300 non-microlithic artefacts (Layers 10-11); another episode of roof-fall and basal sterile sand (Layers 12-16). The age of Layer 10 is unknown, but Layer 11 was deposited >7 ka (Figure 6). These data suggest that the site was visited more frequently after 4 ka than earlier, but was also abandoned for sufficiently long periods that at least two soils developed >11 ka. In 1998, I was able to study the artefacts from V-W 14-15 that were never taken to Bordeaux; that analysis revealed that yellow ochre was being brought to the site >11 ka (Webb and Gunn, 1999); making Walga the oldest occupied rock art site in the southern half of WA. The field notebooks record that many more charcoal samples were taken than were sent for 14C assay, but their whereabouts is unknown, unfortunately. More dates might have clarified the complex stratigraphy Bordes *et al.* (1983) recorded (Figure 6). Specifically, the lower deposits, including the palaeosols, are undated. It is unlikely

that Bordes' trench will ever be reopened, however, given the acrimonious complexity of local Aboriginal politics.

Other research in the Mid-West Ward (2013) might have mentioned includes Davies' (1961; Davies et al., 1977) archaeological finds around the old CSIRO research station at **Ejah** and Pearce's (1979) study of surface scatters and/or stratified artefacts at **Pindaring Rocks**, **Ballinu Spring**, **Quailbadoo Lunette** and **Walga Rock**; part of his analysis of the 'Small Tool' tradition in WA. Pearce was unable to date any of his sites radiometrically because he found no in situ organics suitable for 14C assay; Byrne's (1980) research was similarly constrained. He analysed 40 surface artefact scatters beside the Murchison River, mostly in **Kalbarri National Park**, as regional evidence for the procurement, processing and distribution of raw material suitable for artefact manufacture, particularly silcrete. There is also my unfinished, but partially published, doctoral and subsequent research (Webb, 1992, 1996, 2000, 2007). These sites are often overlooked, possibly because none is 'iconic', in my opinion.

Too much of the other Mid-West data is hidden in heritage consultancy reports, which can be difficult to access. Some firms are notorious for not lodging copies of their reports with the Department of Aboriginal Affairs (DAA), as they should, and/or for refusing researchers access to them, on the dubious grounds of 'client confidentiality', and/or only publishing their data when their sites yield very old 14C dates. The Heritage Act really needs to be revised to include a statutory requirement that a copy of every consultancy report be lodged with DAA; whether any Aboriginal sites were identified, or not. As Morse (2009: 2) commented, the present situation where consultancy information often remains inaccessible and unanalysed in detail is unprofessional, counterproductive, inhibits the growth and refining of archaeological knowledge and does a disservice to the preservation and protection of WA's cultural heritage. The Act has just been revised, but in ways that favour development over site preservation, unfortunately but unsurprisingly.

Gunn and Webb's (2000, 2002, 2003, 2006) reports are available, however. They describe and discuss previously unrecorded Aboriginal sites around Cue, some of which were subsequently excavated (Webb, 2009). Other sites about which data are available include **Williguli**, 50 km north of Geraldton (Schwede, 1995), a series of breakaway shelters profusely decorated with pictograms made using predominantly white pigment; **Allen's Cave**, 35 km southeast of Mullewa (Hovingh, 1995); Windimurra, a rockshelter 70 km southeast of Mount Magnet (Harris, 2002); and two rockshelters at **Mount Gibson**, 175 km southwest of Mt Magnet (Fordyce, 2008). Again, none of these sites is 'iconic' or an SSSI, but all have

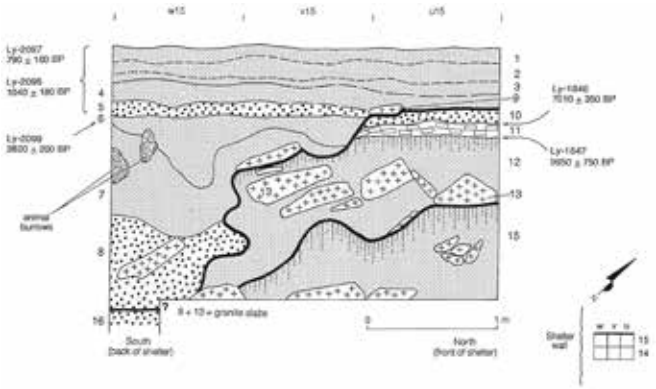


Figure 6: Stratigraphy reported by Bordes *et al.* (1983) at Walga Rock, showing the approximate stratigraphic positions of the radiocarbon dates.

14C dates. They came into use <4 ka, suggesting that Aboriginal occupation of shelters may have been quite recent in this region; although this age could reflect the rate of overhang collapse rather than the true period of occupation (Webb, 2009).

Ward (2013) noted that Aboriginal people clearly occupied Rottnest Island before mid-Holocene sea level rise flooded the landbridge (Dortch and Hesp, 1994), but equally importantly Wadjemup) was an Aboriginal prison for nearly 100 years (Green and Moon, 1997; Green, 2011). At least 3700 men from all over WA were incarcerated there between 1838 and 1903, often for lengthy periods, for crimes that now seem trivial: stealing flour or killing a sheep. Very few of the prisoners convicted of murder were actually hung, but about 350 died, often of influenza, and were buried on the island. Transportation began within a decade of British arrival, the Swan River Colony (now Perth) was founded in 1829, as conflicts arose over access to natural resources, once the Indigenous population realised the British intended to stay. Rottnest Island Prison, Fremantle Roundhouse, Port Arthur and Norfolk Island Prison were all built in the mid-1800s to similar plans (pers. obs.). I consider Wadjemup an 'icon' of the disastrous consequences of colonisation because, apart from a few 'enemy aliens' interned there during World War I, all the prisoners were Aboriginal; whereas the men incarcerated in the other prisons were mostly, or exclusively, white (Bavin, 1994).

Surprisingly, Ward (2013) did not mention **Upper Swan**, on the north bank of the Swan River 20 km north of Perth, which is undoubtedly an SSSI. It is still one of the oldest archaeological sites known in Australia (O'Connell and Allen, 2012). In the late 1970s, Pearce (1979) excavated a stone artefact assemblage from an elevated river terrace, presumably of Quaternary age. He obtained three radiocarbon dates of >35 ka and an infinite 'age' (Pearce and Barbetti, 1981). The 14C activity in the charcoal samples was clearly at the limits of

detection (Chappell *et al.,* 1996), particularly back then. This site merits reinvestigation to establish the 'true age' of the artefacts now that so many absolute radiometric techniques with longer half-lives than 14C are available and potentially applicable to the gravels in which the artefacts were found. Given the contentious inter-relationships between the various Aboriginal factions who claim to speak for the Perth metropolitan region, obtaining the necessary permissions could be difficult, however.

Credit should also be given to Sylvia Hallam's (1971a, 1972, 1974a, 1975, 1977a, 1977b, 1977c, 1978, 1981, 1983a, 1983b, 1984, 1985, 1986, 1987, 1989a, 1989b, 1991a, 1991b, 1991c, 1998, 2002; Hallam and Tilbrook, 1990) pioneering research into the history and pattern of Aboriginal occupation of the Perth Basin. She laid the foundations for the creation of the Discipline of Archaeology at UWA by beginning to teach archaeology courses that were always environmentally informed in the Anthropology Department in the 1970s (Bird and Webb, 2011). Her seminal work '*Fire and Hearth*' has just been updated and reissued (Hallam, 2014). It is also worth noting that, after some very strange detours, the archaeology courses offered by UWA are finally returning to updated versions of Hallam's schema; although the research focus is now almost exclusively on rock art; perhaps explaining why UWA members of AQUA rarely attend meetings.

As well as Upper Swan, several other archaeological sites in WA, all rockshelters, have yielded 14C dates >35 ka (Figure 1): **Carpenter's Gap 1** , although subsequent assays from shelter 3 yielded a different chrono-sequence (Fifield *et al.,* 2001; O'Connor *et al.,* 2014), and **Riwi** in the Kimberley (Balme, 2000); **Juukan 2** and **Djadjiling** on the Hamersley Plateau (Slack *et al.,* 2009; Law *et al.,* 2010); **C99/2** and **Mandu Mandu Creek** on North West Cape (Przywolnik, 2002; Morse, 1993). Like the dates from Upper Swan, the apparently finite ages from these sites are also at the limits of 14C measurement. While these dates may be accurate, only if suitable samples from these sites were assayed using absolute radio-isotopic methods and yielded similar results would their 14C ages be confirmed (Turney and Bird, 2002). Some sites might then prove to be older than their 14C ages, like Devil's Lair (Dortch, 1984; Fifield *et al.,* 2001; Turney *et al.,* 2001a); others might not, as has happened elsewhere in Australia (David *et al.,* 1997; Magee *et al.,* 2009); reflecting the plasticity of 14C 'time' (Rindos and Webb, 1992; Webb and Rindos, 1997). That equally old dates are rarely reported from sites formed in the open air (Upper Swan is locally unique, another reason for considering it an SSSI) is unsurprising; organic materials suitable for 14C assay do not always survive on open air sites in sufficient quantities for even AMS assay.

Apart from Zheng *et al.* (1998, 2002), very little Quaternary research appears to have been undertaken in the inland Southwest in recent decades; although I am hoping to change that in 2015 and one should not overlook Anne Brearley's (2005) masterly Swanland, which discusses the well-known problems now faced by 'estuaries and coastal lagoons' from Kalbarri to Esperance: ground clearance, raised water tables, salination, sediment/nutrient/contaminant input from agriculture, population pressure and water usage.

Mulka's Cave, 300 km southeast of Perth, rates a mention, although its artwork is not spectacular enough to make the site 'iconic'. It could be considered an SSSI, however, because Rossi's (2010, 2014) research has completely revised its usage history. Based on a single ^{14}C date associated with the most deeply stratified of the few *in situ* artefacts they found, Bowdler *et al.* (1989: 31) concluded that the cave 'was occupied in a brief and intermittent fashion, by Aboriginal people since perhaps 500 years ago' and, consequently, of no great significance. Gunn (2006) disagreed, because the cave is profusely decorated. It houses >450 pictograms; predominantly handstencils. Rossi (2014) has now obtained a coherent sequence of seven 14C dates from inside the cave and another nine from artefact scatters around The Humps, the parent bornhardt (Twidale and Bourne, 2004), that indicate that people were visiting the cave by 8000 cal BP; making it the oldest and most profusely decorated rock art site in the southern half of WA, after Walga Rock. Rossi's earlier research vividly documented the destructive effects of unfettered tourism. She showed that >1 m of the sediment inside the cave has disappeared over the last 30 years due most likely to over-visitation (Rossi and Webb, 2007, 2008; Webb and Rossi, 2008). Mulka's Cave is, unfortunately, only 20 km north of Wave Rock, a widely-advertised flared slope on Hyden Rock, another bornhardt (Twidale and Bourne, 2001), that attracts about 80,000 tourists a year, many of whom also visit Mulka's Cave.

Located 7 km north of Devil's Lair, Tunnel Cave yielded 3 m of stratified, archaeological deposit, dated to <20 ka (Dortch, 2004). Such long sequences are rare in WA, indeed they are only really found in the karst of the far Southwest, making both caves SSSIs for the analysis of cultural and environmental change over time (Dortch and Wright, 2010; Dortch *et al.,* 2012); although neither site is 'iconic', in my opinion.

I think that the fossil animals, often found in articulation, in pitfall traps like Tight Entrance Cave , near Margaret River (Prideaux *et al.,* 1999, 2007b, 2010; Ayliffe *et al.,* 2008), and the Thylacoleo Caves, beneath the Nullarbor Plain (Prideaux *et al.,* 2007a) are far better able to contribute to the debate on megamarsupial extinction than the redeposited, disarticulated Murchison material

Ward (2013) mentioned. The importance of articulated remains is that the animal is clearly in situ, it died where it was found (Roberts *et al.*, 2001); whereas a fragmentary fossil, particularly if found in a river bed, could have been transported kilometres downstream from where the animal died, once the carcase began to disintegrate. Dating the sediment around such fragments, which are not in situ (by definition), is not, therefore, going to yield an accurate estimation of when the animal died; merely of when it became embedded where it was found. Direct dating of the bones themselves by ESR and/or U-series might yield reliable death dates (Grün *et al.*, 2010), but if that has been attempted on the Murchison material, the results have not yet been published.

Walshe's (1994) taphonomic analysis of the bones that accumulated in Allen's Cave, South Australia, also merits mention since the Nullarbor should be considered as a geological and biogeographic whole. The luminescence dates (~40 ka) from this cave (Roberts *et al.*, 1996; Turney *et al.*, 2001b), offer some support for the high antiquity Gallus always claimed for the 'finger fluting' motifs in **Koonalda Cave** (Wright, 1971; Flood, 1997: 25-50), 100 km further east. Similar motifs are known in **Orchestra Shell Cave**, in Perth's northern suburbs (Hallam, 1971b, 1974b), and **Morfitt's Cave**, 20 km south of Mandurah, which remains unstudied in detail because the artwork has been badly vandalised. Flood (1997: 51-67) considered the motifs at all these sites were connected with other similarly decorated caves that formed in the Quaternary in the soft coastal limestone found between Perth and New South Wales.

Seeing an articulated *Thylacoleo* skeleton from one of the Nullarbor caves on display in the WA Museum a decade ago made me realise I had seriously under-estimated the size and weight (>100 kg, not 20 kg!) and, probably, the predatory behaviour of this carnivore (Webb, 1998); although the parameters I used were derived from the literature available when I wrote. Increasing *Thylacoleo's* body weight actually strengthens my argument that this top predator may have been driven to extinction by competition with humans, who probably targeted the same prey as *Thylacoleo*. They are carnivores of similar body size, but *Thylacoleo* seems to have been a solitary hunter; whereas humans are social. Group hunting may have enabled people to target their prey more successfully; not that they actually hunted *Thylacoleo*.

At Mildura, the causes of megamarsupial extinction were debated by Judith Field (*et al.*, 2013), a persistent advocate against, and Chris Johnson (Rule *et al.*, 2012), an equally persistent advocate for, human involvement in the process, but many listeners had already made up their minds one way or the other and were unimpressed by the adverse arguments as presented. Until more convincing evidence than has been proffered to date for/against humans/climate as the principal or sole extinction agent can be adduced by either side of the debate, I suspect the issue will remain unresolved; as it did in Mildura.

Finally, while clearly not a Quaternary 'icon', I think the moraine at **Tenindewa**, 35 km northwest of Mullewa, is certainly an SSSI. Where else in the world can one see classic 'tillite' (Figure 7) that is Permo-Carboniferous in age? All the other exposures, nearby, of these Late Palaeozoic glacigenic sediments are lithified (Eyles et al., 2006; Mory *et al.*, 2008); as are the outcrops in the Officer Basin, to be discussed in a separate paper (Webb, in prep.).

CONCLUSION

I hope that, together with the places mentioned by Ward (2013), this brief description of other interesting sites in WA demonstrates that there is more to see in this vast state than the minimal contribution sandgropers make to AQUA meetings might lead one to assume. I am usually the only person from WA, or one of only two or three, who attends; perhaps because so few of the people currently undertaking Quaternary research in WA are members of AQUA. My interest in (glacial) geomorphology started in high school, thanks to a superb geography teacher, so I make a particular effort to go on AQUA fieldtrips – to see different country; especially the glacial geomorphology of New Zealand. I am a little surprised that other WA members of AQUA do not seem to be equally interested in current research in other states or overseas.

I am also often the only person at AQUA meetings who identifies as a (geo)-archaeologist (Webb, 2005); possibly because I began my studies in the Lower and Middle Palaeolithic of Western Europe where an understanding of the Quaternary context is so essential I subsequently studied the subject formally while teaching world prehistory in London. Consequently, I was an active member of the Quaternary Research Association (QRA) for decades, until I moved to Perth.

The invisibility of archaeologists at AQUA meetings contrasts markedly with their presence at the American Quaternary Association (AMQUA) and QRA conferences. I still attend both whenever possible (Webb, 2010, 2012). AMQUA even ensures that at least one of its council members is a self-declared archaeologist, which is fascinating given how recently humans colonised the Americas. At least one of their conference speakers is usually an archaeologist, too. We rarely hear archaeological papers at AQUA; although, expectably, there were several excellent presentations at Mildura.

May I suggest that AQUA consider appointing state representatives, one of whom could be an archaeologist tasked with encouraging their colleagues to become active members of AQUA; although judging by the session titles at some recent Australian Archaeological Association (AAA) conferences, aptly described to me by a non-archaeologist as 'socio-babble', Australian archaeologists and Quaternary scientists live on different planets. I have long been puzzled that the disjunct is so complete (Webb, 2005), when Archaeology and Quaternary Science work hand in hand quite happily elsewhere in the world.

The archaeological papers presented in Mildura all had considerable environmental content and were well-received, but zoo-archaeological or palaeoenvironmental sessions are quite rare at AAA and not necessarily well-attended. It will be interesting to see how many people attend those sessions at this year's meeting in Cairns. The apparent lack of interest in the environment at past AAA meetings may be because the multiple concurrent sessions force attendees to make invidious choices; presenters have told me they spoke to only 10-12 people and might as well have stayed away. Or there may be a more profound disinterest because so much of the Aboriginal archaeological record is superficial and can be attributed to the later Holocene, when climatic conditions were generally as at present; while older sites do not necessarily yield proxy climatic data. These comments about AAA may seem out of place in QA, but some AQUAns also belong to AAA. I hope they will ponder the issues I have raised and debate them at future AAA meetings.

I also hope that AQUA, like AMQUA and the QRA, never introduces parallel sessions. Despite AAA's persistent boasts of its ever-increasing membership, small can be beautiful, as AQUAns appreciate, particularly students giving their first oral presentation; they cannot ask for a kinder, more supportive, audience.

Finally, I am thinking of trying to organise a Quaternary session for AAA 2015, which will be in WA. It would be a way of assessing whether there is enough relevant research being conducted here, or sufficient university support, to underpin a renewed bid in Auckland to hold AQUA 2018 on Rottnest. If that bid were successful, then several of the sites described above could be visited on an extended post-conference fieldtrip. Equally, I hope those conducting Quaternary research in WA of which I am unaware will contact me with ideas for either AAA 2015 or AQUA 2018.

Figure 7: Permo-Carboniferous moraine 30 km northwest of Mullewa (note the person on the left).

ACKNOWLEDGEMENTS

When I moved from London to UWA in 1988, I initially felt as if I had fallen into a cultural black hole. They may not have realised, but my academic lifelines proved to be Alex Baynes, Sylvia Hallam, David Rindos and Karl-Heinz Wyrwoll. I admire Alex's infallible ability to peer at a tiny fragment of jaw and pronounce (authoritatively) *Leporillus apicalis*, or whatever – not that I would dare to doubt him; while Karl-Heinz' advice on matters Quaternary was and is greatly appreciated. I was unable to benefit fully from Sylvia and Dave's eclectic approach to archaeology until I was transferred to the Geography Department, following 'A Series of Unfortunate Events' in the Archaeology Department in 1990-1991. Sylvia's encyclopaedic knowledge of the Aboriginal cultural record, particularly of WA, was and is amazing. She is still very, perhaps too, open-minded about such questions as possible human arrival in Australia before MIS 5e, for which I think there is no convincing evidence. Her willingness to consider such controversial ideas was most refreshing, however, after the stifling atmosphere in Archaeology; while Dave's evolutionary approach to cultural theory was always fascinating, if sometimes bizarrely counterintuitive. Together with Lewis Binford (New Mexico) and David Clarke (Cambridge), both now dead, Dave was one of the most original and innovative theoretical archaeologists I knew. Had he lived longer, I think he would have rivalled Binford and Clarke, generally recognised as ground-breaking theoreticians, although 'pure' theory is not well-regarded by some Australian archaeologists. Like David, Dave died far too young, however.

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THESIS ABSTRACTS

Late Quaternary ice sheet thinning and retreat in southern Victoria Land, Antarctica

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Retreat of the Antarctic ice sheets since the Last Glacial Maximum (LGM) has been associated with sea-level rise and ocean warming on the ice sheet margins, but the significance and relative contribution to eustatic sea-level rise since this time has been difficult to quantify.

This thesis presents new constraints for the timing and retreat of the Skelton Glacier in the Ross Embayment and grounded ice in the Ross Sea, the Ross Sea Ice Sheet (RSIS). Using two nunataks, Escalade and Tate peaks as a gauge for past ice sheet levels, glacial geologic evidence and 10Be and 26Al cosmogenic-nuclide exposure ages provide new and direct constraints on the past extent and timing of retreat of the Skelton Névé over the Late Quaternary. Glacial geological and geochronological evidence from Escalade and Tate peaks show that between 288 ka and 40.3 ka, the ice surface experienced slow deflation, lowering from ≥1431 to 1363 metres above sea level (masl). Ice in the southern Skelton Névé lowered by ~50 m between 40.3 and ~13.6 ka. Records from the eastern margin of Escalade Peak indicate the ice surface of the Skelton Névé was between 50 and 106 m higher than present during the LGM. The ice surface elevation remained close to its maximum ice level prior to 17.2 ka and has thinned by at least 50 m to the present-day level since ~13.6 ka. Thinning continued after 8.7 ka, and likely reached the present-day ice level ~2-3 ka. This lateglacial-Holocene ice-surface lowering is asynchronous from other sites in the Transantarctic Mountains where increased snow accumulation has been reported to have caused thickening up glacier in the early to mid-Holocene. 10Be exposure ages from large (>1 m) boulders in southern McMurdo Sound show that the RSIS had an ice surface elevation ~520 masl on the eastern side of Mount Discovery during the LGM and the onset of deglaciation was ~13.1 ka. The ice surface lowered from ~520 to 234 masl between 13.6 and 9.3 ka; and from 234 masl to the present ice shelf between 9.3 and 6.6 ka. This late-glacial and Holocene chronology from southern McMurdo Sound is consistent with other records in the Ross Embayment, and implies the RSIS experienced rapid retreat during the early to middle Holocene. These results suggest that the majority of ice sheet thinning and retreat in the Skelton Névé and in southern McMurdo Sound began just after melt-water pulse 1A (MWP-1A), a period of abrupt sea-level rise of up to 20 m that occurred between ~14.7 ka and 14.3 ka. Thus, it is unlikely that the RSIS and outlet glaciers from the East Antarctic Ice Sheet (EAIS) that drain into the Ross Embayment made a significant contribution to eustatic sea-level rise at this time. From the distribution and petrography of glacial deposits and the retreat chronology in southern McMurdo Sound a two-stage ice flow model for McMurdo Sound was reconstructed:

A high resolution, multi-proxy analysis of the palaeolimnology of Pyramid Valley, North Canterbury

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(1) Prior to ~18 ka an expanded Koettlitz Glacier lobe of ice flowed north and northeast through the Brown Saddle during the LGM and coalesced with northward flowing ice from the Ross Sea.

(2) Retreat of the Koettlitz Glacier and perhaps other outlet glaciers then accommodated westward and northward ice flow north of Brown Peninsula, fed from grounded ice in the Ross Sea.

These findings reveal that components of both the EAIS and West Antarctic Ice Sheet (WAIS) that drained into the Ross Sea contributed to lateglacial-Holocene sea-level rise. However, it is likely to be in response to warming of the Southern Ocean and sea-level rise primarily driven from the retreat of the Northern Hemisphere ice sheets.

The Pyramid Valley swamp is an iconic site in the history of the discovery of New Zealand's extinct avifauna. The primary objectives of excavations at the site have been to recover bones of different Moa species, but three multidisciplinary excavations since 1939 examined the paleolimnology of the site as well. The earlier excavations identified microfauna in the deposit including Potamopyrgus antipodarum, the common New Zealand micro-gastropod, a number of different ostracods, the remains of Charophyta (macrophyte algae), and other aquatic species. Stratigraphic summaries of the site identified a prolonged, uniform lake phase between two periods of peat deposition. My research was based on the use of eleven sources of proxy information to examine the lake phase of the deposition at centimetre resolution. I used fourteen 14C ages on organic materials within the sequence to establish an age/depth model for the deposit over the past c. 4500 years B.P. Four biological proxies were used (including the presence and numbers of charophyte oogonia, a promising new proxy for lake depth), bulk carbon (C) and nitrogen (N) amounts were measured and stable isotopic profiles for oxygen ($\delta^{18}O$ of gastropod shell carbonate), carbon ($\delta^{13}C$ for bulk sediment samples and gastropod shells), and nitrogen ($\delta^{15}N$, for bulk sediment were obtained). The data indicate that three major changes took place within what has previously been identified as a uniform lake sequence: transition of the original anoxic pond at the base of the lake deposit to a shallow lake at c. 3200 B.P.; the lake becoming shallower for short periods at c. 2700 B.P. and c. 2600 B.P.; and a transition to a much deeper lake between c. 2500 and 2300 years B.P. The period between c. 2700 years B.P. and c. 2400 years B.P. was one of significant climate variability. The proxies recorded another major change between c. 1200 and 1400 years B.P, when the lake drained and a peat bed formed over the desiccation surface of the former lake bed. The period of maximum climatic variability between c. 2700 and c. 2400 years B.P. at Pyramid Valley may have resulted from the more intense ENSO episodes recorded elsewhere in the Pacific at that time. This same period in the late Holocene has been identified in different locations around the world as a period of rapid climate change leading to a 300-year cold period. The use of multiple proxies, both biological and biogeochemical, was a key factor in developing the new model for the depositional and climatic environment as recorded in the Pyramid Valley lake bed.

Holocene coastal changes and extreme wave events inferred from sedimentological and microfaunal investigations – A Case Study from the North West Cape, Western Australia

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Similar to other coastlines worldwide, the coast of northwestern Western Australia (WA) has undergone enormous changes related to the post-glacial sea-level rise of ~120m. Coastal geo-archives record past coastal changes and potentially store geological imprints of (pre)historic extreme wave events such as tsunamis or tropical cyclones (TCs). By investigating the coastal geomorphology and the sedimentary record of these archives, fluctuations of coastal environments throughout time and the occurrence of extreme wave events can be reconstructed, thereby contributing to the understanding of the complex interplay of both gradual and episodic coastal processes.

This study presents a high resolution sedimentary record of two back-barrier depressions located along the Ningaloo Coast in the northwestern part of the Cape Range peninsula (WA), spanning the last ~8000 years. Based on multi-proxy sediment and microfaunal analyses, OSL (Optically Stimulated Luminescence) and 14C-datings, a detailed picture of the Holocene coastal evolution is provided. Back-barrier lagoons with mangroves formed at both sites at the time when the Holocene marine transgression peaked at ~7000 BP. Related to the evolution of the Ningaloo Reef and the development of sandy beach-foredune ridges, both study sites have progressively turned into more protected environments since the mid-Holocene. Since then, reduced sedimentation rates are inferred from the chronostratigraphical findings. The separation of the lagoons from open marine conditions led to the evolution of coastal lakes and, ultimately, back-barrier mud flats with fluctuating ecological conditions, which is reflected in both microfaunal and geochemical data. At both sites, allochthonous sand layers of marine origin found within the sedimentary succession testify the impact of and deposition during one or two washover events, which can be attributed to tsunamis and/or tropical cyclones. These event deposits were dated to 4100-5000 years ago.

The applied sedimentological, microfaunal and dating methods provided useful data to reconstruct the Holocene coastal and palaeoenvironmental evolution at the two study sites Thereby, the study contributes to the data pool of pre-historic extreme wave events (tsunamis and tropical cyclones) in WA during the Holocene.

Psyche Bend Lagoon: from productive wetland to acid wasteland within a century

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The Murray-Darling Basin has been significantly impacted by changed flow regimes and increased fluxes of salts and sediments since European settlement in the 1840s. Floodplain wetlands along the River Murray are subject to an extensive range of human impacts including landscape alteration, water abstraction, elevated saline groundwater tables and, most recently, wetland acidification. Psyche Bend Lagoon is one of the many regulated wetlands on the Lower Murray floodplain, and the site suffered many impacts from regulation in 1891 until the year 2004 when the site became acidified. A high-resolution record of how this wetland has evolved prior to and post-regulation was created in this study using a combination of biological (diatom assemblages), chemical (ITRAX XRF and Loss on Ignition) and physical parameters (grain size). Results of the analysis of a 147 cm core demonstrate that Psyche Bend Lagoon experienced three distinct regimes over the past 120 years. The first is recorded from 147 to 137 cm depth, archiving the natural, pre-regulation state of the site and confirming the existence of wetting and drying cycles. These were characterized by alternating cycles of increasing sand and silt deposition in association with the river diatom *Aulacoseira granulata* and the fresh, benthic diatoms *Stauroneis acuta* and *Eunotia serpentina* respectively. Although fresh, results also show that the site experienced periods of natural increased salinity, turbidity, and that sulfate salts were virtually absent prior to regulation. The second regime is archived between 136 and 12 cm depth, recording the abrupt end of the wetting and drying cycles, changes to diatom assemblages from, initially, peryphitic, fresh, low turbidity macrophyte dominated assemblages to turbid-brackish facultative planktonic diatoms, and later, to highly saline, and sulfur-loving facultative planktonic diatoms. Lastly, sediments laid from 12 cm depth to the top of the core record an unprecedented increase in salinity, organic carbon, sulfate and carbonate deposition at the site between 1996 and 1999, culminating with the precipitation of metals and metalloids in 2004 during acidification of the site. This study demonstrates that, like other sites in the Lower Murray River, the change from a seasonal to permanent water regime and consequent intensified organic matter accumulation, landscape modification, increasing gypsum-rich saline groundwater discharge into the lagoon, mismanagement and the Big Dry in the late 1990's have all contributed to the severe degradation of Psyche Bend Lagoon.

Hands in Pockets: Cultural Environments of the Atherton Tablelands of the past 1,500 years

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The Atherton Tablelands of North Queensland have been a productive environment for Australian Quaternary research. One of the key issues raised by research here is the role of people in prehistoric fire regimes and vegetation change. However, much of the discussion of Pleistocene human impacts on North Queensland environments is based on inadequate knowledge of past human activities due to the scarcity of archaeological data. This situation is in contrast to the late Holocene period, when more abundant archaeological evidence indicates the development of a distinctive rainforest Aboriginal culture, as was also ethnographically observed in the contact period. Several questions remain about the development of this rainforest culture against the palaeoecological context of expanding postglacial rainforest, and the role of people in shaping the configuration of vegetation across the region. While the archaeological evidence fails to conclusively identify significant modification of environment during the late Holocene occupation of rainforest, the palaeoecological evidence similarly fails to conclusively attribute Pleistocene environmental change to anthropogenic causes.

An important factor underlying the linkage between human activity and vegetation change is that of scale, both temporal and spatial. Given the environmental and cultural heterogeneity of the rainforest region of North Queensland an understanding of the spatial scale of human activity and its effects is crucial. Understanding of the temporal resolution of human activities and their aggregation in longer term palaeoecological and archaeological records is also a significant barrier to broader understandings of the human dimension to Australian landscapes. Due to the insufficient resolution of archaeological and palaeoecological data it is unlikely that the scalar characteristics of human interaction with rainforest environments can be directly understood from prehistory. By focusing instead on the recent and historical period a finer examination of the impacts of both Aboriginal rainforest occupation and the well documented post-contact European activities in these rainforest landscapes may be possible.

Analysis of historical and ethnographic records has allowed identification of the characteristics of Aboriginal use and modification of the Atherton Tableland rainforest landscape, and the disruption to such use by the arrival of European explorers, miners, timber-getters, and selectors from 1875. It is apparent from this analysis that the human interaction with rainforest has varied considerably across the region, and that generalisation of environmental change from a limited suite of sites is likely to mask significant finer scale variability and diversity in rainforest landscapes and the interaction of people with them. Historical sources also reveal significant spatial characteristics to both Indigenous and European uses of the rainforest landscape, and emphasise the cultural importance of place, a factor difficult to derive from palaeoecological records of human-environment interaction.

The historical record establishes a strong connection between Aboriginal occupation of North Queensland rainforests and the use of open pockets of sclerophyll vegetation within the rainforest matrix. Open pockets were also the focal points of initial European occupation of the rainforest. These pockets were therefore cultural places delineated by their anomalous vegetation, and have provided a focus for further investigating the properties of Aboriginal and European interaction with the rainforest landscape. Many of the more significant open pockets of the Atherton Tableland have been dramatically altered by the growth of townships or by flooding following the construction of Tinaroo Dam, but several remain relatively unaffected by European development. Palaeoecological analysis of sediments derived from Noopah Pocket and Mooma Pocket in the central region of the Atherton Tableland has been employed to investigate their recent to late Holocene environmental history and association with human activity.

Results of palaeoecological analyses indicate further complexity to the relationship between people, rainforest and climate than has previously been revealed by analysis of crater deposits on the Atherton Tableland. Both Mooma Pocket and Noopah Pocket have been characterised by open vegetation types in the late Holocene, and macrocharcoal records indicate the presence of low levels of burning in the pockets prior to European arrival. It appears likely that Aboriginal use of these spaces included infrequent burning of the grass understorey, without further significant effect on vegetation patterns. In contrast, the European use of the open pockets included the clearing and burning of surrounding rainforest over several decades, a practice that is clearly represented in the palaeoecological records. The effects of this practice were also manifested in changes to the vegetation of the open pockets themselves, which appear to relate to the hydrological effects of rainforest clearing. Finer scale variations in recent climate are also shown to have coincided with the beginnings of European clearing of rainforest, a correlation that may have hastened or magnified the environmental change. These results have implications for understanding the recent history and prehistory of the rainforest region, as well as for the contextualisation of the interaction between people and rainforest deeper into prehistory.

Industrial Past, Urban Future; assessing risks of metal mobilisation in a historically contaminated wetland

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In contaminated wetlands, typically the focus is on monitoring current impact and addressing subsequent remediation. However, knowing the past of the system can play just as important role in determining its future. This is particularly the case if the source of the contaminants is historical.

Reedy Lake, part of the Ramsar listed Lower Barwon wetlands near Geelong, Victoria, has seen a series of agricultural and industrial impacts since the early 1800s with changes involving land clearing, wool scours, tannery and tailings from mining operations.

The project addresses identifying the contaminant legacy from industrial practices and the likely impact of proposed management application for Phragmites australis control on the lake. Proposed water regimes include such strategies as regular drying periods of the lake and flushing with salt water.

Multiple assessment techniques have been applied to sediment cores from Reedy Lake, including iTRAX core scanning, radiometric dating and metal analysis of both total and sequential extraction procedures. By linking these changes in the sediment profile to known flow modifications, as well as historical industries, a comprehensive and detailed timeline of the lake system can be constructed.

Results have shown that the uppermost 25cm of sediment correlated to a time of heightened industrial activity along the catchment. Here multiple concentrated deposits of arsenic and mercury were detected, in quantities that are above ANZECC trigger values. In identifying the metal fractions it has be determined that these deposited metals have a high susceptibility to mobilisation under acidifying conditions. Potential acid sulphate tests on the sediment also revealed this to be a likely result of regular dying of the lake.

This project has been able to determine that legacy wastes left behind long after the industry has left still need to be carefully considered in management policies today and into the future.

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