VOLUME 31 | NUMBER 1 | JULY 2014

Quaternary AUSTRALASIA

New Life Members

Old Dunes

Romps in the Wollemi

SHAPE-ing Up

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Quaternary AUSTRALASIA

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INSIDE FRONT & BACK COVER PHOTO:

Harry Dare, Barngarla Aboriginal archaeological assistant, starting to remove a spit at the beginning of an excavation that revealed artefact layers at 14ka and 18-19ka in the northwest of the Olympic Dam study area. Late Holocene artefacts are exposed on the dune surface and a large pan is visible in the background [Photo HEH].

FRONT COVER PHOTO:

Excavations on a dune in the southern part of the Olympic Dam study area. In the floor of a blowout is a buried late Pleistocene artefact layer and late Holocene artefacts are being excavated along the trench into the western rim of the blowout [Photo HEH].

EDITORIAL

Dear Fellow Quaternarists,

This is a special year for AQUA; it is this year that the Australasian Quaternary science community is returning to Mildura, site of the initial AQUA biennial conference, to mark the organisation's 30-year anniversary. By the time this issue is released, the conference will be underway and we will once again be reminded of the important role this organisation plays in bringing people together and promoting discussion on latest happenings and future directions of things Quaternary.

Circumstances surrounding QA's genesis have been aptly described by Eric Colhoun's retrospective The birth of the Australasian Quaternary Association, which was published in QA's 29th volume (29(2), pp 12-13). In his article Eric gives us a feel for the persistent and ongoing effort of Quaternarists in the late 70's and early 80's to setup the organisation and then establish the flagship newsletter around 2 years later. In a pre-email, pre-online and pre-social media world, QA took on the important role of keeping Quaternarists in touch with each other. And yet in today's world of rapid communication, QA continues to be an important medium for disseminating information amongst the Quaternary community. The 30-year QA archive is now easily perusable on the AQUA website, we thank Rosie Grundell and Jessica Reeves for collating this, and we also thank those organised souls who made the contents of their filing cabinets available to them for scanning.

In this issue of QA, new chronological and geomorphological information is presented for Roxby dunefiled in northern South Australia by Philip Hughes and colleagues. We have several meeting reports: Claire Krause and Amy Predergast provide an overview of the INQUA Early Career Researcher Meeting held in Wollongong; Olivia Burge gives us an interesting summary of the PAGES RAMSAR workshop held in Queenscliff; and lastly Helen Bostock and colleagues provide an update on the latest Southern Hemisphere Assessment of PalaeoEnvironments (SHAPE) workshop and alert us to future SHAPE activities.

We are treated to two book reviews in this issue; Jacqueline Tumney takes us through The archaeology of Australia's deserts by Mike Smith. And Kirsty Douglas covers Desert Lake: Art, Science and Stories from Paruku, edited by Steve Morton, Mandy Martin, Kim Mahood and John Carty. Finally, we are reminded of some of the highs and lows of fieldwork with Len Martin's report on his work in the Blue Mountains.

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

Yours Quaternarily,
Kathryn Fitzsimmons and Pia Atahan *Editors*

PRESIDENT'S PEN

This is a slightly unusual President's Pen, in that we are currently in the process of changing-the-guard of the AQUA Executive. So as out-going and in-coming presidents (notwithstanding a potential coup at the AQUA AGM), we thought we may as well combine forces.

All things being equal, you may be reading this on the bus on the way to Mildura. The 30th anniversary AQUA conference offers a real opportunity to both reflect on some of the major achievements of our members and see how much we have grown as a community – both in size and scope.

The resounding theme of AQUA2014 will be one of people and place and the intrinsic relationship between the two. Several of the sessions will reflect on humans as geomorphic agents, such as Prehistoric Human Impact and The Role of the Quaternary to Inform Management. In addition, we will be running our inaugural "beer-o'clock" session on the topic of "The role of humans in the demise of the megafauna." Through this, we hope to broaden the outreach and relevance of Quaternary to our affiliated fields of archaeology and environmental management. Our research offers a unique perspective on time and place.

And perhaps there is no better place than the Willandra World Heritage region to observe, first-hand, where these worlds intersect. The opportunity to be guided through this landscape by those who have been researching the intricacies of the human-landscape interaction here, in the year of the 40th anniversary of the discovery of Mungo Man, is simply not to be missed. Jim Bowler will reflect on this milestone and his long association with the region and its people in a Public Lecture at the Grand Hotel, accompanied by Roger Jones who will look to the future of this region in a changing climate. This is the heartland of the Australian Quaternary and the New Research in Willandra session will highlight that this is a land that keeps on giving.

We sincerely hope we will see you in Mildura – home of the inaugural AQUA conference, back in 1985. Many thanks to all those who have made this conference possible.

The Presidential Pair,

Jessica Reeves & Helen Bostock
AQUA Presidents

NEWS

NEW OFFICE BEARERS

The AQUA AGM was held on Monday 26 May, graciously hosted be AINSE. As part of proceedings, new office bearers were elected. Congratulations to Helen Bostock, new AQUA President and Scott Mooney, new Vice-President. We are very grateful to Steven Phipps and Duanne White, who will continue in the roles of Treasurer and Secretary, respectively and the to editorial team of Kat Fitzsimmons and Pia Atahan. Jessica Reeves immediately assumes the role of Past President and NCES representative and Peter Almond will replace Marcus Vandergoes in the role of GSNZ representative. Patrick Moss stays on as STA representative.

With a view to ensure that AQUA attracts "new blood" we have created shadowing roles for many of the executive positions. These members will spend the next twelve months shadowing current committee members so that there is a more gradual transfer of knowledge, with the view that these members may stand for committee positions in future years. Congratulations to Steph Kermode (shadow secretary), Lydia MacKenzie (shadow treasurer) and Claire Krause (shadow IT officer).

AQUA-AINSE TRAVEL PRIZE WINNERS

This year, due to the generous support of AINSE, we were able to award 7 travel awards to AQUA student members attending the Mildura conference. Congratulations to Bronwyn Dixon, Ignacio Jara, Kelsie Long, Daniella Mueller, Deidre Ryan, Asadusjjaman Suman and Dorcas Vannieuwenhuyse. We very much look forward to hearing about your research – and of course reading your conference reports in the next issue of QA!

NATIONAL COMMITTEE FOR EARTH SCIENCES

As some of you will be aware, The Academy of Science has been reviewing the structure of the National Committees. The National Committees are entities that widely represent the scientific disciplines and advise the Academy's Council on Australia's representation for the unions of the International Council for Science (ICSU), such as INQUA. This includes funding Australia's membership of INQUA. The Committees were reviewed last year and as a result, The National Committee for Quaternary Research was merged into the larger National Committee for Earth Sciences (NCES). Quaternary interests are well-represented within the NCES, with committee members including Allan Chivas and Jessica Reeves. Other related National Committees include Earth System Science, Antarctic Research and Data in Science.

The new NCES met for the first time in April. Other than getting to know the new members, the key purpose of the meeting was to commence planning for the next Decadal Strategic Plan for Geosciences. The previous decadal plan has been used to gain support for national research priorities and major investments, such as membership of IODP (International Ocean Drilling Project). Together it was instrumental in generating an estimated $500M of outcomes for earth sciences, including the establishment of NCRIS (National Collaborative Research Infrastructure Strategy).

It is expected that the new decadal plan will be developed over the next two years. Consultation will be broad and constructive comments and suggestions are very welcome. The previous decadal plan may be found here: http://www.science.org.au/resources/national-strategic-plan-geosciences-geoscience-%E2%80%93-unearthing-our-future. For further information or to voice suggestions, please contact Jessica: j.reeves@federation.edu.au.

ALBERT MAUCHER PRIZE WINNER – KAT FITZSIMMONS

Congratulations to Kat Fitzsimmons for being awarded the 2013 Albert Maucher Prize in Geoscience of the German Research Foundation. The prize recognises "unconventional research approaches and methods." Kat has been working in the Department of Human Evolution at the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany since 2010, where she heads up the luminescence research team. This prize is a fantastic acheivement and justly awarded. Well done Kat!

AQUA BLOGS

If you don't regularly look at the AQUA website, or are a member of the AQUA facebook page then you may have missed a treat... Ignacio A. Jara has been writing a series of blogs over the last 8 months. Ignacio is originally from Chile, but is currently a PhD student at Victoria University, Wellington. His research involves pollen and charcoal records from New Zealand and southern Chile to detect and compare vegetation and climate changes since the last glaciation. He challenged himself to write these blogs to keep up with the latest literature, broaden his knowledge and sharpening his writing. His blog entries cover a broad range of Quaternary topics, specifically reviewing novel studies carried out in the Southern Hemisphere. Previous posts include:

- Quaternary history of Easter Island
- The demise of the Australian megafauna
- Glacial changes in southern Patagonia
- Arid environments and human occupation
- Changes in radiocarbon reservoir ages in the surface oceans (written by Helen Bostock)
- Dust deposition in the Southern Ocean

Keep up the great work Ignacio!

If you have any suggestions of new topic or particular papers for Ignacio to review in his blog then get in touch (elignaciojara@gmail.com) or if you have any comments about the blogs then he would love to hear them and we can post them up on the website as well. If you would like to contribute a blog on any Quaternary topic that may be of interest to AQUA members (please keep it to less than 500 words) then send it to Helen.Bostock@niwa.co.nz.

Check out www.aqua.org.au at the start of each month to read the latest blog instalment...

Ignacio A. Jara

AUSTRALIAN ARCHAEOLOGICAL ASSOCIATION (AAA)/ AUSTRALASIAN SOCIETY FOR HISTORICAL ARCHAEOLOGY (ASHA) 2014 CONFERENCE

CULTURE, CLIMATE, CHANGE: ARCHAEOLOGY IN THE TROPICS

DECEMBER 1-3, 2014, CAIRNS

The AAA/ASHA annual conference will be held in Cairns this year and the focus of the conference will be on Archaeology in the tropics but will include broader topics encompassing all of Australia and beyond The conference provides a great opportunity for networking with the Australian archaeological community if you are a non-archaeologist. There will be a number of sessions (which are listed in the conference website) that will be of potential interest to the Australasian Quaternary community. In particular, there is an AQUA sponsored session (The Environmental Context for Human Settlement and Occupation of Australia), which provides the opportunity for non-archaeologists to present their research on this topic (which covers the last 60,000 years from pre-settlement to the late Holocene and can be based on a range of proxy data) to an archaeological audience. Submissions for oral and poster abstracts close on 27 June 2014. Acceptance of your abstract will be made via email by 18 July 2014. Conference details can be found at http://australianarchaeology.com/conferences/aaa2014-conference/. For further information, contact Patrick Moss: patrick.moss@uq.edu.au or Sean Ulm: sean.ulm@jcu.edu.au.

INQUA – NAGOYA

Save the date (and your pennies): The XIX INQUA Congress will be held in Nagoya, Japan 27 July – 2 August, 2015. The theme of the conference is: Quaternary Perspectives on Climate Change, Natural Hazards and Civilisation. AQUA was very well-represented at INQUA in Bern in 2011. It would be terrific to do even better this time. For further information, please contact: 2015inqua-sec-ml@aist.go.jp.

QA DELIVERIES

During the production of this issue of QA, both editors managed rather wonderful productions of their own. We welcome to the AQUA family baby Anton, born to Kat on the 24 January and Felix born to Pia on the 3 June. Hearty congratulations and many thanks to you both for managing to find the time to attend to the relatively menial task of getting QA together. Who says women can't do everything?

MEET A MEMBER OF THE AQUA EXECUTIVE COMMITTEE

PIA ATAHAN: CO-EDITOR, QUATERNARY AUSTRALASIA

Spending time in the southwest corner of Australia, surrounded by biodiversity hotspots, it's easy to be enchanted by the mysteries of the natural world and be intrigued by people's place within it. After completing a PhD at the University of Western Australia, focussing on prehistoric human activities and environmental change in the Yangtze River delta of eastern China, Pia worked for the WA Department of Water and appreciated the chance to get a 'behind the scenes' look at water management. Following this she took up a Postdoc at ANSTO in Sydney and expanded her research interests by tackling projects using geochemistry and microfossils to study ancient farming practices in northern China and also study lake sediments at several sites in Australia. Pia has recently returned to WA, updated her camping gear and plans to spend more time beyond the city's limits.

AQUA LIFE MEMBERS

As is customary for many scholarly associations, AQUA acknowledges members who have both made a significant contribution to AQUA and positively influenced the direction of Australasian Quaternary science, more broadly. Current life members include Eric Colhoun, Jim Bowler and John Chappell. Our call for nominations earlier this year brought forward six nominees, all of whom would be worthy of the title of AQUA life member. However, we have restricted ourselves to two – and a balance between palynologists and geomorphologists. It is our pleasure to introduce our two new AQUA life members: John Magee and Peter Kershaw.

AQUA LIFE MEMBER: DR JOHN MAGEE

John Magee is a familiar face among Australian Quaternarists, although often in the background to his more luminary colleagues. I think he prefers it that way. However, we would like to take this opportunity to cast John in the spotlight and thank him for his significant contribution to AQUA. Much of the following is extracted from John's nomination letter written by Prof Patrick De Deckker. Many thanks, Patrick. Thanks also to Giff Miller for providing the photographs.

John commenced his career at the ANU, as a Professional Officer in what was then called the Department of Biogeography and Geomorphology. The department was the training ground for such prominent Quaternarists as Martin Williams, Paul Williams, and John Dodson, and the headquarters for Joe Jennings, Donald Walker, Cliff Ollier, John Chappell, Bob Wasson, Rob Vertessy, to name only a few. John completed his BSc in the Geology Department at ANU and after that worked under the leadership of Jim Bowler. In fact, it is best to describe John as Jim's right arm. He worked at Lake Mungo and contributed enormously to the discoveries made in the Willandra Lakes region, of significance to Australian archaeology, arid zone geomorphology and palaeoclimatology. During that time, John completed an MSc on the sedimentology and climate history of the Prungle lakes nearby the Willandra lakes. His contributions to the understanding of gypsum-forming lakes are now well known.

By then, John was starting to carry out his own investigations. When Jim Bowler left the ANU, John commenced a PhD on a formidable project: to unravel the history of the most significant lake in Australia, Lake Eyre. That was not a simple task, but John undertook this work with the thorough and meticulous attention to detail characteristic of his scientific approach. It involved numerous lengthy fieldtrips to the outback under often arduous conditions. John used, for the time, novel approaches to date and characterise the Quaternary palaeoenvironmental changes at Lake Eyre. The result was an opus on the Lake Eyre basin, published in a number of extremely well cited and far-reaching articles influencing our understanding not only of the Australian arid zone but also its role within the continental climate. John's articles were often co-authored with the eminent Giff Miller from INSTAAR, University of Colorado at Boulder. The synergy between these two researchers saw several papers published in Science, Nature and Geology. Giff still relies on John's knowledge and expertise.

John subsequently continued his endeavours in the arid zone. He was awarded two prestigious ARC postdoctoral fellowships, including a QEII. During this phase of his career, John supervised several Honours students and Kat Fitzsimmons' PhD research, also undertaken in the dunefields of the Lake Eyre basin. As a supervisor, he was an ideal role model for his attention to detail and thorough examination of the scientific method. John always encouraged thorough discussion not only of the science, but of the history of the research and the implications for the work. His field skills in the outback are legendary and he always accepted a challenge to reach the most remote sites, generally with success and minimal vehicle damage. John was, and remains, a caring and constructive mentor, generous with his time.

When his QEII fellowship terminated, John was employed by Geoscience Australia to work on groundwater hydrogeology in the arid zones. John has been a long time member of the Technical and Scientific Advisory Council for the Willandra Lakes World Heritage Area, interacting positively and constructively with local indigenous communities, as well as pastoralists and public servants engaged in the region.

AQUA would also like to thank John for his behind the scenes work on many AQUA conferences and fieldtrips. Congratulations John. Your contribution to Quaternary Science in Australia will not go unacknowledged.

AQUA LIFE MEMBER: PROF PETER KERSHAW

Peter Kershaw is a more likely suspect for life membership – a long and illustrious career producing some of the key Quaternary records that we continue to debate. In the process he has also spawned at least two generations of palynologists. An active long-term member of AQUA, Peter has been a keen participant in most of the AQUA conferences – and leaves many amusing anecdotes in his wake. We thank John Tibby for this very worthy nomination.

Peter Kershaw's major contribution to Quaternary science has been to sleep on a convenient patch of grass during difficult field work and provide distinctive ash bands for future researchers to discover. Beyond that he has, more than any other scientist, developed our understanding of the Quaternary vegetation history of eastern Australia. This work, for the best part of three decades, focused on the Atherton Tableland in north-east Queensland (Kershaw *et al.*, 1993, Kershaw, 1975, Kershaw, 1970) and the state of Victoria (D'Costa *et al.*, 1989, D'Costa *et al.*, 1995, Harle *et al.*, 2002), with foray into locations such as Tasmania (Harle *et al.*, 1993) and New Zealand (Kershaw and Strickland, 1988). More recently, with students and colleagues he expanded his reach into marine palynological records around Australia (Kershaw *et al.*, 2003b) and "the maritime continent" (De Deckker *et al.*, 2003). Through student research, his pollen analytical work has also extended into south-east Asia (Anshari *et al.*, 2001). Peter's work has been cited over 2,500 times and he has an h-index of 19 (Scopus search 25/5/2014).

Peter is best known for his work on the long Quaternary site of Lynch's Crater which initially provided strong evidence for the influence of Milankovitch forcing on Australian tropical climates. This is a theme to which he has returned a number of times in a number of localities (Turney *et al.*, 2004, Kershaw *et al.*, 2003). Lynch's Crater, which has been the primary focus of at least 15 scientific papers, later provided evidence for the impact of the burning practices of indigenous peoples on the Australian landscape (Kershaw, 1986) and more recently, the effect of megafaunal decline on vegetation (Rule, 2012). These studies have re-framed our undertaking of the interaction between early Australians and their environment and captured the imagination of academics and the general public alike.

Beyond north-east Queensland, Peter and colleagues have largely defined the development of the contemporary vegetation of Victoria, demonstrating its progression since the last glacial maximum and earlier in some locations

(Kershaw *et al*., 2004), through the Holocene, and the massive impact of Europeans on that vegetation. The database of sites developed from this work has enabled investigations into modern pollen-environment relationships (D'Costa and Kershaw, 1997) and the history of burning in Australia (Mooney *et al*., 2011).

Peter has supervised a large number of Ph.D. and Masters students. Though the main focus of this activity has been on Quaternary, and to a lesser extent Tertiary, pollen analysis, "APK" as he is known to many of those students has also encouraged the development of other fields, in particular diatom analysis, beetle, plant macrofossil, macrocharcoal and even some ostracod analysis. Although, at times, Peter has feigned frustration with these non-pollen fields of study without his generous facilitation of student field and laboratory costs, these research areas would be much less advanced. Peter's attitude to collaborative publications is a model for us all. He has regularly turned down offers of co-authorship of papers based on Honours and Ph.D. projects, despite playing a highly active role in their development.

Peter's former students are dispersed far and wide. These include an impressive array of permanent academic staff at Adelaide, Deakin, Federation, Queensland, Sydney, UNE and Wollongong Universities. A number of other students have found work in a variety of fields including research-based positions, Federal and State government departments, oil companies and private consulting firms. While Peter would doubtless underplay his role in the success of these graduates, his generosity has been a critical factor in the success of former students.

As part of his (often highly informal) mentoring role, Peter hosted regular gatherings at his home not far from Monash. When these were not descending into drinking games, people being thrown in the pool and the odd new relationship, the "Kershaw group" was able to interact with some of the world's leading Quaternary researchers (such as Herb Wright and Lou Maher).

Ultimately, beyond his substantial contribution to defining the history of Quaternary climate and vegetation in Australia, Peter Kershaw's greatest legacy is his generosity of spirit. With characteristic modesty he once noted that he might not have been admitted to university were he to start a degree in the 21st Century. While this may be true of his ability to comply with increasingly onerous administrative tasks, it underestimates by a large degree his intellect and work ethic.

AQUA would like to thank Peter for continuing to inform and entertain us. We look forward to your antics, intellect and enthusiasm at many conferences to come.

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Sand dune formation over the last 140 ka in the Roxby dunefield, arid northern South Australia

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ABSTRACT

Geomorphic investigations and optical dating integrated in a large-scale archaeological excavation program at Olympic Dam have provided a chronology for dune formation extending back to before the last interglacial. Indurated dune cores of different ages have been in existence for at least 140 ka. The present dunes began building at >55 ka and they had largely formed by 21 ka at the height of the LGM. Dune building declined ~21-14 ka, then increased again, peaking at 13 ka. Stable dune surfaces formed ~12-9 ka and there was little sand accumulation during the Holocene. Parts of the dunes are mantled with loose, laminated sand mobilised after European grazing commenced in the mid-1800s. Most of the archaeological material is exposed at the surface and is of late Holocene age. The dunes also contain layers of stone artefacts (post LGM through to the late Holocene in age) which mark contemporary stable to slightly eroded surfaces. The post LGM archaeological assemblages can be correlated with palaeoclimatic records from other sources and they reflect episodic occupation of this arid landscape during relatively wet periods when the dunes were stable.

LANDSCAPE SETTING AND PROGRAM OBJECTIVE

This investigation arose from an archaeological survey and salvage program in arid northern South Australia described previously by Hughes *et al.* (2011) and Sullivan and Hughes (2013). The study area covers ~600 km^2 surrounding the Olympic Dam mine (Figure 1) in the driest part of Australia, with an annual rainfall of <200mm (Bureau of Meteorology, 2010). There is a very low watershed through the study area, which drained towards Lake Torrens in the east and towards Lake Gairdner in the west but there is no connected surface drainage and only local internal drainage towards large pans and canegrass swamps.

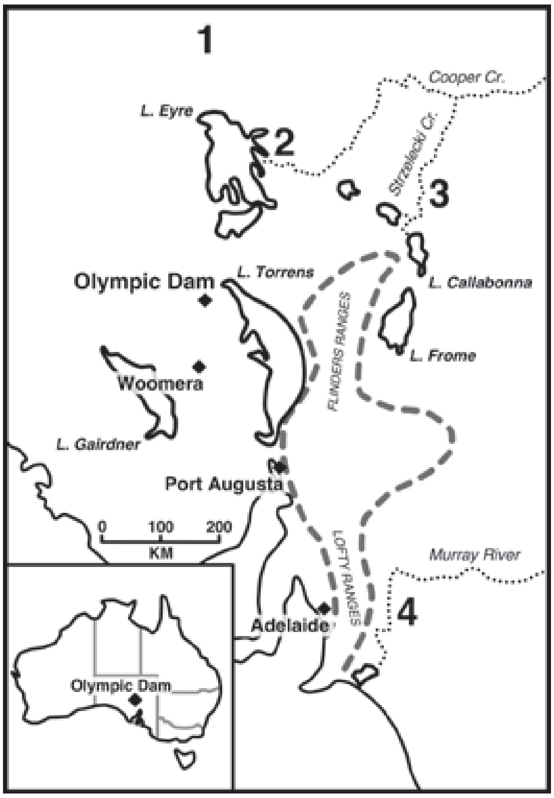

Figure 1. Olympic Dam and other localities mentioned in the text.
1 – Simpson Desert, 2 – Tirari Desert, 3 – Strzelecki Desert,
4 – western Murray basin

The landscape comprises stony desert overlain by discontinuous fields of east-west trending longitudinal sandridges (Figure 2) referred to as the Roxby dunefield[1]. The extensive stony or gibber deserts in the Woomera-Olympic Dam area are developed on ancient tableland surfaces. The superimposed dunes are variably spaced and dune spacing and the consequent nature of the interdunal swales has been demonstrated to be a key factor in the pattern of archaeological site locations (Hughes *et al.*, 2011). Many swales are stony with gibbers ranging from boulder to pebble sizes, but in landscape units where the dunes are closely spaced the swales are virtually all sand-covered. On the wide stony or more clayey swales in areas of widely-spaced dunes there are water-holding depressions. Pans of various areas and varied but generally shallow depths can hold water for days, very large pans become lakes and may hold water for months, and canegrass swamps can hold water for several months after heavy and prolonged rainfall, but such events are rare.

The study was a 7-year research-oriented survey and salvage program. The main purpose was to locate and characterise archaeological sites and their contained materials, as an activity to mitigate the impact of proposed mine expansion. During the survey stages, starting in 2007, >17,000 archaeological sites were recorded. These were surface scatters of stone artefacts and quarries, commonly with associated knapping floors. The subsequent salvage phase involved surface artefact collections from ~150 open sites. Deeper archaeological excavations were undertaken at 28 sites.

Before 2007 several small-area or linear archaeological surveys had been undertaken for specific mine-related infrastructure developments, but otherwise the area had not been investigated previously. To understand archaeological site formation it was necessary to determine the history of sand movement and sand dune formation during the period when the dunes were occupied, so investigating the landscape history evolved as a by-product of the archaeological salvage program.

The history of dune formation in the southeastern part of the Australian continental dunefield (Wasson *et al.*, 1988) has been comparatively well-studied, as reviewed by Fitzsimmons *et al.* (2013). Syntheses of these data are referred to extensively here.

In contrast, south and west of an arc from Lake Eyre South through the Flinders and Lofty Ranges to the mouth of the Murray River, there had been few dating studies of dune formation prior to the work reported here. Near Port Augusta 250 km south of Olympic Dam optical dates with a high margin of error on a single dune

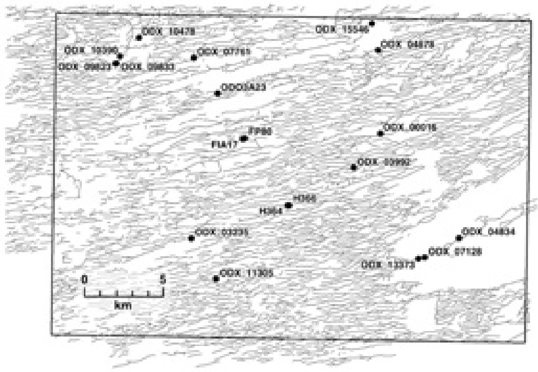

Figure 2. The Olympic Dam study area (black rectangle), the linear dunefield and the location of the optically-dated archaeological sites

indicated that it had accumulated between ~150 ka and 30 ka (Walshe *et al.*, 2001:6-7). Subsequently on a nearby dune an Aboriginal hearth exposed in a deflated area on the crest of the dune was dated to ~40ka (Walshe, 2012), meaning the underlying dune had accumulated by that time. In the Great Victoria Desert ~450 km to the west of Olympic Dam (Sheard *et al.*, 2006) demonstrated that dune formation commenced >250 ka and continued episodically until after 22 ka. On the southwestern edge of that desert ~400 km from Olympic Dam the calcrete-capped core of a low linear dune was dated to 128 ka and the loose overlying red sand at 0.1-0.2m depth to ~5 ka (Lintern *et al.* 2012:14). In the northern Eyre Peninsula ~300 km to the southwest Lintern (2007) optically dated a linear dune and showed most of it accumulated between 27 ka and 17 ka, i.e. during the Last Glacial Maximum (LGM). These studies show that in this broad region there have been multiple phases of dune formation over at least the last 250 ka.

DESERT GEOARCHAEOLOGY

The archaeological and geomorphic contexts are associated. Archaeological visibility requires sufficient numbers of artefacts to have accumulated on a surface to be recognised during surveys, and the presence of such artefact accumulations indicates the surface was stable for a sufficient period of time for people to have occupied it.

The results of the archaeological survey confirmed previous observations and the utility of a predictive model (described in Hughes *et al.*, 2011) that site locations link strongly with landscape elements. Most sites occur on widely spaced linear dunes, and the largest and most complex sites are found on dunes near water-holding bodies, especially large pans and canegrass swamps. Artefact scatters also occur near exposures of good-quality flakeable stone (silcrete, quartzite and chert), as outcrops or as gibber cobbles and boulders on the stony plains or interdunal swales.

[1] This dunefield falls within GAW07, the Roxby Interim Biogeographic Region (DESEWP&C 2012), Roxby Downs station covers the central part of this dunefield and the town of Roxby Downs also occurs within it.

None of these surface scatters of stone artefacts retains any organic materials so they are not amenable to direct dating. None of the excavated deposits contained prehistoric plant remains such as charcoal. Dating buried artefact layers is possible if the sand confining the artefacts is suitable for optical dating. Initial dating demonstrated that the windblown quartz sand is excellent for single grain optically stimulated luminescence (OSL) dating (Sullivan *et al.*, 2012; Sullivan and Hughes, 2013). Most of the surface-visible sites are in blowouts/deflation hollows and in some sites artefacts at their margins were covered by sand. In addition, initial test excavations to 1.2 m demonstrated that a small number of sites contained layers of artefacts buried within the bodies of the dunes, sometimes beneath surface scatters of artefacts, but separated by archaeologically sterile sand. These sites were targeted for more extensive excavation to characterise the different artefact layers, to provide samples for optical dating, and to inform both landscape evolution and patterns of human occupation.

OPTICAL DATING IN THE SALVAGE PROGRAM

Windblown sand provides excellent grains for optical dating as medium-sized quartz grains are ubiquitous and the grains are subject to thorough bleaching during transport. Eighty three samples for optical dating relevant to the history of dune formation were collected from 19 sites (Figure 2), mainly from within or immediately beneath and/or above the artefacts. In addition to hand-excavations, a backhoe was used to dig deeper and more extensive trenches (to 4 m at one site, H366) to obtain material for optical dates from deeper sand, weakly cemented hardpan or watertable layers, or weathered indurated cores, to identify phases of sand mobility and accumulation. The five optical dating samples from ODO3A23 were dated at the University of Washington, as described and discussed by Sullivan *et al.* (2012). The remaining 78 samples detailed in this paper were dated at the University of Adelaide. All but one of these produced useable ages.

Optical dating requires measurement of two components: firstly the background, or environmental radiation, produced by radionuclides within the sedimentary material and by cosmic radiation, and secondly the luminescence energy acquired by the quartz grains within the sediment as a result of stimulation by this radiation during the period of burial. Measurements of the environmental dose rate were made on all the samples using mass spectroscopic methods: inductively coupled plasma mass spectroscopy (ICPMS) for uranium (U) and thorium (Th), and inductively coupled plasma atomic emission spectrometry (ICPAES) for potassium (K). For some of the samples additional measurements of K were made using X-ray fluorescence spectroscopy (XRF), and of U and Th using thick source alpha counting (TSAC). For a number of selected samples, additional in situ measurements of the dose rate were made using a field gamma spectrometer. The cosmic ray contribution to the dose rate was obtained using the relationship between cosmic ray penetration and sample depth, altitude and latitude, as determined by Prescott and Hutton (1994). Water content, which can affect the dose rate and hence the age determination, was measured for each sample. The environmental dose rates were calculated from the above information using the AGE99 programme (Grün, 2009) and are shown in Table 1. Measurements made using different methods were not in such good agreement as might have been hoped. In particular, the field gamma spectrometer measurements consistently yielded higher rates than did the laboratory methods. The dose rates in this study area were however very low (of the order of 0.5 Gy/ka), thus precise and accurate measurement was inherently difficult. In most cases the results were within measurement error and in all cases the weighted average for the different methods was used in the age determination.

Material for dating was prepared using standard procedures to isolate pure quartz grains (see for example Macklin *et al.*, 2013). Grains in the size ranges 125-180 μm or 212-250 μm were selected for luminescence measurements, which were carried out using a Risoe TL/OSL-DA-20 reader fitted with a single-grain laser module. A small number of the early measurements was made using small aliquots (sub-samples) consisting of about 50-100 grains in the 125-180 μm range (see Table 1). All others were carried out using single grains in the 212-250 μm range, as this enables grains which may not be representative of burial time such as intrusive, bioturbated or incompletely bleached grains to be identified and removed from the analysis.

The samples were run using the single aliquot regeneration (SAR) protocol devised by Murray and Wintle (2000). In this protocol a series of radiation (or regeneration) doses is applied to determine the dose required to produce the same luminescence as the natural material. This is equivalent to the total dose received during burial, and is therefore referred to as the equivalent dose (ED). Each irradiation-luminescence cycle was followed by a constant test dose to correct for sensitivity changes. A zero dose to test for recuperation and a repeat of the first dose to test for recycling were also applied. Grains (or aliquots) appropriate for use in the age determination were selected according to the following criteria: a recycling ratio of 85% or more, recuperation 10% or less, and having reasonably smooth luminescence

Table 1. Dose rates and analysis information for samples from Olympic Dam dune study

SAMPLE NO	LAB ID NO	*M	U (PPM)	TH (PPM)	K%	FIELD GAMMA DOSE (GY/KA)	H2O %DRY WT±10%	DEPTH (M)	COSMIC COUNT GY/KA ±10%	DOSE RATE (GY/KA)	ANALYSIS METHOD	EDAGE (GY)	AGE (KA)
FIA17 DDO559-3	Ad11046	IX	0.38±0.04	1.50±0.11	0.10±0.01		2.6	0.35	0.200	0.50±0.03	Small aliquots wt mean	2.3±0.4	4.7±0.9
FIA17 DDO559-2	Ad11045	IX	0.40±0.04	1.83±0.14	0.10±0.01		3.5	0.65	0.199	0.51±0.03	Small aliquots wt mean	4.4±0.9	7.9±0.9
FIA17 DDO559-1	Ad11044	IX	0.46±0.04	1.99±0.15	0.10±0.01		2.7	0.95	0.195	0.52±0.03	Small aliquots wt mean	5.1±0.3	9.8±0.8
FP80 DDQ562-1	Ad11047	IX	0.33±0.03	1.42±0.12	0.10±0.01		1.3	0.225	0.200	0.48±0.03	Small aliquots wt mean	6.8±1.5	14.2±3.1
FP80 DDQ562-2	Ad11048	IX	0.33±0.03	1.45±0.13	0.11±0.01		2.8	0.375	0.200	0.47±0.03	Small aliquots wt mean	10.2±1.2	21.5±2.6
H366 DGB584-3	Ad12008	I G	0.35±0.02 0.35±0.05	1.16±0.06 1.33±0.08	0.09±0.01 0.08±0.01	0.114±0.003	0.5	0.30	0.200	0.45±0.02 0.44±0.02	Zero lum in 97% of grains	0.0±0.1	modern
H366 DFZ585-1	Ad11065	I	0.24±0.01	1.16±0.06	0.09±0.01		1.1	0.39	0.200	0.42±0.02	FMM(3)	0.5±0.1(51%) 1.5±0.1(22%) 3.7±0.1 (27%)	1.1±0.1 3.5±0.2 8.7±0.2
H366 DFZ585-2	Ad11066	I	0.24±0.01	1.16±0.06	0.09±0.01		0.75	0.46	0.200	0.42±0.02	FMM(3)	2.10±0.10(36%) 0.62±0.05(34%) 4.01±0.20(30%)	5.0±0.2 1.5±0.1 9.5±0.4
H366 D4	Ad12009	I G	0.31±0.02 0.41±0.05	1.40±0.071.51±0.08	0.12±0.01 0.10±0.01	0.137±0.003	2.5	0.50	0.200	0.48±0.02 0.52±0.03	CAM	7.3±0.5	14.7±1.2
H366 D3	Ad13036	I G	0.22±0.03 0.40±0.05	1.34±0.09 1.43±0.08	0.11±0.01 0.10±0.01	0.133±0.003	0.2	1.50	0.184	0.43±0.02 0.47±0.02	CAM	9.2±0.2	20.3±1.2
H366 D2	Ad13035	I G	0.25±0.03 0.36±0.05	1.61±0.11 1.51±0.08	0.13±0.01 0.10±0.01	0.132±0.003	0.8	2.50	0.167	0.47±0.02 0.45±0.02	CAM	13.4±0.3	29.5±1.5
H366 D1	Ad11070	IX	0.58±0.03	2.96±0.15	0.36±0.02		7.1	3.5	0.152	0.79±0.03	CMM	21.7±1.4	27.3±2.0
H366 DEN570-2	Ad11053	IX	0.26±0.01	1.25±0.06	0.10±0.01		0.5	0.5	0.200	0.43±0.02	CAM small aliquots	0.49±0.02	1.1±0.1
H366 DEN570-1	Ad11052	IX	0.26±0.01	1.25±0.06	0.10±0.01		0.5	1.0	0.194	0.42±0.02	CAM small aliquots	0.60±0.02	1.4±0.1
H366 DEM569-2	Ad11067	I	0.24±0.01	1.24±0.06	0.11±0.01		1.3	1.34	0.187	0.43±0.02	FMM(2)	1.1±0.1(81%) 6.9±0.2(19%)	2.5±0.3 15.9±0.9
H366 DEM569-3	Ad11068	I G	0.24±0.01 0.40±0.07	1.24±0.06 1.46±0.11	0.11±0.01 0.08±0.01	0.128±0.003	2.2	1.44	0.185	0.43±0.03 0.45±0.02	FMM(2)	1.6±0.1(67%) 6.3±0.2(33%)	3.7±0.3 14.7±0.7
H366 DEM569-4	Ad11069	I	0.24±0.01	1.24±0.06	0.11±0.01		1.9	1.54	0.184	0.43±0.02	FMM(2)	5.1±0.1(59%) 1.7±0.1(41%)	11.8±0.6 4.0±0.3

SAMPLE NO	LAB ID NO	*M	U (PPM)	TH (PPM)	K%	FIELD GAMMA DOSE (GY/KA)	H2O %DRY WT±10%	DEPTH (M)	COSMIC COUNT GY/KA ±10%	DOSE RATE (GY/KA)	ANALYSIS METHOD	EDAGE (GY)	AGE (KA)
H366 DEM569-5	Ad13013	I	0.24±0.03	1.31±0.09	0.11±0.01		0.2	1.75	0.180	0.43±0.02	FMM(3)	5.2±0.1(88%) 0.8±0.1 (4%) 12.6±1.1(8%)	12.3±0.7 2.0±0.2 29.3±2.3
H364 DDX564-1	Ad12123	I	0.23±0.03	1.11±0.08	0.08±0.01		0.8	0.55	0.200	0.41±0.02	FMM(2)	0.81±0.02(81%) 4.7±0.2(19%)	2.0±0.1 11.5±0.6
H364 DDX564-2	Ad12124	I	0.25±0.03	1.21±0.08	0.08±0.01		2.0	0.74	0.199	0.42±0.03	CAM	5.1±0.1	12.3±0.9
H364 DDX564-3	Ad12125	I	0.22±0.03	1.24±0.08	0.10±0.01		2.3	0.81	0.197	0.42±0.02	FMM(3)	4.8±0.1(88%) 0.8±0.1(6%) 12.8±0.8(6%)	11.4±0.6 1.9±0.3 30.5±1.9.
H364 DDQ556-3	Ad11051	I	0.32±0.02	1.49±0.07	0.10±0.01		2.1	0.25	0.200	0.47±0.02	CAM	5.0±0.1	10.6±0.5
H364 DDQ556-1	Ad11049	I	0.32±0.02	1.49±0.07	0.10±0.01		2.6	0.55	0.200	0.46±0.04	CAM	5.6±0.2	12.1±1.2
H364 DDQ556-2	Ad11050	I	0.32±0.02	1.49±0.07	0.10±0.01		1.6	1.0	0.194	0.45±0.02	CAM	6.4±0.2	14.0±1.0
H364 DCV556-5	Ad12006	I	0.28±0.01	1.37±0.07	0.10±0.01		0.9	0.75	0.198	0.45±0.01	FMM(2)	0.8±0.1(65%) 4.2±0.3(35%)	1.7±0.1 9.3±0.9
H364 DCV556-6	Ad12007	I	0.29±0.01	1.36±0.07	0.10±0.01		1.3	0.8	0.197	0.44±0.02	FMM(2)	0.9±0.1(55%) 5.3±0.4(45%)	2.1±0.2 12.0±1.5
H364 DBJ566 D7	Ad11064	I	0.43±0.02	2.58±0.13	0.34±0.02		6.0	1.0	0.194	0.76±0.03	CAM	13.7±0.9	18.0±1.4
H364 DAV556 C8	Ad11063	I	0.48±0.02	2.30±0.12	0.25±0.01		4.0	Uncertain 2-10m	0.175-0.087	0.67±0.02- 0.58±0.02	CAM	76.6±5.3	115±9 to 132±10
ODX00016-5	Ad12014	I	0.35±0.02	2.23±0.11	0.26±0.01		3.8	0.9	0.196	0.65±0.02	FMM(2)	33.8±2.0(92%) 4.83±0.58(8%)	51.9±2.1 7.4±0.9
ODX03235 BAU134-4	Ad13034	I	0.23±0.03	1.48±0.10	0.11±0.01		0.2	0.14	0.200	0.46±0.02	FMM(3)	4.9±0.3(66%) 1.0±0.1(17%) 15.5±1.0(17%)	10.7±0.5 2.2±0.3 33.7±3.0
ODX03235 BAU134-1	Ad12073	I	0.26±0.01	1.45±0.07	0.12±0.01		1.9	0.55	0.200	0.46±0.02	FMM(2)	5.4±0.3(60%) 9.7±0,4(40%)	11.7±0.2 21.0±0.7
ODX03235 BAU134-3	Ad12136	I	0.26±0.03	1.42±0.09	0.11±0.01		1.8	0.685	0.199	0.46±0.02	FMM(4)	6.8±0.4(79%) 3.4±1.0(5%) 14.5±2.8(12%) 41.3±7.4(4%)	15.0±1.2 7.4±1.9 31.5±6.1 89.8±16.1
ODX03235 BAU134-2	Ad12074	I	0.26±0.01	1.39±0.07	0.11±0.01		1.7	0.81	0.197	0.45±0.02	CAM	8.12±0.2	18.3±0.5
ODX03992 CAA550-1	Ad12075	I	0.28±0.01	1.40±0.07	0.11±0.01		4.0	0.7	0.199	0.457±0.021	FMM(2)	5.3±0.02(73%) 32.8±2.0(27%)	11.5±0.4 73±4

SAMPLE NO	LAB ID NO	*M	U (PPM)	TH (PPM)	K%	FIELD GAMMA DOSE (GY/KA)	H_2O %DRY WT±10%	DEPTH (M)	COSMIC COUNT GY/KA ±10%	DOSE RATE (GY/KA)	ANALYSIS METHOD	EDAGE (GY)	AGE (KA)
ODX03992 CAA550-2	Ad12076	I	0.28±0.01	1.60±0.08	0.17±0.01		3.1	0.9	0.196	0.522±0.022		No useable data	Not dateable
ODX04834-1	Ad12122	I	0.37±0.03	2.29±0.14	0.34±0.06		4	Not known?2-10	0.090-0.180	0.63-0.72	CAM	93.7±2.3	130-150
ODX04878 SAM144-2	As13014	I	0.24±0.03	1.20±0.08	0.10±0.01		0.2	0.7	0.199	0.49±0.02	CAM	3.3±0.2	6.7±0.9
ODX07128 FEZ998-1	Ad12116	I	0.26±0.03	1.25±0.08	0.10±0.01		0	0.22	0.200	0.44±0.03	CAM	0.04±0.15	modern
ODX07128 FEZ998-2	Ad12117	I	0.23±0.03	1.24±0.08	0.10±0.01		0	0.39	0.200	0.44±0.03	CAM	3.9±0.1	8.9±0.7
ODX07761-1	Ad12114	I	0.24±0.03	1.18±0.08	0.10±0.01		0	0.16	0.200	0.43±0.03	CAM	0.31±1.3	modern
ODX07761-2	Ad12115	I	0.27±0.03	1.29±0.09	0.10±0.01		1.0	0.31	0.200	0.45±0.03	FMM	4.9±0.2	10.9±0.9
ODX09833-5	Ad12134	I	0.37±0.03	1.82±0.12	0.15±0.01		1.0	0.32	0.200	0.55±0.03	CAM	7.3±0.2	13.3±0.9
ODX09833-6	Ad12135	I	0.43±0.04	1.79±0.12	0.14±0.01		2.0	0.41	0.200	0.55±0.03	CAM	7.9±0.2	14.3±0.9
ODX09833-13	Ad12137	I	0.39±0.04	1.95±0.13	0.16±0.01		2.2	1.27	0.188	0.55±0.02	CAM	9.5±0.2	17.2±0.8
ODX09833-14	Ad12138	I	0.41±0.04	2.04±0.13	0.16±0.01		2.4	1.38	0.186	0.56±0.02	CAM	10.7±0.3	19.1±0.9
ODX09833-21	Ad12142	I	0.46±0.04	2.06±0.13	0.13±0.01		1.0	0.53	0.200	0.57±0.03	CAM	0.05±0.02	0.09±0.04
ODX09833-22	Ad12143	I	0.39±0.04	1.84±0.12	0.18±0.01		1.7	0.565	0.200	0.59±0.03	CAM	6.6±0.2	11.0±0.6
ODX09833-23	Ad12144	I	0.36±0.03	1.90±0.12	0.13±0.01		0.4	0.62	0.199	0.54±0.02	FMM(2)	6.5±0.2(92%) Near zero(8%)	12.1±0.6 zero
ODX09823-15	Ad12139	I	0.33±0.03	1.56±0.12	0.11±0.01		1.6	0.59	0.200	0.49±0.02	CAM	0.08±0.02	0.16±0.04
ODX09823-16	Ad12140	I	0.37±0.03	1.82±0.12	0.13±0.01		5.9	0.66	0.199	0.51±0.02	CAM	5.8±0.2	11.4±0.6
ODX09823-17	Ad12141	I	0.33±0.03	1.60±0.11	0.12±0.01		2.7	0.68	0.199	0.49±0.02	CAM	5.9±0.2	12.2±0.7
ODX09823-3	Ad12019	I A A	0.58±0.03 0.75±0.15 0.95±0.27	4.29±0.21 1.94±0.50 1.98±0.95	0.16±0.01		1.8	0.7	0.199	0.77±0.03 0.65±0.05 0.70±0.07	CAM	8.2±0.5	11.3±1.1
ODX09823-4	Ad12020	I A	0.47±0.02 0.31±0.20	3.53±0.18 3.52±0.68	0.19±0.01		2.1	0.875	0.195	0.70±0.03 0.68±0.07	CAM	9.2±0.6	13.3±1.6

SAMPLE NO	LAB ID NO	*M	U (PPM)	TH (PPM)	K%	FIELD GAMMA DOSE (GY/KA)	H2O %DRY WT±10%	DEPTH (M)	COSMIC COUNT GY/KA ±10%	DOSE RATE (GY/KA)	ANALYSIS METHOD	EDAGE (GY)	AGE (KA)
ODX10390 THB120-1	Ad12021/2	I G	0.39±0.04 0.53±0.06	2.41±0.15 2.26±0.10	0.19±0.01 0.17±0.01	0.196±0.004	4.9	0.2	0.200	0.62±0.03 0.62±0.02	FMM(4)	1.71±0.08(61%) Zero (4%) 0.3±0.1(11%) 7.2±0.4(24%)	2.8±0.2 Zero 0.5±0.3 11.6±0.6
ODX10390 THB120-2	Ad12021	I G	0.43±0.02 0.62±0.06	1.86±0.09 1.99±0.09	0.18±0.01 0.16±0.01	0.192±0.004	0.2	0.5	0.200	0.61±0.02 0.63±0.02	FMM(2)	3.3±0.3(71%) 11.0±0.1(29%)	5.2±0.5 17.3±1.4
ODX10390 THB120-3	Ad12022	I G	0.36±0.02 0.59±0.06	1.69±0.09 2.15±0.10	0.15±0.01 0.19±0.01	0.210±0.005	0.4	0.85	0.197	0.58±0.02 0.66±0.02	FMM(2)	10.1±0.7(61%) 4.0±0.3(39%)	15.4±1.8 6.1±0.5
ODX10390 TCE5	Ad12023	I G	0.54±0.03 0.70±0.07	2.76±0.14 3.16±0.11	0.34±0.02 0.32±0.01	0.311±0.007	4.4	0.9	0.196	0.82±0.02 0.87±0.03	FMM(3)	9.9±0.8(56%) 16.3±1.7(36%) 4.0±0.4(8%)	11.8±1.0 18.8±2.0 4.6±0.5
ODX10478 UAV126-9	Ad12126	II	0.25±0.03	1.31±0.09	0.10±0.01		2.0	0.1	0.200	0.44±0.03	FMM(2)	5.3±0.2(61%) 1.0±0.1(39%)	12.0±0.4 2.3±0.2
ODX10478 UAV126-10	Ad12118	I	0.30±0.03	1.48±0.10	0.11±0.01		5.0	0.4	0.200	0.46±0.03	FMM(2)	6.7±0.4(50%) 12.9±0.8(50%)	14.5±1.4 28.0±1.8
ODX10478 UAV126-11	Ad12119	I	0.30±0.03	1.41±0.09	0.11±0.01		6.0	0.5	0.200	0.45±0.03	CAM	13.0±0.3	28.6±2.1
ODX10478 UAV126-12	Ad12120	I	0.31±0.03	1.86±0.12	0.19±0.01		2.0	0.8	0.197	0.57±0.03	CAM	14.5±0.4	25.3±1.6
ODX10478 UBC132-4	Ad12072	I	0.30±0.02	1.38±0.07	0.11±0.01		3.7	0.58	0.200	0.46±0.03	CAM	6.4±0.4	13.9±0.3
ODX10478 UAC111-1	Ad12070	I	0.35±0.02	1.73±0.09	0.14±0.01		2.2	0.53	0.200	0.52±0.03	CAM	7.6±0.5	14.8±0.3
ODX10478 UAC111-2	Ad12071	I	0.33±0.02	1.58±0.08	0.12±0.01		2.7	0.63	0.199	0.49±0.04	CAM	8.2±0.6	16.9±0.4
ODX11305-2	Ad12121	I	0.31±0.03	1.59±0.10	0.15±0.01		1.0	0.345	0.200	0.52±0.03	FMM(3)	1.0±0.1(63%) 2.9±0.2(17%) 8.4±0.5(20%)	1.8±0.2 5.6±0.5 16.2±1.1
ODX11305-3	Ad13015	I	0.28±0.03	1.49±0.10	0.14±0.01		3.2	0.9	0.196	0.48±0.02	FMM(3)	7.1±0.2(90%) 1.9±0.5(1%) 13.1±1.7(9%)	14.6±0.8 4.0±1.1 27.3±3.5
ODX13373 SQE083-1	Ad12145	I	0.27±0.03	1.27±0.09	0.14±0.01		1.7	0.1	0.200	0.48±0.02	CAM	5.7±0.1	11.9±0.6
ODX13373 SQE083-2	Ad13065	I	0.19±0.02	1.35±0.09	0.14±0.01		0.5	1.20	0.190	0.46±0.02	CAM	5.8±0.1	12.6±0.6
ODX15546-3	Ad12016/4	I	0.31±0.03	1.46±0.10	0.10±0.01		1.0	0.2	0.200	0.45±0.03	CAM	6.5±0.3	13.8±1.1
ODX15546-4	Ad12015/2	I G	0.26±0.03 0.41±0.05	1.33±0.09 1.62±0.09	0.11±0.01 0.09±0.01	0.140±0.004	1.0	0.4	0.200	0.46±0.03 0.49±0.03	FMM(2)	8.4±0.3(85%) 2.3±0.1(15%)	17.7±1.0 4.9±0.3

SAMPLE NO	LAB ID NO	*M	U (PPM)	TH (PPM)	K%	FIELD GAMMA DOSE (GY/KA)	H2O %DRY WT±10%	DEPTH (M)	COSMIC COUNT GY/KA ±10%	DOSE RATE (GY/KA)	ANALYSIS METHOD	EDAGE (GY)	AGE (KA)
ODX15546-5	Ad12015	I	0.39±0.02	3.10±0.16	0.12±0.01		1.2	0.6	0.199	0.61±0.03	CAM	7.6±0.6	12.4±1.1
ODX15546-6	Ad12016	I	0.45±0.02	4.58±0.23	0.12±0.01		3.6	0.8	0.197	0.71±0.03	CAM	9.9±0.7	13.9±1.1
ODX15546-7	Ad12016/2	I G	0.30±0.03 0.38±0.05	1.50±0.10 1.58±0.09	0.12±0.01 0.11±0.01	0.142±0.003	1.0	1.3	0.188	0.48±0.03 0.49±0.02	CAM	11.2±0.2	23.2±1.5
ODX15546-8	Ad12016/3	I G	0.26±0.03 0.44±0.05	1.43±0.10 1.67±0.09	0.13±0.01 0.12±0.01	0.154±0.004	2.0	1.8	0.179	0.45±0.03 0.51±0.02	CAM	11.5±0.3	23.9±1.8
ODX15546-9	Ad12017	I G	0.34±0.02 0.47±0.06	2.39±0.12 1.83±0.03	0.29±0.01 0.17±0.01	0.178±0.004	5.2	2.4	0.169	0.56±0.02 0.55±0.02	CAM	30.8±2.5	55.5±5.0
ODX15546-1	Ad12146	I	0.29±0.03	1.17±0.08	0.08±0.01		1.0	0.1	0.200	0.43±0.03	CAM	9.0±0.2	21.2±1.7
ODX15546-2	Ad13016	I	0.24±0.03	1.15±0.08	0.07±0.01		7.9	1.3	0.188	0.38±0.03	FMM(2)	16.2±0.3(89%) 9.4±0.9(11%)	43.3±3.0 24.7±2.6
ODX15546-11	Ad12018	I G	0.43±0.02 0.62±0.07	2.91±0.15 3.12±0.12	0.37±0.02 0.35±0.01	0.283±0.006	11.8	uncertain 1-10	0.194	0.87±0.03- 0.67±0.03 0.82±0.03- 0.72±0.02	CAM	72.9±4.7	91.1±6 to 105.2±7

Footnotes to Table 1

*M = method used:

I ICPMS used to determine U and Th concentrations. ICPAES used to determine K concentrations (see main text for explanation of abbreviations).

X K determined using XRF as well as ICPAES. The average of the two measurements is shown in the table and used in the age calculation.

G U, Th, K and total gamma dose measured by field gamma spectrometry. The dose rate calculated using these values, and that obtained using ICPMS/ICPAES, were averaged to obtain the dose rate used in the age calculation.

A U and Th determined using TSAC in addition to ICPMS. The dose rate calculated using these values together with the ICPAES value for K, and the dose rate determined using ICPMS/ICPAES were averaged to obtain the dose rate used in the age calculation.

Dose rate

The dose rates determined by different methods (if more than one method was used) are shown. The average of these dose rates (not shown in the table) was used in the age calculation.

Analysis method

CAM: Central age model.

FMM(x): Finite mixture model, where x is the number of components.

For the FIA and FP80 sample sets measurements were made using small aliquots and the weighted mean of individual values was used in the age determination.

EDAge

Where the finite mixture model was used, the ED value of each component is shown, together with percentage of values constituting that component. The values selected for use in the age determination (the dominant or co-dominant ones) are shown normal font, the others in italics. For two samples where the dominant components were the same or very nearly the same (Ad11016 and Ad11218) two selected ages are given

Age

Where the finite mixture model was used, the age determined from the selected component is shown in bold, ages determined from the other components are shown in normal font italics.

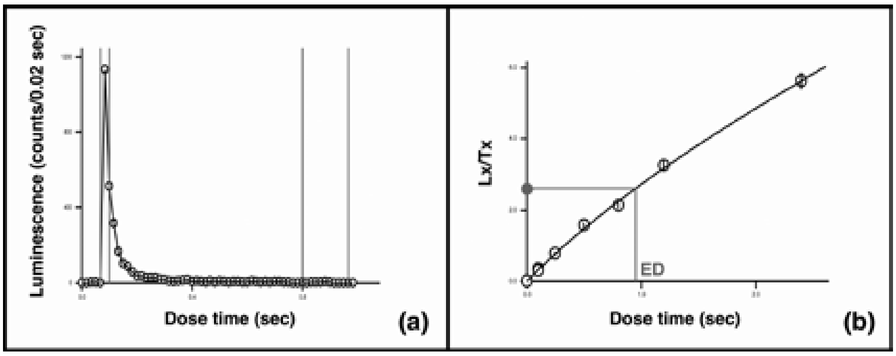

Figure 3. Example of a shine-down and a regeneration curve

(a) Shine-down curve for sample H366 D2, Disc 8 grain 21. The two vertical lines to the left indicate the time interval selected for measurement of the luminescence, the two vertical lines to the right the interval for the background to be subtracted.

(b) Regeneration curve for the same grain, showing luminescence Lx (normalised by the test dose luminescence Tx) as a function of applied dose. The dot on the vertical axis indicates the luminescence of the natural sample, and the intersecting horizontal and vertical lines the interpolation to give the equivalent dose (ED).

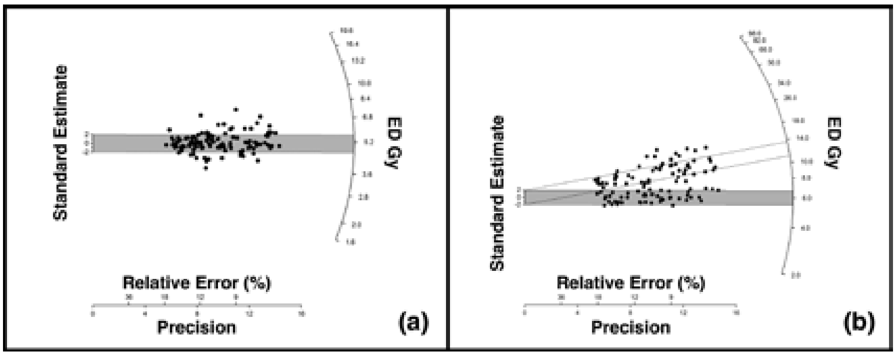

Figure 4. Radial plots showing examples of different equivalent dose distributions.

(a) H364 DDX 564 2. This sample showed a well constrained distribution of equivalent dose values and the Central Age Model was used for analysis, yielding a central dose of 5.11 ± 0.09 Gy, and corresponding age of 12.3 ± 0.9 ka.

(b) ODX010478 UAV126 10. The ED distribution for this sample fell into two distinct groups and was analysed using the Finite Mixture Model. This yielded EDs of 6.7 ± 0.43 Gy (50%) and 12.94 ± 0.81 Gy (50%), and corresponding ages of 14.5 ± 1.4 ka and 28.0 ± 1.8 ka.

shine-down curves and regeneration plots (e.g. Figures 3a and b). For this sample set between 10% and 20% of the grains were accepted per sample, and sufficient grains were run for each sample to ensure a minimum of 100 acceptable grains.

The equivalent dose values obtained for each sample were analysed in order to determine the ED to be used in the age determination, referred to henceforth as EDAge. The majority of the samples showed reasonably well constrained ED distributions and for these the central age model (CAM) (Galbraith *et al.*, 1999) was used to evaluate EDAge, omitting the few and obvious outlying values (see e.g. Figure 4a). About one third of the samples however showed a more scattered distribution of EDs for which the central age model was not appropriate. These distributions were analysed using the finite mixture model (FMM) (Galbraith and Green, 1990) which groups a population of measured values into a number of discrete components and calculates a central value for each component (see e.g. Figure 4b).

For the samples run using small aliquots, EDAge was calculated as the weighted mean of the individual ED values. The ages of the samples were obtained by dividing their EDAge by the corresponding environmental dose rate and are shown in Table 1. Their interpretations are summarised in Table 2.

Throughout their history of accumulation these dune sands have been affected to varying degrees by bioturbation and this is probably the main reason about a third of samples had scattered distributions of EDs. Burrowing by native mammals such as bettongs, bilbies and wombats, and by goannas and frogs, would have disturbed the sand as, in recent times, have rabbits. In some of the excavations lenses of leaves forming the nests of small mammals were found at depth and occasionally frogs were found as the sand was excavated. Beetles, ants, termites and spiders were observed occasionally at depth. Patches of termite nest were seen throughout the excavations at one site, ODX_10390, where all the optical dates had scattered distributions of EDs.

In some cases the minor components were younger, in others older and in some both younger and older, indicating sand grains have moved up and down the profile. In many cases having these secondary components helped in the interpretation of the depositional history of the sites. Although bioturbation has moved sand grains up and down, in almost none of the excavated artefact layers was there evidence of appreciable artefact displacement.

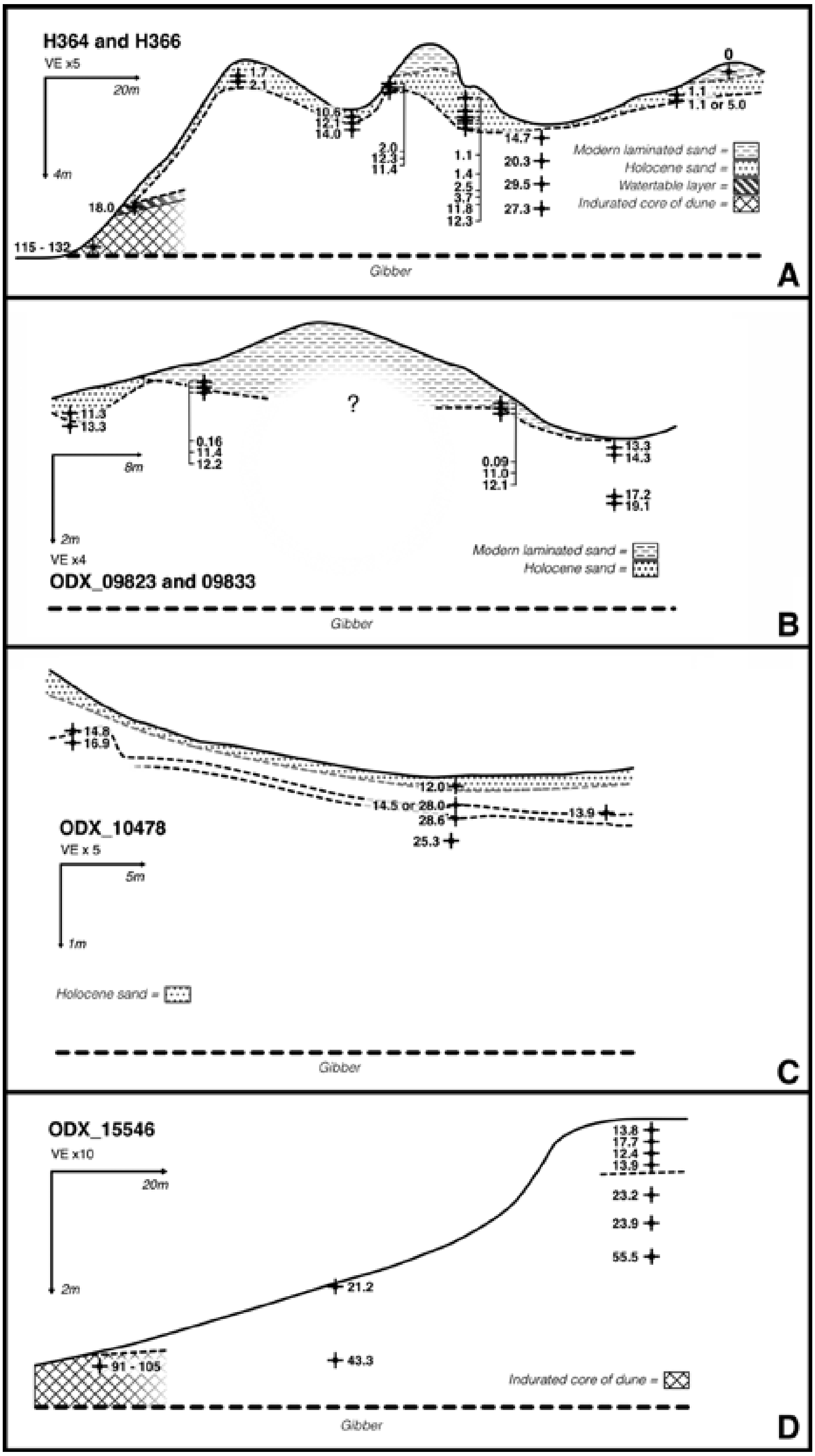

Figure 5. Schematic sections of dunes with multiple dated profiles. In A, B and C the dashed line below the Holocene and/or modern sand marks the dune surface at ~12 ka. In C the deeper dashed lines represent the top of an artefact layer dated across the site to ~14.5 ka, and below that the surface of a continuous layer of indurated sand dated to ~28-29 ka. In D the dashed line below the dune crest is the base of the late Pleistocene artefact layer which extends upwards to just below the surface. In each section the basal dashed line is a generalised representation of the gibber surface extrapolated horizontally from the adjacent swale. In some instances the surfaces may rise above this level.

INTERPRETING DUNE BUILDING HISTORY

The optical dates pertaining to the history of dune formation at Olympic Dam are summarised in Table 2. A summary of that history, based on archaeological and geomorphological evidence as well as optical dating, is presented in Table 3. At most sites the optical dates were obtained from a single excavation but at four sites/site complexes several sand profiles were dated, allowing former surfaces to be inferred across sites (Figure 5).

BEFORE ~90 KA

On many dunes outcrops of weathered, mottled and highly indurated sand with some silt and clay are exposed, especially along their northern toes and occasionally in deep blowouts along their crests. The unconsolidated homogenous sands that form the present dunes appear to lie unconformably over these weathered indurated sands. Samples of this older sand from three widely spaced sites in the northeast, centre and southeast of the study area were selected for dating. Their ages were, from north to south, 91-105 ka, 115–132 ka and 130-150 ka (Tables 2 and 3, Figure 5). It is likely that these are the eroded stumps of former dunes of widely differing ages along the same alignments as the present dunes, but slightly offset to the north. If so, they indicate at least three earlier phases of dune building and subsequent erosion before the present unconsolidated dunes started forming by >55 ka.

Lomax *et al.* (2011:734) identified an aeolian depositional phase from 80-111 ka in dunefields in the western Murray Basin and in the same region Twidale *et al.* (2007) demonstrated that in two of the three dunes they dated, several metres of sand had accumulated between ~157 ka and 95 ka and these sands were essentially the same in character as overlying sands 33-25 ka and younger.

Fitzsimmons (2007:2609-10) dated transverse dune formation at two sites in the southern Strzelecki Desert to between 92 ka and 123 ka. In the Great Victoria Desert there was considerable dune building between >250 ka and 71 ka (Sheard *et al.*, 2006) and dune building was underway in the Port Augusta area by ~150 ka (Walshe *et al.*, 2001). None of the >85 ka sands described in these various studies appears to be as intensely weathered, mottled and indurated as the equivalent units in the Roxby dunefield, where however exposed dune cores or 'stumps' were selected for dating, and the weathering and induration could have been intensified by their exposure.

>55 KA TO 12 KA

Dune building was underway before 55 ka and continued until ~21 ka. No depositional events have been recognised at Olympic Dam that correlate with those described by Lomax *et al.* (2011:723) at 72-63 ka, or by Fitzsimmons *et al.* (2007:2598) in the Strzelecki and Tirari Deserts at 73-66 ka.

At the site with the deepest dated sequence (H366) sand accumulation was most rapid between ~30 ka and 21 ka, the period leading up to and including the peak of the LGM, and characterised by relatively arid and cold conditions and widespread dune activity (Fitzsimmons *et al.*, 2013:90-92). After ~21 ka there was marked decline in or cessation of sand accumulation, lasting to around 14 ka. The latter part of this period occurred when the southern part of the continent experienced a brief humid phase around ~17-15 ka (Fitzsimmons *et al.*, 2013:78).

Thereafter dune building continued, or recommenced and increased, until ~12 ka then decreased again. At several sites there was very rapid accumulation at ~13 ka (Table 3). Fitzsimmons *et al.* (2007:2609) similarly identified a peak of dune activity in the Strzelecki and Tirari Deserts at ~14-10 ka. During this period there was increased dune activity in the southern part of the continent (Fitzsimmons *et al.*, 2013:78), punctuated by short wet phases which are reflected in short-lived lake high stands at Lakes Frome and Callabonna (Fitzsimmons *et al.*, 2013:92) to the east of the Roxby dunefield. De Deckker *et al.* (2011:38, 49) concluded that the wettest period during the deglaciation occurred between 13 ka and 11.2 ka and that such conditions were not experienced again during the Holocene.

~12 KA TO PRESENT

Between about 12 ka and 9 ka dune building virtually ceased and stable surfaces formed. Throughout the Holocene there was very localised accumulation of up to 1m of sand, in a few sites continuing for thousands of years, on low dune crests and flanks adjacent to blowouts (FIA17, H366 and ODX_10390). These Holocene sands commonly contain tiny flakes, indicating they blew/saltated from adjacent blowouts which contained surface scatters of artefacts, and that sand was being locally reworked. In most cases however the terminal Pleistocene-early Holocene dune surfaces have little or no later Holocene sand covering them.

In southern central Australia the early to mid Holocene appears to have experienced increasingly humid and stable climatic conditions, culminating at ~7-5 ka and this was generally a period of low dune activity (Fitzsimmons *et al.*, 2013:92). After ~5 ka there were intermittent peaks of aeolian activity in the central arid zone (Fitzsimmons *et al.*, 2013:92) but these have not been recognised at Olympic Dam.

Across the Roxby dunefield there are widespread occurrences of loose laminated sand, five samples of which have been dated to between 160 years old and modern (0 years). These very recent sands form many of the highest knolls on the dunes (see for example Figure 5A). These sands which were trapped on blowout rims or around vegetation, were mobilised when the land was degraded by overstocking by early European settlers, especially during droughts, and the arrival of rabbits (Badman, 1999:Chapter 6). The dunes then appear to have stabilised again and Hughes has observed relatively little evidence of sand movement over the 35 years he has been working at Olympic Dam. A feature of some dunes in the Roxby dunefield is that at their western ends artefact scatters are exposed on short stretches of eroded indurated dune cores whereas at the eastern ends there has been minor accumulation of modern sand which obscures any artefact scatters which might be present. This indicates that since these dunes stabilised at the end of the Pleistocene there has been minor net movement of sand eastwards, mainly since disturbance by European land use.

RELATIONSHIPS BETWEEN ARCHAEOLOGICAL AND DUNE BUILDING RECORDS

At Olympic Dam the gibber surfaces exposed in the dunefield were an excellent source of stone for flaked artefacts, hammerstones and grinding stones. The diverse aquatic fauna of the canegrass swamps and the prolific waterbird populations they enticed (see e.g. Pedler and Kovac 2013) would have attracted both game animals and people engaged in hunting. The area does not however have permanent drinkable water and could have been occupied temporarily only during wetter interludes in which the shallow surface waterbodies throughout the area filled and continued to hold water for up to several months (see e.g. Hughes and Hiscock, 2005:12). The pattern of human settlement was highly mobile in response to local conditions. Use of this region always

Table 2. Single grain OSL dates that inform the dune history and archaeology at Olympic Dam

SAMPLE LOCATION & NO.	DEPTH (M)	AGE	ARCHAEOLOGICAL CONTEXT	GEOMORPHIC INTERPRETATION
FIA17				
FIA17 DDO559-3	0.4	4.7±0.9	In and below buried early to late Holocene artefact layer in 1m high dune between two blowouts	3m of sand accumulation before ~10ka, then 1m during Holocene
FIA17 DDO559-2	0.7	7.9±0.9		
FIA17 DDO559-1	1.0	9.8±0.8		
Base of dune	4.0			
FP80				
FP80 DDQ562-1	0.225	14.2±3.1	In and below buried late Pleistocene artefact layer in 1m high dune between two blowouts	2.7m of sand accumulated before ~21.5ka, then a hiatus of 7ka followed by a veneer of sand accumulation from ~14ka
FP80 DDQ562-2	0.375	21.5±2.6		
Base of dune	3.0			
H364 AND H366				
Eastern end of site				
H366 DGB584-3	0.3	Modern	None	Localised accumulation ~0.5m of sand in the last 1-5ka, capped by a mound of modern laminated sand. The artefact-bearing sand is probably a mixture of 1-1.5ka grains that accumulated when the artefacts were discarded and 5ka grains brought up from below
H366 DFZ585-1	0.39	1.1±0.1	Immediately above late Holocene artefact layer	
H366 DFZ585-2	0.46	1.5±0.1 or 5.0±0.2	Immediately below late Holocene artefact layer	
Eastern blowout				
H366-D4	0.5	14.7±1.2	None	Most of the dune accumulated during the LGM. No sand <~12ka on floor of artefact-mantled blowout
H366-D3	1.5	20.3± 1.2		
H366-D2	2.5	29.5±1.5		
H366-D1	3.5	27.3±2.0		
Base of dune	5.5			
Eastern flank of dune between eastern and western blowouts				
H366 DEN570-2	0.5	1.1±0.1	None	5m of sand accumulation before 12ka, then an 8ka hiatus, with another 2m of local sand accumulation during the last 4ka. This late Holocene sand contains numerous tiny flakes, indicating it blew/saltated from the artefact-mantled floor of the blowout immediately to the east. Crest of dune to west capped with 1m of modern laminated sand
H366 DEN570-1	1.0	1.4±0.1		
H366 DEM569-2	1.34	2.5±0.3		
H366 DEM569-3	1.44	3.7±0.3	Buried late Holocene artefact layer	
H366 DEM569-4	1.54	11.8±0.6	None	
H366 DEM569-5	1.75	12.3±0.7		
Base of dune	7.0			

SAMPLE LOCATION & NO.	DEPTH (M)	AGE	ARCHAEOLOGICAL CONTEXT	GEOMORPHIC INTERPRETATION
Western flank of dune between eastern and western blowouts				
H364 DDX564-1	0.55	2.0±0.1	Buried late Holocene artefact layer resting on and embedded in 12ka sand	7.5m of sand accumulation before 12ka, then a 10ka hiatus, with another 0.5m of local sand accumulation during the last 2ka. Crest of dune to east capped with 1m of modern laminated sand
H364 DDX564-2	0.74	12.3±0.9		
H364 DDX564-3	0.81	11.4±0.6		
Base of dune	8.0			
Western blowout				
H364 DDQ556-3	0.25	10.6±0.5	None	6.5m of sand accumulation before 12ka, then another 0.5m to ~10.5ka. Floor of blowout is mantled with Holocene artefacts resting on this 10.5ka surface
H364 DDQ556-1	0.55	12.1±1.2	Buried terminal Pleistocene artefact layer	
H364 DDQ556-2	1.0	14.0±1.0	None	
Base of dune	7.0			
Crest of dune west of western blowout				
H364 DCV556-5	0.75	1.7±0.1	Immediately above late Holocene artefact layer	The sand immediately below the artefact layer has a pronounced secondary component of 12ka, indicating sand of that age is at close depth below. ~7.5m of sand accumulation before ~12ka was followed by a 10ka hiatus, with another ~0.3m of sand accumulation after ~2ka. The upper ~0.4m of sand is modern laminated sand
H364 DCV556-6	0.80	2.1±0.2	Immediately below late Holocene artefact layer	
Base of dune	8.0			
Toe of dune on its northwest side				
H364 DBJ566-D7	1.0	18.0±1.4	None	~18ka hardpan – sand slightly mottled and cemented by watertable effects resting unconformably on highly weathered, mottled, indurated >116ka core of former dune
H364 DAV556-C8	Currently at 1.6	115±9 to 132±10		
Base of dune	2.0			
ODX_00016				
ODX16-5	0.9	51.9±2.1	None	~52ka unconsolidated sand at base of northern flank of 6m dune
ODX_03235				
ODX03235 BAU134-4	0.14	10.7±0.5	None	4m of sand accumulation before 15ka, then another 0.7m to ~10.5ka. Dune crest is mantled with artefacts resting on this 10.5ka surface
ODX03235 BAU134-1	0.55	11.7±0.2	None	
ODX03235 BAU134-3	0.685	15.0± 1.2	Buried late Pleistocene artefact layer on crest of dune	
ODX03235 BAU134-2	0.81	18.3±0.5	None	
Base of dune	4.5			

SAMPLE LOCATION & NO.	DEPTH (M)	AGE	ARCHAEOLOGICAL CONTEXT	GEOMORPHIC INTERPRETATION
ODX_03992				
ODX03992 CAA550-1	0.7	11.5±0.4	None	7.5m of sand accumulation before 11.5ka and 0.7 thereafter. Dune crest is mantled with late Holocene artefacts resting at shallow depth on this 11.5ka surface
ODX03992 CAA550-2	0.9	Not dateable	None	
Base of dune	8			
ODX_04834				
ODX04834-1	Currently at surface	130-150	None	130-150ka highly weathered, mottled, indurated core of former sand dune on northern toe of dune
ODX_04878				
ODX_04878 SAM144-2	0.7	6.7±0.9	Immediately below Holocene artefact layer on southern flank of dune	Buried artefact layer resting on ~6.7ka surface of 1.5m dune capped with laminated modern sand
Base of dune	1.5			
ODX_07128				
ODX07128 FEZ998-1	0.22	modern	Immediately above Holocene artefact layer	Buried artefact layer resting on ~9ka surface of 6m dune capped with a veneer of laminated modern sand
ODX07128 FEZ998-2	0.39	8.9±0.7	Immediately below Holocene artefact layer	
Base of dune	6.0			
ODX_07761				
ODX07761 HAN099-1	0.16	modern	Immediately above Holocene artefact layer	Buried artefact layer resting on ~11ka surface of 6m dune capped with a veneer of laminated modern sand
ODX07761 HAN099-2	0.31	10.9±0.9	Immediately below Holocene artefact layer	
Base of dune	6.0			
ODX_09823 & ODX_09833				
Eastern blowout				
ODX09833 NBZ123-5	0.32	13.3±0.9	Immediately above late Pleistocene artefact layer	~1.5m of sand accumulation before 19ka, then another 1m to ~13ka. Artefact layer on floor of blowout rests on ~12ka surface
ODX09833 NBZ123-6	0.41	14.3±0.9	Immediately below late Pleistocene artefact layer	
ODX09833 NBY123-13	1.27	17.2±0.8	Immediately above an older late Pleistocene artefact layer	
ODX09833 NBY123-14	1.38	19.1±0.9	Immediately below an older late Pleistocene artefact layer	
Base of dune	3.0			
Eastern flank of dune between eastern and western blowouts				
ODX09833 NBO123-21	0.53	0.09±0.04	Buried Holocene artefact layer resting on and embedded in 11-12ka sand	Buried artefact layer resting on ~11-12ka surface of 4m dune capped with 0.5m of laminated modern sand
ODX09833 NBO123-22	0.565	11.0±0.6		
ODX09833 NBO123-23	0.62	12.1±0.6		
Base of dune	4.0			

SAMPLE LOCATION & NO.	DEPTH (M)	AGE	ARCHAEOLOGICAL CONTEXT	GEOMORPHIC INTERPRETATION
Western flank of dune between eastern and western blowouts				
ODX09823 NAN112-15	0.59	0.16±0.04	Buried Holocene artefact layer resting on and embedded in 11-12ka sand	Buried artefact layer resting on ~11-12ka surface of 4.5m dune capped with 0.6m of laminated modern sand
ODX09823 NAN112-16	0.66	11.4±0.6		
ODX09823 NAN112-17	0.68	12.2±0.7		
Base of dune	4.5			
Western blowout				
ODX09823 NAB112-3	0.7	11.3±1.1	Immediately above terminal Pleistocene artefact layer	3.5m of sand accumulation before ~11.5ka, then another 0.6m to the floor of blowout, which is mantled with artefacts, including diagnostic late Holocene types
ODX09823 NAB1124	0.875	13.3±1.6	Immediately below terminal Pleistocene artefact layer	
Base of dune	4.0			
ODX_10930				
Crest of dune				
ODX10390 THB120-1	0.2	2.8±0.2	Buried Holocene artefacts throughout	~0.9m of sand accumulation in the mid to late Holocene. Sample 3 has strong secondary component of ~6ka, indicating base of artefact layer may be this age and resting on older sand. Samples 1 and 2 have secondary components of ~11-17ka, indicating older sand has moved up the profile, which was visibly disturbed by termites
ODX10390 THB120-2	0.5	5.2±0.5		
ODX10390 THB120-3	0.85	15.4±1.8		
Base of dune	2.5			
Toe of eastern flank of dune				
ODX10390 TCE-5	0.9	11.8±1.0	None	Slightly weathered and indurated sand in watertable layer between dune and gibber. Disturbed by termites

SAMPLE LOCATION & NO.	DEPTH (M)	AGE	ARCHAEOLOGICAL CONTEXT	GEOMORPHIC INTERPRETATION
ODX_10478				
Blowout				
ODX10478 UAV126-9	0.1	12.0±0.4	Immediately below surface artefacts	~3m of sand accumulation by ~28ka. Slightly cemented to at least 0.5m depth. Hiatus of ~14ka, then 0.4m sand accumulation until ~12ka. Near surface date of 12ka has pronounced secondary component at 2.3ka, indicating there is a veneer of late Holocene sand containing the artefact layer on floor of blowout resting on a ~12ka surface at very shallow depth. The lower artefact layer ~14.5ka beneath the floor of the blowout rests directly on ~28ka surface. In UAV126 the artefact-bearing sand is a mixture of 14.5ka grains that accumulated when the artefacts were discarded and 28ka grains brought up from below
ODX10478 UAV126-10	0.4	14.5±1.4and 28.0±1.8	Immediately above late Pleistocene artefact layer	
ODX10478 UAV126-11	0.5	28.6±2.1	Immediately below late Pleistocene artefact layer	
ODX10478 UAV126-12	0.8	25.3±1.6	None	
ODX10478 UBC132-4	0.58	13.9± 0.3	Immediately above late Pleistocene artefact layer	
Base of dune	3.5			
Eastern flank of dune to west of blowout				
ODX10478 UAC111-1	0.53	14.8±0.3	Immediately above late Pleistocene artefact layer	~3.5m of sand accumulation by ~17.5ka, then virtual cessation over the next 3ka, then 0.5m during the Holocene
ODX10478 UAC111-2	0.63	16.9±0.4	Immediately below late Pleistocene artefact layer	
Base of dune	4.0			
ODX_11305				
Blowout				
ODX11305 AAH108-2	0.345	1.8±0.2	In diffuse late Holocene artefact layer at level of a unifacial point	Most of the sand had accumulated by ~15ka but some accumulation occurred in the Holocene. Upper part of Holocene sand layer noticeably disturbed by rabbits and kangaroos
ODX11305 AAH108-3	0.9	14.6±0.8	Below lowest artefact	
Base of dune	1.5			
ODX_13373				
Dune crest				
ODX13373 SQE083-1	0.1	11.9±0.6	Immediately below surface artefacts	6m of sand had accumulated by 12ka and the upper 1m accumulated very rapidly thereafter. The surface artefacts rest on a ~12ka dune surface
ODX13373 SQE083-2	1.2	12.6±0.6	None	
Base of dune	7.0			

SAMPLE LOCATION & NO.	DEPTH (M)	AGE	ARCHAEOLOGICAL CONTEXT	GEOMORPHIC INTERPRETATION
ODX_15546				
Crest of dune				
ODX15546 NMA164-3	0.2	13.8±1.1	Late Pleistocene artefacts throughout this 13ka sand	The sand throughout is uniformly unconsolidated. Half the dune thickness (~2.5m) had accumulated by 55ka and another 1m by 23ka. There was very little net accumulation over the next 10ka (0.5m) but the top 0.8m accumulated very rapidly about 13ka. A rich artefact scatter rests on this 13ka surface. Signs of animal disturbance throughout profile, especially in the top 1m.
ODX15546 NMA164-4	0.4	17.7±1.0		
ODX15546 NMA164-5	0.6	12.4±1.1		
ODX15546 NMA164-6	0.8	13.9±1.1		
ODX15546 NMA164-7	1.3	23.2±1.5	None	
ODX15546 NMA164-8	1.8	23.9±1.8	None	
ODX15546 NMA164-9	2.4	55.5±5.0		
Base of dune	5.0			
Southern flank of dune				
ODX15546 NNL115-1	0.1	21.2±1.7	None	The sand throughout is uniformly unconsolidated. 1m had accumulated by 43ka and the remaining 1.3m by 21ka. A rich artefact scatter rests on this 21ka surface
ODX15546 NNL115-2	1.3	43.3±3.0	None	
Base of dune	2.3			
Toe of dune				
ODX15546-11	0.5	91±6 to 105±6	None	Highly weathered, mottled, indurated core of former sand dune
ODO3A23				
UW2555	0.395	Modern and 5.09±0.68	Buried Holocene artefact layer resting on ~12.5ka sand	Buried artefact layer resting on ~12.5ka western flank of 6m dune capped with 0.4m of laminated modern sand containing a veneer of Holocene sand at its base
UW2556	0.495	12.1±1.28		
UW2557	0.645	13.9±1.59		
UW2558	0.845	12.8±1.4		
Base of dune	6.0			

Very small assemblages of Holocene artefacts dating to between 5 ka and 10 ka were recovered from only two sites (FIA17 and ODX_10390), indicating that there was little use of this area during the early and mid Holocene, despite the likelihood that, as elsewhere in southern Australia, climatic conditions in this region were more humid and stable than later in the Holocene. It might be that as this was a period of dune stability, some of the assemblages resting on the 12 ka to 9 ka dune surfaces, which are still exposed today or are buried with modern sand, also date from this period.

The topographic, stratigraphic, optical dating and artefact typology evidence indicates strongly that most of the vast amount of surface-visible archaeological material is late Holocene in age. Buried dated late Holocene assemblages were found at FIA17, H364, H366 (two separate occurrences of different ages), ODX_10390 and ODX_11305. Some of the assemblages resting on the 12 ka to 9 ka dune surfaces and still exposed today or buried with modern sand contain artefacts such as backed artefacts, tulas and unifacial points diagnostic of the late Holocene (Hiscock, 2008). This increase in use of the

Table 3. Summary of dune building history at Olympic Dam

AGE	SITES	# DATED EXAMPLES	DUNE BUILDING HISTORY
Modern	H366, ODO_3A23, ODX_07128, ODX_07761, ODX_09823, ODX_09833	6	Loose laminated sand accumulation accompanying early European land use
<10ka	FIA17, H364, H366, ODX_04878, ODX_10390, ODX_11035	8	Overall no dune building Very localised accumulation of up to 1m of sand, in a few sites continuing slowly for thousands of years, on low dune crests and flanks adjacent to blowouts. These Holocene sands commonly contain tiny flakes, indicating they blew/saltated from adjacent blowouts which contained surface scatters of artefacts. This was local sand being reworked
~9-12ka	H364, H366, ODO3A23, ODX_03235, ODX_03992, ODX_07128, ODX_07761, ODX_09823, ODX_09833, ODX_10478, ODX_13373, ODX_15546	15	Stable dune surfaces form Of the still-exposed surfaces 3 are on dune crests and 3 in blowouts (which may be slightly deflated) Of the buried surfaces of this age range 5 are capped with modern sand and 4 with mid to late Holocene sand. These surfaces (exposed and buried) have artefact scatters on them
11-14ka	H364, ODO_3A23, ODX_03235, ODX_09823, ODX_09833, ODX_13373, ODX_15546	7	Sand accumulation continued or recommenced and in most sites increased until ~12ka then decreased again. In three sites (ODX_13373, ODX_15546 and ODO_3A23) very rapid accumulation at ~13ka
14-21ka	FP80, H364, H366, ODX_03235, ODX_09833, ODX_10390, ODX_10478, ODX_15546	8	Marked decline in or cessation of sand accumulation
21-40ka	FP80, H366, ODX_10478, ODX_15546	5	Period of maximum dune building. At site with the deepest dated sequence (H366) most rapid between 30 and 21ka
40->55ka	ODX_00016, ODX_15546	3	Accumulation of present dunes underway by 55ka. Unconsolidated red sand indistinguishable from younger sand
>90-150ka	H364, ODX_04834, ODX_15546	3	Highly weathered, mottled, indurated clayey sand. Stumps of older dunes exposed along the eroded toes of present dunes

would have been infrequent, short-term and by small groups of people, which is consistent with the character of the archaeological sites. As Hughes *et al.* (2011:32) argued, a substantial majority of archaeological sites within the study area represents the residues of short-term occupation of the kind found throughout arid northeast South Australia and arid Australia more generally. Large numbers of small sites containing sparse assemblages in landscape contexts with no access to permanent water are typical archaeological signatures of mobile foragers, in both the Olympic Dam region and other arid zone contexts in Australia (Hiscock, 2008: Chapter 11; Smith 2013; Veth, 2005).

No archaeological deposits dating from the LGM or earlier were observed, however only a relatively small volume of sand covering this age range was excavated. At seven sites (FP80, H364, ODX_03235, ODX_09823, ODX_09833, ODX_10478, ODX_15546) thin but archaeologically-rich layers of stone artefacts dating from the deglacial period (~18ka to 12ka) were found. These episodes of temporary occupation occurred during periods when conditions were relatively humid (~17-14 ka) or when arid conditions with dune building were punctuated with short wet phases (~14-11 ka) (see Fitzsimmons *et al.* 2013). These were climatic interludes in which the shallow surface waterbodies filled and continued to hold water. At such times water would have been available across the southern inland of the continent, and it would have been possible to occupy what are now extremely arid areas. Given that these deglacial wet phases were probably more marked than at any time subsequently, at these times water may have been available for years to decades. Occupation occurred at times of apparent dune stability, with the archaeological material subsequently being buried and preserved when dune activity recommenced as the landscape dried with the return of arid conditions.

area coincided with a probable deterioration in the local climate, at a time when there was increasing climatic variability and drier conditions over much of Australia, indicative of 'ENSO in the El Niño mode' (Reeves *et al.*, 2013:29). Hughes and Hiscock (2005:17) noted that the ability of Aboriginal people to survive the overall decrease in rainfall in this landscape during the late Holocene reflected the development of a successful adaptive strategy, which emerged in recent millennia through a modification of earlier settlement strategies as climatic conditions worsened during the last 5 ka (see Hiscock, 2008:201-206 and Smith, 2013 for discussion of these adaptive strategies in the broader desert environment).

REVIVING GEOMORPHIC OBSERVATIONS THAT THE DUNES ARE OLD

Optical dates have now provided ages for the Australian dunefields (e.g. Gardner *et al.* 1987, Nanson *et al.* 1992), but four decades ago with no dating methods available Mabbutt (1977) and others suggested Pleistocene ages for the Australian continental dunefields on the basis of geomorphic process observations. To determine the formation processes of longitudinal dunes in the Simpson Desert, Mabbutt and Sullivan (1968) used a small transportable powered drill to auger into dunes to identify their silty or clayey cores. This demonstrated that for most dunes the indurated core rose above the level of the adjacent swales, but the technology was not adequate to determine whether the swale surfaces also rose beneath the dunes.

In the Roxby dunefield we have observed that the gibber surfaces commonly rise beneath dunes. Some surfaces on the extensive stony plains are incised over short sectors but most of the drainage lines are barely perceptible, occurring as linear zones of sandy to gravelly sediment. These plains have very low gradients, and their gibber surfaces are overwhelmingly flat and near-horizontal. Except where there has been major dissection, there are virtually no rises, no ridges, and certainly no pattern of parallel ridges on these surfaces, so the sandplains or dunefields overlie what are effectively smooth flat stony surfaces. These surfaces are sometimes exposed in deflation hollows along the crests of dunes, where they are commonly higher than in the adjacent swales.

Total station and differential GPS surveys undertaken at the salvaged sites show that many dune cores rest on gibber-mantled surfaces and that these (sometimes eroded) stony surfaces are consistently >1 m above the adjacent swale surfaces. LiDAR-based contour maps at 0.5 m interval for much of the study area indicate that this is widespread. The overlying dunes in zones of both closer and widely spaced patterns have apparently protected the underlying gibber plain from the slow fluvial lowering and aeolian deflation processes operating in the swales and plains. Cosmogenic dates have demonstrated that similar gibber surfaces to the northwest formed 2-4 million years ago (Fujioka *et al.* 2005). Given the negligible rates of erosion in these arid areas, this supports the conclusion that dunes have remained or re-formed along their current alignments for hundreds of millennia (cf. Fujioka *et al.* 2009 for the Simpson Desert).

PALAEOSOLS AND WATERTABLE LAYERS

In contrast to observations made in other dunefield studies of the presence of distinct palaeosols (e.g. Fitzsimmons *et al.*, 2007:2610; Fitzsimmons *et al.*, 2013:81), no definite palaeosols were observed in any of the excavations at Olympic Dam. With few exceptions the excavated sands were uniformly red, well-sorted, homogenous and loose to slightly firm and friable. Buried layers of artefacts and occasional concentrations of slightly granular or coarser sand in the dune profiles appear to mark stable or slightly deflated surfaces reflecting short, localised pauses in deposition.

At 3.5 m depth at H366 (Figure 5A) the excavation bottomed on slightly mottled, slightly sticky damp sand dated to between ~27 ka and ~30 ka and this was interpreted as a watertable layer. At H364 ~18 ka slightly mottled and cemented (hardpan) sand resting unconformably on highly weathered, mottled and indurated 116 ka sand (Figure 5A) similarly was interpreted as a watertable layer, as was the basal slightly weathered and indurated 12 ka sand at ODX_10390 (Table 2). At ODX_10478 the ~28 ka sand on which the ~14.5 ka buried artefact layer rests across the whole floor of the blowout is slightly weathered and weakly cemented to a depth of at least 0.5 m (Figure 5C). This layer may be a palaeosol formed at the surface of the dune at that time rather than a layer formed solely through fluctuating watertable conditions at depth in dune. Similar but undated weakly cemented layers were found at a few of the other excavated sites.

It should be borne in mind that water and the dissolved nuclides it might contain can have a significant effect on the environmental radiation dose rate and hence the calculated luminescence age. For the deeper samples, which may have been affected by a watertable that has fluctuated in the past, the dose rate measured at the time of sample collection may not be representative of the average dose rate throughout the burial period. Ages determined for these samples should thus be regarded with caution. For example, the anomalously low ages determined for samples H366 D1 and ODX10478 UAV126-12 with respect to their stratigraphic positions (Tables 1 and 2, Figure 5), may be due to the current dose rates being uncharacteristically high.

DID PEOPLE CAMP IN PRE-EXISTING BLOWOUTS?

The widespread existence of surfaces dating to ~12 ka which remain uncovered, or are covered only with thin veneers of late Holocene or modern sand, shows that the morphology of the dune surfaces has not changed greatly since that time. Many of the blowouts in which Holocene archaeological materials are concentrated have been in existence (in some cases as more shallow depressions) since that time. One such persistent blowout occurs at H364 and is indicated by the 12 ka surface in relation to the present surface (Figure 5A)

This resolved a question the team had long asked: did people camp preferentially in blowouts, or were archaeological materials (which are predominantly of mid to Holocene age) deposited on former higher surfaces, then exposed and concentrated by erosion when those surfaces were lowered to form blowouts during the Holocene? The archaeological investigations have shown that although Holocene artefact scatters occur on the surface of (and occasionally at shallow depths in) dune crests and flanks, the overwhelming majority of archaeological material occurs on the floors of blowouts. In the Holocene people did indeed camp preferentially in pre-existing blowouts, probably because of the shelter they provided from the wind, and this demonstrates that the present surface forms of many of the dunes had become established by the beginning of the Holocene.

DISCUSSION AND CONCLUSION

This study has extended our knowledge of the age and dune building history of the Australian continental dunefield to a previously poorly known part of the dunefields. Overall the history of dune formation in the Roxby dunefield accords with the patterns observed elsewhere in the southern and eastern parts of the arid zone. The detailed observations from excavations directed towards identifying and characterising the archaeological record have also provided detailed local histories of dune building and sand movement since the LGM.

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"SHAPE-ing up" – A summary of the Southern Hemisphere Westerly Winds workshop

NIWA, AUCKLAND, NEW ZEALAND, 28TH-29TH JANUARY 2014

Helen Bostock, Drew Lorrey and Steven Phipps

This is a short summary of the 2 day workshop. The longer version can be downloaded from the AQUA website SHAPE project page (http://aqua.org.au/?page_id=56).

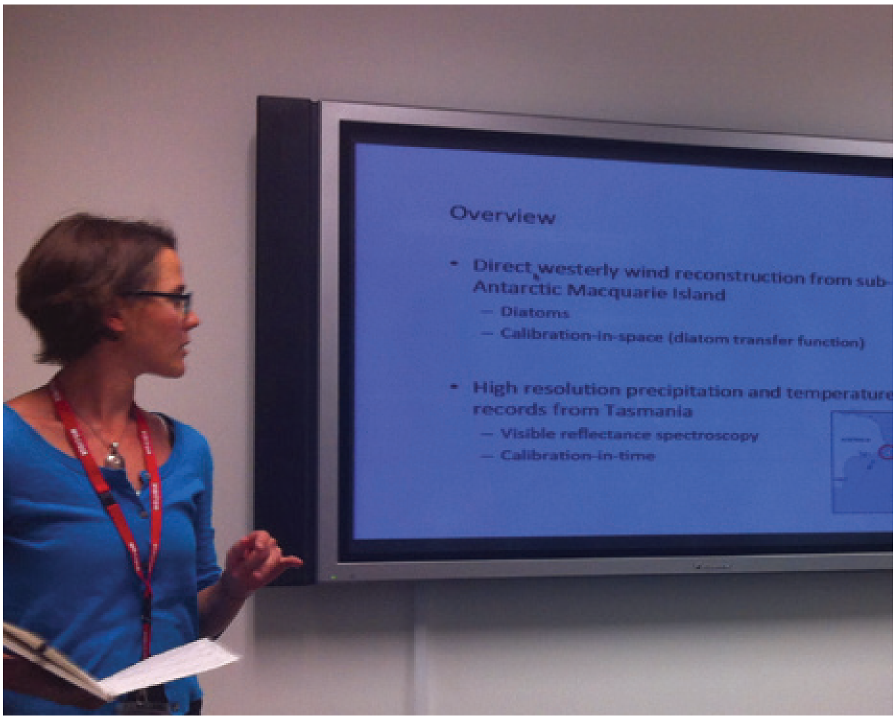
The primary aim of the workshop was to discuss Southern Hemisphere Westerly Winds (SHWW), and to develop several of the SHAPE deliverables that were discussed at the first SHAPE meeting in September 2013. It was also a good opportunity to check in with our SHAPE colleagues in South Africa and South America. A series of presentations were given on the first day of the meeting, including Helen Bostock talking about the Subtropical Front in the oceans around New Zealand and how changes in the front could be proxies for the strength and position of the SHWW. This was followed by a talk from Brian Chase (via Skype from Cape Town) about some work on developing climate records from Hyrax middens (piles of hyrax urine) in South Africa. These middens are sampled in a similar way to speleothems at a very high resolution, but can be analysed for a range of different proxies (stable isotopes, pollen, charcoal, phytoliths, ancient DNA). They have found that cooler periods are wetter, while warmer periods are dryer in this region and there is evidence for a Younger Dryas, rather than an Antarctic Cold Reversal. This suggests that there was a strong atmospheric teleconnnection between the Northern Hemisphere and South Africa during the Younger Dryas.

The focus of many of the talks was on potential precipitation proxies from lakes. Michael Shawn Fletcher reviewed some of the work that he was involved with determining precipitation from pollen data from South American lake cores and the implications for SHWW. He then showed some new records from Tasmania. Michael has been developing a pollen temperature calibration for Tasmania, but this has predicted a few suspiciously anomalous temperatures. They suggest this may be due to the fact that the vegetation has responded to changes in precipitation and fire (peak in charcoal), rather than temperature. Krystyna Saunders also discussed her work from Tasmania looking at a precipitation record for the last 2ka. She has also been involved in some ongoing work in the subantarctic examining lake sediments from Macquarie and Campbell Islands, which are directly influenced by the SHWW. A diatom-salinity transfer function is being used to look for changes in sea spray as a proxy for winds. This is part of a bigger project on the Subantarctic islands being led by Dominic Hodgson from the British Antarctic Survey. Marcus Vandergoes and Heidi Roop both showed data from New Zealand lakes, trying to understand changes in rainfall and evaporation, while Chris Moy presented work from South American lakes. These changes in lake level at a range of different lake sites are linked to rainfall and the position and strength of the SHWW.

Steven Phipps presented a suite of nine transient climate model simulations of the last 8ka, recently completed by the Palaeoclimate Modelling Intercomparison Project. All of the models show a long-term trend towards a more positive phase of the Southern Annular Mode (SAM). He highlighted a recent reconstruction led by Nerilie Abram and suggested the potential to extend her approach further back in time. Maisa Rojas (via Skype from Santiago) gave an overview of a recently funded 3 year multidisciplinary project to understand the link between SHWW and CO_2 over the last 25 ka in South America. The project will involve model outputs, marine cores, lake cores, glacier records and a wide range of proxies. Fabrice Lambert (via Skype) is also part of this project and will focus on dust. Andrew Lorrey demonstrated a new palaeoclimate research platform that has been, and continues to be, developed at NIWA – PICT (Past Interpretation of Climate Tool; pict.niwa.co.nz; Lorrey et al., 2013). One of the main outputs produced from PICT are Southern Hemisphere spatial fields for different climate variables (geopotential, SSTa, precipitation etc). In addition, sampling the multiproxy reconstructions to determine the role different climate drivers (ENSO, SAM, IOD etc) had on generating past changes at local, regional and hemispheric scales is possible. Calculators that determine the contributions to local climate anomalies from GHG changes, insolation, solar variability and volcanism are being added at present and are required for investigating the role atmospheric circulation had on past climate changes on interglacial-glacial time scales. An operational version of PICT that can incorporate Australia and South Africa proxy data is anticipated by the end of 2014.

The rest of the meeting was dedicated to a discussion about a couple of major projects for SHAPE including: the last glacial-Interglacial transition (LGIT) paper that is a promised deliverable to be submitted by 2015. This paper, being led by Michael Shawn Fletcher, will look at the timing of the climate variability and changes from the LGM to the onset of the Holocene and focus on the ecological changes, especially the succession of vegetation. The timing and changes are likely to be asynchronous in different regions, with the aim of testing some of the leads and lags to understand how these spatial patterns may reflect climate driver activity. Steven Phipps will be leading a model-proxy comparison of changes in the SHWW over the last 8 ka, using both PICT and global climate model transient runs. While Andrew Lorrey will be revisiting the New Zealand last 2 ka paper, in association with the PAGES Aus2K team, but using the PICT models to analyse the atmospheric circulation changes in this region. If you think you can contribute to any of these projects then get in touch with the leads listed above.

We are looking forward to seeing some of the preliminary results from these SHAPE projects at the upcoming AQUA conference in Mildura. Other future SHAPE meetings and workshops in 2014 and 2015 for your diary: a workshop on tools for multi-proxy reconstruction and climate modelling in Brisbane, July 2014 – come and learn about state-of-the-art tools for palaeoclimate research. A potential workshop in Chile in early 2015 and of course the INQUA meeting in Nagoya, Japan in July 2015.



TOP – Figure 1. Steven Phipps, leading the discussion, with Helen Bostock, Marcus Vandergoes, Michael Shawn Fletcher, Chris Moy.

BOTTOM – Figure 2. Krystyna Saunders giving a presentation about a record from Macquarie Island.

INQUA Early Career Researcher Meeting

2 – 6 DECEMBER 2013, UNIVERSITY OF WOLLONGONG, AUSTRALIA.

Claire Krause, Amy Prendergast

Claire Krause: Research School of Earth Sciences, The Australian National University, ACT, Australia, claire.krause@anu.edu.au

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During the first week of December, 2013, early career researchers from all over Australia, and from around the world, converged in the University of Wollongong for a week of seminars, workshops and networking.

Monday morning kicked off with a welcome to Wollongong and an introduction to INQUA and the Holocene by Craig Sloss, Colin Murray-Wallace and Alan Chivas. Students and academics from the university then showed us around the University of Wollongong's impressive laboratory facilities. I think we were all left salivating, thinking about all the new analyses we could do there (if only a PhD wasn't just three years!).

The workshops began in the afternoon, with lessons on various geochronological techniques, and helpful hints for oral and poster presentations. We then all headed down to the beach for a bbq and a chance to get to know each other better.

Tuesday morning provided an opportunity for delegates to show off their research in three minutes. It proved to be a huge success, with speakers summarising their studies and highlighting their results, giving us all a taste of the research interests of the group.

More workshops followed on geochemical techniques, before we all jumped on buses and headed out to ANSTO (Australian Nuclear Science and Technology Organisation) for a tour of their facilities. We were again left impressed at the calibre, and size of the facilities available there. Our highly qualified guides at ANSTO seemed to enjoy showing off their nuclear reactor (that can NOT be used to create weapons or power. Oh well...) and massive particle accelerators.

Tuesday night was the conference dinner, held at the Harbourfront Restaurant, down by the ocean, near the Wollongong Lighthouse. The night was heaps of fun, with great food, great views, great company and plenty of booze.

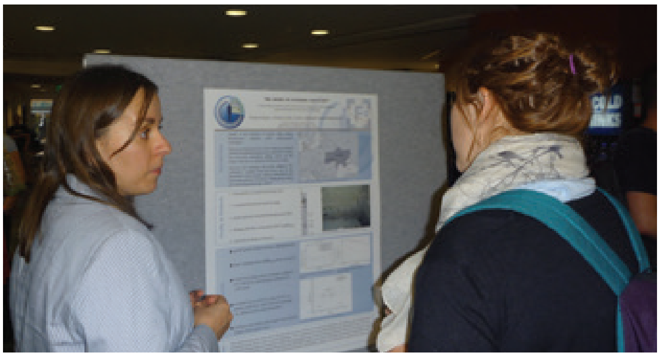
On Wednesday morning, we bravely nursed our hangovers from the night before, and set off for the mid-conference fieldtrip. We were treated to spectacular scenery along the Illawarra coastline, particularly at Sea Cliff Bridge. Throughout the day, our fearless leaders Craig Sloss and Brian Jones gave us an excellent overview of the Quaternary coastal evolution of the region, from lagoon formation to tsunami inundation, as well as a healthy dose of pre-Quaternary geology. We were also lucky enough to have many local experts show us their field sites. A highlight was the walk along the beautiful Thirroul beach to see a well-preserved last interglacial sequence.

Thursday morning began slowly, with introductions to various proxies used by palaeoclimatologists, before we split up into groups to have a go ourselves. Some were given the opportunity to attempt to find and identify various pollens, forams, ostracods, charophytes and diatoms under the microscope. This author quickly realised why she works on the macro-scale, being unable to spot diatoms until she was given one of the "cheat slides", and getting motion-sickness from prodding pollen. Others were taken step-by-step through the intricacies of OSL dating. It gave many of us a real appreciation for how much work goes into calculating a single OSL age!

Thursday afternoon saw the student presentations begin, with the first session on, "Global-scale climate forces". This session consisted of talks on palaeohydrology and monsoons from a range of proxies. The second oral session, titled, "Coasts, sea-level and oceans" saw more great talks on coastal processes and proxies.

Thursday evening was the poster session, where students were able to present posters of their work. The posters were a huge success, allowing great conversations between presenters and other conference attendees. This session was fully catered, which also helped to facilitate great discussions between people.

Friday morning promised to be a very useful session for any early career researcher: writing for publication and grant writing. We were lucky enough to have editor-in-chief of Quaternary Science Reviews, Colin Murray-Wallace, and editor-in-chief of Journal of Archaeological Science, Robin Torrence talk us through the dos and don'ts of journal articles. Following this, we were guided through grant writing by Jan-Hendrik May and



LEFT – RIGHT

Figure 1. Welcome reception. Photo credit: Steph Kermode

Figure 2. Discussing ideas at the poster session. Photo credit: Steph Kermode

Figure 3. Workshop on writing for publication, given by Colin Murray-Wallace. Photo credit: Akio Sato

Figure 4. Group photo taken on the fieldtrip. Photo credit: Adam Griggs

Figure 5. Ostracods and forams lab workshop. Photo credit: Steph Kermode

BOTTOM Figure 6. Conference dinner, held at the Harbourfront Restaurant, overlooking the ocean. Photo credit: Steph Kermode

Colin Woodroffe, who provided us with some very thorough tips and advice on how to prepare and submit a (hopefully) successful grant.

The final three student oral sessions were held on "Sedimentary and proxy records", and "Archaeology", as well as the much anticipated, "other". All sessions were very entertaining, with the speakers doing an excellent job of being both informative, and interesting. We heard about projects from all over the world, from Australia and New Zealand, to Kazakhstan, Russia, Greenland, Morocco and France.

Before we knew it, the meeting had drawn to a close and we were saying our goodbyes and promising to see each other again at the INQUA Congress in Japan in 2015.

A huge thankyou needs to go to the conference organisers, but especially to Steph Kermode and Craig Sloss, for their huge efforts in making the INQUA ECR meeting such a success!

2013 PAGES Ramsar Workshop, Victoria, Australia

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The Ramsar convention recognises and seeks to protect wetlands that have such conservation values they are of international significance. Given the unprecedented pressures wetlands face today, how can an understanding of the past help? And how can paleoecology develop to better assist other scientists and policy makers in addressing these issues? Held in November 2013 in Queenscliff, Victoria, the PAGES Ramsar Workshop focused on answering such questions, and the topical issue of detecting change in ecological character.

Ramsar refers both to the city in Iran, and the intergovernmental convention on the conservation and wise use of wetlands around the globe which was adopted in the same city, in 1971. Since then, 2,171 wetlands have been designated by the 168 contracting parties (a number not far off the 193 members of the United Nations itself). Despite the multiplicity of international treaties on the environment, wetlands are the only ecosystem for which such a degree of international protection exists.

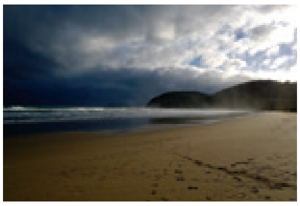
Notwithstanding the Convention's age, the struggle to define change in "ecological character" – and methodologies by which it can be measured – was a theme of the workshop. Ecological character is a nebulous concept, and is separate to the criteria under which wetlands qualify for listing under the Convention. But it is important, for any negative changes in ecological character as a result of direct anthropogenic influence must be reported to the Ramsar Secretariat. It forms the background against which changes in ecological character can be measured. Making assessing change in ecological character a theme of the workshop allowed joint exploration by paleoecologists and ecologists on how the issue might be addressed.

Chief conference organiser and professor at Federation University, Peter Gell, and Deputy Secretary General of the Ramsar Convention, Nick Davidson, opened the workshop with an introduction to respectively the PAGES programme (for the 'neoecologists'), and the Ramsar Convention. They outlined current issues around implementation of the convention (for those whose work is more paleo-focused). Dr Davidson also covered the programme of work being undertaken by the Convention's Science and Technical Review Panel, which is to be informed by the workshop.

Ecological character is assessed as a snapshot, current at the time taken. How then does paeleoecology affect such assessments? It can inform the limits of acceptable change (Rhonda Butcher); it can provide context to the 'generational amnesia' which can affect the perspective of ecological character assessments being undertaken now (for example – Gippsland Lakes: Paul Boon); and it can help managers distinguish negative changes in ecological character of natural causation from human-induced changes, by referencing the changes that have occurred in the past.

Presentations at the workshop made it clear that such assessments are happening none too soon, either. In China, combining multiple data sets using fuzzy methods has revealed that while 20 years ago there were some 50,000 rivers, 28,000 have since been 'lost' (Junguo Liu). Recent degradation (1984 – present) has been revealed through a combination of satellite data, social information and GIS methodologies in the Niger delta, with corresponding implications for the communities reliant on the area (Ayansina Ayanlade). Over the past 50 years, reviews of document and monitoring records revealed that 86% of the lower Yangtze lakes became eutrophic since the 1950s (Xuhui Dong); India lost 50% of wetlands in 20 years and scores 0.5/10 on preparedness for climate change according to the IPCC (Shadananan Nair); and that more than 50% of wetlands have been lost in the North African Mediterranean region since the early 20th century (Roger Flower).

Presentations demonstrated that paleoecological methods can inform forward looking management in a number of ways: by investigating the reasons behind previous cyanobacterial blooms to understand the drivers of recent ones (Cook et al); to provide historical context to current levels of pollutants in sensitive areas and their potential to affect co-located biota (Stephanie Kermode); to better understand the effects of hydrological modification (Stewart Clarke), particularly in remote sites like those in the North African Mediterranean region where monitoring data are often absent (Roger Flower). Xuhui Dong's presentation noted that palaeolimnological analysis of 10 sample lakes revealed significant ecological shifts concentrated mainly in the past 60 years, and that altered hydrological regimes had shown to be a key driver.



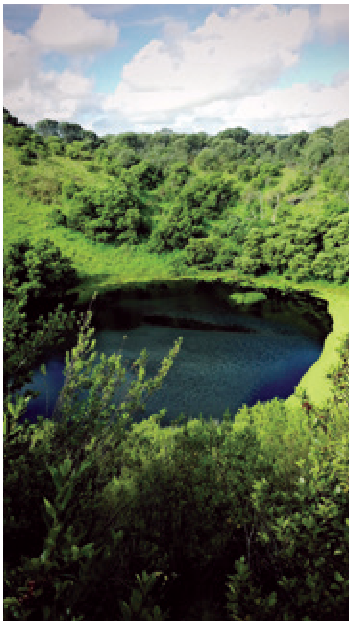


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Figure 1. The view from the workshop venue – Vue Grande, Queenscliff

Figure 2. The beach at the beginning of the Great Ocean Road

Figure 3. The inaptly named but majestic Twelve Apostles

Figure 4. Adventures in fieldwork: Tower Hill Wildlife reserve

"Ecosystem services'" is a term which values ecosystems according to the benefits provided to humans. Discussion arose over whether the concept of ecological character can accommodate anthropogenic values. Notably, the Convention itself has the mission of furthering "sustainable development" of wetland ecosystems; 2014 is the year of "Wetlands and Agriculture". Pierre Horwitz and others raised issues of integrating human use with Ramsar wetlands in their presentations to the workshop. Dr Davidson provided some clarity to the issue by noting that there is a difference between the qualities which make a wetland significant in a national, regional or local setting and the prescribed criteria for international importance. The issue is less contentious where valued ecosystem services require and contribute to a healthy wetland ecosystem.

The workshop was held at the Vue Grande, Queenscliff, and commenced (unofficially) with the great cultural spectacle of the running of the Melbourne Cup at a local pub, and (officially) at a roof-top icebreaker, with views of the Ramsar wetland site that neighbours Queenscliff. Accommodation on-site allowed attendees to continue interactions after the formal programme concluded each day.

The mid-conference fieldtrip took in Port Phillip Bay (Western Shoreline) and the Bellarine Peninsula Ramsar site. For a resident of Christchurch (NZ) where water is sourced untreated from aquifers as the primary residential, industrial and agricultural source, the inclusion of the new waste water facility was quite something. It recycles waste water for Class C uses – irrigation and agricultural, but also Class A – watering gardens, washing cars and irrigating public spaces in new, 'eco-friendly' subdivisions. All this recycled water is diverted from its old destination – an ocean outfall pipe. Meanwhile, Reedy Lake illustrated a management conundrum. Management changes and anthropogenic influence have caused rapid change in the lake, most recently to a high reed cover. Stakeholder interests of hunting, commercial and recreational fishing, passive recreation, research and conservation mean whether more or less active management is taken at the site, not all stakeholders will be satisfied. In addition to being thought provoking the trip provided beautiful views of the coastal and wetland areas. The same day formal dinner was a culinary and entertainment delight and included presentations from Donna Smithyman (Corangamite CMA) and Neville Rosengren (La Trobe University). Dining and conversation went until late, and were followed by nightcaps in the Vue Grande's lounge area.

The final day was one of collaboration, as we split into working groups to discuss how paleo-records of past change might be used under Ramsar and support current requirements. The diversity of presentations given previously in the workshop stimulated plenty of discussion. The groups then returned to create a combined report, which will inform further guidance by Ramsar's Science and Technical Review Panel.

The optional post-conference fieldtrip was a truly international affair, with some 12 nationalities from 15 participants. Highlights included the Great Ocean Rd and its Twelve Apostles, Peter Gell raconteuring fieldwork escapades (and research findings) at Tower Hill, a rainforest walk, and watching Lathams Snipe at the threatened Powling St wetlands, Port Fairy.

Above all, the highlight of the workshop was exploring the synergies which can arise when paleoecological work is integrated into wetland management. The real test will be to keep up such momentum in the face of the challenges that will continue to arise in the future. On a personal note, I absolutely enjoyed meeting, discussing and learning from such bright lights (both current and future) in the fields of both paleoecology and wetland ecology, and left with the knowledge Ramsar wetlands are in as safer hands as possible. Congratulations to the PAGES organising committee (led by Peter Gell) for organising such a stimulating, cohesive and smooth-running workshop.

The author is particularly grateful to Federation University (Australia) and the Department of Conservation (NewZealand) for supporting her attendance at the workshop.

Field Report: Post-bushfire coring of the Temperate Highland Peat Swamps on Sandstone (THPSS) in the Blue Mountains, NSW, December 2013

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INTRODUCTION

The Blue Mountains region, around 80 km west of Sydney, preserves a variety of unique landscapes and ecological communities in a series of National Parks which are collectively listed as the Blue Mountains World Heritage Area. This World Heritage Area also contains a series of mires which are depositional environments that appear to preserve relatively long palaeoenvironmental records. These mires have been recognised as ecologically important, for example, Temperate Highland Peat Swamps on Sandstone, is an Endangered Ecological Community listed under the Environment Protection and Biodiversity Conservation Act 1999 and a Vulnerable Ecological Community under the NSW Threatened Species Conservation (TSC) Act 1995. In the Sydney Basin Bioregion this protection under the TSC Act 1999 also extends to the Blue Mountains Swamps and Newnes Plateau Shrub Swamp both Endangered Ecological Communities, and these all share characteristics with Coastal Upland Swamps in the Sydney Basin Bioregion an Endangered Ecological Community declared in 2012, which occurs at lower elevations.

The Temperate Highland Peat Swamps on Sandstone (THPSS) Research Group was set up to focus on increasing the understanding of these unique environments and in recognition of increasing threats to these ecological communities. Within the group, a diverse array of researchers are focusing on flora, fauna, hydrology, fire ecology, mining impacts. My research with the THPSS is focused on the palaeoenvironmental record contained in these swamps. Due to the arid conditions during the LGM, it is likely that most swamps established and expanded during the postglacial period. Establishing the age of initiation itself is an indication of climatic amelioration, and once formed these swamps are sensitive to environmental change such as the establishment and functioning of El Nino-Southern Oscillation.

Large bushfires that occurred across the Sydney region and NSW in October 2013 affected much of the THPSS research. These fires were prominent in the media and attracted international interest: our dear leader dismissed any link to anthropogenic climate change “Australia has had fires and floods since the beginning of time” (The Washington Times, 2013), and the Federal Environment Minister famously used Wikipedia to dismiss climate-bushfire links (The Guardian, 2013)! While these fires represented a real and severe threat to lives and property (more than 300 homes were destroyed or damaged), the resultant significant reduction in vegetation presented an opportunity for access to more remote sites in the World Heritage Area.

The Blue Mountains present a unique set of environmental factors that facilitate the presence of mires and the accumulation of organic-rich sediments. The accumulation of peat is perhaps more commonly associated with cool and humid climates, with the majority located in higher latitudes and 90% of the global extent located in the Northern Hemisphere (Whinam et al., 2003). Peatlands form when precipitation or available moisture exceeds evapotranspiration, leading to waterlogging (Wust et al., 2008). In the Blue Mountains, a combination of high altitude (up to 1100 m), relatively high rainfall (partly due to the orographic effect of the Great Dividing Range) and a sandstone lithology with relatively horizontal strata interspersed with claystone and shale members facilitates the development of swamps and anoxic conditions that preserve organic-rich sediments through time. Many of the major peat forming environments of the world, such as the high latitudes of the Northern Hemisphere experience much more stable environments, while the climate of eastern Australia is much more variable, especially in terms of moisture balance.

It should be emphasised that the Northern Hemisphere literature often classifies peat-forming environments using criteria that are impractical to apply in the Australian context (e.g. fens versus bogs) (Hope et al., 2009). Here, the broader term mire (or locally swamps) is used in a broader sense.

The sandstone swamps of the Sydney Basin have been host to an array of previous palaeoenvironmental research. Perhaps most relevant, Chalson (1991) examined a series of swamps across an altitudinal gradient, and used palynological indicators and charcoal data to show increased moisture availability, wooded vegetation and fire in the early Holocene, with these variables declining in the mid Holocene before recovering to present levels at about 3-4 Ka. Palaeoenvironmental proxies were also used by Black et al. (2007, 2008) at Goochs Swamp, to suggest higher fire activity in the early and late Holocene, with lower charcoal concentrations between 10 and 6 Ka, broadly similar to the results of Chalson (1991). When considering pre-Holocene environmental change, the number or records available diminishes, partly due to increased dryness in SE Australia during the late Pleistocene and Last Glacial Maximum, as determined by increased dust flux (Turney et al., 2006). Geomorphological evidence suggesting a period of dryness after the LGM in the region: Hesse et al.'s (2003) OSL dating of sand dunes from the Newnes Plateau suggests widespread aeolian activity between ~30 Ka and 12 Ka, perhaps indicative of a treeless landscape at the time (Benson and Baird, 2012).

OCTOBER 2013 FIRES

The month of September 2013 was reported by the Bureau of Meteorology as being the warmest on record across the continent, while average rainfall was maintained across most stations (Bureau of Meteorology, 2013) and was preceded by a wet autumn and mild winter that saw high fuel production in the lead up to spring. At the end of September, the BoM issued the forecast for the remainder of 2013 which estimated that maximum temperature will exceed the long-term median maximum temperature across most of SE Australia.

Following the forecast, early September brought above average temperatures across coastal NSW, with temperatures around 35°C in Sydney, the Blue Mountains and Newcastle, which combined with dry winds from the north-west from 20 to 50 km/h to elevate the fire danger rating to Extreme by the 10th of October (NSW Rural Fire Service, 2013). On the week starting Monday 14th of October, several fires ignited across the state, with many in the Blue Mountains region directly threatening property. By Thursday the 17th, the State Mine and Winmalee fires were intensifying and advancing in front of strong North-Westerly winds (Figure 1), with the State Mine fire front near Lithgow travelling 25 km on this day alone, while 193 homes were destroyed by the Winmalee/ Springwood fire.

By the weekend a State of Emergency was declared, while conditions had eased slightly allowing significant backburning to be undertaken near residential areas, ahead of forecast conditions deteriorating for the week, with Wednesday 23rd predicted to be the worst day. Less severe conditions, the presence of a large firefighting force

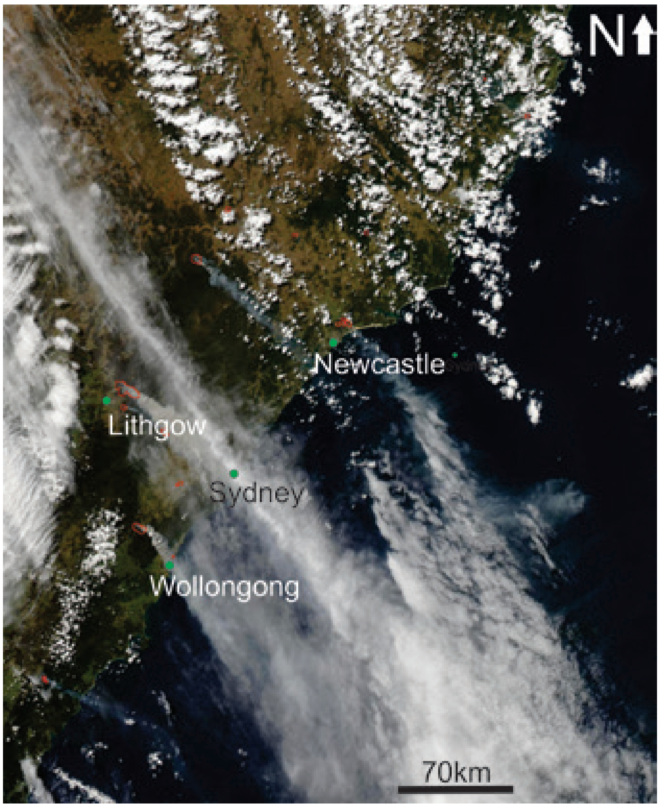

Figure 1. Image of the Sydney region on the 17 October 2013, showing fire locations (red) and wind direction from the North-West at the time. Taken by MODIS aboard the AQUA satellite (http://modis.gsfc.nasa.gov/gallery/).

and considerable back burning led to less damage than was originally predicted. Conditions began to improve after the 23rd, with fires across the state and along this large urban/bushland boundary gradually brought under control and extinguished. This series of events received international coverage, with the head of Climate Negotiations at the UN stating "the science is absolutely clear… heat waves and fires are increasing in their intensity and frequency", only to have the Prime Minister, Tony Abbott counter that "the official in question is talking through her hat" (Sydney Morning Herald, 2013).

GOOCHS CRATER (33°27'17.43"S, 150°16'0.98"E, 960M)

We had originally planned field work for October but the bushfires and closure of the park cancelled those trips, and mid-December was the next chance for fieldwork. While the fires interrupted these plans, they also presented two opportunities: firstly, to directly examine how the Goochs Crater catchment and swamp itself respond to fire events and establish a reference point to gauge post-fire recovery, and secondly to explore previously undocumented sites towards the interior of the Wollemi Wilderness that are further from sources of anthropogenic disturbance.

Our first destination was Goochs Crater where 4WD (fire-trail) access stops at a ridge line 2km to the north of the site, so from here it was a walk south along the spur towards Goochs Crater, which is just inside the Blue Mountains National Park (Figure 2). Our drive and walk in the landscape was very different from previous trips, with almost no unburnt vegetation remaining, although many plants were vigorously resprouting from epicormic buds (only 6 weeks after the fires!).

Goochs Crater was named after Nicholas Gooch, a local bushwalker who 'discovered' the site in 1978, to commemorate his death in 2003, hence the spelling, and the apostrophe is dropped by convention of the Geographical Names Board of NSW. The site, while more a natural amphitheatre rather than a true crater, is an interesting and relatively unique landform. It appears to have formed as a stream on the southern edge of the Newnes Plateau, gradually incised a steep-sided valley, almost a canyon, before flowing out into the Wollangambe River a few hundred metres downstream. At some point after formation, it appears that a large rock fall occurred approximately 200 metres downstream of the watershed, forming a natural dam wall (seen as the far side of July and December pictures in Figure 3) and leading to permanent or semi-permanent accumulation of water behind the wall. Over time, these moist conditions have resulted in the accumulation of peaty sediments, associated with a shallow lake and/or swamp. Floristically, rushes thrive in the semi-permanent surface water of the swamp, a point of difference between this site and other swamps in the region.

While the presence of a peat swamp suggests some hydrological stability, the site does experience marked

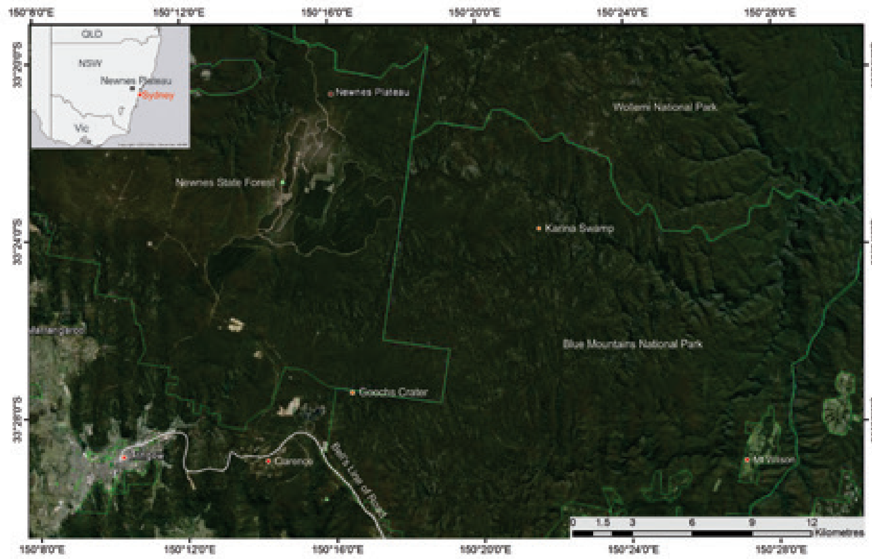

Figure 2. Overview map of the Newness Plateau, showing National Parks and State Forest boundaries in green and the two sites mentioned in text.

Figure 3. Goochs Crater during 2013, going from flooded with 1.5m of water in March, moving towards the more usual wet surface covered by rushes in July, followed by the entire swamp surface and surrounds burnt in the October bushfires, and showing the rapid recovery of swamp surface vegetation. March photo: Albert Chetcuti, October photo: Roger Lembit.

fluctuations in water table. It appears that the usual water level is at about 50cm, although the site can contain up to ~2m of water (Figure 3), before the dam wall is overtopped. The site has also burnt previously, the last time in 1997, although the impact of the Oct. 2013 fire might have been less severe this time as the site was quite wet and regrowth appeared to be occurring rapidly.

From a geomorphological and palaeoenvironmental perspective, the site is interesting due to the very small catchment and the rock-dam that means it is a closed sediment basin. The wetland surface is also flat meaning the sediments accumulating within the crater are unlikely to have experienced erosion, sediment re-working or avulsions, providing a faithful record of the past. The edge of the site is also sensitive to wetting and drying, as well as recording influxes of charcoal and sediment, particularly if rainfall occurs before vegetation can restabilise the steep slopes of the small catchment. To date I have retrieved three cores from the site and 14C dating suggests a record spanning at least since the start of the Holocene (11,700 Cal. BP.) with relatively high accumulation rates of 0.9-1.0 mm/yr.

This work aims to use geochemical proxies and the sedimentary characteristics of the Goochs Crater record primarily to derive a high-resolution, well dated record of Holocene moisture availability. The palaeoenvironmental record from Goochs Crater is being supplemented with similar records from the southern highlands and potentially a lower altitude site within the Blue Mountains, with results aiming at differentiating between site specific and regional scales of environmental change.

We had seen photos of Goochs crater from the week after the bushfires (October 2013 in Figure 3), so we were surprised to see a patch of bright green in a scorched landscape when we arrived on the ridge overlooking the wetland. After a series of probing transects we started coring using a 50cm D-section corer (Jowsey, 1966), and after a few hours work in the December sun, recovered a 7.95m core. The upper 1-2m was fibrous and difficult to core, but from 2-7m the sediments were easier to core and well consolidated. Below 7m there we encountered a transition to first clay and then sandy clays (Figure 4), which eventually halted coring at 7.95m. Coring to this depth, accounting for 5 cm overlap between each core section meant we had 18 core sections, plus equipment, to carry out.

On previous trips following the ridge line into the site was relatively easy; bushwalkers over the years have left a slight trail and lots of bare rocky patches make for easy progress, but the last 200m used to pass through dense heath and then into exceptionally thick scrub on the slopes of the crater. This time, however, the denser vegetation had fared worse in the fire and was almost completely consumed, except for the larger trees, which made moving about substantially easier, especially on the outbound trip with the core sections. The lack of vegetation and hence shade and the black colour of everything increased the already warm summer heat, luckily it was only 2km uphill to the car.

KARINA SWAMP (33°23'16.26"S, 150°21'20.54"E, 820M)

While there are a multitude of fire trails on the Newnes State Forest on the periphery of the Wollemi Wilderness, all access towards the east, into the high relief and incised valleys that attracts so many canyoners to the area (and protects the location of the Wollemi Pine!), is on foot. Following our second aim of exploring remote and well preserved sites, we had identified a swamp from aerial photos at similar elevation to Goochs Crater, although on the eastern edge of the plateau.

In this landscape what might look like a short distance as the crow flies usually requires a circuitous route to avoid deep valleys, abseiling and climbing equipment! The ridgelines are also easier routes: they are drier and in

Figure 4. The coring procedure at Goochs Crater, as well as the 545-595cm core section showing transitional sediments from dark, organic peat to clay/sand below.

Figure 5. An elevated view of Karina Swamp, looking SSW, showing the abrupt transition between the rapidly regenerating swamp and the surrounding, drier vegetation, with two people for scale in the centre of the image.

some cases have sparser vegetation. So, as we set out for an un-named swamp about 7 km east of the edge of the Newnes State Forest and 4.5 km from the end of the nearest road, our planned route looked like 18km return, with a full coring kit, food and 12L of water shared out amongst four. As we followed specific ridges, spurs and saddles we dropped around 200m, and eventually dropped down into the swamp we had aimed for (Figure 5).

The Swamp itself was narrow and ran adjacent to a rocky wall on the eastern side, a characteristic that we have found is often associated with deeper sediment profiles in sandstone swamps, and the swamp was named Karina Swamp after one of our troop whose birthday was being spent in the field. The upper sections of the swamp were very shallow and quite minerogenic, while further downstream the gradient decreased and the sediments became deeper and much more organic, with fewer sandy layers. Further downstream, a distinct streamline had formed and possibly due to the exposed peat surfaces had eroded a channel with pools 1m wide and 1.5m deep. In the middle-lower section of the swamp there were also a series of peat ridges (strings) and hollows (flarks) (Figure 6), arranged perpendicular to the slope/flow of the water. Such patterned mires are more often associated with higher latitude, ombrotropic bogs (Couwenberg and Joosten, 2005; Swanson and Grigal, 1988), and to our knowledge have not been documented on the Australian mainland before. At Karina Swamp the strings were up to 15 cm above the water line and the flarks were water-filled and about an equivalent depth, making the entire structures relatively large!

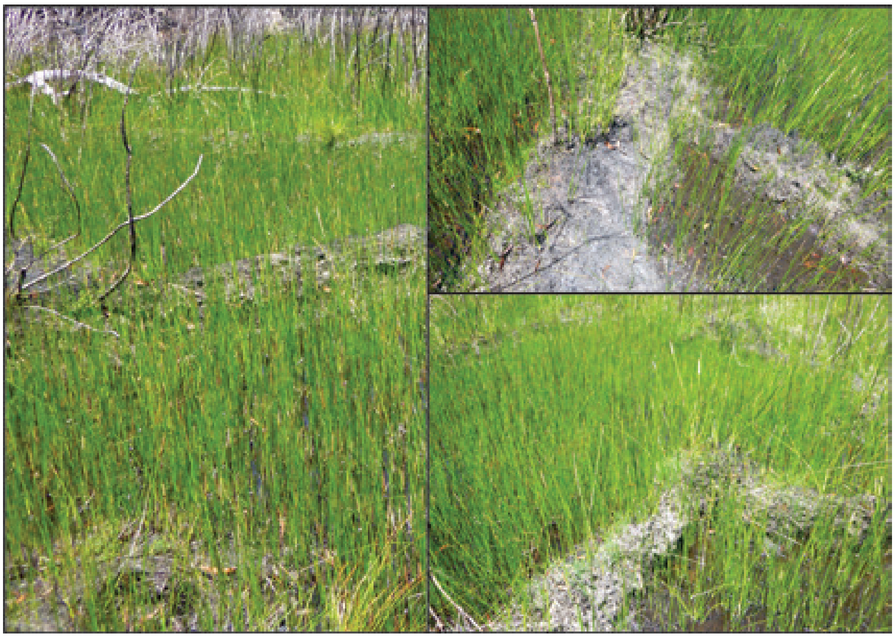

Figure 6. String and Flarks seen on the surface of Karina Swamp after the October 2013 bushfires in the Blue Mountains. These features are unusual for a wetland of this type, especially on the Australian Mainland.

Following a similar strategy of probing transects we selected a location to core from, and extracted a 2.75m core. The familiar sandy/clayey basal sediments were thicker at Karina Swamp however, possibly a function of the larger catchment delivering more sediments before a swamp formed. After wrapping and securing the cores for the walk out, we started the uphill walk out with the extra weight of the cores.

CONCLUSION

The Blue Mountains is an incredibly diverse landscape with dry, heath-topped ridges giving way to swamps and rainforests in the valleys and canyons. The secrets locked in the sediments of the swamps in the region have only just started to be fully appreciated. A chronology for the cores retrieved from Goochs Crater and Karina Swamp in December 2013 is being developed as a framework for further analysis. Continued refinement and development of proxies used to expand our knowledge of long term environmental change are required to better understand the impacts and responses of this World Heritage Area.

ACKNOWLEDGMENTS

Albert Chetcuti and Roger Lembit kindly contributed photos of Goochs Crater. Scott Mooney, Karina Judd, Tyler King and Natalia Brennan provided assistance in the field. Aspects of this work have benefited from discussion with Doug Benson, Geoff Hope, Sarsha Gorissen, Roger Good, Martin Krogh, and Jennie Whinam. This work was supported by a grant from the ANU/ Temperate Highland Peat Swamps on Sandstone Research Program Joint Venture to Scott Mooney, James Goff, Catherine Chague-Goff and Giri Kattel. The Goochs Crater sediments are being dated under a 2014 AINSE Research Award (ALNGRA14019).

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ARC results

Congratulations to the latest recipients of the recently announced Discovery Projects, Future Fellowships and LIEF awards. Here is a summary of those projects related to Quaternary research, including archaeology.

DISCOVERY PROJECTS

THE AUSTRALIAN NATIONAL UNIVERSITY

DP140102059: Abram, Dr Nerilie J; Mulvaney, Dr Robert; Curran, Dr Mark; Treble, Dr Pauline C

Project Summary:

Water resource management is one of the greatest challenges facing sustainable agriculture and urban populations across southern Australia. Key players driving catastrophic droughts in southern Australia are the tropical Indian Ocean Dipole and polar Southern Annual Mode climate systems, which affect moisture availability and transport pathways. This collaborative research project draws together a uniquely-skilled research team to develop targeted coral, ice and cave reconstructions of these climate systems and their impacts on Australian rainfall through the last millennium. This fundamental new knowledge of the drivers of Australian rainfall variability will aid improved predictability of future changes in our valuable water resources.

Total: $480,000.00; Physical Geography and Environmental Geoscience

DP140103591: Haberle, Prof Simon G; Kershaw, Em/Prof Arnold P; Connor, Dr Simon E; van der Kaars, Dr Willem A; Perry, A/Prof George L

Project Summary:

How have interactions between climatic change, human activities and other disturbances over thousands of years shaped the landscapes we know today in Australia? Existing lines of evidence from palaeoecological and archaeological sources point to significant changes to biodiversity, vegetation cover, and fire frequency since the arrival of people into Australia sometime between 50000 to 40000 yr BP. The extent to which humans influenced or overrode natural processes through time remains unclear. High-resolution, multi-proxy data in an innovative vegetation and megafaunal reconstruction will provide the first quantitative assessment of the response of Australian tropical savannas to a range of natural and anthropogenic influences.

Total: $365,000.00; Physical Geography and Environmental Geoscience

DP140101393: Yu, Dr Jimin; Elderfield, Prof Henry

Project Summary:

The history of ocean circulation at the intermediate water depth remains controversial, limiting our understanding of the interplay of ocean circulation, climate changes, and the global carbon cycle. This project aims to generate trace elemental and isotopic records for 10 key locations in the Atlantic Ocean, which constrain physicochemical properties of water masses at unprecedented temporal resolution during the last glacial maximum and the subsequent deglaciation. This multi-proxy approach will reconcile controversy and pin down the evolution of mid-depth Atlantic circulation in the past, and thereby substantially improve our understanding of the climate system.

Total: $303,000.00; Physical Geography and Environmental Geoscience

DP140100384: Bellwood, Prof Peter S; Hung, Dr Hsiao-chun; Piper, Dr Philip J

Project Summary:

The Southeast Asian Neolithic (2500 to 500 BC) was a time of powerful linguistic and biological expansion, especially amongst those early agricultural societies that surrounded the South China Sea. This project will concentrate on: reconstructing the landscapes of Neolithic settlement, greatly different from the vast lowland alluvial landscapes that feed such concentrated populations today; reconstructing the economy of Neolithic food production, especially the archaeological histories of the major crops and domestic animals; and, reconstructing and comparing the material culture of the initial Neolithic, with its immense network of population expansion involving China, Southeast Asia and Oceania.

Total: $401,320.00; Archaeology

GRIFFITH UNIVERSITY

DP140101405: Lambert, Prof David M; Westaway, Dr Michael C; Willerslev, Prof Eske; Matisoo-Smith, Prof Elizabeth (Lisa) A; Millar, Dr Craig D

Project Summary:

The earliest known inhabitants of Australia lived more than 42,000 years ago on the shores of Lake Mungo. This project will present data that show it is feasible to recover complete genomes of some early Australians, in addition to the sex and mitochondrial genomes of others. These data will provide a new understanding of the robust and gracile morphologies of these people, as well as the dispersal patterns of modern humans out of Africa.

Ideas about Australia's First People have been central to the development of theories about the origin of modern humans generally, and therefore this study will be of international significance.

Total: $394,717.00; Anthropology

LA TROBE UNIVERSITY

DP140101049: Edwards, Dr Phillip C; Shewan, Dr Louise G; Webb, Dr John A

Project Summary:

This project will advance theories on early sedentism by investigating Wadi Hammeh 27 in Jordan, settled by Natufian hunter-gatherers at 12,500 BC. This site is claimed as a pre-agrarian, sedentary village but archaeological indicators of sedentism remain ambiguous. This project will resolve the issue by applying new technologies to human skeletal remains from the site to establish the length and frequency of residential occupations. Wadi Hammeh 27 also exemplifies trends towards the dispersal of Natufian social interactions. They will be investigated by tracing the exchange of artefacts and materials between Wadi Hammeh 27 and small, seasonal Natufian sites because these links underlie theories about the advent of agriculture and settled life.

Total: $333,363.00; Archaeology

THE UNIVERSITY OF NEWCASTLE

DP140102659: Wroe, A/Prof Stephen W; Fiorenza, Dr Luca; Parr, Dr William C

Project Summary:

Perhaps no other extinct species has excited scientific or popular imagination as has our closest cousin, the Neanderthal. Who were these people? Once presented as the archetypal brute, it is now increasingly clear that these powerful, large brained humans were capable of sophisticated behaviours and that most of us carry Neanderthal DNA. Yet many questions remain. One of the most persistent is why the distinctive drawn out, prognathous face? The project will address this question, applying and developing recent advances the applicants have made in digital reconstruction and modelling, maintaining Australian research at the leading edge in the fast growing fields of virtual reconstruction and comparative biomechanics.

Total: $339,204.00; Archaeology

THE UNIVERSITY OF NEW ENGLAND

DP140103194: Grave, A/Prof Peter R; Stark, Prof Miriam; Kealhofer, Prof Lisa K; Darith, Dr Ea

Project Summary:

Khmer rulers based at Angkor (9th to 15th century CE) competed to control one of the largest and longest-lived of the pre modern agrarian polities of mainland Southeast Asia. Best known for the monuments, hydraulic works and transportation systems around its urban core, the political and economic control Angkorian elite exerted over the broader Khmer territory remains poorly understood. Through a program of provenancing and dating of Khmer stoneware and kilns (scaled to match the geo-political issues involved) this project will produce the first rigorous spatial, chronologically controlled reconstruction of wider core-hinterland relationships.

Total: $536,558.00; Archaeology

SOUTHERN CROSS UNIVERSITY

DP140100919: Joannes-Boyau, Dr Renaud; Scheffers, A/Prof Anja M

Project Summary:

Knowledge of the timing and distribution of the human lineage is critical for developing and testing evolutionary hypotheses. Unfortunately, many existing chronologies are based on the dating of materials thought to be stratigraphically associated with the fossil, rather than the fossil itself. Significant, recent advances in dating methods allow for the accurate non-destructive direct dating of human remains. This project offers to establish a reliable and consistent chronology for modern human occurrences. This proposal is significant in addressing fundamental problems in our understanding of modern human expansion, by the application of newly-developed techniques that will allow for the reliable direct dating of key modern human fossils.

Total: $121,059.00; Archaeology

JAMES COOK UNIVERSITY

DP140104282: Dirks, Prof Paul H; Roberts, Dr Eric M; Spandler, Dr Carl; Berger, Prof Lee R; Blenkinsop, Prof Thomas G; Jinnah, Dr Zubair A

Project Summary:

In August 2008 the remarkable Malapa fossil site was discovered with remains of the first and only fossils of Australopithecus sediba, a potential direct human ancestor. The fossils are in an exceptional state of preservation, and excavations will start in late 2013, creating a unique opportunity to develop a detailed understanding of the chemical, physical and biological factors that led to burial and fossilisation. This research will focus on the complex interplay between termites, sediment chemistry, landscape conditions and palaeo-climate as contributing factors to fossil preservation. The results will document the environment in which sediba lived and died, and assist future exploration for hominid fossils.

Total: $256,000.00; Geology

DP140101319: Bird, Prof Michael I; Zhou, A/Prof Bin

Project Summary:

This study will use newly developed and fully validated isotope techniques to obtain robustly dated proxy records of vegetation change from the thick deposits of cave guano that occur extensively throughout island Southeast Asia (Sundaland). This project will test the hypothesis that during the Last Glacial Period, there was a substantial contraction of the rainforest towards the equator into refugia. This led to the development of an open 'savannah corridor' connecting savanna north and south of the equator. The project will shed new light on the palaeoclimatology of the region and provide a major contribution to explaining modern biogeographic patterns across Sundaland, as well as the trajectories of early human dispersal through the region.

Total: $306,666.00; Physical Geography and Environmental Geoscience

THE UNIVERSITY OF ADELAIDE

DP140104233: Cooper, Prof Alan; Taylor, Prof Jeremy F; Higham, Prof Thomas F; Orlando, A/Prof Ludovic; Reich, Prof David

Project Summary:

This project will use ancient DNA from permafrost-preserved Steppe bison bones and bovid exome capture systems to build a detailed record of the genomic impacts of rapid climate and environmental change at the end of the Pleistocene (30 to 11 kyr). The project will analyse how ancestral genetic diversity is distributed amongst surviving bison populations, and the role of nuclear loci under selection and drift. It will create a novel temporal dataset of genomic adaptation and evolution, and will generate critical data for studies of evolutionary processes such as extinctions, speciation and conservation biology and management.

Total: $450,000.00; Genetics

DP140103650: Donnellan, Prof Stephen C; Piper, Dr Philip J; Aplin, Dr Kenneth P

Project Summary:

The emergence of agriculture, a key transformational event in human history, seems to have occurred significantly later in island SE Asia than surrounding regions. However, the early stages of agriculture may be archaeologically 'invisible' in the tropics due to simple material culture and housing. This project proposes to use the recent evolutionary history of agricultural rodent pests, all of which emerged in situ from among a native rodent fauna, as a proxy for the origins and spread of agriculture, and its subsequent intensification. This project will use phylogeography and population genetics to infer the history of contemporary rodent populations, combined with archaeozoological and ancient DNA analyses of prehistoric samples to test our inferences.

Total: $465,960.00; Archaeology

UNIVERSITY OF WOLLONGONG

DP140100354: Dosseto, Dr Anthony; Chivas, Prof Allan R; Vigier, Dr Nathalie; Lemarchand, Dr Damien

Project Summary:

The abundance and distribution of Earth's water and soil resources are strongly influenced by the spatial and temporal variability of climatic parameters. Thus, there is a need to understand how climate change, whether of natural causes or induced by human activity, impacts fluvial and soil systems. This project will use novel isotopic techniques to study the links between climate variability, chemical weathering, which produces soil, and sediment transport, which affects fluvial systems and water resources. The composition of stable lithium, boron and calcium isotopes, and of radioactive uranium-series isotopes in sedimentary records will shed new light on our understanding of these processes.

Total: $240,000.00; Geochemistry

DP140104093: Chivas, Prof Allan R; Tyler, Dr Jonathan J; Drysdale, Dr Russell N

Project Summary:

Clumped-isotope geochemistry, a novel method for measuring the temperature of formation of carbonate minerals, will be applied to terrestrial materials (soil carbonates, lake deposits and speleothems) from Australia and New Zealand. The method relates the abundance or 'clumping' of rare isotopes (for example, carbon dioxide of mass 47 as carbon-13, oxygen-18, oxygen-16) extracted from carbonates to their formation temperature and is independent of the oxygen-18:oxygen-16 value of the host water from which the mineral precipitated. The materials to be investigated span the Last Glacial-Interglacial Transition and will provide robust past temperature estimates and the delta-oxygen-18 values of waters, thereby permitting hydrological balances (for example, precipitation/evaporation) to be constructed.

Total: $450,000.00; Geochemistry

FUTURE FELLOWSHIPS

UNIVERSITY OF WOLLONGONG

FT130100532: Rogers, Dr Kerrylee

Project Summary:

Saline coastal wetlands store large amounts of carbon and are potentially the most efficient sinks of carbon amongst natural ecosystems. This project will use isotopic tracers to quantify carbon retention within saline coastal wetlands in southeastern Australia, establish the vulnerability of these wetlands to sea-level rise using estimates of sediment accretion and surface elevation change, and use this information to predict the distribution of saline coastal wetlands and estimate the carbon sequestration potential of coastal wetlands within a 'low-carbon economy'. This project will remove impediments to the proper economic evaluation of saline coastal wetlands and enable restoration coastal wetlands to be used to offset carbon emissions.

Total: $747,020.00: Physical Geography and Environmental Geoscience

THE UNIVERSITY OF ADELAIDE

FT130100748: Ridgwell, Prof Andrew

Project Summary:

Earth history is punctuated by a huge variety of transitions and perturbations in climate, biogeochemical cycling, and ecosystems, some of which may hold direct future-relevant information. In the oceans, these are closely linked in a complex web of feedbacks, as well as to the oxygenation of the ocean and the ultimate geological fate of excessive carbon released into the atmosphere – burial of carbon in sediments. This project will develop a computer model representation of this coupled carbon-climate-life system and test this against the geological record, explore the causes and consequences of carbon release events and extinctions as well as how the ocean floor delivery and preservation of organic carbon responds.

Total: $971,644.00: Geology

THE UNIVERSITY OF SYDNEY

FT130101718 : Alvarez-Mon, Dr Javier

Project Summary:

The Elamite civilisation (circa. 4000 to 525 BCE) formed a remarkably rich but almost unexplored background to later Persian imperialism. This ancient Iranian culture, whose importance has never been recognised, is characterised by a remarkable longevity and an outstanding combination of highland and lowland artistic and cultural traditions. The aim of this project is to articulate the history of the art and culture of the Elamite civilisation for the first time based on analysis, interpretation and publication of its archaeological and artistic record.

Total: $623,187.00: Archaeology

THE UNIVERSITY OF QUEENSLAND

FT130101702: Fairbairn, Dr Andrew S

Project Summary:

Long distance trade in bulk foods, such as grain, is a key strategy for overcoming food insecurity in the modern urbanised world, yet we know relatively little of its history and role in the emergence and stability of the world's first cities and states. Developing new archaeological techniques, this project explores the history of trade in bulk grain in southwest Asia from the Neolithic to Iron Age and its role in stimulating socio-economic change and mediating food insecurity in a period of rapid climatic and political change. In revolutionising our view of ancient food trade it will provide an example from the past to help inform contemporary debates about the efficacy of a key economic strategy in moderating fluctuations in food supply.

Total: $750,080.00: Archaeology

THE FLINDERS UNIVERSITY OF SOUTH AUSTRALIA

FT130101728: Prideaux, Dr Gavin J

Project Summary:

Australia's biota is a product of its unique heritage, tectonic history and most especially its climate. Over the past five million years it has been beset by a series of intense climatic shifts driven by a combination of global and regional factors. This project will be the first to track faunal responses to environmental changes across this critical interval. It will establish the dynamics of the origin of the modern southern vertebrate fauna, analysing changes in diversity, diet and community structure. By exploring associations between phases of faunal turnover and key climatic transitions, it will bring a Southern Hemisphere perspective to evolutionary models of Cenozoic faunal change largely generated to date from Northern Hemisphere data.

Total: $727,300.00; Evolutionary Biology

THE UNIVERSITY OF ADELAIDE

FT130100195: Arnold, Dr Lee J

Project Summary:

The causes of megafaunal extinction in Australia continue to be fiercely debated owing to chronological gaps in the palaeontological record, poorly constrained palaeoenvironmental histories and limited data on long-term faunal responses to climate change prior to human arrival. This project will utilise and advance new luminescence dating methods to provide unparalleled reconstructions of faunal turnover and environmental change over millennial to million year timescales. The chronologies generated through this work will provide a crucial new perspective on the ongoing megafaunal debate and will be used to test key assumptions underpinning anthropogenic – and climate-driven extinction hypotheses on local, regional and continental scales.

Total: $755,320.00; Geology

THE UNIVERSITY OF MELBOURNE

FT130100801: Hellstrom, Dr John C

Project Summary:

Projections of global climate change over the next century are so negative we must look to the Pliocene Epoch, more than 2.5 million years ago, for past analogues. Nonetheless, more recent episodes of rapid global warming during the late Pleistocene might approximate those expected for coming decades. This project will study past Australian regional temperature and rainfall responses to these events, on a high-resolution absolute timescale. The necessary analytical technologies are new, meaning a study of this scope could not previously be attempted, and they will be further developed under this project. Outputs will include spatial patterns and lead/lag relationships which can be used to supplement climate model predictions for Australia.

Total: $755,320.00: Physical Geography and Environmental Geoscience

DISCOVER EARLY CAREER RESEARCHER AWARDS

UNIVERSITY OF WOLLONGONG

DE140100254: Aubert, Dr Maxime

Project Summary:

Recent research revealed that humans were producing rock paintings on the Indonesian island of Sulawesi at least 39 thousand years ago (and possibly up to 46 thousand years ago). The rock art, therefore, is essentially contemporaneous with the earliest cave art in Europe and may be the world's oldest, given the arrival of Homo sapiens in Australia at least 50 thousand years ago. This project will further investigate the early rock art of Sulawesi as well as other key Indonesian islands located along likely migration routes from Borneo to New Guinea. The results will have major implications for our understanding of the cultural behaviour and dispersal of the earliest modern humans to colonise Southeast Asia and Australia.

Total: $395,205.00; Archaeology

LA TROBE UNIVERSITY

DE140101095: Crook, Dr Penelope J

Project Summary:

This project will explore Sydney's history as a marketplace, in a broad-ranging examination of consumer cultures, archaeological relics and trade catalogues from the colonial era. It will build on pioneering new methods to explore the cost, quality and value of thousands of objects of domestic material culture found on archaeological sites in Sydney. It will employ emerging digital technologies to analyse distinctive trends in colonial Australian advertising and the promotion of domestic goods, along with the prices of thousands of goods sold by colonial retailers. The resulting analyses will underwrite new transnational histories of empire, commerce and the social impact of mass consumption at the height of the British empire.

Total: $326,489.00; Archaeology

DISCOVERY INDIGENOUS AWARDS

THE UNIVERSITY OF MELBOURNE

IN140100050: Fletcher, Dr Michael-Shawn

Project Summary:

El Niño events starve southeast Australia of rainfall, resulting in droughts and wildfires. El Niño activity is projected to amplify as global temperatures rise, heralding a serious threat to Australia's water security and the incidence and magnitude of wildfires. The key to understanding the potential effects of future changes in El Niño activity lies in the past. El Niño activity has varied substantially over the last 12,000 years. This project will reconstruct the response of southeast Australian climate, vegetation and fire activity to changes in El Niño activity over this period using lake sediments located in El Niño sensitive locations in Tasmania.

Total: $400,000.00; Physical Geography and Environmental Geoscience

LINKAGE INFRASTRUCTURE, EQUIPMENT AND FACILITIES PROJECTS

THE AUSTRALIAN NATIONAL UNIVERSITY

LE140100047: Arculus, Prof Richard J; Rohling, Prof Eelco J; Roberts, Prof Andrew P; Exon, Prof Neville F; Yeats, Dr Christopher J; O'Reilly, Prof Suzanne Y; George, Prof Simon C; Muller, Prof Dietmar; Aitchison, Prof Jonathan C; Webster, Dr Jody M; Coffin, Prof Millard F; Vasconcelos, Prof Paulo M; Welsh, Dr Kevin J; McCuaig, Prof Thompson C; George, Prof Annette D; Skilbeck, Prof Charles G; Baxter, Dr Alan T; Hergt, Prof Janet M; Gallagher, A/Prof Stephen J; Fergusson, A/Prof Christopher L; Sloss, Dr Craig R; Heap, Dr Andrew D; Schellart, A/Prof Wouter P; Stilwell, A/Prof Jeffrey D; Foden, Prof John D; Kershaw, Em/Prof Arnold P; Howard, Dr William R; Clennell, Dr Michael B; Daniell, Dr James J; Collins, Prof Lindsay B

Partner/Collaborating Eligible Organisation(s):

Queensland University of Technology, The University of New England, Commonwealth Scientific and Industrial Research Organisation, Geoscience Australia, James Cook University, Marine Geoscience Office, Curtin University of Technology, Monash University, The University of Adelaide, Macquarie University, The University of Sydney, University of Tasmania, The University of Queensland, The University of Western Australia, University of Technology, Sydney, The University of Melbourne, University of Wollongong

Project Summary:

Australian membership of the International Ocean Discovery Program: This project is for an Australian membership of the International Ocean Discovery Program. The Program will recover drill cores, situate observatories, and conduct down-hole experiments in all the world's oceans from lowest to highest latitudes to address fundamental questions about Earth's history and processes within four high-priority scientific themes: climate and ocean change – reading the past and informing the future; biosphere frontiers – deep life, biodiversity, and environmental forcing of ecosystems; earth connections – deep processes and their impact on earth's surface environment; earth in motion – processes and hazards on a human time scale.

Total: $3,600,000.00; Geology

LE140100189: Farquhar, Prof Graham D; Brocks, Dr Jochen J; Bird, Prof Michael I; Cernusak, Dr Lucas A; Fallon, Dr Stewart J; Foley, Prof William J; Holtum, Prof Joseph A

Partner/Collaborating Eligible Organisation(s):

James Cook University

Project Summary:

A shared mass spectrometer with compound-specific capabilities to support innovative research in biology, the environment and geology: Stable isotope studies have huge and increasing relevance to environmental studies, many of which form the backbone of understanding Australia's terrestrial and marine systems. Compound-specific isotope analysis yields much more information than is available through bulk methods. The problem has been that the separations were labour-intensive and employed complex wet chemistry. New methods reduce the work-load enough to make compound-specific studies possible. In the case of carbon isotopes, new liquid chromatographic technology removes the need for derivatisations which dilute the natural signal and can render it unusable.

Total: $191,095.00; Ecological Applications

THE UNIVERSITY OF NEW SOUTH WALES

LE140100088: Baker, Prof Andrew; Turney, Prof Chris S; Cartwright, Prof Ian; Shulmeister, Prof James P; Larsen, Dr Joshua; Jenkins, Dr Kim M; Moss, Dr Patrick T; Timms, Dr Wendy A; Pickford, Dr Russell

Partner/Collaborating Eligible Organisation(s):

Monash University, The University of Queensland

Project Summary:

A coupled high temperature elemental analyser – gas chromatograph – mass spectrometer for climate, water and ecological research: This project is for a high temperature, elemental analysis, gas chromatography, isotope mass spectrometry facility. This would permit the analysis of the isotopes of up to four elements in a range of environmental samples such as tree cellulose, ecological samples and dissolved nutrients in surface and ground waters. Results will help improve our understanding of climate – surface water – ground water interactions, ecosystem function, and past climate and environmental change. The new facility will meet the need for organic isotope analyses to better understand the underlying physical processes.

Total: $150,000.00; Geochemistry

LE140100151: Ross, Dr Shawn A; Curnoe, A/Prof Darren K; Field, Dr Judith H; Letnic, Dr Mike I; Mooney, Dr Scott D; Hunter, Prof Jane L; Fairbairn, Dr Andrew S; Weisler, Prof Marshall I; Manne, Dr Tiina; Thompson, Dr Jessica C; Johnson, Dr Ian R; Gibbs, Dr Martin D; Murray, Prof Tim A; Webb, Dr Jennifer M; Stern, Dr Nicola; Frankel, Prof David; Burke, A/Prof Heather D; Morrison, Dr Michael J; Davidson, Prof Iain; Boyd, Prof William E; Thurbon, Dr Joe; Borda, Dr Ann; Brin, Mr Adam; Kansa, Dr Eric C; Schloen, Ms Sandra; Richards, Prof Julian

Partner/Collaborating Eligible Organisation(s):

University of California, Berkeley, The University of Chicago, The University of York, UK, The University of Queensland, The University of Sydney, La Trobe University, The Flinders University of South Australia, Southern Cross University, Intersect Australia Ltd, Victorian Partnership for Advanced Computing, The Center for Digital Antiquity

Project Summary:

Federated archaeological information management systems project: transforming archaeological research through digital technologies: This project will embed the federated archaeological information management systems infrastructure within six leading archaeology departments across Australia. It will develop and expand the mobile field recording system, the national data repository and a suite of online editing and visualisation tools to support archaeologists conducting research projects of national significance. By working closely with research projects and integrating the mobile platform and digital infrastructure within their workflow, this project will ensure that Australian archaeological research data is created in digital, structured, and reusable form, benefiting the preservation of Australian cultural heritage and promoting new research for decades to come.

Total: $400,000.00; Archaeology

UNIVERSITY OF WOLLONGONG

LE140100023: Dosseto, Dr Anthony; Chivas, Prof Allan R; Murray-Wallace, Prof Colin V; Aubert, Dr Maxime; Nutman, A/Prof Allen P; Bennett, A/Prof Victoria C; White, Dr Duanne A; Joannes-Boyau, Dr Renaud; Burton, A/Prof Edward D; Johnston, A/Prof Scott G; Scheffers, A/Prof Anja M; Sullivan, Prof Leigh A; Cartwright, Prof Ian; Fink, Dr David; Cendon, Dr Dioni I; Baker, Prof Andrew; Graham, Dr Ian T; Norman, Dr Marc D; Cohen, A/Prof David R; Eggins, Dr Stephen M; Hesse, Dr Paul; Westaway, Dr Kira E; Goodwin, A/Prof Ian D

Partner/Collaborating Eligible Organisation(s):

Southern Cross University, The Australian National University, University of Canberra, The University of New South Wales, Monash University, Australian Nuclear Science and Technology Organisation, Macquarie University

Project Summary:

Innovative isotopic techniques to study the response of soil and water resources to modern and past climate change: The emergence of innovative isotopic tools has provided unprecedented opportunities to improve our understanding of the processes that shape the earth's resources and environment. The plasma-source mass spectrometer will be dedicated to applying these techniques to earth surface processes, and establishing unique capabilities to decipher how soil and water resources respond to modern and past climate change in Australia.

Total: $360,000.00; Geochemistry

Desert Lake: Art, Science and Stories from Paruku

Steve Morton, Mandy Martin, Kim Mahood and John Carty (Editors)

CSIRO Publishing, 2013, 312 pp. ISBN 9780643106284Hardcover AUD 59.95

Reviewed by Kirsty Douglas
Principal Research Officer
Emerging technologies and their role in Australian society
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Paruku, also known as Lake Gregory, is a terminal floodplain at the end of a desert stream – the ephemeral Sturt Creek – in the south-east Kimberley. But this is only one Paruku. Paruku is also the memory of a Pleistocene mega-lake. It is a record of 50 thousand years of resource management by people living in the east Kimberley. It is a wetland of international significance, a haven for waterbirds. Paruku is an interface between the monsoon and the desert, a haven of ecological abundance amid an expanse of Triodia and sand. It is a landscape of deep cultural significance to the peoples of the Tjurabalan Native Title Area in the Western Great Sandy Desert. Additionally, in recognition of the cultural importance of the wetlands, in 2001, an Indigenous Protected Area (IPA) was declared over 430,000 hectares of the country around Paruku, and includes several groups of Traditional Owners, including Walmajarri, Jaru and Kukatja peoples.

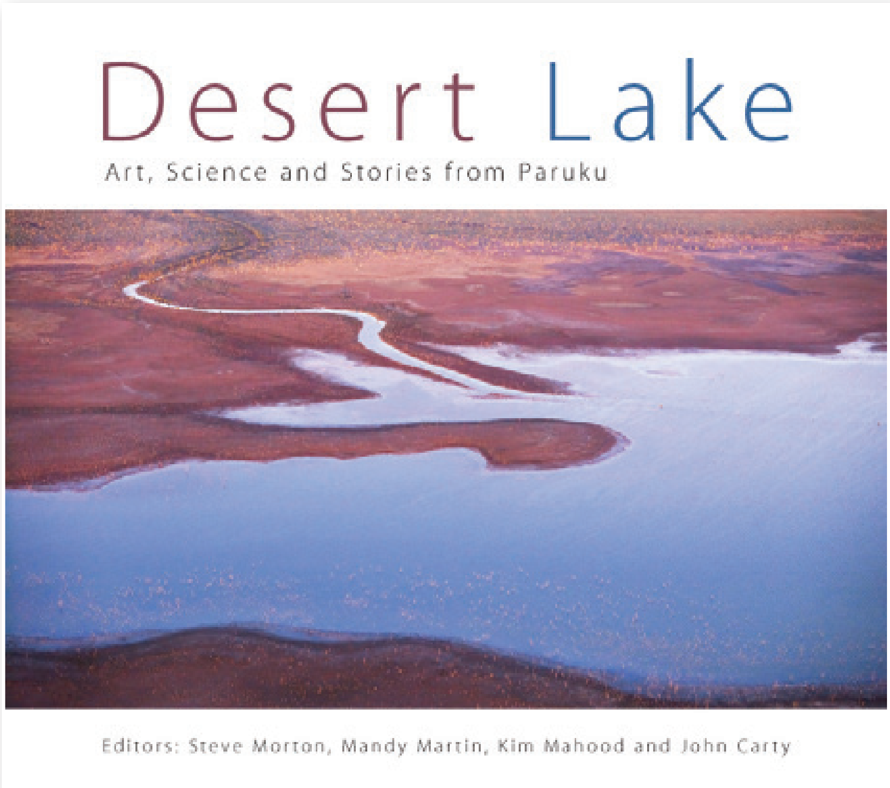

Photo credit: CSIRO Publishing.

The collection Desert Lake: Art, Science and Stories from Paruku is part of a larger Paruku project, and set of projects, spanning decades. Among many, these projects include Jim Bowler's longstanding climatological and geomorphological studies linking Paruku thematically to the Willandra Lakes, another iconic set of terminal desert lakes on the other side of the country, in central NSW, these ones now dry. Freshwater scientists Rob Cossart and Rebecca Dobbs have been regular visitors to Paruku for a number of seasons, and have chronicled the ecology of its "complex of interconnected lakes and wetlands located at the end of a desert river" – together with its overlay of "deep-seated and fascinating cultural connections", focusing on personal relationships and knowledge exchange. Kim Mahood grew up in the region and has collaborated with Traditional Owners in a cultural mapping project for a number of years, many of the stunning products of which illustrate Desert Lake. Anthropologist John Carty has lived and worked with Mulan people at Paruku since 2002. Indigenous artists at Mulan have been painting in a variety of media for several decades, alone, together, and in dialogue or collaboration with outsiders.

The four editors, ecologist Morton, artists Martin and Mahood, and anthropologist Carty, bring a wealth of understanding, both professional and collaborative, to creating and curating the diversity of narratives and images that shape Desert Lake.

The book's structure is roughly chronological, beginning in "Deep Time" with a number of Waljirri narratives. The opening essay by John Carty and Kim Mahood places Paruku at the centre of the Walmajarri understanding of the world: "Everything, for the Walmajarri people, began here. Anything worthwhile that isn't here now, came from here. Everything, and everyone, comes back to here". Then the narrative moves to Walmajarri artist Hanson Pye's exegesis of his 2011 painting, Parnkupirti layers, an image and explanation in dialogue with Bowler's succeeding essay explaining Paruku's geological past and his personal history of interactions with the lake, and with Walmajarri people.

"Recent Times" chronicles the historic past, the ecological and ethnographic present, via first-person narratives, and accounts of scientific cooperation and knowledge exchange; and essays on art, country, and collaboration, and a poem, Paruku suite, by William Fox, round out the second act of the book.

Finally, "The Future" looks at community resilience, empowerment, restoration and protection of the land, remoteness, work and culture, in essays by IPA cultural rangers and Traditional Owners, Hanson Pye and Jamie Brown, by Traditional Owner Shirley Brown, by visitors Guy Fitzhardinge and Jocelyn Davies, and a final mapping vignette by Kim Mahood.

Visually, the book matches the opulence of wetlands in flood, containing wonderful photography including breathtaking aerial and satellite images and detailed close-up shots, paintings by Mulan artists and by other Indigenous artists, and photographs of sculptures produced at Mulan. These are interwoven with Kim Mahood's beautiful collaborative maps and paintings, with photographs of the process of assembling some of the maps, and paintings by a number of talented artists, including magnificent landscapes by Mandy Martin and David Leece. It is a minor but real annoyance, then, that the book does not include a detailed table of images, but I suspect that this was a decision made by the publisher, CSIRO, not by the editors.

There is an interesting difference among the contributor biographies: most of the Indigenous biographies reflect who people are, who they are related to, and their relationships with Paruku; the biographies of non-Indigenous contributors tend to describe what people do.

I note that Paruku is not in fact a "World Heritage wetland" as stated in the introductory essay, although it undoubtedly has many qualities, ably documented and depicted in Desert Lake, that would make it an adornment to the World Heritage List under a number of natural and cultural criteria. It is a Ramsar-listed group of wetlands of international significance. Like the World Heritage List, Ramsar classification is established and administered by UNESCO, but with very different criteria for listing, different regulatory implications in Australia, and a different protective regime.

Like Paruku, Desert Lake is hard to categorise in only three dimensions. It is ambitious, complex and multifaceted, and rewards effort. The structure as a whole does not lead the reader comfortably through a linear narrative, but rather sets her adrift, to float down the anastomosing channels of Sturt Creek in flood, amid intricate human-landscape-water-ecosystem relationships through deep and recent time. With 50 contributors, and essays, vignettes, and images that intermingle Waljirri (creation narratives), traditional knowledge, and memory with traditional and contemporary art, poetry, cartography, photography, ethno-ecology, history, and Western science, it is hard to enumerate every contribution. But the parts work together to create a stunning depiction of a place and its people.

The archaeology of Australia's deserts

Mike Smith

Cambridge University Press, 2013, 432 pp, ISBN: 978 0 521 40745 8, Hardcover AUD115

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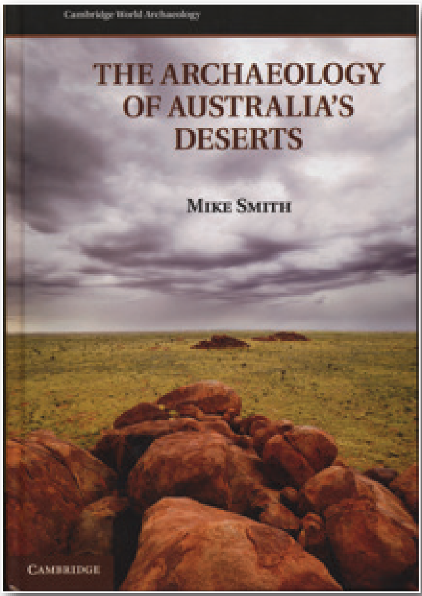

Australia's arid zone comprises over 70% of the continent. At the peak of the last glacial maximum (LGM) this area expanded to a maximum of 6-7 million km^2. A single book that describes the archaeology of this region is a substantial undertaking. Mike Smith sets out to weave a 'big picture' narrative of the archaeology of Australia's deserts, which involves setting the archaeological evidence within a context of ethnographic observations and environmental investigations that date back to the 1840s, when Eyre first set out from the new settlement of Adelaide. 'Big picture' indeed: Smith has accomplished a remarkable feat, covering over 60 years of archaeological research, 45,000 years of human occupation and 26 million years of landscape evolution and environmental change!

Despite this wide scope, and Smith's own acknowledgement that such a broad review "necessarily conflates vast stretches of time" and glosses over "some of the procedural difficulties,... questions of site formation processes and issues of taphonomy", this is a comprehensive synthesis of detailed archaeological data (where it exists), published reports, reviews and unpublished field notes, set within an environmental framework that has become increasingly detailed and fine-grained as a result of the last few decades of research.

The first three chapters set the context for the archaeological data reviewed in later chapters. Chapter 1 puts the occupation of Australia's deserts into a global context, and outlines the themes that have both guided and constrained research in this area: the geography and ecology of deserts themselves; ethnography and human ecology; the nature of archaeological research in the deserts; and the politics of research. This chapter introduces a question that underlies much of the subsequent narrative: "When did life in the desert change to something resembling the ethnographic pattern"?

Chapter 2 then sets the direction of the book, with an account of the history of research that demonstrates how ideas about people and the environment have been intertwined since first contact and the earliest ethnographic documentation. This chronology of the history of research further elaborates upon the themes that have continued to structure research into the desert regions and desert peoples, including questions about environmental change and responses to increasing and ameliorating aridity, the process of initial colonisation and dispersal, the age of rock art, and social developments in the late Holocene.

Each of the remaining chapters focuses on a particular time frame, addressing, in chronological order, themes that are appropriate to the resolution of knowledge from each time span. Chapter 3 focuses on the development of desert environments from the late Tertiary until the late Pleistocene, ~45 ka. This sets the scene for the arrival of the first people. Chapter 4 reviews the record of the earliest human dispersal into the continent's deserts, between 45 and 30 ka. Around 40 sites are dated to this time period; a seemingly low number, but Smith points out that this is, in fact, "one of the best-documented records of early human occupation of a major world desert". Smith's own work over the past 30 years has been integral to establishing the antiquity and nature of Pleistocene occupation documented in this and the following chapter, and no doubt it has been seminal to the development of the ideas presented in the book. However, it should be acknowledged that this work is certainly not over-represented in the presentation of site data.

Chapter 5 investigates the period of increasing, extreme and ameliorating aridity surrounding the LGM, from 30 ka to 12 ka. The impact of the LGM has been of particular interest to archaeologists during the last 30 years, and the nature and location of glacial refugia are a key focus of this chapter. It is somewhat disappointing, then, that knowledge of desert societies during this period seems so limited – this appears to be a result of the nature of occupation and the archaeological record, though, rather than a shortcoming of the archaeological work or Smith's review.

Following the two chapters on Pleistocene evidence, the last four chapters address the Holocene. This imbalance – two chapters dedicated to the first 30,000 years of human occupation, compared to four chapters for the last 10,000 years – reflects the denser and finer-grained archaeological record from the more recent period. The Holocene chapters address the lead-up to the first evidence for the distinctive desert adaptations seen in the ethnographic record (12 – 3 ka, Chapter 6); the role of rock art as part of the religious and political system (~8 – 1 ka, Chapter 7); patterns of long-distance trade and exchange and the development of large-scale production systems between ~5 ka and 1 ka (Chapter 8); and, finally, the last millennium and the archaeological record that demonstrates the final consolidation of the social and political structures identified by the classic ethnographic studies (Chapter 9).

Each chapter, except the first, is structured similarly. An ethnographic or historic anecdote that marks a significant moment in desert research introduces the key themes or questions to be addressed. This not only sets the scene, but serves to remind the reader that archaeology is not just about excavation, artefacts and dates, but about people, society and the search for understanding. Smith then goes on to review the issues and theories that are relevant to the theme of the chapter, before describing the archaeological evidence region by region. An overview or discussion concludes each chapter. This format enables quick review of either the issues or the data and should make the book useful both to those readers interested in the 'big picture' narrative and to those seeking the archaeological detail. Maps and tables summarise the distribution and chronology of the sites discussed in each chapter. Additional tables and figures are clear and useful, and, for the most part, distributed evenly through the text. Unfortunately, the exception to this occurs in the first few pages of the book – the first three figures are somewhat overwhelming, taking up the majority of pages 2 and 3; although Figure 1.3 could have benefited from being shown on a full page. There are also errors with the footnote annotation within Table 5.1. However, these are minor editing quibbles that do not significantly detract from the overall presentation.

As a resource for people interested in arid zone archaeology, this book will be extremely useful, bringing together a comprehensive range of references spanning a vast geographic area. Because it is structured chronologically and thematically, extracting information about a particular site or region requires slightly more effort than investigating a particular time period, but the index seems comprehensive and clear enough to assist readers who have a more specific focus. The maps and tables, as mentioned previously, are also valuable in this respect. A more detailed table of contents may have been useful, though.

Apart from those issues that form the central theme of a chapter (e.g. the nature of abandonment of the arid centre in Chapter 5), Smith does not dwell on areas of current debate. In most cases, though, those debates are acknowledged and outlined: for example, the timing of earliest colonisation, evidence for human firing of the landscape, megafaunal extinction (Chapter 4); the introduction of seed-grinding technology (Chapter 6); and the age of rock engravings (Chapter 7).

Smith's book is also successful as a narrative that explores the structural and social history of desert societies (as such, the title, 'The archaeology of Australia's deserts', seems understated). Using an approach that incorporates the history of research, Smith is able to emphasise the importance of the environmental and ethnographic records as an integral part of that narrative. This work demonstrates that such a story can be told without being reduced to environmental determinism or inappropriate ethnographic analogy.

Smith's primary aim was to achieve a work of historical review and synthesis, revisiting the basic questions about the deep history of desert societies, and in this he has excelled. Smith also hopes to encourage new research, by pointing to gaps in the record and framing new questions to address them. A limited understanding of changes in the early-mid Holocene (Chapter 6) stands out, particularly given the likelihood of increasing population at this time and subsequent significant changes.

If there is one weakness in Smith's work, it is the lack of a concluding chapter. The final review of the social history of desert groups, extending from the late Pleistocene to the last millennium, is almost lost in the last few pages of the last chapter. A final chapter, or a more significant section in the last chapter, would also provide an opportunity to highlight the areas that Smith considers to be priorities for further research. Maybe this is a deliberate omission, a way to encourage future archaeologists to identify the gaps in knowledge that are of particular interest to them, but it seems like a missed opportunity.

'The archaeology of Australia's deserts' is an impressive and elegant work. Informative, comprehensive and engaging, it was a pleasure to read and is a worthwhile addition to the *Cambridge World Archaeology* series and to the bookshelf of any practising or aspiring archaeologist.

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THESIS ABSTRACTS

Basal and englacial melting of temperate glaciers

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Omission of basal and englacial melt processes from temperate glacier mass balance models is an oversight that needs addressing. Mass balance models are one of the most widely used tools for exploring climatological-glaciological processes including the response of glaciers to climatic change. Since surface ablation is the dominant contributor to glacier melt and is relatively easy to measure, it is usually the only source of ablation used in models. Basal and englacial melting processes are traditionally considered insignificant and are more challenging to measure; consequently they are always ignored. This thesis provides new insights into the processes of basal and englacial melting and their importance in correctly quantifying temperate glacier melting.

A review of the literature reveals that while basal melt has been modelled beneath ice sheets, ice streams and ice shelves in polar settings for many years, there are few basal and englacial melting measurements or model estimates for temperate glacier settings. This is addressed in the thesis by using two temperate glaciers to investigate basal and englacial melting processes. The high-precipitation Franz Josef Glacier in New Zealand is used to investigate melting from five sources: geothermal heat flux, friction, strain heating, viscous dissipation in flowing water and heat advection. Initial order-of-magnitude estimates indicate that heat advection as a result of runoff warmer than 0°C from rainfall and snowmelt entering the glacier is one of the major basal melting processes affecting high-precipitation temperate glaciers. This process is estimated to result in mean melting across the ablation zone of up to 1.7 m a–1. Further investigations using a thermo-hydraulic melt model calibrated with field data infer that glacier-averaged melting due to heat advection is approximately twice the melting caused by the rainfall heat flux. This is the equivalent of 7% to the total glacier melt, which is a considerable component of glacier mass balance.

Another significant glacier melting process is a result of friction at the ice-bed interface. This process is investigated at a fast-flowing temperate tidewater glacier, the Columbia Glacier in Alaska using a two-dimensional basal melt model. Prior to the retreat of Columbia Glacier (pre-1980s), the mean basal melt due to friction is estimated to be 61 mm a–1 and during retreat (1980s onwards) this increased to 129 mm a–1. These basal melt rates are the equivalent of 3% and 5% of the total melting for the pre – and syn-retreat glacier profiles respectively. Interestingly, modelling indicates that even if there is a reduction in basal resistance due to high water levels within temperate tidewater glaciers, significant basal melt can still occur if ice velocities are sufficiently fast.

The effect of substantial rock avalanche debris increasing the proportion of basal and englacial melt to surface melt is incorporated into a one-dimensional ice flow model used to investigate the evolution of the Waiho Loop, the terminal moraine of the late glacial Franz Josef Glacier. Assuming that the rock avalanche occurred while the glacier was in a period of retreat, modelled basal and englacial melt accounts for 25% of the total melt discharge between the time rock avalanche debris covers the glacier and the time at which all glacier debris advects past the transient climatic terminus (30 years). Of most significance is that the model, supported by newly acquired basal topography from seismic studies in the vicinity of the Loop, demonstrates that the glacier terminus could not advance during its formation. Thus, the formation of the Loop does not reflect a climate-driven glacier advance; it actually represents no significant advance whatsoever.

At a time when glaciological models are increasingly being used to model climatological-glaciological processes including the response of glaciers to climatic change, greater attention should be given to incorporate basal and englacial melting within models to obtain more accurate model outputs. MATLAB code and MS Excel spread sheets for a one-dimensional glacier model are provided as supplementary data to assist in this process. These models facilitate a straightforward and efficient way to assess whether englacial and basal melting may be significant in any temperate glacier setting. This is an important output of the thesis. Exclusion of basal and englacial melt components when considering glacier mass balance represents a systematic underestimation of melt used for mass balance calculations and models. Modelling indicates that, regardless of the type of temperate glacier setting, basal and englacial melt generally contributes 5–10% to the total glacier melt. This may affect long-term interpretations of mass balance.

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

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

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

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

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

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

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

A paleoclimate-informed examination of flood and drought epochs in the Murray-Darling Basin

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This work demonstrated that the realisation of a high-resolution paleoclimate rainfall network around Australia as determined in the optimal interpolation, would enable an increased degree of variance to be captured in reconstructions of MDB rainfall. In addition, it was revealed that extending the current paleoclimate records of Pacific, Indian and Southern Ocean variability spanning the Common Era will also enable MDB rainfall variability to be reconstructed. Reconstructions of MDB rainfall variability using different networks of paleoclimate data are expected to enable more accurate estimates of long-term flood and drought risks in the MDB. This would then provide a realistic assessment of the baseline risks, thus enabling the adoption of robust water resource management schemes capable of responding to the degree of natural variability identified from paleoclimate-based reconstructions. Such information will also enable future climate scenarios to be adequately constrained, validated and assessed using a multi-centennial or multi-millennial perspective of past hydroclimatic variability.

Spatially Resolved Strontium Isotope Micro-Analysis of Lower and Middle Palaeolithic Fauna from Archaeological Sites in Israel and Southern France

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The use of strontium isotope analysis to provenance biominerals such as bone and teeth has become a regularly applied component of archaeological research. This method works by comparing the isotopic composition of these materials with regional bioavailable soil values, allowing an estimation of the distance and vector of an individual's mobility. New advances in analytical equipment has facilitated the spatially resolved micro-analysis of strontium isotope composition using laser ablation sampling, allowing intra-sample heterogeneity to be quantified. This provides the opportunity to determine not only the overall provenance of a material, but also the degree of mobility during biomineral formation.

This research applies laser ablation multi-collector inductively coupled plasma mass spectroscopy (LA-MC-ICPMS) to 90 teeth of Lower and Middle Palaeolithic faunal prey from Lower and Middle Palaeolithic archaeological sites within Israel and France. These sites span a crucial period in human evolution, characterised by the radiation of multiple hominin species and by dynamic oscillations of climate with attendant changes in fauna and flora. The strontium isotope values from LA-MC-ICPMS analysis in this thesis show a high level of intra-sample variability, which would not have been captured by a traditional analytical methodology. This suggests that, despite some problems in obtaining accurate results due to offsets between solution and laser values, strontium isotope studies that do not utilise spatially resolved micro-analysis are unable to accurately determine mobility.

The results of this research demonstrate that fauna from the archaeological sites of interest—including Amud, Qafzeh, Tabun, Skhull, Holon, Bois Roche, Le Moustier, La Chapelle-aux-Saints, Les Fieux, Pech de l'Aze II and Rescoundudou—appear to have patterns of mobility that are controlled by variables such as species, marine isotope stages (MIS) and regional physiography. Specifically, Persian fallow deer, bison, mountain goat/chamois and fox are frequently mobile between different geological environments during amelogenesis while wild boar and rhinoceros are sessile. The calculated range of distance for minimum possible mobility for each sample is large, ranging from 0 km to 350 km. The median values for minimum possible mobility for each species suggest that wild boar, bison and fox are mobile over the greatest distance while *Bos*, rhinoceros, Persian fallow deer and unidentified deer are mobile over the least. Furthermore, fauna in MIS 4 and 3 are significantly more mobile than in MIS 6 and 5. Fauna from France are more mobile than those from Israel, which is attributed to the location of the archaeological sites adjacent to significant river systems that could serve as conduits of mobility, even during inhospitable climate periods. Overall, these insights show that strontium isotope analysis can be usefully applied to quantifying mobility on a broad temporal and geographic scale, rather than simply being used, as is typical, for locating the source of material within a specific archaeological site.

An environmental record from a stand of Callitris preissii from Queen Victoria Springs, Western Australia

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School of Physical and Environmental Science, University of New South Wales, Australia

Wood increment samples and surveys of remnant Callitris patches in Queen Victoria Springs Nature Reserve (Western Australia) were used in an attempt to expand on understandings of patterns and process in structure and dynamics through established continental frameworks, annually date tree-rings though applying established techniques, and to inform on management and policy decisions on environmental initiatives within south-western Australia at local and regional scales. Callitris was examined as a bioindicator due to its ability to provide climate and ecological proxy records in Australia's arid zone.

The population at Queen Victoria Springs was a mixed community of *Eucalyptus gongylocarpa* and *Callitris preissii* affected by recent heavy rainfalls and fires. Queen Victoria Springs provides the only site recently affect by fire and represents an important contribution. Recruitment at Queen Victoria Springs was seen to be occurring post-fire with high densities of juveniles and low densities of adults despite the presence of camels and rabbits. Large dead but unconsumed Callitris occurred at the border of burnt areas and may support observations elsewhere that mature trees can increase their survival through fuel load suppression in their vicinity.

Significant production of false and absent rings, dampening of site-wide signals by individual signals, ring width variation within individual trees and sample quality degradation by resin deposits and wood decay meant that identification and matching of series was made impossible. Repeated attempts and analysis were conducted before traditional cross-dating attempts were ceased. Common patterns and rings apparent through visual inspection did suggest that annual dating is possible in further work. Use of modern techniques (radiocarbon dating, isotope analysis and ITRAX scanning) was recommended on broad rings which were probably produced from sources of heavy rainfall. This may isolate unique rings from geochemical fingerprints in the formation and should allow for confirmation of broad ring dates.

Developing probabilistic models for predicting tsunami-induced building damage

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The increased availability of post-tsunami damage data over the past decade has led to a growing inventory of empirical fragility curves that probabilistically model the damage response of buildings to tsunamis. However, these curves are not currently accurate enough to be applied effectively in tsunami damage assessments. This thesis addresses this problem by developing new techniques for deriving fragility curves remotely using a novel web-based building survey tool and ”building aware” hydrodynamic inundation models. These techniques were implemented as part of the Tsunami-Impacted Building Collection and Analysis (TIBCA) framework, which was developed to survey, manage and analyse the data necessary to generate fragility curves remotely.

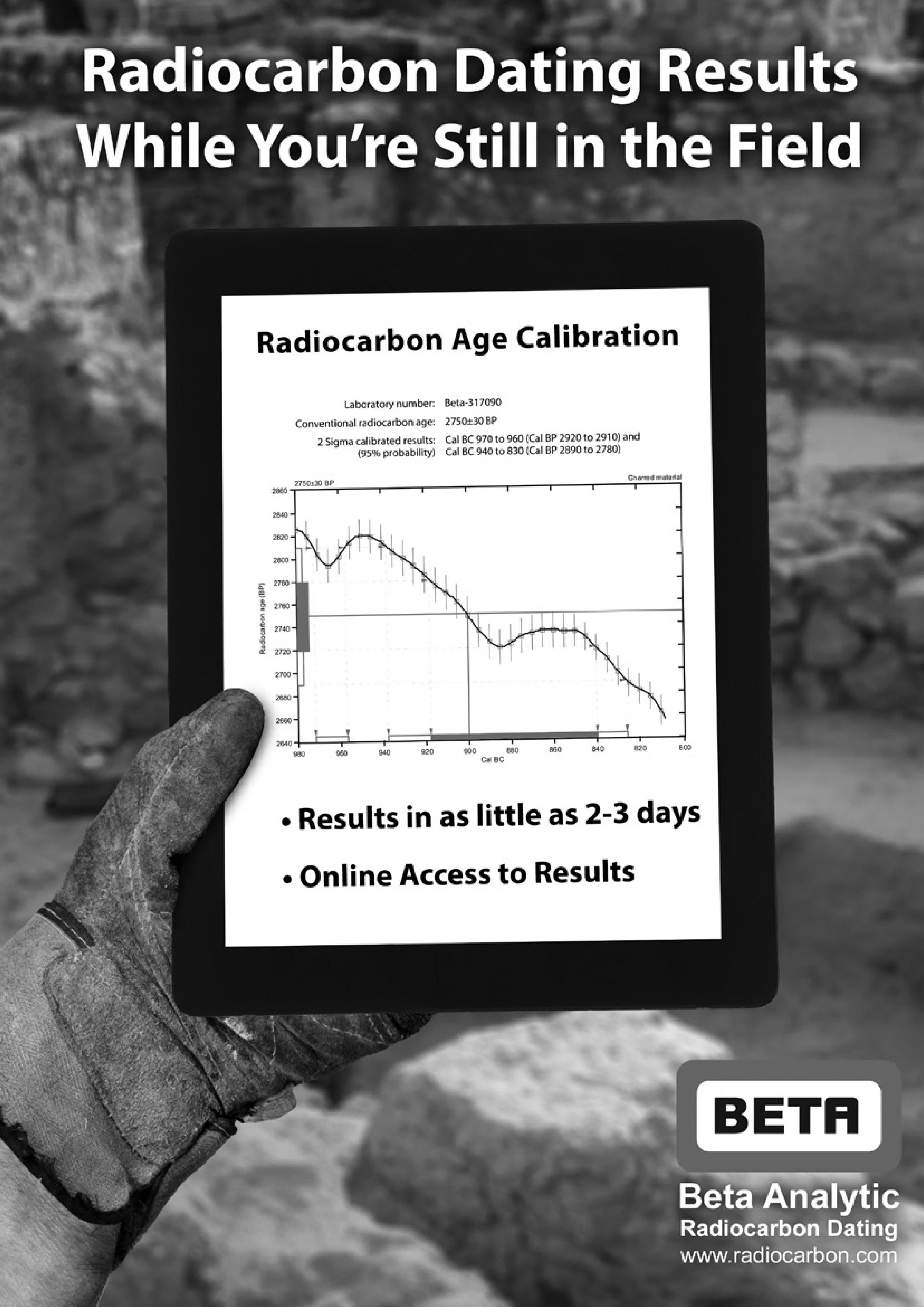
TIBCA was applied to a case study of the 2011 Tohoku-oki tsunami. Here, it was used to first, conduct a building survey to classify the type and damage level of buildings in Yuriage, Japan, using pre – and post-event Google StreetView imagery and second, to conduct a hazard modelling study to estimate their flood depth exposure. The modelling study investigated three high-resolution methods of representing buildings, two considering them as static features and one considering them dynamically to simulate collapse. These ”building aware” models matched well with the field data in Yuriage, with those considering building collapse, in particular, providing the best estimates. Conversely, the building-exclusive models that were tested were unable to reproduce the flow conditions accurately.

In total, 721 buildings were examined and characterised with respect to their type, damage level and hazard exposure. These were used to develop fragility curves for a range of building types, damage states and hazard scenarios. Comparison of these curves to existing field-based work confirmed their accuracy and demonstrated that: (1) the web – based building survey tool was effective at classifying buildings remotely, (2) the ”building aware” models predicted flood depths that correlated with the damage sustained by buildings and (3) the type/damage classification systems that were used were effective at precisely describing building characteristics. As such, TIBCA represents significant advances in terms of increasing the capabilities of remote survey techniques, modelling tsunami inundation in the built environment and developing more accurate and precisely defined fragility curves.

Retired Geologists Society meeting at University House in Melbourne on 16 December 2013.

Left to right: Jim Bowler, Charles Lawrence, Lindsay Thomas, Phil Macumber, Bernie Joyce.

Photo credit Bernie Joyce


Radiocarbon Dating Results
While You're Still in the Field
Radiocarbon Age Calibration
Laboratory number: Beta-317090
Conventional radiocarbon age: 2750±30 BP
2 Sigma calibrated results: Cal BC 970 to 960 (Cal BP 2920 to 2910) and
(95% probability) Cal BC 940 to 830 (Cal BP 2890 to 2780)
2750±30 BP
Charred material
Radiocarbon age (BP)
Cal BC
• Results in as little as 2-3 days
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