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COVER: Cylinder Beach, North Stradbroke Island, taken from the Triassic volcanics of the Point Lookout headland at the northern tip of the island. The "island" was initially a series of coastal dunes on the fringe of the Australian continental shelf, formed from the accumulation of Cainozoic sediments on rocky outcrops during the arid glacial phases of the Quaternary. The inundation of Moreton Bay during the mid-Holocene marine transgression (ca. 6 ka) effectively isolated North Stradbroke into an off-shore island. (Photo: E. Petherick; Caption: L. Petherick)

BELOW: Erosion gullies in the Lake Mulurulu lunette, looking west onto the dry lake bed. Work currently being undertaken at this site, at the northern end of the Willandra Lakes World Heritage Area in western New South Wales, Australia, aims to combine stratigraphy, geochronology and isotope geochemistry techniques to provide a comprehensive environmental history for the lake over the last 40 ka or so of aboriginal occupation in the area. (Photo: T. Kelly)

Editorial

Dear Fellow Quaternarists,

AQUA has always been a strong supporter of its younger members. This issue of *Quaternary Australasia* certainly highlights the diverse work being undertaken by early career researchers – students and postdocs alike - within AQUA, not only in terms of research, but also in their contribution to the research community.

In this issue, two research papers present different approaches to research on Quaternary aridity in Australia. Lynda Petherick and colleagues present a high resolution, multiple proxy record of palaeoenvironmental change from a site on the eastern Australian coast, focusing on fluctuations in aeolian input from the arid interior. Fiona Dyason assesses dental cementum analysis on macropod teeth as an approach to determine seasonal use of archaeological sites in the arid zone. Thanks once again to the reviewers of these manuscripts for their constructive comments.

The Quaternary research community has been busy this year. Many Quaternarists attended the Australian and New Zealand Geomorphology Group meeting in Queenstown, Tasmania in February, braving the inclement weather to discuss glacial, arid, fluvial and tectonically active landscapes. Others attended the Archaeological Science conference held at the Australian National University for a forum on the latest techniques and archaeological issues. Several of our members campaigned for increased awareness of the potential contributions of Quaternary and environmental science to politics at the annual Science Meets Parliament in Canberra; I'm hoping their messages made a lasting impact!

Although this issue has a distinctly Australian focus, our colleagues across the Tasman have been equally busy. This issue includes a call for donations for the newly renamed "Colin Vucetich prize" for tephrochronology in honour of the late scientist. I would like to encourage New Zealand Quaternarists to consider more actively contributing to future issues of *Quaternary Australasia*.

Finally, we pay our respects to the late Professors Jack Mabbutt and Liu Tungsheng, both of whom passed away recently. Professor Tungsheng was respected for his efforts to build strong research connections between China and Australia in the 1970s, and featured in an article in the July issue last year.

Best wishes

Kathryn Fitzsimmons

President's Pen

Dear Quaternarists,

Greetings from Queensland.

I am the newly elected AQUA president and there have been several changes to the AQUA executive which give the organization a decidedly Queensland flavour. I would also like to welcome onboard our new secretary Craig Sloss and treasurer Sam Marx. In addition, we are currently looking for a replacement treasurer from the sunshine state at the moment and should have this position finalized shortly.

I would like to thank the retiring members (Stuart Pearson and Janelle Stevenson) of the AQUA committee for their hard work and dedication in their respective positions of secretary and treasurer. Furthermore, the executive in particular and AQUA in general should be commended for the success of the recent INQUA conference in Cairns. I am looking forward to working with the AQUA executive in developing the next Bi-Annual meeting in South Australia (December 2008), as well as continuing to demonstrate the relevance of Quaternary Science in the public and the political spheres.

I am very honoured to be elected president and hope to continue the exemplary work of the previous presidents (particularly our recently retired president Henk Heijnis) in furthering the cause of Quaternary Science in Australia, New Zealand and beyond.

Best Wishes

Patrick Moss

Past President's Pencil

The recent 2008 annual general meeting was well attended and we now have a new president, secretary and treasurer. I would like to congratulate the new members of the executive on their election to the AQUA executive committee. As our new president stated, the new executive has a Queensland flavour. Congratulations to Patrick Moss (new President), Craig Schloss (secretary) and Sam Marx (treasurer). I would like to thank the whole of the AQUA executive for their tireless work during my time as president (it sure made my job easier).

We now have an AQUA- Biannual field meeting in South Australia to look forward to and an organisation with a sound financial basis. I hope to see many members at the meeting in December. It has been an honour to have been on the AQUA executive, first as secretary and secondly as President.

Yours Quaternarily

Henk Heijnis

Late Quaternary aridity and dust transport pathways in eastern Australia

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Abstract

A high-resolution, multiproxy record of palaeoclimatic and palaeoenvironmental variability extending to ca. 42 cal. ka has been constructed from lake sediment from Native Companion Lagoon (NCL), North Stradbroke Island (NSI), Queensland. Aeolian materials extracted from the lake sediment act as a proxy for aridity in eastern Australia. ICP-MS trace element analysis of the aeolian sediment and subsequent provenancing of the far-traveled dust component show variations in dominant dust source areas for NSI, with periods of increased aridity during the late Pleistocene showing increased input into NCL from the Murray-Darling Basin and central South Australia. Conversely, during periods of decreased aridity, dust is transported to NCL from a wide range of source areas, which may reflect increased sediment supply (e.g. due to increased precipitation under a strengthened summer monsoon regime). Variability in the dominance of continental dust source areas for NCL indicates variability in the position and intensity of dust transport pathways to NSI, reflecting major changes in atmospheric circulation patterns over Australia. Palynological and charcoal analyses from the NCL sediment support the record of aeolian sedimentation, providing an indication of local conditions on NSI.

Introduction

In recent times there have been a number of studies into palaeoclimatic and palaeoenvironmental variability in eastern Australia, providing valuable insights into the nature of the late Quaternary. However, there are still only a few long, continuous, high resolution palaeo-records for the region. The Native Companion Lagoon (NCL) record from North Stradbroke Island (NSI) presented here bridges an important spatial gap between the long palaeo-records from the Atherton Tablelands, northern Queensland (Kershaw, 1976, 1994; Haberle, 2005; Turney et al., 2006), Ulungra Springs, New South Wales (Dodson and Wright, 1989) and Barrington Tops, New South Wales (Dodson et al., 1986; Sweller and Martin, 2001). Palaeo-records from subtropical Australia are rare, with the only record comparable to NCL being the 57 ^{14}C kyr Lake Allom record from Fraser Island (Longmore, 1997; Donders et al., 2006). The Lake Allom record provides important insights into subtropical palaeoclimatic variability during the late Quaternary; however, a hiatus in sedimentation 28-10 ^{14}C kyr means that no data for the Last Glacial Maximum (LGM) and deglaciation are available. There are no such hiatuses in the NCL record, meaning that the record is a continuous representation of the past 42 cal. kyr.

In addition to pollen and charcoal, a record of aeolian dust deposition is presented. Despite the fact that Australian dust has been identified in the Tasman Sea (Hesse, 1994), New Zealand (McGowan et al., 2005) and Antarctic ice cores (Revel-Rolland et al., 2006), high resolution, long, terrestrial records of dust deposition available for Australia are scarce. Indeed, the majority of such records for the Southern Hemisphere extending ≥25 kyr come from Antarctica (e.g. Petit et al., 1990; Grousset et al., 1992; Basile et al., 1997, Petit et al., 1999).

In this paper a 42 cal. kyr multiproxy record of palaeoclimatic and palaeoenvironmental variability from subtropical Australia is presented. Using a geochemical “fingerprinting” methodology, aeolian dust is provenanced to continental source area. Knowledge of the varying dominance of source areas through time allows dust transport pathways for eastern Australia to be reconstructed, and atmospheric circulation patterns to be postulated.

Physical Setting: North Stradbroke Island

NSI is a large sand island located in Moreton Bay, southeast Queensland (Figure 1) (Tejan–Kella et al., 1990). Climate on the island is described as ‘sub-tropical’ under the Köppen classification (Bureau of Meteorology (BOM), 2005), and is characterised by warm, humid summers and relatively mild, dry winters (Clifford and Specht, 1979; Colls and Whitaker, 1990; Thompson, 1992). Annual average rainfall is approximately 1600 mm and the dominant wind direction is southeasterly (Clifford and Specht, 1979; Thompson, 1992).

Situated at the southern end of NSI (Figure 1), NCL is approximately 1 km in length by approximately 0.3 km at an elevation of 20 m a.s..l. NCL is a perched, internally draining lagoon, typical of the majority of freshwater lakes on NSI. As NCL is a closed system, with no fluvial input, it is believed that the only input of sediment is through the deposition of both local and far-traveled materials by wind. The main source of local aeolian sediment is believed to be from the large, parabolic quartz sand dunes that surround NCL.

Such dunes are typical of NSI and are usually vegetated by *Eucalyptus* forest with *Banksia* and *Casuarina* also present. The dunes on NSI were formed over a number of dune-building phases from Marine Isotope Stage 12 (486 – 430 ka) through to the Holocene (Kelley and Baker, 1984; Ward, 2006). The podzol nature of the dunes (i.e. highly porous with low organic and clay content (Consolidated Rutile Limited, 2005)) suggests that overland flow into NCL is rare. Deposition by aeolian processes of local sediments (e.g. from the sand dunes surrounding NCL) is believed to be restricted to the margins of the lake bed. Even when NCL is dry, such as at the time of core extraction, sand transport onto the lake bed is retarded by its peaty nature and rapid colonisation by plants.

Methodology

3.1 CORE EXTRACTION, ASHING & DATING

Using a Russian D-section corer, a 3.8 m organic-rich sediment core was extracted from NCL. The presence of a sand layer at 3.8 m indicates that this is the maximum depth of lake sediment. The core was sampled at 5 mm intervals and dried at 65°C for 65 hours to remove moisture. The dried NCL samples were ashed in a high-temperature furnace at 490°C for 12 hours to remove organic material, retaining the inorganic, aeolian fraction.

Nineteen dried sediment samples (Table 1) for the 3.8 m core were sent to the University of Waikato radiocarbon laboratory, New Zealand, for AMS radiocarbon dating to establish age control (http://www.radiocarbondating.com). The samples were organic-rich lake sediment, with varying concentrations of quartz sand. Samples NC-1-567 and NC-1-677 returned ages close to the limit of radiocarbon dating (Table 1) (Allen and Holdaway, 1995; Fifield et al., 2001), and so should be treated with some degree of caution. In addition, 2 dates (NC-1-270: 13570 ±100 ^{14}C yr. and NC-1-312: 13534 ± 99 ^{14}C yr.) returned age reversals (Table 1). However, the age of NC-1-270 is within the error margins of the radiocarbon dating, and so was considered suitable for describing the age-depth chronology of the record. Even with the inclusion of NC-1-312, the radiocarbon age-depth relationship could be described by the cubic polynomial y = -2E-07x3 + 0.001x2 + 9.1343x, which estimated 98% of the variance. The radiocarbon dates were converted to calendar years using the Hughen et al. (2006) Cariaco Basin chronology (Petherick et al., accepted – a).

3.2 POLLEN AND CHARCOAL ANALYSES

The methodology of van der Kaars (1991) was employed to analyse pollen and charcoal in 66 NCL sediment samples, providing a temporal resolution of ca. 500 years. After the addition of lycopod spores (to assist in the calculation of pollen and charcoal concentrations), sodium pyrophosphate was used to deflocculate the samples. Sodium polytungstate, a heavy liquid solution with a specific gravity of 2.0, was then used to separate the organic fraction (including pollen and charcoal) from the lithogenic fraction. Finally, the pollen grains were stained by acetolysis before being placed onto slides in glycerol for analysis at X 650

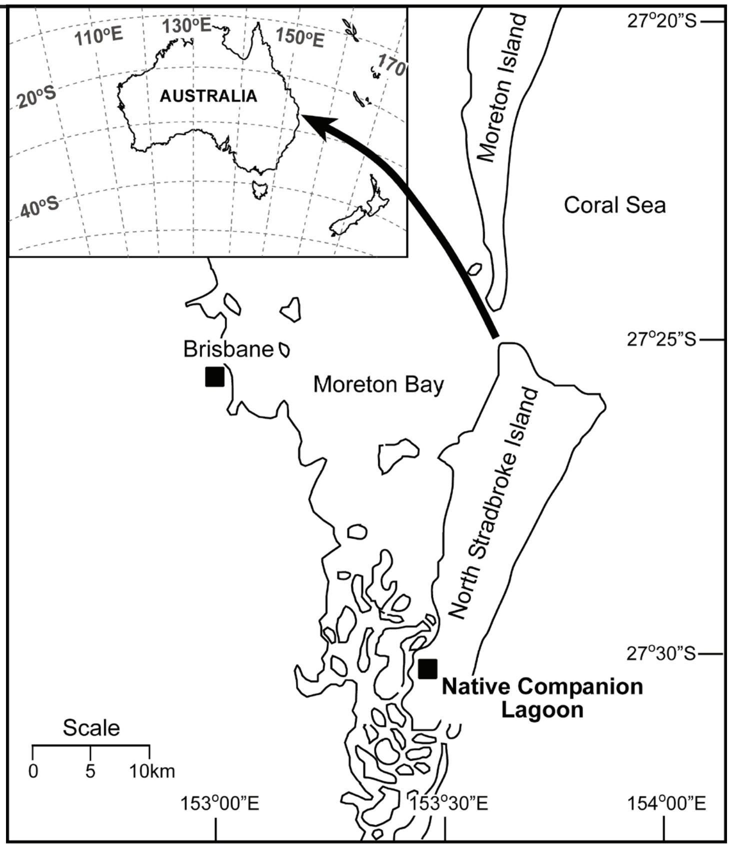

Figure 1: The study site: North Stradbroke Island.

magnification under a light microscope. A minimum of 100 identifiable pollen grains were counted for each NCL sample. Charcoal was identified as black angular particles with a diameter >10 μm. At least 200 charcoal points per NCL sample were counted using the point count method of Clark (1982).

3.3 ICP-MS TRACE ELEMENT ANALYSIS

3.3.1 Sample preparation and analytical techniques

One hundred and thirty-one ashed NCL sediment samples were selected to undergo ICP-MS trace element analysis. In addition, 2 samples from the quartz sand dunes were analysed in order to determine the chemistry of the local aeolian component.

Preparation of the samples for ICP-MS was conducted using the well-established beaker hotplate approach (e.g. Marx et al., 2005). The highly static nature of the samples meant that there was a chance that sediment may stick to the glassware and potentially be lost. To minimise this risk, after weighing the samples were transferred into beakers and suspended in dilute nitric acid (HNO_3). Hydrofluoric acid was used to digest the sediment samples on a hotplate at 100°C overnight. Post-acid digestion, the samples were 2000X diluted and centrifuged. An aliquot of each sample was added to a test tube containing 0.18 g standard solution, which contained known quantities of elements such as rhodium, rhenium and indium which are unlikely to be present in the samples. Sample weight was brought to approximately 12 g with HNO_3 before the samples were centrifuged again. Blank samples went through

Sample ID	Average depth (mm)	Description	Age (^{14}C yr.)	Error (^{14}C yr.)	Age (cal. yr. BP)	Error (cal. yr.)
NC-1-001	5	Organic-rich sediment	540	± 36	544	± 30
NC-1-028	197.5	Organic-rich sediment	1745	± 37	1657	± 52
NC-1-069	395	Organic-rich sediment	6353	± 50	7279	± 50
NC-1-081	455	Organic-rich sediment	6176	± 47	7074	± 78
NC-1-149	792.5	Organic-rich sediment	9222	± 65	10381	± 103
NC-1-177	935	Organic-rich sediment	10130	± 73	11764	± 171
NC-1-207	1090.5	Organic-rich sediment	11478	± 79	13336	± 98
NC-1-224	1172.5	Organic-rich sediment	12714	± 90	14811	± 136
NC-1-256	1334.5	Organic-rich sediment	13467	± 98	15678	± 155
NC-1-270	1403	Organic-rich sediment	13570	± 100	15796	± 157
NC-1-279	1450	Organic-rich sediment	13586	± 100	15814	±158
NC-1-301	1567	Organic-rich sediment	14762	± 116	17629	± 269
NC-1-335	1737.5	Organic-rich sediment	15999	± 132	19140	± 141
NC-1-394	1982	Organic-rich sediment	19311	± 157	22961	± 244
NC-1-528	2667.5	Organic-rich sediment	28684	± 456	34080	± 496
NC-1-567	2862.5	Organic-rich sediment	33187	± 816	38573	± 822
NC-1-677	3482.5	Organic-rich sediment	35757	± 1147	41018	± 1060

Table 1: Results of radiocarbon dating and subsequent calibration of19 NCL samples.

	Average NCL	NC-Q-01	NC-Q-02
Li	6,915	4,876	4,851
Be	1,486	41	49
Sc	17,564	123	217
Ti	12,797,730	328,776	587,765
V	294,299	886	2,093
Cr	108,063	468	1,075
Mn	180,223	4,120	9,954
Co	12,875	94	203
Ni	32,423	123	234
Cu	73,918	393	587
Zn	31,351	803	1,288
Ga	20,808	62	166
As	15,628	97	220
Rb	13,793	277	560
Sr	391,125	1,249	5,786
Y	31,973	659	606
Zr	175,525	7,721	5,818
Nb	18,567	340	776
Mo	6,092	24	43
Cd	337	3	5
Sn	4,127	59	118
Sb	719	87	107
Cs	901	62	67
Ba	179,399	5,158	7,216
La	57,921	529	902
Ce	120,836	1,110	1,816
Pr	14,277	128	212
Nd	53,775	478	773
Sm	10,146	96	148
Eu	1,869	16	22
Gd	2,962	90	121
Tb	6,348	16	19
Dy	6,457	109	113
Ho	1,277	24	23
Er	3,466	73	66
Tm	515	12	11
Yb	3,301	83	73
Lu	485	13	11
Hf	4,895	225	166
Ta	1,361	23	49
W	1,663	34	61
Tl	109	3	5
Pb	46,606	457	1,680
Th	20,495	272	373
U	4,409	98	94

Table 2: Trace element composition of averaged NCL samples and 2 local dune sand samples (NC-Q-01 and NC-Q-02)

the same procedures to provide controls. The samples underwent trace element analysis on the Thermo Electron X Series ICP-MS at the ACQUIRE laboratory, the University of Queensland, following the method of Eggins et al. (1997).

3.3.2 Source area samples

In order to determine continental source area chemistries, 149 samples were collected from across eastern Australia, from regions known to be, or have been, active dust source areas (Figure 2) (e.g. Middleton, 1984; McTainsh et al., 1998; 2005; Bullard and McTainsh, 2003). Dust storms are accountable for the removal of large amounts of soil in semi-arid regions (McTainsh et al., 1998), and as such, surface sediment samples were collected from regions identified as having high frequency of dust storms. For example, recent major dust storm events have occurred in the Simpson Desert/Channel Country (December 1987: Knight et al., 1995), Eyre Peninsula (May 1994: Butler et al., 1995) and western Queensland/Murray Darling Basin (October 2002: McTainsh et al., 2002). Surface sediment samples were collected from sites (e.g. floodplains, dunes, dry lake surfaces, riverbanks) in regions such as these, and underwent identical preparation and ICP-MS analysis as the NCL samples.

3.4 SEPARATION OF LOCAL AND FAR-TRAVELED AEOLIAN COMPONENTS

The NCL sediment samples had a distinct local aeolian component, which needed to be distinguished in order to provenance only the ‘foreign’ far-traveled dust component. The local component was predominantly quartz sand, with a biogenic silica content of <1% (Moss et al., 2006) and as such had very low concentrations of trace elements (Table 2). Conversely, the far-traveled dust was trace element-rich, characterised by elements associated with clays, believed to be sourced solely from the Australian mainland. Four elements (Ga, Ni, Tl and Sc) were used as proxies for far-traveled materials such as clays and goethite allowing local and far-traveled components to be separated by geochemistry (Petherick et al., accepted – b).

3.5 PROVENANCING THE FAR-TRAVELED DUST

Using a geochemical "fingerprinting" technique (Marx et al., 2005; Petherick et al., accepted – b), the far-traveled dust component was provenanced to continental source area(s). The technique involves the statistical comparison of the trace element chemistry of each NCL sample with that of the 149 source area samples in order to find the most likely match. Although 44 trace elements were analysed by ICP-MS, only elements that were conservative (i.e. immobile) through the sediment core were suitable for use in provenancing. As such, elements susceptible to loss through weathering (e.g. alkali earth elements), loss through mineral sorting (e.g. zirconium, hafnium) or high solubility in water (e.g. barium, strontium) were rejected. The concentrations of elements whose behaviour was unknown were plotted against elements known to be conservative in terrestrial environments (e.g. thorium, rare earth elements) (Kamber et al., 2005). Strong linear relationships indicated that the element with previously unknown behaviour was also immobile through the core, and could thus be used to provenance the dust. Eventually, of the 44 elements, we deemed 16 to be immobile through the core, and therefore useful for provenancing.

The chemistry of each NCL sample was compared with potential source area samples using a ternary mixing model (Petherick et al., accepted – b). This statistical comparison was used to establish the contribution of material into NCL from the 3 most likely source areas: comprised of a southeast Queensland source area and 2 continental source areas (Petherick et al., accepted – b). Although 149 samples were taken from regions either currently active or known to be active in the past as dust source areas, it should be noted that there is a possibility that an un-sampled source area contributed to the NCL record.

4.0 Results: The 42 kyr NCL record

4.1 THE NATURE OF THE NCL RECORD

The NCL core was characterised by organic-rich sediment with macrofossils and quartz present in varying concentrations (Figure 3). The record of total (i.e. combined local and far-traveled) aeolian flux shows a series of peaks and troughs for the past 42 kyr and does not appear to be random or noisy (Figure 3). Total aeolian sediment flux ranges from 0.32 g m^{-2} $yr.^{-1}$ to 28.88 g m^{-2} yr^{-1}.

4.2 POLLEN AND CHARCOAL ANALYSES

The NCL pollen record indicates that the vegetation surrounding NCL for the past 42 kyr has been dominated by sclerophyll woodland, predominantly Casuarinaceae (Figure 3). The pollen record correlates well with the record of aeolian sedimentation, with changes in sedimentation corresponding with changes in vegetation around NCL. The NCL charcoal record is also consistent with the record of sedimentation, with periods of increased charcoal corresponding with periods of increased aeolian sediment flux (Figure 3).

4.3 PROVENANCE OF THE FAR-TRAVELED DUST

NCL sediment sample chemistries for the entire record are presented in Table 2 (NB: previous elemental data published by Petherick et al. (accepted – b) represented only 0 – 25 cal. ka, and as such differs slightly from the data presented here).

The results of the dust provenancing identified the continental source areas whose chemistry most closely matches that of the NCL samples. A potential limitation of this geochemical "fingerprinting" method (and inherent in most provenancing studies) is the possibility that all dust source areas in eastern Australia have not been sampled. So, it should be kept in mind that there may be dust transport from source areas that have not been sampled. However, as discussed in Section 3.5, surface sediment samples were collected from regions that are, or have been, dominant dust source areas for eastern Australia (Figure 2), minimizing the likelihood of major input from another region.

Comparison of the geochemistry of the far-traveled dust fraction with that of potential continental dust source area indicated that overall the MDB has been the most dominant dust source area for eastern Australian

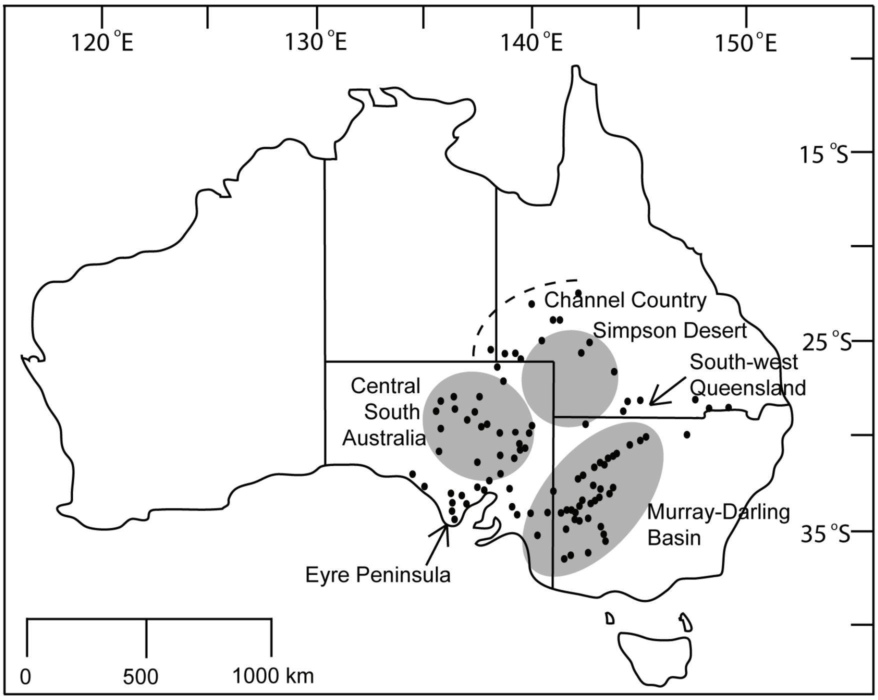

Figure 2: Map showing potential dust source areas for which surface chemistries were established in relation to the location of North Stradbroke Island.

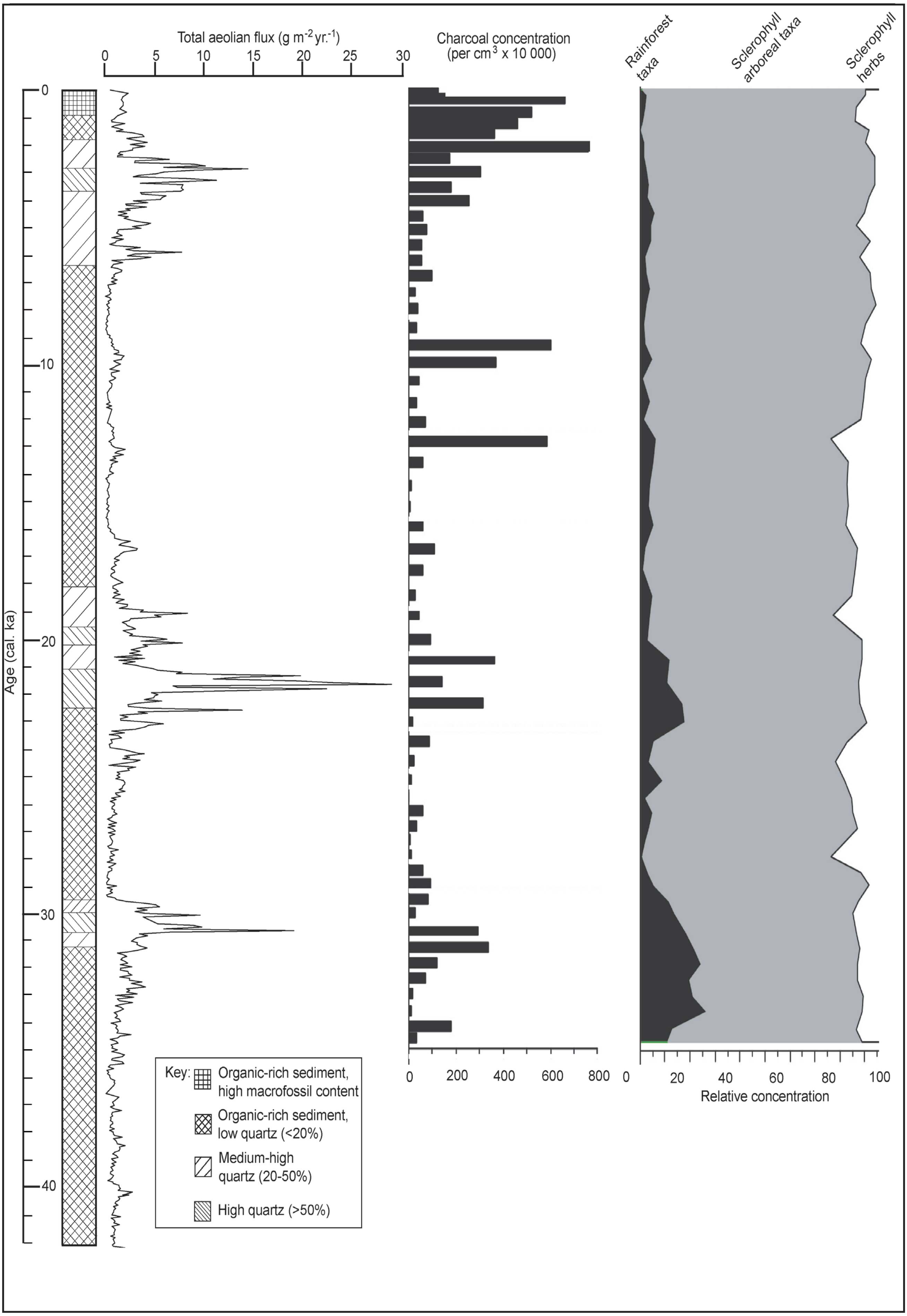

Figure 3: The 42 kyr record from NCL showing core lithology, total aeolian sediment flux, charcoal and pollen.

during the past 42 kyr. Periods of increased aeolian sedimentation in the NCL record are characterised by dust input from the MDB and central South Australia. Periods of decreased aeolian sedimentation are characterised by dust input from a wide range of continental source areas, such as the Channel Country, Eyre Peninsula, southwestern Queensland and the northern MDB.

5.0 Palaeodust transport pathways and aridity in eastern Australia through the late Quaternary

Periods of increased aeolian sedimentation in the NCL record indicate increased dust transport from both local and continental dust source areas. Intensified dust transport indicates increased surface susceptibility to wind erosion, associated with decreased soil moisture and reduced vegetation cover (McTainsh et al., 1998). Such conditions are associated with reduced effective precipitation (defined here as precipitation minus evaporation) and increased aridity. Conversely, periods of decreased aeolian sedimentation suggest a stabilised landscape due to increased effective precipitation.

Three interrelated variables influence the transport of dust from mainland Australia to NSI: aridity and sediment supply in the source area, and atmospheric circulation patterns. Periods of increased aridity in mainland Australia would have been associated with reduced effective precipitation leading to decreased soil moisture and reduced vegetation cover. The extent and type of vegetation cover plays a significant role in the susceptibility of a surface to erosion by the wind (McTainsh et al., 1989; Shao, 2000; Day et al., 2003). As such, sources of moisture such as groundwater supply (a critical factor for vegetation) are also important (Coughlan, 2003).

With the exception of longitudinal dunes, in order for a region (e.g. playas, floodplains) to act continuously as a dust source area, it must have a replenishable supply of sediment (e.g. through fluvial or colluvial deposition) for deflation (McTainsh et al., 1989; 1998; Bullard and McTainsh, 2003). However, even if local conditions are suitable in a potential source area, dust transport to NSI is dependent on favourable weather patterns for dust transport.

5.1 LATE QUATERNARY PALAEOCLIMATES OF EASTERN AUSTRALIA

5.1.1 Pre-Last Glacial Maximum: 42 – 24 ka

The period prior to the Last Glacial Maximum (LGM) is characterised by relatively low aeolian sediment flux, with the exception of a peak centered on ca. 30.8 ka. Vegetation around NCL appears to have been dominated by mixed Eucalypt/*Casuarina* forest. There is also a significant presence of rainforest and relatively high representation of aquatics and ferns. Overall, this indicates that climate on NSI pre-LGM was characterised by increased effective precipitation, leading to a stabilized landscape not susceptible to wind erosion. Charcoal values during this period are high, which is probably a reflection of increased biomass (i.e. *Eucalyptus*) available for burning. However, conditions coeval with the 30.8 ka peak in aeolian sedimentation appear to have been characterised by an increased representation of *Casuarina*, suggesting a drier climate.

The pre-LGM 30.8 ka peak in aeolian sedimentation, indicating increased aridity in eastern Australia, corresponds well with other records emerging from the Southern Hemisphere. For example, records of glacial advance in New Zealand (Suggate, 1990; Suggate and Almond, 2005) and Chile (Denton et al., 1999), New Zealand maar lake records (Alloway et al., 2007), the Taylor Dome (Steig et al., 2000) and Dome C nss-Ca^{+2} (Röthlisberger et al., 2002) records and the EPICA Dronning Maud Land ^{18}O record (EPICA community members, 2006) provide evidence for a period prior to the LGM during which environmental conditions were similar to those during the LGM.

5.1.2 Last Glacial Maximum: 24 – 21 ka

The LGM is shown as the period of maximum aeolian sedimentation in the 42 ka NCL record, which is in agreement with well-established assertion that the LGM was a period of characterised by increased aridity and atmospheric dust concentrations both globally and in Australia (e.g. Bowler, 1976; Jouzel et al., 1995; De Deckker, 2001). Increased dune activity on NSI during the LGM is indicated by the significant input of local sand and dust into the NCL sediment, probably due to decreased vegetation cover associated with decreased effective precipitation and increased landscape susceptibility to fire.

Increased aeolian sedimentation in the NCL record, peaking at ca. 21.9 ka, corresponds with an increased representation of *Casuarina* in the pollen record, indicating similar environmental conditions as during the 30.8 ka peak. Rainforest and eucalypt presence during these periods decreased, suggesting a drier climate.

5.1.3 Last Termination: 21 – 12 ka

The Last Termination is characterised by a generally decreasing trend in aeolian sedimentation, indicating decreased aridity. However, there are several reversals (ca. 20.2 ka, 19.2 ka and 16.8 ka) to what appear to be near-glacial conditions during the termination, which is possibly a reflection of instability in the climate system. Vegetation around NCL during this period was dominated by *Casuarina*, with low representation of rainforest and eucalypts, suggesting conditions were still fairly dry. However, the lower (500 yr.) resolution of the pollen may have just picked out the reversals, and not the overall trend of decreasing aridity.

5.1.4 The Holocene: 12 – 0 ka

The early to mid Holocene (12 – 7 ka) in the NCL record is characterised by comparatively low aeolian sedimentation, indicating decreased aridity.
The dominant vegetation during this period was Casuarinaceae forest, although there was also an increased presence of eucalypts and rainforest. The early Holocene peak in aquatics may indicate 'swampy' conditions at NCL. The early Holocene marks the onset of the presence of *Banksia*, which may be a reflection of the development of 'Wallum' heath which occurs throughout the Holocene period.

Very low aeolian sediment flux (≥ 0.32 g m^{-2} $yr.^{-1}$) during the early Holocene coincides well with a period of humid climate recognised in a number of Australian palaeo-records (e.g. Luly, 1993; Nott and Price, 1994;

Kershaw, 1995; Dodson and Ono, 1997; Dodson, 1998). Under conditions of increased effective precipitation, soil moisture and vegetation cover are likely to have increased leading to reduced susceptibility of surface sediments to wind erosion. The lowest aeolian sediment flux (0.14 g m^{-2} $yr.^{-1}$) in the entire record occurs at 7.6 ka, which may indicate a Holocene climatic optimum characterised by increased effective precipitation. Peaks in rainforest and ferns during this period provide supporting evidence for a phase of increased effective precipitation in eastern Australia.

From ca. 7 ka aeolian sediment flux increases, peaking at 14.43 g m^{-2} $yr.^{-1}$ at ca. 2.9 ka, indicating a period of climatic deterioration. This period of increased aridity may represent a late Holocene dry phase (McGowan et al., 2007), which has been found across eastern Australia as a period of decreased effective precipitation, increased windiness and increased fire frequency (e.g. Bowler et al., 1976; Wasson, 1976; Wasson, 1979; Ross et al., 1992; Harrison, 1993; Luly, 1993; Magee et al., 1995; Shulmeister and Lees, 1995; Ahmad, 1996; Longmore, 1998). Increased terrigenous kaolinite in marine sediments off the coast of southern Australia indicates intensified aeolian activity from 5 ka (Gingele et al., 2007), which is in agreement with the NCL record.

The presence of mangroves in the NCL pollen record during this period suggests higher sea levels, as reported by various authors (e.g. Nanson et al., 1992). Shoreline erosion by transgressing seas and subsequent transport of loose sands by onshore winds is likely to have led to intensified dune building on NSI, which is supported by the increase in sedimentation seen in the NCL record. Stronger onshore winds are also possibly the mechanism by which mangrove pollens were transported to NCL.

Increased charcoal values in the NCL record occur from 2 ka, which may be a reflection of sustained burning associated with intensified Aboriginal occupation of the region. Aeolian sedimentation decreases from ca. 2.5 ka, indicating decreased aridity and the onset of modern climatic conditions. Vegetation around NCL was dominated by Casuarinaceae forest, with an increased representation of grasses possibly indicating a more open understorey. The decreased aridity inferred from the NCL record disagrees with the trend towards drier climatic conditions indicated by several records (e.g. Bowler, 1976; Nott and Price, 1994; Martin, 1999; Hesse et al., 2004). Other records, however, indicate increased effective precipitation in the late Holocene (e.g. Wasson, 1976; Dodson et al., 1986; Mooney, 1997; Sweller and Martin, 2001). These discrepancies may be an indication of increased seasonality, variability and/or instability in the climate system (Kershaw, 1995; Donders et al., 2006), possibly as a result of an increasingly variable ENSO (Stanley and De Deckker, 2001). The late Holocene weakening of the Australian summer monsoon (Wyrwoll and Miller, 2001) was possibly influenced by an intensified ENSO (Moy et al., 2002), and may have resulted in the reduction and subsequent exhaustion of sediment supply in dust source areas.

5.2 DUST TRANSPORT PATHWAYS AND PALAEOCLIMATE

Comparison of the results of the dust provenancing with the multiproxy NCL record indicate that periods of increased aridity are characterised by dust input from source areas distinct from those dominant during periods of decreased aridity (Figure 4). As such, dust transport pathways to NSI are different during periods of increased aridity compared with periods of decreased aridity, indicating that atmospheric circulation patterns for dust transport are also different.

5.2.1 Periods of increased aridity

The record of aeolian sedimentation indicates several periods of increased aridity during the past 42 kyr, such as pre-LGM (ca. 32 – 30 ka), the LGM (ca. 24 – 21 ka) and the late Holocene (ca. 7 – 2.5 ka). During these periods, dust input to NSI appears to be predominantly from the floodplains of the Darling and Murray Rivers and the palaeo-dunes of the MDB (Figure 4 (a)). The influence of dust from the MDB from 25 ka is supported by evidence for the drying out of lakes, waterways and adjacent landscapes in the Basin (e.g. Bowler et al., 1976; Harrison, 1993, Field et al., 2002), providing sediment suitable for deflation. Bullard and McTainsh (2003) propose that the MDB was the dominant dust source area for eastern Australia during the LGM, supported by evidence of increased dune building in the Basin 35 – 10 ka (Lomax et al., 2007).

The late Holocene arid phase is also characterised by dust input from the Darling River floodplains, with some input from the playa lakes (e.g. Lake Frome) of central South Australia. The input of dust from Lake Frome from ca. 5 ka corresponds well with a coeval phase of dune building in the Strzelecki Desert (Lomax et al., 2003).

The dominance of these continental source areas during periods of increased aridity may indicate enhanced meridional southwesterly winds transporting dust to NSI. Although this contrasts the theory of intensified westerly winds during the LGM (e.g. Thiede, 1979; Shulmeister et al., 2004), high concentrations of kaolinite off the east coast of Australia between 0 – 30°S (Griffin et al., 1968) supports our interpretation. This proposed dominance of meridional winds may be due to an equator-ward movement of Rossby Waves, resulting in the penetration of low pressure systems and associated cold fronts further north into the Australian continent (Hurrell et al., 1998).

5.2.2 Periods of decreased aridity

During periods of decreased aridity (as indicated by the record of aeolian sedimentation), such as 42 – 32 ka, 30 – 24 ka, 21 – 7 ka and 2.5 – 0 ka, the playa surface of Lake Frome and the river floodplains of central South Australia appear to have been the dominant dust source areas for NSI (Figure 4 (b)). The dominance of dust from Lake Frome during these periods corresponds well with interpreted increased aridity, aeolian activity and dune building in the region (Fitzsimmons et al., 2007).

Unlike during phases of increased aridity, a wide range of secondary source areas appear to have been active, including the Diamantina River floodplains of the Channel Country, Lake Eyre, the dunes of the Strzelecki Desert, the floodplains of the MDB, the palaeo-dunes of Eyre Peninsula and the Paroo River floodplains of southwest Queensland. The extensive range of influential dust source areas may be a function of increased effective precipitation leading to increased sediment supply for subsequent deflation and transport by the wind.

The dominance of more northern source areas, such as the Channel Country and southwest Queensland, suggests that dust transport in eastern Australia during periods of decreased aridity occurred under a regime of an intensified zonal westerly circulation. However, the humid conditions locally on NSI, inferred from the pollen record, indicates that the southeasterly winds coming off the Tasman Sea were more influential on the coastal climate than the zonal westerly winds.

6.0 Conclusions

The multiproxy record from NCL presented here provides the first high resolution record of aeolian dust deposition for Australia. In addition to a record of palaeoclimatic and palaeoenvironmental variability for the past 42 kyr, dust transport pathways for eastern Australia have been reconstructed using ICP-MS trace element analysis and dust provenancing.

There is a clear distinction in atmospheric circulation patterns between periods of increased aridity and periods of decreased aridity in eastern Australia. Periods of increased aridity are characterised by dust input from the floodplains of the MDB and central South Australia, which is interpreted as signifying an intensification of meridional southwesterly winds. Such conditions may be a result of an equator-ward shift in the position of the Rossby Waves, allowing low pressure systems and associated cold fronts to have greater influence over the Australian continent.

Conversely, periods of decreased dust deposition in the NCL record are thought to signify decreased aridity in eastern Australia. Dominant dust source areas during these periods are Lake Frome and central South Australia, with input from a wide range of secondary source areas including the Channel Country and southwest Queensland. Dust input to NSI from these more northern source areas suggests an intensification of zonal westerly winds, although evidence for humid conditions on NSI indicates that moist southeasterly winds coming off the Tasman Sea had greater influence on the climate of coastal southeast Queensland.

Overall, it appears that organic-rich lake sediments provide an excellent archive of aeolian dust deposits, pollen and charcoal, allowing high resolution multiproxy records of palaeoclimatic and palaeoenvironmental variability to be reconstructed.

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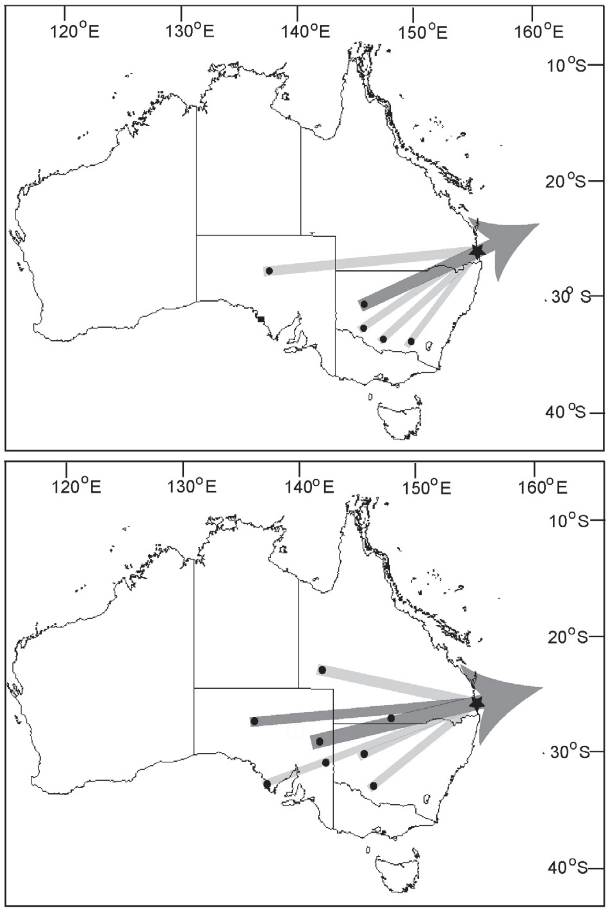

Figure 4: Dust transport pathway models for NSI during periods of (a) increased aridity (32 – 30 ka, 24 – 21 ka and 7 – 2.5 ka), and (b) decreased aridity (42 – 32 ka, 30 – 24 ka, 21 – 7 ka and 2.5 – 0 ka). Location of NSI represented by the star symbol.

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Dental cementum analysis of macropod teeth in Australia: a methodological enquiry

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Abstract
Seasonal use of many Australian arid-zone archaeological sites can be difficult to determine because of the poor preservation of faunal and plant remains. The dental cementum analysis technique can be used to demonstrate seasonality, and relies on a relatively robust part of the faunal assemblage. I analysed the teeth of macropods from arid, semi-arid and temperate zones of Australia. From the individuals that displayed clear banding in their dental cementum it was possible to determine season of death with some accuracy. There were, however, a large number of teeth in which the cementum bands were undefined or very pale. It is possible that these individuals demonstrate that the Australian arid zone is an environment in which cementum bands do not form according to a defined seasonal variation. With further investigation into this technique it could become an important tool in determining the seasonal use of Australian arid-zone archaeological sites.

Introduction
Evidence of seasonal activity or occupation at archaeological sites can be extremely useful in determining subsistence and life ways of prehistoric populations. Common seasonal indicators at archaeological sites include eggshell, growth bands in fish otoliths, plant remains and faunal remains (Bowdler and McGann, 1996; Klevezal, 1996; Pike-Tay et al., 1999). However, determining seasonality based on the presence or absence of these elements can be difficult when preservation is poor (Ward and Larcombe, 2003). Dental cementum analysis studies the seasonal growth bands in the microstructure of mammalian teeth in a similar fashion to otolith analysis (Klevezal and Kleinenburg, 1967). The advantage of this technique is that it relies on a relatively well preserved part of a mammalian faunal assemblage.

Dental cementum analysis has been used by ecologists since the 1960s, particularly in North America (Lieberman and Meadow, 1992; Wilson, 1978), as the age data provided is useful in determining appropriate wildlife management strategies (Thomas and Bandy, 1973). More recently, archaeologists have adapted dental cementum analysis techniques for the study of teeth from archaeological sites (Bourque et al., 1978; Wilson, 1978). This study investigates the use of dental cementum analysis on macropod teeth to determine climatic fluctuations, with a view to using the technique as a seasonality indicator for archaeological studies of Australian prehistoric sites.

The cause of the bands in dental cementum
Cementum bands in mammal teeth can be seen clearly under polarized light (Burke, 1993; Lieberman, 1993; Lieberman and Meadow, 1992). The cause of these bands is debated widely, with many explanations proposed. It has been suggested that the transparent cementum rings are either hyper-calcified (Klevezal and Kleinenburg, 1967) or hypo-calcified (Ohsumi et al., 1963) due to the difference in occlusal forces and nutrition related to seasonal diets. Collagen orientation is also cited as a possible cause for the cementum banding, with different orientations of collagen bands causing differences in appearance.

Factors thought to influence the banding include changes in an animal's nutrition caused by seasonality of dietary components and the occlusal forces required in their consumption (Hylander, 1986; Klevezal and Kleinenburg, 1967; Lieberman, 1994). Factors such as the impact of reproductive activity on the body's nutrition levels and hormones, the effect of climate and latitude have also been suggested as causal factors (Mitchell, 1967), but are refuted by some (Lieberman, 1994) as components of the nutritional or seasonal causes. The majority of theories related to the dental cementum banding of mammalian teeth can be viewed as relating to diet or a combination of season and diet.

The hypothesis that cementum banding is caused by diet has been supported by a manipulative experiment carried out by Lieberman (1993), who fed goats a controlled diet of varying nutritional content and softness. Lieberman (1993) found that there was a marked difference in the visibility and quality of banding between goats fed different foods. Eating hard, nutrient poor foods or eating softer, more nutritious foods resulted in different banding. The difference in food type and quality were thought to be comparable to the difference between the food available in spring/summer and autumn/winter, the winter and summer seasonal variations. This experiment has led to the assumption that cementum banding will be more differentiated in animals from regions with marked differences between winter and summer climates (Stallibrass, 1982).

Studies of dental cementum have been carried out in both Europe (Pike-Tay et al., 1999) and British Columbia (Lieberman and Meadow, 1992; Thomas and Bandy, 1973; Wilson, 1978). The successful use of dental cementum analysis on archaeological and modern specimens generally occurs in areas with a strong seasonal variation. Pike-Tay and Cosgrove (2002) have used dental cementum analysis on archaeological macropod specimens from Tasmania (Australia), a temperate area that has a winter/summer seasonal variation. Controls from the study showed that the cementum banding in *Macropus rufogriseus* (Bennett's wallaby) molars gave accurate seasonal data and could be used to estimate the age of an individual (Pike-Tay and Cosgrove, 2002).

The viability of the technique for investigating arid zone species has not previously been examined, and needs to be taken into account when attempting to analyse dental cementum in Australian species. The Australian arid zone environment has a wet season/dry season pulse, rather than the more temperate winter/summer seasonal variation. The difference in seasonal variation and the effect of frequent drought on the formation of dental cementum is unknown. The effect of arid environments on the formation of dental cementum was the focus of this study.

The effect of a wet season/dry season pulse on the formation of dental cementum bands is highly significant if dental cementum analysis is to be used to determine seasonality in arid zone archaeological sites. If the distinct banding is caused by seasonal food consumption, it is possible that Australian arid-zone species will not have distinct dental cementum bands, due to the comparably short wet season and the effect of frequent and long term drought conditions. In comparing species that range over both arid and temperate environments it would be expected that the temperate-zone individuals would exhibit more distinct banding than their arid-zone contemporaries.

The 30 teeth used for this study were from three species of large macropod, *Macropus rufus* (red kangaroo), *Macropus fuliginosus* (western grey kangaroo) and *Macropus robustus* (euro). These species were chosen as individuals were readily available in large numbers and skulls could be collected from a range of areas, allowing samples to be collected from both arid and temperate environments. Three species were used to eliminate any chance that the results seen were due to the dental peculiarities of a particular species.

All three species are grazing herbivores that are well suited to a diet of grasses, with new shoots eaten as a preference but poor quality grasses also being consumed when little else is available (Hume et al., 1989). This pattern remains consistent across the collection areas. Macropods are generally well suited to periods without access to water, though the *M. rufus* will drink frequently during hot weather and all three species will seek shade during the hottest part of the day (Hume et al., 1989).

Methodology

The teeth used for this study were supplied by Dr. Gavin Prideaux, a palaeontologist at the Museum of Western Australia, from animals collected on road trips between 2001 and 2003 at various sites throughout Australia at different times of year (Table 1). The animals' ages are unknown, but the state of decomposition when the animals were collected was used to estimate how fresh the carcasses were. Dr Prideaux withheld information on collection sites and dates until after the completion of the analysis to prevent any preconceptions during identification. The collection sites of the teeth used in the baseline analysis were therefore mapped after the dental cementum analysis had been completed (Figure 1).

The upper, right third molar (M3) was selected for analysis, as it was present in all individuals. Teeth were removed from the skulls by breaking away the surrounding bone with pliers to minimise damage to the dental cementum layers. The teeth were then sectioned and studied.

Dental cementum analysis; thin ground sectioning

There are two main techniques for preparing sections of teeth for dental cementum analysis. These are stained thin sections and thin ground sections, which Beasley et al. (1992) describe fully in terms of usefulness and practicality for archaeological studies. This study uses the thin ground sectioning technique.

Thin ground sections of the teeth of the animals listed in Table 1 were made by Frank Nemeth of the Geology Department of the University of Western Australia. The teeth were dried overnight at 40 °C before embedding them in Epotech 301 epoxy resin. Resin blocks were then set overnight in an oven at 40 °C, and cut using a 0.3 mm diamond blade to remove the unwanted part of the tooth's root. The new surface was ground smooth using a lapidary wheel and Carborundum powders with 220, 400 and 600 grit. Ground surfaces were then dried on a hot plate before being surface impregnated with Epotech 301 and allowed to dry overnight. The impregnated surface was ground again with 600 grit carborundum powder until smooth. The impregnation/grinding process was repeated until the section's surface was flat and striation free.

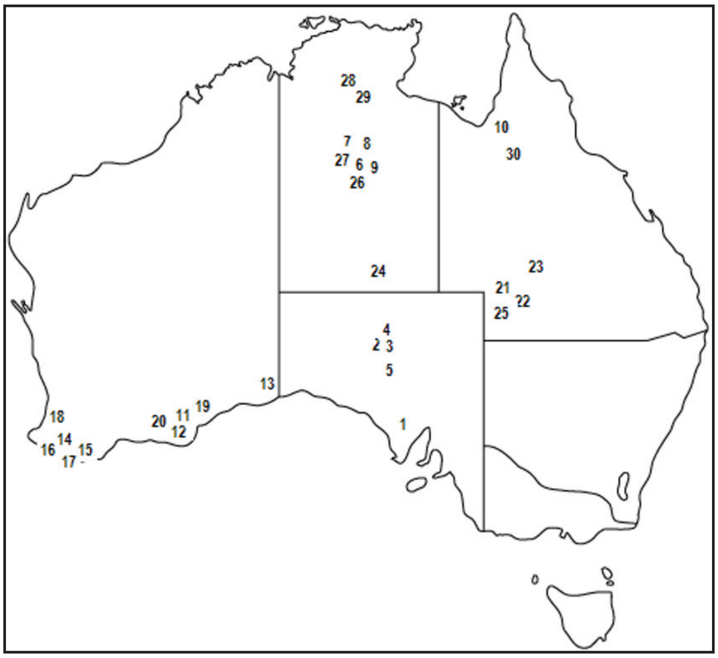

Figure 1. Map of Australia showing locations of collected animals. The numbers on the map correspond with the specimen numbers shown in Table 1.

Slides were prepared by grinding thin sections flat to 2000 µm thickness with a precision Logitech LP30 grinding machine. The polished surface of the section was glued to the prepared slide with Epotech 301 and allowed to set overnight on a hotplate (40 °C). The unwanted part of the upper tooth was then removed with a diamond saw (0.3 mm blade) and the section ground to 70 µm using 600 grit carborundum powder. Grinding of the section was completed with 1200 grit aluminium oxide grinding powder on the Logitech LP30 grinding machine.

Polishing of samples was done in a Planopol 5 polishing machine with 6 µm diamond paste on a Kemet KFA polishing cloth for one hour. Further polishing was done with a Planopol 2 polishing machine and a Kemet MSA cloth for 0.5 hour each with 1 µm diamond paste and 0.25 µm diamond paste.

Three sets of sections were made from each tooth before usable specimens were available. The first set was unusable due to breakages at the polishing stage, and the second set was too thick.

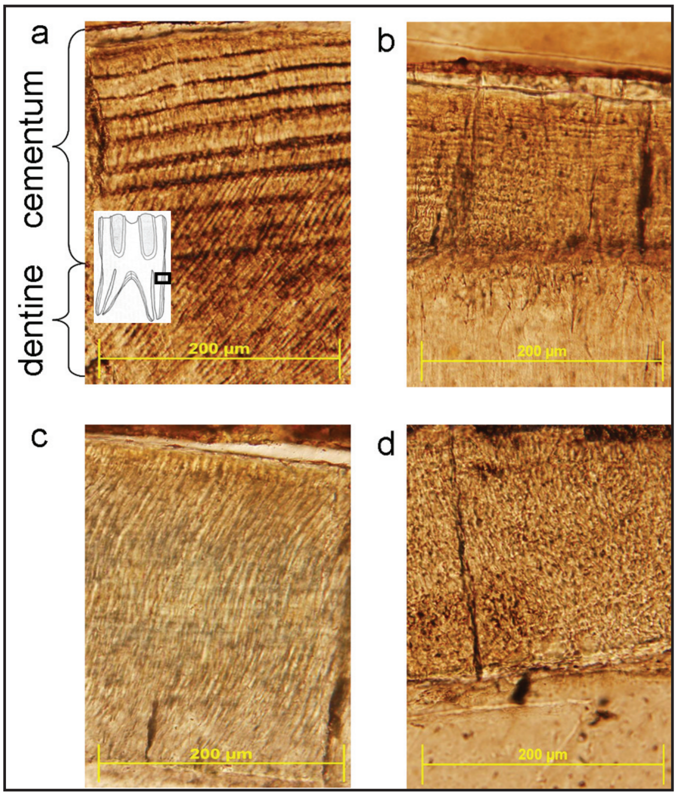

Figure 2. Images of the microscopic dental cementum bands. Each image shows a scale bar, a section of dentine and the dental cementum banding. (a) Enlarged section of cementum banding seen for individual 30, categorized as 'dark banding'; (b) Enlarged section of 'moderate banding' seen for individual 23; (c) Enlarged section of 'pale banding' seen for individual 21; (d) Enlarged section of 'undefined banding' seen for individual 28.

Dental cementum analysis microscopy

Sections were viewed using an Olympus BX50 microscope with phase contrast and polarizing light filters. Images of the slides were captured by Tom Stewart from the School of Animal Biology, University of Western Australia, using an Olympus DP70 camera attachment, and saved as image files with the Olympus DP Controller computer program.

Results - The definition of the seasonal banding

Microscope slides and photographs of the teeth were examined to ascertain the clarity of the cementum banding. The definition of bands ranged from no visible bands to clear, dark banding. The results were classified into 4 subjective categories; 'dark banding', 'moderate banding', 'pale banding' and 'undefined banding' (Figure 2a-d). These categories were based on the colour intensity of the banding seen in photographic images and on the definition of banding that was made visible by altering the focus and polarity filters of the microscope. Figure 2a shows the cementum and dentine. A small diagram of a tooth (inset) shows the location of the sections of cementum banding. The specimen was collected in September 2003, as fresh road kill, thereby indicating that pale cementum bands represent the dry season. For all specimens in the 'moderate banding' and 'dark banding' categories, such as Figure 2a, it was possible to match the colour of the external band to the estimated season of death. In all cases the darker band signified the winter/wet season and the lighter bands signified the summer/dry season.

Table 1 shows the classification of each specimen and the possible relation of banding to environmental conditions. The environment type was referenced from Australian Bureau of Meteorology temperature maps (Australian Bureau of Meteorology, 2006).

For *M. rufus*, the majority of the cementum banding was classified as 'undefined banding' or 'pale banding'. There were two 'moderate banding' slides, one each from the arid and temperate zones, and one slide showing 'dark banding' from the temperate zone (Table 1). Similar results were observed for *M. fuliginosus*, the majority of slides were classified as 'undefined banding' or 'pale banding', with the only example of 'moderate banding' obtained from a temperate zone animal (Table 1). There was one example of 'dark banding' from a semi-arid zone *M. robustus*, and three of 'moderate banding'; two from the arid zone, and one from the semi-arid zone. Slides were clearer when viewed under a microscope than as still images, as adjusting the focus highlighted the cementum banding.

Discussion

Figure 3 shows that the majority of the individuals had undefined or pale banding: no instances of dark banding were identified for arid zone individuals, and only one individual each for semi-arid and temperate environments showed dark banding. The quality of banding is highly variable for individuals both within each environmental zone and between zones. Pike-Tay and Cosgrove (2002) do not rate the quality of banding in

Species	Specimen number	Estimated month of death	Environmental zone	Cementum Banding
M. rufus	1	September	Temperate	Undefined banding
M. rufus	2	September	Temperate	Undefined banding
M. rufus	3	September	Temperate	Dark banding
M. rufus	4	September	Temperate	Moderate banding
M. rufus	5	September	Temperate	Undefined banding
M. rufus	6	August	Arid	Pale banding
M. rufus	7	January	Arid	Pale banding
M. rufus	8	August	Arid	Pale banding
M. rufus	9	August	Arid	Moderate banding
M. rufus	10	September	Arid	Undefined banding
M. fuliginosus	11	January	Semi-arid	Pale banding
M. fuliginosus	12	February	Semi-arid	Undefined banding
M. fuliginosus	13	January	Semi-arid	Undefined banding
M. fuliginosus	14	December	Temperate	Pale banding
M. fuliginosus	15	January	Temperate	Undefined banding
M. fuliginosus	16	November	Temperate	Pale banding
M. fuliginosus	17	December	Temperate	Undefined banding
M. fuliginosus	18	November	Temperate	Moderate banding
M. fuliginosus	19	February	Semi-arid	Undefined banding
M. fuliginosus	20	February	Semi-arid	Pale banding
M. robustus	21	July	Semi-arid	Pale banding
M. robustus	22	July	Semi-arid	Undefined banding
M. robustus	23	July	Semi-arid	Moderate banding
M. robustus	24	September	Arid	Moderate banding
M. robustus	25	July	Semi-arid	Undefined banding
M. robustus	26	August	Arid	Pale banding
M. robustus	27	August	Arid	Moderate banding
M. robustus	28	September	Arid	Undefined banding
M. robustus	29	August	Arid	Pale banding
M. robustus	30	September	Semi-arid	Dark banding

Table 1. Species identification, specimen number and approximate time since death of specimens used in this study. The quality of the cementum banding is shown as undefined, pale, dark or moderate banding.

their study, giving only an accuracy rate of approximately 85%, but this may be a characteristic of cementum banding in macropods.

As mentioned above, the formation of cementum banding has been linked to the impact of reproductive activity on the body's nutrition levels and hormones (Mitchell, 1967). The reproductive capabilities of macropods, such as embryonic diapause during times of drought, may have some influence on cementum banding formation. It has also been shown that pregnancy in macropods has some effect on the endocrine system (Hume et al., 1989), and may have other effects as yet unknown. An investigation of cementum banding in individuals of known age with a known reproductive history would account for any effects of reproductive activity on cementum banding, though such a study would be time consuming and costly.

This variable result independent of environment may also indicate that the seasonal variation in Australia's arid zones is insufficient to produce a distinctive banding pattern. It may signify that the drought conditions seen by Australia in the last few years were sufficient to affect the formation of cementum bands through food type availability. In either case, there are significant implications for using dental cementum banding as an indicator of seasonality in archaeological sites. The lower number of *M. robustus* teeth with undefined banding (3/10) may indicate that some species are more suited than others to this type of analysis. This may however be due to the small sample size and requires further study.

This investigation of dental cementum analysis is an important preliminary study of a technique which could prove invaluable in the analysis of seasonality and selective hunting in Australian archaeological sites. There is a large amount of variation in clarity and thickness of banding seen in this study. This suggests that either the Australian arid/semi arid zone seasonal variation of wet and dry seasons is insufficient for creating defined seasonal bands, or that there are factors other than food type influencing dental cementum banding in macropod teeth. Further study of animals collected over a longer time period, with known environmental data, is required to test this hypothesis. Further investigation of the effects of environmental events such as drought may be used to determine if certain species, such as *M. robustus* are more sensitive to banding.

Conclusion

This study has shown cementum analysis of macropod teeth to be a reliable technique for determining seasonality when banding is visible and quantifiable, which in this case was 60% of the total sample. This technique therefore has the potential to contribute much to our understanding of seasonality and hunting strategies in Australian archaeological sites.

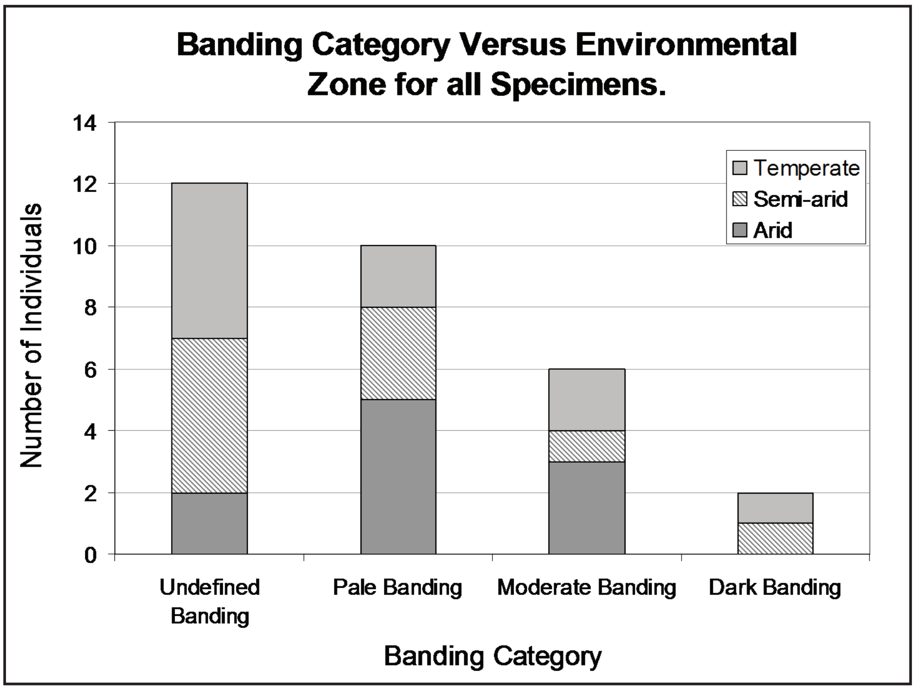

Figure 3. The number of specimens in each of the four banding categories, showing arid, semi-arid and temperate environmental zones.

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Australian and New Zealand Geomorphology Group

13th Conference, Queenstown, Tasmania 10-15 February 2008

Dr Anthony Dosseto

GEMOC National Key Centre/Department of Earth and Planetary Sciences, Macquarie University, NSW

Dr Mark Quigley

School of Earth Sciences, University of Melbourne, VIC (now at Department of Geological Sciences, The University of Canterbury, Christchurch, New Zealand)

On the evening of February 10th, 2008, roughly 150 geomorphologists from across the world gathered on the steps of Penghana House overlooking the town of Queenstown, Tasmania for the 13th ANZGG conference. With wines, beers, and fine foods in hand they met with colleagues, traded stories from the pre-conference field trips and discussed academic interests and the possibilities of future endeavors with positivism and excitement. After a brief and humorous introduction to Queenstown from the Darryl Gerrity the town mayor, most participants retired and/or prepared their talks for the coming day, although several participants explored the riches of Queenstown's bar scene into the wee hours.

Monday began with the ANU-directed film '*Seeing change*' staring John Chappell which paid tribute to Tasmania's rich history of exploration and geologic discovery. This was followed by a day of exciting talks and discussions. Some of the talks in the opening session focused on Australia's neotectonic setting and on possible neotectonic contributions to the evolution of Australian landscapes. Other talks discussed how emerging dating techniques (e.g., uranium-series isotopes, cosmogenic nuclides, luminescence dating) are being utilized to provide quantitative measures of the rates of geomorphic processes and ages of geomorphic features in Australia and elsewhere. Mark Quigley's keynote address provided an overview of the active tectonic and geodynamic regime of the Australian continent from the plate scale to the outcrop scale. The afternoon session focused on developing better chronologies and insights into the nature of geomorphic features including dunes, lake sediments, valley-fills, and glacial moraines in Australia, New Zealand, and Papua New Guinea. Much attention was paid to what these features reveal about the nature of Quaternary climate change, and how geomorphic agents such as streams and glaciers responded to changing climates. Trish Fanning, David Dunkerley and Brad Pillans paid touching tribute to recent retirees (although we doubt this term applies) John Chappell and Martin Williams.

Tuesday began with John Chappell's keynote address on the origin of Australian landscapes, highlighting that many of the modern landforms developed within prior climatic regimes that differed markedly from present. Following talks discussed the promise and pitfalls of luminescence and cosmogenic dating of dunefields, the

Figure 1. (left) Queenstown, as seen from the coach that picked some of us from Hobart on February 10th. Figure 2. (right) Thanks to a thick cloud cover, imagination took a great part in the appreciation of local geology. (photos: A. Dosseto)

Figure 3 (clockwise from top left). A. Queenstown main street on the Thursday. After three cold and wet days, clouds were finally leaving for us to discover the beautiful scenery around Queenstown. B. The Empire Hotel on the Friday morning. In this hotel, geomorphology was re-invented thanks to a generous supply of local ales and wines. C. Queenstown on the final evening of the conference. D. The train that took us to the western coast on the Wednesday field trip. (photos: A. Dosseto)

implications of variations in continental dust flux, the mapping, geochemistry, and geomorphic processes of soils. Tuesday afternoon's talks focused on landscape management and geoconservation, with emphases on Tasmanian and Victorian rivers and their catchments.

Wednesday kicked off with talks on the history of the Mt Lyell mine operation and geology of the ore deposit, followed by a full day field trip. The first part of the field trip included a tour of the Mt Lyell mine site, including the mine workings and new tailings facilities and dam. The group split into two and were treated to great tours, although the weather was slightly uncooperative. Another delicious lunch awaited the group at Penghana, followed by a trip on the West Coast Wilderness Railway along the Queen and King River valleys. The group marveled at the beautiful and rugged landscape that stood before them, and wondered about the time-scales required to generate such an apparently youthful landscape. Following a stop along the banks of the King River for dinner and drinks, the group arrived in Strahan. A walk out to the King River floodplain and delta followed as the sun was setting. The group then separated into two groups and boarded their respective buses, a decision which was to alter the course of their respective evenings. Whilst one bus arrived back in Queenstown on time and left the participants feeling rested and ready for the coming day, the other bus caught fire just outside Strahan. Being a resourceful bunch, this group quickly headed to the pub to wait for the first bus to return. In the end, all was well.

After a cold and wet start of the week, the sun finally made it to Queenstown on the Thursday. In the morning, the evolution of coastal and island geomorphology was discussed, ending with a keynote address by Bruce Thom on the role of coastal geomorphology in planning and management.

In the afternoon, the discussion focused on the evolution of river morphology over short timescales and ended with talks addressing how the study of river geomorphology can be used to assess human disturbance and provide solutions for river rehabilitation planning.

At night, the delegates gathered for drinks and dinner at *Silver Hills*. The geomorphology trivia, conducted by Brad Pillans, was the opportunity for the youngest geomorphologists to have a minute of glory and the older to demonstrate their imperfections... The winner, Ian Rutherfurd, was awarded some geomorphology volumes whose age probably goes beyond the limit of C-14 dating. After a dinner where local beers and wines were well appreciated, some of us braved the cold night to experience the night life of Queenstown and meet with the locals.

The final day of the conference kicked off was focused on fluvial systems where most of the morning was dedicated to talks on river geomorphology in tropical and arid climates. Talks on river management occupied the rest of the day, starting off with a keynote address by Gerald Nanson on a theoretical (and also somewhat philosophical) discussion of fluvial geomorphology. Finally, Ian Houshold and Tim Cohen sent us home with our thanks for such great organization ringing in their ears. After almost a week of scientific discussion fuelled by a fair amount of local ale, some of us felt we needed to hike in the surrounding relief, which gave us the chance to have a last look at the amazing scenery offered by Queenstown.

Figure 4. On the final evening, some of us felt we needed to explore the surrounding relief. From left to right, top: Paul Rustomji, Tim Barrows, Michael Crozier, Trish Fanning, Gerald Nanson and Kat Fitzimmons; bottom: Justine Kemp, Tim Cohen and Toshi Fujioka. (photo: A. Dosseto)

Archaeological Science Conference

The Australian National University, Canberra, Australia
4-6 February 2008

Cameron Atkinson
Australian National University

The inaugural Archaeological Science Conference was held at the Australian National University in Canberra from 4-6 February 2008 to celebrate the launch of ANU's new Masters of Archaeological Science degree program. This event, organised by Matthew Spriggs and Tony Barham, was an opportunity for researchers from across scientific disciplines to discuss issues in archaeological science and foster the development of multi-disciplinary projects. It served to showcase the breadth of archaeological science expertise across the colleges at the ANU supporting the new Masters degree program, and also ANU research linkage with University research teams and facilities elsewhere in Australia and abroad.

Five themed sessions were included in the conference:

- Dispersals, DNA and Bioarchaeology
- Climate Change, Extreme Natural Events and Archaeological and Stratigraphic records of the Australian and Adjacent South-East Asian Coastlines
- Archaeological Science in the Pacific
- Techniques and Approaches in Archaeological Science
- Lithic Artefacts and Archaeological Science

Charley French (University of Cambridge) presented the keynote address at the conference. Professor French addressed the issue of long-term landscape change and management methods used historically to maintain agriculture in semi-arid environments. The presentation focused on the application of geoarchaeology to understanding land management techniques. Case studies were global in extent, with examples from highland Yemen, northern Ethiopia, southern Spain, central Portugal, New Mexico and southern Chile. The paper was a good commentary on climate change and sustainability, and what has been done to deal with these issues in the past as well as potential issues for future planners.

The first set of papers presented was 'Dispersals, DNA and Bioarchaeology'. This set of papers covered a wide range of topics and included a number of dissenting opinions on the topic. Lisa Matisoo-Smith (University of Auckland) and Alan Cooper (University of Adelaide) presented interesting papers on the topic of Polynesian and South American contact. These papers highlighted the diversity of opinions on this key issue and resulted in robust post-session discussion.

The second set of papers was on 'Climate Change, Extreme Natural Events and Archaeological and Stratigraphic records of the Australian and Adjacent South-East Asian Coastlines'. Many of the papers were focused on tsunami and their representation (or absence thereof) in the archaeological and stratigraphic records. Some of these papers were presented as a response to the claims of Bryant and others of Mega-Tsunamis along the Australian coastline. Val Attenbrow (Australian Museum) and Ian Hutchinson presented an excellent paper using many lines of archaeological evidence from NSW sites to dispute these claims. James Goff (NIWA, New Zealand) supported Dr. Attenbrow's conclusions based on geological data found in New Zealand.

The third set of papers was on 'Archaeological Science in the Pacific'. This set of papers ranged from Wal Ambrose's (ANU) presentation on obsidian weathering and dating, Matiu Prebble and Geoff Hope's (ANU) work on palaeoecology and a paper by Peter Shepperd (University of Auckland) presenting his initial thoughts on a portable X-Ray Fluorescence machine.

The session 'Techniques and Approaches in Archaeological Science' contained a range of papers with a strong focus on the contributions that other scientific disciplines can make to archaeology. David Bulbeck (ANU) presented a paper statistical analysis of accuracy in archaeology. Kurt Lambeck (ANU) presented a paper looking at identifying sea level changes in the archaeological record. Bruce Doran (ANU) presented a paper on the potential applications of GIS techniques in archaeology with several examples based on land use planning. Presentations were also given by Kat Fitzsimmons, Stewart Fallon and Rainer Grün (ANU) on geochronological techniques and their applications to archaeology.

The last set of papers presented was on 'Lithic Artefacts and Archaeological Science'. Linda Villiers (Australian Interaction Consultants) presented a paper discussing her work on density and distribution of Aboriginal occupation in the Pilbara region of Western Australia. Ben Marwick (ANU) presented his research on stone tool patterns in response to climate change. The standout paper of this session was Peter Hiscock's (ANU) paper on his work into developing a quantitative measure of Palaeolithic artefact reduction.

At the end of the first day of the conference came the official launch of the ANU Masters of Archaeological Science program. This degree is the first of its kind in Australia. The program is taught across three of the colleges at the ANU (Colleges of Science, Asia and Pacific, and Arts and Social Sciences), and is available over one year full time or two years part-time.

The M.Arch. Science program is a structured mix of taught courses and supervised research projects, with opportunities for individual training and supervision with over 50 ANU researchers, many of whom presented papers at the Conference. Internships are also available through the program. The program aims to facilitate training which bridges across disciplines such as. Regolith Science, Quaternary Environments and Climate Change and Archaeology, with the focus on interdisciplinary research, education and professional skill development within vocationally relevant areas of applied archaeological science. Bursaries and industry-sponsored routes supporting students through the program are now being developed. Companies, Government Departments and groups with interests bridging Archaeology, Quaternary Science and Natural and Cultural Heritage Management are encouraged to contact individuals and research teams who presented at the conference, or the program convenor.

For more information, the abstracts of papers presented at the February Conference can be viewed at : http://arts.anu.edu.au/AandA/archaeology/conference.asp

For more information about the new Masters of Archaeological Science program at ANU and related opportunities for PhD research see:
http://arts.anu.edu.au/AandA/archaeology/marchsci.asp or contact the M. Arch. Science Course Convenor:
Anthony.Barham@anu.edu.au

Science meets Parliament

Canberra, Australia
18-19 March, 2008

Eric D Nicholson

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Summary
Science meets Parliament is a fantastic experience for early and mid-career researchers to not only mingle and network with some of Australia's leading scientists, but also to get the opportunity to meet informally with Parliamentarians. The two day event, held annually since 1999, is designed to introduce scientists to the field of science advocacy and the concept of influencing policy. From listening to science communication, advocacy and policy experts, and by meeting with Parliamentarians themselves, scientists were able to learn just exactly what is required in order to have an impact. For scientists to successfully incorporate their research into good policy, or just to be able to communicate their research to non-scientists, there are several key points they must follow: be clear and to the point; be relevant; be courteous; and always maintain your credibility. If you are well prepared, knowledgeable, and able to understand the perspectives of others, you will be successful.

Report
Earlier this year I had the privilege to represent AQUA at the 2008 Science meets Parliament (SmP) event in Canberra (March 18th & 19th). This annual event, held since 1999, is an opportunity for early and mid-career researchers to learn the finer points of science communication and how to effectively meet with parliamentarians. Also representing AQUA at this year's SmP was Dr Stuart Pearson, a second time SmP attendee and outgoing Secretary of AQUA.

SmP is a two day event. Day one focuses on skill development while day two affords the opportunity to put those new skills into practice through meeting with various parliamentarians and/or their advisors to discuss current scientific research. The workshop held on the first day is simply a series of talks given by experienced science communicators, and those who are knowledgeable in parliamentary processes, about what it takes to influence policy. The entire workshop can ultimately be summarised as an iterative process primarily designed to drive home two key points: knowledge and credibility.

To elaborate, the majority of presenters emphasised the following important items to bear in mind when

Figure 1. The Marble Hall at Parliament House, just prior to the formal dinner. Senator Mary Jo Fisher (SA) talking to Luke Simpkins (MP for Cowan in WA) right foreground. (Photo: Bradley Smith)

speaking to parliamentarians: be clear and concise; know exactly what you need to say, as briefly and simply as possible (i.e. keep it relevant – using analogies with personal meaning works well); know as much as possible about the parliamentarian you will be speaking to (i.e. research their background on the subject you intend to speak about); maintain relevance (ensure the topic warrants the parliamentarian's attention) and be polite at all times (forging long relationships is the key to influencing policy – so follow-up on things you say you will do ASAP!). The principal objective of a policy is to change the behaviour of the population. Thus, the behaviour of a scientist trying to influence a policy must typify this desired outcome. If a policy is to be based upon sound scientific facts, then the science advisor should likewise be consistently knowledgeable and credible.

The first day of SmP also provided an opportunity to meet the scientists with whom I would be meeting Parliamentarians the following day, to discuss strategy and to get to know one another. This group of eminent researchers and science advocates included: Professor Douglas MacFarlane of Monash University, an Australian Research Council Federation Fellow, whose expertise is in the area of advanced materials for a variety of applications including solar cells, advanced batteries and biofuels generation; Ms Karin Schiller, the CEO of the Australian Institute of Agriculture and Science, whose expertise is in representing primary industry bodies; Dr Phillip Schmidt, a geophysicist with CSIRO Mineral Physics in Sydney, who is currently a stream leader in the CSIRO Minerals Down Under Flagship overseeing 3D Mapping Technologies; Ms Janice Wooton, a statistician with the Australian Bureau of Statistics, who has recently started a PhD in mathematical statistics at the Australian National University; Dr Frederic Leusch, an environmental toxicologist at the University of Queensland, who is researching bioassay methods for assessing health risks associated with water recycling for potable reuse; and Associate Professor Manny Noakes, Senior Research Dietician at CSIRO Human Nutrition in Adelaide and co-author of the highly popular CSIRO Total Wellbeing Diet book, whose expertise is in the fields of diet, nutrition and health.

The finale to the first day was a formal dinner at Parliament House in the Great Hall. Dr Clio Cresswell, mathematician and senior lecturer at the University of Sydney, was the MC for the evening and introduced the guest speaker, Professor Neville Nicholls, a senior scientist on the IPCC. Professor Nicholls gave the usually dire and alarming story that is a climate change talk. The subject of climate change is on everyone's lips these days, and it is definitely worth discussion, but perhaps something a bit more optimistic would have made a better dinner speech. Although, while everyone in the room had undoubtedly heard the same story at least once before, perhaps the talk was designed to stir lively and topical discussion with the many Parliamentarians that were seated amongst the scientists at the dinner tables (in between bells frequently calling Senators to late night sessions). Personally, I can testify that the conversations I had throughout the evening were extremely diverse and stimulating. Discussions ranged from current research activities in various laboratories, to the trials and tribulations of being a new Senator, to sustainability and the more fundamental aspects of living in Australia.

My second day of Science meets Parliament got off to a very early start as I had an 8am meeting with Rowan Ramsey (new Liberal MP from the electorate of Grey in SA). Attending this meeting to discuss the topics of 'low carbon emission and renewable technologies; biomass fuel viability; and food versus fuel versus environment' were Karin Schiller and Doug MacFarlane. We all had an opportunity to describe what we do, and what our organisations/laboratories were capable of doing. In particular, I took advantage of my opportunity to describe the utility of palaeoecology as a means to understand the past prior to the advent of environmental monitoring and often prior to any human presence within the landscape, even though this research wasn't entirely related to the topics at hand. Doug however had some very interesting and relevant points to make about biomass fuels and what his lab is doing at Monash. Throughout the meeting, Mr Ramsey was very amicable and polite and the meeting went quite smoothly. Although, perhaps the fact he seemed to be so conscious of the time without any particular given reason, suggested that he was also keen to get on with other matters and that he may have been simply going through the motions of being interested. It can only be hoped that the information we gave him left an impression and he will be supporting renewable technologies in Parliament.

Between the central Committee Room of 2S1, where scientists could meet in advance of their meetings and find out about any changes to their schedules, and the various Parliamentarian offices in which meetings were held, scientists had the rare opportunity to walk through 'corridors of power', which most visitors to Parliament House never see. Parliament House is an exceptionally large building and sufficiently maze-like for those not familiar with the layout. Thankfully, there were a couple of students on hand available to show people to their appointed destinations during the morning. Walking through these normally off-limit areas of Parliament also afforded opportunities to run into high level members of Parliament. In my case, I caught the end of a press release that included Ministers Penny Wong and Peter Garrett. I even managed to share a lift with Deputy Prime Minister Julia Gillard - not an everyday occurrence to be sure.

My second meeting of the day was with Bryden Spurling, adviser to outgoing SA Senator, Natasha Stott Despoja. Also attending this meeting, to discuss the topic of 'higher education and science', were Janice Wooton and Phil Schmidt. As current PhD students, Janice and I highlighted the need for greater maths and science teaching incentives. Janice then provided some relevant statistics on the subject. Our main point was that deficiencies in these fields will only perpetuate such that Australia will continue to suffer from a lack of skilled workers in maths and sciences. We suggested that financial incentives need to be put into place to encourage more highly skilled maths and science teachers

Figure 2. The Marble Hall at Parliament House, just prior the formal dinner. Three Adelaide University representatives at SmP right foreground. Left to right: Dr Kate Hutson, Eric Nicholson (with back to camera) and Dr Bayden Russell, all associated with the Southern Seas Ecology Laboratories. The representatives are talking to Dr Nigel Preston of CSIRO, an internationally renowned expert in aquaculture research and development. (Photo: Bradley Smith)

at the primary and secondary education levels. Then, an enthusiasm for these subjects can be fostered right through to the tertiary education level. Phil reinforced this need by highlighting the fact that his lab, which was once reasonably popular and always had postgraduate students and other researchers coming through it regularly in the past, now had difficulty attracting new researchers even though Phil's lab is part of a CSIRO flagship overseeing brilliant new 3D mapping technologies applicable to the booming mining industry. Part of the problem may be that there is currently a strong job market in Australia, to the detriment of pure research. Australians may be more pragmatic these days and can't see the value of research that might not have any immediate commercial application. This feeds into the notion of advocating new policies, designed to change people's behaviour.

My third and final meeting of the day was with Tony Zappia (new Labor MP for the electorate of Makin in SA). Mr Zappia's topics of interest included 'managing water and drought; and obesity'. Attending this meeting were Manny Noakes and Fred Leusch. As had been warned several times on the first day, Parliamentarians are often called away at the last minute and meetings can be interrupted at any time. This occurred half way through our meeting and Mr Zappia was absent for at least ten minutes. During this time, his assistant Pamela Lockyer stepped in and took notes on Mr Zappia's behalf. I was lucky to be the first one to speak and had Mr Zappia's full attention to describe my research, which seemed to catch his interest due to his formerly being the Mayor of Salisbury. The municipality of Salisbury includes part of my project study region, the mangroves immediately north of Adelaide. Mr Zappia was also quite interested in what Fred had to say about water reuse and the use of bioassays to ensure water quality, even though Fred's message was interrupted by a prolonged intermission. Manny wasn't able to speak at length directly to Mr Zappia, but Ms Lockyer did take copious notes, so one can only hope all Parliamentarians have such able and dedicated assistants. Mr Zappia actually has a background in personal fitness and was once a champion power-lifter, so Manny's message about diet, nutrition and health likely would have been well received had Mr Zappia been present.

A key observation I made through this brief exposure to the Parliamentary process and meeting with Parliamentarians is that time is extremely precious to Parliamentarians. They work incredibly long hours and have to devote their attention to numerous tasks and meetings with many different people on any given day, so it is absolutely crucial that any meeting one has with a Parliamentarian is well planned, to the point and leaves an impact. If what you have to say isn't significant, clearly conveyed and brief, then there is little chance that your message will be truly absorbed and remembered. Thus, it is imperative that any meeting with a Parliamentarian is not taken lightly and their time is never wasted (You may not get another chance to make an impression!). In this light, I am truly grateful to have had the opportunity to have had informal meetings with Parliamentarians.

Since the meetings were not genuine lobbying events, as a scientist, I have gained very useful experience without risking any credibility. These meetings were actually quite an unusual experience as the Parliamentarians were the ones choosing who they met based on how similar their interests were to those of the scientists. Of course, this didn't allow the scientists to have very much lead-up time to prepare adequately for the meetings. In future, I would probably not select so many fields of interest, simply to avoid having meetings in which my field of expertise wasn't relevant. If I get the opportunity to meet with a Parliamentarian again, I am confident that I would be able to successfully convey my message and leave a significant impression.

The rest of my day was much more leisurely without the pressure of meeting with Parliamentarians. I was able to effectively 'turn off' and much more casually take in the rest of the day's proceedings. Almost immediately following my final meeting, I departed by bus to the National Press Club for a lunchtime address by Senator Kim Carr, Minister for Innovation, Industry, Science and Research. The title of Senator Carr's speech was "Science Serving Society". He was an engaging speaker and also quite affable in answering questions from the press after his address. The very formal and even courtly aura surrounding many Parliamentary proceedings seems to disguise some of the 'poisoned barbs' in questions and other controversies.

This theme prevailed throughout Question Period in the House of Representatives, which I viewed from the Public Gallery. In particular, there were a number of seemingly benign and pointless questions from one of the Liberal frontbenchers about Labor Ministerial travels. Before long, there was even an audible sigh from the Gallery when the Speaker would announce another question coming from the particular Liberal Member. However, it later turned out that the questions were simply a somewhat theatrical way of unfolding a seemingly inappropriate acceptance of privately sponsored travel to China, as was reported later by the media. This may explain why the Labor Ministers were getting increasingly frustrated by the questions and also makes one wonder as to the early departure of the Prime Minister, which was followed by marked protest from the Liberals that he should leave Question Period early.

The final part of Science meets Parliament for me was attending a forum in the Main Committee Room on the subject of the Great Barrier Reef (GBR) in 2050. Several eminent GBR researchers spoke about the challenges facing the GBR as we approach 2050. Namely: management of nutrients; changing food webs; and climate change. Much of the news was rather dire, but there were also some reasons for optimism stemming from the establishment of marine protected areas. Professor Terry Hughes was one of the speakers and he gave a clear, concise talk which focussed on solutions toward maintaining the GBR. In particular, he emphasised the role of herbivorous fish, which are crucial in maintaining habitat for corals. These fish control the growth of algae, which may otherwise take over a section of reef, so that new corals are able to become established in vacant areas of the reef.

In summary, the panel of speakers expressed what they thought were the key challenges regarding continued protection of the GBR toward 2050. These were: knowing ecosystem thresholds / tipping points; ocean acidification and the loss of calcifying organisms; and the management / integration of resources – governments and scientists working together. I think this is an appropriate point upon which to finish this report. Regardless of the fantastic research already being conducted by brilliant scientists throughout Australia, nothing can really be achieved for the good of society unless there is effective dialogue between scientists and politicians. Thus, it is important that all scientists are aware of their responsibility to not only perform good research, but to also ensure that their research is being effectively reported to those who have the power to change society. That is, Parliamentarians need to be properly informed through science advocates and lobbyists, who rely on our research so that it can be incorporated into policy. I, for one, would like my research to not just describe inevitable environmental and sociological declines, but to actually contribute to maintaining a sustainable world in which we all have to live.

Promotional document for Parliamentarians: An exercise in scientific communication
Eric Nicholson

Environmental monitoring programs have not existed long enough for us to know what the environment was like prior to human influence. Palaeoecology solves this problem. Palaeoecology essentially means 'ancient ecology'. It is the study of past environments through the use of fossil records. Some organisms are preserved in sediments and their preservation allows us to make sense of the environment for the time period during which they were deposited. In addition, studying the properties of the sediments themselves can shed further light on what has happened over time. This type of research may be described as limnogeology. Together, these fields of study can be used to understand important subjects ranging from climate change, sea level rise, coastal nutrification and vegetation succession through to the impacts of human activities on the environment. *Environmental Change in the Coastal Wetlands near Adelaide, South Australia, as Inferred via Diatom Analysis of Mangrove Sediments*: My project is focused on the coastal wetlands (mangroves) near Adelaide, South Australia. I am studying how this environment has changed since European Settlement. By knowing what this environment used to be like, and how it has changed due to both natural and human influences, I can provide coastal managers with previously unknown information that can allow them to manage the coastline more effectively. My research will ultimately provide a baseline of pre-European environmental conditions, that is, a reference point toward directing more effective management of our coastal resources. Without my research, there would be no way of knowing how the environment once existed, nor how it would need to be restored.

Professor J.A. Mabbutt

I first met Jack Mabbutt in 1969 outside the office of Professor G.H. Dury at the University of Sydney. Jack had been invited by George Dury to examine my Honours thesis and to put me through an oral examination. I only knew Jack by reputation. After saying hello, he announced that he had recently flown over my field area southwest of Cobar in western New South Wales. Combined with his reputation as a tough examiner, and sometimes a bit cranky, the news that he had seen my field area turned my brain to porridge.

But I need not have been fearful. Yes Jack was tough, but in an engaging and supportive way. He was charming, and had a great sense of humour. He had also had a long career as a field geomorphologist in arid lands, and so he knew that extracting data from such places is not easy.

I stayed in touch with Jack for many years. One memorable occasion was in the Simpson Desert in 1975 after the big La Niña wet. All the dunes were covered in flowers, and our international visitors were stunned by their beauty. Jack was in his element. He lectured, cajoled, explained and charmed. The only rough spot occurred when he was asked by a visitor from Paris to stop speaking "French"!

He showed a keen interest in the development of geomorphology in Australia and elsewhere. He published on desert landforms generally, soil and desert pavement formation, desert dunes, alluvial systems, denudation history, and the results of weathering. Throughout he had a strong interest in application, most notably in CSIRO during their Land Systems days and late in his career in the difficult but important field of desertification diagnosis and assessment.

Jack co-edited with Joe Jennings in 1967 "Landform Studies from Australia and New Guinea". This collection made a major impression both nationally and internationally, bringing together an eclectic mix of chapters by expert practitioners. In 1977 Jack wrote "Desert Landforms" in a series of volumes under the general editorship of Joe Jennings, designed as a systematic geomorphology at university level. This book, and indeed the series, was of great value.

Bringing to Australia his experience in North Africa and the Middle East, and of southern Africa, Jack could compare landforms and landscapes. His lectures and seminars were always well illustrated from various parts of the world, and he was able to attract international visitors to the University of New South Wales which he joined in 1966. He was there until 1987 when he retired.

Perhaps my fondest memories of Jack are from the few times I spent with him in the field. He was in his element, telling stories and debating every possible topic.

Jack died peacefully on 24th May 2008 just days after his 86th birthday. Our thoughts are with his family. He will be missed.

Bob Wasson
Charles Darwin University

Liu Tungsheng, Hon. D.Sc. (ANU).
1917 - 2008

Professor Liu Tungsheng's funeral service on March 17th in the Hall of Babaoshan Revolution Cemetery, attended by some 1000 people with representatives from institutions all over China, was a deeply moving closure to a remarkable journey.

In the 33 years since 1975, many of us have shared in the new relationship between Australian and Chinese science, a development due in large part to Liu's visionary role and one which, as he often affirmed, initiated and facilitated China's rapid expansion into the western scientific world.

A major feature of that growth stemmed specifically from the innovative and highly productive research which, despite years of turbulence, established China's loess as the continental reference section for global climatic change. That success reflected Prof. Liu's ability to attract and lead a team of dedicated workers, older and especially younger students, and to deliver results with clarity and vision. From earliest days, he identified the globally important nature of environmental comparisons between Australia and China. For all this he was recognised internationally by his presidency of INQUA, by the Tyler Environmental Achievement award (2002) and the EGU Alexander von Humboldt Medal (2007) as well as by China's Supreme State and Technology Award (2003).

In his death, Australia has lost a colleague, a mentor and friend. Despite that loss, his legacy lives on in the lively exchanges, both intellectual and personal, between workers in both continents today. That exchange provides a fitting continuation of the visionary legacy Liu Tungsheng in life did so much to inspire.

J.M. Bowler

In the early evening of the 16th November 1975, when the Australian National University's Quaternary delegation to China disembarked at Beijing airport to be met by a small crowd of Chinese scientists, the first person to shake my hand and greet us, with smiling eyes and modest but well-spoken English, was Liu Tungsheng.

It was an event verging on the fabulous for Australians and Chinese alike in which the science we had in common supplanted the disparity of our societies. We had no idea what to expect and, by bedtime, were astonished at what we were to see. Behind all this, and the intensely productive research collaborations of the following decades, was Liu Tungsheng; quietly spoken and generously minded yet forceful in discussion, scientist and scholar.

The friendship between us, which developed over time, was not one that probed our individual histories. To this day I wonder how he weathered the repeated political and social upheavals through which he lived and how, against that background, he contrived to do good science. Undoubtedly, there must have been many impediments, compared with which any that I have met shrink into insignificance. He certainly made the most of what was possible and nowhere was this better evidenced than in his influence in promoting the China – Australia relationship within the Chinese Academy of Science. He was a good friend and many of us must feel ourselves privileged for having known him.

D.Walker

Call for donations for Pullar and Vucetich award fund

In April 2007, Colin Vucetich (1918-2007) passed away. His obituary was reported in the previous *QA* newsletter and an extended obituary was published in a tephra-based volume of *Quaternary International* (Lowe et al. 2007). With the endorsement of family members, the Geological Society of New Zealand has re-named the current "W.A. Pullar Prize" as the "Pullar and Vucetich Prize" to commemorate the achievements and lives of both men who worked together on tephra studies in New Zealand for 25 years. The purposes and rules of the re-named award remain as before and can be seen on the Society's website (http://www.gsnz.org.nz/ under 'Rules, policies'). The Society is now calling for donations to be made to the re-named award fund from friends, family and colleagues of Colin Vucetich. (Further donations on behalf of the late Alan Pullar, for whom the fund was initially established, are also welcome.) Donations by cheque (payable to 'Geological Society of NZ') in NZ dollars should be sent to:

Hon. Treasurer (Dr David Skinner)
Geological Society of New Zealand
P.O. Box 38-951
Wellington Mail Centre
Wellington, NEW ZEALAND

A covering note stating that the donation is for the Pullar and Vucetich award fund should be included. Receipts are available on request and NZ donations are tax deductable.

David J. Lowe
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Reference

- Lowe, D.J.; Tonkin, P.J.; Neall, V.E.; Palmer, A.S.; Alloway, B.V.; Froggatt, P.C. 2007. Colin George Vucetich (1918–2007) – pioneering New Zealand tephrochronologist. *Quaternary International* (in press, online 25 July, 2007).

AQUA Biennial Conference

The next AQUA Biennial Conference will be held on December 8-12, 2008 at the TOC-H camp in Victor Harbor, South Australia. The focus of the conference will be Water Resources and Palaeoscience. Further details on registration and field trips will be posted soon. Please send expressions of interest in attending the conference to the conference organiser Dr Jennie Fluin (e-mail: jennie.fluin@adelaide.edu.au).

Mind the Gap: An evaluation of forensic archaeology and tropical taphonomy to verify the need for a tropical forensic field centre in order to bridge the gap in the current literature

JULIET H. MEYER (Honours)
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James Cook University

Within the last few decades, archaeologists have contributed to investigations of forensic cases and recoveries of natural and artificial disaster scenes. The thesis aims to demonstrate this role and discuss how the emerging discipline, forensic archaeology, has not yet met its potential in Australia and other countries; reasons for this will be discussed in the thesis. Forensic archaeologists and other forensic scientists use archaeological methods and theories where appropriate to excavate and interpret death and/or disaster sites which they are investigating. Theories that are applied include the laws and principles of stratigraphy, association and context. A case study from the Rwandan genocide investigation in Kibuye is presented to exemplify the effort provided by forensic archaeologists and associated field specialists in excavation and interpretation of mass graves that are a result of severe violations of human rights perpetrated in that country in 1996.

The principles and laws of taphonomy are also often used in forensic investigations and disaster scenes. In general, it is the post-depositional effects and processes that alter or completely change the chemical and physical components of deceased biological organisms and non-biological objects such as artefacts. The thesis discusses taphonomy in a forensic context and describes its associated components. It acknowledges the importance of studying taphonomy both systematically and longitudinally (i.e. over a long period of time in one location) in order to get precise, thorough results that can be used for comparison in other cases around the world. Contemporary research and subsequent literature has greatly enhanced what is known about post-depositional taphonomic events that occur in and around human and animal cadavers. However, more research is essential.

Taphonomic research facilities in the United States have extensively examined decomposition patterns of human remains. However, the limited number of these facilities hinders the effectiveness and accuracy of results when applied to areas of differing climatic conditions. This is important because climate, thus weather (annual temperature, precipitation and humidity levels) are some of the most influential if not the most influential elements of taphonomic effects and processes. Additionally, these applied research centres provide support for forensic anthropologists and therefore mainly focus on the decomposition of human remains, which is only one factor in the taphonomy of a site. Taphonomy of non-biological objects and features such as artefacts and structures are equally significant, particularly to forensic archaeologists. The thesis also explores the methods currently used to examine forensic taphonomy and the ethical boundaries of research involving deceased human remains.

The thesis strives to illustrate the uniqueness of tropical environments and the significance of further research within this region as this climate promotes degradation of biological and, in some cases, non-biological materials because of warmer temperatures and higher precipitation rates. It describes the extreme paucity of longitudinal data within the tropical zone and asserts this can be rectified with the establishment of a tropical forensic field centre. The thesis considers the potential benefits of a centre. These include performing critical research to help to build theoretically based models of forensic taphonomy, as well as provide training and development opportunities to relevant forensic professionals. There are many people who would profit from the implementation of a tropical forensic field centre, most notably are forensic and taphonomic specialists, law enforcement agencies and the general public. The general population of the world will benefit from the advancement of forensic and taphonomic disciplines, since these will increase speed and efficiency of recovery and interpretation at forensic and disaster sites. All populations in any region of the world are likely to experience or have experienced these sorts of events, examples of which are provided throughout the thesis.

Finally, the thesis explores the potential of Australia as a location for a tropical forensic field centre. It asserts that the relative stability of Australia's political structure and financial strategies, as well as available resources, makes it a prime location for a tropical forensic centre. The thesis concludes with the presentation of James Cook University campus in the tropical region of Cairns as an appropriate example of a suitable university to host a tropical forensic field centre.

Between the desert and the gulf: Evolutionary anthropology and Aboriginal prehistory in the Riversleigh / Lawn Hill region, northern Australia

MICHAEL SLACK (PhD)
Department of Archaeology
University of Sydney

This thesis applies an evolutionary approach to the regional prehistory of the Riversleigh/Lawn Hill region of northern Australia. The research examines *(i)* the timing of colonisation of Australia and *(ii)* the nature of subsequent arid zone settlement and adaptation. Both of these research concerns are addressed through development of a regional settlement and subsistence model that is based within an overall framework of evolutionary theory and specifically from various models used by Human Behavioral Ecology (HBE). Using this approach this research presents new regional archaeological data and develops *(i)* a new model of north Australian Pleistocene settlement relating to Lake/Gulf of Carpentaria and *(ii)* an evaluation of competing models of Aboriginal subsistence during different climatic phases, with a specific focus on the Last Glacial Maximum (LGM).

The model of settlement and subsistence for the study region sets out expected responses of hunter-gatherers to large scale climatic changes over the last 40,000 years. These expectations are evaluated by quantifying changes in the nature of flaked stone technology, and in the frequency and range of faunal remains in archaeological sites.

I argue that climate change forced modifications to hunter-gatherer behaviours that are evident in the archaeological record. Significant behavioural changes occurred during the LGM, and included refuge occupation along the Gregory River, specialization in resources of low rank and conservatism in lithic reduction strategies. During improved climatic conditions, residential mobility increased, and subsistence expanded in range to include more high ranked resources, and lithic reduction altered to include new forms. Similar more subtle changes to settlement and subsistence are also evident during the early and mid Holocene periods.

The results of this thesis support a 'short' 40,000 - 45,000 year chronology of Aboriginal colonisation of Australia and a bio-geographic model of LGM settlement that included refuge occupation of the Gregory River corridor, but probably not Lawn Hill (*after* Veth 1989, 1993). The bio-geographic model used in this thesis stresses the importance of the HBE approach, and an emphasis on developing detailed local and regional archaeological chronologies.

The results of this research show that although further refined data concerning the palaeo-environmental record is needed, the functional approach of Human Behavioural Ecology is a valuable methodology for examinations of the archaeological record, providing theoretical rigor to local scale studies that can contribute to regional and more general models of human behaviour.

Late Pliocene and Early Pleistocene vegetation and climate cyclicity in the western uplands of Victoria, Australia

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The nature and timing of the climatic transition from the relatively warm and wet Tertiary to the cooler and more variable Quaternary are poorly known, both globally and in Australia. In this thesis, pollen analysis of a 40 m long palaeo-maar lake record from Stony Creek Basin (SCB) is used to reconstruct vegetation and climate in the western uplands of Victoria, southeastern Australia, over some 280 kyr of the Late Pliocene and Early Pleistocene. The pollen record is characterised by ~12 cycles of rhythmically alternating rainforest- and open-forest vegetation. Plio-Pleistocene, upland rainforest communities were dominated by conifers (Podocarpaceae and Araucariaceae) and angiosperms typical of Australasian Cenozoic rainforests, but lacked *Nothofagus*. Several of the rainforest taxa are now extinct, at regional (Stemonuraceae, *Agathis*, *Ilex*, *Wollemia*), continental (*Dacrycarpus*, *Dacrydium*, *Beauprea*), or global scale (*Podosporites* cf. *microsaccatus*). Open forest communities were dominated by sclerophyllous *Eucalyptus*, Casuarinaceae, and *Callitris*. Their understories, predominantly composed of taxa still widespread in southern Australian open forests, include genera (e.g. *Plantago*, *Pomaderris*, *Acaena*) not previously recorded from the earliest Quaternary in Australia.

A chronology was developed based on three sources of data. First, zircon fission track ages located the sequence approximately within the latest Pliocene or earliest Pleistocene. Second, based on this approximate age, a magnetic polarity transition within the lower half of the record was identified with the upper boundary of the Olduvai magnetic subchron. Third, submillimetre-scale sediment laminae are evident in parts of the sequence. These were interpreted as annual varves, based on electron microscopic analysis of sediment fabrics on resin-impregnated, polished sections. Varve thicknesses were measured in order to develop a floating chronology. This floating chronology was then anchored to the upper Olduvai boundary, and the amplitude modulated pattern of the rainforest angiosperm time series was correlated with the amplitude modulation of its inferred driver, summer insolation, to place the record within the geological time scale, between c. 1835 and 1555 ka.

Spectral analyses of pollen and other climate proxies indicate that environmental changes were paced by the 23 kyr period of precession. By contrast, the 41 kyr obliquity period, which strongly dominates Plio-Pleistocene marine oxygen isotope records and is associated with fluctuations in global terrestrial ice volume, does not dominate any SCB climate proxy. Rhythmic vegetation and hydrological cycles in the SCB record therefore represent direct responses to fluctuating summer insolation, which were independent from, and presumably out of phase with, globally synchronised glacial cycles.

Quantitative palaeoclimate estimates indicate that seasonal and annual temperatures during the Early Pleistocene were c. 0.5-4°C warmer than present, and that rainfall was higher than present, annually (≥1.2x modern) and, especially, during summer (≥2.4x modern). Such warm temperatures and high summer rainfall, in combination with the precession-dominated climate cyclicity, suggest that Early Pleistocene climate in southern Australia was very different from Late Quaternary climate. The modern intensity and/ or seasonal migration of the subtropical high pressure cell, which dictate Australian rainfall seasonality today, are features that must have evolved since c. 1.5 Ma. In Australia, 'Tertiary' like climates, characterised by high summer and annual rainfall, persisted well into the Pleistocene, and moisture demanding rainforest vegetation remained widespread, at least in upland regions.

Pre-settlement paleoecology of Central Otago's semi-arid lowlands, with emphasis on the role of avian herbivory in South Island dryland ecosystems, New Zealand.

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The vegetation communities that existed in the semi-arid intermontane basins and gorges of Central Otago prior to human settlement ~750 years B.P. are poorly understood. This is because of a lack of fossil evidence and complex restructuring by anthropogenic factors, especially increased fire frequency, and more recently mammalian grazing. There is also little information regarding the effect of the lost fauna on maintaining and structuring presettlement communities, both in Central Otago and throughout the eastern South Island dryland zone. This study aims to provide a clearer understanding of the functioning of pre-settlement ecosystems in dryland Central Otago, particularly the role of the largest vertebrate herbivores, the moa (Aves: Dinornithiformes), and to explore the implications of the extinct fauna for dryland conservation management across New Zealand.

Late Pleistocene and Holocene vegetation communities of the Central Otago lowlands were reconstructed from plant macrofossils, including seeds, leaves, and wood, excavated from rockshelter, cave, and swamp deposits throughout the region. The macrofossils represent three main vegetation types: late Pleistocene to mid (late?) Holocene basin floor wetland herb associations, *Olearia*-shrublands surrounding these wetlands, and mid to late Holocene open scrubland and woodland in gorges and on low altitude slopes, dominated by filiramulate *Olearia, Coprosma,* and *Corokia,* with abundant lianes (*Muehlenbeckia* spp. and *Rubus* spp.) and understorey herbs. Many native tree and shrub species that are presently widespread in the Central Otago lowlands were rare or absent prior to anthropogenic fires (e.g. *Discaria toumatou, Kunzea ericoides, Leptospermum scoparium*). Other tree and shrub species once present are now extinct in the region (e.g. *Coprosma obconica, Plagianthus regius, Pseudopanax ferox*). The loss of these indigenous woody vegetation communities was a major factor contributing to the extirpation of many small bird species, and undoubtedly also reptile and invertebrate species, from the region.

Plant macrofossils from rockshelters included remains of bird nests, identifiable by desiccated feathers and eggshell amongst them. These macrofossils include the first described plant remains from the nests of moa, which were constructed from a shallow bed of twigs of locally available shrubs and lianes. Many of the twigs are 25-30 mm in length and show evidence of having been clipped by moa bills.

Desiccated coprolites, mostly of moa, but also specimens attributed to Finsch's duck (*Chenonetta finschi*) and red-crowned parakeet (*Cyanoramphus novaezelandiae*), were recovered from rockshelter excavations. Moa species associated with a sample of coprolites were identified using ancient DNA analysis, and plant macrofossils from these were examined, together with previously unexamined moa gizzard content samples excavated from mires in the eastern South Island dryland zone. The results indicate that, in addition to previously reported browsing, upland moa (*Megalapteryx didinus*) and heavy-footed moa (*Pachyornis elephantopus*) also functioned as grazers, and seeds in their coprolites are dominantly of low shrubs and ground-cover herbs. Of particular interest was the higher than expected frequency of seeds from the currently rare and threatened 'spring annual' herbs; *Ceratocephala pungens* and *Myosurus minimus* subsp. *novae-zelandiae* (Ranunculaceae), suggesting further research on potential ecological relationships between moa and these plants would be worthwhile. The results of this study have provided a baseline for future conservation and restoration projects in the Central Otago lowlands.

Fixed intertidal biological indicators and Holocene sea-level change at Cape Edgecumbe, Queensland

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Fixed intertidal biological indicators, in the form of calcareous tubeworms and barnacles, have previously been used to identify former sea-levels on the Western Australian and New South Wales coasts, leading to the development of a 2 Stage Model for mid to late Holocene sea-levels in Australia by Baker *et al.* (2001b). This model suggests a highstand of +2 m ± 0.5 m before 3800 cal. yr BP, a rapid fall of approximately 0.7 m at 3700 cal. yr BP, and a sea-level of +1 m ± 0.5 m after 3700 cal. yr BP.

Oyster species *Saccostrea cucullata* and *Crassostrea echinata* are the key marker species of tropical intertidal zones in Queensland. Radiocarbon dating of fossil oysters from subfossil assemblages at Cape Edgecumbe on the Central Queensland coast produced time-elevation data that fits within the 2 Stage Model proposed by Baker *et al.* (2001b). Four oyster samples taken from 1.45 m to 1.74 m above present living oysters returned dates of 4226-5727 cal. yr BP. One oyster sample from 1.30 m was dated at 3868 cal. yr BP, just before the proposed event horizon at 3700 cal. yr BP. Four younger oyster samples, dated between 2623-3079 cal. yr BP, were collected at heights 0.60-1.21 m above present and therefore within Stage 1 of the model. Species change identified within the *in situ* fossil shellcrust suggests a change in environmental conditions after the mid Holocene.

Secondary evidence from Edgecumbe Bay in the form of fossil *in situ* coral and raised beachrock terraces further supports higher than present mid to late Holocene sea-levels for the Central Queensland coast.

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