Holocene records of the Indian Ocean Dipole

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The Indian Ocean Dipole is a recently discovered mode of inter-annual climate variability which occurs in the tropical Indian Ocean. The dipole results in anomalous winds, sea surface temperatures and rainfall throughout the Indian Ocean region, bringing drought to Indonesia and Northern Australia as well as floods to eastern Africa. During 1997 the strongest dipole in recorded history occurred in the Indian Ocean and was accompanied by massive fires in western Indonesia and the widespread death of coral reefs in the Indian Ocean. Developing a better understanding of the natural dynamics and effects of the Indian Ocean Dipole is essential for improved long-ranged forecasts of droughts and floods in the Indian Ocean region, as well as accurate predictions of future climate change world-wide. Sea surface temperature changes in the Mentawai Islands, south-west Sumatra, Indonesia play a key role in driving the Indian Ocean Dipole. In this study we present the proxy environmental signals preserved in the stable isotope and trace element chemistry of modern and Holocene *Porites* coral records from this region can be used to reliably reconstruct recent dipole events. Dipole events are also preserved in the fossil coral records from the Mentawai Islands and provide the first evidence that the Indian Ocean Dipole has been operational for at least the past 6000 years. These results have important implications for the relationship between the Indian Ocean Dipole and El Niño-Southern Oscillation and provide insights into the tolerances of coral reefs to both natural and anthropogenic environmental perturbations.

Pliocene and Quaternary vertebrate faunas from a succession of karstic and related coastal deposits on Barrow Island, northwestern Australia

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Barrow Island is an emergent anticlinal structure situated near the inner margin of the Exmouth Plateau, northwestern Australia. It rises to 60 m asl and is currently separated by a 60 km shallow water strait (to 15 m) from the Onslow coast. The surficial carbonate exposure includes minor ?Eocene Giralia calcarenite, confined to the centre of the island, and various subunits of the mid- to late Miocene Trealla Limestone equivalent, forming the major plateau surfaces and exposures in coastal cliffs. Various Plio-Pleistocene calcarenite and aeolianite units are present around the margin of the island. The Trealla Limestone equivalent supports a spectacular palaeokarst which is best seen in section in 10-30 m high cliffs along the west coast. Its features range from sediment-filled solution tubes and grikes, to large, infilled dolines and partially filled phreatic cavern systems. Most palaeokarst features are infilled by cemented red breccias, occasionally with associated speleothem. Today, Barrow Island supports a skeletal soil mantle and a low hummock-grass steppe dominated by *Triodia wiseana*. Small pockets of *Eucalyptus* spp. and mangroves are present in sheltered valleys and coastal embayments respectively.

Vertebrate fossils have been recovered from a total of six major sedimentary units including cave- and doline-fill breccias, and a coastal aeolianite. Palaeomagnetic determinations conducted on several separate breccias, combined with interpretations of coastal geomorphic history, indicate that breccia formation commenced in the Gilbert Chron, but that most of the larger deposits accumulated during the Gauss Chron. A later phase of sedimentation into partially re-excavated caverns occurred during the early to mid? Pleistocene, and continues on a small scale through to the present.

The earliest vertebrate fauna, of possible late Gilbert Chron age, has yielded a variety of both browsing and grazing kangaroos (including *Sthenurus* sp.), two species of ringtail possums, and single species of bandicoot, marsupial mouse and thylacine. Despite the presence of other small mammals, there is no evidence of rodents in the deposit. The faunal suite points to a mosaic vegetation of grasslands and woodland/shrubland. Several faunas of presumed Gauss age contain abundant remains of bandicoots, bettongs, small wallabies, a brush-tailed possum, marsupial mice (*Sminthopsis*) and a variety of murid rodents (*Pseudomys* spp., *Zyzomys* sp., a new genus of water rat), along with a megadermatid bat. The absence of ringtail possums or browsing kangaroos suggests a disappearance of remnant forest/shrubland habitat by that time. The time interval between these and the earlier fauna is also of great interest insofar as it may include the arrival of murid rodents in Australia.

Two faunas of probable early to mid-Pleistocene age are found in direct stratigraphic association. The earlier fauna, preserved in a remnant cave floor deposit with associated speleothem, contains a diverse suite of mammals including both large and small macropodids, bettongs, two genera of bandicoots, at least four species of dasyurids, a brush-tailed possum, a ghost bat (*Macroderma* sp.), other microchiropteran bats, occasional reptiles and birds, and at least nine species of murid rodents including representatives of the 'newcomer' genus *Rattus*. The diversity of this fauna greatly exceeds that found on Barrow Island today but is similar to that recovered from archaeological deposits of late Pleistocene to early Holocene age on the nearby Montebello Islands; it is presumed to relate to a sea level low stand. The overlying fauna, derived from a silicified aeolianite, has yielded a small fauna that includes a large species of *Isoodon* distinct from that found on the island today.

The Barrow Island faunal succession provides the first record of vertebrate evolution through the late Tertiary and Quaternary of northwest Australia, and a unique opportunity to examine the long-term evolution of an insular fauna.

The timing of the last glacial maximum in Australia

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Only a small part of mainland Australia (12-15 km^2) was glaciated during the last glacial maximum (LGM) (Barrows et al., in press a). Glaciation was much more extensive in Tasmania, and covered as much as 2000 km^2. Despite more than a century of research, the chronology of LGM glacial deposits in Australia has been restricted to a handful of ^{14}C dates only. To place tighter constraints on the timing of the LGM, nearly 100 exposure ages were determined on glacial and preglacial landforms using the cosmogenic isotopes ^{36}Cl and ^{10}Be. A glacial stratigraphy for southern Australia was then constructed from these ages. We found that the LGM type section in Tasmania, the Hamilton Moraine below Lake Margaret, is actually mid Pleistocene in age. The glacier advance of greatest extent during the LGM was the Blue Lake Advance of the Late Kosciuszko glaciation (LK_{BL}). Twenty three ages from eleven LK_{BL}equivalent moraines in seven regions were chosen to define the ages of this event (Barrows et al., in press b). Despite occurring over a region of 8° of latitude and 1500m of elevation in climatically different areas, there is no significant variation in the age of this advance across the region. The age according to ^{10}Be is 17.3 ka and the age according to ^{36}Cl is 19.7 ka. The difference between these ages is believed to be due to errors in the scaled production ratesin one or both isotopes. A peak in periglacial activity occurs at 22.7 ka, dated using ^{36}Cl (Barrows et al., in preparation). In comparison, minium sea-surface temperatures occurred in the neighbouring southwest Pacific Ocean at 20.6 ka and the δ^{18}O maximum occurred at 18.6 ka (Barrows, et al., 2000). The latter age post-dates the sea level minium and is believed to represent a lag in propagating the δ^{18}O signal into the Southern Hemisphere due to slower deep-water circulation during the LGM. The close correspondence between the mean age of the LK_{BL} advance and the peak of periglacial activity according to ^{36}Cl, existing ^{14}C dates and the SST minimum suggests that the LGM was at its coldest in Southern Australia between 20-23 ka.

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Quaternary Relevance: dirty concept or justification? Ruminations of an old man chewing string

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The health and welfare of any intellectual pursuit resonates with the social and political realities of the day. In our own days, issues of eco-irrationalism fuelled by rampant managerialism threaten so many traditional aspects of university research. Where does Quaternary science stand in this context? Traditional values of scholarship have come under a range of new pressures, some would say outright attack. Classical Studies, Greek and History have all come under the axe in various universities. This should ring alarm bells, for so much of our work rates as pure history. History defends itself by its "shaping of society". Earth history may well "shape the earth" but in an increasingly urban environment with a culture almost myopically transfixed on "heroes of sport" who really cares? Is Quaternary history really relevant to any but the scholarly and idealistic members of AQUA? If so, who are they, and are we really delivering the product? Many claims for Quaternary relevance to applied problems of the day are often difficult to support to hard-nosed engineers or model pragmatists. In an environment where human impact now dominates over so many elements of natural change, what hierarchy can be claimed for historically based studies of plants, landscapes, animals or even people for that matter? For those of us imbued with confidence and enthusiasm for our discipline, an important question remains. Are we delivering to those who most need our information? Is academia in this area, really performing to meet Australia's needs?

Maybe we can take a leaf from the many books of our colleague historians. The most successful are good storytellers. Quaternary Australia has some great stories to tell. How are we going to get those stories across?

Mud, mines and rainforest: a short story of human impact in central west Tasmania as derived from Lake Dora

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Evidence of the impacts of mining and forestry in central west Tasmania has been derived from a high-resolution record spanning the last 190 years. The record (which includes data from pollen, trace metals and ^{210}Pb analyses) was obtained from the top 7.5 cm of a 68 cm core extracted from Lake Dora, a sub-alpine tarn in the West Coast Range in central west Tasmania. Lake Dora lies in close proximity (15 to 30 km) and downwind of three major mining centres - Queenstown, Rosebery and Zeehan.

The Lake Dora core was extracted using a modified hammer driven piston corer (Neale and Walker, 1996), which enabled samples to be collected at 0.25 cm intervals. Lead-210 analyses of these samples have provided a high-resolution sedimentation and dating profile, with each sample representing between two and 16 years of history. Anomalies identified in the ^{210}Pb profile suggest periods of increased sediment deposition, which may correlate to local prospecting. A basal age of around 1810 AD was estimated.

Trace metals analyses of the samples indicated substantial elevations in several metals, commencing *ca.* 1900 and increasing sharply in the 1950s and 60s. These concentrations subsequently decreased in the 1970s and early 1980s. Comparisons of these changes with the historical records of mining and associated activities have demonstrated some correlation.

The pollen record derived from the Lake Dora core also exhibits substantial temporal changes, both in terms of species composition and pollen abundance. These changes can be related to trends in the trace metal and ^{210}Pb profiles as well as regional mining and forestry activities.

This study forms part of a larger ANSTO project researching human activity and climate variability in Australia.

Preliminary Investigation of Sediments from Caledonia Fen, Bennison Plains, Victoria.

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Caledonia Fen is a small upper montane swamp located on the western edge of the Bennison Plains in Victoria. The fen has been subjected to a previous palaeecological investigation of the upper 3 m of sediment (in 1979), and is the basis of a current and ongoing palynological investigation of a 17.5 m sediment core (see the abstract by Dr. Merna McKenzie in this book). Despite the excellent record which has been collected using pollen, charcoal and organic content data, the site has not been subjected to any previous form of sedimentological study.

This study, which formed the basis for a B.Sc. honours project was aimed at determining the potential of a large-scale sedimentological investigation of the terrigeneous sediments within Caledonia Fen. Three components of the sediment record were investigated: particle size and distribution using a MasterSizer laser particle size machine; clay mineralogy using a portable infrared mineral analyser; and mineral magnetics using a magnetic susceptibility meter.

A 17.5 m sediment core, which was taken from the centre of the fen in 1997, was sampled at a resolution of 4cm with additional samples taken during regions of high variability of physical sediment composition (i.e. sand bands etc.). A number of shorter sequences from in and around the fen were also subjected to similar analysis.

The clay mineralogy of the fen displayed little variability throughout the sequence of inorganic sediments. The magnetic susceptibility record exhibits a record which appears to be sensitive to post depositional autogenesis or diagenesis, and further investigation of magnetic properties may reveal a very sensitive record of climate change.

The particle size analysis provided the most direct record of catchment hydrology and sedimentology. Analysis of particle size distributions revealed that for the majority of the sequence, which current dating suggests spans the last glacial period, sediment deposition within the fen was primarily a result of the settling of suspended sediment. A number of variations from this normal deposition occur during the sequence, with greater variability toward the base of the sequence. Periods of mass moment within the catchment basin, most likely due to solifluciton or other periglacial activity, were found within the sequence. In addition, periods of deposition from tributaries were also evident. This signifies a significant alteration in fen hydrological processes as the catchment for the fen is very small, and the volume of flow required to deposit well sorted coarse sediments from the tributaries would have to be much higher than any which has been experienced during the Holocene, even during the annual snowmelt.

Investigation of a number of shorter sequences from the margins of the fen suggest that periods of mass movement and tributary flow were more frequent than indicated in the main core record. This is explained by the location of the main core in the middle of the fen, recording only the highest energy events. The increased variability within the lower parts of the sequence may be a result of increased palaeoenvironmental variability during these times, or changes in fen morphology. Evidence from the sequences at the fen margins suggests that the latter is the most likely explanation.

By combining the sediment and (partial) pollen record from the fen, a preliminarily palaeoeclimatic/palaeohydrolic record has been constructed. This record highlights just how variable palaeoenvironmental conditions were during the last glacial period.

The resolution and temporal extent of the Caledonia Fen record, combined with the unique nature of fen and catchment morphology, mean that the sediment record, when completed, will provide an excellent addition to the southeast Australian palaeoenvironmental record, spanning at least until oxygen isotope stage 5.

The sedimentology of the fen will be investigated in greater detail in a Ph.D., which is currently being undertaken by the author. Any suggestions as to sediment properties and techniques which could be applied to the Caledonia Fen record would be greatly appreciated.

McEacherns cave revisited

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McEacherns Cave is a pitfall trap in the Tertiary Gambier Limestone in Lower Glenelg National Park, SW Victoria. Fossil vertebrate deposits in the cave, containing both extinct megafauna and modern species, were first excavated in the mid-1960s (Wakefield 1967) and then in 1977 by Hope. Hopeís aim was to radiocarbon date Wakefieldís sequence in order to date the Late Pleistocene disappearance of the megafauna, as part of a broader study of megafaunal extinctions. However, there is a major stratigraphic disconformity in the sequence and the older sequence containing the megafauna was clearly well beyond radiocarbon limit. The younger sequence, dated to between 2-15ky, contains modern species representing a change from semi-arid to the current dry sclerophyll woodland through that time. The older sediments contain an unusual combination of modern species, suggesting a wet environment, as well as megafauna such as *Zygomaturus*, *Zaglossus* (the giant anteater), and *Sthenurus* spp. Also present is the ëweird and wonderfulí primitive wombat, *Warendja wakefieldi*, known only from this site and Comaum Forest Cave in SA, about 90k north of McEacherns (Hope & Wilkinson 1982, Flannery & Pledge 1987, Pledge 1992). A tentative reconstruction of the geomorphic history of the cave suggests that the older sediments could predate the last interglacial. Budde is currently re-assessing the very large collection of material excavated in the 1960s and 70s, with the aim of conducting a palaeoecological assessment using ecological diversity indices as described by Andrews *et al* (1979). Further stratigraphic work on the site is warranted, in particular the application of modern dating techniques.

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Climate before agriculture

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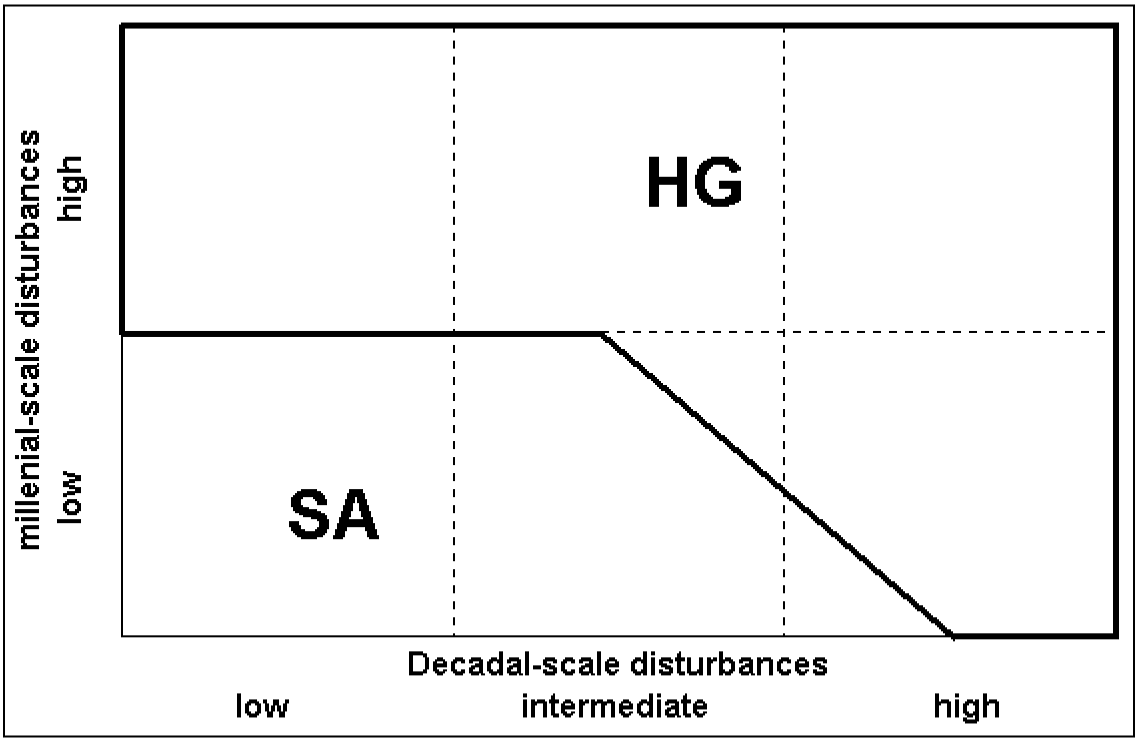
Agriculture commonly is seen as the child of the Holocene, when climates became milder than the preceding ice age; however, the timing of its onset, the number of ways in which it developed and the number of theories to account for it are so various that the role of climate change *per se* becomes obscure. Importantly, when climatic changes across the Pleistocene-Holocene divide are being considered, comparisons should not be made simply in terms of averages, because if averages were all that matter, then the climate and thus the ecosystems of almost any part of today's world could be found *somewhere* in the Pleistocene world, even on the same major land-masses as they are found today. However, the fossil record of the Pleistocene contains plant assemblages that lack exact counterparts today, which suggests an influence of factors other than climatic averages. Although reduced atmospheric carbon dioxide may have been partly responsible, another difference between the late Pleistocene and Holocene was the occurrence of large and very rapid shifts of climate every few millenia, at least throughout large regions of the northern hemisphere (these fluctuations were much faster than those explained by the Milankovitch theory of climatic change).

Ethnographic studies suggest that the magnitude and frequency of environmental disturbances affected prehistoric human subsistence and habitat: species diversity tends to be highest at intermediate frequencies of ecosystem disturbance, and human subsistence strategies are broadened by environmental disturbances. This paper considers the possible effects of climatic fluctuations at millenial and shorter scales on ecosystems and human subsistence, as summarised in the figure below, where higher-frequency variability (times scales from interannual to several decades) is represented by the horizontal axis; low-frequency or millenial-scale climatic switches are represented on the vertical axis. It is proposed that the hunter-gatherer (HG) and subsistence agriculture (SA) realms differ in climatic variability, and that Holocene diminuition of variability in some regions favoured the development of agriculture.


HG
SA
millenial-scale disturbances
low
high
Decadal-scale disturbances
low
intermediate
high

Arid phases in southeastern Australia during the Late Glacial and Holocene from multi-proxy records of playa lakes

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Playas within the seif dunefields of the Murray-Darling Basin consist of relict and active salinas and source-bordering dunes. Geomorphic, sedimentary and palynological records from four playas in southwestern New South Wales provide a history of regional environmental change over the past 20,000 years. Correlation of aeolian (dune) and lacustrine (salina) events is achieved using OSL and AMS radiocarbon age determinations. A major phase of clay dune formation at around 20 Ka indicates that playa basins were deflated at the height of the Last Glacial Maximum. The early Holocene was also arid with a dune-building phase at 8-7 Ka. In contrast, mid-Holocene conditions were relatively humid. Palynological studies from salina sequences indicate that the sub-humid woodland taxon, *Allocasuarina luehmannii*, expanded into far southwestern New South Wales suggesting rainfall may have been around fifty percent higher than present. Enhanced aridity or greater seasonal variation in the climate occurred over the past 4,000 years. Woodland decline, lower water tables and the formation of source-bordering dunes during this period may be due to the onset of El Niño/Southern Oscillation (ENSO)-type events. The past 1,000 years has experienced a slight increase in moisture budgets with some recovery of woodland taxa, rises in groundwater and stabilization of late Holocene lunettes with halophytic vegetation.

Late Pliocene aridity and fire in southwestern Australia

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A crater created by a supposed meteor impact in southern Western Australia contains a well-preserved lake sequence of Upper Pliocene age. This paper reports on the palaeomagnetic record, sediment patterns, and some of the results from pollen, charcoal and diatom analyses.

The palaeomagnetic record shows a good match with the Gaussian chron and includes the Kaena and Mammoth subchrons; and these were used as a basis for developing an age-depth model for the sequence. The sediment was subdivided into an upper unit of four lithozones and a lower unit. The upper unit, which dates from *c*. 2.5 to 3.51 Ma was interpreted to have formed under a generally wetter climate than today, but results of pollen and diatom analyses show some relatively short intervals of semi-arid climate took place around 2.53 and 2.58 Ma. There are also sections of laminated sediments which indicate that between 3.22 and 3.06, and between 3 and 2.87 Ma the climate was more variable and possibly seasonal compared to the rest of the record. The lowermost unit is a poorly laminated grey clay.

The chemical analyses indicate the lake varied in water depth and that salinity and diatom production was related to climate change rather than changes in major nutrients. The palynological analysis is still under construction, but the upper 20 m of sediment confirms woodland and heath taxa, interspersed with some chenopod shrubland phases, and minor elements including *Nothofagus*,*Araucaria*, *Phyllocladus* and other podocarps, which are known from other Tertiary records from southern Western Australia, formed the major vegetation assemblages. This is a combination unknown in the extant flora of the region or indeed from anywhere in Australia. Charcoal is abundant in the record indicating fire was a major environmental feature, long before Aboriginal people inhabited the continent.

These data indicate that the last million years of the Pliocene for south-western Australia endured several episodes of climate variability, thus lending support to the idea that the Pliocene was not a period of uniform cooling trend gradually leading into the Quaternary glacial episodes.

Potential of a small semi-arid lake for Quaternary Studies in the Paroo, NSW

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The palynological and sedimentological research in the arid and semi-arid zone is generally limited to large lakes, often several hundred or thousand square kilometres in extent. The small lakes do not seem to attract as much interest. Although they are likely to possess a better spatial and temporal resolution of record than the larger lakes, they remain unstudied.

Following a preliminary sampling and survey of lakes in the Paroo region (far north-western NSW) a small ephemeral lake, named Palaeolake, was selected for study of its potential for Quaternary studies and possible reconstruction of past environmental and climatic conditions. Considering its location, some gaps in the record were expected. To increase the interpretational potential of the lake sediment data, multi-disciplinary analysis have been undertaken. They involved palynological studies as well as geomorphological and sedimentological analysis. Surrounding dunes have been cored in search of signs of sediment deflation from the lake basin (to estimate the possible extent of the incompleteness of the sediment data). Both dune and lake sediments have been processed for particle size distribution, mineral magnetic susceptibility, percentage organic matter content, pH, salinity, gypsum, caesium-137 content, mineral composition (XRD) and zooplankton content. Complementary SEM and EDS was done on selected particles. Soil samples were analysed for modern pollen representations.

An AMS radiocarbon date for 14,400 ± 150 years BP has been obtained for a depth equivalent to 80-85 cm in the lake sediments, while a sample from 180-190 cm depth had insufficient carbon to be dated using AMS.

Based on the multiple results, four distinctive stages in the Palaeolake environmental history have been identified: a large/deep lake stage, a drying lake stage, a fluctuating lake water stage, and a recent ephemeral lake stage. These stages seem to agree generally with similar events recorded in other arid and semi-arid zone lakes, such as Lake Eyre, Lake Tyrell, and Willandra Lakes.

Lashmars Lagoon Revisited

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Robin Clark's Holocene record from Lashmars Lagoon (Singh *et al*., 1981) has challenged the widely used interpretation for peaks in charcoal abundance - the arrival, or increased activity, of indigenous people (also used in Singh *et al*., 1981). Specifically, the increase in charcoal coincident with the departure of people from Kangaroo Island at 2.5 ka BP was interpreted as a shift from frequent to infrequent burning which enhanced fuel loads to increase the volume of material burnt and so the volume accumulated in the Lagoon's sediments. This was despite negligible change in the pollen record across this period. Recent diatom analyses reveal considerable hydrological and water quality change associated with the change in charcoal accumulation (Illman, 1998). The shift to shallow saline conditions may have provided the REDOX conditions suitable for the production of blackened particles. Such conditions probably prevailed in certain Victorian crater lakes at the beginning of the Holocene and may have produced peaks in pyrite at West Basin (Gell *et al*., 1994) and 'charcoal' at Lake Cartcarrong' (Walkley, unpublished data). Clark (1984) revealed a four-fold increase in material digested by nitric acid - the treatment recommended by Singh *et al*. (1981) to remove dark organic remains other than charcoal - after 2.5 ka BP at Lashmars Lagoon. <u>Hypothesis 1</u>: climate change at 2.5 ka BP increased the salinity of Lashmars Lagoon producing the limnological conditions which produced high volumes of dark, angular fragments.

Recent developments in the use of ^{13}C nuclear magnetic resonance (NMR) to recognise non-living soil organic matter (NSOM) and the isolation of charcoal particles in soil using photo-oxidation (Skjemstad *et al*., 1998) have enhanced understanding of the taphonomy of charcoal particles. Charcoal particles appear to be largely derived from burnt grasses and are quite rapidly broken down into the clay/fine silt fraction with which they are readily transported horizontally, and vertically in the soil profile (Janik, pers. comm.). Australian soils contain a large pool of inert carbon, almost all of which is charcoal. "Soils developed on alluvium, therefore, often contain high concentrations of charcoal not because of on-site burning, but because these soils are zones of accumulation " (Skjemstad *et al*., 1998: 675). <u>Hypothesis 2</u>: climate change at 2.5 ka BP mobilised old, regional charcoal which was transported in the clay fraction to sites of sediment accumulation including Lashmars Lagoon.

<u>Hypothesis Testing</u>: quantify charcoal using NMR and photo-oxidation from Holocene records at Lashmars Lagoon and Boat Harbour Creek, Fleurieu Peninsula.

Postscript: other sites reported in Singh *et al*. (1981) show increased charcoal concentrations in association with dry interglacials.

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Molluscs and Millennia: A long term perspective for Aboriginal shellfishing

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Most of the shell middens along the Australian coastline appear to have been created during the last 3,000 years, and because this seems to have occurred 3,000 years after the sea had reached its present level, many researchers have tried to explain this phenomenon with respect to theories of population increase and/or an intensification of social and economic activities. However, research conducted during the 1980s at Discovery Bay, in southwest Victoria, indicated that shellfishing had probably been carried out throughout the Holocene, and the fact that there appeared to be many more shell middens for the Late Holocene than for earlier periods was due to coastal erosion, rather than an increase in the exploitation of the resource. Since then, there has been very little written in the archaeological literature to contradict this alternative hypothesis, and indeed it has been supported by further archaeological work.

Fire, El Niño, and Rain Forest Dynamics in Northeast Queensland

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A high-resolution contiguous record of macroscopic charcoal particles in sediment cores from Lake Euramoo, northern Queensland has been dated using ^{210}Pb and AMS analysis to allow reconstruction of local fire periods and their relationship to climate during the Holocene. The results have produced the most detailed charcoal record for the Australasian region with sampling resolution ranging from 5-20yr intervals throughout the Holocene. A close correspondence between historical records of land use change, instrumental climate data and the post-European charcoal record suggests that the site is sensitive to changes in the local fire regime. The dates obtained from the lower, more inorganic sections of the sediment cores shows that these sediments were deposited during the last glacial maximum and represent an extension of the previous known age of the site (>9000 yr BP from Kershaw 1970, *New Phytol*. 69, 785-805.). Charcoal levels are low during this period, possibly due to poor preservation. High charcoal values occur during the early Holocene at a time when the catchment was vegetated by dry schlerophyll taxa (*Eucalyptus* and *Casuarina*). Rain forest replaces the dry schlerophyll communiy by 7200 cal yr BP under the influence of increased southeast trades and warmer ocean surface waters. The frequency (and intensity?) of disturbance events associated with fire increased in the last 4700 years, possibly associated with the onset of El Niño-related climate variability.

- What Impact have El Niño Events had on Rain Forest Communities?

  - Reduced extent of rain forest habitat.
  - Shift towards competitive dominance of species adapted to drought/fire or frost. (e.g. *Agathis*, *Mallotus*, *Macaranga*, *Podocarpus*, *Araucaria*)
  - Tendency towards higher species turnover rates within rain forest communities.
  - Slow growing shade-tolerant species become rare
  - Increase in gap-dependent species

Tropical biomass burning appears to be at least partly controlled by orbital forcing (precession), though vegetation change and human activity are also significant factors. This new record will make a significant contribution to our understanding

of the nature and timing of the onset of El Nino-related climate variability in the Australian region and the impact of fire and drought on tropical rain forest communities.

A study of Human Activity and Climate Variability within the Tonalli River Catchment, Greater Blue Mountains World Heritage Area (NSW)

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The Tonalli River Catchment, a tributary at the southern end of Lake Burragorang, in the Greater Blue Mountains World Heritage Area[1] (NSW), was studied to evaluate the spatio-temporal distribution of pollutants from the Yerranderie silver-lead-zinc mine site, abandoned in the late 1920s. Sediment cores were collected in the mouth of the Tonalli River and surface sediment samples were collected in the Tonalli River. The concentrations of Pb, As, Zn, Cu, Cd, Hg and Ag in the sediments were analysed by ICP-MS and ICP-AES techniques. Variability of pollutant input into Lake Burragorang through time was established through ^{210}Pb dating of the core sediments. Published records of rainfall and bushfire data were used to discuss the analytical results and it was established that historically, metal concentration in the sediments, are higher in correspondence with heavy rainfall periods while spatially, metal concentrations decrease with distance downstream of the mines.

[1.] The Greater Blue Mountains Area (GBA) was established in December 2000 and consists of 1.03 million ha of mostly forested landscape on a deeply-incised sandstone plateau 60-180km inland from central Sydney. The site comprises eight protected areas in two blocks separated by a transportation and urban development corridor. Technically speaking, either the Yerranderie mine-site or the Warragamba catchment areas (including Lake Burragorang) are not included in the WHA. However our study site plays a very central role in the southern section of the WHA and has similar features. The GBA-site is particularly noted for its wide and balanced representation of *Eucalyptus* habitats including wet and dry sclerophyll, mallee heathlands, as well as localised swamps, wetlands, and grassland. Ninety *Eucalyptus* taxa (13% of the world's total) occur in the Greater Blue Mountains. The sites hosts several evolutionary relic species; such as the Wollemi pine, which have persisted in highly-restricted microsites.

Holocene environmental change in Tuggerah Lakes: A multi proxy approach

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Estuaries on the east coast of Australia are the result of a period of sea level rise between 10 - 6ka BP, known as the Postglacial Marine Transgression. These estuaries follow the same evolutionary path until ëstillstandí conditions, where estuary infilling was controlled by the balance of sediment input from marine and terrestrial influences. The Holocene infill of Tuggerah Lake has been studied at two localities: Pelican Island which is in close proximity to the present day tidal inlet and within the flood tide delta, and Chittaway Bay, located on the westward side of the estuary in a more central basin setting.

During Holocene evolution, a number of environmental conditions were identified, with evidence provided by magnetic signals, contributions from organic and carbonate material and water content of sediment, and is further supported by SEM and TEM images. The interrelation between sea level rise and sediment input initiated a series of oxic/anoxic events to occur, and seem to be driven by the degree of biological activity, and coincides with the availability of organic matter, reactive iron and sulphur. Iron and sulphate reducing environments dominate most of the core material due to the presence of iron sulpides, typically pyrite, and were highlighted by changes in ARM/SIRM ratios, in which fine grained bacterial magnetite (reflected by higher ARM/SIRM ratios) coincides with iron reducing conditions.

Estuarine environments are useful in depicting environmental and broader scale climatic changes, as the estuary acts as a ëtrapí for the surrounding catchment, providing ëproxyí indicators affected by changing conditions, and subsequently become incorporated into the sediment at the time of accumulation. One particular indicator, such as pollen, reflects a decline in precipitation and greater aridity at 5ka BP, shown by a decline in Casuarinaceae/ Asteraceae combinations, coinciding with an increase in *Eucalyptus*/ grassland associations. At the Chittaway Bay location, there is evidence of salt marsh species at ~2ka BP, positioned at the termination of estuarine mud formation. There appears to be a periodic pattern within the concentration of both total organic carbon and carbonate results recorded at the base of Pelican Island. Dansgaard - Oeschger cycles display a similar periodicicty, but due to the lack of detailed chronological control, such a correlation is viewed with caution.

This study on the changing environmental conditions during the Holocene at Tuggerah Lake shows the dominant control for changing conditions is the role of sea level change, including evidence for the Postglacial Marine Transgression, stillstand conditions and the progression of maturity of the estuary after proposed stillstand conditions. This record of Holocene environmental change can be used for the furture assesment of impact upon the estuary by human occupation in more recent times, for example, to compare the rate of natural anoxia conditions against the rate of human induced anoxia affects.

Dating human impact in the Pacific; where does that carbon come from?

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Palynologists have been annoying prehistorians for decades by finding evidence for possible anthropogenic environmental change, extrapolating an age from some surrounding bulk dates, and then telling the archaeologists to look for sites older than any yet found. If we ignore some very gross examples of this (eg Lake George, certain notorious marine cores from North Queensland etc) there are still problems due to the lack of precise dating. The southwestern Pacific provides a good test case, as occupation is believed to have commenced about 3,000 years ago on coastal sites, so significantly older dates need to be carefully checked. Cores from Aneityum Island, Vanuatu provide examples of a very widespread problem- that the appearance of settlement seems to cause substantial erosion of swamps prior to deposition of post settlement sediment. Thus dating just below inferred settlement horizons can give some very old ages, and old organic material is on hand to contaminate the actual disturbance levels. There may also be problems from the remobilisation of old carbon in soil mantles that are washed into swamps. So as clay and charcoal appear in the record, the dates become older. Both effects are apparent in a series of sites in Viti Levu, Yacata, and Mago islands in Fiji. Since the pollen diagrams often show little sign of mixing, more precise dating can be achieved by AMS dating of a fine fraction that has been given acid, alkali and mild oxidation similar to pollen preparation. This approach has "solved" the problem of early dates for settlement at Bonatoa Bog on the Rewa delta found by Wendy Southern.

Australities: History of an Enigma

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Charles Darwin was given a specimen by Sir Thomas Mitchell in 1836 which he later described (1844) as a volcanic bomb made of obsidian. Darwin's comments were the first scientific reference to these curious glassy objects soon to be found scattered over a large proportion of Australia. But similar objects had been found elsewhere before, in Europe, where they had already proved difficult to interpret. Ranging in shape; with forms including buttons, dumb-bells, discs, spheres and colour; from black to yellow-green and bottle-green such objects are very distinctive. Prof. Franz Suess in 1900 introduced the generic term tektite for all such materials and specific terms such as australite for those from Australasia (the European tektites are called moldavites). They were considered distinct to meteorites in being distributed in particular fields and always being of a very siliceous glassy nature. Mitchell's specimen was collected from the sand plains between the Darling and Murray Rivers, in the southeastern corner of the area now known as the Australasian strewn field. Scientists like Charles Fenner and George Baker would devote years to collection and examination in an attempt to resolve the questions of tektite age and mode of origin. Southwestern Victoria would prove an important place in the development of our current understanding. The position of australites at or near the surface and their shiny unweathered appearance suggested a recent formation and deposition. Stratigraphic interpretation of the deposits was that they were Late Pleistocene to Holocene in age. When radiometric dating of tektites yielded ages of 770,000 years it created greater confusion. The radiocarbon work by E.D. Gill seemed only to confirm the youthful age. The stratigraphic question was clarified in 1999 with the publication of a paper describing detailed work carried out in the Port Campbell Embayment by E.M. Shoemaker and H.R. Uhlherr which showed australites derived from a stratigraphic position in chronological agreement with the radiometric determination. The origin of tektites was even more controversial. In 1938 Fenner listed 15 separate theories as to their mode of origin including relics from prehistoric glass factories and lightning fusing sand in the air. While today the majority of researchers would agree on formation due to the splashing of material out of a meteoroidal impact on Earth (Terrestrial Impact Theory) other theories such as the Extraterrestrial Volcanic Comet Theory persist. Australites remain objects of interest and wonder.

Vegetation dynamics of the Proteaceae in southwest Western Australia

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The humid southwest of Western Australia is geographically and climatologically isolated. An estimate of 9000 species exist in the southwest and 80% of these are generically and specifically endemic to this region (Marchant, 1998). The vegetation is unique and globally significant. The main aim of this study is to determine the vegetation history and Cainozoic development of the Proteaceae in the southwest of Western Australia.

Currently, little is known on the history of the vegetation in the southwest, including the Proteaceae family (which includes *Banksia*,*Grevillea*, *Hakea*, Smokebush). The available fossil records tend to be discontinuous, providing only snap-shots of past vegetation conditions. Often eastern Australian studies are applied to Western Australia on the assumption that the development of vegetation has taken parallel paths on either side of the continent. It is suspected that the history and development of vegetation in Western Australia is different to the eastern areas of Australia.

Limited palynological investigations of vegetation have been conducted in Western Australia. Those that have been done tend to be focused on the Quaternary and there is far more scope for study. A few palynological studies have been done on Eocene deposits, but these tend to be descriptive taxonomic investigations. This study incorporates the Eocene (a pivotal period in plant evolution) through the Pliocene, into the Holocene and comparing this with the present vegetation has not been done. This research will build on the available knowledge of southwestern Western Australian vegetation and climatic history and provide, in particular, a detailed account of the Proteaceous component of past vegetation.

This project aims, therefore, to understand the patterns of Proteaceae development by investigating three sediment sequences of different ages and a modern pollen rain study from the southwest of Western Australia. Lake Lefroy in Kambalda is a present salt lake and palaeochannel containing Eocene deposits that were accessible through a WMC minesite (ëAfricaí). Yallalie, an infilled meteorite impact site, containing a well preserved Pliocene assemblage was recently drilled for palynological analyses. A selection of several early and late Quaternary sites is being considered at present. Modern pollen rain of Proteaceous rich communities in Fitzgerald River, Stirling Range and Mt Lesueur National Parks is being studied to quantify the patterns of pollen representation of major taxa in relation to present vegetation.

The current concern for management of the environment for biodiversity requires such studies. Little is known about biodiversity and vegetation dynamics of the Western Australian environment (Dodson, 1994). Commonly, only broad conclusions can be made. It is not clearly known what has driven the southwest vegetation communities to develop into biodiverse hotspots. Understanding the forces in the environment that have shaped the evolution of the flora in the southwest will enable present communities to be better understood and managed accordingly.

The Quaternary history of the Western Plains of Victoria, Australia: geology, landscape and people

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Quaternary materials make up much of the Western Plains and the landscape itself has largely developed during the Quaternary. During the late Tertiary, about 5 to 6 Ma ago, a shallow sea reached up to the southern margin of the Western Uplands, the east-west spine of Western Victoria which extends from around Kilmore, north of Melbourne, to the Grampians Range and beyond. The retreat of this sea exposed for the first time a marine floor of clays and marls, with many parallel ridges marking successive shorelines. Most of these shorelines ridges have only just been recognised on new radiometric and magnetic imagery. As the sea retreated rivers in the Uplands gradually extended southwards, reworking and burying the marine surface with thin alluvial deposits.

About the same time both the Uplands and the Plains gave birth to a new volcanic province, and over the last 5 Ma nearly 400 scoria cones and lava shields have been built up, with fluid basalt flows spreading laterally around vents, and often southwards for many kilometres down stream valleys. Where the lava blocked drainage lakes and swamps formed, and on the plateau-like flow surfaces irregular ridges and collapse depressions also produced lakes and swamps. Some lava flows have been dated by K/Ar and radiocarbon, and changes in landforms, drainage, and soil and regolith development, can be used to build up a detailed chronosequence through the Quaternary.

Quaternary volcanism has left well-preserved cones, craters and crater lakes, scoria with iridescence, and stony rise lava flows with ropy and glassy surface textures - in fact such an obvious youthful appearance overall that the explorer Major Mitchell, the first person to recognise the area as volcanic in 1836, suggested that eruption had been "within the memory of man". The youngest dated eruption is that of Mt Gambier in nearby southeastern South Australia, at 4000-4300 B.P. by radiocarbon, and perhaps a dozen volcanoes may eventually be found to have erupted within the last 20,000 to 30,000 years. Writers on volcanism on the Western Plains after Mitchell, 1838 have included Brough-Smyth 1858, Bonwick 1858 & 1866, Gregory 1903, Grayson & Mahony 1910, Skeats & James 1937, Gill 1953, and Ollier & Joyce 1964.

Along a line from Port Fairy to Colac, near the southern limit of volcanic activity, groundwater has interacted with rising magma to cause phreatomagmatic explosions, reaming out some 40 or so deep maar craters and building up rims of ash or tuff. Rain and groundwater has filled many of these craters, and in the lakes sediment, pollen and microfauna have accumulated, recording changing climate during the latter part of the Quaternary. Many hundreds of small lakes and swamps can also be found on the flat to undulating clay plains with duplex soils and gilgai developed on lava flows which erupted between 3 and 1 Ma ago. Also on the clay plains larger lakes have built up lunette complexes by deflation; in what is possibly a tectonic depression Lake Corangamite and nearby lakes make up a lake-lunette complex which is also a RAMSAR heritage site. Other evidence of neotectonics is found in faults and monoclines affecting flows and underlying Tertiary sediments, and uplifted blocks are associated with volcanic activity as at the Staughtons Hill volcanic complex. In a number of maar crater and lunette-bounded swamps megafaunal remains were first discovered last century.

Where the Plains have no cover of lava, tuff or lake and river deposits, the Tertiary sediments are near the surface, with distinctive sandy loam topsoils and mottled clay subsoils with much "buckshot" or iron pisolites, and sometimes still retaining the form of old shoreline ridges. Nearer the coast and south of the volcanic areas, karst is often well developed on the limestone coastal plains, with impressive sinkholes and caves, and spectacular coastal cliffs and rock stacks in the Port Campbell area. Westwards around Warrnambool and Port Fairy dunes and lagoons mark modern and interglacial shorelines. Older now partly cemented dunes may show several palaeosols, and syngenetic karst and cave development are of major significance.

Humans have lived in this landscape for probably 50,000 years, experiencing climate and sea level change, and changes in vegetation and in lake level; somewhat more than 20,000 years ago Tower Hill volcano was active, and the sea lay far to the south across the dry Bassian Plain. As the sea level rose, aboriginal occupants of that greater plain would have been forced back until only the modern Western Plains remained. Here they achieved a close form of settlement, building stone houses and setting-up fish and eel traps to provide regular food supplies. The characteristic grasslands of much of the modern Plains may be related in part to aboriginal occupation and fire-farming, so that in a sense a last-glacial treeless landscape has survived. 150 years of European settlement have maintained this grassland through cultivation and grazing, while also marking it with bluestone mansions, farm and town buildings, and stone fences, and many shelter belts of cypress pine and sugargum. The smaller settlers built cottages and grew potatoes on the Tower Hill ash deposits, or ran dairy cows in the stony rises.

The future post-Quaternary landscape may be little different to that of the immediate past. Although crater lake levels are falling dramatically, and salinity can be a major problem in some areas, climate change may not be the predominant factor; perhaps the Plains will be most affected by human activity such as bluegum agroforestry and other changes in land use such as grazing and cropping. Nature however may still have a dramatic role to play if, as many geologists now believe possible, volcanic activity were to return again to the Western Plains.

Figure: Crater of Murroa or Mt Napier (Mitchell 1838)

Pollen records of European impact from billabong sediments on the Murray and Yarra Rivers

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John Dodson and colleagues from the School of Geography, University of New South Wales, made, in the 1980s the first substantial attempt to examine environmental change at high resolution using pollen analysis supported by a number of other proxies, for the last few hundred years within southeastern Australia. From the mixture of sites and results a number of useful insights into the nature and degree of human impact, as well as into the benefits and limitations of various sites and proxy methods, were gained. The approach continues to be championed by Scott Mooney, in particular. As concern increases about environmental degradation supported by some belief that environmental problems may be taken seriously, the construction of baseline data on the dynamics of pre-European landscapes and assessment of the impacts of subsequent human activities will provide increasingly important guides to future management.

In response to perceived future demand, and to help encourage this demand, the Centre and collaborators, supported by a Strategic Monash University Research Fund grant, has embarked on a programme entitled ëEnvironmental Change, Prediction and Managementí with the Murray and Yarra basins selected for ëpreliminaryí study. The programme was also designed to support a collaborative project on ëNatural Archives of Human Activity and Climatic Variabilityí set up by the Australian Nuclear Science and Technology Organisation. Central to this programme is river health, detected largely by the study of diatoms in riverine lakes, in association with *Cladocera*, plant macrofossils, sedimentology, and sediment chemistry. Pollen is used largely to help identify the catchment causes of alterations in stream flow and quality as well as assess or support chronologies developed from radiometric methods.

Cores collected from the lower catchment of the Yarra and middle catchment of the Murray are both considered to cover at least the period of European settlement. The Yarra core illustrates a detailed pattern of changes to vegetation related to initial impact and suggests several subsequent phases of land use. Relationships with diatom assemblages, sediment chemistry and historical data are complex. The Murray core indicates a period of pre-European natural variability prior to initial impact associated with high levels of burning and other types of instability before establishment of agriculture. It shows clear correspondence to changes in water chemistry, in particular pH as determined by diatoms. Both cores show predictably high values for exotics and the Yarra core, in particular, shows an interesting pattern of exotic plant colonisation. These patterns will be important to dating the records. It is considered, from increases in native opportunists in addition to alterations in canopy forest or woodland composition and sediments, that substantial changes to the landscape had taken place before evidence of exotics, and the use of pre-exotic pollen spectra as an indication of pre-European settlement must be adopted cautiously. Environmental variability is lowest within the latter parts of both records and, although a major reason must be river regulation, this feature must be taken into account in any proposed future alterations to landscapes, including rehabilitation.

Preliminary results from a palaeoecological study of a billabong on the Yarra River, Victoria

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The catchment of the Yarra River has been subject to more than 160 years of non-indigenous occupation and is now inhabited by over three million people. Whilst much of the upland region of the Yarra River has a pristine catchment, the middle and lower sections of the river have been subject to intensive land use. Studies of the physicochemical status and ecological health of the middle and lower reaches of the Yarra indicate that the river generally has poor water quality. The floodplain of the Yarra River has been substantially modified by flood levee and drainage system construction along with other urban developments.

A combination of modern ecological monitoring, sediment geochemistry and palaeoecological investigation is being used to establish pre- and post-European contact conditions for the Yarra River floodplain. This poster focuses on the results gained from fossil diatom assemblages in sediments from Bolin Bolin Billabong.

The fossil record shows that the post-contact ecology of the billabong has not been stable, but rather has altered through different states, presumably reflecting changing historical land-use. Results indicate that substantial changes in sediment attributes, trophic state, vegetation (see Kershaw, Kershaw and Reid, this volume) and acidity have occurred in the billabong as a consequence of post-contact land-use. This poster concludes that the major changes to Bolin Bolin Billabong have been related to differential sediment delivery, associated with varying historical impacts on the Yarra.

Stable isotope and trace element geochemistry of speleothems from Cliefden Caves, central NSW: Implications for palaeoclimate reconstruction

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This study examines the geochronology and stable isotope and trace element geochemistry of three Late Quaternary stalagmites from Cliefden Caves, central NSW, with the aim of producing a palaeoclimate reconstruction of the region. Geochronology was determined by alpha spectrometry, stable isotopes by mass spectrometry and trace elements by ICP-AES.

The periods of calcite deposition were found to be late Holocene (3 -< 1ka), the first part of marine isotope stage 3 (60 - 53 ka) and the first part of marine isotope stage 5c (105 - 88 ka). Each of the speleothems represents periods where environmental conditions were sufficiently moist and warm to produce abundant soil CO_2 and percolation water (and hence calcite precipitation). The stalagmite ages are presently being refined by TIMS U-series dating.

This paper will focus primarily on the stable isotope and trace element geochemistry of one stalagmite, MC4 (105 - 88 ka). Several significant trends were found in this sample: the δ 13C and δ 18O record exhibits a positive correlation (r = 0.64); Sr and Ba concentrations exhibit a positive correlation (r = 0.55); and Ba and δ 13C show a negative correlation, (r = -0.57). Magnesium concentrations are variable and show no correlation with either Ba or Sr, indicating that its variability may be driven by different processes (Fairchild *et al* 2000). Of significance is the negative correlation observed between Ba and δ 13C, which is consistent across the three speleothems. This relationship has also been observed in a N.Z. maritime speleothem (Hellstrom & McCulloch 2000).

The enhanced Ba levels at times of isotopically light carbon may emerge as a useful palaeoclimate proxy indicator, and is the subject of ongoing research. Explanations may lie in the variation of Ba sources; the hydrological factors related to the chemical properties of Ba (and Sr); and/or the complexation of Ba (and Sr) by soil organic acids and subsequent incorporation into the speleothems.

There is considerable variation in the studied parameters within each of the stalagmite growth periods. In MC4, for example, there are three major peaks and troughs in stable isotopes, with δ 13C values ranging from -4.90 to -10.43% and δ 18O values ranging from -1.73 to -5.36%. This suggests considerable variability in hydrological and biological activity at Cliefden during Stage 5c.

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A high resolution record of vegetation and climate through the last glacial cycle from Caledonia Fen, the southeastern highlands of Victoria, Australia

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Caledonia Fen is an unusual high altitude site (1280 m a.s.l) contained within a small enclosed basin eroded into the side slopes of the Snowy Range by a trellised tributary of the Caledonia River. The tributary differentially eroded strata of a broad syncline in the Snowy Plains Formation, after which sediments filled the depression base. These sediments provide what is likely to be a continuous pollen record through the last glacial cycle. Details of past vegetation are provided by pollen samples analysed at 4 cm intervals through the top 12 m of an 18 m sediment core taken from the centre of the site. Dating has been problematic with age reversal of AMS radiocarbon dates below the oldest date of 21,000 years BP at 1.8 m, and Uranium/Thorium dates indicating ages of 60,000 years BP at both 7 m and 17 m with a beyond 350,000 years BP date at 17.6 m. Recent OSL dates are in accord with an AMS date of 18,000 at *c.* 240 cm and a Uranium/Thorium date of *c.* 60,000 at *c.* 7 m. Results of OSL dating below 7 m are awaited. Previously the record to 7 m was considered most likely to cover the whole glacial cycle, but relating the recent OSL dates to AMS and Uranium/Thorium dates makes it possible that the 7 m peat band represents early Isotope Stage 3 interstadial.

The Holocene, the inferred interstadial at *c.* 7 m and the basal sediments at 18 m are characterized by organic sediment. The Holocene and 7 m pollen records are derived from aquatic fen vegetation and minor bog vegetation surrounded by eucalypt forest or woodland. These periods also have significant values of the understorey woody plants *Pomaderris* and *Dodonaea* and low values of Poaceae and Chenopodiaceae with Asteraceae (blunt-spined type) virtually absent. All other periods are represented by inorganic silty clays, have low eucalypt percentages and high values of Poaceae, Asteraceae and Chenopodiaceae. This indicates substantially lower temperatures and precipitation with the treeline below the altitude of the site. There are only subtle variations within these periods except for a phase of high *Tasmannia, Monotoca* and Epacridaceae, and occasional exciting submillenial events of probable higher temperatures. The completion of the detailed and highly sensitive record should elucidate the dynamics of alpine and forest vegetation in relation to climate and biomass burning through almost one whole glacial/interglacial cycle.

Accurate dating of the record has major implications for the assessment of past environments in southeastern Australia as a whole. It will also provide a good test of the synchroneity of climate change in the northern and southern hemispheres as the site reveals millenial/submillenial scale oscillations previously only documented for the northern hemisphere.

Late-Holocene lake eutrophication of Dique do Tororo, Salvador, Bahia, north eastern Brazil.

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Once concealed behind thick *Matto Atlantico* forest, and characterized by its acid, oligo-dystrophic, black waters, Dique do Tororoí is now situated in the urban heart of South Americaís oldest European settled city, Salvador da Bahiaí. As a result of this latest chapter in the short history (<1010yrs B.P. +/-130yrs) of Dique do Tororoí, its waters and sediments in the last two centuries have become eutrophic and suffer from heavy metal contamination. Ironically, Dique do Tororoí is now recognized as the sporting, cultural and religious hub of this unique city of 2.5 million people. Palaeolimnological records were extracted from the lake and sub-sampled for diatoms, pollen and sedimentary pigments. Through these analyses (except pollen) and the description of sedimentary sequences, a detailed account of the marked limnological changes that have occurred during the Late-Holocene as a result of human impact are evident.

Landscape reconstruction in aid of Minoan archaeology: A case study for the Archaeological Site Directors at Palaikastro, East Crete

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One hundred years of excavation and interpretation at the coastal Minoan site of Roussolakkos, at Palaikastro, East Crete, leaves us not only with Minoan treasures in museums and an *apothiki* (store-room/workroom) full of artifacts awaiting interpretation, but also a series of puzzles.

1. maritime trade must have taken place, but where is the harbour?
2. substantial stone wall building, including cut blocks, took place: where were the quarries?
3. the stone walls were surmounted by mud-brick: from among such stony ground, where did the clays come from?
4. a thousand years of pottery making: where did the clays come from?
5. why did the people of Roussolakkos have to re-locate their wells?

It is shown that:

a. the coastline has changed over the three thousand years since Minoan times. Studies of cliff retreat and the formation of a small sandy barrier, subsidence, and the accumulation of back-barrier sediments, shows that the remains of any harbour that existed will now be off-shore.

b. the dry stone foundations and walls included many ënatural blocksí from local talus but where ëworked blocksí were needed, aeolianite from a nearby quarry (known now as Ta Skaria) was used.
c. the clays are from a nearby valley that looks wide and well-developed enough to be natural, but is in fact, artificial.
d. the digging-out of the valley changed groundwater movement and dictated the digging of new wells.

These findings aid in interpretation of the archaeological results.

This study shows that archaeological site directors who ëdivertí some of their finds for support of landscape reconstruction can find that benefits outweigh opportunities foregone.

The development and application of a method for the reconstruction of past climates in Australia using fossil beetles

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Steep environmental gradients, strong correlations between temperature and rainfall, and the potential impact of variation in CO_2concentrations complicate the interpretation of past climate change in eastern Australia. Physical or biological proxies with independent responses to temperature, rainfall, and atmospheric content would be ideal candidates for deriving quantitative estimates of past climate. These seldom exist or are widely applicable. The ecological diversity of beetles and the fact they can be specifically identified negates several of these inherent limitations. The distribution of individual beetle taxa is determined by a multitude of parameters, however, it has been demonstrated that for most predators, scavengers and generalist herbivores, climatic parameters are paramount.

I will outline the development of a taxon-based method for the reconstruction of Quaternary climates in Australia using fossil beetles. For extant assemblages, the method enables reliable and accurate estimation of summer and winter temperatures and several rainfall parameters. The accuracy of the estimates, when compared to modern climatic data, depends on the number of taxa in the assemblage having bioclimatic profiles, and the presence of stenotopic ëindicatorí taxa. Estimates of mean summer and winter temperatures to within ±1.5°C, and mean annual rainfall to within ±150mm are routinely achieved. A late Pleistocene fossil assemblage from Spring Creek in western Victoria is described to illustrate the application of the method the Quaternary deposits. The Spring Creek deposit, dated to >40 kyr. B.P., contains a diverse aquatic and riparian assemblage similar to those occurring on the western volcanic plains today, but containing a number of taxa not presently found in the region. Reconstruction of the climate at the time of deposition of the Spring Creek fauna indicate cooler winter temperatures, a summer climate similar to today, and a similar, perhaps slightly greater annual rainfall. Aquatic caddis assemblages reveal similar temperature regimes. Significantly, pollen assemblages from Spring Creek are essentially ëglacialí in character, dominated by grasses and daisies, with small numbers of*Casuarinaceae*, very few Myrtaceae, and small but consistent amounts of *Pimelia*, *Plantago*, *Myriophyllum*, and Ranunculaceae.

Palaeoclimatic reconstruction using fossil beetles is limited by few of the factors that apply to the quantitative reconstruction of past climates using pollen assemblages. In Australia it is, however, less generally applicable than pollen analysis because of the difficulties in obtaining fossil bearing material in sufficient quantities, especially from extended sequences. Nonetheless, beetle-based climatic reconstructions from small slices of the Quaternary can be compared with associated pollen data to assess and refine pollen-climate relationships.

The use of ostracoda in the palaeoenvironmental reconstruction of the Gulf of Carpentaria, from the last interglacial to present

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Ostracods are ubiquitous micro-organisms, found in marine, estuarine, continental and hyper-saline waters. Identification of ostracodal assemblages, indicative of ecological facies, allows the palaeoenvironmental reconstruction of localities that have experienced changing aquatic conditions. This study discusses ostracod valves that have been extracted from core material from the Gulf of Carpentaria, Australia. Interpretation of palaeoenvironments is determined by species identification and facies delineation. Special attention has been given to dissolution and other diagenetic affects.

The Gulf of Carpentaria is an epicontinental sea (max. depth 70m) between Australia and Papua New Guinea, bordered to the east by Torres Strait (currently 12m deep) and to the west by the Arafura Sill (53m below present sea level). Throughout the Quaternary, during times of low sea-level, the Gulf has been separated from the open waters of the Indian and Pacific Oceans, forming Lake Carpentaria, perched above contemporaneous sea-level with outlet channels to the Arafura Sea. During 1997, six sediment cores were collected by the IMAGES III program from the Gulf of Carpentaria. The longest of these cores, MD972132, reaching a depth of 14.84m, was collected near the deepest part of the modern Gulf and is presented here.

Prior to the establishment of Recent marine conditions, the core may be broadly divided into two sections; a lower marine and an upper non-marine phase, The base of the core has returned dates of around 125ka by both thermal- and optically stimulated luminescence techniques (Chivas *et al*., in press). These dates were obtained from a barren quartzose unit, with evidence of subaerial exposure, overlain by a shallow-marine facies. This sequence suggests the sea-level rise associated with the Last Interglacial. The marine phase consists of assemblages varying from restricted estuarine to open shallow marine indicating oscillations of sea-level about the Arafura Sill.

The non-marine phase, first evidenced by a lake-shore facies at a core depth of 920cm is predominantly composed of shallow, saline lacustrine taxa. Drying of the lake is apparent, with iron-mottled quartz, calcareous nodules and ostracods showing dissolution between 680-560cm. Saline lacustrine conditions return, briefly interrupted by another incursion of marine waters at 490-380cm. The onset of the south-east Asian monsoon is implicated by the freshening of lake waters reaching a maximum just prior to the most recent marine transgression, dated at around 9.7ka (conventional radiocarbon years)(Chivas *et al*, in press).

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The Age of Eruption of Tower Hill Volcano, Southwest Victoria, Australia

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Tower Hill is a maar volcano of regional significance in Western Victoria. The excellent preservation of its geomorphic features suggests a young (late Quaternary) age. Early work by Gill and others seemed to confirm this with estimates of age between 6500 and 8700 BP. Subsequently studies of crater lake sediment cores by DíCosta and others from Monash University, gave an age exceeding 23,000 BP. We report here two new estimates of the age for this volcano. Radiocarbon dating of plant material preserved in the floor of a Tower Hill tuff quarry and thermo-luminescence dating of quartz in sediments preserved on a coastal headland and buried by the tuff give concordant age estimates. The agreement of these two dating techniques gives confidence in the assigned age of 32,950 ± 650 BP based on radiocarbon. This age dates the start of the eruption and a technique to determine the end of the eruptive phase will be discussed.

Palynological evidence for Plio-Pleistocene vegetation and climate cyclicity in the western uplands of Victoria

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Preliminary results are provided of palynological analysis of 40 metres of organic-rich silt-clay sediment recovered from a small (~300 metre diameter) palaeo-lake, the Stony Creek Basin, at 600 metres a.s.l. near Daylesford, in the Western Uplands of Victoria.

Based on palynostratigraphic considerations, preliminary analysis of magnetic polarity (reversed polarity in the uppermost 21 metres analysed to date), and a fission track date (1.74 Ma) from detrital zircons buried in the lake sediments, the sequence apparently accumulated during the late Pliocene or Early Pleistocene, probably over some 300-500 kyr.

Pollen analysis of the uppermost ~8 metres reveals repetitive, distinctive changes in pollen dominance, evidently reflecting dramatic vegetation change. Several complete vegetation cycles are presented, which appear to reflect rapid climatic oscillations during the late Pliocene or early Quaternary. These cycles generally involve a repetition of floristic associations and patterns of taxon replacement, but there are also some differences between cycles in the presence/absence of certain taxa. Broadly, the record shows alternation between periods during which diverse cool temperate (microtherm) rainforest taxa, in particular various Podocarpaceae, played an important role in the upland vegetation, and periods when this vegetation apparently disappeared, at least locally, to be replaced by open forest/sclerophyll trees with some herbaceous and shrub taxa. Cupressaceae (probably *Callitris*), (*Allo*)*Casuarina*, and Myrtaceae (mostly *Eucalyptus*) pollen alternately dominate these open forest periods.

Organic matter content in the sediment corresponds to these changes in pollen abundance: highest organic matter is found during phases of greatest rainforest representation, and lowest organic matter during phases of *Casuarina* + herb/shrub dominance. Although only the uppermost few cycles have so far been analysed for pollen, the organic matter curve suggests the sediment pile records approximately 10-14 climatic cycles.

Many of the rainforest taxa represented are now extinct, either from western Victoria (*Podocarpus*, *Symplocos*, *Quintinia*,*Rapanea*, *Myrsine*, *Phyllocladus*, Cunoniaceae, Araucariaceae) or from most or all of Australia (*Ilex*, *Dacrydium*, *Dacrycarpus*,*Beauprea*, and Tertiary form-taxa related to *Microcachrys*).

The rapid alternation between rainforest vegetation with characteristically "Tertiary" composition, and more familiar "Quaternary" open forests, is biogeographically important for understanding the nature and timing of the development of the overwhelmingly sclerophyllous mid and late Quaternary vegetation of southeastern Australia. Moreover, the record suggests that much more diverse cool temperate rainforests than any existing in Australia today were capable of repeated range expansion and contraction during alternating favourable and unfavourable climates around the Tertiary/Quaternary boundary.

Environmental History of the Upper South East of South Australia

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Wetland degradation in the Upper South East of South Australia is an urgent management concern. Scant recent environmental data is available for the region and long term monitoring data is lacking. Usually a palaeoecological analysis is able to reveal environmental change in the medium to long term past. However, the region is not conducive to palaeoecological investigation due to a fluctuating upper groundwater aquifer and alkaline soils which have destroyed most microfossils. It was found that the diatom assemblage was preserved in the wetlands of the region for the period of European settlement. Analysis of the diatom assemblage enabled production of an inferred salinity curve. In combination with a small amount of historical information that was available, the salinity trend for the wetlands, for the period of European agricultural activities, was identified. It was found that while groundwater salinity has been increasing, the wetland areas have experienced a freshening of surface water. This is due to an increase of through flow of surface water, a results of constructed drainage systems flushing salts from the wetlands. Despite the freshening of wetlands they continue to degrade due to the changed hydrology, an impact of the drainage structures.

Last-glacial maximum to Holocene diatom-inferred environmental change from Tower Hill, Victoria

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The nature of climate change during the last deglaciation, and consequent environmental response(s) is one of the most widely researched and vigorously debated aspects of Quaternary science. The nature and extent of short-lived "events" during this period have received considerable attention, with the best documented being the Younger Dryas (YD), a cold reversal from 13 to 11.2 CAL ky BP. Evidence for Younger Dryas events is most conclusive from high latitude Northern Hemisphere environments. Recent research has, however, attributed a variety of environmental changes to the YD in equatorial (eg: Roberts *et al*., 1993, Maslin and Burns, 2000) and southern Hemisphere environments (eg: Denton and Hendy, 1994), although a number of contrasting studies exist (eg: Bennett *et al*., 2000).

Sites in Australia, and the Southern Hemisphere generally, can significantly contribute to understanding the nature of environmental change in the transition from the last glacial maximum (LGM) to the Holocene. In particular, there is considerable debate about the extent to which cold reversals observed in Antarctic ice cores are synchronous with the YD in the Northern Hemisphere, with both cooling (Stein *et al*., 1998) and warming (Monnin *et al*., 2001) being proposed. As Broecker (2000) observes, documenting the timing of climate change in Southern Hemisphere sites informs our understanding about fundamental climate dynamics, such as the coupling of the ocean-atmosphere system.

There is a paucity of sites in mainland Australia with continuous sedimentation through this transition period. North West Crater, a nested scoria cone in the Tower Hill complex (western Victoria), is one site that has demonstrated relatively rapid and continuous deposition from the LGM to the Holocene (DíCosta *et al*. 1989) and is presently a focus of high resolution, multi-proxy study. Here we present preliminary diatom results from this study. Although diatoms are not preserved through the whole of the transition period, they indicate a highly variable moisture balance following the LGM.

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Estimating palaeoclimates and prediction errors from pollen data:

A comparison of techniques

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Kershaw and Bulman (1996) and DíCosta and Kershaw (1997), respectively, developed and expanded a pollen database for climate reconstruction in southeastern Australia (now focused on Victorian and Tasmania). The database relates "pre-European" pollen spectra to climatic parameters. We assess the utility of the database by:

- evaluating which climate variables appear to most influence pollen assemblages,
- comparing the performance of a number of transfer function techniques for climate reconstruction.

The BIOCLIM derived climate parameters used in the database are shown in Table 1. All temperature and precipitation parameters (with the exception of ranges) are, respectively, highly correlated with mean annual temperature ($r^2 \geq 0.70$, $p < 0.005$) and annual precipitation ($r^2 \geq 0.88$, $p < 0.005$). Statistical evaluation of the influence of climate variables on the modern pollen assemblages using Canonical Correspondence Analysis (CCA), shows that all precipitation parameters (with the exception of RCVAR) explain a similar amount of pollen variance (>15.5%). Given this, our precipitation based transfer functions focus on annual precipitation. Temperature parameters were less important in explaining taxon distribution, with annual mean temperature accounting for approximately 10% of pollen variance.

Table 1: BIOCLIM parameters generated for pollen database sites

TANN	Annual mean temperature
TMNCM	Minimum temperature of the coolest month
TMXWM	Maximum temperature of the warmest month
TSPAN	Annual temperature range (ie: 2 to 3)
TCLQ	Mean temperature of the coolest quarter
TWMQ	Mean temperature of the warmest quarter

TWETQ	Mean temperature of the wettest quarter
TDRYQ	Mean temperature of the driest quarter
RANN	Annual precipitation
RWEM	Precipitation of the wettest month
RDRYM	Precipitation of the driest month
RCVAR	Coefficient of variation of monthly precipitation
RWETQ	Precipitation of the wettest quarter
RDRYQ	Precipitation of the driest quarter
RCLQ	Precipitation of the coolest quarter
RWMQ	Precipitation of the warmest quarter

Much of the influence of individual variables overlaps (or "covaries"). Hence the CCA technique was extended, using variance partitioning (Borcard *et al.*, 1992) which removes the effect of (selected) co-variables. This analysis showed that annual mean temperature explained a significant amount of variation not accounted for by annual precipitation and vice versa. Variance partitioning also showed that, in the context of strong correlations between variables, reconstructing a larger number of climate parameters is unlikely to provide significantly more (reliable) information.

Given that CCA showed that annual precipitation (RANN) and annual mean temperature (TANN) are important in explaining pollen distribution, we assessed the performance of a variety of transfer function techniques in predicting RANN and TANN in the modern data set. A variety of analog matching techniques, along with weighted averaging regression and calibration of pollen data was evaluated. Analog matching operates by attributing to a site (or fossil sample) the climate characteristics of sites with similar pollen assemblages, while weighted averaging utilises taxon optima to derived climate estimates.

There is a significant relationship between "measured" modern climate parameters (derived from BIOCLIM) and those predicted from the pollen data. For annual precipitation the best relationship between measured and predicted values (r^2=0.72, p<0.005; Root Mean Squared Error=351 mm) was derived using Squared Chord Distance (Overpeck *et al.*, 1985). For mean annual temperature, the Canberra metric performed best (measured v. predicted values, r^2=0.60; p<0.005; Root Mean Squared Error=1.96° C).

Estimates of past climates from a variety of Western Victorian crater lakes have been developed using the above analogue matching methods. Firm interpretations are hampered by the lack of good analogues, a problem which tends to increase with time before present.

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Breaking the radiocarbon barrier and early human occupation at Devil's Lair, southwestern Australia

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There are currently two competing hypotheses concerning the time at which people arrived on the Australian continent. Conventional radiocarbon chronologies suggest arrival ~40,000 yr BP, while chronologies based largely on optical dating favor arrival by at least 50,000 yr. Here we report AMS-14C ages obtained by both an acid-base-acid pretreatment with bulk combustion (ABA-BC) and a newly developed acid-base-wet oxidation pretreatment with stepped combustion (ABOX-SC), applied to hand picked charcoal from the earliest occupation levels of the Devil's Lair site in southwest Western Australia. Initial occupation of this site has previously been dated by conventional 14C techniques to 35,000 yr BP. While the ABA-BC ages are indistinguishable from background beyond 42,000 yr BP, the ABOX-SC ages form a coherent 14C stratigraphy to ~55,000 yr BP. The ABOX-SC chronology suggests that people were in the area by at least 48,000 cal yr BP. Optically stimulated luminescence (OSL), electron spin resonance (ESR) ages, U-series and Emu eggshell carbonate 14C dating are in agreement with the ABOX-

SC 14C chronology. These results, based on four independent techniques, reinforce arguments for an earlier colonization of the Australian continent.

Regionally extinct taxa and vegetation dynamics in an Early Pleistocene palynological record from Pejark Marsh, a volcanic maar in the Western Plains of Victoria

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A fission-track dated discontinuous palynological record from Pejark Marsh, a volcanic maar near Terang in the southeastern Western plains of Victoria, shows evidence of the nature of vegetation dynamics in the region from the Early to Mid Pleistocene period. Represented amongst the minor pollen taxa, of predominantly rainforest affinity, are some that are now regionally extinct. The determination of which taxa were reworked from the underlying Oligo-Miocene Gellibrand Marl and which were coeval with the Early Pleistocene pollen record proved difficult and a number of occurrences are still uncertain. Overall the major pollen taxa recorded are similar to those that have dominated the vegetation of the region during the late Quaternary, with evidence of variation from forest during the warm and moist interglacials to dry steppe and open woodland during glacial periods. However, this variability is subdued in the basal part of the sequence, while the upper part shows marked oscillations. It is likely that extinctions and the increase in the strength of vegetation cycles are due to the development of increased climatic variability, particularly increased aridity during glacial periods, in the Middle to Late Pleistocene. Overall, the Early Pleistocene pollen record of Pejark Marsh represents an extension of the vegetation history of the Western Plains to form part of a developing regional Quaternary biostratigraphy.

Palaeoecology of Arltunga and Palm Valley Amphitheatre (NT) using rodent middens

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Stick-nest rat middens, collected from Arltunga in the eastern Macdonald Ranges and the Palm Valley Amphitheatre of the Northern Territory, record the animals and plants that were living in the vicinity while the middens were accumulating. The middens are expected to be between 50 and 15 000 years old and can be reliably dated (Head *et al* 1998; Pearson *et al* 1999). Similar middens have provided useful palaeoecological material in North and South America, Africa and the Middle East (Betancourt *et al* 1990) however progress in Australia has been relatively modest (Pearson & Betancourt submitted). Preliminary analysis of middens has demonstrated that they contain significant amounts of environmental material including macrofossils of plants (Berry 1993) and animals (Pearson *et al* submitted). They also contain pollen and phytoliths (Allen *et al* 2000; McCarthy *et al* 1996; Pearson 1999; Pearson & Dodson 1993).

The prospective sites for midden collection were identified using GIS and local expertise. Prof Julio Betancourt, as a research visitor on the project, assisted from a bed in Alice Springs Hospital! An intensive field search preceded sub-sampling a large number of middens. Middens were sampled in the quartzite overhangs of Arltunga (n=16) and the sandstone overhangs in Palm Valley Amphitheatre (n=9).

Pollen and macrofossils in the stick-nest rat middens are used to reconstruct the plants and animals living in the area in the past. That reconstruction is compared with other fossil materials modern surveys and computer generated predictions of the environmental parameters controlling the distribution of individual taxa. The aim of these projects is to model the environmental changes that would explain the fossil record. This will assist in reconstructing past climates, and in this region the key issues are the changing behavior of the monsoon and ENSO cycles during the last 15 000 years. The information will enhance our understanding of the past plants and animals present in the arid zone and how climatic systems such as ENSO and the monsoon affect long-term vegetation dynamics.

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Isotope Stratigraphy of Bega Swamp, Southern NSW

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Bega Swamp is located on a granitic plateau at the eastern edge of the southern tablelands of NSW at 1080m altitude, about 20km south-east of Nimmitabel and 35km north-west of Bega. Peat accumulation in this valley fill is primarily by autochthonous deposition of the restionaceous shrubs and sphagnum of the swamp (Green *et al*., 1988). As part of research initiated by Dr Gurdip Singh a 2742mm-long core was extracted in 1980, frozen and sliced with a bandsaw into 489 2mm slices (with 2-4mm lost with each slice) to produce the most detailed pollen diagram in the Southern Hemisphere. Chronological control is provided by 110 ^{210}Pb and ^{14}C dates, the latter being on the NaOH soluble, the NaOH insoluble fractions and the fine and coarse acid-washed fractions (Polach and Singh, 1980). The basal date, 13,500 ± 320a B.P. is the oldest known in NSW at this altitude (Hope *et al*., 2000).

For this study 172 sub-samples (1-2g) were taken from core 80-II, the second core obtained in 1980, decarbonated and ground to a powder in preparation for isotopic analysis. Carbon content and carbon isotope ratio were determined using a Carlo Erba NCS1500 elemental analyser coupled to a Micromass Prism III mass spectrometer. Isotope ratios were compared with the results of 12 determinations made on modern plants collected from the swamp. d ^{13}C values for modern vascular plants on Bega Swamp range between -26.1â and -27.4â, values which are similar to those obtained on a peat exposure spanning the last 1800 years at Wingecarribee Swamp in the Southern Highlands of NSW near Wollongong (E. Smith, unpub hons thesis). However the Bega Swamp core displays a wider range, varying from -25.6â to -29.1â. The data do not display a secular change in isotope value indicative of a long-term change due to fractionation associated with diagenesis although this may possibly be seen in the last 250 years.

Hope *et al*. (2000) proposed two age-models based on the dates mentioned above; one with continuous deposition and the other with hiatuses between ca. 7,400 to 6,000y B.P. (1700mm depth) and 450 to 250y B.P. (520mm depth) which they conjecture may have been the result of fire on the bog. The possible hiatus at 1700mm depth is also the location of the largest and most abrupt change in d ^{13}C values seen in the core, changing from -29â at 1712mm to -27â at 1623mm. If the continuous-deposition chronology is accepted this implies a very rapid change in conditions between 7ka and 6ka. The alternative chronology implies a much more gradual change in conditions during the hiatus.

There is a significant correlation ($P<0.001$) between high carbon content and more negative d ^{13}C values, although there is considerable scatter ($r^2=0.26$). However the ënormalí interpretation that high carbon contents and more negative d ^{13}C values indicate wetter conditions and low carbon content and less negative d ^{13}C values indicate drier conditions does not apply here, particularly during the Holocene. The lowest carbon contents and least negative d ^{13}C occur 5,000-6,000y B.P., during the peak in closed wet forest (Hope *et al*., 2000) and the highest carbon contents and most negative d ^{13}C occur during periods with more open forest elements (eg. *Casuarina*).

A possible explanation is that the negative excursions in the curve represent increases in the amount of *Sphagnum*, which is expected to have d ^{13}C <-30 (Rice, 2000), at the core site. Given that *Sphagnum* is now largely restricted to the swamp margins, this may indicate an overall increase of *Sphagnum*. This would also account for the core having more negative d ^{13}C than the vascular plants. If the isotope ratio of the peat does reflect the *Sphagnum*/vascular plant mass balance then the distinct shift to less negative values seen after the proposed mid-Holocene hiatus can be taken to indicate a decrease in *Sphagnum* following disturbance of the swamp surface.

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