Australasian Quaternary Association/Friends of the Pleistocene

Pop-up Conference 2021

Programme – Day 1 (8th July 2021)

8:15 AEST	Welcome Introduction / housekeeping (Lynda Petherick + Michelle McKeown)	
8:30	Keynote: Amy Prendagast	What sclerocronology can do for archaeology and palaeoenvironment studies
Session 1 – Lake, Rivers, and Landscapes (Convener: Nick Patton)		
9:15	Matiu Prebble	Buried forests of Ōtautahi/Christchurch: reconstructing lake formation and river avulsion events in swamp city over the last 2500 years
9:30	Julia Short	Understanding the first human impact on aquatic ecosystems: a case study from New Zealand
9:45	Asika Dharmarathna	Holocene climate variability in south-eastern Australia; inferred from oxygen isotopes in sedimentary cellulose at Lake Surprise, Victoria.
10:00	Briony Chamberlayne	Palaeohydrology of the southern Coorong Lagoon, inferred from oxygen isotope ratios of the bivalve Arthritica helmsi
10:15	Levente Laczko	It was THIS Big: Estimating palaeochannel size and discharge in the Murray-Darling Basin
10:30	Jack Flanagan	Keeping it underground! Reconstructing a Quaternary groundwater discharge basin in South-eastern Australia.
Break		
Session 2 - Lake, Rivers, and Landscapes (Convener: Rachel Rudd)		
11:00	Charlie Maxson	Fourier transform infrared spectroscopy as a tracer of organic matter sources in lake sediments
11:15	Emma Rehn	More to charcoal than meets the eye: Testing techniques for the separation of fire products as proxies for occurrence and intensity
11:30	Mark Constantine	A comparison of fire in two interglacials at Lake Couridjah, Thirlmere Lakes
11:45	Matthew Forbes	Differentiating between the d13C signature from environmental conditions and SOM cycling in eastern Australian peat sediments.
12:00	Alexander Francke	Catchment vegetation and erosion controls soil carbon cycling in SE Australia during two Glacial-Interglacial complexes
12:15	Matthew Adeleye	Last glacial palaeoenvironment of the Bassian Land Bridge, southeast Australia
12:30	Ting Li	Environmental change inferred from multiple proxies of sediment from 18 cal kyr BP at Lake Barrine, NE Australia
Lunch break		

1:30	AQUA AGM	
Session 3 – PICOs (Convener: Michelle McKeown)		
2:15	Agathe Lise-Pronovost	Geomagnetic field changes in Australia and applications for Quaternary Sciences
2:20	Lucinda Duxbury	Fire and ecosystem change on Kangaroo Island, South Australia, over the past 5,000 years
2:25	Alice Laming	How fire activity has changed over the last 500 years in Buchan, East Gippsland
2:30	Cait O'Shea	Indigenous burning practices: a solution for modern-day land management?
2:35	Harriet Magee	A history of burns: fuel and fire patterns in East Gippsland forests pre and post-cessation of Aboriginal landscape burning
2:40	Nevena Kosarac	Reconstructing a fire and climate history using a stalagmite from Crystal Cave, south-west Western Australia.
2:45	Rebecca Ryan	Boron Isotopes and FTIR Spectroscopy to Identify Past Fire Conditions
2:50	Anthony Dosseto	Novel proxies to decipher 100 yr of fire regimes in south-eastern Australia
2:55	PICO Q&A	
Break		
Session 4 – Chronology and Modelling (Julia Short)		
3:30	Jenni Hopkins	Developing efficient cryptotephra identification in Aotearoa/New Zealand marine sediments.
3:45	Rachel Wood	The inbuilt age of charcoal fragments in a sand-bed stream, Macdonald River, NSW, Australia
4:00	Priya	Reconstructing the late Pleistocene climate sequence at Alexandra Cave, Naracoorte, using trapped charge dating and palaeoenvironmental proxies
4:15	Sophie Williams	Historical sea-level change in southeastern Australia
4:30	Nick Patton	Using surface roughness to date coastal dunes at Fraser Island and Cooloola Sand Mass, Australia
4:45	Martin Kohler	K'gari and Cooloola – one dune system?

Programme – Day 2 (9th July 2021)

8:45 AEST	Welcome Introduction / housekeeping (Annie Lau + Priya)	
9:00	Keynote: Shaun Eaves	Climate reconstruction from New Zealand glaciers: a 10-year tenure
Session 5 – Climate and Cryosphere (Convener: Mark Constantine)		
9:45	Olivia Traux	Evidence of SAM and ENSO influence on last millennium Antarctic climate from paleoclimate data assimilation
10:00	Peter Almond	A test of the Zealandia Switch at millennial timescales.
10:15	David Barrell	Hypothesized southern driver for orbital and millennial-scale climate shifts and implications for the bipolar seesaw
10:30	Josephine Brown	The Australian monsoon in new simulation of mid-Holocene from ACCESS-ESM1.5 climate model
Break		
Session 6 – Climate and Cryosphere (inc. Speleothems) (Convener: Olivia Traux)		
11:00	Danielle Udy	How is salty snowfall in Antarctica linked to Australian rainfall?
11:15	Alexander Forster Wall	Possible new mid-Holocene ENSO record from the southern Indo-Pacific Warm Pool
11:30	Zuorui Liu	Implication of Mammoth Tooth Enamel in Reconstruction of Paleo-Environments in Southern Germany during MIS3 at Different Temporal Resolutions
11:45	Liza Kathleen McDonough	Past fires and post-fire impacts reconstructed from a southwest Australian stalagmite
12:00	Kale Sniderman	Vegetation (in)stability and moisture-balance during the Last Glacial Maximum in southwest Western Australia: new insights from speleothem palynology
12:15	Matt Ryan	Source-to-sink archives of vegetation change since the Last Glacial Maximum, Waipaoa Sedimentary System, New Zealand
Lunch break		

Session 7 - PICOs (Convener: Priya)		
1:20	Zoë Thomas	The forgotten Hemisphere: phases of carbon accumulation since the last glacial
1:25	Stephen Piva	Down-sizing: examining volcanic impacts on vegetation at millimetre scale
1:30	Haidee Cadd	A continental perspective on the timing of the 'Last Glacial Maximum' in Australia
1:35	Priya Parsons O'Brien	Going beyond the limits: Investigating the potential for an 'ancient kauri' (*Agathis australis*) tree-ring chronology to extend beyond the limits of radiocarbon dating
1:40	Bohao Dong	Using giant clam shell geochemistry to understand past environmental change and human-environment interaction in the South Pacific
1:45	Chloe Stringer	Using freshwater sclerochronology to investigate Late Quaternary environmental change and seasonal resource use in the Central Murray Basin
1:50	Meghan McAllister	Leaf wax lipid biomarkers: Reconstructing the palaeoenvironments experienced by early H. sapiens at archaeological sites across Southeast Asia & Australia.
1:55	Simon Haberle	A new database for pollen and spores in the Asia-Pacific: The Australasian Pollen and Spore Atlas (APSA v2.0).
2:00	PICO Q&A	
Session 8 – Humans and ecosystems (Convener: Willy Henriquez)		
2:15	Gilbert Price	20 years since 'Roberts et al.': Gains and gaps in the megafaunal extinction debate
2:30	Molly Quinn	Early Aboriginal Occupation of the Sydney Basin
2:45	Sarah Cooley	Response, resilience, and recovery: An endangered fire-sensitive endemic conifer and its relationship with fire.
3:00	Kira Westaway	Connecting rock art to ritual practices in the Kimberley using OSL dating.
3:15	Simon Connor	Australia's past cultural landscapes revealed
Break		
Session 9 – Oceans and Coasts (Convener: Sarah Cooley)		
3:45	Anthony Shorrock	Relationship between sedimentation and sea level in a northern Hikurangi Trough turbidite plain: Insights from IODP Expedition 372B/375, Site U1520
4:00	Ben Roche	Dynamic mud deposition in the lower Waihou River, New Zealand
4:15	Ingrid Ward	Revealing records of inundation from marine sediment records within the Montebello Islands, NW Australia
4:30	Vikki Lowe	Using radiolarian assemblages to track glacial-interglacial changes in the South West Pacific
4:45	Ben Houseman	Manifestations of the Mid-Pleistocene transition in the South-West Pacific
5:00	Dan Ellerton	Middle Pleistocene sea-level change linked to the formation of Fraser Island and initiation of the Great Barrier Reef

Keynote – Day 1

Dr Amy Prendergast

Dr Amy Prendergast research focuses on exploring the relationship between humans and environmental change. She studies how humans and our hominin ancestors responded to rapid environmental changes over the past several million years. She has worked at sites across North Africa, Western Asia, Southeast Asia and Australia.

Amy employs geochemical records in combination with growth increment analyses (sclerochronology) from biogenic carbonates to generate high-resolution records of environmental change and seasonality. She focuses on generating records from archaeological sites to facilitate reconstructions of human-environment interaction. She is involved in both proxy development and palaeoenvironmental reconstruction.

Amy is a Senior Lecturer and ARC DECRA Fellow in the School of Geography, Earth, and Atmospheric Sciences at the University of Melbourne. She previously held an Alexander von Humboldt Postdoctoral Fellowship at the University of Mainz in Germany and a McKenzie Fellowship at the University of Melbourne.

What sclerochronology can do for archaeology and palaeoenvironment studies

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Sclerochronology is the study of the physical and chemical variations in the accretionary hard tissues of biogenic material such as mollusc shells, fish otoliths, and teeth. It has much to add to the fields of palaeoclimatology and human-environment interaction. Humans respond to changes in their local environment on daily to seasonal timescales. Therefore, robust assessments of the impact of environmental change on human behaviour requires an understanding of local environmental change at seasonal to sub-seasonal resolution. Sclerochronology provides some of the few sub-seasonal resolution palaeoenvironmental proxies in the mid to high latitudes and in many cases these proxies provide quantitative palaeoenvironmental time series. Obtaining these records from food-refuse archaeological specimens enables the reconstruction of a more detailed picture of how humans responded to changing climatic regimes in the past and allows an assessment of hunting and foraging seasonality. In this talk, I will present an overview of some of our latest research in archaeological sclerochronology from both the Northern and Southern Hemispheres. I will present an overview of studies ranging from the role of rapid environmental changes in the expansion of early modern humans and the extinction of Neanderthals during the late Middle Palaeolithic of the Levant, to the application of sclerochronology to Indigenous archaeological sites in Australia.

Session 1

Buried forests of Ōtautahi/Christchurch: reconstructing lake formation and river avulsion events in swamp city over the last 2500 years

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Extant lowland forest remnants and fossil deposits of former forests in Canterbury, Aotearoa/NZ are very rare, limiting baseline knowledge for understanding past ecosystem processes, especially in Ōtautahi/Christchurch City. The recently uncovered buried standing forests found in the suburbs of Halswell and Hoon Hay offer a unique opportunity to address this shortfall, to better understand the past forest ecosystem dynamics of the Canterbury Plains. As part of an ongoing post-graduate research course based in the School of Earth and Environment, several geomorphic and palaeoecological aspects of these deposits are being explored, with initial results presented here. The arrangement and size of stumps measured so far indicate even-aged forest stands, based on the estimated trunk diameter, with organic sediments associated with the base of these stumps revealing plant macrofossils including the abundant seeds of Lophomyrtus, Coprosma spp., Cordyline, Rubus spp. and Muehlenbeckia spp. , with Dacrycarpus dacrydioides seeds and leaves and macro-invertebrate remains. Fossil pollen and spores reveal similar signatures of D. dacrydioides and Prumnopitys taxifolia. Radiocarbon ages on these macrofossil reveal consistent ages of 2500 yr cal. BP. This fossil rich deposit is buried by fluvial and lacustrine silts (with high concentrations of charophyte oospores) and clays derived from the Waimakariri River, which currently flows to the north of the city. Repeated river evulsion events over the last 2500 years, the last occurring at around 600 yr cal. BP, created a patchwork of forest indicative of a highly dynamic alluvial environment. The potential drivers and consequences of these and future evulsion events are discussed.

Understanding the first human impact on aquatic ecosystems: a case study from New Zealand

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Understanding aquatic ecosystem response to the first human impacts on landscapes is often impossible due to long human habitation in many regions of the world (i.e. in Africa, the Middle East, Australia) or because the first human migrations co-occurred with marked climate change (e.g. in the Americas and northern Eurasia). Due to its short period of human occupation, New Zealand is in a unique position to provide insights into lake response to initial human-induced landscape change. Polynesians arrived in New Zealand ~800 years ago and settled rapidly across the two main islands. Vegetation on the South Island was transformed, and in the Canterbury high country, the region of this study, native forests were converted to tussock grassland. We examined the diatom record from two small lakes; Emma and Emily, and two medium-sized lakes; Heron and Pearson, to explore aquatic ecological response to this landscape change. The expectation was that smaller lakes would be more responsive to landscape change. The lacustrine response to deforestation within the catchment, however, was more pronounced in the large lakes Pearson and Heron. In Lake Pearson, diatom assemblages shift a mix of planktonic and benthic taxa to a primarily planktonic assemblage. In Lake Heron, there were major shifts between planktonic taxa Discostella stelligera and Aulacoseira ambigua, representing increase water column nutrient concentrations. While lakes Emma and Emily experienced significant changes in diatom assemblages, these were associated with changes between numerous benthic and epiphytic taxa. This study indicates that major ecological shifts occurred early in Canterbury high country lakes, following the first human activity in the area, while simultaneously demonstrating the complexity of lake systems in the region. This study suggests that lake ecosystems were highly vulnerable to landscape alterations and that, furthermore, they may exist in novel states that are difficult if not impossible to restore.

Holocene climate variability in south-eastern Australia; inferred from oxygen isotopes in sedimentary cellulose at Lake Surprise, Victoria.

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During the Holocene, south-eastern Australia experienced periods of multi-year drought. However, the scarcity of quantitative, high-resolution climate records from the region means understanding of the frequency and intensity of such events is limited. Where conditions are suitable, oxygen isotopes preserved in lake sediments are a useful tool for reconstructing past climate and environmental conditions. Here, we present preliminary results from a ca. 8700 ka record from Lake Surprise in western Victoria, from which we analysed $\delta^{18}O$ of aquatic cellulose, alongside organic carbon/nitrogen ratios, organic carbon isotopes and XRF (ITRAX) inferred elemental composition. Our interpretation of the palaeo- data is supported by ~3 monthly monitoring of water and sediment geochemistry to track the modern hydrology of the lake. Our preliminary results show a strong positive correlation between meteorological precipitation data and sedimentary calcium (carbonate deposition) over the last 150 years, likely linked to changes in primary productivity. As a proxy for lake-water $\delta^{18}O$, the aquatic cellulose $\delta^{18}O$ record is also correlated with carbonate concentration, reinforcing our interpretation of $CaCO_3$ deposition in the lake during wet periods. The cellulose $\delta^{18}O$ record indicates a trend of gradually increasing aridity over the last 8 ka, with a notable extremely wet period ca. 7.5–7 ka and a dry period ca 2–1.5 ka. Further work will focus on increasing the resolution of the data to better identify the frequency and duration of key events and quantifying natural hydroclimatic variability, alongside continued geochemical monitoring and modelling to better constrain the interpretation of the palaeoclimate record.

Palaeohydrology of the southern Coorong Lagoon, inferred from oxygen isotope ratios of the bivalve *Arthritica helmsi*

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Understanding the resilience of aquatic ecosystems to climate and human impacts requires a long term perspective that is rarely attainable via standard monitoring programs. This is evident in the South Lagoon of the Coorong in South Australia where a history of ecosystem management has been based on limited knowledge of the range of natural variability. Here, we present a ~1750 year record of hydrological variability inferred from the oxygen isotope ratios of the bivalve *Arthritica helmsi*. Analysis of the controls of oxygen isotope fractionation in modern waters, and modern populations of *A. helmsi* inform the interpretation that the oxygen isotope ratios of shells preserved in the Coorong sediments reflect the precipitation/evaporation balance of lagoonal waters. Centennial scale variability in the oxygen isotope based hydroclimate record from the Coorong is consistent with other records in the region, contributing to a deeper understanding of the scale of natural hydrological variability in southeastern Australia during the last 2000 years. While the sedimentary bivalve data suggest that the lagoon was slightly less saline in pre-European times, the range of oxygen isotope variability within sedimentary bivalve shells is not statistically distinguishable from the range predicted by the hydrological conditions of the modern day Coorong South Lagoon, suggesting that present day hydrological conditions are not markedly unusual in the context of the past 1750 years. As a consequence, our bivalve oxygen isotope data suggest that major hydrological alterations to the Coorong South Lagoon – for example flushing the lagoon with sea water – could result in a departure from the natural hydrological state of the system over the last 2000 years.

It was THIS Big: Estimating palaeochannel size and discharge in the Murray-Darling Basin

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The Murray-Darling Basin (MDB) of southeastern Australia is host to a vast array of river channels both modern and relict, comprising multiple distributive fluvial systems (DFS). Morphologic and sedimentologic contrasts between modern channels and their respective palaeochannels have been utilized as evidence for late Quaternary hydrologic and climatic change, with prior studies suggesting palaeochannel formation under much larger discharge regimes. Reconstruction has been hampered by difficulty in reliably comparing palaeodischarge and accurately characterising palaeohydrology. Utilising new high resolution DEMs of previously dated palaeochannels, this study mapped the bankfull width and meander wavelength of the modern and relict Murrumbidgee and Macquarie rivers to determine their longitudinal trends, as a measure of flow variability, and derive estimates of bankfull discharge at the head of the DFS for historical comparison. Downstream channel trends suggest the surveyed palaeochannels to be of similar planform to their modern rivers – single channel, laterally unconfined and of variable sinuosity – but operating on much larger scales. Comparison between the modern and surveyed palaeochannels suggests palaeochannels were formed under highly variable flow, dissipating with distance downstream. The degree of flow variability (rate of channel contraction) shows agreement with the palaeochannel size and supports a temperature-driven model of enhanced runoff efficiency under colder climates during the last 20 ka to 80 ka. Colder conditions were linked to higher seasonality of discharge and greater runoff efficiency (greater bankfull discharge) related to seasonal snowmelt, lower evapotranspiration and greater catchment connectivity. Modern and future discharge is lower, and is likely to continue to decline, despite warmer temperatures and, possibly, higher precipitation.

Keeping it underground! Reconstructing a Quaternary groundwater discharge basin in South-eastern Australia.

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Paul Hesse
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The Riverine Plain of south-eastern Australia contains a trove of rich paleoenvironmental relicts, representing the unique hydroclimatic conditions under which they formed. Lake systems include sediment archives of depositional history in their nearshore and bordering dune (lunette) geomorphic landforms. Fluctuating periods of high lake levels with intermittent periods of deflation (and subsequent dune building) can be interpreted from the high-resolution stratigraphy preserved within these landforms. An ephemeral groundwater discharge lake, known as Lake Sunrise, lacking major fluvial connectivity, was chosen for this study. Nearby lake basins, such as the Willandra and Urana Lakes systems, rely on fluvial inflows as well as groundwater fluctuations to produce 'lake full' conditions. By contrast, Lake Sunrise responds largely to fluctuations in the regional groundwater table.

A stratigraphic framework based on particle size, mineralogy and single-grain optically stimulated luminescence (OSL) age estimates was developed. The series of clay lunettes reveal four distinct depositional events throughout the late Quaternary; the outermost lunette: ~77 ± 9 ka - 61 ± 9 ka, the inner dune structure: < ~ 68 ±5 ka and the innermost lunette: ~ 45 ± 3 ka and 24 ± 1 ka. The three youngest events coincide with the 'lake full' conditions experienced at Lake Mungo; however, the oldest unit at Lake Sunrise represents a regionally distinct hydrological episode, absent in other lake and fluvial systems. This suggests that groundwater discharge basins may experience a 'lag' effect between filling events, following prolonged surface hydrological activity and groundwater recharge. This study highlights the value of isolated lake basins for palaeoenvironmental interpretations and understanding the interactions of surface/ sub-surface flows over extended timeframes.

Session 2

Fourier transform infrared spectroscopy as a tracer of organic matter sources in lake sediments

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The source of sedimentary organic matter in lakes can help to elucidate climate and catchment variation and processes that reflect lake development. Common techniques for tracing sediment organic matter sources, such as the stable isotopes and elemental concentrations of C and N, can be too imprecise to identify the specific provenance of organic matter. By contrast, organic geochemical techniques such as gas or liquid chromatography and nuclear magnetic resonance provide detailed organic molecular characterisation but are both expensive and time consuming. Fourier Transform Infrared (FTIR) spectroscopy is a rapid, non-destructive, and well-established method for determining the constituents of lake sediments. However, the potential for identifying the sources of organic matter in lake sediments has yet to be fully explored. In this study, we assess the extent to which FTIR can be used to identify varying organic matter sources through analysis of modern autotrophs from Blue Lake, North Stradbroke Island, Australia. Three groups of autotrophs: terrestrial plants, aquatic macrophytes, and algae were identified in the FTIR data through principal component and cluster analyses. We investigated spectral processing techniques to identify the technique that could most accurately classify autotroph samples. The three autotroph groups were correctly classified 90% of the time. Processed spectra then became the basis of a model that used multivariate random forests to estimate sediment organic matter composition source from a sediment record from Blue Lake that spans the last 7500 years. FTIR-based estimates suggested that throughout the history of the lake, algae contributed the highest amount of organic matter to the sediment samples analysed. These results allow a refinement of a previous study of C:N and δ13C from the same core and suggests that alterations in C:N and, particularly, δ13C reflect chemical changes in algae through time. This study demonstrates that FTIR spectroscopy is a promising tool to elucidate sources of sediment organic matter in lake sediments.

More to charcoal than meets the eye: Testing techniques for the separation of fire products as proxies for occurrence and intensity

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Abstract:

People and climate can both have complex influences on fire regimes. Disentangling these factors when looking at fire in the past is difficult, as common fire proxies like charcoal may capture the climate signal most strongly through measures of total area and volume of biomass burned. Contrastingly, human fire management is more closely associated with changes in fire intensity while not necessarily altering total area burned.

Investigating these nuances in past fire records requires us to first understand what it is that we are looking at when counting charcoal under the microscope: what these products represent in terms of fire, and how to partition them in the lab. This work partly builds on previous research by Turner et al. (2004) who demonstrated significant count differences for charcoal when processed using a range of methods, including the use of bleach.

We discuss two potential methods for estimating relative fire intensity in records of past fire. Firstly, charcoal counts for unbleached and bleached samples. Secondly, the isolation of pyrogenic carbon (resistant, stable carbon that is generated in greater proportions with increasing fire intensity) by hydrogen pyrolysis alongside charcoal counting. Preliminary results from two lacustrine sites in Victoria, southeast Australia provide insights into the strengths and limitations of these methods, including potential preservation effects. Inconsistent differences were found between unbleached and bleached charcoal counts, with the largest difference recorded in the uppermost sample at both sites. Noticeable differences were found between pyrogenic carbon and both types of charcoal counts for both sites, but once again with no consistency in trends.

A comparison of fire in two interglacials at Lake Couridjah, Thirlmere Lakes

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Significant uncertainty remains regarding pre-instrumental fire regimes in eastern Australia. TLonger perspectives on fire in our pyrogenic landscapes are of relevance to management policy as we move forward into a warmer world.
Here we present the long-term record of fire from a well-dated sediment core (LC2) taken from Thirlmere Lakes National Park, NSW. LC2 extends from the present to ~140,000 years. We investigated the fire regimes of the present (marine Isotope stage (MIS) 1) and penultimate (MIS 5e) interglacial, which were relatively similar with the exception of the presence/absence of people. We reconstructed past fire using two preparations methods for charcoal (one a simple sieving method using water, and the second using 4% NaClO), which allowed us to better consider low intensity/severity fire. In addition, we modelled charring intensity (CI) derived from FTIR-spectra of charcoal (Constantine et al. 2021).
The results of this study suggest that quantification of charcoal accumulation rates (CHAR) provides only a partial and potentially biased understanding of past fire regimes. We found that CHAR (mm2/cm3/yr) was broadly similar across both interglacial periods. During both deglaciation events (Termination II MIS 6-5e and Termination I MIS 2-1) CHAR was variable and occasionally high, but became steady at low levels throughout the respective interglacial. CI, however, suggest substantial differences in the intensity/severity of fire during these two deglaciations. Throughout MIS 6-5, there is little variability in CI, suggesting wildfire conditions were consistent in intensity despite changing conditions. However, in MIS 2-1, the late Pleistocene and early Holocene is characterized by high variability in CI, with minimum values indicative of low intensity fires. From the mid-Holocene onward, CI stabilizes at high levels broadly similar to MIS 5e. Though cryptic, high CI variability could signal anthropogenic interference in the local fire regime as populations contracted into refugia during cold periods. The research offers important caveats for any simplistic suggestions regarding identifying the signal from anthropogenic fire and reiterates the over-whelming signal in long term fire record associated with climate.

References

Constantine, M., Mooney, S., Hibbert, B., Marjo, C., Bird, M., Cohen, T., Forbes, M., McBeath, A., Rich, A., & Stride, J. (2021). Using charcoal, ATR FTIR and chemometrics to model the intensity of pyrolysis: Exploratory steps towards characterising fire events. Science of The Total Environment, 783, 147052. https://doi.org/10.1016/j.scitotenv.2021.147052

Differentiating between the d13C signature from environmental conditions and SOM cycling in eastern Australian peat sediments

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The analysis of stable carbon isotopes is commonly used in Quaternary science to reconstruct the environmental conditions and vegetation contributions to sedimentary sequences. However, the measured d13C signature of the total organic matter (OM) pool can also reflect other complexities within depositional environments. The peats of the Thirlmere Lakes system in the southern section of the Blue Mountains World Heritage Area provides an excellent opportunity to closely scrutinise such d13C dynamics. These deposits are rich in TOC (20-40%) meaning analytical techniques such as 13C-NMR, used to characterise the OM pool, can be applied effectively. Furthermore, the identification of several peat units deposited over the last ~130 ka allows for temporal comparisons. d13C values determined for a 7 m sediment sequence from Lake Couridjah representing both the MIS 1 and MIS 5e interglacial periods vary by up to 4 to 6‰. These trends were subsequently identified in two other sediment sequences (Lake Baraba and Lake Werri Berri) proximal to Lake Couridjah. Initially we interpreted our results as reflecting a C3 dominated vegetation environment with MIS 1 wetter than MIS 5e, following the established relationship between water stress and d13C enrichment. However, spectral analysis of the OM pool indicates that d13C is driven by changing OM dynamics rather than large changes in environmental conditions. In these environments, the greater presence of carbohydrates (i.e. cellulose) in MIS 1 result in more depleted d13C values. In contrast, the MIS 5e peat is dominated by relative inert OM C fractions including charcoal and lipids (such as leaf waxes), which influences environmental proxies such as C/N. Thus, it is likely that the older MIS 5e peat is a more decomposed version of the active MIS 1 peat, and thus differentiating environmental conditions between the two using d13C alone is not particularly illuminating. To overcome this, we describe the d13C values for a coarse charcoal and high temperature hydrogen pyrolysis fractions, modern vegetation, catchment POC and DOC, and n-alkanes composition and generate catchment carbon models for both MIS 1 and MIS5e. Finally comparing the size of the OM pools of both interglacial deposits can provide useful information in estimating the carbon storage capacity of peat deposits in eastern Australia over these time scales.

Catchment vegetation and erosion controls soil carbon cycling in SE Australia during two Glacial-Interglacial complexes

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Soil Organic Carbon (SOC) represents up to 80% of the terrestrial carbon pool. However, it is highly debated if soil carbon is a net atmospheric carbon source or sink. This is mainly due to a paucity of information on the fate of SOC during soil erosion, which affects oxidation during the storage, transportation, and final deposition of SOC. The Southern Hemisphere may play a dominant role in the global SOC - atmosphere carbon cycle, since changing climates can cause the expansion or contraction of terrestrial biomass across vast continental areas, for example in temperate to semi-arid Australia.

Here, we investigate the interplay between catchment erosion (quantified by means of uranium isotopes), vegetation cover (pollen), the wetland response (diatoms), and catchment-wide carbon and nitrogen cycling (carbon and nitrogen isotopes) on glacial/interglacial time scales in south-eastern Australia. The analyses are applied to the sediments of Lake Couridjah (Thirlmere Lakes) SW of Sydney. The recovered lake sediments cover the time interval between ~140 ka and 100 ka, and between ~17.6 ka and present day (Forbes et al., 2021). This offers an outstanding opportunity to study SOC cycling across different glacial/interglacial boundary conditions.

Partial Least-Square Regression (PLSR) analyses reveal robust phase-relationships between catchment erosion, vegetation density, and carbon and nitrogen cycling during both glacial-interglacial complexes. The data imply that the density of the catchment's sclerophyll mid- to understory vegetation, and not the amount of rainfall, has the dominant effect over catchment erosion, and over SOC storage in the catchment. Wetter and warmer conditions promote the expansion of dense sclerophyll vegetation, reducing (increasing) catchment erosion while simultaneously increasing (decreasing) SOC storage as well as lake productivity and lake carbon storage. This would imply a positive relationship between warmer and wetter climates and atmospheric CO2 sequestration in the Thirlmere catchment.

Forbes, M. et al., 2021. Comparing interglacials in eastern Australia: A multi-proxy investigation of a new sedimentary record. Quaternary Science Reviews, 252.

Last glacial palaeoenvironment of the Bassian Land Bridge, southeast Australia

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The Bassian Land Bridge linking lutruwita/Tasmania and the mainland of Australia during the last glacial period allowed biotic dispersals and humans migration between the two regions. Palaeo-environmental conditions associated with biotic dispersals on the land bridge remain speculative due to insufficient palaeoecological data from the area. A 35,000-year record of vegetation, fire regimes and lake level changes from one of the larger Bass Strait islands (Cape Barren Island) is presented here. A significant shift in vegetation from woodland to grassland was recorded on the Bassian Land Bridge from ~29,000–14,000 years ago under the full glacial climate. Floristic richness, fire activity and lake levels also declined through this period. Phylogenetic evidence from extant open vegetation communities supports the suggestion that open vegetation plant taxa, such as the grasses, where readily dispersed between lutruwita/Tasmania and the Australian mainland during the last glacial period. Results from this study also support the idea of widespread dry grasslands across southeast Australia during the last glacial maximum.

Environmental change inferred from multiple proxies of sediment from 18 cal kyr BP at Lake Barrine, NE Australia

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Lake Barrine (17.25°S, 145.64°E) lies in a maar crater on the Atherton Tableland, tropical NE Australia forming 18,000 years ago after volcanic eruptions. The 65 m depth stratified lake provides a detailed sediment record of climate and environmental change in tropical north Queensland. Here we develop a 20-year resolution multi-proxy palaeoenvironmental data series (μ-XRF elemental data, δ13CTOC, TOC and C/N ratio) to reconstruct the hydroclimatic and tropical rainforest dynamics of northeastern Australia over 18,000 years. The data series are supported by 22 accelerator mass spectrometer (AMS) radiocarbon dates, from an 8 m-long sediment sequence from Lake Barrine.
The μ-XRF elements and elemental ratios, such as Ti, K, Ca, Mn/Fe and Inc/coh ratios, and bulk organic geochemistry showed that both late Pleistocene and Holocene included three distinct climate periods. The late Pleistocene consisted of two wet, cool periods from 18.4 to 16 cal kyr BP and from 12.5 to 11.5 cal kyr BP, and one dry, warm period from 16 to 12.5 cal kyr BP. The Holocene compromised a dry, warm early Holocene from 11.5 to 7.7 cal kyr BP, a wet, warm middle Holocene from 7.7 to 5 cal kyr BP, and a wet, cool late Holocene from 5 to 1.5 cal kyr BP. Mn/Fe ratio was used to reconstruct temperature in Lake Barrine for the first time because low ground minima temperature (≤ ~5 °C) is the main driver of deep mixing in this lake. Our reconstructed precipitation is consistent with records in the same climate region, but opposite to precipitation patterns in northern hemisphere tropics. However, the temperature documented at Barrine is in concert with sites in the same climate region and those in northern hemisphere tropics. This phenomenon infers that the bipolar seesaw of Intertropical Convergence Zone may cause the opposite precipitation in the low latitudinal regions in northern and southern hemispheres whereas temperature may be modulated globally.

Key words: paleoclimate change, northeastern Australia, bulk organic geochemistry, μ-XRF, maar lake

Session 3

Geomagnetic field changes in Australia and applications for Quaternary Sciences

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We may not see it, but we rely on the Earth magnetic field everyday. The Earth magnetic field deflects harmful charged particles from the sun and constitutes one ingredient for life on the planet and for our modern technologies. The history of geomagnetic changes back in time is also a useful dating tool for Quaternary Sciences. Here I present recent, ongoing and projected paleomagnetism work focused on Australia and I discuss the potential for developing new regional dating tools for Paleosciences and Archaeology.

The studied materials from Australia include lake and marine sediments, cave deposits, lava flows, and archaeological artefacts. We find that archives from the most recent Holocene period offers the highest resolution (up to multi-decadal). Archives from the Last Glacial Period offers a unique opportunity to look at the regional expression of well-documented global geomagnetic instabilities (Laschamp and Mono Lake excursions). In addition to building dating tools for the Quaternary community, adding new high-quality paleomagnetic data to the global dataset will put Australia on the (paleomagnetic) map and help improve the next generation of geomagnetic field models.

Fire and ecosystem change on Kangaroo Island, South Australia, over the past 5,000 years

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Fire has long been a familiar and important part of Australian landscapes. However, anthropogenic climate change has heralded major shifts in fire regimes, negatively impacting ecosystems. These effects are expected to worsen in coming years, but there remain difficulties with projecting fire regime trajectories and their environmental impacts, in part due to a lack of data on centennial to millennial timescales. Uncertainties remain concerning the independent effects of climate and human impact on bushfires, and the long term impacts of fire on both terrestrial and aquatic ecosystems.

This study aims to address these uncertainties by returning to Lashmars Lagoon, Kangaroo Island, a site of pioneering palaeoenvironmental research in South Australia. Kangaroo Island presents a fascinating case study, due to the putative abandonment of the island by ancient Aboriginal populations 2,450 ± 300 cal yrs BP. As such, it represents a unique opportunity to study the impact of cessation of Aboriginal management practices on ecosystems prior to European invasion.

We collected sediment cores from Lashmars Lagoon, which we estimate to span the past 5,000 years. We are combining multiple palaeoecological and geochemical proxies to infer both fire and hydroclimate variability, augmented by an age model based on Pb-210, Pu isotopic profiling and C-14 dating. We will also analyse sedimentary ancient DNA (*sed*aDNA), which we hope will provide novel insights into the occurrence of taxa not usually detected through conventional palaeoecology. Our aim is to provide insights into the drivers of palaeofire and ecosystem response to changing fire regimes, with relevance to contemporary bushfire predictability and environmental management.

For this conference, we will present preliminary data with a particular focus on the recent historical period. The potential and challenges of using lake *sed*aDNA in an Australian context will also be discussed.

How fire activity has changed over the last 500 years in Buchan, East Gippsland

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Supervisor- Michael Shawn-Fletcher

Fire has always been an integral part of Australia's landscape, and pre-European Invasion, it was used by Aboriginal People to care for and manage landscapes, for hunting and for ceremony. Forced dispossession caused the cessation of Aboriginal land management across much of Australia, and consequently landscapes have changed significantly. The increasing frequency and severity of bushfires in Australia, particularly the 2019/2020 east Victorian fires, has caused an increased need for research to understand the relationship between southeast Australian landscapes and fire to aid efforts at mitigating future catastrophic fire events. Sedimentary analysis can be used to better understand landscapes and fire activity by examining the stratigraphic layers contained in soil and wetland cores. Pollen and charcoal analysis can help understand fire events and vegetation change through time, as well as identifying the introduction of exotic species. Geochemistry of the core can be used to understand factors such as post-fire erosion to allow a fuller picture of the landscape change through time. Finally, radiometric dating can be performed on soil cores to date the stratigraphic layers and the timing of changes recorded in the core sequence. This research focuses specifically on a wetland core from Buchan, East Gippsland, to understand past fire activity in the area and the impact of the cessation of Aboriginal cultural burning and fire management. The wetland lies within the scene captured by Eugene von Guerard (1867) in his famous lithograph, *Junction of the Buchan and Snowy Rivers, Gippsland*, providing ethnopictoral evidence of the landscape under (or shortly following) Aboriginal management to compare with the sediment data. Additionally an archaeological excavation is being undertaken nearby the site (300 m to the southwest) along the Snowy River, which records evidence of local site use and occupation for at least the past 1000 years. The key research questions to be tackled include: How has fire activity (severity/frequency) changed since the cessation of Aboriginal land management? What are the underlying factors of fire activity change? How accurate are colonial paintings of pre-European Australian landscapes?

Indigenous burning practices: a solution for modern-day land management?

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"Have catastrophic bushfires always been a part of the landscape in southeast Australia? Or did European settlement and the removal and suppression of indigenous burning practices lead to alterations in fire regimes? There has been much discussion around the potential use of indigenous cultural burning in modern fire management because of its ability to keep landscape-scale fuel loads low, perhaps reducing the occurrence of devastating high-intensity bushfires.

My research is based in East Gippsland (Victoria) and forms part of a larger project that will investigate fire history and vegetation change throughout southeastern Australia before and after European invasion.

I will present a high-resolution charcoal record of a 1500 year-old core collected from Elusive Lake, the largest permanent freshwater lake in Gippsland. I will discuss how charcoal and pollen deposits combined with geochemical analyses can help to paint a picture of past fire regimes that may help to inform modern day land management practices."

A history of burns: fuel and fire patterns in East Gippsland forests pre and post-cessation of Aboriginal landscape burning

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The catastrophic bushfires of 2019-20 summer significantly impacted the southeast of Australia. Intense fires propagated across the East Gippsland regions, burning temperate forests to an unprecedented extent. The catastrophic burns have sparked political and academic discussions about the absence of Indigenous cultural burning as European settlement caused the cessation of traditional landscape management practices. Due to European settlement and the violent disruption to Aboriginal burning practices, the empirical information on the direct impact of cultural burning on fuel types and loads is inadequate. Additionally, the correlating shifts in fire intensity and fire severity over time remains relatively unexplored. The critical question of human fire paradigms and land management is whether such unprecedented and highly intense burns are part of the Aboriginal landscape and an embedded dynamic of fire as an ecological factor?
To address these gaps, this Masters research proposes an analysis of the subfossil record spanning the past 500 years to address three research questions. (1) Have the composition and the amount of fuels changed since the suppression of Aboriginal cultural burning? (2) Have fires become more frequent since the suppression of Aboriginal cultural burning? (3) Have fires become more intense since the suppression of Aboriginal cultural burning?
To reconstruct this history of fire activity and vegetation dynamics the study will employ palaeoecological methods to two lagoon sites at Point Hicks, East Gippsland, a data-poor region. In doing so, this project will apply an analysis of fossil charcoal, fossil pollen, dendrochronology, radiometric dating, geochemistry, and Fourier Transformed Infrared Spectroscopy (FTIR) to the organic-rich sediment records for a multi-proxy understanding. For this conference, I will present the first instalment of the results: high-resolution charcoal data of a fire reconstruction from one of the lagoon sites (Dougs lagoon).

Key words: fire, fuel load, Aboriginal landscape burning, fire activity, fire intensity, landscape evolution, palaeoecology.

Reconstructing a fire and climate history using a stalagmite from Crystal Cave, south-west Western Australia.

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Bushfires are a major natural hazard, with a growing impact on communities and ecosystems in Australia and worldwide. However, our understanding of long-term past fire intervals and behaviour is limited by low temporal resolution. Cave stalagmites offer a novel opportunity to reconstruct long, high-resolution datasets of past fire and climate with a precise chronology.

CRY-S1 is a cave stalagmite from Crystal Cave, Margaret River, south-west Western Australia. Monitoring has shown that speleothems from shallow caves are more likely to record fire events as pulses of ash-derived elements and evaporative enrichment of $\delta^{18}O$. However, Crystal Cave is located approximately 30 m below the surface, indicating that past fire events can also be recorded in a deep cave system. This may be on account of the cave's fracture flow contribution enabling a more direct connection with the surface, or the catchment morphology.

This Honours project aims to compile and analyse fire and climate data over 300 years using new and existing datasets for stalagmite CRY-S1. We assess $\delta^{18}O$ and $\delta^{13}C$ isotope data, as well as a suite of trace elements. Past studies have determined that fire events can be identified through ash-derived elements in stalagmite laminae. Elements of interest include phosphorous, strontium and zinc. Results from ^{14}C analyses will be used to test a hypothesis that large fires will eliminate young carbon in soils, altering the stalagmite $^{14}C/^{12}C$ ratio. An age depth model was obtained using annual lamina counts from Sr synchrotron mapping.

Studying trace elements and isotope signals in this context increases our understanding of how past fire and climatic changes can be interpreted through stalagmite geochemistry. This Honours project will contribute to a world first project which uses stalagmites to construct annually-resolved records of fire frequency and intensity.

Key words: speleothems, stalagmites, fire, bushfire, past environments, paleofire, paleoclimate, paleoenvironments

Boron Isotopes and FTIR Spectroscopy to Identify Past Fire Conditions

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Bushfires are commonplace in the Australian landscape, driving biodiversity and landscape change at a continental scale. The 2019-20 bushfire was considered unprecedented in extent across the southeast coast, however, current records, relying largely on remote sensing data and radiocarbon dating of charcoal, paint an incomplete portrait of past fire severity, meaning such definitive conclusions cannot be drawn. This also limits the efficacy of mediation, mitigation and post-fire recovery efforts. The aim of this project is to calibrate two novel techniques 1) boron isotopes and 2) Fourier Transform Infrared (FTIR) Spectroscopy against known fire occurrence in the Upper Nepean Catchment of New South Wales to determine their suitability as proxies for past high severity fire events.
The 2013 bushfire season saw extensive areas of the Upper Nepean Catchment burn, effecting sediment transport and providing opportunity for calibration. Creeks were selected such that they drain an area experiencing the highest severity fire to maximise the signal to be detected by these proxies. Boron isotopes was conducted on the clay fraction, with a general decreasing trend observed with depth as atmospheric and biological inputs decline. The charcoal-rich layer, however, sees an obvious shift to heavier B isotope composition.
Potassium bromide (KBr) and attenuated total reflectance (ATR) FTIR spectroscopy were applied to bulk sediments, highlighting changes in molecular composition with depth and exposure to fire. Heating induces the transformation of compounds from long-chain aliphatics to heat-resistant aromatics which can be observed in the spectra from both methods. There is also an observable change in mineralogy and thermal decomposition of C-C, C-N and C-O bonds, creating a signature associated with fire. By calibrating these two proxies in parallel, the opportunity to understand fire characteristics on signature formation is presented. Further investigation is needed over longer time scales; however, these results prove promising for the formation of catchment-scale fire records which could be adapted to Australia and global fire hotspots alike.

Novel proxies to decipher 100 yr of fire regimes in south-eastern Australia

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Our understanding of past fire regimes (severity, extent) is limited by the availability of remote sensing data, thus to the past 20-40 yr. Over longer timescales, there is little information on the properties of the fire. The aim of this project is to develop new tools to provide information about the intensity and/or severity of past fire events. Boron isotopes in detrital sediments are used in combination with lithium and uranium isotopes, to determine the severity of past fires. Fourier-Transform Infrared (FTIR) spectroscopy on detrital sediments and charcoal are used to inform about the intensity of past fires. The project first focuses on soils that have experienced recent high-severity fires (e.g. 2019-2020 fires in the Blue Mountains) to investigate how isotopic and spectroscopic signals are acquired. Then, the aim is to sample sedimentary deposits covering the past 100 yr to (i) calibrate isotopic and spectroscopic tools on recent, well-characterised fire events and (ii) extend our understanding of past fire regimes to the past century.

Preliminary results show that the boron isotope composition of soil clays is sensitive to at least high severity fires. The FTIR spectra of soil clays also show a characteristic signature following fires, allowing for broadly constraining the temperature of the fire. Similar observations were made for sediments deposited in creek beds, suggesting that these signals are preserved during fluvial transport. The next steps of this project are to recover sediments from reservoirs built in the last 100 yr to apply those isotopic and spectroscopic tools.

Session 4

Developing efficient cryptotephra identification in Aotearoa/New Zealand marine sediments.

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Tephra studies in Aotearoa/New Zealand have been undertaken for the past c. 180 years, and have been used to develop detailed chronologies for past eruptions. However, recent developments in non-destructive analytical techniques are affording hidden, additional tephra (cryptotephra) to be discovered. Here I present some of our initial research into the development of efficient cryptotephra identification in marine sediments off Aotearoa/New Zealand. ITRAX-scanning data including magnetic susceptibility, density, and XRF geochemical concentrations are combined with statistical data analysis to show that cryptotephra can be pinpointed within long core sections. Cryptotephra extraction and concentration techniques have also been developed at Victoria University of Wellington to further streamline the sample preparation method. These techniques have been successfully applied to a sediment core from offshore east coast New Zealand to identify hidden deposits of the Taupō tephra, and further constrain a previously unresolved core chronology.

The inbuilt age of charcoal fragments in a sand-bed stream, Macdonald River, NSW, Australia

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Charcoal in fluvial and lacustrine environments can have a considerable inbuilt age, confounding efforts to approximate sedimentation age with radiocarbon dating. Carbon is sequestered in tree rings during growth, and may be hundreds of years older than the charring event ('old wood effect'). Charcoal is then transported and stored at various positions along hillslopes before reaching the valley floor where it may be stored in floodplains and other riverine landforms. Charcoal supplied to river channels may be stored in bars, benches and other landforms or transported as saltating bedload or suspended load within the water column. Time spent in each of these storage and transport phases adds inbuilt age to the charcoal.

To examine the extent of the inbuilt age, we redated charcoal that was collected and first dated using conventional methods by Blong and Gillespie (1978) in the Macdonald River, NSW. In that study, charcoal was sieved and four size fractions of bulk charcoal dated. The smallest fragments had a greater age than the largest.

In this study, 31 individual charcoal fragments from the 2-3 mm size fraction, (SUA-618, 1050-670 calBP) were dated. Only two date to the time of collection, and the oldest was 1700-1590 calBP. It is clear that large numbers of individual charcoal fragments need to be dated to obtain the correct age of deposition when radiocarbon dating charcoal. Bulk samples containing multiple charcoal fragments will produce an erroneously old age. To assess whether it is possible to select charcoal with the least inbuilt age prior to dating, we characterized the taphonomic and dendrological features of the dated charcoal fragments. The impact of inbuilt age on Bayesian modeling in OxCal was assessed, and a revised Charcoal Outlier model is proposed for dating charcoal from lacustrine and fluvial settings.

Blong and Gillespie, 1978, Nature, 271, 739-741

Key words: radiocarbon dating, charcoal, inbuilt age, age model

Reconstructing the late Pleistocene climate sequence at Alexandra Cave, Naracoorte, using trapped charge dating and palaeoenvironmental proxies

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The drivers of Australia-wide megafaunal extinction during the late Pleistocene remain poorly resolved. Hypotheses include individual or synergistic combinations of climate fluctuations, human impacts through hunting or habitat alteration by landscape burning. Moreover, the relationship between extinction dynamics and long term glacial - interglacial environmental change is not yet understood. Using a series of complementary geochronological, palaeoecological and geochemical techniques on a sedimentary sequence in Alexandra Cave, Naracoorte, this study provides improved reconstructions of past climates in south-east South Australia prior to, and around the time of, megafaunal extinction. Optically stimulated luminescence and electron spin resonance dating constrain the age of the sedimentary sequence to Marine Isotope Stage (MIS) 1 – 5. Preliminary environmental reconstructions undertaken using carbon isotopes of charcoal and Itrax micro X-ray fluorescence analysis reveal high precipitation during late MIS 5, while MIS 4 was arid. Decreased organic matter and increased sedimentation rates in mid-late MIS 3 suggest a change in landscape conditions, consistent with an environmental shift around the time of megafaunal demise locally. The Last Glacial maximum was arid, with frequent local fires, followed by a shift during the Holocene, marked by an increase in precipitation.

Key words: Luminescence dating, electron spin resonance dating, charcoal, isotopes, Naracoorte, megafauna extinction

Historical sea-level change in southeastern Australia

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Geological proxy records from across the globe show that sea level has deviated considerably from the late Holocene background rate. These relative sea-level records show that rates of sea-level rise during the late nineteenth century and early twentieth century were especially high compared to the preceding centuries. This acceleration occurred before anthropogenic forcing became dominant and the cause of the acceleration remains uncertain. Records from Australia and New Zealand indicate that the rise may have been more rapid in the Southern Hemisphere in comparison to the Northern. However, current proxy records do not match instrumental records and so more reconstructions are needed to document with greater veracity sea-level change in the region. Here we test the hypothesis that melting Arctic-land based ice during the early twentieth century warm period was responsible for the acceleration, as meltwater from Arctic and Greenland ice results in sea-level rises in the mid-latitudes of the Southern Hemisphere. In order to test this hypothesis, we created three new sea-level reconstructions for southeastern Australia. To reconstruct relative sea level, we generated local and regional transfer function models using modern and fossil salt-marsh foraminifera. We established chronologies for each core using a combination of 14C, 210Pb, stable lead and calendar dates in the new Bayesian age-depth modelling R program 'Plum'. We use a Gaussian-Process model and compare our estimates to instrumental records of sea-level change. Our new records show a sea-level acceleration over the twentieth century. However, timings in the onset of the acceleration differ between sites.

Using surface roughness to date coastal dunes at Fraser Island and Cooloola Sand Mass, Australia

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The SEQ dune field hosts hundreds of onlapping parabolic and transgressive dunes that span > 800 ka. Previous studies have elucidated that major phases of dune emplacement have occur during sea-level highstand associated with glacial-interglacial cycles. However, little is known about the mechanisms controlling dune activation and emplacement when sea-level remains more or less constant. Here, 827 Holocene dunes on Fraser Island and the Cooloola Sand Mass are mapped and a surface roughness model is utilized to estimate timing of dune emplacement. Major phases of dune activity are governed by sea-level fluctuations whereas their spatial distributions are controlled by changes in swash/drift alignment of the coast. The implications of this work suggest that with the current sea-level rise, dune activity will continue to increase placing a greater threat to coastal ecosystems and communities.

K’gari and Cooloola – one dune system?

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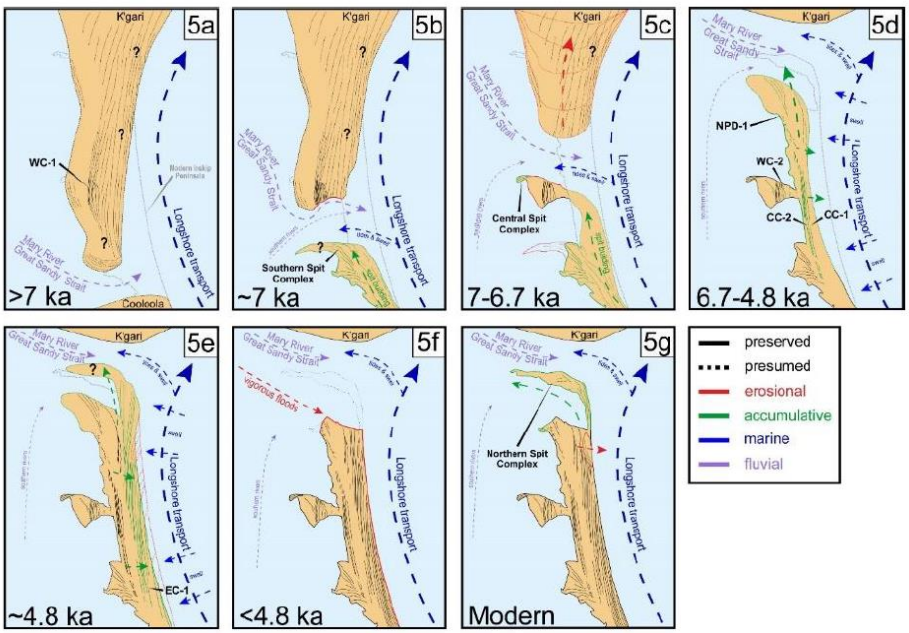
Were K’gari and Cooloola ever connected or one dune system? Geomorphic features of Inskip peninsula include remnant parabolic dunes, numerous beach ridges with foredunes, and a series of spits. Together these features provide insight into Holocene coastal evolution and changing marine conditions between K’gari and Cooloola. A remnant beach ridge/foredune complex at the northern portion of Inskip may have been connected to K’gari and a river/tidal channel which separated it from the Cooloola Sand Mass to the south. This channel avulsed northward in the early mid-Holocene (after 8.8 ka) with spit development from the south and was followed by a phase of beach-ridge/fore-dune complex development that started by ~6.7 ka. Erosive and longshore processes continue to be highly active because of tidal interactions between Great Sandy Strait and the Coral Sea. This detailed study of Inskip Peninsula’s evolution aids significantly in future coastal management decisions, and provides evidence for World Heritage Area extension for the Cooloola Sand Mass, including the incorporation of Inskip Peninsula itself. It also contributes to the global understanding to coastal evolution in an area of strong wave and tidal interaction.

Key words: beach ridges, climate proxies, coastal evolution, coastal geomorphology, eastern Australia, OSL dating



Keynote – Day 2

Dr Shaun Eaves

Dr Shaun Eaves is a Lecturer in Physical Geography at Victoria University of Wellington with research interests in geochronology, glaciology, and Quaternary palaeoclimate.

Climate reconstruction from New Zealand glaciers: a 10-year tenure

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The value of alpine glaciers as climate proxies is long established, but the tools of the trade for climate reconstruction from these archives continues to evolve. In this presentation, I will review recent advances in key methodologies for extracting quantitative climate information from mountain glaciers, outline what we have learnt about past climate change from their application to late Quaternary glacial sequences in the Southern Alps, and suggest future research priorities.

Session 5

Evidence of SAM and ENSO influence on last millennium Antarctic climate from paleoclimate data assimilation

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Results from the Last Millennium Reanalysis, a paleoclimate data assimilation, show that low-frequency tropical pacific SST variability played an important role in regulating surface conditions in Antarctica during the last millennium. However, the circulation pattern we find in the LMR reconstruction departs significantly from the CCSM4, CESM1, and other CMIP5-generation past1000 simulations, which underscores that models are underestimating multidecadal to centennial variability.

A test of the Zealandia Switch at millennial timescales.

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A recent hypothesis dubbed the Zealandia Switch elevates the importance of the Southern Hemisphere westerly winds (SWW) in controlling orbital timescale climate change. In doing so, it circumvents the "Fly in the Milankovitch Ointment" that hatches from an emphasis on summer insolation at 65 deg N. The hypothesis emphasises the effect of SH winter duration on the position and intensity of the SWW as the modulator of global climate. A more southerly location of the SWW during short SH winters allows synchronous leakage of tropical ocean heat into high latitude ocean basins in both hemispheres, and consequent deglaciation. The proponents of the Zealandia Switch also claim the same mechanism (though with different drivers) may explain millennial timescale climate shifts.

In this offering, I investigate the anatomy of a millennial scale LGM warming event on land and in the oceans surrounding NZ, extending to coastal Antarctica, synchronising records via a tephra as much as possible. The consistency or otherwise with model simulations of the Zealandia Switch are then offered as a test of the fundamental physical plausibility of the proposed mechanisms.

Key words: Milankovitch hypothesis, LGM, Southern Hemisphere westerlies, Kawakawa Tephra

Hypothesized southern driver for orbital and millennial-scale climate shifts and implications for the bipolar seesaw

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A recent paper (Denton et al. 2021 - QSR 257; 106771) hypothesizes that global synchrony of ice-age climate shifts is more satisfactorily explained by a southern rather than northern driver. Orbital forcing of the locus of the austral westerlies in relation to the Australia/New Zealand landmasses affords a mechanism for significantly altering Southern Ocean to tropical Pacific oceanic circulation, with rapid and substantial effects on global temperature. The 'Zealandia Switch' is also suggested to be operative on millennial timescales, with global climatic effect. The bipolar seesaw associated with millennial-scale climate shifts is suggested to be an illusion, reflecting an inter-regional phenomenon. Southern-driven global warning created catastrophic northern ice-melt, producing extreme seasonality where winter freezing of summer meltwater on the North Atlantic overwhelmed the signature of warmer summers. Ironically, by this hypothesis, northern millennial-scale stadials were really interstadials with their true character masked by inter-regional seasonality with attendant impacts on the northern biosphere and hydrosphere. It is recommended that existing datasets be re-evaluated in relation to the new hypothesis.

The Australian monsoon in new simulation of mid-Holocene from ACCESS-ESM1.5 climate model

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Changes in the seasonal cycle of insolation at the mid-Holocene have been identified as a driver of variability in the intensity of summer monsoons in both Northern and Southern Hemispheres. Reduced Southern Hemisphere summer insolation is expected to weaken the northern Australian summer monsoon due to reduced continental heating and suppressed onshore flow of monsoon winds. The response of northern Australian monsoon rainfall to mid-Holocene conditions is investigated in a new palaeoclimate simulation of 6000 years BP using the Australian ACCESS-ESM1.5 climate model, following the Paleoclimate Modelling Intercomparison Project Phase 4 (PMIP4) experimental design. The ACCESS-ESM1.5 mid-Holocene simulation of monsoon changes is also compared with the full set of PMIP4 models.

Session 6

How is salty snowfall in Antarctica linked to Australian rainfall?

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Recent research has demonstrated that Antarctic ice core records that are sensitive to atmospheric circulation changes can provide valuable palaeoclimate proxies for Australia's highly variable rainfall. One important example is the Law Dome (East Antarctica) ice core summer sea salt concentration record which is significantly correlated to rainfall variability in subtropical eastern Australia. This record has been used to develop a 1000-year rainfall proxy for eastern Australia and is currently used to improve the quantification and management of water security risks. However, the physical mechanisms underpinning this relationship are unknown. Here we demonstrate, through synoptic typing, favourable atmospheric circulation characteristics that directly connect East Antarctica and Australia. Synoptic typing enables the examination of daily scale weather processes to help bridge the knowledge gap between large scale climate forcings, the ice core record and rainfall conditions in Australia. These results will enhance the usefulness of ice core proxies and assist with determining where it is appropriate to use the ice core record as a remote rainfall proxy.

Possible new mid-Holocene ENSO record from the southern Indo-Pacific Warm Pool

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The El Niño Southern Oscillation is a major driver of drought and flooding in the western tropical Pacific and influences the global climate. The mid-Holocene is thought to be a time of intensification or perhaps the onset of the modern ENSO system. The West Timor speleothem record presented here is the first annually-resolved mid-Holocene d18O data from this part of the IPWP. The base of the flowstone has been dated to ~6.2 ka using U–Th. We hypothesise regular, quasi-decadal depletions in d18O in the record may indicate droughts related to ENSO. We compare this to a variety of other proxies extracted from the flowstone and put our work in the context of other records in the region.

Implication of Mammoth Tooth Enamel in Reconstruction of Paleo-environments in Southern Germany duringMIS3at Different Temporal Resolutions

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Stable isotopes from mammalian tooth carbonate are increasingly implemented in archeological and paleontological studies for paleo-environmental and paleo-ecological reconstructions. However, there are still relatively few studies which focused on local, sub-annual paleo-climatic variations, as they require archives of particularly high temporal resolution. In this paper, we explored the potential of mammoth tooth enamel in reconstructions of paleo-environmental and paleo-climatic conditions at various temporal scales.

Three molar teeth of woolly mammoth (Mammuthus primigenius) discovered in South-West Germany were analyzed for oxygen (δ18O) and carbon (δ13C) isotopic compositions. The samples were radiocarbon dated to fit into three different time windows during the Marine Isotope Stage 3 (MIS 3), approximately 42-33ka BP. One of the teeth was in a stadial period while the other two were during earlier inter-stadials. Temporally successive enamel powder was analyzed for δ18O oscillations, which tracked seasonal changes of paleo-environmental properties such as precipitation and air temperature. Comparisons of δ18O values at intra-enamel, inter-enamel and inter-individual levels enable paleo-environmental reconstructions at sub-annual, decadal and millennial scales respectively. We effectively captured more than ten seasonal cycles in each time window, and by comparison, the stadial sample shows more depleted δ18O values, and intermediate amplification of seasonality compared to the two inter-stadial ones. These results consummated our understandings to MIS3 climatic conditions, as well as demonstrated the massive paleo-environmental information preserved mammoth teeth, which have an abundant reserve and can be employed as the archive to construct a high-resolution Quaternary database.

Key Words: paleo-environments, paleo-climates, stable isotopes, Quaternary, Germany, woolly mammoth.

Past fires and post-fire impacts reconstructed from a southwest Australian stalagmite

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Stalagmites provide records of past changes in climate, vegetation, and surface events, with cave dripwaters shown to respond to fires. It is, therefore, most likely that these cave mineral deposits capture the environmental effects of palaeo-wildfires in their chemical and physical properties, as well as the climate conditions antecedent to palaeo-fire events. We analysed multiple proxies in stalagmite (YD-S2) from a shallow cave in south-west Western Australia. Principal Component Analysis revealed that short term peaks in combinations of phosphorus, copper, aluminium, lead and zinc in the stalagmite correspond to the timing of documented fire events occurring in the modern portion of the record. One particularly significant fire event is identified at 1897 ± 5 CE and shows a clear peak in P interpreted to be derived from ash, and a peak in $\delta^{18}O$ interpreted to indicate evaporation of sub-surface water during the heat of the fire. A post-fire threshold rise in organic matter content and a shift in calcite fabric associated with higher and more variable drip rates are consistent with a post-fire changes in surface-cave hydrology resulting from heat-induced deformation of the shallow karst bedrock brought about by the intensity of this fire. The combination of climate and fire sensitive proxies in YD-S2 indicates that the 1897 ± 5 CE wildfire was preceded by a multi-decadal dry period. We also identify lower and less variable peak phosphorus concentrations in the pre-European period that are consistent with low-intensity cultural burning by Indigenous Australians. The YD-S2 record shows the potential of stalagmites in capturing the climate-fire relationship and the effects of land-management practices on wildfire frequency and intensity.

Key words: Palaeo-fires, stalagmite, stable isotopes, LA-ICP-MS, Synchrotron micro XRF

Vegetation (in)stability and moisture-balance during the Last Glacial Maximum in southwest Western Australia: new insights from speleothem palynology

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Little is known about the climates and vegetation of southwest Western Australia (WA) during the last glacial maximum (LGM). This is unfortunate, for at least two reasons. First, southwest WA hosts a spectacular, hyperdiverse shrubland flora, and debates about the processes that generate and maintain that biodiversity cannot be resolved without a better understanding of the vegetation's past responses to glacial climates. Second, the region is well-placed for evaluating the nature of Southern Hemisphere atmospheric circulation during the LGM, yet the region's existing Pleistocene palaeo-data is ambiguous and poorly dated.

In this talk we will present and discuss pollen records recovered from southwestern WA stalagmites that grew during the LGM, from two caves: one in the relatively moist and cool, forested south, near Margaret River; and one in the relatively warm and dry, shrubland-dominated north, near the floristic diversity hotspot at Eneabba.

Several authors have speculated, based mainly on phylogeographic, floristic and biogeographic evidence, that LGM climates in southwest WA must have been less extreme than in other regions such as south-eastern Australia. However, we find that southwest LGM vegetation structure, and floristic dominance, were quite different from today. Yet at the same time, a number of characteristic shrub taxa locally present today near each cave, remained present during the LGM. The modern geographic ranges of some of these taxa are sufficiently narrow to support meaningful quantitative climate reconstructions. Those reconstructions indicate that LGM soil moisture availability in the southwest was, at the very least, not substantially lower than today; or, less confidently, soil moisture availability was actually higher than today. This is despite substantial reduction in woody biomass relative to the Holocene, which we are forced to attribute to a combination of low atmospheric CO_2 and cold LGM temperatures for which there is no modern analogue in WA.

Key words: speleothems, pollen, Last Glacial Maximum, Late Pleistocene, vegetation, Western Australia, palaeoclimate

Source-to-sink archives of vegetation change since the Last Glacial Maximum, Waipaoa Sedimentary System, New Zealand.

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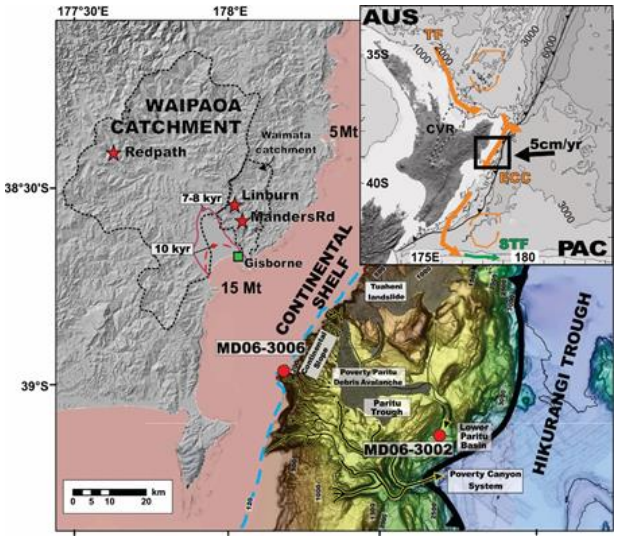
Records of terrestrial vegetation change capturing the last deglacial between ~18 and 6.5 ka from the Gisborne/East Coast region of the North Island, have been challenging to obtain. Arid conditions combined with the unstable landscape characteristic of the tectonically and volcanically active region precluded development and persistence of lake and bog sites suitable for preservation of long, continuous pollen records. However, lacustrine sediments preserved in abandoned meander channels on relict fluvial terraces provide a hitherto untapped source of pollen records.

Three such sites in the Waipaoa Sedimentary System (WSS) have been sampled to yield discontinuous pollen records; Redpath (16.3-14.1 ka); Linburn (18.3-8.5 ka); and Manders Rd (14-2 ka). These pollen data are further supported with a 18-7 ka pollen record from marine core MD06-3002, lower Poverty Bay continental slope, and a ~13-0 ka pollen record from the continental shelf. Ages were constrained by radiocarbon dating and tephrochronology. For the early deglacial, both the onshore and offshore data imply cool climate conditions, with herbs and alpine trees and shrubs, and stands of beech or mixed beech/podocarp forest likely populating the exposed continental shelf. By ~15.5 cal ka BP much of the region was under forest.

At MD06-3006, the highest proportions of mangrove pollen (*Avicennia marina*) and the thermophilous shrub *Ascarina lucida* occur between 11-6.5 ka. This timing is consistent with evidence for a post-glacial rise in sea-level and inundation of the Waipaoa floodplain between 10-7 kyr. The presence of these taxa suggest climate was warm and humid during the early Holocene, with mangroves presently found further north (1°) in the Bay of Plenty. Ferns increase following frequent volcanic disturbances, with a 10x increase in *Pteridium* spores at ~~1312 AD consistent with Polynesian arrival.



Session 7

The forgotten Hemisphere: phases of carbon accumulation since the last glacial

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Peatlands have been increasingly recognised as an important component of global carbon storage, with estimates suggesting they account for 20-30%. While the most extensive peatlands are found in the Northern Hemisphere, there are substantial deposits found in the mid- to high-latitudes of the Southern Hemisphere, but these are often overlooked in global studies. Here we collate basal radiocarbon ages of peat formation in across the Southern Hemisphere and analyse their temporal and spatial distribution. We find distinct phases of peat formation independent of Northern Hemisphere growth and discuss the potential drivers of these phases.

Down-sizing: examining volcanic impacts on vegetation at millimetre scale

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Previous palynological studies of volcanic impacts on vegetation from lacustrine sedimentary records have been limited by coarse sampling resolution and poor depth control. However, for hazard analysis and volcanic risk assessment it is critical to understand both the immediate and long-term timeframes of environmental responses to past volcanic eruptions. The aim of this study is to determine the degree, nature and duration of terrestrial vegetation disturbance following large explosive volcanic eruptions from Taupō supervolcano, New Zealand. This will be achieved through the development of detailed, ultra-fine resolution pollen diagrams for the pre- and post-eruption sediment at Lake Rotokauri and Onepoto maar by slicing and processing LL-channel derived samples at a regular interval of one millimetre. Common issues related to core sub-sampling, such as contamination, have been addressed by adapting milli-slicing techniques and cleaning protocols developed by the 2006 Lake Suigetsu project. The specially designed milli-slicer provides depth control with millimetre-precision, which is a significant increase in operational stratigraphic resolution that enables the examination of landscape and vegetation responses to volcanic disturbance above the Taupō and Ōruanui Tephras at a higher degree than previously possible.

Key words: Volcanic impacts, Taupō eruption, Ōruanui supereruption, ultra-fine resolution palynology

A continental perspective on the timing of environmental change during the last glacial maximum (LGM) in Australia

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The timing and duration of the coldest period in the last glacial stage, often referred to as the last glacial maximum (LGM), has been observed to vary spatially and temporally. In Australia, this period has often been characterised by colder, and in some places more arid, climates than today. It has also been hypothesised that the LGM in Australia occurred over multiple stages and at different times geographically, however this hypothesis is yet to be tested objectively. In order to gain a greater understanding of the timing of climate and environmental changes during the LGM period we conducted a continental meta-analysis on all available proxy records (n=37), primarily pollen records, to examine spatial and temporal patterns of change during the period 35 – 15 ka.

Our continental meta-analysis that suggests Australia experienced an extended period of maximum cooling, with low productivity vegetation that may have occurred as a combined response to as a combined response to reduced temperatures, lower moisture availability and atmospheric CO2. Our analysis also provides evidence for widespread synchronous timing of environmental conditions associated with the most extreme climate conditions during the LGM. These results have implications for how the spatial and temporal coherence of climate change, in this case during the LGM, can be best interrogated and interpreted.

Going beyond the limits: A case study investigating the potential for an 'ancient kauri' (*Agathis australis*) tree-ring chronology to extend beyond the limits of radiocarbon dating

Authors

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Supervisors

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'Ancient kauri' are subfossil samples of the endemic New Zealand tree (*Agathis autralis*) used in dendrochronological and radiocarbon calibration studies. A stockpile of 163 subfossil tree-ring samples has been accumulated but their palaeoclimate potential has never been investigated. The samples are thought to have the potential to form a master chronology that extends at the boundary and beyond the radiocarbon dating limit (i.e. 50, 000 years ago). This will be explored through the application of modified analytical protocols that involve forgoing the conventional step of visual ring-width pattern matching (i.e. crossdating using a microscope) and instead interrogate the ring-width measurements to find matching growth patterns using the custom designed software package 'COFECHA'. The cluster of matching samples will produce a floating tree-ring chronology that will then be radiocarbon dated to identify the associated time period.

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Using giant clam shell geochemistry to understand past environmental change and human-environment interaction in the South Pacific.

Bohao Dong

Supervisor: Amy L. Prendergast

Climate change has been of consistent and considerable concern for the past decades. Paleoenvironmental proxies can reconstruct paleoenvironmental conditions and provide critical baselines for understanding paleoenvironmental changes, which allow us to have better adaptations to current and future climate changes.

Giant clams (*Tridacnidae* spp.) have been found to hold great potential as a novel and reliable paleoenvironmental proxy with high-resolution. Both the isotopic and trace element composition of the giant clam shells are affected by the surrounding seawater. Therefore, we can faithfully reconstruct paleoclimate records by analysing the geochemical composition of the giant clam shells, including SST, DIC, insolation, primary productivity and extreme weather events.

Giant clams have a widespread habitat in the subtropical-tropical Pacific region. Comparing with other proxies, giant clams have advantages in easily accessible, *in-situ* growth, clearly increment bands and long lifespan. Giant clams will settle in a stationary location and record *in-situ* environmental records in their up to 100 yrs' lifespan. The clear annual and daily shell increment bands can provide monthly and daily paleoenvironmental reconstruction resolution and have potential for hourly ultra-high resolution.

For my PhD research project, I aim to use and develop $\delta^{13}C$, $\delta^{18}O$ and trace element ratios in both modern and fossil giant clam shells from the Great barrier Reefs and Fiji as a reliable paleoenvironmental proxy with ultra-high-resolution. In addition, a tank experiment will be included in my project to investigate a more specific relationship between surrounding environmental parameters and geochemical compositions of the shells.

The results of my PhD research project aim to (1) discover the more specific relationships between shell geochemical records and paleoenvironmental parameters. (3) obtain ultra-high-resolution records of the South Pacific paleoenvironmental change. (2) have a better understanding of the human-environment interactions and allow better adaptations to current and future climate changes.

Using freshwater sclerochronology to investigate Late Quaternary environmental change and seasonal resource use in the Central Murray Basin

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Sclerochronology refers to the study of growth patterns and associated geochemistry in the accretionary hard tissues of biological organisms, such as molluscs and coral. While popular with marine molluscs, the use of freshwater mollusc sclerochronology in paleoclimate investigations has been limited so far. Although the high variability of freshwater systems can make the interpretation of this archive more challenging, freshwater molluscs can provide important high-resolution information about the environment of a specific habitat or location. Furthermore, freshwater shells are commonly found in middens and other archaeological sites along modern and ancient river systems, therefore they provide vital insight into human-environmental interactions. The Central Murray Basin in northwest Victoria is one region in Australia where freshwater shell middens are common, with the earliest middens so far dating to c. 15,000 BP. In general, the area has a high density and diverse range of Aboriginal cultural sites, most associated with the ancient or modern Murray River, however many sites have not been excavated or undergone detailed analysis. Previous research has shown that the region underwent great environmental change over the last 40,000 years, with the river area being most productive c. 17,000 to 9,000 years ago. Further research is needed to understand how humans were affected by and adapted to these environmental changes.
This paper will outline a planned research project into the sclerochronological analysis of the Murray River freshwater mussel, *Alathyria jacksoni*. The research aims to determine whether *A. jacksoni* can provide robust and reliable paleoenvironmental and seasonality records through a modern proxy study. Once established, the project aims to use sclerochronological analysis of archaeological material to investigate Late Quaternary environmental change and understand seasonal resource use within the Central Murray Basin.

Key words: sclerochronology, freshwater molluscs, Murray River, human-environmental interaction, paleoclimate

Leaf wax lipid biomarkers: Reconstructing the palaeoenvironments experienced by early H. sapiens at archaeological sites across Southeast Asia & Australia.

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Current understandings of local environmental conditions that early H. sapiens encountered when they first arrived into Southeast Asia (Sunda) and Australia (Sahul) between Marine Isotope Stages (MIS) 5-2 (124-11.7 ka), is incredibly sparse. In this talk I will discuss my doctoral research; the potential of developing a high-resolution, quantitative palaeoenvironmental proxy in and around the local environments of archaeological cave sites through the extraction and analyses of leaf wax lipid biomarkers (n-alkanes). Reconstructing local site environments across Sunda and Sahul is imperative for the advancement of Southeast Asian (SEA) and Australian Pleistocene geoarchaeology, contributing to an improved comprehension of past human-environment relations. Moreover, research findings will contribute to better understand the current debate surrounding the possible existence and extent of a savannah corridor through mainland and island SEA. Improving our understanding of how early H. sapiens adapted to a landscape subject to significant sea level immersions and regressions can assist in addressing present uncertainties surrounding adapting to a future of sea level rise. Given the hot and humid conditions of the tropics causing degradation of valuable archaeological material, leaf wax n-alkanes have been selected due to their resilience against degradation and have been recorded to preserve in the geological record for several million years. Expected results will form rare and valuable quantitative palaeovegetation reconstructions generated from the study of archaeological sediments from a range of sites in Southeast Asia and Australia. This will allow for cross-site comparison to establish differing spatial vegetation and environment conditions. Alongside additional geoarchaeological investigations to refine site occupational history, it should be possible to further elucidate the influence of environmental conditions on early H. sapiens migration and settlement patterns.

A new online database for pollen and spores in the Asia-Pacific region: The Australasian Pollen and Spore Atlas (APSA v2.0).

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Advances in the fields of environmental, health and biological sciences often are built upon access to high quality reference collections that support ongoing and generate future research endeavours. Traditional approaches to archiving and using pollen and spore reference collections have relied on onsite use and hardcopy exchange of material which is time consuming, labour intensive and is unsustainable over long time periods. The building of a pollen and spore reference collection into a widely accessible online Atlas is emerging as a fundamental resource needed across these wide fields of research. We have built a digitally archived and searchable online reference collection of key Australasian pollen and spore grains that will provide a critical resource to support emerging areas of high profile research including work in: airborne allergens and respiratory disease, past, present and future environmental change, evolutionary and systematic biology, biostratigraphy (Cretaceous to Tertiary floras), and forensic sciences. The disestablishment of the APSA website in 2020 after 14 years of service to the palynological community, led to a new APSA platform being developed that is being launched in 2021. The new website hosted by the Australian National University is more stable and secure and includes improved modes of data upload enhancing the functionality and relevance for a wide range of disciplines.

Session 8

20 years since 'Roberts et al.': Gains and gaps in the megafaunal extinction debate

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In 2001, Bert Roberts and colleagues published a suite of new dates for a variety of extinct Pleistocene 'megafaunal' species of Australia (Science 292[5523]:1888–1892.). In their paper, they argued for the widespread, continental extinction of all megafauna around 46 ka and suggested an anthropogenic driver behind the losses. Their contribution stirred-up immense debate over the timing and causes of extinction of the megafauna with some proponents squarely rejecting their ideas whilst others have embraced it. Like it or loathe it, the paper has gone on to become particularly influential in the field of Quaternary extinctions and is now one of the highest-cited papers on any aspect of Australian palaeontology. In the two decades that have followed, numerous new studies have emerged: Some have provided new stratigraphic and temporally constrained data for the various species; others have explored taxonomic issues; some have attempted to reconstruct the life histories of the extinct taxa; others have used proxies to test extinction hypotheses; and in more recent years, a 'big data' extinction modelling approach integrating geochronological information has emerged. Despite the plethora of studies, there are still many holes in the datasets necessary to adequately test the leading extinction hypotheses, and even more myths that promulgate through the scientific literature about how well 'we' even seem to know what happened. In this presentation, I'll briefly explore the gaps and gains across the field in the last 20 years and bust one or two myths along the way. The take-home message is that we are still very far from having a clear answer surrounding the demise of the megafauna. Closer integration of seemingly disparate datasets and greater collaboration between Quaternary scientists will be critical to generate the basic data necessary to better piece together the story of the emergence and extinction of Australia's megafauna.

Early Aboriginal occupation of the Sydney Basin

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Early occupation in Australia is usually associated with sites in Arnhem land or the Northern Kimberley at around 65-50 ka, or inland lake systems such as Mungo at 40 ka. However, sites in the Sydney Basin have not generally been dated to prior than 30 ka. The Parramatta sand body in the Sydney Basin contains artefacts that have been preliminarily dated to ~30 ka using OSL single aliquot dating. In this study we investigate the antiquity of the artefacts found in the Sydney Basin by collecting a series of optically stimulated luminescence (OSL) samples from the cultural layers of the sand sheet. Instead of using a single aliquot approach, we opted for single-grain techniques to isolate the most bleached grains. We combined this with a detailed particle size analysis to determine the sedimentary origins of the sand body, as this has a direct influence on the statistical model employed to analyse the single grains. Resulting particle size analysis and age estimates suggested that the sediment was likely aeolian and provided evidence of early Aboriginal occupation of Parramatta at ~33 ka.

Key words: optically stimulated luminescence, sediment, indigenous

Response, resilience, and recovery: An endangered fire-sensitive endemic conifer and its relationship with fire.

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Tasmania hosts a number of the world's last endangered 'Gondwanan' conifers. These long-lived slow-growing species dominate hyper fire-sensitive ecosystems throughout the northwest Tasmanian landscape. The strange occurrence of these ancient hyper fire-sensitive species within a landscape in which fire (both human and lightning induced) has been critical in shaping, presents an uncertain future for the continuation of these species within this setting. This poses a number of questions, such as, can these systems recover from fire? If so, how long does recovery take? What are the pathways of recovery? What conditions cause these generally inflammable systems to burn (e.g., climate, fuel load, fuel type)? And how do these factors influence the post-fire regeneration of these systems?

This PhD project uses the endemic fire-sensitive conifer *Athrotaxis cupressoides* (Pencil Pine) as a target species to understand how climate, species composition and fire type influence the distribution of long-lived trees with slow demographics, and their resilience to disturbance. Such species' response often lags behind rapid climatic shifts, leaving populations stranded outside their suitable climate envelopes following changes in climate. This lag exposes these kinds of organisms to potential extinction from future climate change and increased fire disturbance.

Multiple study sites were targeted across the Central Plateau in Tasmania, presenting a range of climate envelopes suited to historical and contemporary Pencil Pine growth, to test the hypothesis that this species is migrating altitudinally in response to climate change. Ongoing biogenic analysis, geochemistry, Fourier Transformed Infrared Spectroscopy (FTIR), and radiometric dating of organic-rich sediments within extant and fire-killed Pencil Pine stands will be undertaken to understand ecological dynamics, which will be coupled with local-scale climate reconstructions using stable isotope analysis of speleothems proximal to these study sites. For this conference, I will orally present high-resolution charcoal data from three sites, accompanied by selected pollen data.

Key words: Pencil Pine, palaeoecology, palaeoclimatology, Tasmania, resilience, fire, climate.

Connecting rock art to ritual practices in the Kimberley using OSL dating.

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The rock art sequence of the remote Kimberley region of tropical northwestern Australia is likely to prove one of the longest and most complex anywhere in the world. The art evolved in stages with different styles reflecting different communities and belief systems, which provides many clues to the nature of the painters. Unlike the ancient cave art of Europe (Pike et al., 2012) or the paintings recently dated in Southeast Asia (Aubert et al., 2014; 2018), the Kimberly art remains central to the cultural beliefs of the Indigenous population of the region today. But how do we connect the art with the people that drew them and reconstruct the nature of the earliest Australians? Excavations conducted inside and outside of the most decorated rock shelters provides the best opportunity for making these connections. The Gunu site complex on the remote Mitchell River region of the northwest Kimberley provides a valuable opportunity to forge that connection using OSL dating of mud wasp and rock shelter sediments. In this talk I will review the excavations connected at Gunu Rock (sometimes called Reindeer rock) in the sand sheet adjacent to the rock art panel, and Gunu Cave – floor deposits in an extensive rock shelter. These excavations provided evidence of two phases of Holocene occupation; 7-8-2.7 ka and 1.06 CalBP, which correlate with the Wanjina art style dated using mudwasp nests (Ross et al., 2012). The youngest phase contains quartz crystals that were reduced by freehand percussion to make small flake tools. These tools, called 'Nguni' by the locals, are prominent in historical ritual practices associated with the most recent Wanjina belief system that is still practiced today by the local Wunambal Gaambera people.

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Australia's past cultural landscapes revealed

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Australia has rich cultural landscapes that have been curated for millennia through Indigenous caring-for-country practices. But why have palaeoecologists often failed to find traces of these practices in the Quaternary record? In this presentation, we argue that biases in pollen data have masked the underlying signals of the cultural landscape. REVEALS modelling, a technique developed to produce realistic estimates of past vegetation and land cover, indicates that cultural landscapes were much more widespread in Southeastern Australia than previously inferred from uncalibrated pollen data. This is largely due to the poor representation of grass pollen compared to prolific pollen producers like *Eucalyptus*, Casuarinaceae and conifers. Our reconstructions show that Australia's most fire-prone forests were once much grassier and that flammable shrubs have invaded these zones since the disruption of Indigenous cultural burning in the colonial period. These forest and woodland zones have shifted from their pre-colonial baselines and are on an ecological trajectory that promotes the occurrence of high severity fires. The reinvigoration of cultural landscapes, and the practices that shaped them for millennia, should be a priority in mitigating destructive fires and celebrating Australia's rich cultural heritage.

Key words: palaeoecology, pollen analysis, modelling, quantitative land-cover reconstruction

Session 9

Relationship between sedimentation and sea level in a northern Hikurangi Trough turbidite plain: Insights from IODP Expedition 372B/375, Site U1520

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Gravity flow processes are one of the most significant drivers of sediment transport and deposition in submarine environments. Their deposits have traditionally been avoided by paleoceanographers, but their characteristics can provide valuable records of how sedimentary, tectonic and oceanographic processes function and how they vary over time. A long (>500 m) sediment record was recently acquired from Site U1520 in the northern Hikurangi Trough as part of the International Ocean Discovery Program (IODP) Expedition 375. The upper ~106 m (Unit I) provides a continuous, high-resolution record of a turbidite succession that contains sediments associated with the last glacial-to-Holocene climate transition. An analysis of Unit I sediments, integrated with bathymetric and seismic reflection data, was undertaken to provide insight into this unique sedimentary record.

This sedimentary succession is primarily composed of siliclastic turbidites, from which six lithofacies were identified that represent a continuum of clay-rich, low-density turbidites (1–4) to transitional- or high-density turbidites/low-strength debrites (5–6). Sedimentation rates during the last glacial maximum (LGM) are some of the highest globally recorded (up to 9.73 m/ka), while interglacial sedimentation rates are significantly lower (0.5–1.5 m/ka) but still high compared to other continental slope regions around New Zealand and the world. The changes in these rates are linked to shifts in sea level associated with glacial-interglacial climate cyclicity, with age-depth models indicating that there is a rapid transition between sedimentation regimes during transitional stages. These shifts could be indicative of a sea level threshold that allows for sediment to bypass the shelf and feed the continental slope directly. Gravity flows at Site U1520 are interpreted as being predominantly sourced from the Māhia Canyon and from overspill of the Hikurangi Channel; their deposits have infilled the trough floor of the northern Hikurangi Margin and have formed geomorphic features that include cyclic steps and buried submarine channels. This study provides new insights into the sedimentological and oceanographic processes that have been active during the Quaternary on the Hikurangi Margin and how they responded to changing environmental conditions.

Key words: turbidites, Hikurangi Margin, sedimentation rates, glacial-interglacial cyclicity

Dynamic mud deposition in the lower Waihou River, New Zealand

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Mud deposits are considered to be diagnostic of low energy environments despite relatively recent work showing that mud deposition can also in high energy settings. Muds deposited at high flow velocities have now been documented both in flume studies and in the rock record, but have not been shown in modern environments. This study bridges this gap by quantifying, in situ, the flow parameters and sedimentological characteristics of mud deposited in the lower Waihou River where tides, river flow, and marine water interact.

At each of five study sites, oceanographic instrumentation was deployed for a neap-spring cycle to provide information about flow velocities, salinity, and suspended sediment concentration. Immediately following instrument deployment, co-located vibrocores and sediment samples were collected. The vibrocores contained interspersed beds of mud and sand, the proportions of which varied along the fluvial to marine transition (FMT).

Cores display a number of styles of mud beds, including beds deposited by fluid muds. Microstructural analysis gave insight into the mechanisms driving the deposition of these dynamic muds and this information was compared against the parameterized flow conditions in the river. Ultimately, the results allow us to say that: 1) muds are deposited at the same flow velocities as sand; 2) depositional position along the FMT can be constrained using mud-characteristics and this can improve paleoenvironmental reconstructions; and, 3) carbon buried in estuaries is controlled, in part, by mud depositional style and this can be used to inform global carbon budgets.

Revealing records of inundation from marine sediment records within the Montebello Islands, NW Australia

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This presentation presents preliminary analyses from marine core records taken within the lagoons of the Montebello Islands, on the edge of the inner continental shelf off NW Australia (Fig. 1). These lagoons preserve unique records that document the post-glacial transgression and past cyclonic activity, and hence are likely to provide an unrivalled record of palaeoenvironmental change and landscape evolution for this region. This in turn provides critical contextual information to link with the archaeological and early faunal records in this region that indicate humans occupation from ~ 50,000 – 7,000 yrs ago (Veth et al. 2017). Whilst analyses are still ongoing, this presentation outlines initial geochemical (ITRAX) and chronological (14C) dates from some of these core records and some hot-off-the-press highlights from the June 2021 geoarchaeological fieldtrip!

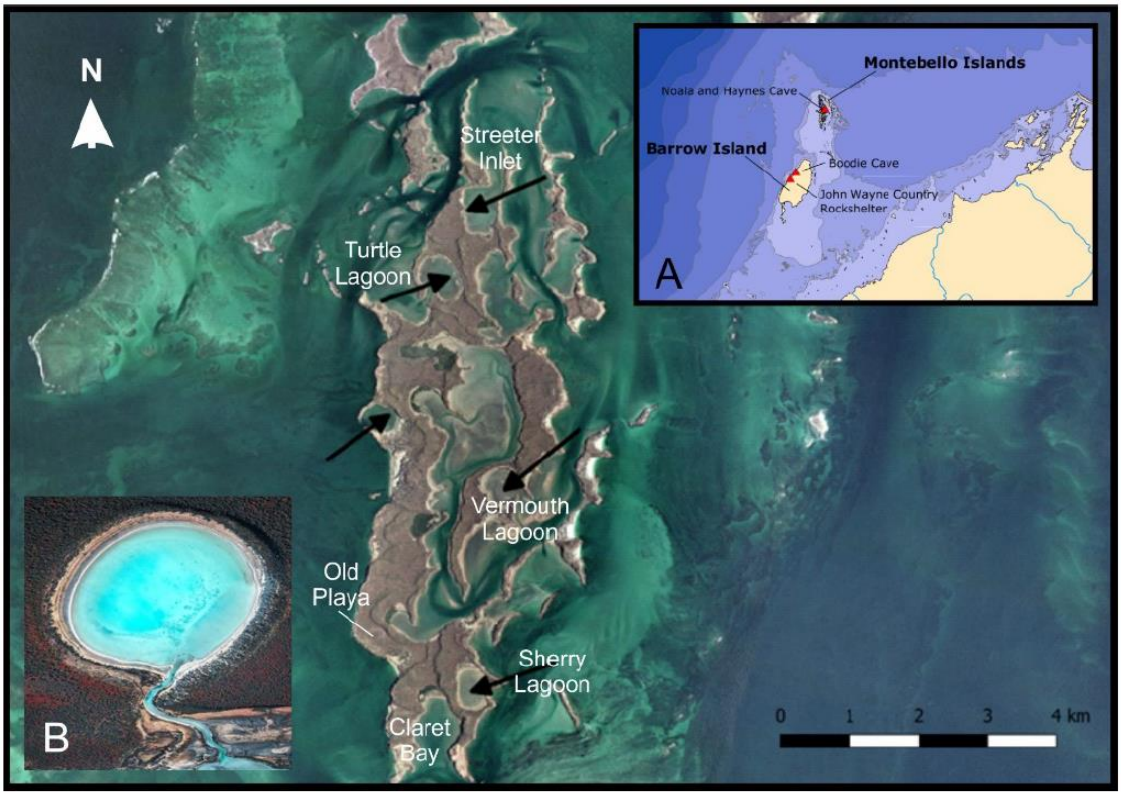

Fig. 1 Location of Montebello Islands in NW Australia, showing location of Noala and Haynes Caves, and also Boodie Cave on Barrow island (inset A). Black arrows point to the infilled playa lakes/lagoons, which are similar to those now found in Shark Bay (inset B, photo: scottjonphotography via IG). Labelled locations are those which were sampled.

Using radiolarian assemblages to track glacial-interglacial changes in the South West Pacific

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The Southern Ocean plays a critical role in driving atmospheric CO2 variation over a glacial cycle by influencing uptake and outgassing from the deep ocean. However, the timing and sequence of subsurface processes involved are not yet understood. Siliceous radiolarians inhabit the subsurface waters (~100-400 m) of the world's oceans, potentially providing critical information about these subsurface processes. Here, we present the first Southern Ocean - Pacific - Water Mass Index using radiolarian core top census data in the South-west Pacific Sector and use this to look at glacial-interglacial changes in subsurface processes. The index is applied to down core radiolarian assemblages at core sites Y8, Y9 and E27-23 in the South West Pacific, and shows significant shifts in the fronts and water masses over the last glacial cycle.

Manifestations of the Mid-Pleistocene Transition in the South-West Pacific

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During the mid-Pleistocene transition (MPT) 1200-800 ka, glacial-interglacial cycles (G-IG) changed in frequency, amplitude and characteristics, from symmetrical 40 kyr cycles prior to 1200 ka, to roughly 100 kyr cycles with a distinct “saw tooth” like shape after 800 ka. Over this transition there was no significant change in orbital forcing, this indicates that the MPT was caused by changes internal to the Earth’s climate system. A number of hypotheses have been proposed. However, the global benthic δ18O record most commonly used to examine changes in G-IG cycling over the last 5.3 Ma, the LR04 benthic stack, only incorporates one core from the South-West Pacific. As a result, it is not clear how the MPT manifests in the South-West Pacific.

This project is the first attempt at compiling and synthesizing all of the available datasets that examine the MPT in the South-West Pacific. Datasets of ten marine sediment cores representing a latitudinal transect and depth transects were compiled from online databases, by contacting researchers and accessing initial drilling reports. A consistent age model was created for all datasets using the new software PaleoDataView. Spectral analysis was then performed on the datasets to examine the orbital frequencies within the datasets using R statistics software and the Astrochron package. Changes in stable isotope values (δ18O, δ13C) and average sea surface temperatures across G-IG cycles were examined to investigate changes in oceanic circulation that occurred across the MPT.

Spectral analysis of the datasets shows a general trend of 40 kyr cycles prior to the MPT and both 100 kyr and 40 kyr frequencies post MPT. However, several records reveal a non-uniform cyclostratigraphy across the datasets, pointing for a need to re-examine some sites at a higher resolution. The data also suggest three primary changes occurring in the oceanography of the South-West Pacific over the MPT. Evidence from benthic δ18O values for a more pronounced influx of southern sourced waters entering the Pacific via the Deep Western Boundary current across MIS 24-22 (936-836 ka), likely driven by an increased production of Antarctic Bottom Water (AABW). Variations in benthic δ13C values indicate changes in the carbon cycle and ocean circulation, and possible increases in the mixing of intermediate and deep-water masses at around ~ 1 Ma. Finally, evidence from planktic δ18O values and average sea surface temperatures (SST) show an increased instability of the Subtropical Front near New Zealand, manifested as a more pronounced latitudinal migration between G-IG cycles during the MPT.

Middle Pleistocene sea-level change linked to the formation of Fraser Island and initiation of the Great Barrier Reef

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The Cooloola Sand Mass (CSM) and Fraser Island (K'gari) in south east Queensland, Australia, form the terminus of one of the world's longest longshore drift systems. They contain the oldest and most stratigraphically complete age sequences of coastal dunes on the planet and represent multiple large-scale dune building events over the Pleistocene. The basal units of each dune field have been dated between ca. 1 Ma and 0.8 Ma and their formation was directly related to the increased amplitude of sea-level fluctuations during the Middle Pleistocene Transition. Coincidentally the oldest ages of formation for the extant Great Barrier Reef (GBR) is ca. 0.6 Ma and it is suggested that the formation of Fraser Island and the CSM played a role in the formation of the GBR.

Here we present the results of a detailed stratigraphical and chronological investigation along the exposed cliff sections of the CSM and Fraser Island. Optically stimulated luminescence dating conducted on the oldest preserved units yielded ages >0.8 Ma which were independently verified using a novel application of paleomagnetic analysis on the well-developed iron pans found within buried paleosol horizons. Reversed and transitional polarity (prior to 773 ka; Matuyama/Bruhnes Chon) results were collected from the oldest dune sands verifying that the majority of the exposed dune units are Middle Pleistocene in age. Once emplaced, Fraser Island acted as a barrier to northwards sediment transport along the east Australian coastline which facilitated wide spread coral reef growth in the southern and central GBR.

Key words: Middle Pleistocene Transition, Milankovitch Cycle, reef formation, sea-level change, longshore drift, coastal dunes, optically stimulated luminescence, paleomagnetism