VOLUME 41 | NUMBER 2 | DECEMBER 2024

Quaternary AUSTRALASIA

Radiolarians and the story of past oceans

Submission to the ANSTO research portal grant scheme

3D-printed landforms and landscapes for geomorphic outreach, education, and research

AQUA LIFE MEMBERS

Current life members are Jim Bowler, Eric Colhoun, John Chappell (dec), Peter Kershaw, John Magee, Matt McGlone, Geoff Hope (dec) and Jeannette Hope.

Jim Bowler
(Photo credit: socialpolicyconnections.com.au)

Eric Colhoun
(Photo credit: Tim Barrows)

John Chappell (dec)
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Peter Kershaw
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Matt McGlone
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Geoff Hope (dec)
(Photo credit: https://iceds.anu.edu.au/people/academics/professor-geoffrey-hope)

Jeannette Hope
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Quaternary AUSTRALASIA

ISSN 0811-0433

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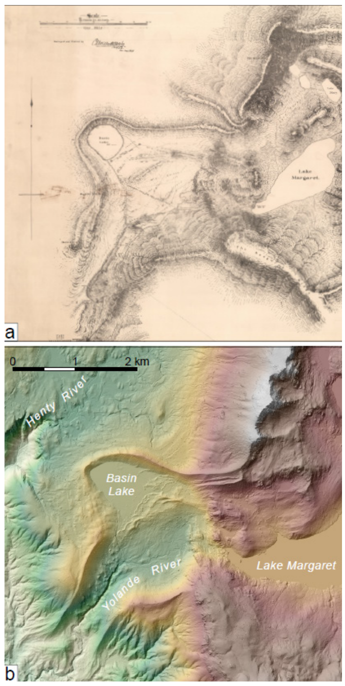
Front cover photo:

Tea trees reflected in Brummiera (Brown Lake), Minjerribah – see The meaning of Minjerribah: AQUA 2024 (Photo credit: Eleanor Steele).

Below:

Representations of glacially-influenced terrain near Lake Margaret, Tasmania, including Hamilton Moraine: a) hand-drawn nineteenth-century map; b) hill-shaded DEM – see 3D printed landforms and landscapes for geomorphic outreach, education, and research (Photo credit: Nicholas Roberts).



EDITORIAL

Dear Quaternarists,

In this edition, we are thrilled to introduce the first President's Pen from Tim Barrows, who shares insights into his vision and priorities for the Australasian Quaternary Association (AQUA). We also feature several engaging Student Reports recounting the valuable experiences and takeaways from our recent AQUA conference, held this year at the Moreton Bay Research Station on Minjerribah (North Stradbroke Island) from 24–28 June.

This issue celebrates the achievements of our community's emerging scholars. We proudly include a collection of Thesis Abstracts that showcase the breadth and diversity of Quaternary research across our region—from the rugged landscapes of New Zealand's South Island to the diverse ecosystems of southeastern Australia, tropical Australasia, and Wallacea. Congratulations to our PhD and Master's graduates on the successful completion of their studies!

We are also excited to share an innovative Research Article exploring the use of 3D-printed landforms and landscapes. This piece highlights the evolution of 3D printing in enhancing outreach, education, and research in the field of Quaternary science, illustrating the potential of this technology to bring complex geological and geomorphological concepts to life.

Additionally, we bring you valuable advice from our past president, John Tibby, who provides a practical guide on navigating the Australian Nuclear Science and Technology Organisation's (ANSTO) Research Portal to submit successful research grant applications. John's insights are a must-read for anyone looking to access ANSTO facilities for Quaternary studies.

Lastly, we're pleased to include a special contribution from Richard Gillespie, who takes us on a nostalgic journey back to the 1970s with memoirs from his fieldwork in southeastern Australia. His reflections offer a fascinating glimpse into the early days of Quaternary research and the evolving landscape of our field.

We hope you enjoy this diverse issue and find inspiration in the articles and reports. Thank you for your ongoing support of AQUA and the Quaternary community.

All the best for another year!

Lauren Linnenlucke
Editor

Emma Rehn
Shadow Editor

We encourage authors to use dual place names where possible (e.g., Kati Thanda-Lake Eyre), to acknowledge Country where the work was undertaken, and to acknowledge any Traditional Owner groups involved in the work.

AQUA acknowledges the Traditional Owners of the lands and seas of Australasia on which we live, work and conduct research, and we pay our respects to Elders past and present.

PRESIDENT'S PEN

Dear AQUA colleagues,

I am delighted to be writing this as AQUA's new President. I have been passed an organisation in great shape and I am very grateful to previous committees. In 1997, I attended my first meeting at Lake Eyre, hosted by John Magee. The trip out there and back through such an ancient landscape was a real eye-opener for me. The meeting was held in tiny shearer's quarters, and there must have been 35 or so of us crammed into the shed. AQUA was created to be deliberately informal and this definitely fit the bill. Every aspect of it was informal. The group was close-knit, friendly, and the presentations were all interesting. I felt at home and decided this was going to be my professional organisation. I have only missed one meeting since then (Fraser Island when I was living in the USA).

As an enthusiastic PhD student, I set about offering to make AQUA's first site on the "World Wide Web" and wrote the pages in HTML using a text editor. I also set up an email list server at the ANU to provide a forum for communication for the organisation. I started digitising old *Quaternary Australasia* issues, and Kate Harle started modernising the newsletter. We lost some informality but became more organised.

After 15 years, my old website wasn't cutting it anymore, and AQUA commissioned a new site, and I stood down as the "Information Technology Editor". It is time to look again at the website and see whether it needs updating and is fulfilling our needs. Our old list server and email address provider are also outdated and haven't kept pace with security changes in the fight to keep spam out of our inboxes. The face of social media is also changing, and our Facebook page and "Twitter" accounts don't reach all members. We'll look to see what improvements we can make.

One of the first things I've done is include an Acknowledgment of Country on the website and in *QA*. I encourage members to acknowledge Traditional Owners and use dual naming where appropriate. I recently led an update to our constitution to modernise it. I want to explore a climate change statement, as many scientific organisations have done. We are in the unique position to be specialised in what is natural climate change. We are still in the process of registering with the Australian Tax Office, and I hope to finalise becoming a Deductible Gift Recipient soon so we can help members give back to the community. We'll keep monitoring diversity in the organisation and doing what is necessary to keep a level playing field. I was delighted to see that a third of our attendees for our last AQUA meeting were students. If you are one of those students, I hope you choose AQUA as your organisation and stay with us for your career. Please volunteer to help us out.

For all our members, this is your organisation. If you have any suggestions for AQUA, please let me know!

Professor Tim Barrows
AQUA President

AQUA Conference 2024 attendees at Minjerribah/North Stradbroke Island.

FIELDWORK IN SA, LATE 1970S

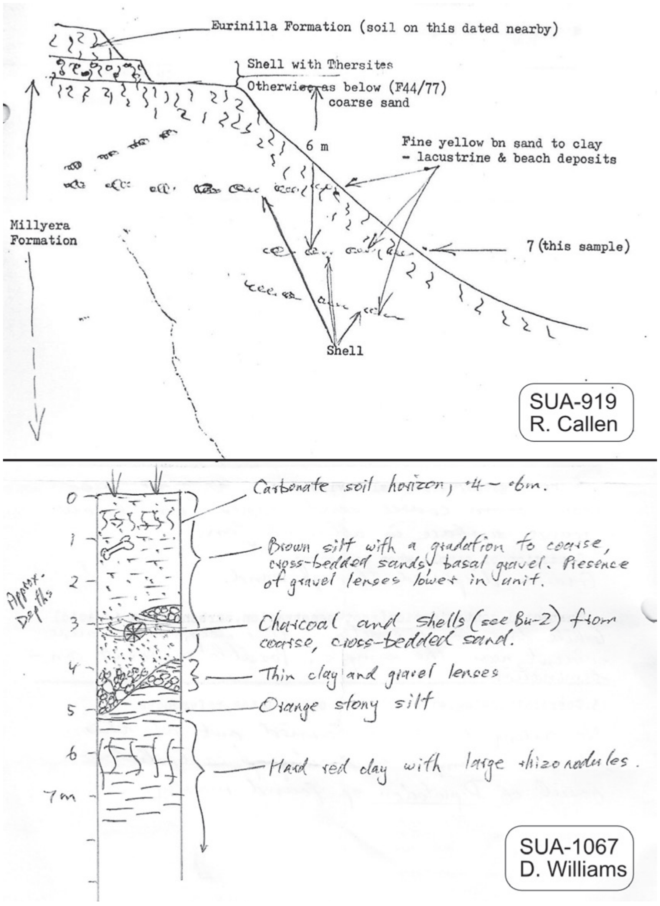
Richard Gillespie

Roger Callen, then with the South Australian (SA) Mines Department, invited me on a trip to Lake Frome and nearby small lake environments to see what might be done with radiocarbon dating on soil carbonates of that large ephemeral/salt lake and other eroded sections. Roger was interested in testing whether or not soil carbonates and nodules in the arid southern Strzelecki Desert gave reliable ^{14}C dates, a contentious debate in the 1970s, while I was running the Sydney University Radiocarbon Laboratory (SUA lab code) and had some meagre experience in that topic. Roger, his young son and I left Adelaide in his Subaru all-wheel-drive station wagon, heading north and met up with Dominic Williams, Jim McNamara, and a couple of others with two 4WD vehicles somewhere in the Flinders Ranges. Dom was looking everywhere for eggshells of the extinct giant flightless bird *Genyornis newtoni* (Williams, 1981; Figure 1) and the bones of extinct marsupial megafauna (Figure 2). A good place for an overnight stop near a small lake in rocky country was found, where Jim caught a rabbit and cooked it for part of the evening meal.

Top Right – Figure 1: The late Dominic Williams scanning an exposed section of sediments in the Flinders Ranges of South Australia, looking for traces of extinct megafauna.

Figure 2: Large disintegrating marsupial bone eroding out from mixed sediment section, Flinders Ranges.

Below – Figure 3: Our three vehicles in a field of daisies, near Lake Millyera close to Lake Frome, SA.



Clockwise from top left:

Figure 4: One of the many eroded sections at lakes Moko, Pinpa, and Millyera, SA, where we collected soil carbonate samples for radiocarbon dating.

Figure 5: Large salt crystals deposited on the margin of one of the three small lakes sampled.

Figure 6: Salt bush flatlands leading west toward the distant Lake Frome, Flinders Ranges beyond the lake.

Figure 7: The team collecting soil carbonate samples from former shoreline of the Lake Frome salina, near the Poontana Creek confluence.

Figure 8: Drawings of sample locations by Roger Callen and Dom Williams, copied from SUA lab submission sheets.

So, we set out for Lake Frome, along the way driving through huge fields of daisies near the small Lake Millyera (Figure 3), one of several locations east of Frome (Lakes Moko, Pinpa and Millyera) where eroded sediments showed layers with soil carbonates (Figure 4) and in places very large salt crystals (Figure 5). Then it was flatlands with saltbush everywhere, with Lake Frome and beyond that the Flinders Ranges in the distance (Figure 6). At one tricky spot, Roger's Subaru got stuck in deep sand, which required digging out the wheels then laying masses of saltbush and mulga sticks to make a kind of solid ramp the car could use and power out. When we finally reached the dry salina of Lake Frome, a lot of soil carbonate and nodule samples were collected from the northern former shorelines near the Poontana Creek confluence (Figure 7). I took all the samples back to my Sydney lab for processing and ^{14}C dating, in some cases dating both inner and outer parts of the same nodule.

Was it worth such an arduous excursion into the South Australian arid zone? It was expensive because of the distances travelled and the then fairly modest cost of the radiocarbon work (~$100/sample). Certainly, Roger and I thought that the science was important, and after further work with a mutual colleague Bob Wasson, a paper was published in 1983 (Callen et al., 1983), saying that pedogenic carbonate dates in the southern Strzelecki Desert were several thousand years too young, contrary to previous ^{14}C dating results from the ANU lab, and that they do not yield reliable ages for pedogenesis. This created some further debate among the staff and clients of the two Australian Liquid Scintillation Counting ^{14}C laboratories: the longer-established ANU lab (where Henry Polach and John Head taught me the rudiments of radiocarbon) and my Sydney lab.

An interesting trip for me, meeting Roger Callen, Dom Williams, and Jim McNamara for the first time, seeing country I had not previously visited, and to help with sample collection so I knew what kind of environment they came from. I learned a lot of soil science, stratigraphy, and many other topics from Roger, Dom, and the others, our evening campfire discussions were very wide-ranging and friendly. But also poignant, because I never saw the really nice guy and talented geologist Dom again; he died much too young a year after that 1983 paper was published. Much later I met Jim again at the South Australian Museum, where I looked (in vain) for extinct marsupial bones that contained enough collagen for radiocarbon dating. These were the kind of studies done in the 1970s, when you needed about 40-50 grams of calcium carbonate to get a decent late Pleistocene ^{14}C date, and the degree of difficulty was high because, so little was known about when pedogenesis took place in the semi-arid and arid zones in Australia. A couple of Roger's field notes/lab sheets (Figure 8) show his great knowledge of the region; he named the Coonarbine and Millyera Formations and many other geological layers for SA map sheets.

By the time that paper was published, I had moved on to the new technology Accelerator Mass Spectrometry (AMS) radiocarbon lab at Oxford (OxA lab code), where we required milligrams instead of grams of carbon for the radiocarbon measurements.

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RADIOLARIANS AND THE STORY OF PAST OCEANS: LEANNE ARMAND TRAVEL AWARD REPORT

Kelly-Anne Lawler

Australian National University, Canberra, Australia

Professor Leanne Armand was more than just my PhD supervisor; she was a mentor and a friend. I met her during my undergraduate studies at Macquarie University, spent two months with her on the RV Investigator on the edge of the Antarctic sea ice during my Master of Research, and relocated to Canberra so she could supervise my PhD at the Australian National University.

While Leanne specialised in the study of Southern Ocean diatoms (phytoplankton with skeletons made of silica), she always encouraged me to explore a different path so that I could carve out my own niche and establish my identity as a researcher independently of her. I chose to start my journey in scientific research by focusing on Southern Ocean radiolarians (zooplankton with skeletons made of silica) – so perhaps I didn't stray too far...

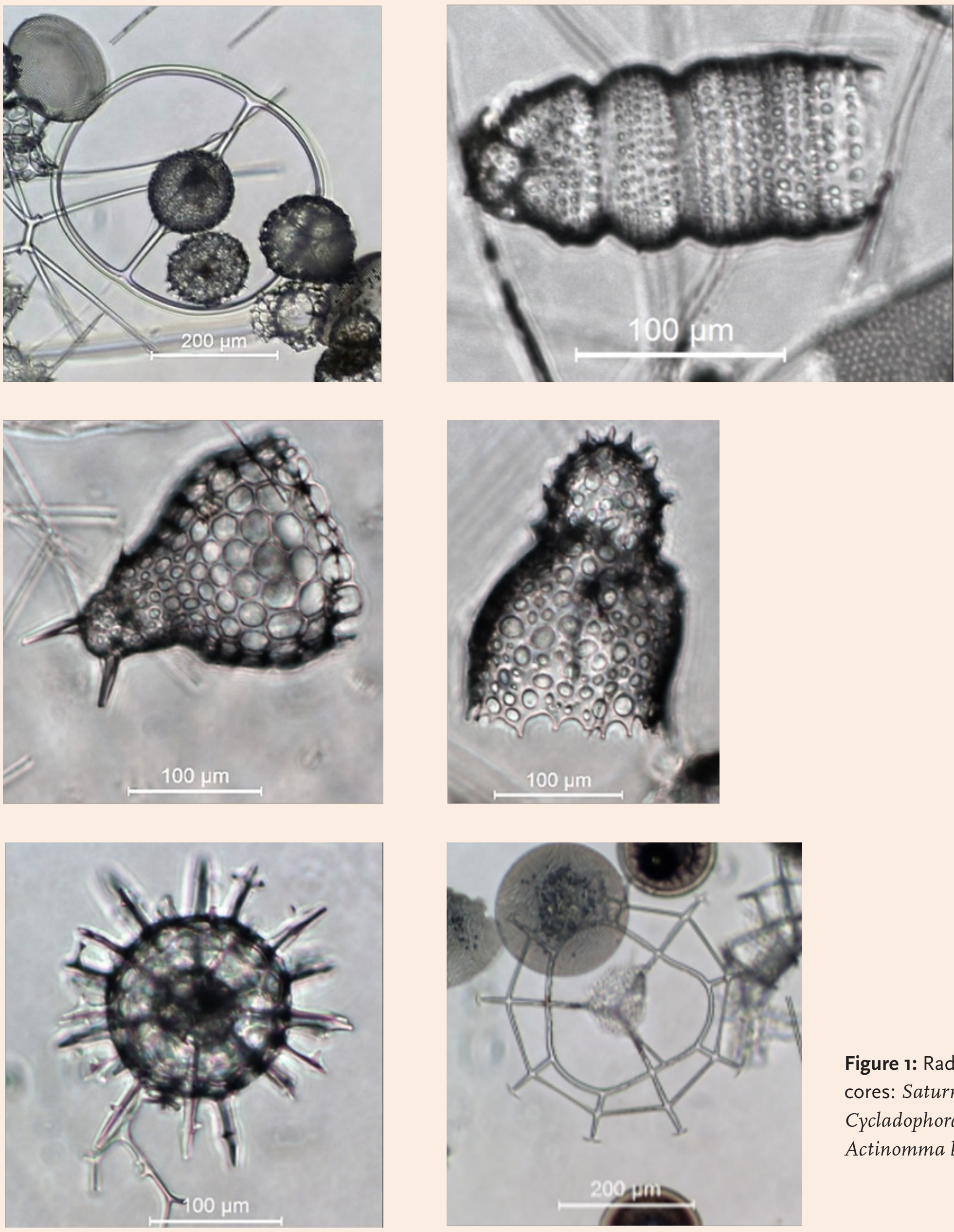

Figure 1: Radiolarians from Sabrina Coast sediment cores: *Saturnalis circularis*, *Botryostobus* sp., *Cycladophora bicornis*, *Antarctissa strelkovi*, *Actinomma boreale*, and *Enneaphormis rotula*.

Radiolarians are unicellular marine microzooplankton, tens to hundreds of micrometres in size, and the type of radiolarians that are most commonly found in seafloor sediments have intricate skeletons made of biogenic silica. While living, radiolarian species prefer certain ocean conditions and after their death, they sink to the seafloor, where they become part of the sedimentary record. When we retrieve sediment cores from the seafloor, the radiolarians inside can reveal what past ocean conditions were like in the water above.

To support me in my research, Leanne kindly connected me with Dr Giuseppe Cortese, an expert in Southern Ocean radiolarians. Working with Dr Cortese has been a terrific experience. I have learned about the taxonomic identification of Southern Ocean radiolarians as well as a techniques used to investigate their relationship with the modern marine environment and how this can tell us about the past. It was an honour to receive the 2024 Leanne Armand Travel Award, and I used this award to fund my visit with Dr Cortese at GNS in New Zealand in August 2024.

The primary goal of my visit was to deepen my understanding of Southern Ocean radiolarian species and how they reflect different stages of marine interglacial periods in a sediment core retrieved from the Sabrina Coast, East Antarctica – the marine exit point of the Totten Glacier. Observations show that, as well as melting from above, warm, modified Circumpolar Deep Water enters the cavity beneath the Totten Glacier via a trough and contributes to the basal melt of the glacier. Changes in the temperature of this water could help explain both past and future changes in the mass of the Totten Glacier.

During my time at the Institute of Geological and Nuclear Sciences Limited (GNS), Dr Cortese and I worked on analysing the radiolarian taxa found in samples from a Sabrina Coast sediment core. We focused on identifying radiolarian assemblages that are characteristic of various stages of interglacial periods, particularly those that may indicate the presence of warmer, deep waters. This collaborative effort was highly successful, resulting in the identification of key species and assemblages that serve as indicators of environmental changes over the past 300,000+ years.

The knowledge I gained from this visit has significantly improved my thesis. By identifying several radiolarian assemblages and linking them to distinct environmental conditions, I can better interpret the sediment cores from the Sabrina Coast, leading to more accurate reconstructions of past ocean-ice sheet dynamics. This has strengthened my thesis and its contributions to understanding Southern Ocean palaeoceanography.

These results will be the highlight of my PhD thesis, which I am aiming to submit in early 2025. I will present my radiolarian work at the Australian Antarctic Research Conference and at the American Geophysical Union Conference in late 2024.

I would like to thank Dr Cortese and GNS for hosting me, and also express my gratitude to the Australasian Quaternary Association (AQUA) for administering this grant.

MEGAFAUNA ON THE DARLING DOWNS: AQUA 2024 PRE-CONFERENCE FIELD TRIP

Chloe Stringer

The University of Melbourne, Melbourne, Australia

This year, I was fortunate enough to attend the AQUA 2024 pre-conference field trip to the Darling Downs. Under the fierce and extremely knowledgeable leadership of Gilbert Price, we embarked on a two-day adventure where we encountered volcanoes, ancient trees, megafaunal remains, and more.

Early on Saturday 22, June we piled into two minibuses and set out from the leafy and bush turkey-populated UQ St Lucia Campus. Over 15 people came along on the trip, with a great mixture of students and established academics from around the country and abroad, with specialisations reaching from dendrochronology to ancient tsunamis, and everything in between.

Our first main stop was Cunningham's Gap, which is part of the remains of the ancient Main Range Volcano (22-25 Ma) and is host to part of the UNESCO Gondwana Rainforest World Heritage Area. It serves as the main path connecting the Darling Downs to the Coast and even appears in the Dreamtime stories of the Yuggera Ugarapul People of the Fassifern Valley, who believe that the Gap was formed by bounding kangaroos who were freed from an enclosure. The ascension to Cunningham's Gap from the Fassifern Valley was breathtaking; it did not take much imagination to picture the Main Range Volcano, despite millions of years of erosion. At the Gap, we went for a short boardwalk through the Gondwana Rainforest. It was here that the broad specialities of the group really came to the fore; under the ancient forest canopy, we had the fantastic opportunity to learn from Heather Haines and Simon Haberle about the important record that these species hold for our understanding of the palaeoecology of the region (Figure 1).

Figure 1: Participants listen to Simon Haberle speak about paleoecology in the Gondwana Rainforest (Photo credit: Gilbert Price).

A few hours later, now surrounded by the vast farmland of the Darling Downs, we stopped at the Glengallan Homestead for a lunch of tea and sandwiches and to learn more about the colonial history of the region. The Homestead was established in 1864 by Scotsman John Deuchar, and it survived a tumultuous ownership plagued by debt, alcoholism, and abandonment before being added to the Queensland Heritage Register in 1992. The building remains grandiose, and much effort has been put into its preservation. The property is littered with signs sharing stories and facts about the house's ownership and use, including stories from the women, children, and staff. My favourite story came from a newspaper article about the housewarming party held at the house in 1868, where people danced from 9 pm to 6 am, stopping only briefly for supper at midnight!

After this, we moved on to what was my highlight of the trip: a viewing of Ian Sobbe's private palaeontological collection and workshop. Ian Sobbe is a predominantly self-trained palaeontologist who has avidly been collecting and preparing fossils from the region since he was a young boy. He has donated many specimens to the Queensland Museum and has published his findings in several articles. As Gilbert explained, there is still so much to learn about Australia's ancient megafauna, making the contributions of amateur palaeontologists such as Ian extremely valuable. Ian and his wife, Dianne, warmly welcomed us into their home. You could tell immediately that Ian was just itching to show us his most recent discovery: one of the most complete sets of Marsupial Lion remains (*Thylacoleo carnifex*) to have been discovered in Australia. His museum was brimming with locally collected items and other specimens that Ian had purchased from further afield, all curated in an extremely professional manner: truly, a fossil nerds paradise. Some of my highlights included a *Diprotodon* skull about 1m in length and the skull of a Marsupial Lion, which appears to have been bitten by a crocodile! There was also a huge collection of rocks and minerals for those less interested in the biological. He then showed us around his back shed, where he prepares recently excavated specimens for display and further research (Figure 2). Here, Ian showed us the mostly articulated remains of the rear quarters of a female *Diprotodon*, still sitting in the massive plaster cast that was used to safely excavate and transport the remains from their excavation site to Ian's workshop. Ian's experience with these fine preparation methods has led to other palaeontologists asking for his assistance in the preparation of fossils from around Australia and the world, and we had the privilege to see some of his works in progress on that day.

After an evening full of food, a good night's rest, and, for some, karaoke, the next day, we had the privilege of being shown the Kings Creek fossil deposits by Ian and Gilbert. Erosion of the extensive Pleistocene palaeochannels of the Kings Creek Catchment means that fossils are eroding out of the banks, and Ian explained that he usually finds the most fossils when visiting after heavy rains. We were left free to fossick in the soil. I found lots of ancient freshwater mussel shells, which was exciting as they're relatives to the mussels I have been working on for my PhD. The most impressive find must have been the fossilised kangaroo pelvis that Peter Almond uncovered! Ian carefully salvaged the remains and took them back to his workshop for preparation and further research. I think we all revelled in the opportunity to have a dig in the dirt and wonder on what roamed the landscape 10,000s of years ago.

Overall, the trip was fantastic; I enjoyed the opportunity to discover a new part of Australia through a Quaternary science lens. It was great to get to know people conducting such interesting and diverse research within Australia and beyond and, in certain cases, get to learn from their experience while in the field. Thank you to Gilbert Price, Helen Bostock Lyman, and the conference Organising Committee for hosting an amazing field trip and AQUA conference.

Figure 2: Ian Sobbe (front left) explains how he prepares fossils in his workshop (Photo credit: Gilbert Price.)

THE MEANING OF MINJERRIBAH: AQUA 2024

Eleanor Steele

School of Earth, Atmosphere and Environment, Monash University, Clayton, Australia

AQUA 2024 was my first Quaternary science conference, and it was a wonderful week of hearing about exciting research, connecting with other students, and having many interesting discussions. AQUA was an incredibly supportive environment, and this made talking about my Honours project less daunting and more enjoyable.

As someone who learns best outside, doing things, I found the highlight of the conference to be the midweek field trip. The Gorge Walk was an amazing opportunity to see the humpback whale migration, and spotting manta rays, turtles, and dolphins from the point with other AQUA attendees was a lot of fun. However, the trip to Bummiera (Brown Lake), a perched lake and women's place, was my favourite part. It is such an extraordinary spot, and it gave a real-world backdrop to many of the talks on lake sediment cores and pollen records for someone who doesn't work with these palaeoenvironmental archives. John Tibby spoke about cores from the lake, demonstrating its persistence over the last 40,000 years with continual deposition of organic sediment, suggesting a positive regional moisture balance. Jonathan Marshall expanded on his talk about Eighteen Mile Swamp. He told us how Bummiera (Brown Lake) has been ecologically affected by recreational activities. The many theories on how fish got in there – I believe a firefighting helicopter was one theory.

The public talk by Justine Kemp and Patrick Moss was a nice bookend to the day learning about Minjerribah and spoke about Minjerribah's formation, Quandamooka custodianship, and post-European impacts. Justine discussed evidence for human occupation on Minjerribah from ~50 ka, with charcoal records indicating anthropogenic burning and heat-treated stone artefacts appearing in the sediment record ~30 ka. Both the talk and the field trip provided context and a Quaternary perspective for the island we were visiting.

After falling in love with Minjerribah, I was shocked to find out at the infamous quiz that Minjerribah meant the 'place of many mosquitoes'. For some reason, I'd imagined a more beautiful meaning after seeing its picturesque landscapes. No mosquitoes bothered me, but the wails and screeches of the curlews at night were certainly something!

For me, Minjerribah will always mean something special. My first AQUA, my first poster presentation, and my first time on the second-largest sand island in the world!

Thank you, AINSE, for the student travel grant that enabled me to attend the conference and thank you to everyone involved in the organisation of the conference (especially Helen Bostock, who carried our quiz team all the way to the win). I had a great time and learnt so much. I look forward to the next AQUA!

Top – Figure 1: View across Bummiera from the shore to the melaleuca forest.

Bottom – Figure 2: Tea trees and a cloudy blue sky reflected in the lake as the sun lowered for the day.

AQUA 2024: A MOSTLY COHERENT REPORT

Fletcher Nixon

Discipline of Earth Sciences, School of Physics, Chemistry and Earth Science, University of Adelaide, Adelaide, Australia

AQUA 2024 was the first AQUA conference I've been able to attend in person, and – since the AEIC 2024 vanished under suspicious circumstances – I can confirm that it's the best one I have attended (n = 4). The people were awesome, and it was so cool to discuss all sorts of Quaternary environments with so many passionate researchers. The fantastic venue at the UQ Moreton Bay Research Station in Dunwich on beautiful Minjerribah/North Stradbroke Island didn't hurt either. There was free food, a ten-metre walk from my accommodation to the talks, and a great spot to watch people try to find a way back to their off-site accommodation after a few drinks – it was like heaven.

This was finally a time to export my ramblings about isotopes, rocks, and past climates to a broader audience, undoubtedly to the immense relief of my friends and family. Talks happened. I gave one, too, but I will bring no report on that to darken the light of day. However, rumour has it that my central Australian temperature data drew a gasp from at least one attendee, which I will cherish for the rest of my life. I was both surprised and impressed by the lack of technical issues – something that I had previously considered ubiquitous for conferences. Two poster sessions provided a great chance to engage more with various researchers' pet projects, with several students also getting in on the action. My theory that you can always identify geologists by their use of hand movements to explain different concepts remains intact.

Other highlights included whale watching at Point Lookout, where I temporarily disobeyed orders and instead looked at some cool rocks, and watching the *Megafauna: What Killed Australia's Giants?* documentary while enthusiastically cheering whenever someone I knew appeared. Sharing a room with three other snoring guys (all of whom were – and presumably still are – awesome) was an interesting experience, with everyone racing to fall asleep first. To my dismay, I was informed that I do indeed snore, contrary to my partner's assurance. We also had a chance to explore the metropolis of Dunwich, where we observed up to four cars driving at a time. Nash Griffiths thought he saw a fifth, but I don't believe him. I would talk about the trivia contest, but some things are still sacred, and what happens at the trivia contest stays at the trivia contest. This has absolutely nothing to do with the fact that my team was robbed.

Figure 1: The University of Adelaide crew.
Back row: (from the left): Jonathan Tyler, Nashley Griffiths, Darren Ray, Fletcher Nixon, Mahfuzur Rahman, and Alexander Franke.
Front row: (from the left): Vanessa Nowinski and Kym Edwards.

All in all, AQUA 2024 was an awesome conference, and I'd like to thank everyone involved in organising it (especially those who bestowed me with a student travel award to get there). I had a great time, and I hope to see you at the next one. In the meantime, may your instruments always be functioning, your data of the highest quality and easily interpreted, and your papers swiftly published.

PS If anyone has seen any of the following travertine samples at Flinders University, could you please send them to me? As a reward, I can offer you a free drink or a photograph of some money.

BER C, DAL 1A, HAM 3, WAR A

REFLECTIONS ON THE AQUA 2024 CONFERENCE

Kym Edwards

The University of Adelaide, Adelaide, Australia

Attending the AQUA 2024 conference was an incredibly rewarding experience, filled with learning opportunities, networking, and unforgettable moments both in and out of the conference's main activities. Among the many highlights, the most exciting for me was attending multiple presentations on phytolith research. Going from never seeing a presentation on phytoliths to a conference with three talks on the subject was truly a treat. Each presentation opened new windows into how these microscopic silica particles can inform our understanding of past environments and revealed the immense potential of this research.

Meeting and networking with other early career researchers who were also passionate about phytoliths made the conference even more memorable. I connected not only with attendees but also with those in the phytolith community who could not attend, fostering relationships that I know will continue to develop long after the conference ends. These interactions reinforced one of the most valuable aspects of attending conferences: the chance to build a supportive network of colleagues who share similar research interests.

Outside of the academic talks, the social events at the conference were equally enjoyable. The early morning group swims at sunrise, followed by a walk to a local café for takeaway coffee, became a calming routine that helped me recharge before a long and busy day of presentations and activities. It also provided a unique opportunity to meet like-minded people working in different research areas – people I likely wouldn't have had the chance to interact with otherwise.

Another unforgettable highlight was the whale sightings. As someone who has made several trips to whale-watching spots only to miss them, getting the chance to see not just one but numerous whales was a dream come true. I had been hoping for a sighting or two, but the sheer number of whales exceeded all my expectations. I honestly lost count, and each sighting was just as awe-inspiring as the last.

Tim's famous quiz night, which had been highly anticipated, lived up to the hype. It was a great way to unwind at the end of the conference, and the friendly competition brought everyone together in a relaxed setting. An added bonus: winning the awesome "Go Extinct! Megafauna" game!

Reflecting on the overall experience, it is clear that the AQUA 2024 conference was much more than a professional gathering. It was a chance to immerse myself in cutting-edge research, build valuable connections, and enjoy the natural beauty of the conference location. I left the conference feeling inspired, filled with new ideas for my research, and with a stronger network of colleagues. I am already looking forward to the next AQUA conference. All of this would not have been possible without the generous financial support from AQUA and AINSE, so a big thank you for the opportunity.

Figure 1: AQUA early morning swimmers enjoying the second-best sunrise of the trip.

A WEEK OF SUN AND QUATERNARY SCIENCE AT AQUA 2024

Laura McDonald

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On June 24th, I embarked on a journey involving a plane, train, bus, and boat, ultimately arriving at Minjerribah for the AQUA 2024 conference. Since starting my PhD in 2022, this was my third conference, and it was undoubtedly my favourite. Minjerribah/North Stradbroke Island felt like a winter oasis, and the Moreton Bay Research Station served as an excellent venue for discussing advancements in Quaternary science across Australasia.

The warm and inviting atmosphere of the AQUA community made me feel instantly at ease. It was refreshing to see presenters share their data while acknowledging the uncertainties and complexities surrounding their findings. As a student, it's easy to assume that more experienced researchers have everything figured out, but I found it reassuring to learn that this isn't always the case. I was also impressed by the diverse range of locations, timescales, deposits, and methods that the AQUA community researches. As a pollen person, I was particularly intrigued by the work on phytoliths, which I had previously known little about, and their application in reconstructing vegetation in Australia's arid zones – ka pai for this work.

One of the highlights of the conference was the trip to Point Lookout, where I not only saw but also heard my very first whale. As a Kiwi, I revelled in the opportunity to observe kangaroos up close and spot a koala at Brown Lake. Watching *Megafauna: What Killed Australia's Giants* was a fantastic end-of-day activity, especially with some of the documentary's stars in attendance. A non-academic takeaway from the week was learning about the State of Origin and observing from the expressions of the locals in the pub that it was not a good night for Queensland.

The quiz night at the Straddie Brewery was a memorable experience, providing a fun test of how closely we had been paying attention during the talks, with topics ranging from MT-MCEOFs to diatoms. Now that I'm back in New Zealand, I find myself missing the warm weather, although I don't miss the early morning wake-ups from the curlews. I am deeply grateful for the travel grant that made my attendance at the AQUA 2024 conference possible.

I look forward to seeing everyone again and hearing how their work has progressed by the time AQUA 2026 rolls around. Following AQUA 2024 will certainly be a tough act.

Figure 1: Laura and Greer at Point Lookout.

Top – Figure 2: Quiz night (Peter, Holly, Laura and Gavin).

Left – Figure 3: Laura at Brown Lake.

Right – Figure 4: Winning quiz team.

AQUA 2024: SCIENCE AND MEMORIES

Mahfuzur Rahman

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It was a great honour that I received a travel grant to attend the biannual Australasian Quaternary Association (AQUA) conference, held on the stunning Minjerribah/North Stradbroke Island, Australia, from 24-28th June 2024. As this was my first time attending a conference in Australia, I was filled with excitement and anticipation. The beautiful location added to the thrill, making it not just a scientific event but also a memorable personal experience.

The AQUA conference was exceptionally well-organized, with each session focusing on a particular discipline within the Quaternary sciences. It also offered a perfect balance between scholarly activities and opportunities for interaction. I had the privilege of meeting both senior and early-career Quaternary researchers from across Australia and New Zealand. It was inspiring to learn about the breadth of research being undertaken in the Quaternary field, ranging from climate change studies to geomorphological investigations.

One of the highlights of the conference was delivering my oral presentation on my preliminary PhD research during the hydroclimate session. The experience was both nerve-wracking and rewarding. I received valuable feedback from several experts in the field, which will be instrumental in shaping the future direction of my research. Additionally, I had the pleasure of co-authoring a poster, which sparked lively discussions and further connections with fellow researchers.

Beyond the formal sessions, the AQUA conference fostered a welcoming atmosphere that encouraged networking and camaraderie. The field trip provided a wonderful opportunity to explore the island's unique Quaternary landscape, adding a practical dimension to the scientific discussions. The quiz night was another entertaining highlight, where we all enjoyed some friendly competition while deepening our knowledge of Quaternary science. The food and hospitality provided during the conference were fantastic, enhancing the overall experience. I was also fortunate to have spent quality time with my lab mates, making the event even more special. These moments of bonding, both professional and personal, will be cherished for years to come.

In closing, I would like to extend my heartfelt thanks to AQUA for granting me the opportunity to attend this remarkable conference. It was an invaluable experience, one that has left a lasting impact on my academic journey. I look forward to attending future AQUA conferences and continuing to be part of this vibrant community.

SUBMISSION TO THE ANSTO RESEARCH PORTAL GRANT SCHEME: A POSSIBLE PATHWAY TO SUCCESS

John Tibby

University of Adelaide

This article provides some brief guidance on applying for support from the Australian Nuclear Science and Technology Organisation's (ANSTO) Research Portal scheme. I have been a member of the ANSTO Environmental, Earth Sciences and Archaeology Committee for the last six years, and before that, I was a member of the former equivalent Australian Institute of Nuclear Science and Engineering (AINSE) committee. My experience on the committee has been a positive one, with committee members and ANSTO scientists being highly supportive of applicants. The views expressed here are my own.

The ANSTO Research Portal provides a wonderful opportunity for Quaternary scientists to gain access to a very wide range of facilities, some of which are detailed here (with a full list available after registering on the Portal). These include analysis of carbon and nitrogen isotopes, water isotope analysis, trace element analyses of sediments and water, and access to the Synchrotron. However, the majority of requests from the Quaternary community are for support for Itrax X-ray fluorescence (XRF) core scanner and radiometric dating. The latter is either radiocarbon (^{14}C) and/or radionuclide dating – primarily ^{210}Pb dating but sometimes in combination with Plutonium-(241,240,239) or Caesium-137 (^{137}Cs), which is usually (and should be! – see Appleby, 2001 for discussion) used to check and refine ^{210}Pb chronologies. Hence, this piece focuses on those requests.

Requests to the Portal have a very high rate of success and, arguably, this has resulted in submissions that are at times less than ideal. It's also the case that ANSTO scientists are sometimes too busy and/or too polite(!) to provide critical observations of study designs. In particular, and presumably because it generates a large amount of data in a "cheap" and non-destructive manner, Itrax scanning requests often have poor justification in terms of the nature of the questions. This suggests that interpretation is likely to occur *post hoc* and in ways that are less than ideal. Given that there is a *very* wide range of data generated, with the potential to transform those data in numerous ways (see Kemp et al., 2020 for an Australian-focused discussion), it could be argued that there is the potential for a sort of "fishing exercise" in which investigators "see" patterns from a multitude of possibilities with the potential for confirmation bias.

It would be good, therefore, both for the nature of applications and for Quaternary science more generally, to formalise some hypotheses at the application stage. Lastly, of course, Itrax data should be calibrated to traditionally determined sediment chemistry, and indeed, it is possible (though not common) to apply for such analyses through the Portal.

The requests for radiocarbon analysis are generally of reasonable to high quality. However, at times, there is a lack of clarity about the nature of material being dated and the extent to which samples are already available. As feasibility is a key criterion for judging the proposals, it is an unwritten rule that requests for analysis where the samples are not "in hand" are not supported. This applies to all requests. There are times when the scientific objectives cannot be met because too few ^{14}C dates are requested. On the other hand, applications that request a large number of dates are more highly scrutinised. Blaauw et al. (2018) provide a useful means of assessing how many dates are needed for sediment sequences, and applications that provide justifications such as this have traditionally been well-supported. For projects with long timelines, it is possible to request a first round of radiocarbon dates, obtain the results, and then request another focused on periods of interest. This process, however, takes more than a year, given the relatively lengthy decision-making time of the committee and the time taken to obtain results.

With regard to ^{210}Pb, there is often a need for improvement. Arguably, it's not possible to obtain a reliable ^{210}Pb chronology without at least ten determinations, yet requests for fewer determinations are common. ^{210}Pb, on its own, is not sufficient to provide accurate sedimentation rates without an objective check of modelled ages. There are often stark differences between different ^{210}Pb models, and they should be evaluated with other radionuclides and/or other markers (Appleby, 2001). Traditionally, this has been mostly undertaken using caesium-137. However, the relatively short life of ^{137}Cs means that this technique is increasingly less valuable for this purpose, and plutonium concentrations and isotope ratios *are a much better alternative* (Leslie and Hancock, 2008). These analyses can be requested through the Portal, and analysis ideally occurs after the determination of (preliminary) ^{210}Pb chronologies to best target the timely and costly analysis. It is also worth noting that the constant rate of supply (CRS) based ^{210}Pb chronologies need an estimate of sediment bulk density to support the modelling. Lastly, staggered submissions of ^{210}Pb samples are often recommended (e.g., in two batches of six samples) to ensure analyses are not wasted on material that is too old and to target dates.

The criteria used to determine success in these grant rounds have historically not been provided. This is the situation I have been lobbying to change (since it could bias against newer members of the community). However, in the interim, I wanted to provide an insight into the criteria. It's important that applicants are aware that assessment of the applicant's track record (relative to opportunity) makes up one-third of the ranking score. This is not captured in the heading "Profile of Research Team", so answers to this question have, unsurprisingly, at times been narrative. In this context, it is important that everyone, but especially ECRs, highlight their potential and successes in this section.

The ANSTO Research Portal Scheme is a very generous taxpayer-funded resource with a high success rate. I hope that it will continue to be available to the Quaternary community. If you're applying for the first time (or the tenth time!) contact the relevant ANSTO scientist in plenty of time to discuss your proposal. These scientists bring invaluable expertise and experience. Feel free to ask me about the commentary above.Good luck!

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Right Top – Figure 1: ANSTO ITRAX XRF core scanner with sediment core loaded. (Photo credit: Lauren Linnenlucke).

Right Middle – Figure 2: Pb-210 ANSTO Laboratory. (Photo credit: Patricia Gadd).

Right Bottom – Figure 3: Emma Rehn completing pretreatment of samples in the ANSTO ^{14}C laboratory. (Photo credit: ANSTO).

3D-PRINTED LANDFORMS AND LANDSCAPES FOR GEOMORPHIC OUTREACH, EDUCATION, AND RESEARCH

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ABSTRACT

Three-dimensional (3D) printing is being increasingly used in geoscience research, education, and outreach. However, it is underutilised in applications focused on landforms and landscapes. In Australasia, such opportunities are enhanced by ever-expanding LiDAR coverage, which in Tasmania is approaching 80%. Mineral Resources Tasmania (MRT) recently began producing LiDAR-derived, 3D-printed geomorphic models to enhance geoscience communication with diverse groups and is integrating these models into site investigations and surficial mapping. Custom-made physical 3D-models are easily achievable but require a basic understanding of 3D-printing, geographic information systems (GIS), and computer-aided design (CAD). Some simple considerations will streamline the creation and maximise the impact of both 3D-printed models and their precursor digital counterparts. An open-access 3D-digital library of Australasian landforms and landscapes would aid education and outreach as well as comparative geomorphic studies across our region. The Australasian Quaternary Association (AQUA) community is well positioned to help establish, design, and populate an Australasian 3D-geomorphology library.

INTRODUCTION

Three-dimensional (3D) models of landforms and landscapes are instrumental for geoscience conceptualisation and communication. For centuries, naturalists and geoscientists produced them as hand-drawn relief maps and perspective sketches (Patterson, 2000), including isometric block diagrams (Sopwith, 1834; Lobeck, 1924). Scaled physical models of landscapes provide further utility (Stanley, 1947; Turner and Derman, 1982), as demonstrated by those used across Australia's National Parks to illustrate terrain and geoscience concepts to park visitors. Producing these physical models was traditionally a time-intensive endeavour; bespoke models required tedious handcrafting, whereas mass-produced models required specialised manufacturing capacity. Consequently, physical models of landscapes and landforms have been used in only a small fraction of the projects and contexts in which they could be useful.

Technologies of the late twentieth and early twenty-first centuries have revolutionised the creation of physical terrain models. Expansion of digital elevation model (DEM) coverage and development of increasingly powerful GIS programs enable digital 3D-models, commonly of high resolution, to be created with ease. Since its development four decades ago, 3D-printing now allows for simplified prototyping, production, and fine-tuning of physical geomorphic models. Together, elevation data, geospatial software, and 3D-printers are opening diverse doors to Quaternarists, including in rapid, easy production of landform and landscape modes with accuracy and detail never before possible.

To help illustrate earth-surface processes and Quaternary terrain evolution in mountainous parts of lutruwita/Tasmania, Mineral Resources Tasmania (MRT) recently began 3D-printing models of specific landscapes and landforms (e.g. Figure 1). Thus far, we have focused on glacial and some slope processes. However, with appropriate adjustments, the approach is applicable to downscaling any landforms and landscapes to handheld or desktop models. Other members of the AQUA community have likely contemplated – if not already implemented – geomorphic 3D-printing in their teaching and research.

We take this opportunity firstly to encourage others to try geomorphic 3D-printing and offer suggestions based on our experience. The process is surprisingly easy, but some key steps and considerations will save time, limit misprints, and increase the quality and effectiveness of 3D-models. Our second aim is to propose an open-access digital library of Australasian landforms and landscapes, and gauge interest among AQUA members to help develop it. That digital-model library would further simplify 3D-model printing, as well as enhance public education and outreach, university teaching, research activities, and geo-heritage awareness across our region.

3D-PRINTING AND ITS GEOSCIENCE APPLICATIONS

Additive manufacturing – or '3D-printing' – is a relatively recent and continually evolving technology. Numerous online sources recount its development and milestones (e.g. González, 2020; Turney, 2021; Brown, 2023).

It was conceptualised in 1945 and first prototyped in the early 1970s using melted wax. Various new approaches were developed and patented during the 1980s, and the first commercial 3D-printers were sold. The 1990s saw the advent of additional techniques and expansion into printing new types of objects, among them metal components and organs. Hundreds of patents expired in the early 2000s, improving 3D-printer affordability, especially for consumer and hobbyist models. Increasing focus on open-source approaches enabled further growth, as did self-replicating 3D-printing, in which 3D-printers are themselves 3D-printed. Printing services that fabricate and deliver user-uploaded models began appearing in 2008, expanding 3D-printing capabilities to those without printers. Bolstered by media coverage, these various twenty-first-century factors have fuelled an explosion of desktop 3D-printers over the past ~15 years, with countless 3D-printer manufactures currently operating. In addition to polymers cured through cooling or chemical bonding, printing materials now include 'bio-ink' used for tissue printing, various metal alloys, and concrete. Their diverse applications span medicine, construction, architecture, engineering, manufacturing, and entertainment.

Geoscientists consider features ranging from molecules, mineral crystals, and pollen grains to landscapes, lithologic units, and tectonic plates. Consequently, 3D-printing's ease of scaled-model generation can benefit diverse geoscience fields (Hasiuk, 2014; Ishutov et al., 2018), including numerous Quaternary science

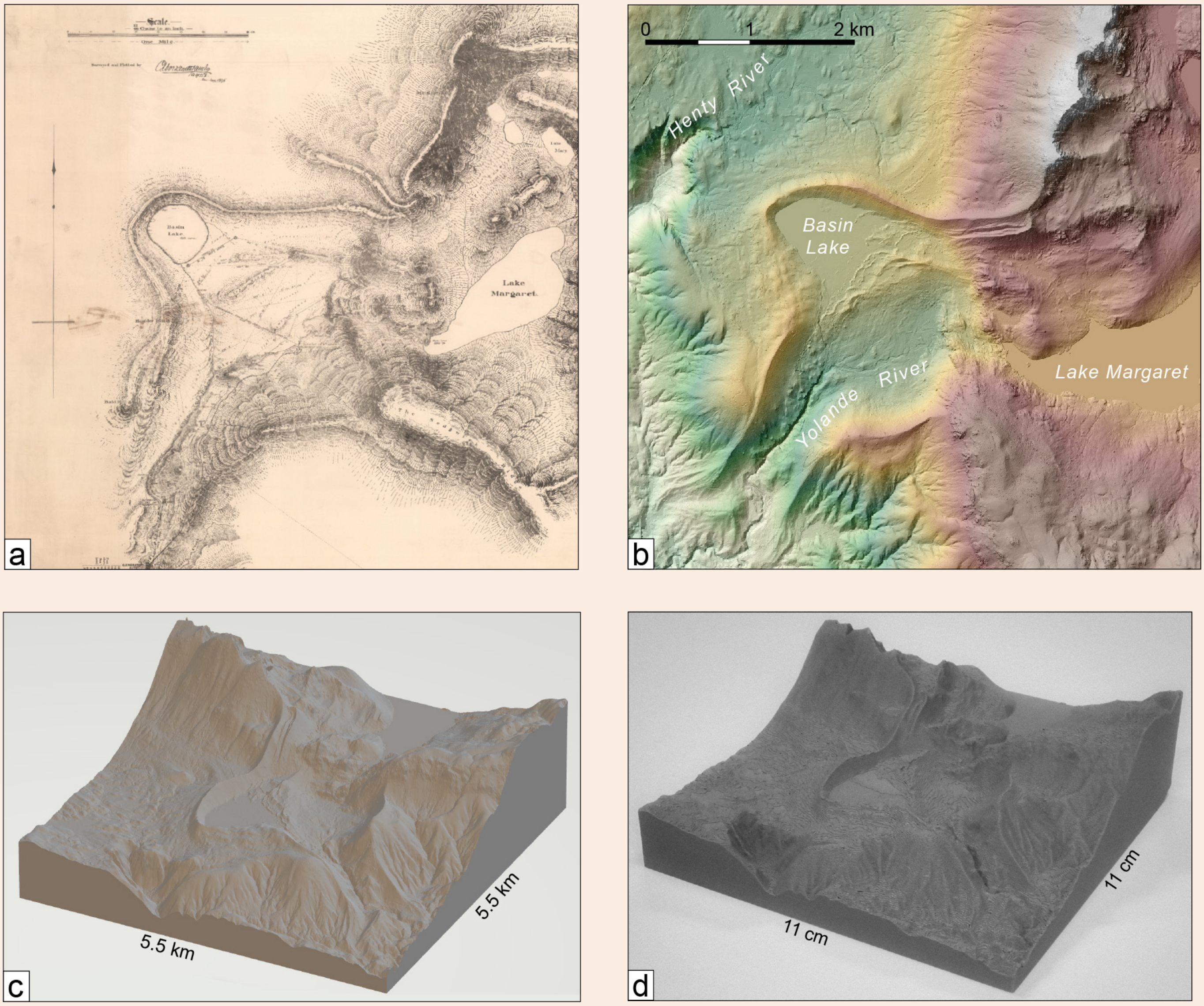

Figure 1: Representations of glacially-influenced terrain near Lake Margaret, Tasmania, including Hamilton Moraine: a) hand-drawn nineteenth-century map; b) hill-shaded DEM; c) 3D digital model; d) 3D-printed model. Models are 1:50,000 scale, measure 11 cm in each oriental axis, and use 1.5x vertical exaggeration. All representations are 5.5 km on each side. Sources are Mount Lyell Mining & Rail. Co. (1895) (a) and Elvis 1 m LiDAR (b, c, d).

applications, by enhancing upscaled, full-scale, and downscaled representations. In mineralogy, 3D-printing has promise for improving the teaching and visualisation of crystallography (e.g. Kitson et al., 2014). Palynologists, including Australasian Quaternarists (e.g. Stevenson and Kaikkonen, 2019), have been upscaling microflora with 3D-printing for years. Applications for full-scale models include copying fragile or valuable items, such as macrofossils. Specific palaeontologic applications of full-scale (or nearly full-scale) 3D-printing include specimen reconstruction and restoration, experimentation, and geo-heritage communication (Johnson and Carter, 2019; Ziegler et al., 2020). Preserving specimens as 3D-printed replicas can be particularly important for Quaternary subfossils, which are commonly fragile because of limited or lack of mineralisation. The technique is also applicable to the replication of geologic materials as full-scale hand specimens or slightly downscaled outcrops (Squelch, 2018). Downscaled physical models are also an excellent way to display 3D geologic bodies and can leverage existing digital models that include Quaternary units (e.g. Bombardieri et al., 2024) or entirely comprise them (e.g. Lee et al., 2017).

Geomorphology is 3D-printing's lowest-hanging fruit. Other applications generally require the compilation of digital 3D-models through project-specific means, such as scanning electron microscopy, structure-from-motion photogrammetry, computed tomography, or geophysics and computational modelling. However, 'scanning' of surface morphology has already been completed for most of Earth's subaerial surface at coarse (e.g., 90 m to 1 km) to moderate (e.g., 10 m to 30 m) resolution by multiple remote sensing techniques, typically with open access. Additional high-resolution (e.g., 0.5 m to 2 m) digital elevation models (DEMs) are publicly available for many areas, including much of New Zealand, parts of Australia, and even entire USA and European countries. Submerged terrain has been widely recorded, albeit generally at much lower resolutions. These and other readily available digital elevation datasets greatly simplify geomorphic 3D-printing.

THE TASMANIAN EXPERIENCE

Over recent months, MRT has employed relatively simple 3D-printed models of terrain sculpted by glacial and hillslope processes. Their uses span wide-ranging objectives and audiences (Figure 2): (1) discussing *Tassie's Ancient Ice* with the general public at Beaker Street Festival during National Science Week; (2) highlighting the utility of geomorphology for geomechanics and engineering during *Introduction to Engineering Geomorphology – Thinking in 4D*, a one-day Australian Geomechanics Society (AGS) course for engineering geologists and geotechnical engineers; (3) engaging budding geoscientists through first-year geology tutorials at the University of Tasmania; and (4) explaining interpretations of Tasmania's complex glacial history during a paired Geological Society of Australia (GSA) field trip and a Royal Society of Tasmania community presentation. In all cases, the models enhanced communication with participants. They provided complementary insights to descriptions, field photographs, and sediments viewed as either hand specimens or *in situ* exposures. These 3D-printed, handheld models consistently increased discussion-based engagement and helped elicit insightful questions.

Among those sessions, a particular model featured heavily due to its diversity of glacially eroded, glacially deposited, and non-glacial landforms. It covers the Lake Margaret area in Western Tasmania's Tyndall Range (Figure 1a-d). Cirque glaciers, valley glaciers, and small ice caps sculpted the range's uplands during repeated Pleistocene glaciations, while ice-marginal and proglacial deposition delivered sediment to adjacent lowlands of the Henty and Yolande valleys. The area's most conspicuous feature is the ~300 m-high Hamilton Moraine, which is Tasmania's (Colhoun et al., 1996) and, thus, Australia's tallest moraine. Moraines in this area span several Marine Isotope Stages (MIS) (cf. Barrows et al., 2002). They include the last glacial terminal moraines southeast of Basin Lake (MIS 2), Hamilton Moraine enclosing Basin Lake (~MIS 8 to MIS 10), and Henty Valley lateral moraines (one or more glaciations prior to ~MIS 10) (Figure 1b). Widths of the Hamilton Moraine and the older, underlining lateral moraines suggest that each is a composite feature formed during multiple glaciations. This helps explain the range of exposure ages (352-190 ka) reported for Hamilton Moraine by Barrows et al. (2002). The more subdued morphology of Henty Valley's lateral moraines attests to their greater age. Indeed, reversely magnetised valley-bottom glaciolacustrine sediments several kilometres farther up-valley indicate that ice flowed down Henty Valley prior to 780 ka (Pollington, 1991).

Due to their diversity in mechanism, extent, and age, these landforms display a wide range of scale and clarity. Such a range of morphologies makes them a useful example to test the utility of 3D-digital (Figure 1c) and printed (Figure 1d) models for conveying different landform types and textures. Several distinct landforms – particularly cirques of the Tyndall Range, the high-relief Hamilton Moraine, and the likely meltwater-carved gorge along Yolande River – are very apparent in the 1:50,000-scale physical model and were frequently detected by non-geoscientists. Smaller distinct features, such as the last glacial end moraines and the largest

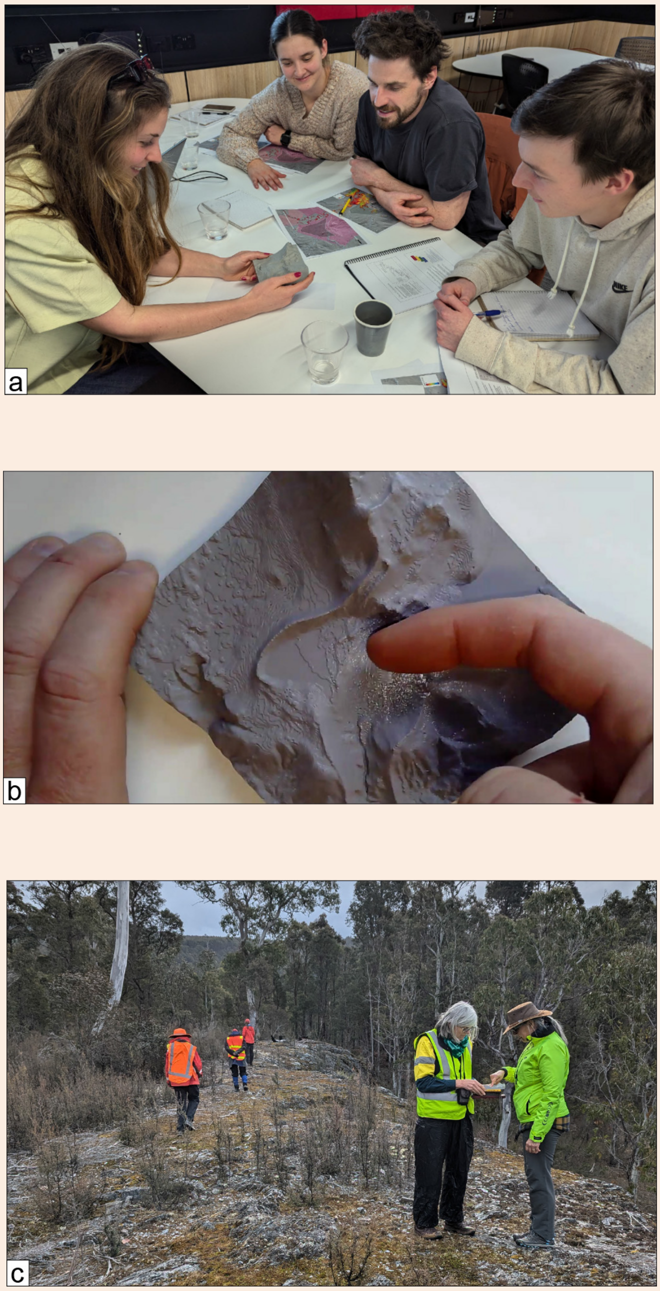

Figure 2: Presenting 3D-printed physical models during various geoscience communication activities: a) hands-on group discussion in AGS's Engineering Geomorphology course; b) display via document projector during hybrid in-person/online University of Tasmania geology teaching; c) assisting in-field landscape interpretation during a GSA glacial geology field trip. The foreground and middle ground of 'c' is the long axis of the glacially streamlined bedrock viewed in the same general orientation as Figure 3.

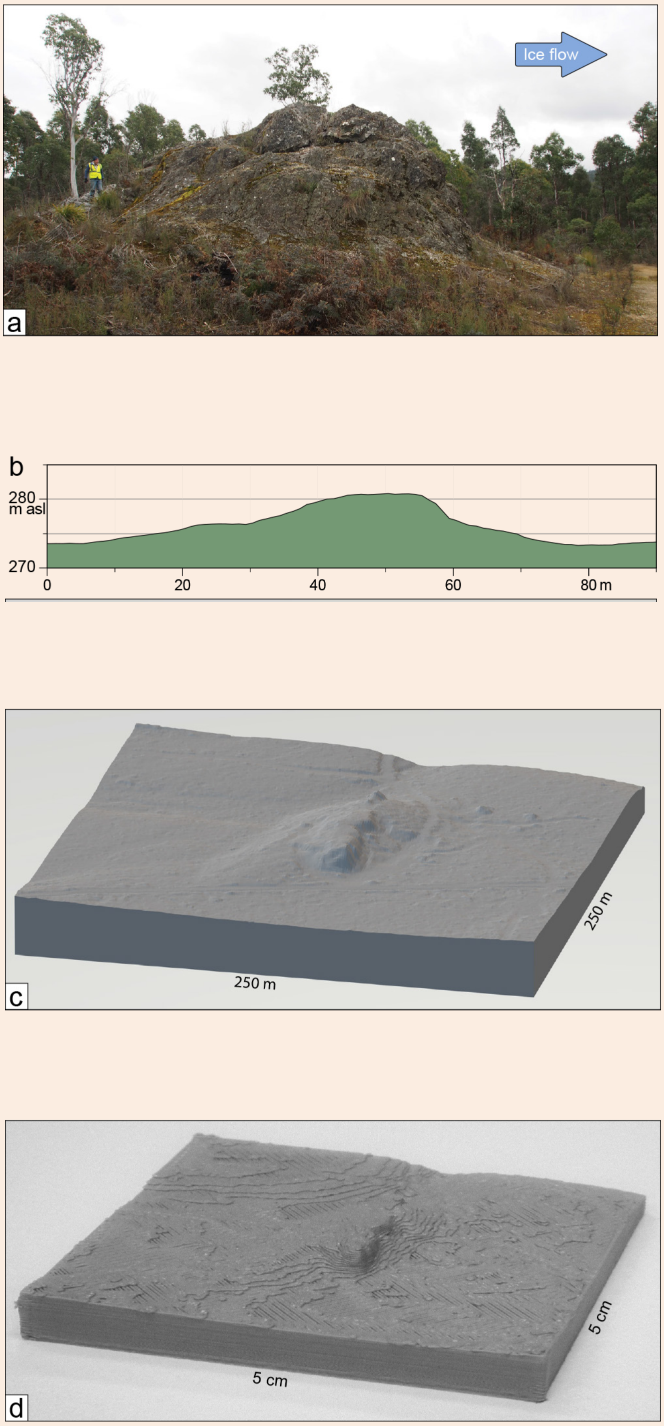

Figure 3: Roche moutonnée near Lemonthyme Power Station viewed in various ways: a) on-site from Patons Road (note person for scale); b) GIS-created topographic profile; c) 3D digital model; d) 3D-printed model. Models are 1:5,000 scale, measure 5 cm in each horizontal axis (equivalent to 250 m on the ground), and use 1.5x vertical exaggeration. The data source is Elvis 1 m LiDAR (b, c, d).

glacial erratics, are more difficult to observe at this scale. Subdued features of substantial size, such as the old lateral moraine range underlying Hamilton Moraine, are visible in the printed model from certain angles and with certain illumination conditions. However, their contrasting textures are easily picked up by touch. This highlights a specific benefit of high-accuracy 3D-printed models: they make geomorphology more accessible to the visually impaired (Horowitz and Schultz, 2013) and augment it for the sighted.

Glacially streamlined bedrock provides another excellent example of the tactility of 3D-physical models. A roche mountonnée along Patons Road near Lemonthyme Power Station is one of the best and most accessible examples of glacially streamlined bedrock in Australia. This feature's asymmetry, reflecting pressure melting and polishing on its stoss side and re-freezing and plucking on its lee side, is visible in the field (Figure 3a). That asymmetry is even more evident in LiDAR-derived profiles (Figure 3b) and digital 3D-models (Figure 3c). Due partially to the scale of reproduction (1:5,000) and size of the feature (~8 m high, 105 m wide, 65 m long) relative to the 1 m-resolution LiDAR used, its 3D-printed morphology is somewhat 'chunky', although still apparent (Figure 3d). Handling the model better reinforces the glacier's influence; a thumb or finger easily glides over the roche mountonnée in the down-valley (down-ice) direction but gets stuck when running up the valley. Depiction of this feature in a 1:25,000 landscape-scale model during a recent field trip to the site (Figure 2c) nicely illustrated its context and associations with surrounding, geomorphically subdued Early Pleistocene glacial deposits.

PRODUCING 3D-PRINTED AUSTRALASIAN GEOMORPHIC MODELS

WORKFLOW

Workflows for developing 3D-printed models from LiDAR or other DEMs are varied and are similar to workflows used for pollen grains (cf. Stevenson and Kaikkonen, 2019). Details on making 3D-models from DEMs are available from numerous online sources, including OpenTopography, Makerspace, and the Swiss Federal Office of Topography. Novice geomorphic model creation can be as simple as searching data and creating a digital model using the TouchTerrain web interface (Hasiuk et al., 2017) and then submitting that model to an online 3D-printing service.

A flexible yet still streamlined approach using only freely available data and software comprises just eight simple steps:

1. Download publicly available DEM tiles or seamless DEM.
2. Load DEM(s) in QGIS and merge individual tiles into a single raster.
3. Calculate model coverage and output physical model size to achieve an appropriate, ideally round, scale (e.g. 1:50,000 for landscapes, 1:5,000 for specific landforms).
4. Digitise the model footprint as a rectangular vector polygon with appropriate horizontal dimensions and rotation using QGIS's advanced digitising tools.
5. Use QGIS's 'DEMto3D' plugin to convert the DEM to a stereolithography CAD file (.stl extension), which represents the surface geometry of a 3D-object.
6. Preview the resultant digital model using Microsoft's 3D Viewer app or any other STL-compatible freeware, including slicing software.
7. Review the digital model and 'slice' (translate the digital 3D-object into a layer-based form 3D-printers can read and render) it in Bambu Studio or other freely available slicing software.
8. Send the model to your 3D-printer (MRT used a Bambu Labs P1S).

ELEVATION DATA

High-resolution bare-earth LiDAR provides a vegetation-free representation of land surfaces and excellent flexibility for 3D-model production. Publicly available 1-m-resolution LiDAR is available for Australia from Elvis (Australia's Elevation and Depth Foundation Spatial Data portal, https://elevation.fsdf.org.au) and for New Zealand from Land Information New Zealand (https://data.linz.govt.nz). However, elevation models are by no means limited to existing, publicly available LiDAR collections. Various privately held LiDAR datasets can be purchased, although the dispersed storage of such datasets complicates their identification; the other drawback is, of course, their cost. Drone-acquired optical terrain models and LiDAR elevation models enable the production of large-scale, high-resolution geomorphic models of specific landforms. Projects underway using MRT's LiDAR drone system illustrate that producing such models is relatively straightforward once workflows are established.

Photogrammetric models can be made using optical imagery. Unlike LiDAR, these produce digital surface models (DSMs) in which vegetation cover, rather than underlying ground surfaces, are represented. Archival aerial photographs are well suited to this approach due to their typically systematic acquisition with model side lap and substantial forward lap. In some areas, historical air photos are now freely available online. For instance, Tasmanian air photos since the first surveys in 1945 are freely downloadable via Land Tasmania's GIS-based Aerial Photo Viewer. Numerous photogrammetric software packages requiring varying levels of input data, such as ground-control points and camera files, are available. They include open-source packages that greatly automate DSM production from unordered photograph collections (e.g., Schonberger and Frahm, 2016).

Lower resolution elevation data of national near-global coverage supports the production of small-scale 3D-models of entire regions. Those datasets include terrain models developed using optical satellites (e.g., Advanced Spaceborne Thermal Emission and Reflection Radiometer [ASTER] Global Digital Elevation Map, 30 m resolution) and radar satellites (e.g. Shuttle Radar Topography Mission [SRTM] 1-arc second Global DEM, ~30 m resolution). Australia's National Digital Elevation and Depth Model, available through Elvis, locally improves upon 30 m-resolution SRTM data using LiDAR. Intermediate-resolution DEMs and DSMs in Australia include 5 m, LiDAR-derived coverage (Geoscience Australia, 2015) and 10 m, satellite-derived, multitemporal data for many coastal areas (Bishop-Taylor et al., 2019, 2024). Bathymetric models, such as Geoscience Australia's recently complied 30 m model for Bass Strait (Beaman, 2022), can similarly be used for 3D-printing of subaqueous geomorphology. Australasian data beyond Australia and New Zealand is currently very limited. In addition to near-global datasets such as SRTM, some LiDAR elevation data are available through OpenTopography (https://portal.opentopography.org). TouchTerrain (Haisuk et al, 2017) also provides facility to help locate moderate – to coarse-resolution datasets.

3D-PRINTING

Various 3D-printing techniques are available, many of which build models layer by layer. The most common method for geomorphic 3D-printing and many other desktop applications is fused deposition modelling (FDM), also called fused filament fabrication. In this material-extrusion process, spooled thermoplastic filament is heated and dispersed through a downward-pointing nozzle. A computer-guided printhead moves horizontally, laying down a continuous bead of material that quickly sets as it cools. As each layer is completed, the printhead rises slightly before beginning the next layer. FDM uses the same thermoplastics as moulding techniques, thus accommodating diverse colours and material properties. Depending on nozzle diameter, layer heights typically range from 0.4 mm to 0.05 mm. Thinner layers increase model detail and smoothness but also increase print time. Thicker layers offer some benefits; their conspicuous layering reduces realism and obscures fine detail but gives the effect of pseudo-contour lines that may enhance visualisation in some scenarios and aids comparison with topographic maps. Beyond generally lower cost and the need only for a stand-alone printer, FDM's main benefit is strength, although breakage can occur along contacts between layers. Importantly, the print media is not rapidly degraded by UV exposure.

Stereolithography (SLA), sometimes called optical fabrication or vat photopolymerisation, is a viable alternative for desktop-printed 3D-geomorphic models. In this photochemical fabrication process, a liquid photo-polymerising resin is solidified by ultraviolet light. A computer-guided laser transforms the liquid resin's surface into a solid polymer. The resulting 3D-solid grows layer by layer as a rising stage progressively elevates the model above the liquid. Its main advantage is improved fine detail and more realistic surface texture. Layer heights range from 0.10 mm to 0.05 mm, and overlapping curing of subjacent layers contributes to model strength and smoothness. However, the materials are generally weaker than FDM outputs and become increasingly brittle with exposure to UV radiation, thus limiting their application, especially for outdoor use. The model shape and internal structure must be planned to prevent liquid resin from being trapped within. Costs are generally greater than FDM printing, and equipment beyond the printer is needed.

IMPORTANT CONSIDERATIONS

Additional considerations will help optimise model appearance, properties, cost, and production time. Many desktop printers limit models to 250 mm in each dimension. A larger model can be printed as separate segments and then joined together, but how these will be joined should be considered and tested ahead of time. Nonetheless, handheld models are easier to work in most applications, including community outreach, in-class or online teaching, and field trips. The model scale also depends on data resolution and real-world feature size. Specific landforms (Figure 3) are likely to be represented at scales between 1:1,000 and 1:10,000 using LiDAR DEMs. Entire landscapes (Figures 1 and 2) are likely to be represented at scales between 1:25,000 and 1:100,000 using LiDAR or, for smaller scales, possibly moderate-resolution elevation models. Broad physiographic regions produced at scales closer to 1:250,000 or even 1:1,000,000 do not require LiDAR's typical data resolutions and can instead use moderate-resolution or even low-resolution elevation data, such as SRTM or ASTER. In all cases, a suitably rounded scale denominator is advisable to achieve consistency and aid comparison between models. Comparing models of the same scale or easily divisible scales (e.g. 1:25,000 vs 1:100,000 – a 4x difference) is much easier than comparing incompatible scales (e.g. 1:27,927 vs 1:38,106 – a 1.364x difference).

Vertical exaggeration depends on relief, feature subtleness, and scale. Conspicuous features will need little to no exaggeration, whereas subtle landforms, such as low longwave-length dunes, may necessitate substantial exaggeration. For a given landscape, greater vertical exaggeration may be required at smaller scales to ensure finer features remain discernible. A vertical exaggeration of 1.5x is sufficient for accentuating the Patons Road roche mountonnée in a large-scale (1:5,000) landform-specific model (Figure 3c,d), whereas a 2.5x exaggeration is necessary to make it clearly visible in a smaller scale (1:25,000) model covering a broader part of Forth Valley. When deciding on vertical exaggeration, it is important to consider not only how well key features can be seen but also how well they can be felt.

More advanced model adjustments and configurations are possible. Print media with wide-ranging material properties and colour are available, particularly for FDM printers. These can be combined in the printing of the same model, for example, to provide colour coding or demarcate elevation intervals with contour layers. Basic grey filament has worked well in most conditions for the models produced by MRT. Its semi-gloss finish and moderate tone allow good contrast due to shadow and reflection under a wide range of lighting conditions (Figure 2). Some glare can result on single-layer surfaces under direct light beneath a document projector (Figure 2b) or outdoors. Model glare is reduced where more detailed printing imparts a rougher surface texture, which would be further mitigated by using filament that imparts more of a matte finish. Model components can be printed to stack or fit together, providing opportunities to represent stratigraphy, structures, and even complex geological relationships. In such cases, printers need to be carefully set up to ensure high-accuracy, snug-fitting components.

Print parameters are numerous and impact model appearance, accuracy, cost, and ease. For FDM printing, key printer parameters are nozzle diameter and layer thickness. The most common nozzle diameters are 0.4 vs 0.2 mm, which determine the volume of material being extruded. For a given nozzle, the layer thickness can be adjusted to produce greater detail through a greater number of thinner slices or faster printing through fewer thick slices. The structure and density of infill (the model's hidden, internal, open-framework geometric pattern) influence strength, mass, and print time. The nature of handheld geomorphic models favours lightweight, quickly produced models as strength is of less concern. However, infill that is too widely spaced may cause errors in surface rendering. Other parameters can be fine-tuned in FDM printing to improve model appearance and accuracy, including temperature, flow rate, pressure advance, retraction, and tolerance. These generally need to be set only once for a given filament type.

PROTOTYPING AND TEST PRINTING

With the array of parameters that can be adjusted in 3D-printing, prototyping is particularly helpful in avoiding suboptimal outputs and wasted resources. Some prototyping can be done digitally prior to printing. This is especially true for broad-scale features that will be similar in both the digital and physical models. In the example of the Lake Margaret glacial features (Figure 1), the degree of vertical exaggeration was chosen by exporting and investigating STL-format digital models with values of 1.0, 1.5, 2.0, and 2.5x; that allowed selection for a 1.5x as the most appropriate exaggeration without the need to print four separate models. Slicing software will help visualise the impacts of nozzle diameter and layer thickness. However, the true effects of these parameters and other fine-tuning are best appreciated through printing tests.

Taking the time to test print with different parameter combinations prior to producing final models helps identify potential problems and optimise parameters. Avoidable pitfalls include long printing times, unnecessarily heavy models, and insufficient or superfluous model detail. A key benefit of test printing is evaluating trade-offs between improved quality and increased print time. They are best conducted for a small area that displays a large range of land-surface shapes and textures. The test prints in Figure 4(a-d) for a subset of the 1:50,000-scale model covering Hamilton Moraine and Basin Lake illustrate the influence of varying just two FDM parameters: nozzle diameter and layer height. Not surprisingly, combining a narrower nozzle and thinner layers improves print detail (Figure 4a), whereas combining a wider nozzle and thicker layers minimises print time (Figure 4d). The former may be the best choice for a final-model appearance. However, only a slight reduction in detail can save a lot of time, which is preferable in the case of printing interim or numerous models. The second most detailed model (Figure 4c) is very similar to the most detailed one (Figure 4a) but took only one-quarter of the print time and even looks better than one that took longer to print (Figure 4b).

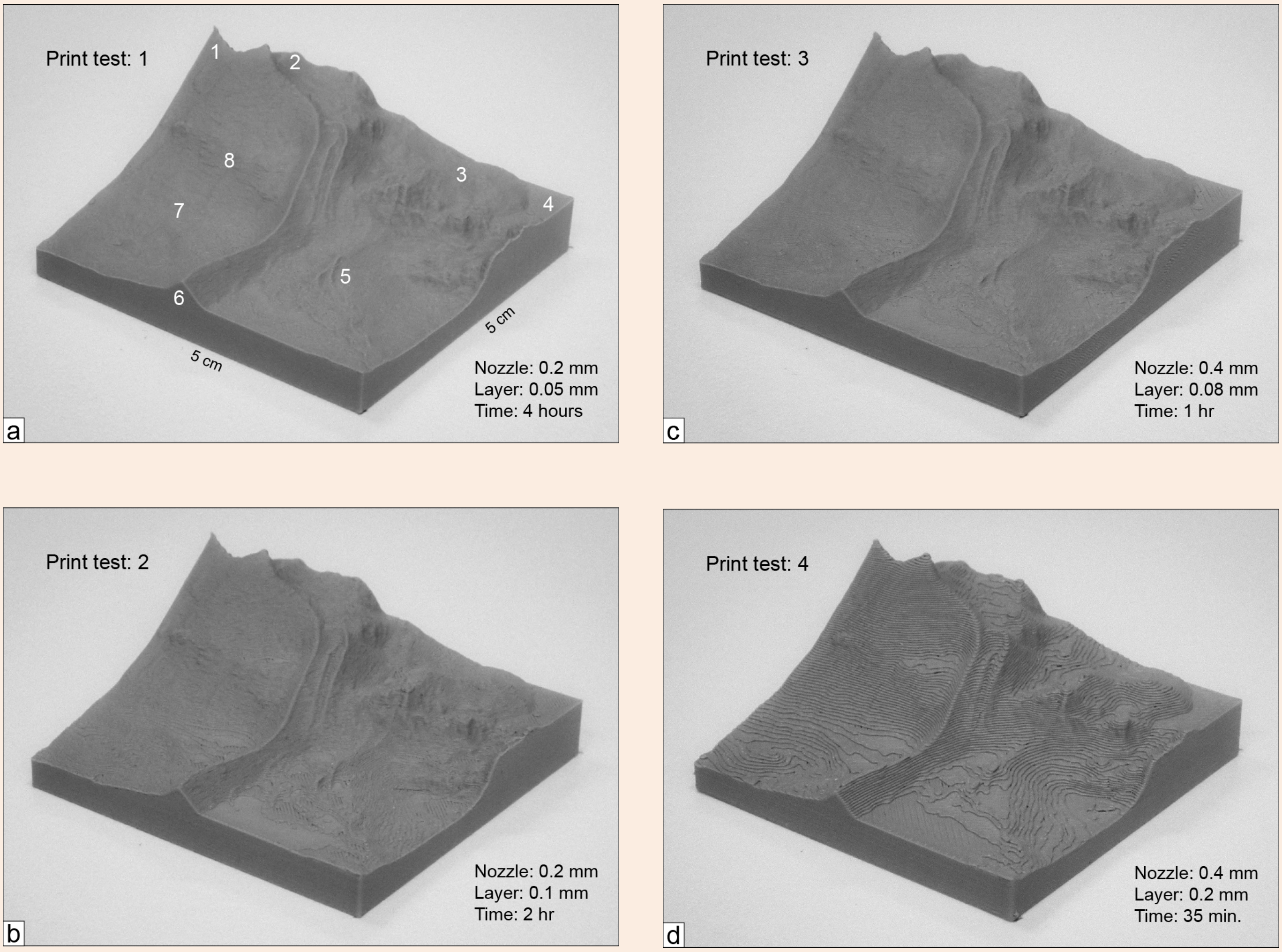

Figure 4: Prototyping using a small subset of the Lake Margeret landscape model. Each test print uses a different combination of nozzle diameter and layer thickness, resulting in print times ranging from 35 minutes to 4 hours. Print test 1 (a) provides the most detail, whereas print test 4 (d) had the shortest print time. Print test 3 (c) provides the second clearest detail with a print time of only 1 hour, and thus the best trade-off between print time and print quality. Models are 1:50,000 scale, measure 5 cm in each oriental axis (equivalent to 2.5 km on the ground) and use 1.5x vertical exaggeration.

The data source is Elvis 1 m LiDAR. Features include: 1 – arête, 2 – cirques, 3 – glacially smoothed bedrock, 4 – lake surface, 5 – last glacial terminal moraine, 6 – Middle Pleistocene terminal moraine, 7 – Early or Middle Pleistocene lateral moraine, 8 – gullied bedrock slope (see Figure 1 for broader landscape context).

PROSPECT FOR AN AUSTRALASIAN 3D-GEOMORPHOLOGY LIBRARY

Open-access 3D-file repositories are a central part of the global 3D-printing community. They allow the sharing of and easy access to print-ready digital models of just about anything imaginable. MakerBot's *Thingiverse* is the largest, with over 600 thousand models. Many agencies, including NASA, host websites offering niche 3D-printable models and several geological surveys. Some websites even address Quaternary science and palaeoenvironmental topics, such as the 3D Pollen Project (Wilson, 2023). Various repositories include some terrain models, typically of iconic peaks. However, there is scope for a geomorphic 3D-file repository showcasing Australasia's highly varied terrain, which spans flat lowlands to rugged uplands, hyper-arid deserts to rainforests, tropical to sub-arctic islands, and tectonically quiescent to rapidly uplifting landscapes.

An Australasian 3D-geomorphology library would enhance the ease and impact of 3D-printed geomorphic models across the region for outreach, education, and research. Research would benefit through increased opportunities for visualisation and comparative geomorphology. Teaching and public engagement would benefit through the greater incorporation of 3D-models, whether digital, in print, or hands-on. Secondary benefits might include greater representation of Australasian landscapes and landforms in university curricula globally. To ensure comprehensive coverage for geoscience education, the database could be supplemented with extra-regional features that are absent in Australasia, such as landscapes sculpted by continental glaciation.

Key considerations for setting up the library include deciding on the platform and host, setting data and metadata standards, planning content organisation and permissions, and establishing a process for submissions. Drawing on experience from the creation of 3D-libraries in other geoscience fields, such as palynology, will help facilitate these steps. An open-access resource is critical to making real-world examples of Australasian landforms and landscapes accessible to everyone. However, an Australasian 3D-geomorphology library need not be the only output. The digital repository would lay the groundwork for an Australasian Landform Atlas, which could be delivered across multiple media: 'flat' print or electronic documents, interactive digital 3D-models, and physical 3D-models.

This initiative will greatly benefit from the involvement of the AQUA community. However, it should include input from allied organisations addressing geomorphology (Australia & New Zealand Geomorphology Group), geohazards (AGS, New Zealand Geotechnical Society), and geology (GSA, Australian Institute of Geoscientists, Geoscience Australia, Geoscience Society of New Zealand, and Institute of Geological and Nuclear Sciences Limited). Combining the interests and expertise of members from across these geoscience fields will enable a more holistic view of Australasia's diverse landscapes and landforms.

CONCLUSIONS AND OUTLOOK

Physical, 3D-printed models can enhance Quaternary science, education, and outreach in many ways. Geomorphic printing stands out among other applications for being especially easy to implement. The cost and time of digitising features have already been done through remote sensing projects that deliver DEMs of wide-ranging detail, commonly at limited or no cost to end users. Requisite GIS, CAD, and slicing software can be freely accessed, leaving printing as the principal cost. Even without purchasing a printer or supplies, physical geomorphic models can be produced using online 3D-printing services, albeit with some delay. The ease of and opportunities for geomorphic printing will only increase as DEM coverage and quality, 3D-printing technologies and cost, and the Quaternary community's familiarity with them all continue to improve.

Basic considerations make 3D-printed geomorphic models and their digital foundations even smoother. They include choosing appropriate (and appropriately rounded) scales and vertical exaggerations, as well as striking the right balance between detail, weight, strength, print time, and cost. Some of these parameters can be vetted in the digital realm. Other parameters benefit from test prints of subset areas. Familiarity with GIS, CAD, and the basics of 3D-printing is advantageous but can be easily acquired by new users.

The benefits of 3D-printied geomorphic models are far more important than their ease of production. Such models offer many advantages: making geomorphology more approachable for non-specialists; reducing reliance on digital or other communication equipment in some contexts; enhancing at-scale, side-by-side comparison of geographically distant features; extending beyond visual interpretation to tactile interpretation; and increasing accessibility of geomorphology for those with impaired vision. The recent implementation of 3D-printed landforms and landscapes at MRT illustrates many of these advantages.

The precursor digital models required for 3D-geomorphic printing offer their own benefits, regardless of whether physical models are made. An open-access digital library of Australasian 3D-geomorphology comprising community-submitted models would be an excellent resource for Quaternary science professionals, students, and enthusiasts, including the general public. Such a repository would capture, represent, and communicate the large diversity of landforms and landscapes across our region. The opportunities are vast. AQUA members are well positioned to help plan the way forward for an Australasian 3D-geomorphology library. The first step is gauging interest within the AQUA community– please reach out if you would like to get involved.

ACKNOWLEDGEMENTS

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THESIS ABSTRACTS

ENVIRONMENTAL HISTORY OF THE ARTHUR'S PASS AREA, SOUTH ISLAND, NEW ZEALAND, SINCE THE LAST GLACIAL MAXIMUM

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This study provides a climatic and wider palaeoenvironmental history of the Arthur's Pass Valley, Southern Alps, New Zealand, covering the last deglacial and the Holocene. The work focuses on glacial chronology and modelling of the Otira, Bealey, and Temple Basin glacial systems during the last major deglaciation (from about 18,000 to 12,000 years ago) to quantify changes in temperature. Holocene environmental reconstructions are based primarily on sedimentological and palaeoecological investigations of two cores from the Lance's Tarn complex near the saddle between the Otira and Bealey Rivers. Both the glacial and core records are interpreted in the context of changes in westerly wind flow.

At the global LGM, about 26,000-20,000 (i.e., 26 to 20 ka) years ago, glaciers covered the whole of the Arthur's Pass Valley. Major ice loss occurred from the start of the deglaciation period about 18 ka, with the first preserved valley terminal moraines north of Arthur's Pass Township recording a still-stand at c.16 ka when the temperature was – 3.2 ± 0.5 °C cooler than present. Thereafter, tributary valleys on the eastern side of Arthur's Pass Valley rapidly deglaciated while western tributaries maintained significant glaciers. By 11-10 ka, glaciers had disappeared from Arthur's Pass Valley and had largely retreated into their tributary valleys.

From the Otira and Bealey glaciers, there is a clear Antarctic Cold Reversal (ACR) signal. The ACR displays a double peak with an initial (colder) event at 14.4 ka, the onset of which was rapid but of short duration (temperatures cooler by 2.7 ± 0.5 °C than today). This was followed by a second ACR terminal position dated to 13.6 ka, reflecting a second stillstand (or minor re-advance), signifying about 0.25 °C warming from the initial ACR advance. The narrow time window for the initial event suggests an atmospheric teleconnection, and it is postulated that enhanced SW flow during the early ACR triggered the readvance.

In agreement with other regions in New Zealand, there is no evidence for a Younger Dryas (YD) re-advance in Arthur's Pass. However, there is evidence that the recession from ACR advance positions during the YD chronozone period was marginal and that extended ice persisted into the early Holocene.

From geochemical and palaeoecological data, the westerly wind flow was relatively stronger from 11.5 ka to 9.5 ka and then weakened through to 7.5 ka. This is very similar to dendrological and glacial records from Tasmania and Patagonia and suggests zonal symmetry in the westerlies in the early Holocene. There is a hiatus from about 7 ka to 2.5 ka in the Lances Tarn core sedimentation record which is used for vegetation assemblage reconstructions. After 2.5 ka there is a gradual weakening of westerlies, which are inferred not to have been as strong as those in the early to mid-Holocene. This contrasts with southern New Zealand and Southern Ocean sites and suggests a southward shift in the core of the westerlies in the late Holocene.

Little Ice Age (LIA) cooling is identified from a glacial re-advance moraine just below the cirque headwall of the Otira Glacier at c.350 years ago. Dominant SW flow associated with positive Southern Annular Mode-like and/or El Niño-Southern Oscillation-like conditions are inferred for this period. Human impacts in the valleys started about 700 years ago and intensified after European arrival in the 19th century. These impacts largely involved deforestation in the catchments and mimic the effect of cooling by creating artificial grasslands, so LIA cooling cannot be confirmed from these ecological data.

CHARACTERISTICS OF N-ALKANES IN TROPICAL SEDIMENT – IMPLICATIONS FOR PALAEOENVIRONMENTAL RESEARCH

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There are still significant knowledge gaps in our understanding of the Quaternary palaeo-history of tropical Australasia. Sedimentary archives, such as lake or cave sediments and their associated proxies have properties that can illuminate past climate and ecology, and provide insight into how people have interacted with their environment.

Biomarkers such as *n*-alkanes are increasingly being used to study past vegetation assemblages as they have the potential to preserve well when compared to other widely used proxies such as pollen. In addition, as compound-specific isotopes can be measured on *n*-alkanes, there is great potential for investigating vegetation sources more directly than can be achieved when using isotopes measured on bulk organic material. *n*-Alkanes, which are hydrocarbons associated with plant leaf waxes, are the focus of the work presented in this thesis. While these biomarkers have been studied widely in the northern hemisphere, there is still a lack of palaeoenvironmental research using *n*-alkanes and compound-specific isotopes in the southern hemisphere. Specifically, the work presented in this thesis will focus on *n*-alkanes in tropical Australasia, a region from which few palaeoenvironmental records exist, and which is a particularly challenging environment in which to preserve biomarkers and other bio-proxies. Thus, this PhD will provide additional and complementary environmental information to that provided by commonly used palaeoenvironmental proxies such as pollen.

A selection of existing and some new sites were analysed for elemental and molecular sediment properties from across tropical Australasia, including from cave deposits, lakes, and swamps/springs, while one temperate site was also investigated. Several indices derived from *n*-alkanes, including compound-specific carbon isotopes, were compared to other proxies, including in two cases modern vegetation samples, as well as to other existing records to investigate how these biomarkers are influenced by environmental conditions and how useful they are as palaeoenvironmental proxies in the given settings. The focus of this thesis is on the characteristics of *n*-alkanes and implications for palaeoenvironmental research rather than an explicit quantitative examination per site.

It was found that *n*-alkanes and associated compound-specific isotopes are a valuable environmental proxy in a wide range of settings. They were well preserved in several records, particularly in organic-rich sediment such as peats. They were, however, not well preserved in cave sediments and oxidised lacustrine sediments but nevertheless are shown to be viable biomarkers in a wide range of settings, even when only partially preserved. In large catchments, they were found to be most useful, having better preservation potential, but more importantly, to differentiate changes in the vegetation assemblage through time. In small catchments, they were found to be influenced more by localised vegetation, for example, by aquatic sedges growing within a particular swamp, and thus were less likely to capture broader vegetation changes. In such settings, which were more subject to drying and exposure of the lakebed, they were also less likely to be preserved.

Major shifts in *n*-alkane distribution during the mid- and late Holocene were observed in the Lake Ira Lalaro record from Timor-Leste (a relatively large catchment), accompanied by shifting compound-specific ^{13}C values by 2‰. Both proxies indicate that the site was characterised by expanding grasslands during the mid-Holocene, shifting to more woody vegetation in the late Holocene. It was therefore demonstrated that *n*-alkanes can work well as terrestrial vegetation proxy when derived from larger catchments.

In smaller catchments such as Black Springs and Table Top Swamp, these records tend to be strongly impacted by the abundance of aquatic vegetation with similar *n*-alkane and compound-specific carbon isotope characteristics to terrestrial plants. It is therefore more difficult to work out shifts between different plant-functional types. Interpretation of lacustrine records was, however, easier than from cave records in regard to palaeoclimatological research questions.

Altogether, it was demonstrated that sampling modern vegetation is critical for *n*-alkane analysis as conventional assumptions about the association of *n*-alkanes with particular vegetation groups were found not to be straightforward. This was particularly the case in the smaller catchments with largely very local sources of organic matter, making interpretation difficult without calibration. Where it was possible to sample vegetation, it was also possible to distinguish between different sources of *n*-alkanes; the dominant chain-lengths in trees and shrubs were mostly found to be C_{27} and C_{29}. Grasses and sedges including aquatic sedges produced predominantly longer *n*-alkane chain-lengths C_{31} and C_{33}. There were however exceptions from these patterns. Mid-chain *n*-alkanes, commonly associated with aquatic macrophytes, were found to be produced in significant amounts by terrestrial vegetation as well. The TAR_{aq} and the P_{aq} proxies were found to work well for discriminating between local aquatic and terrestrial input, as was indicated, for example, by much higher values in the cave sequences examined in this thesis. In general, because of the variability in *n*-alkanes between sites measured in this study, it is recommended to sample modern vegetation to account for *n*-alkane and organic matter sources. This will improve interpretations of palaeoenvironmental vegetation records as it is not always possible to make generalised interpretations.

In the Thirlmere Lakes site, the only temperate site examined within the thesis, it was found that over a short period of time, modern climate (precipitation) had a stronger impact on carbon isotopes than on *n*-alkane average chain-lengths (ACL) in modern vegetation. While ^{13}C in plant samples appeared to have shifted between drier and wetter environmental conditions, ACL did not show any significant differences. Future research should further investigate this potential lag between proxies over longer time frames.

Overall, the work presented in this thesis shows that *n*-alkanes and compound-specific isotopes hold great potential for expanding the quality and quantity of information on vegetation change in tropical Australasia during the late Quaternary. Despite this potential, it also demonstrates that additional work is required to better understand *n*-alkane-plant relationships. This would further improve the utility of the use of *n*-alkanes as palaeoenvironmental proxies in tropical Australasia.

SEDIMENTOLOGY OF LAKE-MARGIN LUNETTES IN THE CORANGAMITE REGION, SOUTHEASTERN AUSTRALIA

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Research on past climatic and hydrologic conditions is of high relevance when faced with the challenges of anthropogenic climate change. With water as an essential factor, variability in hydroclimate can affect landscapes as well as human settlements to a high degree.

Within the already highly hydroclimatically variable Australian continent, we investigate sedimentary deposits, including lunettes, commonly found on the downwind side of ephemeral lakes, as well as aeolian and fluvial deposits.

Especially lunettes are valuable palaeoenvironmental archives, with their sediment sequences recording hydrologic conditions in their basins during their deposition.

Samples were taken from three lakes in the Western Plains of the Newer Volcanics Province in Victoria: Lake Corangamite, Beeac, and Murdeduke.

The area is characterised by complex morphologies, including multiple volcanic eruption centres as well as huge sedimentary deposits, which resulted in the hypothesis that a Megalake had previously existed in the Western Plains basin.

This, as well as the episodic salinity increasingly becoming a problem with the arrival of European settlers and their pastoral agriculture, makes the area highly interesting.

Using a combination of Optically Stimulated Luminescence (OSL) dating, remote sensing, and sediment analyses, a palaeolake extent, albeit smaller than previously hypothesised, as well as cascadic overflow points were identified.

At Lake Beeac, a depositional phase at ~42 ka was identified, followed by two deposits during lake drying conditions at ~33 and ~28 ka at Lake Murdeduke.

Immediately pre-LGM (Last Glacial Maximum), aeolian deposition occurred at Lake Corangamite.

After a long inactivity, deposition resumed at Lake Murdeduke during lake full conditions ~5 ka, whereas aeolian deposition occurred once more at Lake Corangamite around 3.6 ka, indicating variability in the late Holocene.

With the arrival of European settlers and the onset of pastoralism, reactivation occurred at the sampling sites of Lake Murdeduke, with four samples dated at ~200 years.

HYDROCLIMATE CHANGE RECONSTRUCTED FROM LAKE-MARGIN LUNETTES AROUND GARIWERD IN SOUTHEASTERN AUSTRALIA

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Hydroclimate, defined as the interconnection of hydrology and climate, is highly important to assess environmental change. Especially in drought-prone regions, variability in hydroclimate can trigger major changes in landscape stability and affect ecosystems and human settlements.

The highly variable hydroclimate with great variations in spatial and temporal landscape response in southeastern Australia highlights the need for an improvement in the coverage of geochronologic and palaeoenvironmental studies focusing on the reconstruction of hydroclimatic conditions. Lunettes, as transverse shoreline dunes at lakes, are valuable palaeoenvironmental archives at the edge of Australia's dryland, as their sediment characteristics are altered through the conditions present during deposition, and they are geomorphic proxies for the extent of the past dryland margins.

In contrast, the lakebed is not a suitable archive due to deflation. Periodic lake drying and lakebed deflation would result in clay pellet deposition, whereas clean beach sand indicates full lake conditions. In this study, the history of lake filling and drying is investigated based on the lunettes for three former lakes (Lake Toolondo, Bryans Swamp, and Nekeeya) around the mountain range Gariwerd/Grampians Ranges in western Victoria, Australia. This area is chosen due to its proximity to the semi-arid margin and the possibility to investigate whether an orographic effect on hydroclimate around the mountain range is preserved in the lunette's record.

Toolondo is located west, Bryans Swamp in a southern valley, and Nekeeya east of Gariwerd/Grampians Ranges. Optically stimulated luminescence (OSL) dating is used to constrain ages for sedimentation phases. Sediment characteristics, such as grain size and elemental composition, are derived through laser diffractometry and portable X-ray fluorescence (pXRF) and are used as proxies for lake conditions. This study enables the identification of the hydroclimatic history preserved in lunettes around Gariwerd/Grampians Ranges.

At Toolondo, drying lake conditions are preserved from ~100-80 ka. A minor lake full phase with lunette deposition is recorded at ~55 ka at Toolondo and Nekeeya. This is followed by major continuous to persisting sandy lunette deposition from ~34-30 ka to 16 ka at all three lakes. Afterwards, minor full lake lunette deposition or partly reworking occurred at Toolondo and Bryans Swamp from ~11-10 ka and at all three lakes from ~7-5 ka and ~2.4-1.7 ka.

More recent activity is dated to ~0.6 ka and <150 yrs at Toolondo and Nekeeya. The mostly continuous water availability at the lakes investigated highlights the importance of snow melt and vegetation response in mountainous regions during periods of generally higher aridity.

Within this study, no evidence for an orographic effect of the mountain range Gariwerd/Grampians Ranges onto past lake hydrology could be found. Instead, latitudinal effects, the proximity to the mountain range, and the catchment characteristics seem to have a greater effect on water availability within the studied lakes. The obtained results bring up the hypothesis of a "megalake" at Bryans Swamp through linkage with the adjacent Mahoney Swamp before 32 ka.

This study improved the knowledge about spatial and temporal variability in hydroclimatic conditions and their landscape response and provides further evidence for more water availability during the extended Last Glacial Maximum (LGM) due to either decreased evaporation, increased rainfall, or snow melt. The data can be used to guide future approaches to quantify climatic parameters in the past.

EXPLORING ENVIRONMENTAL AND CLIMATIC COMPLEXITY BETWEEN SUNDA AND SAHUL: INSIGHTS FROM WALLACEA USING MULTIPROXY SPELEOTHEM AND LACUSTRINE RECORDS

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The climatic and environmental history of Wallacea and the surrounding region is understudied. It is a region at the intersection of multiple global climate systems, with unique biodiversity and a long and complex history of Hominin occupation. Yet many islands have no published palaeoenvironmental/palaeoclimatic archives, leaving their natural histories to be inferred from broad, regional climate interpretations. This thesis evaluates the records that do exist, their geographic and temporal extents and resolutions. A meta-analysis of all existing records in Austral Malesia shows a paucity of archives from Wallacea—especially terrestrial records—compared with surrounding areas. Temporal sample resolution decreases steeply with time, annually resolved records extend to only ~11,000 years ago, and the purported variability of the Holocene may be an artefact of sampling bias. To address this, the thesis sets out to analyse archives on the large islands of Timor and Seram. A 3 m pollen record from Lake Nefona in Timor Barat was radiocarbon dated to ~2000 yr BP. It suggests a past, fluctuating between closed Syzygium rainforest and open Eucalypt savanna, interacting with fire and possibly influenced by human activity.

Seven speleothems from Seram and one from Timor were analysed, adding two localities in the region to just eight published previously. Floating chronologies based on annual lamina were anchored using a series of 20 conventional U/Th dates, U/Th using laser ablation, 22 radiocarbon dates, and the ^{14}C bomb pulse. Speleothems were dated to brief windows from MIS 4 through to modern. Stable isotope and lamina growth rate analyses of these speleothems were conducted at the annual resolution, providing insights into the hydrology of the region at times when no other annual resolution records were previously available. CS-◂XRF was conducted on specimens, yielding trace elemental analyses as sub-annual resolution, allowing interpretation of the IASM during the last glacial, deglacial, and Holocene. The one specimen from Timor suggested conditions approximately 2600 years ago were similar to today but with regular peaks in rainfall every 10–15 years, possibly due to a confluence between ENSO and IOD. Specimens from Seram reveal a complex relationship with the regional climate systems, including a change from year-round rainfall (as it is today) to significantly seasonal rainfall, likely driven by the IASM, during somewhat drier times. Further, the apparent driest times in these records, around 10 and 64 ka, appear to have no seasonal pattern. That is, the Seram seems to have a monsoonal climate pattern when it is not very wet (as it is today) nor very dry. This monsoonal "sweet spot" seems to have existed during the last glacial in Seram, except in the driest extremes when the IASM may have been entirely inactive.

UPCOMING MEETINGS

2024

DECEMBER 2024

Australian Archaeological Association Annual Conference 2024
Venue: Cairns Convention Centre, Gimuy (Cairns), Australia
Date: 3 – 6 December 2024
https://www.aaaconference.com.au

2025

APRIL 2025

European Geoscience Union Conference
Venue: Austria Center Viena (ACV), Austria and Online (Hybrid)
Date: 27 April – 2 May 2025
https://www.egu.eu/news/announcements

JUNE 2025

10th World Archaeological Congress (WAC)
Venue: Darwin, Australia
Date: 22 – 28 June 2025
https://worldarchaeologicalcongress.com/wac10

JULY 2025

New Zealand Archaeology Association (NZAA) Annual Conference
Venue: Club Mount Maunganui, Mount Maunganui, New Zealand
Date: 15 – 18 July 2025
https://nzarchaeology.org/event/nzaa-annual-conference-2025

NEWSLETTERS

PAGES – Past Global Changes – Early Career Networks
Engage with other ECR's to facilitate exchange of ideas and skills.
https://pastglobalchanges.org/ecn/intro

SEMINAR SERIES

Pal(a)eoPERCS (Palaeo Early Career Seminars) Series
Weekly seminars given by ECRs across palaeo – disciplines
https://paleopercs.com

RECENT PUBLICATIONS

Alloway, B. V., Lowe, D. J., Jensen, B. J. L. & Plunkett, G. (2025). Tephrochronology. In: Elias, S.A. (editor) *Encyclopaedia of Quaternary Science, 3rd edition*, vol. 5, pp. 780-838. Elsevier, Amsterdam. https://doi.org/10.1016/B978-0-323-99931-1.00125-2

Bray, J., Wasson, R. J., Srivastava, P. & Ziegler, A.D. (2023). Floods and Debris Flows Ladakh: Past History and Future Hazards. In: Humbert-Droz, B., Dame, J., Morup, T. (editors). *Environmental Change and Development in Ladakh, Indian Trans-Himalaya*, pp. 31-52. Springer. https://link.springer.com/chapter/10.1007/978-3-031-42494-6_3

Hopkins, J. L., McIntosh, P. D., Vink, J., Slee, A. & Moss, P. (2024). First detection in Australia of cryptotephra likely to be derived from the 25.6 ka ruanui supereruption in New Zealand. *Quaternary Science Reviews* 341, 108856. https://doi.org/10.1016/j.quascirev.2024.108856

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Palmer, A. S., Lowe, D. J. & Almond, P. C. (2025). Pedostratigraphy. In: Elias, S.A., (editor) *Encyclopaedia of Quaternary Science, 3rd edition*, vol. 5, pp. 749-769. Elsevier, Amsterdam. https://doi.org/10.1016/B978-0-323-99931-1.00265-8

Ryan, R., Thomas, Z., Simkovic, I., Dlapa, P., Worthy, M., Wasson, R., Bradstock, R., Mooney, S., Haynes, K. and Dosseto, A. (2024). Assessing changes high-intensity fire events in southeastern Australia using FTIR spectroscopy. *International Journal of Wildland Fire* 33, WF24064. https://doi.org/10.1071/WF24064

Sundriyal, Y., Kumar, S., Chauhan, N., Kaushik, S., Kumar, V., Rana, N. & Wasson, R. (2024). An integrated approach of machine learning and remote sensing for evaluating landslide hazards and risk hotspots, NW Himalaya. *Remote Sensing Applications: Society and Environment* 33, 101140.

Quaternary AUSTRALASIA

Quaternary Australasia publishes news, commentary, notices of upcoming events, travel, conference and research reports, postgraduate thesis abstracts and peer-reviewed research papers of interest to the Australasian Quaternary research community. Cartoons, sardonic memoirs and images of mystery fossils are also welcome.

The Australasian Quaternary Association (AQUA) is an informal group of people interested in the manifold phenomena of the Quaternary Period. It seeks to encourage research by younger workers in particular; to promote scientific communication between Australia, New Zealand and Oceania; and to inform members of current research and publications. It holds biennial meetings and publishes the journal Quaternary Australasia twice a year.

Full annual membership of AQUA with an electronic subscription to QA is AUD70. For students, unemployed or retired people, the membership is AUD25. The AQUA website (www.aqua.org.au) has information about becoming a member; alternatively, please contact the Treasurer.

Membership is valid for one year, from January 1st to December 31st. While members are welcome to renew their membership at any time throughout the year, their membership will only be valid until 31 December, and late subscriptions will not be adjusted pro-rata.

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