PERTH, WESTERN AUSTRALIA

PALAEO DOWN UNDER 3

10-14 JULY 2023

ABSTRACT BOOK & CONFERENCE GUIDE

CONTENTS

PALAEO DOWN UNDER 3
10-14 JULY 2023

Organising committee

Kenny Travouillon (Western Australian Museum); AAP Chair
John Gorter; AAP Vice Chair
Daniel Mantle (MG Palaeo); AAP Treasurer
Helen Ryan (Western Australian Museum); AAP Secretary
Sarah Martin (Geological Survey of Western Australia); AAP Publications Officer
Elizabeth Dowding (Friedrich-Alexander-Universität Erlangen-Nürnberg); AAP Webmaster
Kailah Thorn (Western Australian Museum)
with past contribution from Heidi Allen (Geological Survey of Western Australia)

Scientific committee

Dr Alison Blyth (Curtin University)
Dr Elizabeth Dowding (Friedrich-Alexander-Universität Erlangen-Nürnberg)
Assoc. Prof. David Flannery (Queensland University of Technology)
Dr Scott Hocknull (Queensland Museum)
Dr Sarah Martin (Geological Survey of Western Australia)
Prof. Kate Trinajstic (Curtin University)

Symposium chairs and workshop instructors

Dr Marissa Betts (University of New England)
Prof. Glenn Brock (Macquarie University)
Dr Alice Clement (Flinders University)
Prof. Kliti Grice (Curtin University)
Dr James Holmes (Uppsala University)
Dr Peter McGoldrick (University of Tasmania)
Dr Indrani Mukherjee (University of New South Wales)
Prof. John Paterson (University of New England)
Dr Eva Sirantoine (Chemostrat Australia Pty Ltd)
Prof. Kate Trinajstic (Curtin University)
Dr Elizabeth Dowding (Friedrich-Alexander-Universität Erlangen-Nürnberg)

Fieldtrip organisers

Heidi Allen (Geological Survey of Western Australia)
David Flannery (Queensland University of Technology)
David Martin (Geological Survey of Western Australia)
Arthur Mory (Geological Survey of Western Australia)
Helen Ryan (Western Australian Museum)

Abstract volume design and layout by Sarah Martin (Geological Survey of Western Australia).

Cover images courtesy of: Sarah Martin, Geological Survey of Western Australia (left, left centre, and right centre); Kate Trinajstic (right).

WELCOME TO PALAEO DOWN UNDER 3!

It is with great pleasure that I, on behalf of the Australasian Palaeontologists committee, welcome you to Perth for Palaeo Down Under 3. I would like to acknowledge that this conference is being held on the traditional lands of the Whadjuk-Noongar people, and pay our respects to their leaders, past, present and emerging.

The committee has been working on this event since we took office four-and-a-half years ago. It has been a rather bumpy ride, with COVID19 affecting the planning, and shifting the conference from last year to this year.

It is great to see over 100 palaeontologists attending the conference, not only from all over Australia, but also palaeontologists from all over the world, including New Zealand, China, South Korea, United Kingdom, Ireland, Sweden, Germany and the United States of America. It will be a diverse conference, covering the earliest life on earth to more recent Quaternary megafauna. We also have five great plenary speakers that will present their life's work in their area of expertise.

Perth is usually one of the sunniest cities in Australia, but as our winter is the rainy season we are likely to have a rather wet conference. Despite this, there is plenty to do and see, and hopefully you will take the opportunity to do some sightseeing during your visit. Our events aim to give you a taster of some iconic parts of Perth and Western Australia, including the icebreaker and mid-conference tour at the WA Museum and the conference dinner at King's Park. With the conference hosted in the Perth Cultural Centre, there should also be ample opportunities to try some of the excellent dining and nightlife options available within Perth CBD, Northbridge and further out into the city. And, of course, some of you will have the chance to see more of WA by going on the pre-conference tour to the Pilbara or post-conference tour to the Mid West region.

Regardless of what you choose to do during your time, the committee and I wish you all the best for your stay in Perth, and a safe and successful PDU3 conference!

Kenny Travouillon
Chair of Australasian Palaeontologists

THANK YOU TO OUR SPONSORS

Platinum

BUSINESS EVENTS PERTH

Gold

GOVERNMENT OF WESTERN AUSTRALIA

WESTERN AUSTRALIAN MUSEUM

Bronze

EROMANGA NATURAL HISTORY MUSEUM

GEOLOGICAL SURVEY WESTERN AUSTRALIA

MGPALAEO geological and stratigraphical consultants

About the conference logo

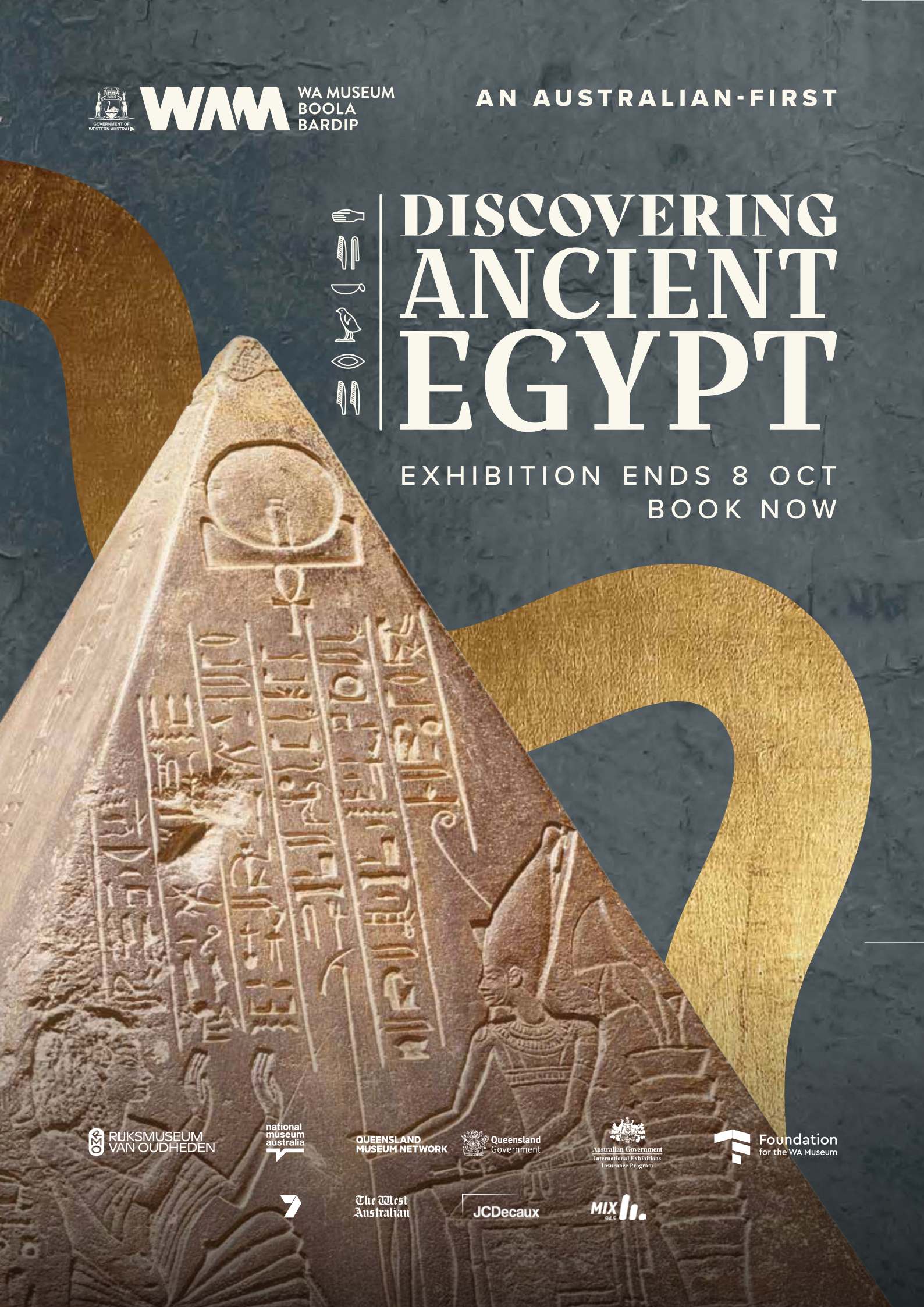
Conference logo designed by Nellie Pease, University of Queensland. Nellie explains her design concept as follows:

'I've included a few key fossils from Western Australia in this logo. From the centre outwards, I've included the string-of-pearls Horodyskia williamsii *fossils, the Shark Bay stromatolites, the trace fossils of the Tumblagooda Sandstone, the arthropod* Kalbarria*, a Gogo fish, some Permian glossopterids, some Jurassic conifers and ferns, the Broome dinosaur trackways, and* Thylacoleo*. They're arranged roughly in chronological order, in the shape of an ammonite, to represent WA's Miria Marl fossils, which are the largest collection of Cretaceous ammonites in the world. I wanted to include some plant and invertebrate fossils in this, to show that palaeontology is the study of all living things over all evolutionary time — not just the big recognisable ones!'*

PALAEO DOWN UNDER 3 10-14 JULY 2023

A display of all the artworks submitted as part of the conference logo competition will be on display in the poster area for the conference duration.

Thank you to all the talented artists who submitted ideas as part of this competition.


WA MUSEUM
BOOLA
BARDIP
AN AUSTRALIAN-FIRST
DISCOVERING
ANCIENT
EGYPT
EXHIBITION ENDS 8 OCT
BOOK NOW
RIJKSMUSEUM
VAN OUDHEDEN
national
museum
australia
QUEENSLAND
MUSEUM NETWORK
Queensland
Government
Australian Government
International Exhibitions
Insurance Program
Foundation
for the WA Museum
The West
Australian
JCDecaux
MIX
94.5

About the venues

Located within the heart of Perth city, the Cultural Centre is a vibrant, inclusive and attractive draw card for Perth residents and visitors alike. The precinct is made up of the Art Gallery of Western Australia, Western Australian Museum Boola Bardip, State Library of Western Australia, The Blue Room, PICA (Perth Institute of Contemporary Arts), the State Theatre Centre of Western Australia, and North Metropolitan TAFE. Situated between the Perth city train station and Northbridge's retail, food, beverage and entertainment precinct, the Cultural Centre is a dynamic and lively public space with easy access and free WiFi.

The conference will be based within three main venues within the Perth Cultural Centre (map below): **The State Library of WA**, **WA Museum Boola Bardip** and the **Art Gallery of WA**. See pages 15–18 for information on each venue.

Delegates are encouraged to attend the **icebreaker event on Sunday afternoon** in order to complete registration and pick up their name tags and welcome packs. For those unable to attend this event, or for single day registrants, a registration and enquiries desk will be located in the State Library foyer on each of the conference days both before sessions and during break times.

TIMETABLE AND ACTIVITIES

Note: detailed final timetable will be provided online and in print at conference registration.

Saturday 1 July to Sunday 9 July 2023

Pre-conference field trip — Precambrian palaeontology highlights package.

Organisers: David Flannery (QUT), Heidi Allen (GSWA) and David Martin (GSWA).

Sunday 9 July 2023

Icebreaker reception: 5–8 pm, Hackett Hall, Western Australian Museum Boola Bardip

Delegates are encouraged to attend this event to receive their registration badges and packs prior to the conference's official start on Monday morning. It's also an excellent opportunity to meet your fellow delegates in a relaxed social setting!

This event is included as part of the conference registration fee.

Monday 10 July 2023

	State Library theatre	WA Museum Learning Studios
09:00	**Registration (State Library theatre foyer)**	
09:10	Welcome to country and Opening address	
09:30	**Symposium: Arthropod Palaeobiology and Evolution**	
10:30	**Morning tea (State Library theatre foyer)**	
11:00	**Symposium: Arthropod Palaeobiology and Evolution (cont.)**	
12:00	**Plenary: David Flannery,** The search for ancient microbial life on Mars	
13:00	**Lunch**	
14:30	**General sessions**	**Workshop: R for Palaeontology**
15:50	**Afternoon tea (State Library theatre foyer)**	
16:20	**General sessions**	**Workshop: R for Palaeontology (cont.)**
17:20	**End Monday**	

Tuesday 11 July 2023

	State Library theatre	WA Museum Learning Studios
09:10	**General sessions**	
10:30	**Morning Tea (State Library theatre foyer)**	
11:00	**Symposium: The digital revolution in Palaeontology**	
12:00	**Plenary: Kate Trinajstic,** Exceptional preservation of organs and musculature in early vertebrates from the Gogo Formation Konservat-Lagerstätte	
13:00	**Lunch**	**13:30 Collection managers meetup**
14:30	**Symposium: The digital revolution in Palaeontology (cont.)**	
15:50	**Afternoon tea (State Library theatre foyer)**	
16:20	**Symposium: The digital revolution in Palaeontology (cont.)**	**Workshop: GPlates tutorial**
17:20	**End Tuesday**	

Wednesday 12 July 2023

	State Library theatre
09:10	**Symposium: Mid-Proterozoic macroscopic life**
10:50	**Comfort break**
11:00	**Plenary: Pam Reid,** All microbialites are not created equal: lessons from the Bahamas and Shark Bay, Western Australia
13:00	**Lunch**
13:30	**Mid-conference museum visit: WA Museum Boola Bardip**
17:00	**End Wednesday**
TBA	**ECR social event; venue TBA**

Thursday 13 July 2023

	State Library theatre	Art Gallery Theatrette
09:10	**General sessions**	**Symposium: Telling Ediacaran and Paleozoic time**
10:30	**Morning Tea (State Library theatre foyer)**	
11:00	**General sessions**	**Symposium: Telling Ediacaran and Paleozoic time (cont.)**
12:00	**Plenary: Steve Salisbury,** The changing face of Australia's dinosaurian fauna: reflections on the past and glimpses into the future	
13:00	**Lunch**	
14:30	**General sessions**	**General sessions**
15:50	**Afternoon tea (State Library theatre foyer)**	
16:20	**General sessions**	**General sessions**
17:20	**Travel from Cultural Centre (Francis St, Northbridge) to Kings Park**	
18:00	**PDU3 Conference dinner, Frasers Restaurant**	
22:00	**Travel from Kings Park to Cultural Centre (Francis St, Northbridge)**	
22:30	**End Thursday (?)**	

Friday 14 July 2023

	State Library theatre	Art Gallery Theatrette
09:10	**General sessions**	**Symposium: Molecular palaeontology and taphonomy**
10:30	**Morning Tea (State Library theatre foyer)**	
11:00	**General sessions**	**General sessions**
12:00	**Plenary: Matt McCurry,** Palaeoecology and taphonomy of the McGraths Flat Lagerstätte	
12:00	**Lunch**	
14:20	**General sessions**	**General sessions**
15:20	**Afternoon tea (State Library theatre foyer)**	
15:40	**PDU3 AWARD CEREMONY & AAP AGM (State Library theatre)**	
17:00	**End Friday sessions**	

Public talk: Friday 14 July 2023, 5 pm, WA Museum Boola Bardip, L3, East Terrace.

Mike Archer - Thegosis, aka tooth sharpening

Tickets cost **$10 per person**, and are **not** included as part of the conference registration fee.
Booking is available via the WA Museum website, QR link provided with talk abstract on p. 26.

Monday 17 July to 20 July 2023

Post-conference field trip — Kalbarri and Geraldton.

Organisers: Helen Ryan (WAM) and Arthur Mory (GSWA)

Symposia

The PDU3 timetable will include five symposia, spread across the five days of the conference.

Arthropod palaeobiology and evolution (Monday, sessions 1 and 2, State Library theatre)
Chairs: Prof. John Paterson (University of New England) and Dr James Holmes (Uppsala University)

This session will cater to researchers investigating any aspect of arthropods and their fossil record. Presentations will cover a broad range of topics such as anatomy, functional morphology, development, systematics, taphonomy, palaeoecology, biogeography, and biostratigraphy.

The digital revolution in palaeontology (Tuesday, sessions 2–4 , State Library theatre)
Chairs: Prof. Kate Trinajstic (Curtin University) and Dr Alice Clement (Flinders University)

Advances in computing, tomography and 3D printing have enabled a digital revolution in palaeontology. Databases are allowing palaeontology data to be applied to questions in evolutionary biology, biostratigraphic correlation and climate change. Virtual preparation creating three-dimensional digital models is becoming the norm in palaeontological research allowing various downstream analyses in the field of biomechanics, 3D geometric morphometrics, palaeohistology and more. These techniques have the advantage of being non-destructive and allow visualisation of internal structures, previously not possible. However, there are also challenges in curating, storing and sharing these data. This symposium will present research on all aspects of digital palaeontology including important insights into fossil anatomy, development, palaeobiology and the curation and access of digital data.

Mid-Proterozoic macroscopic life (Wednesday, session 1, State Library theatre)
Chairs: Dr Peter McGoldrick (University of Tasmania) and Dr Indrani Mukherjee (University New South Wales)

The nature and significance of the earliest large eukaryotes are poorly understood. Undisputed crown group fossils date from *ca* 1 Ga, but several potential eukaryotic macrofossils are known from much older rocks (perhaps to *ca* 2.1 Ga). Australian examples include the Stirling biota in Western Australia and 'string of beads' (*Horodyskia* sp.) from Western Australia and Tasmania. Multidisciplinary approaches have the potential to shed new light on these contentious fossils. Simple descriptions can be complemented by modern microanalytical techniques that speak to biogenicity, and geochemical proxies can reveal the redox structure of the sedimentary environments in which the organisms lived and died. This session presents research concerning the origin, nature and (palaeo-)environmental setting of Proterozoic fossils, ichnofossils and (non-stromatolite) microbialites from the time between the end of the GOE and the first of the Neoproterozoic 'Snowball Earths'.

Telling Ediacaran and Paleozoic time: chronostratigraphic correlation in Australasia and beyond (Thursday, sessions 1 and 2, Art Gallery theatrette)
Chairs: Dr Marissa J Betts (University of New England) and Prof. Glenn Brock (Macquarie University)

There is a plethora of exciting and important research being done globally in the multidisciplinary area of chronostratigraphy and correlation of Ediacaran and Paleozoic successions in Australasia and beyond. The session will present studies employing classic approaches — e.g. biostratigraphy, stable isotope chemostratigraphy, zircon-based geochronology — and those integrating emerging techniques or developing novel methods, e.g. database-driven modelling or targeting unconventional mineral phases and/or isotopic systems for dating.

Molecular palaeontology and taphonomy (Friday, session 1, Art Gallery theatrette)
Chairs: Prof. Kliti Grice (Curtin University) and Dr Eva Sirantoine (Chemostrat Pty Ltd)

Exceptionally preserved fossils in deep time can uncover information on ancient environments and extinct species and evolution, and an understanding about the mechanisms / processes involved in their preservation. Molecular palaeontology applies state of the art analytical techniques, not limited to but including biomarker analysis, stable isotopes, and imaging techniques, to reveal organic molecules archived in the fossil record.

Plenary talks

Each of the conference's five plenary talks are open to the public at a cost of $15 per person. Tickets are available via Humanitix — QR codes linking to the ticket pages can be found next to each plenary abstract (this volume, pages 20–25).

Poster sessions

Posters will be on display in the State Library theatre foyer every day during break times (including lunch). Poster presenters are encouraged to stand nearby their posters during morning and afternoon tea breaks to promote discussion.

Registration and enquiries desk

As noted previously, a registration and enquiries desk will be located in the State Library theatre foyer for the conference duration and will be staffed before the first session and during morning and afternoon tea.

The registration table can be approached for general information on the conference, events, and virtual tours. Past volumes of the Australasian Palaeontologists Memoir will also be purchasable at this desk (cash or card payment only).

A laptop will be set up at the registration desk to allow speakers to upload and test their PowerPoint slides; speakers are asked to ensure that their slides are uploaded at least one session prior to their allocated presentation time.

Virtual tours

Ediacaran biota. The best way to experience this tour is as a downloadable VR experience; however, for those without a headset, several pieces of content are available online, including a 360° image gallery, 3D Ediacaran model viewer, and information on 3D prints of the models

now in use by tour guides throughout Brachina Gorge. We thank the Project LIVE team from the University of South Australia for making this experience available for PDU3.

Kalgoorlie Virtual Field Experience. This virtual field trip exploring the geology of the Kalgoorlie–Boulder region was developed by Curtin University as an accessible, online field experience. The tour is best explored using a smart phone or tablet, as navigation within the experience can be controlled by rotating the device in real space. We thank Curtin University's School of Earth and Planetary Science for providing access to this experience during PDU3.

Links to these virtual tours will also be provided at the registration desk, and can be used at any time during the conference.

Conference dinner

The conference dinner will be held at the State Reception Centre above Fraser's Restaurant (60 Fraser Ave, West Perth WA 6005) on **Thursday 13 July at 6 pm.** Located within iconic Kings Park and overlooking the Perth CBD and Swan River, we encourage all delegates to join us for an evening to remember.

Free transport will be provided for conference participants between Kings Park and the Perth Cultural Centre. Transport to Kings Park will depart at **5.30 pm at the bus stop on Beaufort Street** (outside the WA Museum and opposite The Court Hotel), and will depart Kings Park at 10 pm to return the Cultural Centre.

Seats are still available; enquire at the registration desk. A conference registration is not required to attend — partners and colleagues welcome!

Workshops

Workshop numbers are limited by room capacity (50 people) on a first come, first served basis. Please use the relevant Google form (QR link provided) to book a place.

R for Palaeontology

Monday 10 July, 2.30 pm onwards, WA Museum Learning Studios

Palaeontologists have increased access to large datasets and powerful statistical processes. R programming provides palaeontologists the opportunity to quickly sort, filter, organise, and analyse data. Within this workshop, attendees will be introduced to the foundations of R programming, be provided script to apply to their own research, and a pathway to develop their skills.

- **Instructor:** Elizabeth M. Dowding
- **Required:** own laptop, R and R Studio downloaded.
- **Level:** Introductory.

Picking your plate reconstruction: an introduction to GPlates

Tuesday 11 July, 4.20 – 5.20 pm, WA Museum Learning Studios

Plate-reconstructive models and palaeogeographies are powerful tools for palaeontologists to contextualise data. The mostly commonly used platform for plotting and manipulating fossil occurrences is GPlates.

GPlates is open-source software that combines interactive plate-tectonic reconstructions, geographic information system functionality and raster data visualisation. In this workshop, the basics of plate model generation, best practice for palaeontologists, and how to select a reconstruction will be showcased.

- **Instructor:** Elizabeth M. Dowding
- **Required:** own laptop, GPlates downloaded.
- **Level:** Introductory.

Collection managers meet-up

Tuesday 11 July, 13.30 pm, WA Museum Learning Studios

Collection curators and technicians are invited to a casual round-table discussion about the challenges of managing physical collections. It is hoped that by establishing connections, curators can work collaboratively towards best-practice in storage, ethics and digitisation for collections large and small. Entry will be open to all.

Early career casual meet-up

Wednesday 12 July, time and place to be confirmed in the final conference timetable

Early career researchers and students are invited to attend this casual social and networking event.

Mid-conference museum tour

Wednesday 12 July, 13.30 pm; meet outside WA Museum Boola Bardip main entrance

Come journey through the newest showcase of Western Australian nature, science and culture — WA Museum Boola Bardip. This tour will rotate through three of the main galleries in the museum, with each tour leg consisting of a specialist talk discussing the gallery highlights, followed by time to explore each space.

This optional free event is offered as part of conference registration.

Documentary filming

Conference registrants are reminded that a documentary filmmaker will be present during PDU3, working on the documentary 'Think of a Palaeontologist'. Information on the film and its topic can be found on the conference website (link at right). Additional information can be found at the Registration desk during the conference.

Conference dining guide

Delegates will be responsible for their own lunches on conference days, with ample time provided for delegates to head out to cafes and restaurants in the area.

The options listed to the right represent a sample of available options for eating within Northbridge; options are listed (from top to bottom of page) in increasing distance from the Perth Cultural Centre. All listed options include vegetarian options and are able to cater for food allergies and intolerances. In addition, all meet basic accessibility requirements, although some sites may be more suitable than others based on individual needs.

If you are organising an informal get-together (such as lunch or drinks) across the week, please be mindful to choose a venue accessible to all. Items to consider include ramps, table and seating height and style, the arrangement of the space and distance between tables, and noise and lighting levels.

Catered events:
We kindly request that individuals without dietary requirements refrain from consuming specially marked foods at catered events. The special diet options are designated for those with dietary restrictions or allergies, and it is essential that everyone has access to adequate amounts of food suitable for their needs. Your cooperation and understanding in this matter are greatly appreciated.

ACCESSIBLE
LOCAL FOOD

Museum Epoch Cafe — $7 - $25
Coffee, wine, cake, pastries, sandwiches, burgers, wraps.
8:30am - 3:30pm.
Lunch 11am-2pm.

Picabar — $16 - $28
Share plates, burgers, classy versions of pub staples. GF options
Open 11am 'til late

Art Gallery Cafe — $5 - $11
Coffee, juices, toasties, and sweet treats
8am - 5pm

The Court — $20 - $26
Pub food and pizza menu. GF options available
Open midday, kitchen closes at 8pm

The Brass Monkey — $14 - $38
Share plates, pub food, and small pizzas. GF and vegan options
11am - late

Baguettes — $6 - $12
Corner of Williams & Francis Streets. Made to order baguettes, sandwiches

Guzman y Gomez — $12 - $20
Mexican eats. Burritos, nachos, tacos, quesadillas. GF & vegan options available
10:30am - 10:55pm

James St Foodcourt — $8 - $18
Various cusines, ask individual stalls about dietary reqs. Range of prices.

Roy'Als Burgers — $12 - $23
Burgers, wings, loaded fries. GF buns available.
11:30am - 9pm

No Mafia — $14 - $33
Share plates and pasta.
Dinner 5-10pm
Lunch avail on Fridays from 12pm

Franco Forte — $14 - $33
Spaghetti bar - choose your sauce style menu.
Vegan and GF options
Dinner only, 5 - 9pm

Yagan Square — $12 - $30
Food court options including Hiss & Smoke japanese grill, Gangnam Korean BBQ.

Accessibility

The organising committee is committed to making Palaeo Down Under 3 as enriching and enjoyable as possible for all participants, and we ask that all attendees strive for the same ideal.

Although we have made every effort to organise an accessible conference, we acknowledge that accessibility is a continuous journey, and there may be areas where we can further improve. We value your feedback and invite you to share suggestions on how we can enhance your experience during the conference. Your input is crucial in helping us create an inclusive and welcoming environment for all participants.

Transport and venue access

Information on accessibility and transport within the City of Perth (including the Cultural Centre precinct) can be found via the link at right.

ACROD parking

There is one ACROD parking bay (9 m long x 2.3 m wide) on Francis Street, adjacent to the ramp between the State Library and the WA Museum. The bay gives ACROD permit holders two hours of free parking between 8 am and 6 pm, Monday to Saturday. Further information about the ACROD parking bay is available via the link at right.

Paid undercover parking is available everyday until midnight under the State Library of Western Australia at $2.90 per hour. ACROD parking bays are available on both levels — 5 bays on the ground level and 2 bays on the basement level. There are lifts in the centre next to the ACROD bays and at the William Street end of the car park, and ramp access from the car park onto James Street. Further information on this car park is available via the link at right.

Level/Ramp access

Ramp access to the Perth Cultural Centre is available from Francis Street, located between the State Library and WA Museum Boola Bardip buildings. This ramp also leads to the WA Museum Boola Bardip main entrance.

Accessible drop-off bays

There are two 15-minute pick-up bays available on Francis Street outside Central TAFE and opposite the State Library. Further information about the pick-up parking bay is available via the link at right.

Public transport

The Cultural Centre is located a short distance from bus stops on Beaufort Street, and approximately 500 m from Perth Busport. There is a tactile path leading from the Perth Train Station, through the Cultural Centre to the main entrance of the State Library.

State Library

The State Library is largely accessible via wheelchair, including through public lifts. Information on the Library building, including entrance and lifts, is available via a printable map, linked here.

Accessible toilets
A unisex accessible toilet is available on the Ground Floor of the State Library, in the Theatre foyer (adjacent to the Francis Street entrance).

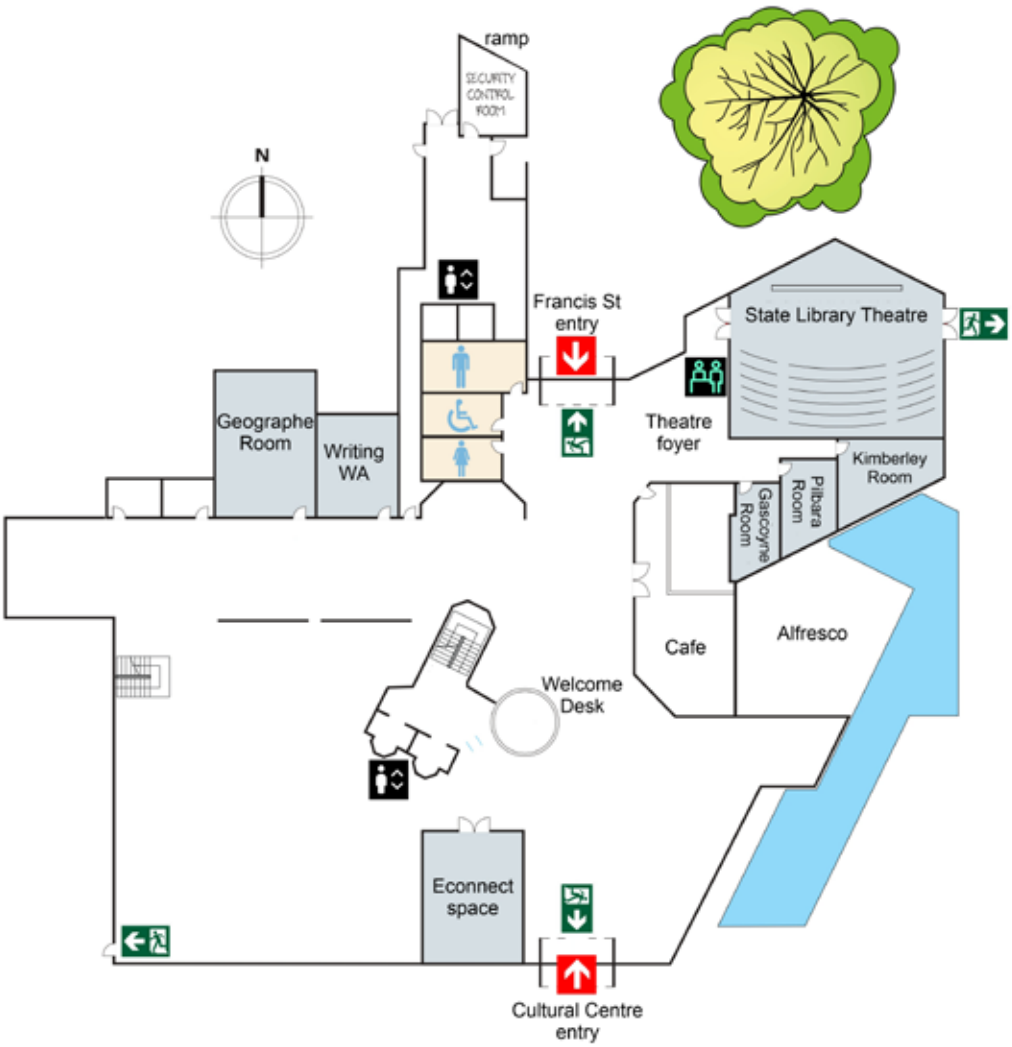
Male and female disabled toilets are available on Levels 1, 2 & 3. The individual cubicles in the standard toilets are not wheelchair accessible.

Accessibility computers
The State Library hosts 3 PCs with enhanced accessibility functions. All three have larger screens and are on adjustable desks; two have large keyboards and a trackball mouse. Bookings can be made at the Library's Welcome Desk.

Hearing loops
Hearing loop facilities are available in the State Library Theatre. Please let the organising committee know if you require the use of a hearing loop.

Theatre seating
The State Library Theatre has tiered seating accessed via stairs. Limited seating is available on the lowest level, including five seats and space for approximately four wheelchairs. Please leave the lower rows available for those delegates who have difficulty with stairs.

There will also be designated seating areas provided for individuals with mobility impairments or those who require specific seating arrangements in the welcome function area and at morning and afternoon teas. Please do not block access to these seats.

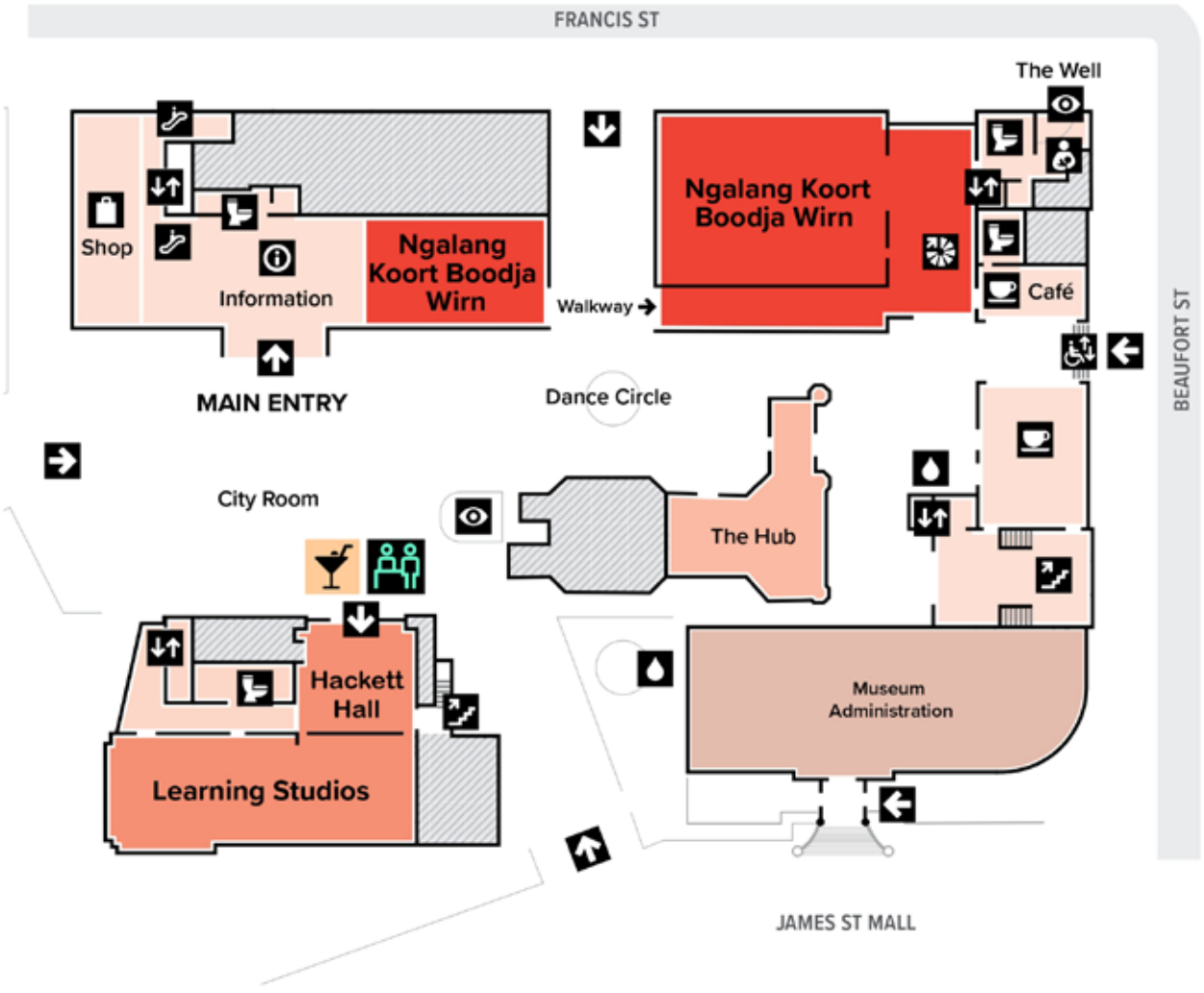


WA Museum Boola Bardip

WA Museum Boola Bardip has wheelchair access to the exhibition galleries, shop, grounds and cafe, both internally and externally. Lifts providing access to exhibition galleries are suitable for wheelchair access. Wheelchairs are available free of charge from the Information desk at the main entrance. Walking aids are also available for use; call 1300 134 081 to check availability. The Museum welcomes guide and assistance dogs with full access rights.

Visual Supports
Before your visit, print out the visual supports and checklist to help you develop a visual plan of your time at the Museum. This can help to structure a big day out, making it more enjoyable for everyone.

Visual Stories
Written in consultation with the Autism Association of Western Australia, these Visual Stories provide a general guide for what to expect and what to do when visiting the new WA Museum Boola Bardip. The stories provide key information to help you plan your visit and make the experience more predictable. There are two options to choose from, each representing different age groups.



WA Museum Boola Bardip has collaborated with the Autism Association of Western Australia to develop these inclusive supports.

Sensory Maps
Sensory Maps identify sensory-friendly spaces in the Museum — areas that tend to be quieter and less crowded, have seating and tactile engagement and activities.

Please note: As the Museum's building and exhibitions change, parts of these maps may not always be up to date.

Quiet times and quiet spaces
The Museum tends to be quieter between 3 pm and 5 pm on weekdays during term time. In the main building, on levels 1, 2 and 3, there are lounge seating areas outside the galleries. The Old Gaol in the courtyard also has small rooms with seating that provide a quieter space.

Information on these visual and sensory supports can be found at the link provided.

Art Gallery of Western Australia

Entrance to the Art Gallery theatrette is on ground level, via a side entrance directly opposite WA Museum Boola Bardip (see the main Perth Cultural Centre map on p. 6).

Access to the theatrette requires no lifts or stairs, and the space has accessible seating. Unfortunately, the toilets closest to this theatrette are not wheelchair friendly; it is recommended that those who need accessible toilets use the bathrooms in the State Library, or public toilets within the main Art Gallery building.

There are two public lifts within the main part of the Art Gallery. The main lift provides access to the first floor gallery spaces and is located in the central Concourse. A second lift allows access to the Centenary Galleries. The second lift is located in the rest area between two of the ground floor gallery spaces.

Walking frames, manual wheelchairs and an electric buggy are available for visitor's use within the Art Gallery. These are provided free of charge from the Gallery Reception. Bookings are advisable to ensure availability. Please provide 24-hour notice for the electric buggy as it will need to be charged. Bookings telephone +618 9492 6601.

State Reception Centre, Fraser's Restaurant, Kings Park

Parking
Parking is available for people who hold a valid ACROD pass (or equivalent Australian Disability Parking Permit) in all parking locations throughout Kings Park. The parking map linked here includes the locations of all ACROD bays available in Kings Park and Botanic Garden.

There are also a number of drop-off zones located across Kings Park, including Fraser Circle, Fraser's Restaurant, Wadjuk Carpark, the Western Australian Botanic Garden, Forrest Carpark and at Rio Tinto Naturescape Kings Park.

There is lift and ramp access to the State Reception Centre from the ground level and car park. The building hosts accessible toilets on both levels.

PALAEO DOWN UNDER 3

10-14 JULY 2023

PLENARY ABSTRACTS

(in timetable order)

The search for ancient microbial life on Mars

David Flannery*

David Flannery [david.flannery@qut.edu.au], School of Earth and Atmospheric Sciences, Queensland University of Technology, 2 George St, Brisbane, QLD 4000, Australia.

Several decades of study, notably including ancient rocks in Australia's Pilbara region, have led to the revelation that complex microbial ecosystems were ubiquitous on Earth for at least the last three and a half billion years. Earth's first billion years, which presumably saw the origin and early evolution of life, seem destined to remain a mystery since no well-preserved sedimentary rocks have survived from this time period.

Technological progress is now allowing us to look further afield to rocky planets elsewhere in our solar system. Mars retains sediments that were deposited four or more billion years ago, and recent Mars rover missions have discovered habitable environments preserved in this record. The race is now on to collect and return samples that may contain evidence for life on an early Mars, the keys to understanding life's origin on Earth, and ultimately our place in the universe.

Biography:
David is a planetary scientist with an interest in ancient habitable environments of the inner solar system and the technology needed to explore them. Formerly based at Caltech and NASA JPL where he developed science instrumentation for space missions, he now lives in Brisbane, Australia, where he is a long-term planner for NASA's Perseverance Rover mission.

In: Abstract book and Conference Guide: Palaeo Down Under 3, 10–14 July 2023. Australasian Palaeontologists, Perth, Western Australia, 129 pp.

PALAEO DOWN UNDER 3
10-14 JULY 2023

Exceptional preservation of organs and musculature in early vertebrates from the Gogo Formation Konservat-Lagerstätte

Kate Trinajstic*

Kate Trinajstic [K.Trinajstic@curtin.edu.au], School of Molecular and Life Sciences, Curtin University, Kent Street, Bentley, WA 6102, Australia.

The sediments of the Gogo Formation represent the basinal deposits of a Late Devonian reef complex that today crops out across the Kimberley region of Western Australia. It has long been recognised for the diversity of the fauna and the exquisite 3D preservation of the fossils, but only recently has the preservation of the soft anatomy been realised. The use of synchrotron and neutron micro tomography has revealed the extensive regions of the musculature in placoderms, the earliest jawed fishes, resulting in a reinterpretation of how the neck and abdominal muscles were organised in these fishes (Trinajstic *et al.* 2013). The internal organs, comprising eyes, heart, stomach, liver and guts has provided the first direct evidence that the earliest jawed vertebrates conformed to the extant vertebrate body bauplan (Trinajstic *et al.* 2022). In addition, the absence of lungs indicates that like sharks, placoderms used their large livers for buoyancy and that lungs originated in Osteichthyes. The earlier discovery of an embryo, complete with an umbilical cord, provided the earliest evidence of viviparity in the fossil record (Long *et al.* 2008) and together these discoveries have greatly furthered the understanding of early vertebrate anatomy and life history.

Long, J.A., *et al.*, 2008. Live birth in the Devonian period. *Nature 453*(7195), 650–652.

Trinajstic, K., *et al.*, 2013. Fossil musculature of the most primitive jawed vertebrates. *Science 341*(6142), 160–164.

Trinajstic, K., *et al.*, 2022. Exceptional preservation of organs in Devonian placoderms from the Gogo lagerstätte. *Science 377*(6612), 1311–1314.

Biography:
John Curtin Distinguished Professor Kate Trinajstic has been working as a palaeontologist in Western Australia for the last 23 years, having graduated with a PhD from UWA, where she continued as a postdoctoral fellow until moving to Curtin University in 2009 as a Curtin Research Fellow. She was awarded the Malcolm McIntosh Prize for Physical Scientist (2010), one of the prestigious Prime Minister's Prizes for Science for her work using synchrotron and micro CT to investigate and interpret soft tissues preserved in fossil fish. In 2011, she was awarded a QEII Fellowships from the ARC to continue work on soft-tissue preservation within the Gogo fishes. With colleagues she discovered fossil embryos and presented the earliest evidence of live birth within jawed vertebrates and has led research on soft-tissue anatomy of the Gogo fishes.

All microbialites are not created equal: lessons from the Bahamas and Shark Bay, Western Australia

R. Pamela Reid*, Erica P. Suosaari, Amanda M. Oehlert, Clément G.L. Pollier, and Christophe Dupraz

R. Pamela Reid [preid@rsmas.miami.edu], Department of Marine Geosciences, Rosenstiel School of Marine, Atmospheric, and Earth Science, University of Miami, Miami, FL 33149, USA and Bahamas Marine EcoCentre, Miami, FL 33158, USA; Erica P. Suosaari [suosaarie@si.edu], Bahamas Marine EcoCentre, Miami, FL 33158, USA, Department of Mineral Sciences, National Museum of Natural History, Smithsonian Institution, Washington, DC 20560, USA, and Bush Heritage Australia, 395 Collins St., Melbourne, VIC 3000, Australia; Amanda M. Oehlert [aoehlert@rsmas.miami.edu] and Clément G.L. Pollier [clement.pollier@earth.miami.edu], Department of Marine Geosciences, Rosenstiel School of Marine, Atmospheric, and Earth Science, University of Miami, Miami, FL 33149, USA; Christophe Dupraz [christophe.dupraz@geo.su.se], Department of Geological Sciences, Stockholm University, SE-106 91 Stockholm, Sweden.

As living representatives of Earth's earliest ecosystems, modern microbialites provide a window to the past, allowing us to address critical questions regarding microbialite accretion and growth. In this presentation, we consider how environmental and microbial forces that characterise living ecosystems in the Bahamas and Shark Bay interact to form an initial microbialite architecture, which in turn establishes distinct evolutionary pathways. A new conceptual 3D model for microbialite accretion is presented, which emphasises the importance of a dynamic balance between extrinsic and intrinsic factors in determining initial architecture. We then explore how early taphonomic and diagenetic processes modify initial architecture, culminating in various styles of preservation in the rock record. The timing of lithification of microbial products is critical in determining growth patterns and preservation potential. Results show that all microbialites are not created equal; the unique evolutionary history of an individual microbialite matters.

Biography:
Pam is Professor of Marine Geosciences at the Rosenstiel School of Marine and Atmospheric Science, University of Miami. Specialising in sedimentological studies of modern carbonate environments, she has more than a hundred peer reviewed scientific publications. A focus of Pam's research for the past three decades has been modern microbial buildups in the Bahamas and Shark Bay, Western Australia. Working closely with microbial ecologists, molecular biologists, and geochemists, Pam has spearheaded extensive field campaigns and laboratory studies that have resulted in fundamental new insight into processes forming living analogs of Earth's oldest macrofossils.

Photo: Pam preparing to sample Bahamian stromatolites, Exuma Cays. Credit: Jack Fell

PALAEO DOWN UNDER 3
10-14 JULY 2023

The changing face of Australia's dinosaurian fauna: reflections on the past and glimpses into the future

Steven W. Salisbury*

Steven W. Salisbury [s.salisbury@uq.edu.au], School of Biological Sciences, The University of Queensland, Brisbane, QLD 4072, Australia.

New discoveries, reassessments of old specimens, and the sharing of First Nations knowledge have dramatically transformed our collective understanding of Australia's dinosaurian fauna over recent decades.

Before the 1980s, Australian dinosaurian fossils were rare. These fossils were regarded either as relics of dinosaurs that had gone extinct elsewhere, or as early representatives of groups typical of the Northern Hemisphere. More recent discoveries from mid-Cretaceous rocks have shown that most Australian dinosaurs display affinities with groups that were spread across landmasses that were previously part of Gondwana. Megaraptoran theropods, titanosauriform sauropods, non-hadrosauriform ornithopods and parankylosaurian thyreophorans are now key elements of Australia's dinosaurian fauna.

New insights into Australia's dinosaurian fauna prior to the mid-Cretaceous have come mainly from footprints. Reassessments of tracks from the Upper Triassic and Jurassic coalfields of Queensland point to the presence of early sauropodopomorphs, small- and large-bodied theropods, thyreophorans and small-bodied ornithopods. A much-expanded understanding of the dinosaurian track fauna of Western Australia's Broome Sandstone shows that the general composition of Australia's mid-Cretaceous dinosaurian fauna was present at the start of the Cretaceous, but contained colossal sauropods, large hadrosaur-like ornithopods, and a higher diversity of both thyreophorans (including stegosaurs) and theropods.

Significantly, recent research on the dinosaurian tracks of Western Australia has been conducted through respectful collaboration with First Nations peoples. Knowledge of dinosaur tracks in the Saltwater Culture of the West Kimberley is woven into the Bugarrigarra ('Dreamtime'). Goolarabooloo Knowledge Holders have shared parts of this knowledge with people who will listen and treat it respectfully as part of Country. The 'opening of the knowledge valve' in the Kimberley has provided a glimpse of what post-colonial palaeontology might look like in Australia, where different ways of knowing about fossils enrich their value as part of our unique natural, geological and cultural heritage.

Biography:
Steve Salisbury is an Associate Professor in the School of Biological Sciences at The University of Queensland, where he is head of the UQ Dinosaur Lab and Chair of First Nations Engagement. He is also an Associate Editor for the Journal of Vertebrate Paleontology, and a Scientific Board member of the Jurassic Foundation, an international funding body dedicated to helping advance the careers of young scientists and researchers in underprivileged nations.

Steve's research focuses on the evolution of Gondwanan continental vertebrates, in particular dinosaurs and crocodilians. He is also interested in vertebrate biomechanics and using living animals to better understand the anatomy, behaviour and evolution of extinct ones. Since completing his PhD in 2001, Steve's research has taken him all over Australia, New Zealand and even the frozen vastness of Antarctica.

Some of Steve's research highlights include the description of *Isisfordia duncani*, the world's most primitive modern crocodilian, the recognition of an avian infectious disease in *Tyrannosaurus rex*, and an iconoclastic reboot of Australia's dinosaur 'stampede' at Lark Quarry (most of them were swimming!). In the Kimberley,

he works closely with local First Nations groups, and in 2011 his research there helped secure National Heritage Listing for the dinosaurian tracks of the Dampier Peninsula, and subsequently contributed to the collapse of a $40+ billion LNG development at Walmadany (James Price Point), 50 km north of Broome. The results of Steve's team's six-year study of the dinosaurian tracks of the Walmadany area were published as the 2016 Memoir of the Journal of Vertebrate Paleontology.

Photo: Steven Salisbury at Roebuck Bay, Western Australia. Credit: Julia Rau.

In: Abstract book and Conference Guide: Palaeo Down Under 3, 10–14 July 2023. Australasian Palaeontologists, Perth, Western Australia, 129 pp.

Palaeoecology and taphonomy of the McGraths Flat Lagerstätte

Matthew R. McCurry*, Tara Djokic, David Cantrill, Paulo Vasconcelos, Patrick Smith, and Michael Frese

Matthew R. McCurry [matthew.mccurry@austmus.gov.au], Tara Djokic [t.djokic@unsw.edu.au], and Patrick Smith [Patrick.Smith@austmus.gov.au], Australian Museum, 1 William St, Sydney, NSW 2010, Australia; David Cantrill [david.cantrill@rbg.vic.gov.au], Royal Botanic Gardens Victoria, Private Bag 2000, South Yarra, VIC 3141, Australia; Paulo Vasconcelos [p.vasconcelos@uq.edu.au], School of Earth Sciences, The University of Queensland, Brisbane, QLD 4072, Australia; Michael Frese [michael.frese@canberra.edu.au], Faculty of Science and Technology, University of Canberra, Bruce, ACT 2601, Australia.

The recent discovery of McGraths Flat, an exceptionally well-preserved fossil deposit from New South Wales, has provided new insight into the palaeoecology of Miocene mesic ecosystems and the taphonomy of iron-rich fossil deposits. This talk will provide an overview and update of the discoveries being made at McGraths Flat. This Konservat-Lagerstätte hosts a rich diversity of microfossils, plants, fungi, insects, spiders, and vertebrate remains. The age of the deposit (16–11 Ma) has been determined using SEM imaging of microfossils on the surface of the goethite-rich sediments. We also used a combination of automated electron microscopy imaging and citizen science for the analysis of microfossils. The replacement with goethite has resulted in exceptional preservation of internal soft tissues and structures. Representative examples of fossils from the deposit (including a mygalomorph spider, a retropinnid fish and a bee) will be used to showcase the value of exceptionally preserved fossils for our understanding of the recent past. We propose a taphonomic model for the preservation of the fossil site based on preliminary geochemical analyses, faunal analyses and field mapping. Our analyses suggest that the iron in the deposit derived from nearby basalts that accumulated in the waters of an oxbow lake before precipitating to encase a wide variety of animal and plant species.

Biography:
Dr Matthew McCurry is a vertebrate palaeontologist employed at The Australian Museum and The University of New South Wales. His work has focused on understanding the ecology of extinct species using direct evidence from fossils as well as biomechanical analyses. In 2022 he led a paper documenting a new Miocene Lagerstätte named McGraths Flat. The site has yielded many interesting discoveries that will form the basis of his talk.

Photo: Matthew McCurry examining a fossil from McGraths Flat. Credit: Salty Dingo

Thegosis, aka tooth sharpening

Mike Archer*

Mike Archer [m.archer@unsw.edu.au], School of Biological, Earth & Environmental Sciences, University of New South Wales, Sydney, NSW 2052, Australia.

Most people don't think too much about how and why their teeth do what they do. Yet to those of us who are palaeontologists (which is why we're here for PDU3) or odontologists focused on discovering how teeth work, few things could be more important in terms of understanding the deliciously complex and fascinating entanglement teeth have not only with our food, but also with our deep-time history, complex social behaviours, feelings of stress, nightmares, flaking of tooth enamel, self-sharpening mechanisms (thegosis), painful jaw joints and muscles, and even our instincts to use our teeth as weapons to defend or attack others. Some dentists don't understand these things are related and, as a result, can make serious and costly mistakes by mismanaging what may be relatively easily solved problems that don't require reshaping your teeth or interfering with what are normal and important activities for everyone including tooth-grinding.

This presentation will explain how and why most animals from sea urchins to guinea pigs, including we humans, use and importantly maintain, through the process called thegosis, their teeth so they can serve as lethal weapons as well as sharp food-processors. It will also explain the relationships between teeth, human aggression, beards, smiles, dog growls and many other complex but fascinating animal behaviours that are too often seriously misunderstood. Understanding these things and how many other animals use their teeth to avoid unwanted conflicts might even help to reduce the likelihood of a World War III.

Biography:

Professor Mike Archer AM, FAA, DistFRSN, FRZS, FACE, FWAAS (BA, Princeton Univ.; PhD, UWA) was born in Sydney, Australia, in 1945 but grew up in the Appalachian Mountains area of the USA (where he learned to make moonshine and play the 5-string banjo). Since 1967 when he returned to Australia as a Fulbright Scholar, he has been a Research Assistant in the Western Australian Museum, Curator of Mammals in the Queensland Museum, Director of the Australian Museum in Sydney, Dean of Science at the University of New South Wales and currently Professor at UNSW. Most of his research has focused on fossil deposits particularly those in the Riversleigh World Heritage Area since 1976, developing innovative strategies to save endangered living species such as the critically endangered Mountain Pygmy-possum, and efforts to bring iconic Australian species such as the extinct Gastric-brooding Frog back to life. He has supervised/co-supervised more than 100 Honours, MSc and PhD research students and produced >400 scientific publications and books.

In: Abstract book and Conference Guide: Palaeo Down Under 3, 10–14 July 2023. Australasian Palaeontologists, Perth, Western Australia, 129 pp.

PALAEO DOWN UNDER 3
10-14 JULY 2023

ORAL ABSTRACTS

in alphabetical order of first author surname

* indicates presenting author

Western Australian fossils in another dimension!

Heidi J. Allen*, Sarah K. Martin, Ben Myers, Simon P. Johnson, and David McB. Martin

The state of Western Australia boasts a fossil record that extends over a period of at least 3.5 billion years, making it the longest record of life anywhere on Earth. The Geological Survey of Western Australia (GSWA) palaeontology collection includes approximately 45 000 macrofossils and 16 000 slides of fossil material primarily from WA fossil localities. GSWA also curates knowledge of WA's fossil heritage within a Palaeontology and Geoheritage Section (within the State Geoscience Branch) whose activities include palaeontology project work, palaeontology collection management, geoheritage administration, and public advice on both topics. GSWA has recently adopted 3D technology in palaeontology and geoheritage projects with the acquisition of two handheld Artec 3D scanners. Some examples of the integration of 3D models in GSWA palaeontology project work includes the systematic description of macrofossils from both core and outcrops; detailed morphometrics and description of specimens on loan from other collections; and work on modern microbialite localities. Geoheritage applications consist primarily of scanning significant outcrops or observed damage at vulnerable sites, which will permit ongoing observation and site management. For the collections, 3D scanning will be used to disaster-proof type and figured macrofossils by creating a digital 'back-up' of these critical specimens. Scanning will also improve the collection's accessibility, permitting international and interstate researchers to work on materials without needing to physically loan specimens in some instances. This contribution will present case studies of GSWA palaeontological projects applying 3D technology.

Heidi-Jane Allen [Heidi.allen@dmirs.wa.gov.au], Sarah Martin [Sarah.Martin@dmirs.wa.gov.au], Simon Johnson [Simonpaul.Johnson@dmirs.wa.gov.au], and David Martin [David.Martin@dmirs.wa.gov.au], Geological Survey of Western Australia, Department of Mines Industry Regulation and Safety, 100 Plain St, East Perth, WA 6004, Australia; Ben Myers [Ben.Myers@thinglab.com.au], Thinglab, 7A Kent St, Yarraville, VIC 3013, Australia.

Exploring the origins of complex life: documenting the first occurrence of the 'string of beads' from the North Australian Craton

Heidi J. Allen*, Christopher Phillips, David McB. Martin, Peter Haines, Yongjun Lu, and Imogen Fielding

Horodyskia, originally recognised from the Appekunny Formation, Montana, are problematic bedding-plane markings that resemble a 'string of beads'. Later recognised in Western Australia, Tasmania, Siberia, India and China, its biological affinity has remained contentious. *Horodyskia* has been variably referred to as prokaryotic colonies, fungi, brown algae, foraminifera, trace fossils, eumetazoans or abiotic in origin, with documented occurrences ranging in age from Mesoproterozoic–Ediacaran.

Here we document a sample from the Kimberley region of WA, originally collected by Arthur Wade in 1924 from flaggy sandstones of the Wade Creek Formation and accessioned in the Commonwealth Palaeontology Collection (CPC194). Previously interpreted as a crustacean trace fossil, this specimen is assigned to the genus *Horodyskia* based on comparable morphology. Distinctive tool marks are present in other material from the locality (CPC195), as well as features that might represent a holdfast similar to those documented with *Horodyskia* from elsewhere.

The age of the Wade Creek Formation is poorly constrained; however, limited detrital zircon geochronology yielded a LA–ICP–MS maximum depositional age at 1658 ± 18 Ma (GSWA 216675). The youngest zircons from the unconformably overlying Ahern Formation has a LA–ICP–MS maximum depositional age of 1316 ± 26 Ma (GSWA 216677). These data together suggest the Wade Creek Formation broadly overlaps with the age of other known WA occurrences of *Horodyskia*. All 49 previously documented WA occurrences are located on the West Australian Craton; this *Horodyskia* locality from the Osmond Basin on the North Australian Craton could have applications in validating differing tectonic models for the assembly of Proterozoic Australia.

Heidi-Jane Allen [Heidi.allen@dmirs.wa.gov.au], Christopher Phillips [Christopher.Phillips@dmirs.wa.gov.au], David Martin [David.Martin@dmirs.wa.gov.au], Peter Haines [Peter.Haines@dmirs.wa.gov.au], Yongjun Lu [Yongjun.Lu@dmirs.wa.gov.au], and Imogen Fielding [Imogen.Fielding@dmirs.wa.gov.au], Geological Survey of Western Australia, Department of Mines Industry Regulation and Safety, 100 Plain St, East Perth, WA 6004, Australia.

Using geometric morphometrics to identify interspecific differences in snake and varanid fossils

Ammresh*, Jane Melville, and Alistair Evans

The large-scale biodiversity and macroecological patterns we observe today are an outcome of a long and dynamic evolutionary history. Synthesis and integration of fossil data is critical for resolving the temporal dynamics of ecological communities, which will then allow an understanding of processes driving current patterns and predicting into the future. I aim to look at snake and varanid fossils from five fossil sites in different latitudinal gradients across Australia (Chillagoe Caves, Queensland; Mount Etna, Queensland; Cathederal Cave, New South Wales; Lower Glenelg Caves, Victoria; and Naracoorte Caves, South Australia). By using a geometric morphometric (GM) approach, I hope to identify distinctive osteological characters in extant species and compare them with the most commonly retrieved element for varanids (the maxillae and dentaries) and snakes (vertebrae). GM will be used to compare shape disparity of these elements through time, including extant diversity. Many sites have relegated snake vertebrae as unidentifiable down to a species or genus level due to the extremely homogeneous shape of the vertebrae. However, it is hoped that utilising a GM approach will allow us to identify these species to as far down the tree as possible, thereby allowing further insights into species distributions and occurrences, as well as answering macroecological questions and assisting in climate modelling.

Ammresh [ammresh@monash.edu] and Alistair Evans [alistair.evans@monash.edu], School of Biological Sciences, Monash University, 25 Rainforest Walk, Clayton, VIC 3800, Australia; Jane Melville [jmelv@museum.vic.gov.au], Terrestrial Zoology, Natural Zoology, Museums Board of Victoria (Museums Victoria), GPO Box 666, Melbourne, VIC 3001, Australia.

Walking 'worms' in ancient armour: geometric morphometrics of the enigmatic Cambrian lobopodian *Microdictyon sinicum*

Eleanor Beidatsch*, Nicolás Campione, Michael Steiner, Jianni Liu, and Marissa J. Betts

Microdictyon was an early onychophoran from the Cambrian (*ca* 518 Ma). Historically, *Microdictyon* fossils were limited to hard, isolated plates found globally alongside other small shelly fossils (Topper *et al.* 2011). Poor preservation of soft tissues made it difficult to taxonomically place *Microdictyon*, and full morphological resolution was only achieved following the discovery of complete body fossils in the Chengjiang Lagerstätte, China (Pan *et al.* 2017). *Microdictyon sinicum* was erected based on these fossils, which revealed that the plates were serially paired sclerites extending the length of a worm-like body, with all but one pair associated with a set of soft legs (Chen *et al.* 1995). Despite this important discovery, there has been no quantitative study of the nature of sclerite variation, of how sclerite shape changes along the body or of sclerite shape change during growth. To explore sclerite variation and growth, this study applied 2D geometric morphometrics to 33 complete (or near complete) specimens of *M. sinicum* from Chengjiang, sourced from original photos and published literature (Chen *et al.* 1995). Each sclerite was digitised separately, totalling 235 sclerites, each outlined by a series of 49 sliding semilandmarks and one topologically homologous landmark. Following a generalised Procrustes analysis, a principal component analysis revealed consistent grouping of sclerites in morphospace along PC1, describing anteroposteriorly elongate to dorsoventrally elongate shapes. This morphospace tracks a transition of sclerite shapes along the body, with significant pairwise differences between many sclerite positions. Interestingly, sclerite shape is not correlated to the size of the organism at any position, indicating largely isometric growth in *M. sinicum*, suggesting similar developmental progression to their modern relatives (Oliveira *et al.* 2019). This study shows that geometric morphometrics can reveal critical new data for enigmatic taxa like *M. sinicum*, such as trends in sclerite shape transition, and can shed light on long-standing questions regarding development trends in problematic fossil taxa.

Chen, Jun-Yuan, Zhou Gui-Qing & Ramskold, L., 1995. The Cambrian lobopodian *Microdictyon sinicum*. *Bulletin of National Museum of Natural Science 5*, 1–93.

Oliveira, I.D.S., Kumerics, A., Jahn, H., Müller, M., Pfeiffer, F. & Mayer, G., 2019. Functional morphology of a lobopod: case study of an onychophoran leg. *Royal Society Open Science 10*, 191–200.

Pan, B., Topper, T.P., Skovsted, C.B., Miao, L. & Li, G., 2017. Occurrence of *Microdictyon* from the lower Cambrian Xinji Formation along the southern margin of the North China Platform. *Journal of Paleontology 1*, 59–70.

Topper, T.P., Brock, G.A., Skovsted, C.B. & Paterson, J.R., 2011. *Microdictyon* plates from the lower Cambrian Ajax Limestone of South Australia: Implications for species taxonomy and diversity. *Alcheringa: An Australasian Journal of Palaeontology 3*, 427–443.

Eleanor Beidatsch [ebeidats@myune.edu.au], and Nicolás Campione [ncampion@une.edu.au], Palaeoscience Research Centre, University of New England, Armidale, NSW 2351, Australia; Michael Steiner [michael.steiner@fu-berlin.de], Shandong University of Science and Technology, College of Earth Science and Engineering, 579 Qianwangang Road, Qingdao, 266590, People's Republic of China; Jianni Liu [eliljn@nwu.edu.cn], State Laboratory of Continental Dynamics, Shaanxi Key Laboratory of Early Life and Environment and Xi'an Key Laboratory of Paleo-bioinformatics, Northwest University, No.229, North Taibai Avenue, Xi'an, Shaanxi, People's Republic of China; Marissa J. Betts [marissa.betts@une.edu.au], Palaeoscience Research Centre/LLUNE, University of New England, Armidale, NSW 2351, Australia.

The shellies will tell all: multi-proxy stratigraphy and correlation of the Thorntonia Limestone (Cambrian Stage 4 – Wuliuan) southeastern Georgina Basin

Marissa J Betts*, James D. Holmes, Patrick M. Smith, Evelyn M. Mervine, Daniel A. Stirling, and John R. Paterson

Biostratigraphy and correlation of the Cambrian successions of northern Australia have been predominantly based on trilobite and agnostid occurrences. Select studies have documented the associated shelly fossils that occur in these successions, but they have remained underutilised for applications of relative dating and correlation. Several recent (Australian and international) studies have demonstrated that Cambrian shelly fossil assemblages have great capacity to facilitate regional and global correlation. New cores drilled near Boulia (western Queensland) through the Cambrian succession in the Georgina Basin have yielded an abundant and diverse shelly fossil fauna, extracted from the Thorntonia Limestone and overlying Arthur Creek Formation via traditional acid-leaching methods. This study concentrates on the Thorntonia Limestone from these cores, integrating the biostratigraphic ranges of shelly fossils with new lithologic and stable-isotope chemostratigraphic data in order to place the unit in a regional and global chronostratigraphic context. This study has documented the ranges of a total of 38 fossil taxa from the Thorntonia Limestone, including trilobites, agnostids, bradoriids, lobopodians, brachiopods, molluscs, hyoliths, echinoderms and 'sponges'. This fauna demonstrates close affinity (often via species-level correlations) with successions in other northern Australian Cambrian basins, but also with units in South Australia, New South Wales and other Cambrian palaeoterranes, e.g. Laurentia, North and South China, Antarctica and West Gondwana. Previously, the Thorntonia Limestone has been considered upper Cambrian Series 2, Stage 4 (Ordian) in age across the southern Georgina Basin, with an additional early Wuliuan (early Templetonian) interval in the northeast. We present evidence that in the Boulia area of the basin the Thorntonia Limestone spans from upper Stage 4 (Ordian) through much of the Wuliuan (Templetonian) and potentially into the lower Drumian (Florian), with further implications for locating the Series 2 – Miaolingian boundary in Australia, sequence stratigraphic modelling of the Georgina Basin, and palaeobiogeographic interpretations.

Marissa J. Betts [mbetts7@une.edu.au], Palaeoscience Research Centre/LLUNE, University of New England, Armidale, NSW 2351, Australia; James D. Holmes [jamesholmes83@gmail.com], Department of Earth Sciences, Palaeobiology, Uppsala University, Villavägen 16, Uppsala 752 36, Sweden; Patrick M. Smith [Patrick.Smith@australian.museum], Palaeontology Department, Australian Museum Research Institute, Sydney and Department of Biological Sciences, Macquarie University, Sydney; Evelyn M. Mervine [e.mervine@uq.edu.au], Group Technical and Sustainability, Anglo American, Level 11, 201 Charlotte St, Brisbane, QLD 4000, and School of Earth and Environmental Sciences, The University of Queensland, Brisbane, QLD 4072, Australia; Daniel Stirling [Daniel.stirling@angloamerican.com], Anglo American Exploration, Level 11, 201 Charlotte St, Brisbane, QLD 4000 Australia; John R. Paterson [jpater20@une.edu.au], Palaeoscience Research Centre, University of New England, Armidale, NSW 2351, Australia.

Chronostratigraphy of the Cambrian Series 2 – Miaolingian boundary, western Stansbury Basin, South Australia

Courtney Birksmith, Glenn A. Brock*, Marissa J. Betts, James D. Holmes, and Zhiliang Zhang

The GSSP of the Series 2 – Miaolingian (= traditional lower–middle Cambrian) boundary has been ratified in South China based on the first appearance of the trilobite *Orychtocephalus indicus* coincident with a major negative δ13C excursion (Redlichiid–Olenellid Extinction Carbon isotope Excursion; ROECE). Unfortunately, *O. indicus* does not occur in Australian–Antarctic Cambrian successions and a lack of well-constrained isotopic data, along with cryptic disconformities, has impeded recognition (let alone formal definition) of the Series 2 – Miaolingian boundary in East Gondwana. New multiproxy data integrating chemostratigraphy (δ13C and δ18O) and shelly fossil biostratigraphy from subsurface cores in the western Stansbury Basin, South Australia, is presented. The sharp -5.3 ‰ δ13C peak in the Stansbury Limestone in core CURD-9 and the ~ -2.7 ‰ δ13C in core Port Julia-1A is interpreted to represent the global ROECE event and the Series 2 – Miaolingian boundary in this basin. The last occurrence of *Redlichia* sp. seemingly occurs below the ROECE level. New range extensions of key guide taxa including *Pagetia* sp. indet. within the Stansbury Limestone, below the interpreted ROECE event, is consistent with known occurrences of this genus in the GSSP. The enigmatic non-trilobite ecdysozoan *Chalasiocranos exquisitum* and the palaeoscolecid priapulid *Kaimenella* sp. aff. *K. reticulata* also occur below the ROECE horizon. A distinctive assemblage of organophosphatic brachiopods ranges across the interpreted Series 2 – Miaolingian boundary in the cores with *Micromitra* spp. restricted to Miaolingian Series. Importantly the brachiopod assemblage can be correlated between basins from South Australia, Northern Territory, New South Wales and Queensland, providing a potential means of approximately bracketing the Series 2 – Miaolingian boundary in East Gondwana.

Courtney Birksmith [courtney.birksmith@hdr.mq.edu.au], and Glenn A. Brock [glenn.brock@mq.edu.au], School of Natural Sciences, Macquarie University, NSW 2109, Australia; Marissa J. Betts [mbetts7@une.edu.au], Palaeoscience Research Centre, University of New England, Armidale NSW 2351, Australia; James D. Holmes [jamesholmes83@gmail.com], Department of Earth Sciences, Palaeobiology, Uppsala University, Villavägen 16, Uppsala 752 36, Sweden; Zhiliang Zhang [zhiliang.zhang@nigpas.ac.cn], State Key Laboratory of Palaeobiology and Stratigraphy, Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, Nanjing 210008, People's Republic of China.

That's random: the metre-scale distributions of *Dickinsonia* from Nilpena Ediacara National Park

Phillip C. Boan*, Scott D. Evans, and Mary L. Droser

The oldest evidence of motile complex benthic multicellular organisms occurs in Ediacaran aged rocks, and taxa such as the iconic *Dickinsonia*. At Nilpena Ediacara National Park (NENP), South Australia, the excavation of 33 fossiliferous bedding planes of the sandstone-dominated Ediacara Member of the Rawnsley Quartzite reveals in situ complex communities of these early motile forms. At NENP, *Dickinsonia* occur in abundance, with over 500 individuals preserved across the site's fossiliferous beds providing the opportunity to examine both inter- and intraspecific spatial distributions. In this study, we investigated six beds using Spatial Point Pattern Analysis (SPPA). Beds vary in mat type and maturity, taxonomic diversity, and *Dickinsonia* population size. Five out the six populations were fitted to a completely spatially random pattern, with an outlier exhibiting signs of environmental heterogeneity. No variation in spatial distribution was found when populations were split between large and small individuals, and these two size cohorts had no effect on each other's spatial distributions. Distributions examined in relation to other taxa on the beds indicated no spatial competition; rather, two beds showed attraction between *Dickinsonia* and other motile taxa. One possible explanation for this could be a result of inefficient nutrient absorption during osmotrophy, attracting other organisms to *Dickinsonia* as it fed. Gross spatial distribution and bivariate results imply that *Dickinsonia* was not impacted by spatial impediment from interspecific competition, metre-scale environmental heterogeneity, or other external factors for the majority of abundant populations (>20 individuals). Additionally, we find no indication of intraspecific competition for *Dickinsonia* or any change in the preferred food-resources with growth. These results differ from benthic sessile taxa *Tribrachidium*, *Rugoconites*, and *Obamus*, which all show varying degrees of aggregation NENP beds.

Phillip C. Boan [pboan001@ucr.edu], and Mary L. Droser [droser@ucr.edu], University of California, Riverside, Geology 1242, 900 University Ave, Riverside, CA 92521, USA; Scott D. Evans [sde22b@fsu.edu], Florida State University, Department of Earth, Ocean and Atmospheric Sciences 1011 Academic Way Tallahassee, FL 32303, USA.

Shaping up: morphology of *Tribrachidium* from Nilpena, South Australia

Tory Botha*, Emma Sherratt, Mary Droser, Jim Gehling, and Diego García-Bellido

The Ediacara biota is a suite of globally distributed, exceptionally preserved, soft-bodied fossils spanning from 575 Ma to the base of the Cambrian. Nilpena Ediacara National Park in the Flinders Ranges of South Australia preserves one of the most morphologically and taxonomically diverse assemblages of this period. *Tribrachidium heraldicum* is one of the more abundant taxa at this site (over 200 specimens) and is described as a circular organism, 3–40 mm in diameter, showing triradial symmetry. Our study utilises the application of rotational geometric morphometrics to determine whether any morphological change occurred between the specimens found in the Ediacara Member and the overlying informal Nilpena member, by observing their positioning in the morphospace. Additionally, 95 specimens of a new species of *Tribrachidium* have been collected and are compared to the type species *T. heraldicum* to quantify the morphological differences.

Tory Botha [tory.botha@adelaide.edu.au], and Emma Sherratt [emma.sherratt@adelaide.edu.au], School of Biological Sciences, Molecular Life Sciences Building, North Terrace Campus, The University of Adelaide, Adelaide, SA 5005, Australia; Mary Droser [droser@ucr.edu], University of California, Riverside, Geology 1242, 900 University Ave, Riverside, CA 92521, USA; Jim Gehling [gehling.jim@bigpond.com], Earth Sciences Section, South Australian Museum, North Terrace, Adelaide, SA 5000, Australia; Diego García-Bellido [diego.garcia-bellido@adelaide.edu.au], School of Biological Sciences, Molecular Life Sciences Building, North Terrace Campus, The University of Adelaide, Adelaide, SA 5005, and Earth Sciences Section, South Australian Museum, North Terrace, Adelaide, SA 5000, Australia.

Integrating biostratigraphy and chemostratigraphy with new U–Pb ID–TIMS dates from subsurface lower Cambrian rocks in the western Stansbury Basin, South Australia

Jack Castle-Jones*, Marissa J. Betts, Stefan Löhr, James D. Holmes, and Glenn A. Brock

The western Stansbury Basin is an early Cambrian sedimentary package of carbonates and siliciclastics, deposited in a carbonate platform to ramp environment on the Yorke Peninsula, South Australia. Research into the oldest Cambrian formations (Winulta Formation, Kulpara Formation and Parara Limestone) is hindered by poor surface outcrop; most stratigraphic data is derived from sampling fully cored petroleum drill holes (notably SYC 101 and Minlaton 1 cores), supplemented by sampling in active commercial quarries and rare surface outcrop. Current fossil ranges and occurrences of key small shelly taxa are at odds with contemporaneous formations of the Arrowie Basin in the Flinders Ranges, a consequence of the difficulty in sampling on Yorke Peninsula. To resolve this disparity, the goal of this research was to undertake detailed and systematic chronostratigraphic sampling of the oldest formations. Biostratigraphic work is ongoing, but preliminary results reveal that the Parara Limestone records the *Kulparina rostrata* Zone in a thin basal band, the *Micrina etheridgei* Zone in the lower part and the *Dailyatia odyssei* Zone in the Koolywurtie Limestone Member. Zircons recovered from three separate ash beds in the Parara Limestone in SYC 101 were analysed using ID–TIMS, which recovered U–Pb ages of 514.8 ± 0.2 Ma, 515.4 ± 0.2 Ma and 517.5 ± 0.2 Ma respectively, the latter being the oldest recovered geochronological date from any Cambrian sedimentary succession in Australia. The δ13C chemostratigraphy from SYC 101 and Minlaton 1 drill cores reveals the presence of a sharp positive excursion, interpreted to be the global MICE event stratigraphically between the 515.4 ± 0.2 Ma and 517.5 ± 0.2 Ma zircon dates within the *Pararia bunyerooensis* trilobite biozone. This multi-proxy chronostratigraphic approach facilitates high-resolution regional correlation with the Arrowie and eastern Stansbury basins, with potential links to Cambrian basins elsewhere in the world.

Jack Castle-Jones [jack.jones1@students.mq.edu.au], and Glenn A. Brock [glenn.brock@mq.edu.au], School of Natural Sciences, Macquarie University, NSW 2109, Australia; Marissa J. Betts [mbetts7@une.edu.au], Palaeoscience Research Centre, University of New England, Armidale, NSW 2351, Australia; Stefan Löhr [stefan.loehr@adelaide.edu.au], Department of Earth Sciences, Metal Isotope Group (MIG), University of Adelaide, Adelaide, SA 5005, Australia; James D. Holmes [jamesholmes83@gmail.com], Department of Earth Sciences, Palaeobiology, Uppsala University, Villavägen 16, Uppsala 752 36, Sweden.

Fossil rodents from Queensland: the story so far

Jonathan Cramb*, Julien Louys, Scott Hocknull, and Gilbert J. Price

Murid rodents form a substantial part of the modern Australian mammal fauna. Two major lineages are represented: hydromyines that arrived in Sahul during the late Neogene, and species of *Rattus* that probably arrived during the Pleistocene. Hydromyines have a fossil record in Australia extending to the middle Pliocene, but this is fragmentary and understudied, so reconstructing their evolutionary history relies heavily on molecular data. This creates a bias towards surviving lineages that likely skews our understanding of their biogeographic histories. Pliocene and Quaternary fossil deposits in Queensland have arguably produced the most significant records of the deep history of murids in Australia. Middle Pliocene fossils from Chinchilla are among the oldest in the country but preserve only a single named species, *Pseudomys vandycki*. New material collected since the description of this species suggests a taxonomic re-evaluation of this taxon may be warranted. Further north, the murids from the early Pleistocene Rackhams' Roost deposit at Riversleigh form the oldest diverse assemblage in Australia. It includes early representatives of several living clades (e.g. *Leggadina*, *Zyzomys*), but also seems to include evidence of additional invasions of Sahul by non-hydromyine murids. As these fossils are currently the only evidence of these incursions, they clearly warrant further taxonomic attention. By the middle and late Pleistocene, most fossil assemblages of murids from deposits outside Queensland are essentially modern taxonomically. In contrast, those in Queensland still contain numerous extinct taxa. This is best illustrated by fossils from the Mount Etna caves, where an entirely extinct assemblage of murids was associated with closed rainforest palaeoenvironments. Extinct murids are also a feature of fossil assemblages from Floraville, Chillagoe, and the Broken River. At face value, these records suggest that Pleistocene environmental changes had more severe effects on Queensland faunas in comparison to those in other parts of Australia.

Jonathan Cramb [jonathan.cramb@qm.qld.gov.au] and Scott Hocknull [scott.hocknull@qm.qld.gov.au], Queensland Museum, PO Box 3300, South Brisbane BC, QLD 4101, Australia; Julien Louys [j.louys@griffith.edu.au] Australian Research Centre for Human Evolution, Griffith University, Brisbane, QLD 4101, Australia; Gilbert J. Price [g.price1@uq.edu.au] School of Earth and Environmental Sciences, The University of Queensland, Brisbane, QLD 4072, Australia.

Quantification of MISS textures to untangle the relationship between matground and macrofossils of the Avalonian Ediacaran

Katie M. Delahooke*, Alexander G. Liu, Nile P. Stephenson, Charlotte G. Kenchington, and Emily G. Mitchell

The Avalonian Ediacaran fossils of Newfoundland comprise some of the oldest examples of complex macro-organisms. Prior to the advent of bioturbation in the Cambrian, the Ediacaran sea-floor was bound by microbial mats, which appear as an extensive and disparate range of microbially induced sedimentary structures (MISS) alongside these fossils. The importance of Ediacaran matgrounds, in both exceptional fossil preservation and as a food source, has been proposed by several authors, particularly in relation to the younger Ediacaran succession of South Australia. However, the relationship between microbial textures and Avalonian macrofossils has not yet been explored. In this study, we use two forms of quantitative texture analyses, namely surface metrology and persistent homology, to describe MISS textures in a novel way and to determine the impact of matground heterogeneity on Avalonian organisms. Surface metrology consists of calculating a suite of parameters, each describing a certain aspect of surface topography such as maximum peak height and skewness. The second method, persistent homology, is a topological method that instead describes shape through changes in connectivity of structures across multiple spatial scales. These analyses were applied to high-resolution 3D scans of 5.97 m^2 of the *ca* 574 Ma Pigeon Cove surface in Mistaken Point Ecological Reserve, Newfoundland, Canada. First, surface metrology and persistent homology were used to characterise different morphotypes of ivesheadiomorphs — 'pizza-disc' like structures — recovering several distinct clusters. Secondly, surface metrics were calculated via a moving window to map textural changes across the entire surface. We then used inhomogeneous Poisson models, random forests and maximum entropy to ascertain whether the spatial position of small rangeomorph fossils (n=62) were correlated to the textural heterogeneity. As MISS textures are a proxy for mat characteristics, we thus determine how matgrounds interacted with Avalonian ecological dynamics.

Katie M. Delahooke [kmd47@cam.ac.uk], Alexander G. Liu [agscl2@cam.ac.uk], and Charlotte G. Kenchington [cgk27@cam.ac.uk], Department of Earth Sciences, Downing St, University of Cambridge CB2 3EQ; Nile P. Stephenson [nps36@cam.ac.uk] and Emily G. Mitchell [ek338@cam.ac.uk], Department of Zoology, Downing Pl, University of Cambridge, CB2 3EJ, UK.

The Plio–Pleistocene is a clear departure from the present: ecological shifts evidenced from fauna at the Darling Downs, Queensland, Australia

Larisa R.G. DeSantis*, Gilbert Price, and Julien Louys

The continent of Australia is currently warming approximately thirty-five percent faster than the rest of the globe, with the warmest year on record coinciding with the most extreme bush fires. Although the effects of ongoing climate change are apparent over the past century, Australia has experienced pronounced aridification since the late Miocene/early Pliocene, transitioning from tropical forests to more open habitats. To better contextualise ongoing climate change, we assess the ecology and palaeobiology of mammalian faunas in Australia from the Pliocene to the Present in the Darling Downs region of Queensland Australia. Via the analysis of stable isotopes from tooth enamel and dental microwear texture analysis of the chewing surfaces of teeth, we clarify the ecology and palaeobiology of medium to large marsupials from the Pliocene Chinchilla Sands and Pleistocene Eastern Darling Downs faunas. By comparing these ancient marsupial mammal communities to extant marsupial mammals that inhabit these regions today, we further demonstrate that the most dramatic changes between past ecosystems are clearly between those of the Present and the Plio–Pleistocene — indicating that the Darling Downs region of today is disparate as compared to the past. Most notably, *Macropus giganteus* consumes vegetation that is ~5.6‰ higher in δ13C values today than during the past, indicating feeding in a significantly more open landscape. The Pliocene and Pleistocene of the Darling Downs are instead dominated by mixed-feeding and browsing taxa, with several taxa exhibiting diets disparate from modern analogues (e.g. an abundance of C4 browsers). Collectively, these deep-time temporal comparisons are a clear example of how ecological communities observed today do not represent the full range of ecological niches occupied in the past and highlight the dramatic climate-departures experienced today.

Larisa R.G. DeSantis [Larisa.desantis@vanderbilt.edu], Department of Biological Sciences, Vanderbilt University, Box 351634 Station B, Nashville, TN 37235-1634, USA; Gilbert Price [g.price1@uq.edu.au], School of Earth and Environmental Sciences, The University of Queensland, Brisbane, QLD 4072, Australia; Julien Louys [julian j.louys@griffith.edu.au], Australian Research Centre for Human Evolution, Griffith University, Brisbane, QLD 4101, Australia.

Billabong beauties — using freshwater mollusc fauna to reconstruct the palaeoecology of the Griman Creek Formation (Cenomanian), Lightning Ridge, Australia

Sherri Donaldson*

For over 100 years, rainbow-hued, opalised fossils have been found by artisanal miners around the outback town of Lightning Ridge, New South Wales. Here, the Griman Creek Formation (GCF), a key Cenomanian (100.2 – 96.6 Ma) deposit (Bell *et al.* 2019), preserves evidence for the final retreat of the intercontinental Eromanga Sea and subsequent emergence of fluvial floodplains. Terrestrial and aquatic vertebrate fossils are well known from the area due to their preservation as opal pseudomorphs; however, the numerous invertebrate and plant fossils have remained understudied. Freshwater molluscs comprise the vast majority of biomass recovered from the GCF and held in public collections, with tens of thousands of specimens available to study. This original study comprised over 21 000 individual specimens, with taxa divided into two classes, Bivalvia and Gastropoda, further split into four families: three gastropods (aquatic Thiaridae and Viviparidae, and a terrestrial Succineidae) (Hamilton-Bruce *et al.* 2002, Hamilton-Bruce & Kear 2010), and a family of bivalves (Unionidae) (Hocknull 2000). Mollusc fossils frequently retain morphological features that reveal how they functioned during life. This combined with known ecological preferences of modern analogues makes them excellent proxies for palaeoecological reconstructions. Through using known life habits and environments, this study identified four ecological niches across the region: riparian zones; flowing river channels and creeks; shallow riverbanks and ponds; and shallows and mudflats. Additionally, evidence of trophic interactions with other taxa (including predation) (Kear & Godthelp 2008) has helped refine the palaeogeography of the region. Ecological data were built into a model that mapped taxa occurrences across the 2000 km^2 region using GIS technology, reconstructing these complex ancient waterways for the first time.

Bell, P., Fanti, F., Hart, L., Milan, L., Craven, S., Brougham, T. & Smith, E., 2019. Revised geology, age, and vertebrate diversity of the dinosaur-bearing Griman Creek Formation (Cenomanian), Lightning Ridge, New South Wales, Australia. *Palaeogeography, Palaeoclimatology, Palaeoecology 514*, 655–671.

Hamilton-Bruce, R. & Kear, B., 2010. A possible succineid land snail from the Lower Cretaceous non-marine deposits of the Griman Creek Formation at Lightning Ridge, New South Wales. *Alcheringa 34*(3), 325–331.

Hamilton-Bruce, R.J., Smith, B.J. & Gowlett-Holmes, K.L., 2002. Descriptions of a new genus and two new species of viviparid snails (Mollusca: Gastropoda: Viviparidae) from the Early Cretaceous (middle-late Albian) Griman Creek Formation of Lightning Ridge, northern New South Wales. *Records of the SA Museum 35*(2), 193–203.

Hocknull, S., 2000. Mesozoic freshwater and estuarine bivalves from Australia. *Memoirs of the Queensland Museum 45*(2), 405–426.

Kear, B.P. & Godthelp, H., 2008. Inferred vertebrate bite marks on an Early Cretaceous unionoid bivalve from Lightning Ridge, New South Wales, Australia. *Alcheringa 32*, 65–71.

Sherri Donaldson [sherri.donaldson@edu.ac.uk], School of Geosciences, University of Edinburgh, Grant Institute, The King's Buildings, James Hutton Road, Edinburgh, EH9 3FE, Scotland, UK.

The Integrated Record of Ancient Life: palaeo-databasing for a Big Data future

Elizabeth M. Dowding*, Emma M. Dunne, and Ádám T. Kocsis

Online data repositories and FAIR practises have fundamentally changed palaeontology. Over the last decades, the increasing availability and accessibility of palaeontological data have both broadened the scope of palaeontological research, and opened up entirely new avenues of investigation. Though there is only one fossil record, it is represented in multiple, scattered databases such as the Paleobiology Database, iDigBio, Neptune, Neotoma, New and Old Worlds, the Geobiodiversity Database, the New Zealand Fossil Record File, and Triton. These databases were initially created and developed in relative isolation and are maintained by a few extremely dedicated individuals, who represent only a fraction of the community that uses these data. Many palaeontological databases were created with particular research questions in mind, and over time have been fruitfully exploited in unintended ways. The result is numerous 'data islands', which hold a wealth of information yet are extremely difficult to integrate. This is due to multiple interconnected factors, including differences in data standardisation, aging database systems, and redundancy in existing data. Additionally, the absence of long-term funding constantly threatens the maintenance and development of palaeontological databases. We will show that the use of compiled data in palaeontology has moved faster than the development of best practices for data management, funding, data citation, and academic recognition. A system-wide upgrade to the palaeontological data infrastructure is urgently required to sustain and increase current levels of research. The Integrated Record of Ancient Life (IRAL) is a community-driven initiative to develop and host an integrated data repository with a standardised data infrastructure. The first steps of IRAL have been to build a community of database users, developers, and maintainers to develop strategies for solidifying a sustainable future for palaeontological data and research. This presentation will also outline goals and pathways of the IRAL, in which we invite all to join.

Elizabeth M. Dowding [dowdingem@gmail.com], Emma M. Dunne [emma.dunne@fau.del], and Ádám T. Kocsis [adam.kocsis@fau.de], Friedrich-Alexander-Universität Erlangen-Nürnberg, Loewenichstraße 28 91054 Erlangen, Germany.*

Tiny leviathans of the Pacific Rim: insights into the morphology of immature archaic toothed baleen whales

Ruairidh Duncan*, Alistair Evans, Justin Adams, and Erich Fitzgerald

The baleen whales (Mysticeti) peaked early in their diversity during the Oligocene epoch throughout the Pacific rim and the northern Atlantic Ocean. This diversity was in large part a consequence of the abundance of toothed mysticetes, a paraphyletic group of cetaceans that possessed both archaic baleen whale characteristics and fully denticulate jaws. They are absent from post-Oligocene strata, and only the edentulous Chaeomysticeti persist to the modern day. Although numerous genera are described, the dearth of referred specimens presents hindrances to our understanding of phylogeny, development, and palaeoecology. Such informative samples include those representing ontogenetic variation, as well as those preserving phylogenetically and functionally informative morphology. In this study, we describe immature specimens from two pivotal clades of toothed Mysticeti: the species rich Aetiocetidae of the North Pacific and the far less speciose Mammalodontidae of the western South Pacific. The new aetiocetid material, from the Olympic Peninsula of Washington, USA, preserves exceptional detail of undersampled anatomy, permitting identification of ontogenetic changes and description of rarely preserved morphologies. One specimen from the lower Oligocene Makah Formation represents *Fucaia*, an early aetiocetid recovered from two nearby sites. This specimen is exceptionally preserved in comparison to most Aetiocetidae, preserving nasal turbinates and a partial postcranial skeleton. The skull morphology is relatively similar in proportion to presumed skeletally mature specimens of *Fucaia*. A new specimen of Mammalodontidae from the upper Oligocene Jan Juc Marl of Victoria, Australia, is also described. This represents an ontogenetically young individual which is stratigraphically older than any previously described toothed mysticetes from Australia. This specimen is noteworthy as it preserves the auditory regions of the basicranium and possesses an earbone morphology quite unlike any previously described mammalodontid. Collectively, this material permits insights into previously undescribed anatomy and the palaeobiology of two putatively transitional mysticete families.

Ruairidh Duncan [ruairidh.duncan@monash.edu], and Alistair Evans [alistair.evans@monash.edu], Evans EvoMorph Lab, Room 226, 18 Innovation Walk, School of Biological Sciences, Monash University, Clayton, VIC 3800, Australia; Justin Adams [justin.adams@monash.edu], 10 Chancellor's Walk, Monash University, Clayton, VIC 3800, Australia; Erich Fitzgerald [efitzgerald@museum.vic.gov.au], Museum Victoria, P.O. Box 666, Melbourne, VIC 3001, Australia.

A molecular dissection of an exceptionally preserved fish: soft-tissue preservation in the world's most productive lacustrine lagerstätte

Amy L. Elson*, Jessica. H. Whiteside, Joseph Bevitt, Lance Grande, and Kliti Grice

The well-studied inorganic fossil record has provided a basis towards understanding the evolution of organisms over geologic time; however, rarer-preserved organic molecules often associated with exceptional fossils have been massively understudied in comparison. The Green River Formation (54–47 Ma; Smith *et al*. 2010) represents a suite of extremely productive lakes in the United States of America, spanning Utah, Colorado, and Wyoming. These lacustrine deposits are renowned across the globe for their abundant and exceptional fossil preservation, yielding excellent fossils of flora and fauna preserved during a critical interval of evolutionary and climatic change in a hot-house, early Cenozoic world (Zachos *et al.* 2001). Here, results from an extensive series of imaging techniques, along with organic, inorganic, and isotopic analyses are presented. Fossil samples collected from the Green River Formation (in August 2022) include a wide array of exceptionally preserved vertebrates, plants, and coprolites. Delicate soft tissue, along with vertebrae from the spinal column, thin bones, eyes etc., have been isolated and extracted from a large *Diplomystus* fish sample collected from the famous 18-inch layer in Fossil Lake, Green River Formation (Grande 2001). This permits unprecedented biomarker comparison between different compartments of a fossilised fish versus the surrounding matrix, supporting the isolation of different microbial (and therefore biomarker) communities within well-preserved fossils. Careful organic geochemical analysis of excellent fossil samples collected 'fresh' from the field has allowed for an increased understanding of the past evolution and environments of these organisms, as well as the unique conditions leading to exceptional soft-tissue and molecular preservation.

Grande, L., 2001. An updated review of the fish faunas from the Green River Formation, the world's most productive freshwater lagerstätten. In *Eocene biodiversity: unusual occurrences and rarely sampled habitats*. Gunnell, G.F., ed., Springer Science, New York, USA, 1–38.

Smith, M.E., Chamberlain, K.R., Singer, B.S. & Carroll, A.R., 2010. Eocene clocks agree: Coeval $^{40}Ar/^{39}Ar$, U-Pb, and astronomical ages from the Green River Formation. *Geology 38*, 27–530.

Zachos, J., Pagani, M., Sloan, L., Thomas, E. & Billups, K., 2001. Trends, rhythms, and aberrations in global climate 65 Ma to present. *Science 292*, 686–693.

Amy L. Elson [amy.elson@curtin.edu.au] and Kliti Grice [K.Grice@curtin.edu.au], WA Organic and Isotope Geochemistry Centre, The Institute for Geoscience Research, School of Earth and Planetary Sciences, Building 500, Curtin University, Kent St, Bentley WA 6102, Australia; Jessica H. Whiteside [jhwhiteside@sdsu.edu], Department of Geological Sciences, 5500 Campanile Dr., San Diego State University, San Diego, CA 92182-1020 USA; Joseph J. Bevitt [jbv@ansto.gov.au], Australian Nuclear Science and Technology Organisation, Research Office, B3, New Illawarra Road, Lucas Heights, NSW 2234, Australia; Lance Grande [lgrande@fieldmuseum.org], The Field Museum, 1400 South DuSable Lake Shore Drive, Chicago, Illinois, USA.

Early Eocene tree frog from the Tingamarra Local Fauna, Murgon, with new approaches to identify Australian anurans

Roy M. Farman*, Michael Archer, and Suzanne J. Hand

The origins and evolution of Australia's frogs are poorly understood. Although the present Australian frog fauna is diverse and assumed to have originated in South America and later from Asia, it has a scant fossil history. The diversification of Australia's oldest frogs, and the dispersal of frogs from South America via Antarctica, are both thought to have occurred during the early Eocene or before according to molecular phylogenies. Herein, we present a new fossil frog from the early Eocene Tingamarra fossil locality at Murgon, southeastern Queensland, Australia. We compare the new Tingamarra fossil frog's diagnostic ilium with those of four Gondwanan families using micro-computed tomography scans and three-dimensional geometric morphometrics. The earliest-known tree frog in Australia is identified from this Tingamarra fossil ilium, which, according to morphometric and morphological investigations, represents a pelodryadid frog belonging to the genus *Litoria*. All fossil frogs from Australia have been shown to be most closely related to congeners that are alive today. The Tingamarra *Litoria* species not only provides a new fossil calibration for molecular phylogenies of pelodryadids and frog phylogenies more generally, it also confirms that pelodryadids were present in Australia by the early Eocene, when Australia was still connected to Antarctica and South America as one of the last remnants of Gondwana.

Roy M. Farman [r.farman@unsw.edu.au], Michael Archer [m.archer@unsw.edu.au], and Suzanne J. Hand [s.hand@unsw.edu.au], School of Biological, Earth and Environmental Sciences, University of New South Wales, Sydney, NSW 2052, Australia.

Raiders of the lost art: revealing the lost patterns of molluscan fossil shells with UV light

Mahala Fergusen*, Elizabeth Reed, and Diego García-Bellido

The Murray Basin of southern Australia is home to a succession of Cenozoic formations called the Murray Group (late Paleocene to late Pliocene). These units preserve an incredibly rich and diverse array of marine invertebrate fauna. It was from this area that Ralph Tate first described much of the southeastern Australian Cenozoic molluscan fauna in the late 19th century. However, never detailed before are the colour patterns these shells possessed in life. Pigment degrades quickly after death and is rarely preserved in fossil specimens; however, in modern molluscan systematics, colour and pattern are often used in species descriptions. When viewed under ultraviolet (UV) light, fossil pigmentation patterns can be revealed as many shells present fluorescence. Here, the original pigmentation patterns are revealed for several taxa from the early middle Miocene Murbko Marl Member of the Cadell Formation, north of Blanchetown, South Australia.

Mahala Fergusen [mahala.fergusen@adelaide.edu.au], Elizabeth Reed [liz.reed@adelaide.edu.au], and Diego García-Bellido [diego.garcia-bellido@adelaide.edu.au], School of Biological Sciences, Molecular Life Sciences Building, North Terrace Campus, The University of Adelaide, Adelaide, SA 5005, Australia; Elizabeth Reid and Diego García-Bellido also Earth and Biological Sciences, South Australian Museum, North Terrace, Adelaide, SA 5000, Australia.

Micro-ornamentation, ultrastructure, and homology among early Cambrian tommotiids

Alyssa Fjeld*, Zhiliang Zhang, and Glenn A. Brock

Tommotiids are an important but enigmatic group of early Cambrian lophotrochozoans, characterised by a complex external skeleton called a scleritome composed of fused or cataphract organophosphatic sclerites produced by marginal accretion. Currently, tommotiids are informally subdivided into three main groups: mobile, slug-like camenellans, which have a complex array of sclerites arranged in serial rows along the length of the body, and two sessile groups, the tubiform eccentrothecimorphs and bimembrate tannuolinids. Tommotiids are found in hyperabundance in lower Cambrian carbonate deposits across the Arrowie Basin, South Australia, which provided the raw material research presented here. This research focused on detailed comparison of micro-ornamentation and internal ultrastructure of fused sclerite rings and a wide range of isolated sclerite morphotypes of key eccentrothecimorph taxa, as well as the paterinate brachiopod *Askepasma*. New data reveal that 1st and 2nd order lamination, penetrative polygonal structures (PPS), and ornamental textures are shared among all eccentrothecimorphs and all described *Askepasma* species. The mode of fusion between sclerites in the scleritome of *Eccentrotheca helenia* is revealed for the first time. Bulbous micro-ornament and internal PPS structures provide a strong base for sclerite articulation for eccentrothecimorphs, whereas these ultrastructures are weakly developed in paterinate brachiopods. The close similarity and variety of micro-ornament and distinctive ultrastructure between eccentrothecimorphs and paterinate brachiopods strongly supports a homologous relationship and suggests eccentrothecimorphs can be placed in the stem of the Brachiozoa (Brachiopoda + Phoronida).

Alyssa Fjeld [alyssa.fjeld@monash.edu], School of Biological Sciences, 18 Innovation Walk, Monash University, Clayton, VIC 3800, and School of Natural Sciences, Macquarie University, NSW 2109, Australia; Zhiliang Zhang [zhiliang.zhang@nigpas.ac.cn], State Key Laboratory of Palaeobiology and Stratigraphy, Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, Nanjing 210008, People's Republic of China; Glenn A. Brock [glenn.brock@mq.edu.au], School of Natural Sciences, Macquarie University, NSW 2109, Australia.

Tooth breadth evolution within Sauropodomorpha and implications for taxonomic identification of isolated teeth

Timothy G. Frauenfelder, Sienna A. Birch, Phil Bell, and Nicolas Campione*

Sauropod teeth are commonly categorised taxonomically by slenderness index (SI; apicobasal length/mesiodistal width) which quantifies breadth, and compression index (CI; labiolingual/mesiodistal width) which quantifies cross-sectional circularity. SI values <4 represent broad crowns (e.g. *Camarasaurus*) and >4 represent narrow crowns (e.g. *Diplodocus*; Chure *et al*. 2010). CI has been mostly used to distinguish between tooth morphotypes observed in titanosaurids. Although both indices are used to infer high-level taxonomic affinities, little is known about the linear relationships between the constituent measurements or how the indices vary intra-cranially and at lower taxonomic levels. Here, we evaluate these relationships using a novel dataset of sauropod teeth (N = 968) spanning all major sauropod groups. Results indicate significant differential scaling within Sauropodormopha for both indices, in slope and elevation (SI; R2 = 0.65, p≈0, CI; R2 = 0.81, ≈0). Broad-crowned sauropods mostly display positive allometry in SI compared to isometry in narrow-crowned sauropods. This distinction is less clear with CI as most sauropods display isometry, whilst non-sauropod sauropodomorphs (e.g. Plateosauridae) display positive allometry. An ANOVA reveals SI varies significantly with genus and tooth position (p = 0.001). Specifically, jaw type is significant within Plateosauridae, whilst tooth position is significant within titanosaurids. Overall, variation within CI is restricted to genus (p = 0.001), with some evidence for variation in jaw type and sidedness (e.g. *Losillasaurus*). Whilst indices have taxonomic utility, there are caveats. The measurements used exhibit significant allometry, indicating that index values are size-dependent. Furthermore, the indices may not accurately reflect heterodont conditions present among early-branching sauropodomorphs. Differences between these taxa and titanosaurids may represent the shift towards anterior-packing of teeth that potentially coincides with bulk-feeding and larger body sizes (Sander 2013). We highlight the importance of quantifying taxonomic relationships within an allometric and multi-factor framework, which can be used to inform hypotheses regarding physiological and palaeoecological drivers influencing tooth shape evolution.

Chure, D., Britt, B.B., Whitlock, J.A. & Wilson, J.A., 2010. First complete sauropod dinosaur skull from the Cretaceous of the Americas and the evolution of sauropod dentition. *Naturwissenschaften 97*, 379–391.

Sander, P.M., 2013. An evolutionary cascade model for sauropod dinosaur gigantism-overview, update and tests. *PloS One 8*(10), p.e78573.

Timothy G. Frauenfelder [timothy.frauenfelder@gmail.com], Sienna A. Birch [tbroughm@une.edu.au], Phil Bell [pbell23@une.edu.au], and Nicolas Campione [ncampion@une.edu.au], University of New England, Armidale, NSW 2351, Australia.

Were jellyfish stranded on a shoreline sand *ca* 850 million years ago in the Amadeus Basin of central Australia?

John D. Gorter* and Phillip S. Plummer

Except for the Arumbera Sandstone, a unit that spans the Ediacaran–Cambrian boundary, the entire Neoproterozoic succession of the Amadeus Basin was generally believed to be devoid of metazoan fossils. This is despite features resembling biogenic traces being reported in the earliest geological mapping reports. Here we report on several curious, rounded impressions preserved upon the surface of a sandstone bed from the basal Neoproterozoic unit, the quartzitic Heavitree Formation that dates to about 850 Ma, and compare them with fossils of stranded medusae described previously elsewhere (Hagadorn *et al.* 2002). These new features are additional to two other forms of likely metazoans, one burrowing (vertical tubular structures) and one sessile (cup-shaped carapaces), that were recently posited as extant and active during the earliest stages of the Neoproterozoic (Plummer 2021). Together, these fossils suggest the Amadeus Basin harbours evidence of macroscopic life preceding the start of the Ediacaran by some 215 million years. Confirmation of an organic origin would support the recent proposal (Plummer 2021) that the Amadeus Basin was a crucible for 'failed evolutionary trials' prior to the successful metazoan colonisation of the Ediacaran seas.

Hagadorn, J.W., Dott, R.H. Jr. & Damrow, D., 2002. Stranded on a Late Cambrian shoreline: Medusae from central Wisconsin. *Geology 30*(2), 147–150.

Plummer, P.S., 2021. Was the Amadeus Basin of central Australia a crucible for pre-Ediacaran macro-biotic evolutionary trials? *Transactions of the Royal Society of South Australia 145*(2), 124–142.

John D. Gorter [johngorter1@gmail.com], PO Box 711, Claremont, WA 6910, Australia; Phillip S. Plummer [phil.plummer@adelaide.edu.au], Department of Earth Sciences, University of Adelaide, North Terrace, SA 5005, Australia.

Enigmatic fossil observations in the southern Sydney Basin

Nigel Gray*

A transect survey and marine fossil count undertaken near Ulladulla, New South Wales may provide evidence of a shallow-marine equivalent of a deep marine 'black smoker' with significant fossils concentrations in and around a dyke-filled fault structure. It can be deduced that the fault-dyke system was active during deposition of the host mid-Permian volcaniclastic rocks. Furthermore, enigmatic fossil locations at high elevations in the southern Sydney Basin, correlated with structural current-flow direction measurements could provide an interpreted origin of the host rocks other than sedimentary.

Nigel Gray [nlg2225@gmail.com], GPO Box 2902, Brisbane, QLD 4001, Australia.

Ediacaran biota of the Mopunga Group, western Georgina Basin, central Australia

Peter Haines*

The shallow marine and predominantly siliciclastic Mopunga Group (Elyuah, Grant Bluff, Elkera and Central Mount Stuart Formations, in ascending order) disconformably overlies Cryogenian glacigenic units, and is in turn disconformably overlain by fossiliferous lower Cambrian siliciclastic strata. The Tops Member of the lower Central Mount Stuart Formation contains the Mount Skinner biota, reported by Mary Wade (1969) to include two taxa, *Skinnera brooksi* and *Hallidaya brueri*, interpreted as medusa of scyphozoan grade of complexity. *Hallidaya* was subsequently found in the lower Arumbera Sandstone of the adjacent Amadeus Basin. During regional mapping for the Northern Territory Geological Survey in the late 1980s and early 2000s, the current author recorded numerous additional localities of the Mount Skinner biota north of the original Wade site, and also located distinct fossil assemblages, yet to be described, at lower and higher stratigraphic levels within the Mopunga Group. The original Mount Skinner biota is more diverse than originally reported, and includes trace fossils as well as body fossils. A single specimen, closely resembling *Tribrachidium*, is yet to be described. The assemblage appears to be stratigraphically restricted, usually to an interval no more than 20 m thick, despite similar, although barren facies above and below. The enigmatic *Arumberia banksii*, originally described from the Arumbera Sandstone and generally considered a Microbially Induced Sedimentary Structure (MISS), is very common at the Mount Skinner horizon and is a useful marker. The older Grant Bluff Formation contains *Aspidella*, *Intrites* and tubular fossils. Carbonate interbeds within the overlying Elkera Formation locally contain the stromatolite *Tungussia julia* originally described from the Julie Formation of the Amadeus Basin. The Adnera Member of the upper Central Mount Stuart Formation locally contains a distinct biota dominated by tubular body fossils and rare *Palaeopascichnus*.

Wade, M., 1969. Medusae from uppermost Precambrian or Cambrian sandstones, Central Australia. *Palaeontology 12*, 351–365.

Peter Haines [peter.haines@dmirs.wa.gov.au], Geological Survey of Western Australia, Department of Mines, Industry Regulation and Safety, 100 Plain St, East Perth, WA 6004, Australia.

New discoveries in Australian temnospondyl palaeontology

Lachlan Hart*, and Tim Ziegler

Temnospondyl amphibians are a key component of many Australian Mesozoic ecosystems, being particularly prominent in Triassic-aged deposits. Australia was also home to the world's last-known temnospondyl, *Koolasuchus cleelandi*, from the Early Cretaceous polar biota of Victoria (Warren *et al.*, 1997). Discoveries of new temnospondyl species have slowed in recent years, with the most recent Australian taxon, *Microposaurus averyi*, being named in 2012 (Warren 2012). Here we will present two new Australian temnospondyl taxa, the first in over a decade. The fossil of the first new taxon was discovered in the mid-1990s, in a sandstone block (intended to be used in the construction of a retaining wall) derived from Lower–Mid Triassic Terrigal Formation at Kincumber Quarry, Central Coast, New South Wales. It was subsequently donated to the Australian Museum but has not been formally studied until now. The fossil is remarkable as it is a near-complete skeleton and includes preservation of soft tissue. This taxon represents the first chigutisaurid temnospondyl from New South Wales, and shows that large-bodied brachycephalic temnospondyls inhabited Australia long before the end-Triassic extinction event. The second, as yet unnamed, new taxon is represented by an associated cranium and mandible from fluvial sandstone in the Lower Cretaceous (Barremian–Aptian) upper Strzelecki Group of Victoria. The location of the source deposit proximal to the *K. cleelandi* type locality indicates the taxa were likely coeval. The new skull's morphology and dimensions indicate a temnospondyl of considerably narrower cranial form than the typically parabolic chigutisaurid *Koolasuchus*, suggesting a feeding ecology and habit distinct from the latter. The presence of coeval Cretaceous temnospondyls refutes the notion of *Koolasuchus* as an isolated relict and shows this ancient group was still successfully adapting to changing environments late in its evolutionary history.

Warren, A., 2012. The South African stereospondyl *Microposaurus* from the Middle Triassic of the Sydney Basin, Australia. *Journal of Vertebrate Paleontology 32*, 538–544.

Warren, A., Rich, T.H. & Vickers-Rich, P., 1997. The last last labyrinthodonts? *Palaeontolographica Abteilung A 247*, 1–24.

Lachlan J. Hart [L.Hart@unsw.edu.au], Earth and Sustainability Science Research Centre, School of Biological, Earth and Environmental Sciences (BEES), University of New South Wales, Kensington, NSW 2052, Australia; Australian Museum Research Institute, 1 William Street, Sydney, NSW 2010, Australia; Tim Ziegler [tziegler@museum.vic.gov.au], Museums Victoria, GPO Box 666, Melbourne, VIC 3001, Australia.

An end-Permian extinction pattern in the deep-water Dongpan Section, South China, related to expansion of an Oxygen Minimum Zone

Weihong He, Elizabeth A. Weldon*, and Tinglu Yang

In the deep-water Dongpan Section, a two-stage end-Permian extinction pattern indicates that palaeoenvironmental deterioration in the Youjiang Sub-basin, South China, had strong links to the expansion of an Oxygen Minimum Zone (OMZ) and increasing intensity of oxygen deficiency. In the first stage, the deep-water (deeper than 200 m, but not reaching the benthic zone) radiolaria (Order Albaillelaria) were quickly wiped out, primarily by anoxia associated with the intensification of an OMZ in the region. The OMZ then appears to have undergone vertical expansion. Initially progressing upward to the surface waters and impacting all the intermediate water depth radiolaria (Latentifistularia) and most shallow-water forms (Entactinara and Spumullaria). Before progressing downward to the benthic zone wiping out some of the benthos (including most species of ostracods and foraminifers), which were not well adapted to the dysoxic conditions. Finally, in the second stage, the benthic brachiopods and bivalves that were more tolerant of hypoxic conditions, and relics of the shallow-water radiolarians, went extinct. The whole ecosystem, from the benthic zone to the surface waters, appears to have been devastated along the southwestern continental margin of the sub-basin. This two-stage extinction pattern, demonstrating a reduction in diversity and the last appearances of both plankton and benthos, is consistent with modern analogues that result during the vertical and horizontal expansion of OMZs (Fuenzalida *et al.* 2009, Diaz *et al.* 2013).

Diaz, R.J., Eriksson-Hägg, H. & Rosenberg, R., 2013. Hypoxia. In: *Managing ocean environments in a changing climate: Sustainability and economic perspectives*. Noone, K.J., Sumaila, U.R. & Diaz, R.J., eds, Elsevier, Massachusetts, 67–96.

Fuenzalida, R., Schneider, W., Garcés-Vargas, J., Bravo, L. & Lange, C., 2009. Vertical and horizontal extension of the oxygen minimum zone in the eastern South Pacific Ocean. *Deep-Sea Research II* 56, 992–1003.

He Weihong [whzhang@cug.edu.cn], State Key Laboratory of Biogeology and Environmental Geology and School of Earth Sciences, China University of Geosciences, Wuhan 430074, People's Republic of China; E.A.Weldon [l.weldon@deakin.edu.au], School of Life and Environmental Sciences, Deakin University, Geelong, VIC 3216, Australia; Tinglu Yang [yang@geology.so], Faculty of Geosciences, East China University of Technology, Nanchang 330013, People's Republic of China.

Preservation, erosion, and the utility of ichnotaxa: geometric morphometrics of theropod dinosaur tracks (*Megalosauropus broomensis*) from the Lower Cretaceous Broome Sandstone, Western Australia

Brooke E. Holland*, Anthony Romilio, and Steven W. Salisbury

The extent to which factors such as preservation and erosion affect the appearance of fossilised dinosaurian tracks is poorly understood. Similarly, the way data is extracted from the documentation of tracks and how is it incorporated into ichnotaxonomic diagnoses is often a subjective process. To test this, we focus on *Megalosauropus broomensis*, a theropod track known exclusively from the Lower Cretaceous (Valanginian–Barremian) Broome Sandstone of the Dampier Peninsula, Western Australia. Tracks from this area occur in the intertidal zone and are subject to near-continuous erosion by wave action. *Megalosauropus broomensis* is well represented and can be differentiated relatively easily from other theropod ichnotaxa; however, at what point abiotic factors such as preservation and erosion influence its ichnotaxonomic assignment remains unclear. Utilising a set of theropod tracks and trackways from the Broome Sandstone assumed to be *M. broomensis*, objective outlines were created from 3D photogrammetric models and analysed using principal component analysis and multivariate analysis to investigate how preservation and erosion affect the shape of tracks. Our results indicate that although erosion can obscure some features, certain diagnostic parameters such as track length to width, digital impression extension length, and digital impression length ratios, remain relatively consistent despite the apparent high degree of variation associated with erosion and preservation. Linear discriminant analysis of diagnostic parameters of tracks assigned to *M. broomensis* and other theropod ichnotaxa provided strong levels of morphometric separation, with accurate exclusion of unreasonably diagnosed tracks using 95% confidence intervals. The diagnostic parameters identified have thus far remained specific to *M. broomensis*, providing a robust approach for confidently assigning diagnostic criteria to ichnotaxa despite extreme states of preservation and erosion. Future use of this method can increase confidence and clarity of ichnotaxonomic diagnoses, leading to more accurate assessments of trackmaker distribution and behaviour.

Brooke E. Holland [b.holland@uq.net.au], and Steven W. Salisbury [s.salisbury@uq.edu.au], School of Biological Sciences, The University of Queensland, Brisbane, QLD 4072, Australia; Anthony Romilio [a.romilio@uq.edu.au], Office of the Deputy Vice-Chancellor (Research & Innovation), The University of Queensland, Brisbane, QLD 4072, Australia.

Molecular palaeontology of the Lower Devonian Rhynie Chert

Alex Holman*, Paul Greenwood, Peter Hopper, Arndt Schimmelmann, and Kliti Grice

The Rhynie Chert, modern-day Scotland, is a Lower Devonian hot-spring system preserving one of Earth's oldest terrestrial ecosystems. Flooding with silica-rich hot-spring water resulted in silicification of plants, fungi, algae, and invertebrates, which are preserved in remarkable detail (Garwood *et al*. 2020). The palaeontology and palaeobiology of the Rhynie Chert has been extensively studied; however, its organic geochemistry is comparatively under-explored. We present an organic geochemical study of a Rhynie Chert specimen donated by the Smithsonian National Museum of Natural History, Washington DC. Initial screening of the sample by RockEval pyrolysis showed that extractable organic compounds (bitumen) were present, but most organic carbon was concentrated in the insoluble kerogen fraction. Alongside traditional solvent extraction, catalytic hydropyrolysis (HyPy) was therefore employed to crack the kerogen into fractions that can be analysed by typical chromatographic techniques (Love *et al*. 1995). Organic matter from bitumen and kerogen contained molecular biomarkers derived from biological molecules during diagenesis, including hopanes and steranes from bacteria and eukaryotes respectively. An unusually high proportion of rearranged steranes (diasteranes) was observed, attributed to the oxic and acidic conditions of the hot-spring environment (Teece *et al*. 2022). The polycyclic aromatic compound perylene, from the pigments of lignin-degrading fungi, was detected in the kerogen. This fits with the abundant fossilised fungi in the Rhynie Chert (Strullu-Derrien *et al*. 2014) and supports the early development of plant–fungi interactions in terrestrial ecosystems. Most remarkably, intact sterols, including the plant sterol β-sitosterol, were detected; this is the oldest reported intact sterol and demonstrates the exceptional preservation of organic compounds within the Rhynie Chert. We have demonstrated that sterols are physically entrapped within the silicate matrix of the chert, protecting them from degradation and alteration. This work has shown that well-preserved ancient cherts have the potential to be valuable molecular archives of early ecosystems.

Garwood, R.J., Oliver, H. & Spencer, A.R.T., 2020. An introduction to the Rhynie chert. *Geological Magazine 157*, 47–64.

Love, G.D., Snape, C.E., Carr, A.D. & Houghton R.C., 1995. Release of covalently-bound alkane biomarkers in high yields from kerogen via catalytic hydropyrolysis. *Organic Geochemistry 23*, 981–986.

Strullu-Derrien, C., Kenrick, P., Pressel, S., Duckett, J.G., Rioult, J.-P. & Strullu, D.-G., 2014. Fungal associations in *Horneophyton ligneri* from the Rhynie Chert (c. 407 million year old) closely resemble those in extant lower land plants: novel insights into ancestral plant–fungus symbioses. *New Phytologist 203*, 964–979.

Teece, B.L., Guido, D.M., Campbell, K.A., Van Kranendonk, M.J., Galar, A. & George, S.C., 2022. Exceptional molecular preservation in the Late Jurassic Claudia palaeo-geothermal field (Deseado Massif, Patagonia, Argentina). *Organic Geochemistry 173*, 104504.

Alex Holman [A.Holman@curtin.edu.au], Paul Greenwood [p.greenwood@exchange.curtin.edu.au], Peter Hopper [peter.hopper@curtin.edu.au], and Kliti Grice [k.grice@curtin.edu.au], WA Organic and Isotope Geochemistry Centre, The Institute for Geoscience Research, School of Earth and Planetary Sciences, Building 500, Curtin University, Kent St, Bentley WA 6102, Australia; Arndt Schimmelmann [aschimme@indiana.edu], Department of Earth and Atmospheric Sciences, Indiana University, 1001 E 10th Street, Bloomington, IN 47405-1405, USA.

Morphological disparity dynamics of the initial Cambrian trilobite radiation

James D. Holmes

Trilobites are a group of biomineralising marine euarthropods that appear abruptly in the early Cambrian Period, *ca* 521 million years ago. Presumed phylogenetic diversity and biogeographic provincialism in the earliest trilobites has resulted in the general view that this group experienced a substantial period of unobserved 'cryptic' diversification prior to their appearance. However, recent work has highlighted inconsistencies with this interpretation and shown that the trilobite fossil record is likely to closely reflect their origins as a clade (Holmes & Budd 2023). This provides an important opportunity to assess detailed patterns of morphological diversity ('disparity') across an early animal radiation, with the knowledge that the trilobite fossil record is likely to be accurately capturing such patterns. Here I measure 'cumulative disparity' in functionally important trilobite cephalic structures (outline, glabella and eye ridges) during their initial radiation across Cambrian Series 2 (*ca* 521–506 Ma), using a family level dataset of 47 species (Holmes 2023). Results show that patterns of disparity vary in different structures, but in all cases show initial rapid increases. With the cephalic outline included, disparity reached a maximum extremely quickly, driven largely by convergent evolution of genal spine morphologies in different groups. In contrast, excluding the outline and focusing on glabellar and eye ridge morphology resulted in a more restrained increase in disparity, more in line with taxonomic diversity. Taken together, these patterns suggest that the abrupt appearance of trilobites most likely reflects a rapid evolutionary radiation occurring in 'real time', rather than a 'pseudo-radiation' where lineages that diverged previously suddenly appear in the fossil record. Such patterns may be driven by survivorship biases like the 'push of the past', and provide potential support for the 'early burst' model of adaptive radiation.

Holmes, J.D. & Budd, G.E., 2022. Reassessing a cryptic history of early trilobite evolution. *Communications Biology 5*, 1177.

Holmes, J.D., 2023. Contrasting patterns of disparity suggest differing constraints on the evolution of trilobite cephalic structures during the Cambrian 'explosion'. *Palaeontology 66*, e12647.

James D. Holmes [jamesholmes83@gmail.com], Department of Earth Sciences, Palaeobiology, Uppsala University, Villavägen 16, Uppsala 752 36, Sweden.

Silicified pedunculate kutorginates from the early mid-Cambrian (Wuliuan) of Jordan, and their evolutionary significance

Lars Holmer*, Leonid E. Popov, Mansoureh Ghobadi Pour, and Zhifei Zhang

Exceptionally preserved, silicified and articulated complete shells of the rhynchonelliform kutorginate brachiopods *Trematosia radifer* (Richter & Richter) and *Kutorgina* sp. nov. are recorded from the lower mid-Cambrian Burj Formation (Wuliuan), Jordan. Silicified cylindroid protrusions, emerging posteriorly between the valves of both taxa, most likely represent silicified pedicles. The short pedicles differ considerably from the pedicles of living crown-group rhynchonelliforms, and in both taxa they are hollow and appear to have been quite flexible. The pedicle is very strongly annulated in *Kutorgina* sp. nov., whereas *Trematosia radifer* has less distinctive annulation. The silicified pedicles of both taxa are most similar to the exceptionally preserved pedicle found emerging posteriorly from attached in situ shells of *Nisusia sulcata* from the mid-Cambrian (Drumian) of Utah. Similar and exceptionally preserved pedicles are also known from other Cambrian rhynchonelliform brachiopods, including *Longtancunella*, *Alisina*, and *Kutorgina?* from the early Cambrian Chengjiang Lagerstätte of southern China (Zhang *et al.* 2011a, b), but these emerge from the ventral apical foramen rather than from between the valves as in *Kutorgina* sp. nov. and *Trematosia radifer*. Like in *Nisusia*, the Jordanian *Kutorgina* and *Trematosia* are also provided with an apical foramen in addition to the posterior adult pedicle, and it strengthens the view that the apical foramen may represent the earliest attachment of the larvae, which subsequently became non-functional through ontogeny in some early rhynchonelliforms; both types of attachment strategies may have appeared early in the stem lineage of the Rhynchonelliformea (Holmer *et al.* 2018a, b).

Holmer, L.E., Zhang, Z., Topper, T., Popov, L. & Claybourn, T., 2018a. The attachment strategies of Cambrian kutorginate brachiopods, the curious case of two pedicle openings and their phylogenetic significance. *Journal of Paleontology 92*, 33–39.

Holmer, L.E., Popov, L., Ghobadi Pour, M., Claybourn, T., Zhang, Z., Brock, G.A. & Zhang, Z., 2018b. Evolutionary significance of a middle Cambrian (Series 3) in situ occurrence of the pedunculate rhynchonelliform brachiopod *Nisusia sulcata*. *Lethaia 51*, 424–432.

Zhang, Z., Holmer, L.E., Popov, L.E. & Shu, D., 2011a. An Obolellate Brachiopod with Soft-Part Preservation from the Early Cambrian Chengjiang Fauna of China. *Journal of Paleontology 85*, 460–463.

Zhang, Z., Holmer, L.E., Qiang, Q., Han, J. & Shu, D., 2011b. The exceptionally preserved Early Cambrian stem rhynchonelliform brachiopod *Longtancunella* and its implications. *Lethaia 44*, 490–495.

Lars Holmer [lars.holmer@pal.uu.se], Department of Earth Sciences, Palaeobiology, Uppsala University, Villavägen 16, Uppsala 752 36, Sweden; Leonid E. Popov [lepbarry@yahoo.co.uk] and Mansoureh Ghobadi Pour [mghobadipour@yahoo.co.uk], National Museum Wales, Cathays Park, Cardiff CF10 3NP, Wales, UK; Zhifei Zhang [elizf@nwu.edu.cn], Northwest University, No.229, North Taibai Avenue, Xi'an, Shaanxi, People's Republic of China.

The evolution of Precambrian reefs and marine conditions

Ashleigh V.S. Hood*, and Malcolm W. Wallace

The oxygenation of Earth's surficial environments is one of the most significant processes in Earth history, affecting almost every biological, environmental and geological system. However, while they are intrinsically linked, the relative timing of the evolution of complex life and the build-up of oxygen in Earth's early oceans remain poorly constrained. Shelfal marine environments, particularly reef systems, formed important Precambrian habitats that were strongly influenced by Earth's oxygen evolution, and hosted a variety of complex microbial frameworks. Here we characterise selected Precambrian reef complexes using combined geobiological, sedimentological and depth-specific geochemical analysis to constrain the link between ecosystem complexity and shallow-marine chemical conditions. Precambrian reefs comprise diverse frameworks made of microbial and more complex ecosystems (e.g. stromatolites, cuspate microbialites, calcimicrobes and biomineralisers), but also host carbonate phases precipitated directly from seawater. These marine cements and microbialites have been analysed by laser ablation geochemical analysis to determine depth-specific marine conditions. A review and comparison of Precambrian reef systems highlights the link between marine conditions and reef framework development through Earth's early evolution. Here, comparison is made between the Archean Campbellrand platform, South Africa; the Paleoproterozoic Pethei Group, Canada, and the Neoproterozoic reefs of Australia, Namibia and Canada. In particular, the discovery of several new reef complexes from the Neoproterozoic advances our understanding of reef evolution during this transitional period in Earth's history. In most cases, the most complex, diverse reef frameworks existed in the deepest reef-margin facies, and are characterised by low-light, low-oxygen marine conditions. These include cuspate microbialites and chambered structure frameworks, which are common in Precambrian deep-water settings. It is possible that these deep reef-margin environments represented relatively chemically stable marine habitats through Earth's early history, but became less important after the widespread oxygenation of the oceans in the Phanerozoic.

Ashleigh V.S. Hood [ashleigh.hood@unimelb.edu.au], and Malcolm W. Wallace [mww@unimelb.edu.au], School of Geography, Earth and Atmospheric Sciences, University of Melbourne, Parkville, VIC 3010, Australia.

The relation between Cretaceous belemnite families Belemnitellidae and Dimitobelidae: new insights from specimens kept in the Australian Museum

Alexey P. Ippolitov* and Patrick M. Smith

The mid-Cretaceous was a time of growing provincialism of the cephalopod biota. Starting from the late Cenomanian, the Northern Hemisphere seas were inhabited exclusively by the members of the family Belemnitellidae, while epicontinental seas of the Southern Hemisphere were occupied by the members of the family Dimitobelidae, which first appeared during the Barremian or early Aptian. The distribution areas of both taxa do not overlap anywhere and the origins for both families remain unclear, despite most authors consider both of them to be closely connected to the late (Aptian–Albian) members of the sub-global family Belemnopseidae. Recent phylogenetic analyses placed all three groups into a monophyletic clade Pseudoalveolata (Stevens *et al.* 2023), leaving the precise relations between dimitobelids and belemnitellids unresolved. Some new assumptions derive from the poorly known characters of dimitobelid phragmocones, studied on several perfectly preserved *Dimitobelus macgregori* specimens kept in the Australian Museum. First of all, these specimens demonstrate a petite dorsal saddle on a septal line — and this character is in full accordance with septal line configuration previously recorded for belemnitellids (Schlüter 1876). The same character is shared by all isolated dimitobelid phragmocones in the same collection. Secondly, some smaller dimitobelid specimens demonstrate a clear dorsal keel on the phragmocone — again a similar structure is recorded in Belemnitellidae (e.g. Schlüter 1876, Gustomesov 1980) — but it is not observed in the phragmocones of the Aptian belemnopseid *Mesohibolites*. The similarity between phragmocones of belemnitellids and dimitobelids is also supported by the similarity of some secondary characters of the rostra. Considering the stratigraphic ranges of the families, it may be assumed that belemnitellids possibly derived not from a belemnopseid, as it is normally accepted, but from some dimitobelid ancestor.

Gustomesov, V.A., 1980. Phragmocone of Belemnella. *Paleontological Journal 14*, 58–62. (translation of the original publication in Russian)

Schlüter, C., 1876. Cephalopoden der oberen deutschen Kreide. II Theil. *Palaeontographica 24*, 1(121)–143(263), pls. 36–55.

Stevens, K., Pohle, A., Hoffmann, R. & Immenhauser, A., 2023. Bayesian inference reveals a complex evolutionary history of belemnites. *Palaeontologia Electronica 26.1*, a13.

Alexey P. Ippolitov [ippolitov.ap@gmail.com], School of Geography, Environment and Earth Sciences, Victoria University of Wellington | Te Herenga Waka, 21 Kelburn Parade, Wellington 6012, New Zealand; Patrick M. Smith [Patrick.Smith@austmus.gov.au], Palaeontology Department, Australian Museum Research Institute, Sydney, NSW 2010 and Department of Biological Sciences, Macquarie University, Sydney, NSW 2109, Australia.

The nature and phylogenetic affinity of the enigmatic Indian belemnoid *Belospirula*: the riddle resolved

Alexey P. Ippolitov*, Bhawanisingh G. Desai, and Ajit V. Vartak

Belospirula is a poorly known genus of Cretaceous coleoids, originally described from the lower Albian strata of the Cauvery Basin (South India) by Ayyasami & Jagannadha Rao (1987). It is characterised by a very peculiar, hook-curved rostrum, resembling those of early Tertiary spirulids. While the authors considered it to be a possible link between belemnites and spirulids, such an assumption contradicts accepted scenarios. In more recent publications, *Belospirula* was considered either to be a taxon of 'uncertain affinity' (e.g. Riegraf *et al.* 1998) / 'invalid name' (Mondal *et al.* 2023) or, most often, completely neglected. The latter option is true for both large-scale revisions of coleoid evolution (Fuchs 2006, Bizikov 2008) and specialised papers discussing scenarios of belemnite–spirulid transition (Fuchs *et al.* 2013). Based on new, extensive collections from the type locality, we re-establish the position of *Belospirula* within the coleoid system. The structure of the rostrum undoubtedly supports the belemnite nature. Morphological comparison between *Belospirula* and typical members of the Austral family Dimitobelidae reveals multiple shared characters, clearly defining its placement within Dimitobelidae (paired ventrolateral alveolar furrows, presence of dorsal keel on the phragmocone). In particular, *Belospirula* is phylogenetically close to the members of the genus *Tetrabelus*, known from India and the Antarctic peninsula. Moreover, we demonstrate a set of transitional forms, showing that the taxon under study is not a member of some long-ranging and unique dimitobelid lineage, but a short-ranging, highly specialised form, probably endemic for the early Albian of the Cauvery Basin.

Ayyasami, K. & Jagannadha Rao, B.R., 1987. New belemnoid from the Cretaceous of South India. *Geological Survey of India Special Publication 11*, 409–412.

Bizikov, V.A. 2008. *Evolution of the Shell in Cephalopoda*. VNIRO Publishing, Moscow, 444 pp. (Russian with extended English summary)

Fuchs, D., 2006. Fossil Erhaltungsfähige Merkmalskomplexe der Coleoidea (Cephalopoda) und Ihre Phylogenetische Bedeutung. *Berliner paläobiologische abhandlungen 8*, i–iii + 115 pp., 24 pls.

Fuchs, D., Iba, Y., Ifrim, C., Nishimura, T., Kennedy, W.J., Keupp, H., Stinnesbeck, W. & Tanabe, K., 2013. *Longibelus* gen. nov., a new Cretaceous coleoid genus linking Belemnoidea and early Decabrachia. *Palaeontology 56,* 1081–1106.

Mondal, S., Hazra, S. & Chakraborty, N., 2023. Absence of Belemnites in the Post-Cenomanian Marine Successions of Cauvery Basin, India: Role of Sea Level, Paleogeography, and Belemnite Paleoecology. *Journal of the Geological Society of India 99*, 177–186.

Riegraf, W., Janssen, N. & Schmitt-Riegraf, C., 1998. Cephalopoda dibranchiata fossiles (Coleoidea) II. *Fossilium Catalogus Animalia 135*: 5–512.

Alexey P. Ippolitov [ippolitov.ap@gmail.com], School of Geography, Environment and Earth Sciences, Victoria University of Wellington | Te Herenga Waka, 21 Kelburn Parade, Wellington 6012, New Zealand; Bhawanisingh G. Desai [bhawanigd@gmail.com], Pandit Deendayal Energy University, Gandhinagar, Gujarat 382007, India; Ajit V. Vartak [vartakajit@yahoo.com], Nowrosjee Wadia College, Pune 411001, India.

Locomotion of the 'giant wallaby' *Protemnodon*: insights from humeral morphology and limb proportions

Christine M. Janis* and Billie Jones

Extant macropodoids (kangaroos and relatives) all employ some form of quadrupedal locomotion at slow speeds and, except for the Musky rat-kangaroo (*Hypsiprymnodon moschatus*), hop at faster speeds. However, large extant kangaroos (Macropodinae) approach or exceed the optimum size (~50 kg) for hopping, due to the need to maintain a crouched limb posture at large size and hence experiencing increasing stress on joints and tendons. The diversity of past large (>100 kg) kangaroos, including sthenurines (Sthenurinae, short-faced kangaroos) and species of *Protemnodon* (Macropodinae), may have had more limited hopping than large extant macropodines like red and grey kangaroos. Some sthenurines (likely bipedal striders) exceeded the estimated maximum size for hopping (~150 kg). Large *Protemnodon* species (e.g. *P. anak* and *P. brehus*) did not appear optimised for hopping: although they had a long tibia, like most other macropodines, they had short feet, relatively long and robust forelimbs, and a long neck. Limb proportions reveal a unique combination of anatomical features: relatively short metatarsals, resembling tree-kangaroos; robust forelimbs of more equal length to the hind limbs, resembling tree-kangaroos and *H. moschatus*, but with a long forearm; and a long olecranon process, like burrowing species. These proportions indicate forelimbs that were important in weight-bearing during locomotion. *Protemnodon* humeral articulations resemble those of fully terrestrial quadrupeds, indicating more reliance on quadrupedal locomotion than in extant large kangaroos: the proximal articulation is ovoid, with a large greater tuberosity (indicating support rather than mobility), while the distal articulation is rectangular with an enlarged trochlea and a pronounced capitular tail (indicating reduced supination). All of these features lead us to propose that large *Protemnodon* species had limited hopping locomotion and were more habitually quadrupedal than large extant kangaroos.

Christine M. Janis [christine_janis@brown.edu] and Billie Jones [billie.jones5@hotmail.co.uk], Bristol Palaeobiology Group, School of Earth Sciences, University of Bristol, Wills Memorial Building, Bristol, BS8 1RJ, UK.

Global radiation history of the first oceanic tetrapods: dissecting evidence from Australia and the Scandinavian Arctic

Benjamin P. Kear*, David W. Haig, Aubrey J. Roberts, and Jørn H. Hurum

Tetrapods first radiated into oceanic environments after the cataclysmic end-Permian mass extinction (Scheyer *et al.* 2014), which marked the beginning of the Age of Dinosaurs, 251.9 million years ago (Ma). Popular hypothesis suggests that an ecological succession then took place across the earliest Triassic (Scheyer *et al.* 2014), with marine temnospondyl amphibians initially invading pelagic predator niches, but being replaced by ichthyopterygian marine reptiles during the late Smithian crisis (LSC), *ca* 249.6 Ma (Dai *et al.* 2022). However, such step-wise extinction recovery is contextually ambiguous following the discovery of middle-to-late Smithian (*ca* 250 Ma) ichthyopterygian fossils from the Scandinavian Arctic (Kear *et al.* 2023). Here, we integrate additional field data and phylogeny-based ancestral area estimations for the dominant marine temnospondyl clade Trematosauridae (*sensu* Steyer 2002). This group was globally distributed in fluviatile, paralic and offshore environments throughout the earliest Triassic (Hammer 1987), and therefore tracks the corresponding radiation of oceanic amphibians. The geologically oldest Induan (Griesbachian – lowermost Dienerian) trematosaurids occur in riverine to tidally influenced depositional settings from northeastern Australia (Nield *et al.* 2006) and East Greenland (Kear *et al.* 2016). Unequivocal open marine trematosaurids otherwise manifest in lower Olenekian (lower–mid-Smithian) distal shelf deposits on Svalbard (Kear *et al.* 2016), and approximately coeval epicontinental marine sequences from northwestern Australia (Kear *et al.* 2018). Similar time-correlated habitat transitions typify trematosaurids found elsewhere around the world (Fortuny *et al.* 2018). Indeed, our ancestral area analyses pinpoint a fluviatile–paralic cosmopolitan dispersal from northern Pangaea during the Induan. Opportunistic offshore incursions by regionally disparate trematosaurid lineages subsequently took place in the early Olenekian, concurrent with the proliferation of oceanic reptiles (Kear *et al.* 2023). Finally, Tethyan littoral trematosaurids persisted into the Middle Triassic (early Anisian: Schoch 2011), thus postdating the LSC and demonstrating a parallel, rather than step-wise evolution of the earliest Mesozoic marine tetrapods.

Dai, X., Tuan, Z., Brayard, A., Mingtao, L., Liu, X., Jia, E., Du, Y., Song, H. & Song, H., 2022. Calibrating the late Smithian (Early Triassic) crisis: New insights from the Nanpanjiang Basin, South China. *Global and Planetary Change 201*, 103492.

Fortuny, J., Gastou, S., Escuillié, F., Ranivoharimanana, L. & Steyer, J.S., 2018. A new extreme longirostrine temnospondyl from the Triassic of Madagascar: phylogenetic and palaeobiogeographical implications for trematosaurids. *Journal of Systematic Palaeontology 16*, 675–688.

Hammer, W.R., 1987. Paleoecology and phylogeny of the Trematosauridae. In *Gondwana Six: Stratigraphy, Sedimentology, and Paleontology*. McKenzie, G.D., ed., *American Geophysical Union, Geophysical Monographs 41*, 145–156.

Kear, B.P., Poropat, S.F. & Bazzi, M., 2016. Late Triassic capitosaurian remains from Svalbard and the paleobiogeographical context of Scandinavian Arctic temnospondyls. *Geological Society, London, Special Publications 434*, 113–126.

Kear, B.P., Fordyce, R.E., Hiller, N. & Siversson, M., 2018. A palaeobiogeographical synthesis of Australasian Mesozoic marine tetrapods. *Alcheringa 42*, 461–486.

Kear, B.P., Engelschiøn, V.S., Hammer, Ø., Roberts, A.J. & Hurum, J.H., 2023. Earliest Triassic ichthyosaur fossils push back oceanic reptile origins. *Current Biology 33*, R178–R179.

Nield, C.M., Damiani, R.J. & Warren, A.A., 2006. A short-snouted trematosauroid (Tetrapoda, Temnospondyli) from the Early Triassic of Australia: the oldest known trematosaurine. *Alcheringa 30*, 263–271.

Scheyer, T.M., Romano, C., Jenks, J. & Bucher, H., 2014. Early Triassic marine biotic recovery: the predators' perspective. *PLoS One 9*, e88987.

Schoch, R.R., 2011. A trematosauroid temnospondyl from the Middle Triassic of Jordan. *The Fossil Record 14*, 119–127.

Steyer, J.S., 2002. The first articulated trematosaur 'amphibian' from the Lower Triassic of Madagascar: implications for the phylogeny of the group. *Palaeontology 45*, 771–793.

Benjamin P. Kear [benjamin.kear@em.uu.se], The Museum of Evolution, Uppsala University, Norbyvägen 16, SE-75236 Uppsala, Sweden; David W. Haig [david.haig @uwa.edu.au], Oceans Graduate School, The University of Western Australia, 35 Stirling Highway, Crawley, WA 6009, Australia; Aubrey J. Roberts [a.j.roberts@nhm.uio.no], and Jørn H. Hurum [j.h.hurum@nhm.uio.no], Natural History Museum, University of Oslo, P.O. Box 1172 Blindern, NO-0318 Oslo, Norway.

A fossil seabird avifauna (Aves: Procellariiformes) from the Pliocene of Taranaki, New Zealand

Sophie Kelly*, Paul Scofield, Catherine Reid, and Vanesa De Pietri

Procellariiformes are an order of pelagic seabirds, including albatrosses, petrels and shearwaters, with a biogeographic range across the world's oceans. They are a key component of today's avifauna and had a similarly crucial role in past ecosystems, survived by multiple fossil specimens. The islands of New Zealand are significant for procellariiform diversity and evolution and have been a favoured habitat for at least 16 million years. This research studies the pre-Quaternary procellariiform fossil record from Pliocene marine deposits in the Taranaki region of North Island, New Zealand. Fourteen fossil specimens from the Canterbury Museum and private collections are reported on, with nine of the specimens analysed using a comparative morphology approach utilising both extinct and extant species from regional collections and published literature. Osteological characters were assessed using various techniques, including computer modelling of CT scan data, to warrant generic or specific differentiation from other Taranaki material and modern species. The description of these specimens reveals the taxonomic diversity of procellariiforms in Taranaki during the Pliocene, a time before the onset of major avian extinction events. Gaps in the knowledge of procellariiform evolution are also addressed, including the need for more published material on Pliocene seabird fossils and the unclear taxonomic relationships between extinct and modern procellariiform species. This research describes specimens representing three genera of petrels in the family Procellariidae (*Procellaria*, *Ardenna* and *Puffinus*), including the first taxonomically robust record of a *Puffinus* shearwater, the smallest seabird fossil described from the region. The described material adds to the existing record of procellariiform fossils, and the project is significant as it involves multiple contemporaneous specimens from a single area, allowing the extent of the fossil seabird fauna in Taranaki to be explored.

Sophie Kelly [sophie.kelly@pg.canterbury.ac.nz], Catherine Reid [catherine.reid@canterbury.ac.nz], and Vanesa De Pietri [vanesa.depietri@canterbury.ac.nz], School of Earth and Environment, University of Canterbury, Private Bag 4800, Christchurch 8140, New Zealand; Paul Scofield [pscofield@canterburymuseum.com], Canterbury Museum, 11 Rolleston Ave, Christchurch 8013 and School of Earth and Environment, University of Canterbury, Private Bag 4800, Christchurch 8140, New Zealand.

A megaraptoran (Dinosauria: Theropoda) frontal from the upper Strzelecki Group (Early Cretaceous) of Victoria, Australia

Jake Kotevski*, Ruairidh J. Duncan, Adele H. Pentland, James P. Rule, Patricia Vickers-Rich, Thomas H. Rich, Erich M.G. Fitzgerald, Alistair R. Evans, and Stephen F. Poropat

Cretaceous non-avian theropod dinosaurs from Australia are poorly understood, primarily because almost all specimens described thus far comprise isolated postcranial elements. Only three cranial elements (other than teeth) referable to Theropoda have been reported to date: the left and right dentaries of *Australovenator wintonensis* Hocknull *et al.,* 2009 from the Winton Formation (Cenomanian – lowermost Turonian) of Queensland, and an isolated surangular from the Eumeralla Formation (lower Albian) of Victoria. Here, we describe an isolated, practically complete frontal (with fused parietal fragment) from the upper Strzelecki Group (lower Aptian) collected from the under-sampled Shack Bay site near Inverloch, Victoria. The frontal is the first non-mandibular cranial element of a Cretaceous non-avian theropod to be reported from Australia. The results of our phylogenetic analyses, which were conducted using both parsimony-based and Bayesian-based methods, support the referral to Megaraptora. The specimen shares several synapomorphies with frontals from other members of the less inclusive Megaraptoridae, including an anteroposteriorly elongate postorbital articulation, a truncated articular surface for the nasal, subquadrangular shape in dorsal view, a mediolaterally transverse frontoparietal suture, and no articulation point for the lacrimal on the frontal. However, the Shack Bay frontal appears to be plesiomorphic relative to other megaraptoran frontals, lacking dorsoventrally high walls of bone to posteriorly emarginate the nasal and prefrontal articular surfaces (Porfiri *et al*. 2014, Coria & Currie 2016). The morphology of this frontal may imply that Early Cretaceous Australian megaraptorans had less specialised skulls than later forms, despite evidence that the group appeared to have already developed their characteristic hypertrophied manual unguals, as evidenced by the 'Punchbowl Claw' (lower Aptian: Poropat *et al*. 2019). The Shack Bay frontal is both the geologically oldest megaraptoran cranial element known in Australia and worldwide. The presence of this specimen provides further support for the apparent dominance of Megaraptora as the apex predators of eastern Australia during the Early Cretaceous.

Hocknull, S.A., White, M.A., Tischler, T.R., Cook, A.G., Calleja, N.D., Sloan, T. & Elliott, D.A., 2009. New mid-Cretaceous (latest Albian) dinosaurs from Winton, Queensland, Australia. *PLOS One 4*, e6190.

Coria, R.A. & Currie, P.J., 2016. A New Megaraptoran Dinosaur (Dinosauria, Theropoda, Megaraptoridae) from the Late Cretaceous of Patagonia. *PLoS One 11*, e0157973.

Porfiri, J.D., Novas, F.E., Calvo, J.O., Agnolin, F.L., Ezcurra, M.D. & Cerda, I.A., 2014. Juvenile specimen of Megaraptor (Dinosauria, Theropoda) sheds light about tyrannosauroid radiation. *Cretaceous Research 51*, 35–55.

Poropat, S.F., White, M.A., Vickers-Rich, P. & Rich, T.H., 2019. New megaraptorid (Dinosauria: Theropoda) remains from the Lower Cretaceous Eumeralla Formation of Cape Otway, Victoria, Australia. *Journal of Vertebrate Paleontology 39*, e1666273.

Jake Kotevski [kotevskij2401@outlook.com.au], Ruairidh J. Duncan [ruairidh.duncan@monash.edu], and Alistair R. Evans [alistair.evans@monash.edu], Evans EvoMorph Lab, Room 226, 18 Innovation Walk, School of Biological Sciences, Monash University, Clayton, VIC 3800, Australia; Adele H. Pentland [pentlandadele@gmail.com], and Stephen F. Poropat [steve.poropat@curtin.edu.au], Western Australian Organic & Isotope Geochemistry Centre, School of Earth

and Planetary Science, Curtin University, Bentley, WA 6102, Australia; James P. Rule [jrule.palaeo@gmail.com], Natural History Museum, Cromwell Rd, South Kensington, London SW7 5BD, UK; Patricia Vickers-Rich [pat.rich@monash.edu], School of Earth, Atmosphere and Environment, Monash University, Melbourne, VIC 3800, Australia; Thomas H. Rich [trich@museum.vic.gov.au], and Erich M.G. Fitzgerald [efitzgerald@museum.vic.gov.au], Museum Victoria, P.O. Box 666, Melbourne, VIC 3001, Australia.

The quest for an Australian Cambrian stage scale

John R. Laurie*, Peter D. Kruse, Glenn A. Brock, James D. Holmes, James B. Jago, Marissa J. Betts, John R. Paterson, and Patrick M. Smith

The chronostratigraphic scale is a hierarchical scheme that is subdivided into increasingly smaller units, from eonothem down to the level of the substage. Constituent unit boundaries typically coincide with individual bioevents. As these intervals become smaller, their geographic utility tends to shrink such that for communication, the next highest unit in the scale is used where the original unit is inapplicable. Where appropriate units are unavailable, confusion reigns. A stadial subdivision of the Australian Miaolingian and Furongian was completed in 1993 with the publication of the definition of the Furongian Iverian Stage. One stage, the Ordian, was initially suggested as the lowest stage for what is now the Miaolingian, but is now considered to belong to upper Series 2 of the Cambrian. No older stages have been defined. Indeed, the base of the Ordian has not been defined, due in part to the poor understanding of Series 2 chronostratigraphy in central-northern Australia. A long-standing impediment to the establishment of lower Cambrian stages in Australia arises from the fact that the entire Australian stadial scheme for the Miaolingian and Furongian series was established in the cratonic basins of central-northern Australia, whereas the lower Cambrian is best developed in South Australia. With the rapid increase in knowledge of the biostratigraphic successions in the South Australian lower Cambrian (Terreneuvian and Series 2) over the last two decades, the time seems ripe for the establishment of such a stadial subdivision. Such a subdivision will have to cope with the jump from the mostly Miaolingian–Furongian succession in central-northern Australia to the mostly Terreneuvian and Series 2 succession in South Australia. Taxa that can be used for such a stadial subdivision include trilobites, phosphatic brachiopods, archaeocyaths, 'small shelly fossils', molluscs and acritarchs, as each has provided the basis of zonations in the South Australian successions.

John R. Laurie [john.r.laurie@gmail.com], Geoscience Australia, Symonston, ACT 2601 and School of Natural Sciences, Macquarie University, North Ryde, NSW 2109, Australia; Peter D. Kruse [archaeo.kruse@gmail.com], South Australian Museum, Adelaide, SA 5000, Australia; Glenn A. Brock [glenn.brock@mq.edu.au], School of Natural Sciences, Macquarie University, North Ryde, NSW 2109, Australia; James D. Holmes [jamesholmes83@gmail.com], Department of Earth Sciences, Palaeobiology, Uppsala University, Villavägen 16, Uppsala 752 36, Sweden; James B. Jago [Jim.Jago@unisa.edu.au], University of South Australia-STEM, Mawson Lakes, SA 5095, Australia; Marissa J. Betts [Marissa.Betts@une.edu.au], Palaeoscience Research Centre/LLUNE, University of New England, Armidale, NSW 2351, Australia; John R. Paterson [jpater20@une.edu.au], Palaeoscience Research Centre, University of New England, Armidale, NSW 2351, Australia; Patrick M. Smith [Patrick.Smith@austmus.gov.au], Australian Museum Research Institute, 1 William St, Sydney, NSW 2010, Australia.

New insights into the postcranial anatomy of Gondwana's most complete ankylosaurian: *Kunbarrasaurus ieversi*, from the Lower Cretaceous (Albian – (?)lower Cenomanian) of Queensland, Australia

Lucy G. Leahey*, Ralph E. Molnar and Steven W. Salisbury

The majority of Gondwana's ankylosaurian dinosaurs have been discovered within Australia. Over ten specimens are known, the majority from Queensland. Two genera have been formerly established — *Minmi* and *Kunbarrasaurus*. *Minmi* was the first ankylosaurian discovered and best known of the Australian ankylosaurs, whereas *Kunbarrasaurus ieversi* (only partially described) is represented by one of the world's most complete ankylosaurian skeletons and the best-preserved dinosaurian fossil from eastern Gondwana. A full description of the postcranium is currently being undertaken. Preliminary phylogenetic studies have revealed that *K. ieversi* sits basal to, or basally within, the Ankylosauria, such that it is closely related to basal thyreophorans.

Similar to the history of the majority of Australia's ankylosaurian discoveries, other Gondwanan landmasses have produced mainly isolated and fragmentary specimens, to the point where some taxa have been reassessed as either 'nomen dubium' or even non-ankylosaurian (Arbour & Currie 2015). Recent discoveries and new material from known sites, as well as the re-evaluation of existing specimens, has shown that the diversity of Gondwanan ankylosaurs is greater than previously thought. Furthermore, a new phylogenetic study has not only revealed that some of these genera (*Antarctopelta* and *Stegouros*) have affinities with *K. ieversi*, but that together they form a new basal clade, Parankylosauria (Soto-Acuña *et al.* 2021). These results reaffirm *K. ieversi*'s intermediate phylogenetic position between basal thyreophorans and ankylosaurians. The current study has revealed that the postcranium of *K. ieversi* shares similarities with basal thyreophoran *Scelidosaurus*, particularly with regard to the appendicular skeleton. Further study of the *K. ieversi* holotype will provide anatomical insights into the transition between the basal thyreophorans and ankylosaurians.

Australian, and Gondwanan, ankylosaurians have often been regarded as 'relictual' taxa. However, recent evidence highlighting the diversity of thyreophorans in the southern continents is set to alter not only our understanding of Gondwanan ankylosaurs, but also the early evolution, diversity and palaeobiogeography of the clade worldwide.

Arbour, V.M. & Currie, P.J., 2015. Systematics, phylogeny and palaeobiogeography of the ankylosaurid dinosaurs. *Journal of Systematic Palaeontology 14(5)*, 385–444.

Soto-Acuña, S., Vargas, A.O., Kaluza, J., Leppe, M.A., Botelho, J.F., Palma-Liberona, J., Simon-Gutstein, C., Fernández, R.A., Oritz, H., Milla, V., Aravena, B., Manríquez, L.M.E., Alarcón-Muñoz, J., Pablo Pino, J., Trevisan, C., Mansilla, H., Hinojosa, L.F. Muñoz-Walther, V. & Rubilar-Rogers, D., 2021. Bizarre tail weaponry in a transitional ankylosaur from subantarctic Chile. *Nature 600*, 259–263.

Lucy G. Leahey [lucyleahey@hotmail.com], and Steven W. Salisbury[s.salisbury@uq.edu.au], The University of Queensland, Brisbane, QLD 4072, Australia; Ralph E. Molnar [ralph.molnar@gmail.com], University of California, Museum of Paleontology, Berkeley, CA 94720-4780, USA.

Germ-soma differentiation and reproduction of early Cambrian acritarch *Concavaesphaera ornata* n. gen. n. sp.

Wei Liu, Zongjun Yin*, Bing Pan, Bing Shen, Lin Dong, Guoxiang Li

As a significant evolutionary innovation, multicellularity has independently evolved multiple times throughout the evolutionary history of eukaryotes, making a substantial contribution to the diversity of this critical group (Knoll 2011). In retracing the multicellularity of eukaryotes, deep-time fossil records play an irreplaceable role. In this paper, we report a new acritarch, *Concavaesphaera ornata* n. gen. n. sp., from the early Cambrian Kuanchuanpu biota (535 Ma). These fossils are generally spherical, with diameters ranging from 450 to 950 μm, and feature a cyst with complex ornaments. Inside, there are two groups of cells varying in size. Larger cells, being relatively fewer in number, reside within individual sac-like cavities distributed along the inner wall of the cyst. Statistical data show a positive correlation between the diameter and cavity volume during the development of large cells. Small cells, being numerous, have a diameter of about 15 μm, and fill the entire interior of the specimens. We interpret the large cells as reproductive cells and the small cells as somatic cells. The results show that *Concavaesphaera* evolved multicellular complexity equivalent to that of modern *Volvox*, with germ-soma differentiation and separation (Kirk 1998, Umen 2014, 2020). Available evidence suggests that the similarities between *Concavaesphaera* and *Volvox* are more likely the result of convergent evolution. Therefore, *Concavaesphaera* may represent an extinct multicellular eukaryote that evolved during the Cambrian explosion, and possibly documents an independent instance of multicellularity within eukaryotic evolutionary history. This research implies that multicellularity evolved many more times in eukaryotes than previously estimated.

Kirk, D.L., 1998. Developmental and Cell Biology Series. Volvox*: Molecular-Genetic Origins of Multicellularity and Cellular Differentiation.* Cambridge University Press, Cambridge, 398 pp.

Knoll, A.H., 2011. The Multiple Origins of Complex Multicellularity. *Annual Review of Earth and Planetary Sciences 39*, 217–239.

Umen, J.G., 2014. Green algae and the origins of multicellularity in the plant kingdom. *Cold Spring Harbor Perspective Biology 6*, a016170.

Umen, J.G., 2020. *Volvox* and volvocine green algae. *Evolutionary Development 11*, 1–13.

Wei Liu [lwsess@pku.edu.cn], Bing Shen [bingshen@pku.edu.cn] and Lin Dong [lin.dong@pku.edu.cn], School of Earth and Space Sciences, Peking University, Beijing 100871, People's Republic of China; Zongjun Yin [zjyin@nigpas.ac.cn], Bing Pan [bpan@nigpas.ac.cn], and Guoxiang Li [gxli@nigpas.ac.cn] Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, Nanjing 210008, People's Republic of China.

New discoveries of exceptionally well-preserved fishes from the Upper Devonian Gogo Formation of Western Australia

John Long*, Kate Trinajstic, Petar Tomic, Josh Bland, and Alice Clement

Fish fossils from the Frasnian Gogo Formation of Western Australia are found as uncrushed, 3D-preserved remains ranging from complete individuals to isolated single bones (Trinajstic *et al.* 2022a). Some have soft-tissue preservation with muscles and even soft organs preserved (Trinajstic *et al.* 2022b). Gogo is one of the most diverse vertebrate assemblages of this age with over 50 species of placoderms, osteichthyans and sharks that once inhabited the algal–stromatoporoid reef environment (Long & Trinajstic 2010). Recent collection from the sites has produced new taxa from the formation, as well as more complete representation of species originally described from incomplete type material (Long & Trinajstic 2018). New smaller taxa of torosteid arthrodires indicate that micro-predatory niches were occupied by fishes on the reef system. New osteichthyan remains include a strange braincase with the posterior half of the skull roof intact. It is a basal sarcopterygian allied to coelacanths but lacking the typical shield pattern seen in all coelacanths. A new coelacanth known from two specimens is currently under study and shows many features that have enabled us to do a thorough phylogenetic and morphometric analysis of the group. Lungfishes are well represented at Gogo with some 12 taxa, and new research on dipnoan feeding biomechanics is in progress to elucidate trophic relationships. One stem-shark (acanthodian) and a selachian were described and a new, slender scaleless form is currently under investigation. New research directions will focus on palaeoecology and feeding biomechanics of major groups and ecological robustness modelling of the ancient reef ecosystem to compare with modern coral-reef ecologies.

Long, J.A. & Trinajstic, K., 2010. The Late Devonian Gogo Formation Lagerstätte of Western Australia: Exceptional Early Vertebrate Preservation and Diversity. *Annual Review of Earth and Planetary Sciences 38*, 255–279.

Long, J.A. & Trinajstic, K.M., 2018. A review of recent discoveries of exceptionally preserved fossil fishes from the Gogo sites (Late Devonian, Western Australia). *Earth and Environmental Science Transactions of the Royal Society of Edinburgh 108*(1), 111–117.

Trinajstic, K., Briggs, D.E. & Long, J.A., 2022a. The Gogo Formation Lagerstätte: a view of Australia's first great barrier reef. *Journal of the Geological Society 179*, jgs2021-105.

Trinajstic, K., Long, J.A., Sanchez, S., Boisvert, C.A., Snitting, D., Tafforeau, P., Dupret, V., Clement, A.M., Currie, P.D., Roelofs, B., Bevitt, J.J., Lee, M.S.Y. & Ahlberg, P.E., 2022b. Exceptional preservation of organs in Devonian placoderms from the Gogo lagerstätte. *Science 377*(6612), 1311–1314.

John Long [john.long@flinders.edu.au], Petar Tomic [tomi0028@flinders.edu.au], Josh Bland [blan0102@flinders.edu.au], and Alice Clement [alice.clement@flinders.edu.au], College of Science and Engineering, Flinders University, PO Box 2100, Adelaide, SA 5001, Australia; Kate Trinajstic [K.trinsjstic@curtin.edu.au], Faculty of Science and Engineering, Curtin University, Kent St, Bentley, WA 6102, Australia.

A journey into the Paleocene Waipara Greensand in the Canterbury Region, New Zealand

Leigh Love*, Vanesa L. De Pietri, Al Mannering, and R. Paul Scofield

Career pressures on professional palaeontologists to undertake teaching, produce high-quality publications, apply for funding, and tackle collection management have reduced the available time in the field to make new discoveries. Amateur fossil collectors are thus essential in ensuring new discoveries are made. Through nurturing the enthusiasm of amateurs, fossil collectors can become citizen scientists. Amateurs that live near notable fossil sites allow systematic and repetitive searching and allow advantage to be taken of weather events that may expose fresh material. Outcrops of the Paleocene (62.5 – 56 Ma) Waipara Greensand Formation, exposed along the banks of the Waipara River, are of global importance in palaeontology, as they contain crucial snapshots into the evolution of marine ecosystems after the K–Pg extinction event. Here, Leigh Love describes the journey of one such amateur, now into its 17th year, inspired to search in the greensands only a few minutes from his home. The first vertebrates in the Waipara gorge were found in the 1990s by another 'amateur', Al Mannering, who today does all the fossil preparation of the specimens recovered by Leigh. Through Leigh's efforts searching the constantly eroding greensands, these deposits are now producing a complete ecosystem including birds, a diverse shark fauna, a fragmentary but intriguing assemblage of fish, sponges, corals, bivalves and giant turtles. Leigh recounts his experiences, from finding his first set of penguin bones, and reviews his finds, which include several penguins (e.g. *Crossvallia waiparaensis*, Rosies Penguin, an enigmatic giant penguin, the first complete wing of a stem-group penguin) and flying birds (*Australornis*, a tropic bird and bony-toothed bird). Several new taxa are introduced, and the future of the site is discussed.

Leigh Love [lvlove@xtra.co.nz], Vanesa De Pietri [vanesa.depietri@canterbury.ac.nz], and Al Mannering [alman@slingshot.co.nz], School of Earth and Environment, University of Canterbury, Private Bag 4800, Christchurch 8140, New Zealand; R. Paul Scofield [pscofield@canterburymuseum.com], Canterbury Museum, 11 Rolleston Ave, Christchurch 8013 and School of Earth and Environment, University of Canterbury, Private Bag 4800, Christchurch 8140, New Zealand.

New insights into Permian–Triassic palynology of the Bonaparte Basin, northern Australia, with comparisons to Timor-Leste

Daniel Mantle*, Carey Hannaford, Ryan Owens, Eujay McCartain, Barry Taylor, Daniel Peyrot, and John Backhouse

Extensive palynological reviews of key late Permian and Triassic intervals in the Petrel and Vulcan sub-basins and adjacent areas within the Ashmore Platform and Londonderry High have resulted in considerable new insights into the biostratigraphy of the Bonaparte Basin. These in turn have led to reviews of the regional sequence stratigraphy, lithostratigraphy and palaeoenvironmental interpretations, thus providing the basis for future palaeogeographic and palaeoclimatic studies. A key focus was put on the End Permian Extinction (EPE) and subsequent recovery floras of the earliest Triassic in the Petrel Sub-basin. Many traditional spore-pollen marker events from eastern Australian reference sections are either too rare, entirely absent, or occur out of sequence on the North West Shelf (northwestern Australia) to allow recognition of the critical P–Tr boundary zones — namely the *Playfordiaspora crenulata*, *Protohaploxypinus microcorpus* and *Lunatisporites pellucidus* zones. Thus, a new combination of marker spores and pollen, palynofacies shifts, and environmental signatures were utilised to allow for a more consistent identification of this boundary interval regionally. A further critical study interval was the thick mid-Triassic Onslow Microflora successions in the northern Bonaparte Basin, which was compared with similar intervals cropping out in Timor-Leste. The Carnian *Samaropollenites speciosus* Zone is of particular interest as it ties in closely with the warming period associated with the Carnian Pluvial Episode, an event that had significant influence on global climates and the biosphere, and yet remains understudied in eastern Gondwana.

Daniel Mantle [dan.mantle@mgpalaeo.com.au], and Carey Hannaford [carey.hannaford@mgpalaeo.com.au], MGPalaeo, Unit 1, 5 Arvida Street, Malaga, WA 6090, Australia; Ryan Owens [Ryan.Owens@ga.gov.au], Geoscience Australia, GPO Box 378, Canberra, ACT 2601, Australia; Eujay McCartain [eujay.mccartain@uwa.edu.au], Daniel Peyrot [daniel.peyrot@uwa.edu.au], and John Backhouse [john.backhouse@uwa.edu.au], School of Earth Sciences, The University of Western Australia, 35 Stirling Highway, Perth, WA 6009, Australia; Barry Taylor [Barry.Taylor@woodside.com], Woodside Energy Ltd, Mia Yellagonga, 11 Mount Street, Perth, WA 6000, Australia.

Make *Horodyskia williamsii* great again!

David McB. Martin*, and Heidi J. Allen

Distinctive Mesoproterozoic bedding-plane markings that resemble a 'string of beads' were first recognised from the Belt Supergroup of North America by Robert Horodyski, and later assigned in his honour to the genus *Horodyskia* on the basis of interpreted biogenicity. *Horodyskia* has since been documented from the Mesoproterozoic Bangemall Supergroup of Western Australia, the Rocky Cape Group of Tasmania, and the Debengda Formation of Siberia, as well as from the Tonian of China and Ediacaran of China and India. Despite four decades of study, both the biogenicity and classification of *Horodyskia* remain contentious, and as a result its evolutionary significance is commonly overlooked.

Western Australian examples of these enigmatic structures, first discovered in 1985 by Ian Williams, were assigned to *Horodyskia williamsii* in 2010. These bedding-plane features are now known from 76 localities in the Stag Arrow and Backdoor Formations, and material from 49 of these has been sampled and used in systematic descriptions. The Geological Survey of Western Australia Paleontology Collection has 477 samples, excluding material recently repatriated from the South Australian Museum. No new localities have been identified in the Bangemall Supergroup since systematic description, but the age of the Backdoor Formation is revised to *ca* 1400–1300 Ma, which has important implications for the often-overlooked significance of these macroscopic Mesoproterozoic tissue-grade fossils.

This presentation reviews the history of discovery and naming of *Horodyskia williamsii*, current understanding of its distribution, depositional environment, taphonomy and age, and the significance of associated organic and inorganic structures, as well as its differences compared to *Horodyskia moniliformis* and *Horodyskia minor*. This will hopefully inspire renewed interest and recognition of its biostratigraphic and palaeobiological importance.

David McB. Martin [david.martin@dmirs.wa.gov.au], and Heidi Allen [Heidi.allen@dmirs.wa.gov.au], Geological Survey of Western Australia, Department of Mines, Industry Regulation and Safety, 100 Plain St, East Perth, WA 6004, Australia.

A south polar refuge for land ecosystems during the end-Permian hyperthermal event (Tasmania Basin, Australia)

Chris Mays*, Christopher R. Fielding, Tracy D. Frank, Michael T. Hren, Stephen M. Forsyth, Vivi Vajda, and Stephen McLoughlin

A series of crises have sculpted Earth's biological evolution, and these can be defined by changes in both biodiversity and productivity. For the first time, we deploy a method for detecting changes in land-plant productivity through a major mass extinction: the end-Permian event (EPE; *ca* 252 Ma). Two previously unreported records of the EPE were studied from cored non-marine strata of the Tasmania Basin, Australia, from the palaeo-south polar circle (~75°S). The EPE was characterised by brief but major reductions in plant productivity (>95%) followed by long-term stasis at much lower (≥65%) than pre-extinction levels. This productivity collapse corresponds to the synchronous 'dead (or depleted) zone' previously identified across eastern Australia. A combination of ecosystem and environmental proxies indicate: 1, a negative carbon isotope excursion immediately followed by enhanced weathering; 2, continental ecosystem collapse was likely exacerbated by a marked increase in wildfire activity; 3, reduced post-EPE land plant productivity limited the spread of wildfires, contributing to an Early Triassic 'charcoal depression'; 4, weathering indices indicate a pulse in continental erosion owing to rapid deforestation, fuelling freshwater microbe proliferation in continental water-bodies; and 5, the climax wetland *Glossopteris* flora was replaced by a low-biomass forests including a pulse in opportunistic lycophytes. Application of this battery of standardised methods across eastern Australia revealed a distinct gradient of ecosystem stressors and responses to the EPE, with the highest magnitudes of weathering, wildfires and microbial blooms and productivity reductions at lowest palaeolatitudes. This lends strong support for the recurrence of 'polar refugia' for terrestrial ecosystems during extreme warming events. The severe productivity drop, here supported by a suite of established collapse markers, provides a novel method for detecting and characterising continental ecosystem disruptions throughout most of the Phanerozoic.

Chris Mays [cmays@ucc.ie], School of Biological, Earth and Environmental Sciences, Environmental Research Institute, University College Cork, Distillery Fields, Cork T23 N73K, Ireland; Christopher R. Fielding [christopher.fielding@uconn.edu], Tracy D. Frank [tracy.frank@uconn.edu], and Michael T. Hren [michael.hren@uconn.edu], Department of Earth Sciences, University of Connecticut, Beach Hall, 354 Mansfield Road (Unit 1045), Storrs, CT 06269, USA; Stephen M. Forsyth [smforsyth@internode.on.net], 55 Malunna Road, Lindisfarne, TAS 7015, Australia; Vivi Vajda [vivi.vajda@nrm.se], and Stephen McLoughlin [steve.mcloughlin@nrm.se], Swedish Museum of Natural History, Svante Arrhenius v. 9, SE-104 05, Stockholm, Sweden.

Mid-Proterozoic macrofossils: a bit PISS or MISS — why give a TOS?

Peter McGoldrick*, Jessica Van Spall, Wendi Bulfin, Josh Guilliamse, and Donna Satterthwait

Bedding surfaces of finer grained sedimentary rocks are often decorated with a variety of structures. Many are readily explained as a result of physical processes acting during sediment deposition and subsequent burial-compaction (Physically Induced Sedimentary Structures — PISS). During the Phanerozoic, the activities of living organisms left their traces in most sedimentary settings. By contrast, in the 'mat-world' of the Precambrian, sedimentary rocks often display textures indicating the presence of (former) microbial communities. These have been grouped together as Microbially Induced Sedimentary Structures — MISS (e.g. Noffke *et al.* 2001, Schieber *et al.* 2007). Textured organic surfaces (TOS — Gehling & Droser 2009) are a subset of MISS. However, as well as macroscopic bed-surface textures produced by microbes, importantly, TOS can include megascopic organisms. This presentation describes MISS and TOS features from two mid-Proterozoic fossil occurrences. Unmineralised sideritic siltstones and shales, precisely dated at 1.595 Ga (Page & Sweet 1998), from the Century zinc mine display a variety of carbonaceous textured surfaces. Large (up to 800 µm) and complex microfossils are also present. Rare megascopic structures that resemble the Neoproterozoic ichnotaxon *Intrites punctatus* are present in a few samples. The combination of megascopic TOS features and complex microfossils suggests large eukaryotes were present in the anoxic outer shelf setting of the Century rocks. The Laan fossil site in northwestern Tasmania (see posters by Van Spall *et al.* & McGoldrick *et al.,* this meeting) is between 1.45 and 1.33 Ga (Halpin *et al.* 2014). It contains abundant *Horodyskia* and other large 'morphotypes', some of which can be interpreted as fossils of soft-bodied eukaryotes. MISS are common and microbial processes likely played an important role in fossil preservation (see Bulfin *et al.*, this meeting). Together the Century and Laan sites have important implications for the nature and lifestyles of early eukaryotes and these will be discussed. Importantly, fossil vestiges of mid-Proterozoic megascopic eukaryotes may be 'hiding in plain sight' having been mistakenly classified as MISS (not TOS).

Gehling, J.G. & Droser, M.L., 2009. Textured organic surfaces associated with the Ediacara biota in South Australia. *Earth Science Reviews 96*, 196–206.

Halpin, J.A., Jensen, T., McGoldrick, P., Meffre, S., Berry, R.F., Everard, J.L., Calver, C.R., Thompson, J., Goemann, K. & Whittaker, J.M., 2014. Authigenic monazite and detrital zircon dating from the Proterozoic Rocky Cape Group, Tasmania: Links to the Belt-Purcell Supergroup, North America. *Precambrian Research 250*, 50–67.

Noffke, N., Gerdes, G. & Klenke, T., 2001. Microbially Induced Sedimentary Structures — A New Category within the Classification of Primary Sedimentary Structures. *Journal of Sedimentary Research 71*, 649–656.

Page, R.W. & Sweet, I.P., 1998. Geochronology of basin phases in the western Mt Isa Inlier, and correlation with the McArthur Basin. *Australian Journal of Earth Sciences 45*, 219–232.

Schieber, J., Bose, P., Eriksson, P.G., Banerjee, S., Sarkar, S., Altermann, W. & Catuneanu, O., 2007. *Atlas of Microbial Mat Features Preserved within the Siliciclastic Rock Record.* Elsevier Science, Amsterdam, 324 pp.

Peter McGoldrick [p.mcgoldrick@utas.edu.au], Jessica Van Spall [jvan0@utas.edu.au], Wendi Bulfin [wbulfin@utas.edu.au], and Donna Satterthwait [Donna.Satterthwait@utas.edu.au], CODES, University of Tasmania, Locked Bag 66, Hobart TAS 7001, Australia; Josh Guilliamse [Joshua.Guilliamse@dmirs.wa.gov.au], Geological Survey of Western Australia, Department of Mines Industry Regulation and Safety, 100 Plain St, East Perth, WA 6004, Australia.

Newly described anatomy of a Devonian stem-tetrapod fish illuminated by neutron tomography

Corinne L. Mensforth*, Alice M. Clement, Joseph J. Bevitt, and John A. Long

One of the most significant events in vertebrate evolution was the fish-to-tetrapod transition, which loosely also covers the water-to-land, fin-to-limb and gill-to-lung transitions. These events can be traced back in connection to anatomical changes observable in several stem-tetrapod fishes and early tetrapod taxa that lived during the Devonian and Carboniferous periods. These stem-tetrapod fishes gave rise to all extant tetrapods, including amphibians, reptiles, birds and mammals, and as such provide vital insight into early tetrapod evolution. *Koharalepis jarviki* is a stem-tetrapod fish known only from a single specimen preserved in 3D that was discovered in Antarctica in 1971. It has been the subject of two studies to date, its initial description and some brief revisions based on X-ray tomography. The phylogenetic position of *Koharalepis* remains unclear due to a lack of data and is the subject of the current study. A new 3D scan dataset was produced on the ANSTO Dingo neutron beam that captured images of undescribed internal features. The dataset enabled the production of digital 3D models enabling description of novel anatomy, including the endocranium, vertebral ring centra and palatoquadrate. Furthermore, due to the 3D preservation of *Koharalepis*, the creation of the braincase's internal endocast is possible. The braincase and its internal endocast will be examined in comparison to other stem-tetrapod fishes to determine changes in neural anatomy over the water-to-land transition. This study will provide a greater understanding of the evolution of the stem-tetrapod fishes and the wider tetrapod lineage.

Corinne L. Mensforth [mens0009@flinders.edu.au], Alice M. Clement [alice.clement@flinders.edu.au], and John A. Long [john.long@flinders.edu.au], Flinders University, GPO Box 2100, Adelaide, SA 5001, Australia; Joseph J. Bevitt [jbv@ansto.gov.au], Australian Nuclear Science and Technology Organisation, Research Office, B3, New Illawarra Road, Lucas Heights, NSW 2234, Australia.

Evidence of a new megaraptorid theropod from the Upper Cretaceous (Cenomanian–Turonian) portion of the Winton Formation of Opalton, Central West Queensland, Australia

Christina A. Nielsen-Smith*, Jay P. Nair, Matthew C. Lammana, and Steven W. Salisbury

Fossils of non-avian theropod dinosaurs are extremely rare in Australia, with most specimens comprising isolated and fragmentary remains. The sole exception is the megaraptorid *Australovenator wintonensis* Hocknull *et al.*, 2009, represented by a partial skeleton from the Upper Cretaceous (Cenomanian–Turonian: Tucker *et al*. 2013, 2017) portion of the Winton Formation, near Winton, Central West Queensland. Here we report a non-avian theropod specimen from Koa Country near Opalton (Central West Queensland) that is also from the Cenomanian–Turonian portion of the Winton Formation but clearly distinct from *A. wintonensis*. The specimen is a left metacarpal I, permitting comparisons with a range of non-avian theropods, including multiple named taxa from Australia. The general morphology of the specimen is consistent with metacarpal I of other megaraptorids, displaying a block-like overall profile that is proximodistally longer than mediolaterally wide, with a trapezoidal proximal outline and a well-developed proximomedial process (Novas *et al.* 2016, Naish & Cau 2022). Significantly, the specimen is distinct from the metacarpal I of all currently named megaraptorids, presenting a suite of autapomorphic traits. Based on these observations, we propose that the specimen represents a new megaraptorid taxon. Comparisons with metacarpal I of the *A. wintonensis* holotype indicate that the Opalton megaraptorid possessed a much larger, more robustly constructed manus. The discovery of a new megaraptorid taxon from Opalton suggests that these theropods were both taxonomically and morphologically more diverse in the Winton Formation than previously thought and highlights the dominance of this clade in apex predator niches within Australia's mid-Cretaceous dinosaur faunas.

Hocknull, S.A., White, M.A., Tischler, T.R., Cook, A.G., Calleja, N.D., Sloan, T. & Elliott, D.A., 2009. New Mid-Cretaceous (latest Albian) dinosaurs from Winton, Queensland, Australia. *PLoS One 4*, 1–51.

Naish, D. & Cau, A., 2022. The osteology and affinities of *Eotyrannus lengi*, a tyrannosauroid theropod from the Wealden Supergroup of southern England. *PeerJ 10*, e12727.

Novas, F.E., Aranciaga Rolando, A.M. & Agnolin, F.L., 2016. Phylogenetic relationships of the Cretaceous Gondwanan theropods *Megaraptor* and *Australovenator*: the evidence afforded by their manual anatomy. *Memoirs of Museum Victoria 74*, 49–61.

Tucker, R.T., Roberts, E.M., Hu, Y., Kemp, A.I.S. & Salisbury, S.W., 2013. Detrital zircon age constraints for the Winton Formation, Queensland: Contextualising Australia's Late Cretaceous dinosaur faunas. *Gondwana Research 24*(2), 767–779.

Tucker, R.T., Roberts, E.M., Darlington, V. & Salisbury, S.W., 2017. Investigating the stratigraphy and palaeoenvironments for a suite of newly discovered mid-Cretaceous vertebrate fossil-localities in the Winton Formation, Queensland, Australia. *Sedimentary Geology 358*, 210–229.

Christina Nielsen-Smith [c.nielsensmith@uq.net.au], Jay P. Nair [jayraptor@gmail.com], and Steven W. Salisbury [s.salisbury@uq.edu.au], School of Biological Sciences, The University of Queensland, Brisbane, QLD 4072, Australia; Matthew C. Lamanna [lamannam@carnegiemnh.org], Section of Vertebrate Paleontology, Carnegie Museum of Natural History, 4400 Forbes Avenue, Pittsburgh, PA 15213, USA.

Placoderm diversity in the high palaeolatitude Waterloo Farm Lagerstätte

Ryan Nel*, Robert W. Gess, and Kate M. Trinajstic

Until recently most Devonian research focused on vertebrates in low-latitude palaeotropical faunas from Australia, China, Europe, and North America — with little being known from the palaeoantarctic strata of Africa, southern South America, and western Antarctica. The recent discovery of Early, Mid, and Late Devonian placoderms from the Cape Supergroup strata, South Africa (Chaloner *et al*. 1980, Long *et al*. 1997, Anderson *et al*. 1999), assists in remedying this biogeographical blind spot. The most significant site yielding polar placoderms is the Late Devonian Waterloo Farm Lagerstätte, a black-shale deposit of the Witpoort Formation (Witteberg Group) located near Makhanda in South Africa (Gess & Hiller, 1995, Long *et al*. 1997, Anderson *et al*. 1999, Gess & Trinajstic 2017, Gess & Whitfield 2020). The site contains a large diversity of fossil fauna and flora (Gess & Hiller 1995), providing a unique insight into a Late Devonian (Famennian) estuary. A large number of placoderms have been recovered from the site, of which four taxa have, as yet, been described. These are *Bothriolepis africana (*Long *et al*. 1997), *Groenlandaspis riniensis* (Long *et al*. 1997), *Africanaspis doryssa* (Long *et al*. 1997, Gess & Trinajstic 2017) and *Africanaspis edmountaini* (Gess & Trinajstic 2017). Subsequent to their diagnosis, a large number of additional specimens have been collected, including both material attributable to existing taxa, and representative of novel taxa. Insights from this material highlight the need for revision of existing taxa and diagnosis of new taxa, in addition to study of ontogeny. Mid Devonian placoderms have been collected from the Klipbokkop Formation (Bokkeveld Group) in South Africa of which only one species, *Groenlandaspis (Barrydalaspis) theroni* (Chaloner *et al*. 1980), has been described. A large number of groenlandaspid-like fossils have been collected from the Formation, and with subsequent description will aid in the understanding of Mid-Devonian placoderm diversity. The increasing interest in Devonian pisceans, particularly placoderms, adds interest to those from the high palaeolatitude setting of South Africa, which contribute to understanding of early vertebrate evolution and diversification.

Anderson, M.E., Almond, J.E., Evans, F.J. & Long, J.A., 1999a. Devonian (Emsian–Eifelian) fish from the Lower Bokkeveld Group (Ceres Subgroup), South Africa. *Journal of African Earth Science 29*, 179–194.

Chaloner, W.G., Forey, P.L., Gardiner, B.G., Hill, A.J. & Young, V.T., 1980. Devonian Fish and Plants from the Bokkeveld Series of South Africa. *Annals of the South African Museum 81*(3), 127–157.

Gess, R.W. & Hiller, N., 1995. A Preliminary Catalogue of Fossil Algal, Plant, Arthropod, and Fish Remains from a Late Devonian Black Shale Near Grahamstown, South Africa. *Review of Palaeobotany and Palynology 89*(3), 417–428.

Gess, R.W. & Trinajstic, K.M., 2017. New morphological information on, and species of placoderm fish *Africanaspis* (Arthrodira, Placodermi) from the Late Devonian of South Africa. *PLoS One 12*(4), 1–30.

Gess, R.W. & Whitfield, A.K., 2020. Estuarine fish and tetrapod evolution: insights from a Late Devonian (Famennian) Gondwanan estuarine lake and a southern African Holocene equivalent. *Biological Reviews 4*(94), 865–888.

Long, J.A., Anderson, M.E., Gess, R. & Hiller, N., 1997. New placoderm fishes from the Late Devonian of South Africa. *Journal of Vertebrate Paleontology 17*(2), 253–268.

Ryan Nel [ryan2nel@gmail.com], Geology Department, Rhodes University, Grahamstown, South Africa; Rob W. Gess [robg@imaginet.co.za], Geology Department, Rhodes University, and Albany Museum, Somerset Street, Grahamstown, South Africa; Kate M. Trinajstic [K.Trinajstic@curtin.edu.au], School of Molecular and Life Sciences, Curtin University, Kent St, Bentley, WA 6102, Australia.

Taxonomic review of the genus *Dasycercus* (Dasyuromorphia: Dasyuridae) using modern and subfossil material, and the description of three new species

Jake Newman-Martin*, Kenny J. Travouillon, Natalie Warburton, Milo Barham, and Alison J. Blyth

There has long been much apprehension surrounding the genus *Daycercus*, and the species therein. Previous efforts have been made to clarify the taxa; however, this has been difficult as no craniodental characters have been identified. This is especially the case when dealing with subfossil material, meaning it is impossible to confidently identify *Dasycercus* material to species level. Currently two species are recognised: *D. cristicauda* and *D. blythi*, with the previously named *D. hillieri* considered a junior synonym of *D. cristicauda*. This investigation aimed to integrate modern, historical and subfossil material from across Australia, and establish cranial and dental morphological characters that enable phylogenetic and morphometric analysis of taxa to provide the most comprehensive review of the genus to date. As a result, we were able to established a set of craniodental characters for both *D. cristicauda* and *D. blythi*, confirming the validity of each taxa. Results also support the validity of the previously proposed *D. hillieri*, as well as three newly identified taxa: *D.* sp. nov. 1, *D.* sp. nov. 2, and *D.* sp. nov. 3. These results indicate that *Dasycercus* is far more diverse than previously believed. These results were only clear once subfossil material was identified, highlighting the need for craniodental characters and their inclusion when reviewing genera.

Jake Newman-Martin [jake.newman-martin@student.curtin.edu.au], Milo Barham [Milo.Barham@curtin.edu.au], and Alison J. Blyth [Alison.Blyth@curtin.edu.au], Curtin University, Kent St, Bentley, WA 6102, Australia; Kenny J. Travouillon [Kenny.Travouillon@museum.wa.gov.au], Western Australian Museum, Collections and Research, Locked Bag 49, Welshpool DC, WA 6986, Australia; Natalie Warburton [N.Warburton@murdoch.edu.au], Harry Butler Institute, Murdoch University, 90 South Street, Murdoch, WA 6150, Australia.

Periostracum in Cambrian helcionelloid and rostroconch molluscs: comparison to modern examples

Yeongju Oh*, John S. Peel, Yong Yi Zhen, Patrick M. Smith, Mirinae Lee, and Tae-Yoon S. Park

The periostracum is a non-calcified organic layer that covers the mineralised layer of mollusc shells. It is prone to decay during post-mortem burial, which has resulted in limited reports of fossilised periostracum, especially from the Paleozoic era. In this study, we present radially arranged threads found on the outer surface of Cambrian mollusc groups, such as helcionelloids and rostroconchs, which we interpret as fossilised periostracal structures. These radial threads were confirmed at least in 15 specimens with a widespread palaeogeographic distribution, including Gondwana (Australia), Siberia, western Laurentia (Utah), and eastern Laurentia (Greenland). The stratigraphic range of these occurrences spanned from Stage 4 to the Drumian. The radial threads always cover the outermost surface of sclerites at regular intervals and originate from the apex of helcionelloids or the umbo of rostroconchs. Detailed observation has revealed that the radial thread structures were developed by the accumulation of units consisting of an imbricated edge and comarginal increments. Morphologically, the radial threads are highly comparable to: 1) adhesive lines found in fossil and modern species of anomalodesmatan bivalves; and 2) periostracal projections of viviparid gastropods. These representatives are developed as part of the periostracum, suggesting that diverse periostracal architectures were readily developed during the mid-Cambrian across various low-latitude palaeocontinents.

Yeongju Oh [yjoh@kopri.re.kr], and Tae-Yoon S. Park [typark@kopri.re.kr], Division of Earth Sciences, Korea Polar Research Institute, 26 Songdomirae-ro, Yeonsu-gu, 21990 Incheon, Republic of Korea, and Polar Science, University of Science and Technology, Daejeon, 34113, Republic of Korea; John S. Peel [john.peel@pal.uu.se], Department of Earth Sciences (Palaeobiology), Uppsala University, Villavägen 16, SE-752 36 Uppsala, Sweden; Yong Yi Zhen [yong-yi.zhen@regional.nsw.gov.au], Geological Survey of New South Wales, WB Clarke Geoscience Centre, 947-953 Londonderry Road, Londonderry, NSW 2753, Australia; Patrick M. Smith [Patrick.Smith@austmus.gov.au], Palaeontology Department, Australian Museum Research Institute, Sydney, NSW 2010, Australia, and Department of Biological Sciences, Macquarie University, Sydney, NSW 2109, Australia; Mirinae Lee [mirinae.lee@kopri.re.kr], Division of Earth Sciences, Korea Polar Research Institute, 26 Songdomirae-ro, Yeonsu-gu, 21990 Incheon, Republic of Korea.

The early Cambrian Emu Bay Shale radiodonts revisited

John R. Paterson*, Diego C. García-Bellido, and Gregory D. Edgecombe

The lower Cambrian (Series 2, Stage 4) Emu Bay Shale (EBS) Konservat-Lagerstätte on the northeastern coast of Kangaroo Island, South Australia, has yielded a wealth of knowledge on early animal anatomy, diversity, evolution, ecology, and preservation. Among the many key discoveries are the remains of radiodonts — a clade of stem-group euarthropods possessing a pair of spinose, arthrodised frontal appendages, large compound eyes, a ventrally positioned oral cone, and a series of segmental body flaps used for swimming. The two EBS radiodont species are revised based on new field collections and insights from recent phylogenetic analyses and advances in knowledge of radiodonts globally. *'Anomalocaris' briggsi* Nedin, 1995, the most common EBS radiodont, is designated the type species of a new monotypic genus of Tamisiocarididae. The less common taxon, previously identified as *Anomalocaris* aff. *canadensis* Whiteaves, 1892, is now assigned to a new species within that genus. Oral cones are assigned to both species, based in part on associated pairs of frontal appendages. Shared characters of the EBS oral cones add support for a sister group relationship between Tamisiocarididae and Anomalocarididae. An ovate head element resembling that of *Tamisiocaris borealis* from the Sirius Passet Konservat-Lagerstätte in Greenland is assigned to *'A.' briggsi*, informed by the sister group relationship between these taxa. Isolated radiodont body flaps and sets of setal blades in the EBS cannot be confidently assigned to a species, although relative abundance suggests that many or most are likely *'A.' briggsi*. The inner attachment margin of the body flaps is sharply defined and may represent a suture at which flaps are shed in moulting.

John R. Paterson [jpater20@une.edu.au], Palaeoscience Research Centre, School of Environmental and Rural Science, University of New England, Armidale, NSW 2351, Australia; Diego C. García-Bellido [diego.garcia-bellido@adelaide.edu.au], School of Biological Sciences, University of Adelaide, Adelaide, SA 5005, and South Australian Museum, North Terrace, Adelaide, SA 5000, Australia; Gregory D. Edgecombe [g.edgecombe@nhm.ac.uk], The Natural History Museum, Cromwell Road, London SW7 5BD, UK.

Advances in Australian amber palaeontology: middle Eocene bioinclusions from Anglesea, Victoria — reconstructing a subpolar terrestrial greenhouse ecosystem

Maria Paulsen, and Jeffrey Stilwell

Fossiliferous amber from Anglesea, Victoria, has been previously reported as preserving diverse bioinclusions of plants, arthropods and microorganisms (Stilwell *et al.* 2020). These discoveries open important new windows into formerly underrepresented Austral terrestrial ecosystems, relative to those of the Boreal realm from the mid-Paleogene. Here, new major discoveries of organisms from the same locality are presented with detailed taxonomic identifications based on Micro-CT Synchrotron (MCT) results. Renewed efforts and subsequent observations have shed light on past arthropod (insect and arachnid) and bryophyte distributions in southern greenhouse high palaeolatitudes (55°S), and also on the palaeoecology of rainforest inhabitants. Significantly, several taxa identified in the amber are extant in modern Australian ecosystems, thus representing relict Gondwana lineages with significant conservation ramifications today.

Stilwell, J.D., Langendam, A., Mays, C., Sutherland, L.J.M., Arillo, A., Bickel, D.J., De Silva, W.T., Pentland, A.H., Roghi, G., Price, G.D., Cantrill, D.J., Quinney, A. & Peñalver, E. 2020, Amber from the Triassic to Paleogene of Australia and New Zealand as exceptional preservation of poorly known terrestrial ecosystems. *Scientific Reports 10*, 5703.

Maria Paulsen [maria.paulsen@monash.edu], and Jeffrey D. Stilwell [Jeffrey.Stilwell@monash.edu], School of Earth, Atmosphere and Environment, Monash University, 9 Rainforest Walk, Clayton, VIC 3800, Australia.

Utilising tomography of extant basal chondrichthyans to determine the evolution and homology of fins

Jacob Pears*, Catherine Boisvert, and Kate Trinajstic

Questions regarding the serial homology of the pectoral and pelvic fins have recently been reignited with the discovery of fossils from China with paired fin folds, providing fossil evidence for the fin fold theory. Controversy exists due to significant differences between the musculature of the pectoral and pelvic girdle, as well as muscle attachment to other skeletal bones in extant vertebrates. To address these questions, we investigated the skeletal elements and musculature of both the pectoral and pelvic skeleton in placoderms, the earliest jawed vertebrates, and compare them with basal sharks. Using micro-CT of chimaeroid and placoderm fin skeletons and comparative skeletal studies, we found that chimaeroids and selachians exhibit a pattern of pelvic-fin development that recapitulates the evolution of pelvic-fin morphology from stem to crown gnathostomes. Previous synchrotron investigation on the preserved musculature have demonstrated distinct head and pectoral-fin muscles in placoderms, whereas crown chondrichthyans exhibit involvement of the cucullaris muscle in both head depression and fin elevation. Our findings show that the fin musculature is very similar between the pectoral and pelvic fins within arthrodire placoderms, alongside consistent fin size and position. We propose that the pronounced differences between fins emerged in crown gnathostomes.

Jacob Pears [jacob.pears@postgrad.curtin.edu.au], Catherine Boisvert [C.Boisvert@curtin.edu.au], and Kate Trinajstic [K.Trinajstic@curtin.edu.au], School of Molecular and Life Sciences, Curtin University, Kent St, Bentley, WA 6102, Australia.

A new ornithocheirid pterosaur from the Toolebuc Formation (middle–upper uppermost Albian) of northeast Australia

Adele Pentland*, and Stephen F. Poropat

The Australian pterosaur record largely comprises isolated and fragmentary remains. Only one specimen, the holotype of *Ferrodraco lentoni* Pentland *et al.*, 2019 from the Upper Cretaceous Winton Formation (Cenomanian), is represented by substantial associated material (Pentland *et al.* 2019, 2022). Most of the Australian pterosaur record derives from the Lower Cretaceous Toolebuc Formation (middle–upper uppermost Albian) in the Eromanga Basin, Queensland. Indeed, three of the four named Australian pterosaur taxa derive from this unit — *Mythunga camara* Molnar & Thulborn, 2007, *Aussiedraco molnari* Kellner, Rodrigues & Costa, 2011 and *Thapunngaka shawi* Richards Stumkat & Salisbury, 2021. Herein, I describe a new pterosaur specimen from the Toolebuc Formation that preserves cranial and postcranial axial and appendicular elements, constituting more than 20% of the skeleton. The new specimen is the most complete pterosaur reported from Australia to date. The skull is represented by a partial crested premaxilla, a near-complete mandible with comparatively small mandibular crest, thirty teeth and both ceratobranchials. The postcranial axial skeleton is represented by two cervical vertebrae and at least three partial dorsal ribs. Appendicular elements include the left scapulocoracoid, right syncarpus, metacarpals and manual phalanges from the left and right wings, right wing phalanges, and a left hind limb comprising the femur, tibia, a metatarsal, and pedal digits. Based on impressions in the surrounding matrix, it is likely that more elements were initially preserved but lost prior to collection. The new pterosaur differs from *Aussiedraco molnari*, *Thapunngaka shawi* and *Ferrodraco lentoni* in that it possesses a dorsoventrally short mandibular crest. Its dentition is less robust than that of *Mythunga camara*. Preliminary phylogenetic analyses resolve the new specimen in a polytomy with two Australian pterosaur taxa, *Mythunga camara* and *Ferrodraco lentoni*. Alternatively, the new specimen is resolved in a polytomy with *Caulkicephalus trimicrodon* (United Kingdom), *Guidraco venator* (China) and *Ludodactylus sibbicki* (Brazil).

Kellner, A.W., Rodrigues, T. & Costa, F.R., 2011. Short note on a pteranodontoid pterosaur (Pterodactyloidea) from western Queensland, Australia. *Anais da Academia Brasileira de Ciências 83*(1), 301–308.

Molnar, R.E. & Thulborn, R.A., 2007. An incomplete pterosaur skull from the Cretaceous of north-central Queensland, Australia. *Arquivos do Museu Nacional, Rio de Janeiro 65*, 461–470.

Pentland, A.H., Poropat, S.F., Tischler, T.R., Sloan, T., Elliott, R.A., Elliott, H.A., Elliott, J.A. & Elliott, D.A., 2019. *Ferrodraco lentoni* gen. et sp. nov., a new ornithocheirid pterosaur from the Winton Formation (Cenomanian–lower Turonian) of Queensland, Australia. *Scientific Reports 9*(1), 13454. https://doi.org/10.1038/s41598-019-49789-4

Pentland, A.H., Poropat, S.F., White, M.A., Rigby, S.L., Bevitt, J.J., Duncan, R.J., Sloan, T., Elliott, R.A., Elliott, H.A., Elliott, J.A. & Elliott, D.A., 2022. The osteology of *Ferrodraco lentoni,* an anhanguerid pterosaur from the mid-Cretaceous of Australia. *Journal of Vertebrate Paleontology*, e2038182. https://doi.org/10.1080/02724634.2021.2038182

Richards, T.M., Stumkat, P.E. & Salisbury, S.W., 2021. A new species of crested pterosaur (Pterodactyloidea, Anhangueridae) from the Lower Cretaceous (upper Albian) of Richmond, North West Queensland, Australia. *Journal of Vertebrate Paleontology*, e1946068. https://doi.org/10.1080/02724634.2021.1946068

Adele Pentland [pentlandadele@gmail.com], and Steve F Poropat [steve.poropat@curtin.edu.au], Western Australian Organic and Isotope Geochemistry Centre, School of Earth and Planetary Science, Curtin University, Kent St, Bentley, WA 6102, Australia, and Australian Age of Dinosaurs Museum of Natural History, Winton, QLD 4735, Australia.

A nearly complete skull of the sauropod dinosaur *Diamantinasaurus matildae* from the Upper Cretaceous Winton Formation of Australia: implications for the early evolution of titanosaurs

Stephen Poropat*, Phil Mannion, Sam Rigby, Ruairidh Duncan, Adele Pentland, Joseph Bevitt, Trish Sloan, and David Elliott

Titanosaurian sauropod dinosaurs were diverse, abundant, and globally distributed throughout the Cretaceous. However, few titanosaurian taxa are represented by multiple skeletons, let alone skulls. *Diamantinasaurus matildae*, from the lower Upper Cretaceous Winton Formation of Queensland, Australia, was previously represented by three specimens, including one that preserves a fragmentary skull (Poropat *et al.* 2021). We describe a fourth specimen of *Diamantinasaurus matildae*, which preserves a more complete skull and partial postcrania (Poropat *et al.* 2023). The skull of *Diamantinasaurus matildae* shows many similarities to that of the coeval *Sarmientosaurus musacchioi* from Argentina (Martínez *et al.* 2016), providing further support for the inclusion of both taxa within the clade Diamantinasauria. The replacement teeth within the premaxilla of the new specimen are morphologically congruent with teeth previously attributed to *Diamantinasaurus matildae*, and Diamantinasauria more broadly, corroborating those referrals (Poropat *et al.* 2022). Plesiomorphic characters of the new specimen include a sacrum comprising five vertebrae (also newly demonstrated in the holotype), rather than the six or more that typify other titanosaurs. However, we show that there have been a number of independent acquisitions of a six-vertebrae sacrum amongst Somphospondyli and/or that there have been numerous reversals to a five-vertebrae sacrum, suggesting that sacral count is relatively plastic. Other newly identified plesiomorphic features include: the overall skull shape, which is more similar to brachiosaurids than 'derived' titanosaurs; anterior caudal centra that are amphicoelous, rather than procoelous; and a pedal phalangeal formula estimated as 2-2-3-2-0. These features are consistent with either an early-branching position within Titanosauria, or a position just outside Titanosauria, for Diamantinasauria. The new *Diamantinasaurus matildae* specimen helps to shed light on the early assembly of the titanosaurian bauplan, as well as elucidating diamantinasaurian palaeoecology.

Martínez, R.D.F., Lamanna, M.C., Novas, F.E., Ridgely, R.C., Casal, G.A., Martínez, J.E., Vita, J.R. & Witmer, L.M., 2016. A basal lithostrotian titanosaur (Dinosauria: Sauropoda) with a complete skull: implications for the evolution and paleobiology of Titanosauria. *PLOS One 11*, e0151661.

Poropat, S.F., Kundrát, M., Mannion, P.D., Upchurch, P., Tischler, T.R. & Elliott, D.A., 2021. Second specimen of the Late Cretaceous sauropod dinosaur *Diamantinasaurus matildae* provides new anatomical information on skull and neck evolution in early titanosaurs and the biogeographic origins of Australian dinosaur faunas. *Zoological Journal of the Linnean Society 192*, 610–674.

Poropat, S.F., Frauenfelder, T.G., Mannion, P.D., Rigby, S.L., Pentland, A.H., Sloan, T. & Elliott, D.A., 2022. Sauropod dinosaur teeth from the lower Upper Cretaceous Winton Formation of Queensland, Australia, and the global record of early titanosauriforms. *Royal Society Open Science 9*, 220381.

Poropat, S.F., Mannion, P.D., Rigby, S.L., Duncan, R.J., Pentland, A.H., Bevitt, J.J., Sloan, T. & Elliott, D.A., 2023. A nearly complete skull of the sauropod dinosaur *Diamantinasaurus matildae* from the Upper Cretaceous Winton Formation of Australia and implications for the early evolution of titanosaurs. *Royal Society Open Science 10*, 221618.

Rigby, S.L., Poropat, S.F., Mannion, P.D., Pentland, A.H., Sloan, T., Rumbold, S.J., Webster, C.B. & Elliott, D.A., 2022. A juvenile *Diamantinasaurus matildae* (Dinosauria: Titanosauria) from the Upper Cretaceous

Winton Formation of Queensland, Australia, with implications for sauropod ontogenetic growth. *Journal of Vertebrate Paleontology 41*, e2047991.

Stephen Poropat [steve.poropat@curtin.edu.au], and Adele Pentland [pentlandadele@gmail.com], Western Australian Organic and Isotope Geochemistry Centre, School of Earth and Planetary Science, Curtin University, Kent St, Bentley, WA 6102, and Australian Age of Dinosaurs Museum of Natural History, Winton, QLD 4735, Australia; Phil Mannion [p.mannion@ucl.ac.uk], Department of Earth Sciences, University College London, Gower Street, London WC1E 6BT, UK; Sam Rigby [samantha.rigby@hotmail.com], Australian Age of Dinosaurs Museum of Natural History, Winton, QLD 4735, Australia and School of Science, Computing and Engineering Technologies, Swinburne University of Technology, Hawthorn, VIC 3122, Australia; Ruairidh Duncan [ruairidh.duncan@monash.edu], School of Biological Sciences, Monash University, Clayton, VIC 3800, Australia; Joseph Bevitt [jbv@ansto.gov.au], Australian Centre for Neutron Scattering, Australian Nuclear Science and Technology Organisation, Sydney, NSW 2234, Australia; Trish Sloan [sloantrish77@gmail.com], and David Elliott [david.elliott@aaod.com.au], Australian Age of Dinosaurs Museum of Natural History, Winton, QLD 4735, Australia.

Up the guts: an Australian sauropod preserving skin and probable gut contents

Stephen Poropat*, Samantha Rigby, Adele Pentland, Phil Bell, Nathan Enriquez, Philip Mannion, Joseph Bevitt, Mackenzie Enchelmaier, Trish Sloan, David Elliott, and Kliti Grice

Diamantinasaurus matildae is rapidly becoming one of the most completely understood Cretaceous sauropod dinosaurs. To date, four specimens of this taxon have been described from the Cenomanian-aged Winton Formation of Queensland, northeastern Australia (Poropat *et al.* 2021, 2023, Rigby *et al.* 2022). However, significant gaps remain in our anatomical understanding of *Diamantinasaurus matildae*, particularly in its axial skeleton, and this has hindered the accurate constraint of its feeding envelope. Although it has been hypothesised on the basis of tooth microwear analyses that *Diamantinasaurus matildae* was not a low browser (Poropat *et al.* 2022), this remains to be tested. Here we describe a new specimen of *Diamantinasaurus matildae* that is the most complete sauropod discovered in Australia to date. This specimen fills many gaps in our anatomical understanding of the axial skeleton of *Diamantinasaurus matildae*, and also provides significant insights into its external appearance and feeding habits, as it preserves a substantial quantity of fossilised skin (a first for an Australian sauropod) and probable gut contents (a first for any sauropod worldwide). Both impressions and true skin (with subcutaneous tissue) are preserved, which will enable the thickness of the skin of *Diamantinasaurus matildae* to be constrained across at least one body region. The scales are small relative to the overall size of the animal, as has been demonstrated in other sauropods for which skin is preserved (Pittman *et al.* 2022). The probable gut contents are preserved as an iron- and/or phosphate-rich layer (~2 m^2, <15 cm thick), with skin on the outside and thoracic ribs embedded within. Synchrotron and neutron tomography scanning has revealed abundant plants internally. Geochemical analyses will be undertaken to test the hypothesis that these specimens are genuine gut contents; if so, then they will provide direct evidence of a sauropod's last meal for the first time.

Pittman, M., Enriquez, N.J., Bell, P.R., Kaye, T.G. & Upchurch, P., 2022. Newly detected data from *Haestasaurus* and review of sauropod skin morphology suggests Early Jurassic origin of skin papillae. *Communications Biology 5*, 122.

Poropat, S.F., Kundrát, M., Mannion, P.D., Upchurch, P., Tischler, T.R. & Elliott, D.A., 2021. Second specimen of the Late Cretaceous sauropod dinosaur *Diamantinasaurus matildae* provides new anatomical information on skull and neck evolution in early titanosaurs and the biogeographic origins of Australian dinosaur faunas. *Zoological Journal of the Linnean Society 192*, 610–674.

Poropat, S.F., Frauenfelder, T.G., Mannion, P.D., Rigby, S.L., Pentland, A.H., Sloan, T. & Elliott, D.A., 2022. Sauropod dinosaur teeth from the lower Upper Cretaceous Winton Formation of Queensland, Australia, and the global record of early titanosauriforms. *Royal Society Open Science 9*, 220381.

Poropat, S.F., Mannion, P.D., Rigby, S.L., Duncan, R.J., Pentland, A.H., Bevitt, J.J., Sloan, T. & Elliott, D.A., 2023. A nearly complete skull of the sauropod dinosaur *Diamantinasaurus matildae* from the Upper Cretaceous Winton Formation of Australia and implications for the early evolution of titanosaurs. *Royal Society Open Science 10*, 221618.

Rigby, S.L., Poropat, S.F., Mannion, P.D., Pentland, A.H., Sloan, T., Rumbold, S.J., Webster, C.B. & Elliott, D.A., 2022. A juvenile *Diamantinasaurus matildae* (Dinosauria: Titanosauria) from the Upper Cretaceous Winton Formation of Queensland, Australia, with implications for sauropod ontogenetic growth. *Journal of Vertebrate Paleontology 41*, e2047991.

Stephen Poropat [steve.poropat@curtin.edu.au], and Adele Pentland [pentlandadele@gmail.com], Western Australian Organic and Isotope Geochemistry Centre, School of Earth and Planetary Science, Curtin University, Kent St, Bentley, WA 6102, Australia and Australian Age of Dinosaurs Museum of Natural History, Winton, QLD 4735, Australia; Samantha Rigby [samantha.rigby@hotmail.com], Australian Age of Dinosaurs Museum of Natural History, Winton, QLD 4735, Australia and School of Science, Computing and Engineering Technologies, Swinburne University of Technology, Hawthorn, VIC 3122, Australia; Phil Bell [pbell23@une.edu.au] and Nathan Enriquez [nenrique@myune.edu.au] Palaeoscience Research Centre, School of Environmental and Rural Science, University of New England, Armidale, NSW 2351, Australia; Philip Mannion [p.mannion@ucl.ac.uk], Department of Earth Sciences, University College London, Gower Street, London WC1E 6BT, UK; Joseph Bevitt [jbv@ansto.gov.au], Australian Centre for Neutron Scattering, Australian Nuclear Science and Technology Organisation, Sydney, NSW 2234, Australia; Mackenzie Enchelmaier [mackenzieenchelmaier@outlook.com], Trish Sloan [sloantrish77@gmail.com], and David Elliott [david.elliott@aaod.com.au], Australian Age of Dinosaurs Museum of Natural History, Winton, QLD 4735, Australia; Kliti Grice [k.grice@curtin.edu.au] Western Australian Organic and Isotope Geochemistry Centre, School of Earth and Planetary Science, Curtin University, Kent St, Bentley, WA 6102, Australia.

Permian Bryozoa of southern Gondwana — thriving in a cold climate

Catherine M. Reid*, Yuta Tamberg, Patrick N. Wyse Jackson, and Marcus M. Key, Jr.

Permian bryozoan faunas from Tasmania and New South Wales are of low diversity, as might be expected in a high-latitude location in a waning ice-house world. They are dominated by the eurytopic trepostomes and fenestrates, with few of the cystoporate or cryptostome forms that dominate warmer and northern Permian seas. Where cystoporates prevail, they exhibit the largest mouths and lophophores, meaning they can consume the largest food particles at the highest rates. However, in southern Gondwanan seas the trepostomes and fenestrates occupy broader trophic niches than they occupy elsewhere, and in the absence of cystoporates, trepostomes exhibit expanded mouth and lophophore sizes. In this way, they are able to take advantage of new food resources, with expanded mouth size (larger range of food particles) and lophophore diameter (higher feeding rates). In addition, Paleozoic groups are able to feed as efficiently as modern bryozoans, suggesting that feeding capacity was not a limitation for Paleozoic-only forms through the end-Paleozoic extinction (Reid & Tamberg 2021). These southern trepostome bryozoans also form notably large colonies and are heavily calcified in comparison to other Paleozoic bryozoans. This is contrary to what might be expected in higher-latitude locations where oceanographic principles dictate that calcium-carbonate saturations states will be lower and challenge skeletal precipitation in carbonate shelled invertebrates. Indeed, other bryozoan groups follow this principle in the Paleozoic. The expanded feeding capacity of the southern Gondwanan forms appears to be supporting trepostomes' ability to overcome poor calcite saturation states and precipitate larger skeletons, perhaps also influencing their initial survival of the end-Paleozoic extinction (Reid et al. 2022).

Reid, C.M. & Tamberg, Y., 2021. Trophic partitioning and feeding capacity in Permian bryozoan faunas of Gondwana. *Palaeontology 64*, 555–572.

Reid, C.M., Wyse Jackson, P.N. & Key, M.M., 2022. Latitudinal influences on bryozoan calcification through the Paleozoic. *Paleobiology*, 1–13.

Catherine M. Reid [catherine.reid@canterbury.ac.nz], School of Earth and Environment, University of Canterbury, Private Bag 4800, Christchurch 8140, New Zealand; Yuta Tamberg [yutamberg@gmail.com], Department of Marine Sciences, University of Otago, Dunedin, New Zealand; Patrick N. Wyse Jackson [wysjcknp@tcd.ie], Department of Geology, Trinity College, Dublin, Ireland; Marcus M. Key, Jr. [key@dickinson.edu], Department of Earth Sciences, Dickinson College, Pennsylvania, USA.

Carbonate microfacies, depositional environments and biostratigraphy of the lower Cambrian Second Plain Creek Member, Wilkawillina Limestone, central Flinders Ranges, South Australia

Stephanie A. Richter Stretton*, John R. Paterson, and Marissa J. Betts

The early Cambrian (538–509 Ma) marks the most significant diversification of complex animal life in Earth's history — the Cambrian explosion. Lower Cambrian rock packages are very well preserved across the Flinders Ranges, South Australia, and most have received extensive scientific attention. However, the Second Plain Creek Member (SPCM) of the Wilkawillina Limestone only crops out within the Bunkers Graben in the Ikara-Flinders Ranges National Park, preventing intensive study since initial field-based investigations (Clarke 1990). The SPCM directly overlies a distinctive marker horizon called the Flinders Unconformity (FU) or Red Crust, and underlies the slope facies of the Mernmerna Formation. The SPCM has been known to yield a rich Cambrian small shelly fossil (SSF) fauna, but the biostratigraphy, wider correlation and depositional environment/s of the SPCM were poorly resolved. To address this, this study employed a multi-proxy approach, combining SSF biostratigraphy, stable-isotope chemostratigraphy and carbonate microfacies analysis to determine the depositional environment, species diversity and stratigraphic ranges of key SSFs for relative dating and correlation. This study revealed that the SPCM has a highly diverse SSF fauna of over 25 species, including tommotiids, brachiopods, bradoriids and molluscs, and that these faunas were deposited in a high-energy inner-ramp environment that frequently experienced intense reworking. These faunas can be correlated with the upper *Micrina etheridgei* Zone and lower *Dailyatia odyssei* Zone (Cambrian stages 2–3, *ca* 517 Ma). The Bunkers Graben represents the most continuous section of the Wilkawillina Limestone, making this study a significant contribution to the understanding of the Cambrian succession in the Flinders Ranges, South Australia. Resolving the depositional environment of the SPCM clarifies the transition from the Wilkawillina Limestone to the overlying Mernmerna Formation — usually obscured by the FU — in addition to contributing to understanding of the evolution of the Red Crust itself.

Clarke, J.D.A., 1990. Platform carbonate deposition and diagenesis, Woodendinna Dolomite and lower Wilkawillina Limestone (Early Cambrian), Wilkawillina Gorge, South Australia. *Australian Journal of Earth Sciences 37*, 471–483.

Stephanie A. Richter Stretton [srichte2@myune.edu.au], John R. Paterson [jpater20@une.edu.au], and Marissa J. Betts [mbetts7@une.edu.au], Palaeoscience Research Centre, School of Environmental and Rural Science, University of New England, Armidale, NSW 2351, Australia.

The geochronology, palaeoenvironments and palaeontology of Robertson Cave Inner Chamber, Naracoorte

Ben Robertson*, Lee Arnold, Liz Reed, and Lloyd White

Robertson Cave Inner Chamber in the Naracoorte Cave Complex (NCC) preserves a 4 m sedimentary infill record that is relatively unexplored for geochronology and palaeoenvironmental history. The Inner Chamber also preserves undated megafauna remains and evidence of long-term overwintering activities of the critically endangered Southern Bent-Wing bat (Department of Environment, Land, Water and Planning, Victoria 2020). This presentation outlines results obtained from new geochronology (single-grain OSL dating) (Arnold *et al.* 2018) and geochemistry (XRF, XRD) to contextualise the palaeontological, palaeoenvironmental and palaeoconservation significance of the Robertson Cave sedimentary sequence. The study demonstrated the suitability of OSL dating in this deep cave setting by examining modern surface samples and samples from sediment horizons affected by syndepositional mixing. Results revealed that the sediment infill sequence covers a longer time period (*ca* 75 to 10 ka) than previously indicated by radiocarbon dating (Forbes *et al.* 2007). The entire sequence was deposited between marine isotope stages (MIS) 4 or late MIS5 to early MIS1, with high sedimentation rates evident in late MIS3, the MIS2 glacial, and early MIS1, and disconformities coinciding with major climatic transitions at the MIS4/3, MIS3/2, and MIS2-1 boundaries. Two OSL ages from the lowermost unit constrain the timing of in situ megafauna fossils to *ca* 75–60 ka, making Robertson Cave Inner Chamber one of only three well-dated NCC caves preserving late MIS5 to MIS4 megafauna remains. XRF and XRD analyses indicated the presence of multiple guano-rich layers with elevated sulphate, phosphate, organics, and trace-metal concentrations, implying complex diagenetic processes and confirming a geochemical signature of bat overwintering activities extending back to the last interglacial complex.

These findings have broader implications for understanding the sediment accumulation dynamics of NCC roof window cavities in relation to changing climate conditions (glacial–interglacial cycles). They also reinforce the palaeontological and palaeoconservation significance of Robertson Cave, particularly the long-term resilience of its critically endangered Southern Bent-Wing bat populations.

Arnold, L.J. & Demuro, M., 2018. Dating and optically stimulated luminescence. In *The Encyclopedia of Archaeological Sciences*. López Varela, S.L., ed., John Wiley & Sons Ltd, Hoboken, New Jersey, USA. doi: 10.1002/9781119188230.saseas0151

Department of Environment, Land, Water and Planning, Victoria, 2020. *National Recovery Plan for the Southern Bent-wing Bat* Miniopterus orianae bassanii. Victorian Government, Melbourne, 44 pp.

Forbes, M.S., Bestland, E.A., Wells, R.T. & Krull, E.S., 2007. Paleoenvironmental reconstruction of the Late Pleistocene to Early Holocene Robertson Cave sedimentary deposit, Naracoorte, South Australia. *Australian Journal of Earth Sciences, 54*(4), 541–559. doi: 10.1080/08120090601078388

Ben Robertson [ben.t.robertson@adelaide.edu.au], and Lee Arnold [lee.arnold@adelaide.edu.au], School of Physics, Chemistry and Earth Sciences, Mawson Building Room 107, University of Adelaide, North Terrace Campus, Adelaide, SA 5005, Australia; Liz Reed [liz.reed@adelaide.edu.au], School of Ecology and Evolutionary Biology, Benham, floor 1, University of Adelaide, North Terrace Campus, Adelaide, SA 5005, Australia; Lloyd White [lloydw@uow.edu.au], School of Earth, Atmospheric and Life Sciences, Faculty of Science, Medicine and Health, Room 173, Building 41, University of Wollongong, NSW 2522, Australia.

A new fossil species of *Bothriembryon* (Gastropoda: Bothriembryontidae) from the Nullarbor of Western Australia

Helen E. Ryan*, Kenny J. Travouillon, Jason M. Bennett, Sarah K. Martin, Kailah M. Thorn, and Corey S. Whisson

Fossil *Bothriembryon* specimens were found from the northwestern edges of the Nullarbor Plain, Western Australia, approximately 300 km inland from the current southern coastline. This locality is significant as extant species of *Bothriembryon* from the Nullarbor are confined to within 50 km of the coastline. Principle Component Analysis (PCA) was used to compare the Nullarbor *Bothriembryon* species with a morphologically comparable extant species from the Eucla Basin, *Bothriembryon barretti,* and geographically similar fossil species: *B. kremnobates*, and *B. praecursor*. Results showed strong support for a new fossil species of *Bothriembryon*, which will be described. The specimens are found as internal moulds within pisolitic calcrete overlying the early Miocene Colville Sandstone (Lowry 1970). The geological setting of the pisolitic calcrete is poorly studied; here we discuss a recent palynological and U–Th in calcite study of the host calcrete to provide an age constraint, as well as a characterisation study on the composition of the pisolites. The age of the type locality of *B. praecursor*, Kangaroo Well, Northern Territory, was also re-evaluated. *Balbaroo fangaroo* and *Ganawamaya gillespieae* specimens found at Kangaroo Well were correlated with dated sites from Riversleigh, Queensland, and found to be early Miocene in age.

Lowry, D.C., 1970. Geology of the Western Australian part of the Eucla Basin. *Geological Survey of Western Australia Bulletin 122,* 1–201.

Helen E. Ryan [helen.ryan@museum.wa.gov.au], Department of Earth and Planetary Sciences, Western Australian Museum, 49 Kew Street, Welshpool, WA 6106, Australia; Kenny J. Travouillon [Kenny.travouillon@museum.wa.gov.au], and Kailah M. Thorn [Kailah.thorn@museum.wa.gov.au], Department of Terrestrial Zoology, Western Australian Museum, 49 Kew Street, Welshpool, WA 6106, Australia; Jason M. Bennett. [Jason.bennett@uwa.edu.au], School of Earth Sciences, University of Western Australia, 35 Stirling Highway, Perth, WA 6009, Australia; Sarah K. Martin [sarah.martin@dmirs.wa.gov.au], Geological Survey of Western Australia, Department of Mines, Industry Regulation and Safety, 100 Plain Street, East Perth, WA 6004, Australia; Corey S. Whisson [corey.whisson@museum.wa.gov.au], Department of Aquatic Zoology, Western Australian Museum, 49 Kew Street, Welshpool, WA 6106, Australia.

From small things: eukaryotic diversity in the mid-Proterozoic

Donna Satterthwait*, and Peter McGoldrick

Rare and strange-looking mid-Proterozoic fossils from Queensland and Tasmania appear to have a close affinity to those currently classified in the Amoebozoa, a phylum of single-celled eukaryotic organisms. To date, fossils with amoebozoan features have been found in carbonaceous shales from the Century Zinc Mine, northwestern Queensland, as well as from the Laan Quarry in northwestern Tasmania. Tuffs from the Century Zinc Mine have been dated at 1.595 Ga, and hence provide a minimum age constraint for the origins of the phylum. Recently revealed genomic data suggests that despite the different appearance of extant amoebae, this monophyletic group has diversified into complex cellular structures like slime moulds, foraminifera, and xenophyophores. A scenario is described here accounting for the evolution of this diversity. Extant Amoebozoa will be defined using their structural and life-cycle characteristics along with genomic data. This diversity represents remnants of an early radiation of experimental, marginal ancient lines developed in unoccupied environments or habitats, with sufficient prey, no predators and lacking competition.

Donna Satterthwait [Donna.Satterthwait@utas.edu.au], and Peter McGoldrick [p.mcgoldrick@utas.edu.au], CODES, University of Tasmania, Locked Bag 66, Hobart, TAS 7001, Australia.

Pygmaclypeatus daziensis reconsidered and the ancestral appendicular organisation of Cambrian artiopods

Michel Schmidt*, Xianguang Hou, Dayou Zhai, Huijuan Mai, Jelena Belojević, Xiaohan Chen, Roland R. Melzer, Javier Ortega-Hernández, and Yu Liu

The Cambrian Stage 3 Chengjiang biota in South China is one of the most influential Konservat-Lagerstätten worldwide thanks to the fossilisation of diverse non-biomineralising organisms through pyritisation (Hou *et al.* 2017). Despite their contributions to understanding the evolution of early animals, several Chengjiang species remain poorly known owing to their scarcity and/or incomplete preservation. Here, we use micro-computed tomography (Liu *et al.* 2015) to reveal in detail the ventral appendage organisation of the enigmatic non-trilobite artiopod *Pygmaclypeatus daziensis*, one of the rarest euarthropods in Chengjiang (Zhang *et al.* 2000), and explore its functional ecology and broader evolutionary significance. *Pygmaclypeatus daziensis* possesses a set of uniramous antennae and 14 pairs of post-antennal biramous appendages, the latter of which show an unexpectedly high degree of heteronomy based on the localised differentiation of the protopodite, endopodite and exopodite along with the antero-posterior body axis. The small body size (less than 2 cm), the presence of delicate spinose endites and well-developed exopodites with multiple paddle-shaped lamellae on the appendages of *P. daziensis* indicate a nekto-benthic mode of life and a scavenging/detritus feeding strategy. *Pygmaclypeatus daziensis* shows that appendage heteronomy is phylogenetically widespread within Artiopoda — the megadiverse clade that includes trilobites and their relatives with non-biomineralising exoskeletons — and suggests that a single exopodite lobe with paddle-like lamellae is ancestral for this clade.

Hou, X.G., Siveter, D.J., Siveter, D.J., Aldridge, R.J., Pei-Yun, C., Gabbott, S.E., Xiao-Ya, M., Purnell, M.A. & Williams, M., 2017. *The Cambrian fossils of Chengjiang, China: the flowering of early animal life*. John Wiley & Sons, New York, USA, 248 pp.

Liu, Y., Scholtz, G. & Hou, X.G., 2015. When a 520-million-year old Chengjiang fossil meets a modern microCT – a case study. *Scientific Reports 5*, 12802.

Zhang, X., Han, J. & Shu, D., 2000. A new arthropod *Pygmaclypeatus daziensis* from the early Cambrian Chengjiang Lagerstätte, South China. *Journal of Paleontology 74*, 979–983. doi:10.1666/0022-3360(2000)074< 0979:ANAPDF>2.0.CO;2

Michel Schmidt [michel.m.schmidt@mail.de], Xianguang Hou [xghou@ynu.edu.cn], Dayou Zhai [dyzhai@ynu.edu.cn], Huijuan Mai [jennymhj@ynu.edu.cn], Xiaohan Chen [pascal260@126.com], and Yu Liu [yu.liu@ynu.edu.cn], Yunnan Key Laboratory for Palaeobiology, Institute of Palaeontology, Yunnan University, North Cuihu Road 2, Kunming 650091, People's Republic of China; Jelena Belojević [jelena.belojevic@bi.mpg.de], and Roland R. Melzer [melzer@snsb.de], Department Biology II, Ludwig-Maximilians-Universität München, 82152 Planegg-Martinsried, Germany; Javier Ortega-Hernández [jortegahernandez@fas.harvard.edu], Museum of Comparative Zoology and Department of Organismic and Evolutionary Biology, Harvard University, 26 Oxford Street, 791 Cambridge, MA 02138, USA.

Treasures from the crypt — Geoscience Australia's untapped fossil resources

Natalie I. Schroeder*, and John R. Laurie

Geoscience Australia (GA) houses one of the largest fossil collections in Australia, consisting of vertebrate and invertebrate macrofossils, and microfossils of all denominations. It includes material from all states and territories past and present, including Papua New Guinea and Antarctica. Although our collections have been used extensively by researchers both in Australia and overseas, much more could be done to further refine our understanding of the geology of the continent and evolution of life in the region.

The institution evolved primarily from the Bureau of Mineral Resources, Geology and Geophysics (BMR) established in 1946, through the Australian Geological Survey Organisation (AGSO, from 1992 to 2001), to the current Geoscience Australia. With each name change, the institution's remit diversified considerably, but the BMR's main objective was the systematic geological and geophysical mapping of the continent as the basis for informed mineral exploration. Much of the main fossil collection was collected during this time by BMR geologists and palaeontologists, mainly for biostratigraphic dating to assist in the geological mapping of sedimentary basins.

Perhaps the most well-known part of the collection is the Commonwealth Palaeontological Collection (CPC), which consists of over 45 000 type and other published specimens. Much of this material was published by BMR/AGSO/GA palaeontologists in the course of mapping the continent, and has subsequently been used for more detailed stratigraphic work. This collection continues to grow.

Apart from the CPC, much of the material in the 1150 drawers of the collection remains only partly studied. In addition, there are also thousands of microfossil slides, from onshore cores and outcrop samples, and offshore cores and dredge samples, many of which have undergone preliminary examination. All this material is available for the study of all aspects of palaeontology, and we welcome enquiries regarding use of our holdings.

Natalie Schroeder [Natalie.Schroeder@ga.gov.au], and John Laurie [John.Laurie@ga.gov.au], Geoscience Australia, GPO Box 378, Canberra, ACT 2601, Australia.

Komlopteris: a persistent lineage of corystosperms ('seed ferns') spanning the Early Jurassic to the Eocene of Gondwana

Miriam Slodownik*, Robert S. Hill, and Stephen McLoughlin

Komlopteris emerged at the Triassic–Jurassic transition and persisted until the Eocene. Therefore, it includes the youngest known representative of the 'seed ferns' (pteridosperms; a polyphyletic group of early-emerging seed-bearing plants characterised by fern-like leaves). Our study aimed to assess the diversity and distribution of *Komlopteris* throughout the Mesozoic and Paleogene of Gondwana. New fossil material and morphological data were used to provide insights into the systematics of post-Triassic leaves assigned to this genus. By differentiating species based on diagnostic macro- or micro-morphological features, ten species were recognised. The oldest records of the genus are from the earliest Jurassic from Argentina. *Komlopteris* reached peak diversity and biogeographic range in the Late Jurassic and earliest Cretaceous, but declined after the Aptian. From the mid-Cretaceous until its last known occurrence in the Eocene, *Komlopteris* appears to have been restricted to Australia. *Komlopteris* represented a common, though rarely dominant, component of Jurassic to Paleogene plant assemblages in the Southern Hemisphere. Morphological similarities to the predominantly Triassic *Dicroidium* and *Kurtziana* and co-occurrence with *Alisporites*/*Falcisporites*-type pollen suggest an umkomasialean affinity for *Komlopteris*. Thus, this lineage survived both the end-Triassic and end-Cretaceous mass extinctions likely due to its distribution in the climatically buffered humid high latitudes.

Miriam Slodownik [miriam.slodownik@adelaide.edu.au], and Robert S. Hill [bob.hill@adelaide.edu.au], School of Biological Sciences, University of Adelaide, North Terrace, SA 5005, Australia; Stephen McLoughlin [steve.mcloughlin@nrm.se], Swedish Museum of Natural History, Svante Arrhenius v. 9, SE-104 05, Stockholm, Sweden.

Early Ordovician trilobites from Barnicarndy 1 stratigraphic well of the southern Canning Basin, Western Australia

Patrick M. Smith* and Heidi J. Allen

Twenty-three trilobite taxa have been described from the Lower Ordovician (Tremadocian to Floian) Nambeet Formation, retrieved from the Barnicarndy 1 drill core, Canning Basin, Western Australia (Smith & Allen in press). This includes one new genus, and six new species. This fauna can be divided into three stratigraphically distinct assemblages: a lower *Apatokephalus* sp. – gen. et sp. nov. Assemblage (2177.50 – 2382.94 m depth); *Asaphellus trinodosus* Assemblage (2030.07 – 2177.52 m depth); and *Asaphellus* sp. nov. Assemblage (1595.83 – 2001.88 m depth). The two stratigraphically lowest assemblages are consistent with a late to latest Tremadocian age (both within the *Paroistodus proteus* conodont Zone). The third, and highest, assemblage is consistent with a mid-Floian age (within the stratigraphically higher *Oepikodus communis* conodont Zone). This contribution refines previous biostratigraphic work based on an age-diagnostic conodont fauna (Zhen *et al.* 2022) and demonstrates the stratigraphic utility of using multiple taxonomic groups for more robust biostratigraphic age estimates.

Smith, P.M. & Allen, H.J., in press. Early Ordovician trilobites from Barnicarndy 1 stratigraphic well of the southern Canning Basin, Western Australia. *Alcheringa*.

Zhen, Y.Y., Allen, H.J. & Martin, S.K., 2022. Early Ordovician conodonts from Barnicarndy 1 stratigraphic well of the Southern Canning Basin, Western Australia. *Alcheringa 46*, 43–58.

Patrick M. Smith [Patrick.Smith@austmus.gov.au], Australian Museum, 1 William St, Sydney, NSW 2010, Australia and, Department of Biological Sciences, Macquarie University, Sydney, NSW 2109, Australia; Heidi J. Allen [heidi.allen@dmirs.wa.gov.au], Geological Survey of Western Australia, Department of Mines, Industry Regulation and Safety, Mineral House, 100 Plain Street, East Perth, WA 6004, Australia.

Trilobites and agnostids from the Ordian–Templetonian (Cambrian Series 2, Stage 4 – Miaolingian, Wuliuan) Coonigan Formation, far western New South Wales

Patrick M. Smith*, Peter A. Jell, Michael R. Leu, and Yong Yi Zhen

Twenty-eight trilobite and five agnostid taxa, including eight new species, are reported from the Cambrian Ordian–Templetonian boundary (Series 2, Stage 4–Miaolingian, Wuliuan) within the Coonigan Formation, Gnalta Shelf, far western New South Wales. The fauna suggests that the First Discovery Limestone Member and overlying white shale within the unit may be discontinuous, with only a single species (*Dinesus* sp. nov.) common to both. The First Discovery Limestone has a latest Ordian (*Xystridura negrina* Zone) age, and the overlying white shale is slightly younger, being early Templetonian (*Pentagnostus praecurrens* Zone). This is supported by age-diagnostic genera (i.e. *Redlichia* and *Onaraspis*) in the First Discovery Limestone, and the zonal eponym in the overlying white shale. This succession matches the typical 'Sequence 1(1a) / Sequence 2' disconformity pattern observed in the Thorntonia Limestone and overlying Arthur Creek Formation documented from drill cores in the nearby southern Georgina Basin (Laurie 2012, and references therein). Co-occurrence of *Pagetia silicunda* and *Xystridura fracta* (=*X. gayladia*) in both the First Discovery Limestone and lower Giles Creek Dolostone (*Xystridura gayladia* assemblage) of the Amadeus Basin in central Australia, suggests these two units are age equivalent. This is despite recent interpretations to the contrary (Smith *et al.* 2015a, b), indicating that regional stratigraphical schemes in the Amadeus Basin need to be reviewed.

Laurie, J.R., 2012. Biostratigraphy of the Arthur Creek Formation and Thorntonia Limestone, Georgina Basin. In *Proceedings of the Central Australian Basins Symposium 3, Alice Springs, 16–17 July, 2012*. Ambrose, G.J. & Scott, J., eds, Northern Territory Geological Survey, CD ROM, 1–6.

Smith, P.M., Brock, G.A. & Paterson, J.R., 2015a. Fauna and biostratigraphy of the Cambrian (Series 2, Stage 4; Ordian) Tempe Formation (Pertaoorrta Group), Amadeus Basin, Northern Territory. *Alcheringa 39*, 40–70.

Smith, P.M., Paterson, J.R. & Brock, G.A., 2015b. Trilobites from the Giles Creek Dolostone (Cambrian Series 3, Stage 5; Templetonian) Amadeus Basin, central Australia. *Papers in Palaeontology 1*, 167–200.

Patrick M. Smith [Patrick.Smith@austmus.gov.au], Australian Museum, 1 William St, Sydney, NSW 2010, and Department of Biological Sciences, Macquarie University, Sydney, NSW 2109, Australia; Peter A. Jell [amjell@bigpond.com], School of Earth Sciences, University of Queensland, St Lucia, QLD 4072, Australia; Michael R. Leu [michael.leu@bigpond.com.au]; Yong Yi Zhen [yong-yi.zhen@regional.nsw.gov.au], Geological Survey of New South Wales, Division of Mining, Exploration and Geoscience, Department of Regional New South Wales, W.B. Clarke Geoscience Centre, 947–953 Londonderry Road, Londonderry, NSW 2753, Australia.

Community development in the Avalonian Ediacaran

Nile P. Stephenson*, Katie M. Delahooke, Charlotte G. Kenchington, Andrea Manica, and Emily G. Mitchell

Bedding planes from the Avalonian Ediacaran (*ca* 580–560 Ma) preserve some of the oldest complex macroscopic life as census communities on the ancient deep-sea floor. These communities are highly compositionally variable, and variability between communities might be explained by death events at different points in community succession. Prior models of succession in the Avalonian have suggested that taxa are specialised to certain successional stages as seen in most modern systems (Clapham *et al.* 2003). These models also suggest that communities became more tiered (via competition avoidance) throughout succession. However, recent work has shown that most Avalonian communities were dominated by stochastic processes (e.g. reproduction) rather than deterministic processes (e.g. competition, niche processes) (Mitchell *et al.* 2019). How these stochastic processes would play out over community development is not known. To test how communities vary throughout succession, we mapped 21 Avalonian fossil beds from Newfoundland, Canada and Charnwood Forest, England. By comparing the relative abundance and areal coverage of specimens within these communities, we can approximate the degree of community succession as communities move from relatively high-abundance early successional stages to relatively high-areal coverage late successional stages as a consequence of growth and survival (Clarke 1990, Durden *et al.* 2015). By comparing the curves of cumulative abundance and areal coverage, we were able to determine relative levels of community development. We then investigated whether the degree of community development was correlated with the degree of tiering, specimen height, areal coverage, and community composition. We found that degree of tiering was not correlated with community development and that there is limited evidence for deterministic pathways of succession. Instead, we found further support for the domination of largely stochastic, meta-community-like colonisation–recolonisation processes in the Avalonian, indicating that high community variability was likely driven by reproduction, disturbance, and recolonisation dynamics rather than competition or niche processes.

Clapham, M.E., Narbonne, G.M. & Gehling, J.G., 2003. Paleoecology of the oldest known animal communities: Ediacaran assemblages at Mistaken Point, Newfoundland. *Paleobiology 29*, 527–544.

Clarke, K.R., 1990. Comparisons of dominance curves. *Journal of Experimental Marine Biology and Ecology 138,* 143–157.

Durden, J.M., Bett, B.J., Jones, D.O.B., Huvenne, V.A.I. & Ruhl, H.A., 2015. Abyssal hills — hidden source of increased habitat heterogeneity, benthis megafaunal biomass and diversity in the deep sea. *Progress in Oceanography 137,* 209–218.

Mitchell, E.G., Harris, S., Kenchington, C.G., Vixseboxse, P., Roberts, L., Clark, C., Liu, A.G. & Wilby, P.R., 2019. The importance of neutral over niche processes in structuring Ediacaran early animal communities. *Ecology Letters 22,* 2028–2038.

Nile P. Stephenson [nps36@cam.ac.uk], Andrea Manica [am315@cam.ac.uk], and Emily G. Mitchell [ek338@cam.ac.uk], Department of Zoology, Downing Pl, University of Cambridge, CB2 3EJ, UK; Katie M. Delahooke [kmd47@cam.ac.uk] and Charlotte G. Kenchington [cgk27@cam.ac.uk], Department of Earth Sciences, Downing St, University of Cambridge CB2 3EQ, UK.

Mind the gap: leveraging biostratinomic variability to refine the records of Ediacaran tubular organisms and morphologically convergent structures

Rachel L. Surprenant*, James G. Gehling, and Mary L. Droser

The Ediacara biota represent the oldest complex, community forming organisms on Earth (575–539 Ma) (Matthews *et al.* 2021) and can be divided into three successive assemblages: the Avalon, White Sea, and Nama (Xiao & Laflamme 2009). While most well-known for charismatic morphotypes such as Dickinsoniomorphs, the most abundant morphotype of the White Sea Assemblage is the hollow, elongate, and simple morphotype: tubular organisms. Importantly, these tubular taxa persist as an abundant component of the Nama Assemblage, whereas classic members of the Ediacara Biota (e.g. *Dickinsonia*, *Spriggina*) go extinct (Darroch *et al.* 2018, Evans *et al.* 2022). For these reasons, tubular organisms hold broad evolutionary significance. However, the nature of this importance remains unconstrained because they are commonly misidentified as other, morphologically convergent, fossils and sedimentary structures (Jensen *et al.* 2006). Additionally, there is no established framework for distinguishing between tubular genera, an oftentimes difficult task due to a lack of diagnostic characters and common biostratinomic overprint observed in the morphogroup. As a result, the relationships between tubular taxa, and whether their success describes a phylogenetic lineage or convergent evolution, is unclear. To broach this complex issue, we present a comparative analysis of tubular organisms (i.e. *Funisia*, *Aulozoon*, and *Somatohelix*), non-tubular fossils (e.g. *Plexus*, *Helminthoidichnites*, macroalgae), and sedimentary structures (e.g. synaeresis cracks) from the Nilpena Ediacara National Park, South Australia. The tubular taxa are found to share a suite of preservational modes, resulting from their elongate and hollow body plans, that aid in distinguishing between tubular taxa and other morphologically convergent forms. Further, tissue integrity and population structure are identified as mechanisms for distinguishing between tubular genera. These features are synthesised to create a framework for the holistic identification and description of tubular taxa that can be leveraged to fill the biostratinomic-related gaps in our knowledge of the tubular morphotype.

Darroch, S.A., Smith, E.F., Laflamme, M. & Erwin, D.H., 2018. Ediacaran extinction and Cambrian explosion. *Trends in Ecology & Evolution 33*, 653–663.

Evans, S.D., Tu, C., Rizzo, A., Surprenant, R.L., Boan, P.C., McCandless, H., Marshall, N., Xiao, S. & Droser, M.L., 2022. Environmental drivers of the first major animal extinction across the Ediacaran White Sea-Nama transition. *Proceedings of the National Academy of Sciences 119*.

Jensen, S., Droser, M.L. & Gehling, J.G., 2006. A critical look at the Ediacaran trace fossil record. *Neoproterozoic Geobiology and Paleobiology*, 115–157.

Matthews, J.J., Liu, A.G., Yang, C., McIlroy, D., Levell, B. & Condon, D.J., 2021. A chronostratigraphic framework for the rise of the Ediacaran macrobiota: new constraints from Mistaken Point Ecological Reserve, Newfoundland. *GSA Bulletin 133*, 612–624.

Xiao, S. & Laflamme, M., 2009. On the eve of animal radiation: phylogeny, ecology and evolution of the Ediacara biota. *Trends in Ecology & Evolution 24*, 31–40.

Rachel L. Surprenant [rsurp001@ucr.edu], and Mary L. Droser [droser@ucr.edu], University of California Riverside, 900 University Ave, Riverside, CA 92521, USA; James G. Gehling [gehling.jim@bigpond.com], South Australian Museum, North Terrace, Adelaide, SA 5000, Australia.

Squamate wars episode one: the phantom specimens in the fossil mammal collection of the Field Museum

Kailah M. Thorn*

The majority of fossil squamates in Australian museum collections are not identified beyond 'snake' or 'lizard indet.'; we know they exist but have no idea what they are. Unique combinations of apomorphic osteological characters create an Identifiable Taxonomic Unit (ITU) that can then be compared to reference material from extant or known extinct taxa. Whether or not individual species-level identifications can be applied to every specimen, family or morphotype, ITUs have been sufficient to elucidate palaeoecological patterns (Ramm *et al*. 2022). Identification refinements also rearrange material in museum collections, aiding targeted taxonomical research. A three-week trip to examine Western Australian material in the collections of the Field Museum in Chicago in late 2022 refined 837 'lizard' records from cave deposits across the Nullarbor Plain, now representing at least 15 different ITUs. Sixteen ITUs across 386 records from other Western Australian Cenozoic deposits in this collection were also noted. The volume of Australian reptiles in the fossil mammal collection was unknown until this visit, as much of this material was in bulk unsorted trays. The use of ITUs allowed for preliminary investigation of presence/absence, and abundance changes through time and between locations. Spiny-tailed skink osteoderms (cf. *Egernia stokesii badia*) are recorded for the first time on the Nullarbor Plain, coinciding with previously published Pleistocene mammalian taxa also indicative of a woodland environment. Comparisons of the reptile fauna from deeper, better-dated excavations, and those from further west and north, are in progress to find more suitable ecologically informative ITUs from neighbouring habitats.

Ramm, T., Thorn, K.M., Hipsley, C.A., Müller, J., Hocknull, S. & Melville, J., 2022. Herpetofaunal diversity changes with climate: evidence from the Quaternary of McEachern's Deathtrap Cave, southeastern Australia, *Journal of Vertebrate Paleontology*, *41*, e2009844. DOI: 10.1080/02724634.2021.2009844

Kailah M. Thorn [Kailah.thorn@museum.wa.gov.au], Department of Terrestrial Vertebrates, Western Australia Museum, 49 Kew Street, Welshpool, WA 6101, Australia.

Mass-death assemblage of Pleistocene megafauna (*Diprotodon optatum*: Marsupialia) at Du Boulay Creek, Western Australia

Kenny J. Travouillon*, Helen Ryan, Gilbert J. Price, Kailah M. Thorn, and Jayde Williams

Discovered in 1991 by a worker monitoring noxious weeds, the Du Boulay Creek fossil locality in the Pilbara is one of the most northern fossil localities in Western Australia containing *Diprotodon optatum*, the largest marsupial that existed. A near-complete skeleton was recovered over two expeditions by the Western Australian Museum (WAM) in 1991 (led by Alex Baynes) and 1992 (led by John Long), which is still today the most complete skeleton found in the state. Two other partial skeletons were also recovered by WAM thanks to the support of the Robe River Mining Group. Luminescence dating of sediment adhering to one of these specimens has proven unreliable due to partial bleaching of grains; it remains possible that the fossils are >80 000 ka. In collaboration with Citic Pacific Mining, WAM returned to the site in 2022 for new surveys where ten additional partial skeletons were discovered, including the first two skulls found at the site. Fieldwork was undertaken in 2023 with the aim to study the taphonomy of the site and collect new materials for dating. The site is unusual in the presence and abundance of individuals of a single species, which may tell us more about the biology of *D. optatum*. The taphonomic assessment of the site will help us understand how the individuals were accumulated in the creek and test if the individuals died in situ or were washed in during floods, possibly as bloated carcases caught up in mangroves.

Kenny J. Travouillon [kenny.travouillon@museum.wa.gov.au], Helen Ryan [helen.ryan@museum.wa.gov.au], and Kailah Thorn [kailah.thorn@museum.wa.gov.au], Western Australian Museum, 49 Kew Street, Welshpool, WA 6101, Australia; Gilbert J. Price [g.price1@uq.edu.au], School of Earth and Environmental Science, The University of Queensland, Brisbane, QLD 4072, Australia; Jayde Williams [22705445@student.uwa.edu.au], University of Western Australia, 35 Stirling Highway, Perth, WA 6009, Australia.

Significance of biomarkers and biomolecules in exceptionally preserved coprolites and ferns in Carboniferous siderite concretions

Madison Tripp*, Lorenz Schwark, Jochen J. Brocks, Paul Mayer, Jack Wittry, and Kliti Grice

Soft-tissue preservation is unusual, and thus provides valuable insights into the fossil record. Carbonate concretions are commonly associated with soft-tissue preservation, forming as a product of rapid mineralisation induced by changes in the microenvironment immediately surrounding an organic-matter rich nucleus. Anoxia prevents extensive aerobic decay and thereby promotes the preservation of soft tissues, which are otherwise rarely found preserved in sediments. Such conditions are also favourable for the preservation of molecular fossils (biomarkers) and biomolecules, which provide important insights into the fossilising organism and palaeoenvironment. A detailed organic geochemical analysis of soft-tissue fossils in siderite concretions from the Mazon Creek Lagerstätte demonstrates the importance of carbonate concretions for identifying source-specific biomarkers. A range of specimens, including coprolites and fossil ferns, were separated from their concretionary matrices to investigate the presence and distribution of fossil organism versus environmentally derived biomarkers across the fossil-bearing concretions. The coprolite fossil revealed an unusually high proportion of cholesterol-derived biomarkers, with C_{27} steranes overall comprising greater than 95% of the total steranes. Comparatively, the matrix of each fossil showed much lower abundances of overall steranes. Cholesterol is ubiquitous in animal tissues, whereas a plant-derived sterane distribution would be expected to contain higher proportions of C_{29} sterane biomarkers. Therefore, the abundance of animal steroid biomarkers supports the interpretation of a carnivorous diet for the coprolite producer. A range of fossil plants, representing true ferns, seed ferns and articulate plants (relatives of modern horsetails), were also investigated. Predominant C_{30} phytohopanoids and aromatised arborane/fernane biomarkers were identified exclusively in Carboniferous 'true ferns' (e.g. *Pecopteris* sp.). This study provides important new insights into the biological source and diagenetic fate of fern-derived hopanoid-bearing biomarkers, which have previously had ambiguous sources. Notably, carbonate concretion preservation of isolated fossil specimens allowed arborane/fernane compounds to be unambiguously associated with the 'true fern' fossil types.

Madison Tripp [madison.tripp@postgrad.curtin.edu.au], and Kliti Grice [K.Grice@curtin.edu.au], Organic and Isotope Geochemistry Centre, School of Earth and Planetary Science, Curtin University, Kent St, Bentley, WA 6102, Australia; Lorenz Schwark [lorenz.schwark@ifg.uni-kiel.de], Institute for Geosciences, Christian-Albrechts-University of Kiel, Ludewig-Meyn-Straße 10, 24118 Kiel, Germany; Jochen J. Brocks [jochen.brocks@anu.edu.au], Research School of Earth Science, Australian National University, Building 142, Mills Road, Acton, ACT 2601, Australia; Paul Mayer [pmayer@fieldmuseum.org], and Jack Wittry [wittryj@yahoo.com], Field Museum of Natural History, 1400 S Lake Shore Dr, Chicago, Illinois 60605, USA.

Late Quaternary cave fossils of small-bodied vertebrates from the Broken River region, northeastern Queensland

Vikram Vakil*, Jonathan Cramb, Gilbert J. Price, Julien Louys, and Gregory E. Webb

In recent years, reports of small/medium-sized mammals from Australia's tropical north have shown marked declines in diversity. Small-bodied mammals inhabit restricted ecological niches and their diversity and abundance are severely affected by habitat loss, over-predation and competition from introduced predators and herbivores, respectively, and other anthropogenic impacts. Long-term changes in their habitats can be better understood by investigating the late Quaternary fossil record of these mammals from limestone karst caves that are conducive to their preservation. Taxonomic analysis of Pleistocene cave fossils from the Broken River region, northeastern Queensland, shows the presence of new but extinct species of hopping mouse (*Notomys* sp.) and rock rat (*Zyzomys* sp.) from differently-aged deposits, alongside several extinct and locally extirpated taxa. The younger, pre-European surface deposits additionally reveal fossils of many locally extirpated taxa like the Cape York Bandicoot (*Isoodon peninsulae*), Swamp Rat (*Rattus lutreolus*), Plains Mouse (*Pseudomys australis*), Forrest's Mouse (*Leggadina forresti*) and Common Ringtail Possum (*Pseudocheirus peregrinus*), amongst others. The Broken River fossil record indicates that late Quaternary Australian extinctions may be more severe than previously realised. It also demonstrates significant range contractions of some species (*I. peninsulae*, *R. lutreolus*) since the deposits accumulated. Other species (*P. australis*, *L. forresti*) suggest a previously expanded arid zone, whereas others (*P. peregrinus*) indicate the presence of mixed habitats. Their absence in the area today could be a result of habitat loss. These cave fossils therefore serve as a baseline to infer local palaeoenvironmental conditions at the time of their accumulation, and additionally reveal that the current distributions/abundances of these taxa may not represent their complete range of ecological variability. Future targeting of such fossils from well-dated sites in the region might aid us in better understanding the response of Broken River fauna to past changes.

Vikram Vakil [vikram.vakil@uqconnect.edu.au], Gilbert J. Price [g.price1@uq.edu.au], and Gregory E. Webb [g.webb@uq.edu.au], School of Earth and Environmental Sciences, The University of Queensland, Brisbane, QLD 4072, Australia; Jonathan Cramb [jonathan.cramb@qm.qld.gov.au], Queensland Museum, Brisbane, QLD 4101, Australia; Julien Louys [j.louys@griffith.edu.au] Australian Research Centre for Human Evolution, Griffith University, Brisbane, QLD 4101, Australia.

Tooth shape in Mesozoic marine reptiles

Joshua White*, Tim Denham, Valentin Fischer, and Matt McCurry

Marine reptiles filled important ecological roles in the world's oceans throughout the Mesozoic, roles that were subsequently occupied by marine mammals after the Cretaceous/Paleogene extinction event. One method of tracking changes in the ecological roles of species is by observing their dental morphology; however, these are traditionally done with qualitative analysis. This approach makes tracking shifts in diet through time challenging. Here, we generated a dental morphospace of various groups of marine reptile teeth using euclidean measurement based on the enamel crown on most known dental morphologies present in marine reptiles. Our results show most variation in tooth morphology occurs in tooth robusticity (75.5%), followed by tooth curvature (15.8%). The dental morphospace clusters on conical, slightly recurved region regardless of functional guild, taxonomic group and geological age. Furthermore, two regions of the morphospace — robust, recurved teeth and thin, straight teeth — are unoccupied by species in the dataset, suggesting a trade-off between ability to withstand loads (robusticity), puncture efficiency and grip. We observed considerable overlap in morphospace occupation across time and between taxonomic groups. Our results suggest that there are strong selective pressures causing convergent evolution in marine reptile dentition, but more work is required to map how changes in tooth shape influence functional abilities.

Joshua White [Joshua.white@anu.edu.au], Research School of Physics, Department of Materials Physics, Australian National University, Canberra, ACT 2601, and Australian Museum Research Institute, 1 William Street, Sydney, NSW 2010, Australia; Tim Denham [tim.denham@anu.edu.au], School of Archaeology and Anthropology, Banks Building, Australian National University, Canberra, ACT 2601, Australia; Valentin Fischer [v.fischer@uliege.be], Evolution & Diversity Dynamics Lab, Université de Liège, 4000 Liège, Belgium; Matt McCurry [Matthew.McCurry@austmus.govau], Australian Museum Research Institute, 1 William Street, Sydney, NSW 2010, Earth and Sustainability Science Research Centre, School of Biological, Earth and Environmental Sciences, University of New South Wales, NSW 2052, and Paleobiology, National Museum of Natural History, Smithsonian Institution, Washington, DC 20560, USA.

The *Jimbacrinus bostocki* obrution lagerstätte in the lower Permian Cundlego Formation near Gascoyne Junction, Western Australia

Robbert J. Willink*, and Thomas Kapitany

Invertebrate fossils are preserved in slabs of calcareous silty sandstone exposed in riverbeds near the township of Gascoyne Junction, Western Australia. Based on regional mapping, these rocks have been assigned to the shallow-marine Cundlego Formation, which has been dated to the early Permian. Many of the slabs have the cladid, inadunate crinoid *Jimbacrinus bostocki* Teichert, 1954 preserved in large numbers, with densities up to 200 individuals per square metre observed. Articulated crowns of this crinoid with complete or partial stems attached are often found haphazardly aggregated in pods.

Based on an examination of numerous fossiliferous slabs, more details on the morphology of *Jimbacrinus bostocki* itself are provided, particularly on juveniles of this species, which, unlike adults, have stems that bear cirri. The stem of adults, which lacks an obvious holdfast, is acutely bent immediately below the calyx before being preferentially directed linearly in the homocrinid (E-BC) symmetry plane.

Jimbacrinus crowns are commonly preserved with their arms arranged in a protective manner, also referred to as the 'trauma' posture. It is inferred that such individuals were transported alive by storm-induced turbidity currents from a feeding position on a marine shelf to deeper, possibly more anoxic, waters, often accumulating en masse in syndepositional lows on the sea floor, such as in swales. They were subsequently smothered by, and rapidly buried in sediment. In totality, these fossiliferous deposits are considered to meet the criteria of an 'Obrution Lagerstätte'.

From a taphonomic and functional morphologic analysis, possible options for the feeding posture of *Jimbacrinus bostocki* are discussed. Because of its advanced arm morphology comprising mainly oblique muscular articulations between brachials, the question is also posed as to whether this crinoid was in fact motile, not sessile. If so, it would have given it an ability to escape from approaching benthic predators.

Teichert, C., 1954. A new Permian crinoid from Western Australia. *Journal of Paleontology 28(1),* 70–75.

Robert J. Willink [robblink@ozemail.com.au], 11 Coral Sea Court, Sunshine Beach, QLD 4567, Australia; Thomas Kapitany [tomk@crystal-world.com], Crystal World, 13 Olive Road, Devon Meadows, VIC 3977, Australia.

Novel sauropod tracks from the Lower Cretaceous (Valanginian–Barremian) Broome Sandstone of the greater Broome area, Dampier Peninsula, Western Australia

Gemma L. Wise*, Anthony Romilio, Jay P. Nair, and Steven W. Salisbury

Western Australia has a rich record of dinosaur tracks. Coastal exposures of the Broome Sandstone on the Dampier Peninsula in the West Kimberley preserve the world's most diverse dinosaurian ichnofauna, providing a unique insight into the palaeoecosystems of Australia during the Valanginian–Barremian portion of the Early Cretaceous. Extensive studies over the past decade have established a rich record of ichnological diversity in the Broome Sandstone exposed along the 25 km stretch of coastline in the Walmadany area, 50 km north of Broome. Although less thoroughly documented, track-bearing horizons of the Broome Sandstone also occur along the coast around Broome. Although it appears to be stratigraphically broadly coeval with Walmadany, the exposures of Broome Sandstone around Broome represent a more distal depositional setting and contain an ichnofauna that is distinct from that of Walmadany. Although highly abundant, the majority of sauropod tracks in the Broome area are morphologically indistinct. Historically, this has hindered their referral to a specific ichnotaxa. Recent extensive ichnological surveys of the greater Broome Area have revealed morphologically distinct tracks and trackways that provide evidence of a novel sauropod ichnotaxa. In this study, we explore the morphology and trackway metrics of these tracks from multiple track-bearing platforms. The new *Parabrontopodus*-like ichnotaxon can be distinguished from other sauropod tracks in the Broome Sandstone based upon the presence of a unique combination of diagnostic morphological traits and trackway metrics. It represents the seventh type of sauropod track to be recognised in the Broome Sandstone and adds to the globally significant diversity of the Broome ichnofauna. This research provides a basis for assessing and comparing the faunal composition of two near contiguous, temporally equivalent areas representing differing depositional environments in a region where osteological remains are absent.

Gemma Wise [g.wise@uq.net.au], Anthony Romilio [a.romilio@uq.edu.au], Jay P. Nair [jayraptor@gmail.com], and Steven W. Salisbury [s.salisbury@uq.edu.au], School of Biological Sciences, The University of Queensland, Brisbane, QLD 4072, Australia.

Environmental controls on the preservation of Precambrian organic-walled microfossils

Christina R. Woltz*, Ross P. Anderson, Nicholas J. Tosca, and Susannah M. Porter

Precambrian organic-walled microfossils (OWMs) are primarily preserved in mudstones and shales that are low in total organic carbon (TOC). Recent work suggests that high TOC may hinder OWM preservation, perhaps because it interferes with chemical interactions involving certain clay minerals that inhibit the decay of microorganisms. To test if clay mineralogy controls OWM preservation, and if TOC moderates the effect of clay minerals, we compared OWM preservational quality (measured by the level of pitting on fossil surfaces and the quality of wall margins) to TOC, total clay, and specific clay mineral concentrations from 78 shale samples ranging in age from 1600 to 650 Ma. The probability of finding well-preserved microfossils positively correlates with total clay concentrations and negatively correlates with TOC concentrations. Further, we found no evidence that TOC moderates the effect of clay minerals on OWM preservation, supporting an independent role for both factors. Within the total clay fraction, well-preserved microfossils are more likely to occur in shales with high illite concentrations and low berthierine/chamosite concentrations; however, the magnitude of their effect on preservation is relatively small. Therefore, there is little evidence that clay chemistry is important in OWM preservation. We propose that OWM preservation is largely regulated by physical properties that isolate organic remains from microbial degradation such as food scarcity (low TOC) and low sediment permeability (high total clay content).

Christina R. Woltz [cwoltz@stanford.edu], Department of Earth and Planetary Sciences, Stanford University, 450 Jane Stanford Way, Stanford, CA 94305-2115, USA; Ross P. Anderson [ross.anderson@earth.ox.ac.uk], All Souls College and the Department of Earth Sciences, University of Oxford, Oxford OX1 4AL, UK; Nicholas J. Tosca [njt41@cam.ac.uk], Department of Earth Sciences, Downing St, University of Cambridge, CB2 3EQ, UK; Susannah M. Porter [porter@geol.ucsb.edu], Department of Earth Science, University of California, Santa Barbara, Lagoon Rd, Santa Barbara, CA 93106, USA.

A redescription of *Prognathodon waiparaensis* and reassessment of its phylogenetic position

George Young*, Vanesa L. De Pietri, Catherine Reid, and Paul Scofield

Mosasaurs were a group of secondarily aquatic reptiles that were one of the major vertebrate predators of the Late Cretaceous seas. New Zealand's mosasaur assemblage is very diverse, including more than five genera. One of these, *Prognathodon waiparaensis* Welles & Gregg, 1971, is known only from the holotype, CM Zfr 108, recovered from the Waipara River of North Canterbury, New Zealand. Although this has been previously described in Welles & Gregg's (1971) monograph, a redescription of CM Zfr 108 allows comparisons with material unearthed in the more than 50 years following this work, and for a better understanding of its phylogenetic placement, which has proved unstable in many recent analyses. In addition to redescribing CM Zfr 108, 3D surface scans were taken to digitise the material to allow for easier sharing of data for future work. The redescription has resulted in minor updates to the work of Welles & Gregg (1971) and has allowed comparisons with other recently described species of *Prognathodon*, as well as other mosasaur taxa. The comparative work has also raised questions about the taxonomic placement of *P. waiparaensis*, as well as whether all material is derived from a single individual. Although it was a cosmopolitan genus during the Campanian–Maastrichtian, *P. waiparaensis* shows affinities for other Gondwanan *Prognathodon* species, but with a biogeographic trend that differs from that of other Zealandian mosasaurs.

Welles, S.P. & Gregg, D.R. 1971. Late Cretaceous marine reptiles of New Zealand. *Records of the Canterbury Museum 9*, 1–111.

George Young [george.young@pg.canterbury.ac.nz], Vanesa De Pietri [vanesa.depietri@canterbury.ac.nz], and Catherine Reid [Catherine.reid@canterbury.ac.nz], School of Earth and Environment, University of Canterbury, Private Bag 4800, Christchurch, New Zealand; Paul Scofield [pscofield@canterburymuseum.com], Canterbury Museum, 11 Rolleston Avenue, Christchurch 8013, New Zealand.

Did Bryozoa miss the Cambrian explosion?

Zhiliang Zhang*, Zhifei Zhang, Junye Ma, Paul D. Taylor, Luke C. Strotz, Sarah M. Jacquet, Christian B. Skovsted, Feiyang Chen, Jian Han, and Glenn A. Brock

Bryozoans (moss animals) are a distinctive phylum of aquatic sessile lophophorate organisms that construct a modular colonial exoskeleton (organic and calcitic) (Taylor 2020). The presence of six major orders of bryozoans with advanced polymorphisms in lower Ordovician rocks strongly suggests a Cambrian origin for the largest and most diverse lophophorate phylum. However, bryozoans had been unique among animal phyla well-represented in the fossil record in lacking Cambrian representatives, suggesting they may not have been part of the 'Cambrian Explosion' of life. The millimetric, erect, bilaminate, secondarily phosphatised colonial skeleton of *Protomelission gatehousei* (Brock & Cooper 1993), discovered from the early Cambrian of South Australia and South China, unveils an early Cambrian origin for Bryozoa. The minute size, uniform dimensions and shape of the monomorphic zooecial capsules, modular construction, organic composition and linear budding growth geometry represents a mixture of Stenolaemata and Gymnolaemata character traits suggesting *P. gatehousei* is a potential stem-group bryozoan (Zhang *et al.* 2021). This aligns the origin of Bryozoa with all other lophophorate phyla in Cambrian Age 3 and suggests an organic, bilaminate colony is ancestral for the group, as well as reconciling the fossil record with molecular clock estimations for the origination and radiation of Bryozoa (Erwin 2020). Although some fossils of similar age discovered at Xiaoshiba in China challenge the interpretation of *Protomelission gatehousei* as a bryozoan (Yang *et al.* 2023), the two sets of fossils demonstrate distinct morphological and taphonomic differences. *P. gatehousei* meets almost all morphological criteria expected in an ancestral fossil bryozoan, which is consistent with the inferred basal phylogenetic position of *Protomelission* by phylogenetic analyses, and has been supported by latest studies of the early evolution of bryozoans (Orr *et al.* 2022, Pruss *et al.* 2022, Simpson & Jackson 2022).

Brock, G.A. & Cooper, B.J., 1993. Shelly fossils from the Early Cambrian (Toyonian) Wirrealpa, Aroona Creek, and Ramsay Limestones of South Australia. *Journal of Paleontology 67*, 758–787.

Erwin, D.H., 2020. The origin of animal body plans: a view from fossil evidence and the regulatory genome. *Development 147*(4), dev182899.

Simpson, C. & Jackson, J.B., 2022. Bryozoan revelations. *Science Advances 8*(13), p.eabp 9344.

Orr, R.J., Di Martino, E., Ramsfjell, M.H., Gordon, D.P., Berning, B., Chowdhury, I., Craig, S., Cumming, R.L., Figuerola, B., Florence, W. & Harmelin, J.G., 2022. Paleozoic origins of cheilostome bryozoans and their parental care inferred by a new genome-skimmed phylogeny. *Science Advances 8*(13), p.eabm 7452.

Pruss, S.B., Leeser, L., Smith, E.F., Zhuravlev, A.Y. & Taylor, P.D., 2022. The oldest mineralized bryozoan? A possible palaeostomate in the lower Cambrian of Nevada, USA. *Science Advances 8*(16), p.eabm8465.

Taylor, P.D., 2020. *Bryozoan paleobiology*. John Wiley & Sons, Hoboken, New Jersey, USA, 336 pp.

Yang, J., Lan, T., Zhang, X.G. & Smith, M.R., 2023. *Protomelission* is an early dasyclad alga and not a Cambrian bryozoan. *Nature 615*(7952), 468–471.

Zhang, Z.L, Zhang, Z., Ma, J., Taylor, P.D., Strotz, L.C., Jacquet, S.M., Skovsted, C.B., Chen, F., Han, J. & Brock, G.A., 2021. Fossil evidence unveils an early Cambrian origin for Bryozoa. *Nature 599*(7884), 251–255.

Zhiliang Zhang [zhiliang.zhang@nigpas.ac.cn] and Junye Ma [jyma@nigpas.ac.cn], Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, Nanjing 210008, People's Republic of China; Zhifei Zhang [elizf@nwu.

edu.cn], Luke C. Strotz [lukestrotz@gmail.com], and Jian Han [elihanj@nwu.edu.cn], Northwest University, Xi'an 710069, People's Republic of China; Paul D. Taylor [p.taylor@nhm.ac.uk], Natural History Museum, London SW7 5BD, UK; Sarah M. Jacquet [jacquets@missouri.edu], University of Missouri, Columbia MO 65211, USA; Christian B. Skovsted [christian.skovsted@nrm.se], Swedish Museum of Natural History, SE-10405 Stockholm, Sweden; Feiyang Chen [feiyang.chen@cumt.edu.cn], China University of Mining and Technology, Xuzhou 221116, People's Republic of China; Glenn A. Brock [glenn.brock@mq.edu.au], Macquarie University, Sydney, NSW 2109, Australia.

PALAEO DOWN UNDER 3
10-14 JULY 2023

POSTER ABSTRACTS

in alphabetical order of first author surname

* indicates presenting author

New insight into the dinocyst succession from the DSDP Hole 263, offshore Western Australia

John Backhouse*, and Daniel Peyrot

A restudy of the palynological succession from DSDP Hole 263, drilled in the southeastern Cuvier Abyssal Plain, offshore Western Australia, reveals more diverse dinoflagellate cyst associations than initially determined. The Cretaceous interval starts in the Valanginian–Hauterivian *Systematophora areolata* Dinocyst Zone and extends into the lower Aptian *Odontochitina operculata* Dinocyst Zone. Crucially, Albian and younger Cretaceous strata are not present, and the Cretaceous is overlain by Paleocene or younger units. Genera such as *Aprobolocysta*, *Batiacasphaera*, *Circulodinium* and *Muderongia* exhibit high diversity. Similar diversity is present in nearby deep-water wells and ODP sites. Comparison with other sections drilled in the framework of the international DSDP, ODP and IODP programs indicates that the *Odontochitina operculata – Muderongia australis* Dinocyst zones are well represented in deep-water settings from the Argo Abyssal Plain to the Naturaliste Plateau. Conversely, the underlying *M. testudinaria – S. areolata* Dinocyst zones are thin in DSDP263, and are poorly represented at other locations along the western margin of Australia. Zones older than the *S. areolata* Zone are present at some other sites. The stratigraphic interval in DSDP263 can be correlated to the zonation originally determined for the Warnbro Group in the Perth Basin, and with the Australia-wide zonation scheme. This demonstrates the consistency of the dinoflagellate cyst biostratigraphic zonation along the western margin of Australia, although variations in diversity and dinocyst abundance also reveal the presence of microfloral differences caused by changing basinal location and depositional setting.

John Backhouse [jbackhou70@yahoo.com], and Daniel Peyrot [daniel.peyrot@uwa.edu.au], School of Earth Sciences, The University of Western Australia, 35 Stirling Highway, Perth, WA 6009, Australia.

In: Abstract book and Conference Guide: Palaeo Down Under 3, 10–14 July 2023. Australasian Palaeontologists, Perth, Western Australia, 129 pp.

The micromammal assemblage from Tibana 1 locality, upper Miocene (early Vallesian) of the Moldavian Platform, northeastern Romania

Daniel D Badea*, Bogdan G Rățoi, and Mihai Brânzilă

The assemblage of micromammals collected from an upper Miocene locality Tibana 1 of the Moldavian Platform is described (see Săndulescu 1984). This faunal association contains rodents, insectivores and lagomorphs. One of the most important rodents is *Byzantinia bayraktepensis*, with the occurrence here the first appearance of this species in the upper Miocene Moldavian Platform, Romania. The presence of *Byzantinia bayraktepensis*, which is also known from localities in Turkey, can be correlated to MN8 and MN9 (Bayraktepe 1, Yenieskihisar, Dereikebir, Mahmutköy, Pismanköy and Tuğlu; see Ünay 1980, Rummel 1998, Joniak & de Bruijn 2015), suggesting a late Astaracian or early Vallesian correlation. *Lophocricetus minuscilus*, *Progonomys chatalai*, *Neocricetodon* sp. and *Myomimus dehni* taxa are also recorded. *Lophocricetus minuscilus*, a species of jumping mouse is recorded here for the first time in the late Miocene of Romania. The group of insectivores (order Eulipotyphla) is represented by two species: *Desmanella* sp. and *Petenyia* sp. A single lagomorph tooth was identified from sediment and assigned to *Ochotona* sp. Based on the rodent assemblage, the age of this faunal association is interpreted as upper Miocene, early Vallesian (MN 9). The faunal diversity recorded from this locality provides important information for future palaeoenvironmental research. In addition, this work on the Tibana 1 locality provides an important contribution to the study of late Miocene micromammals from the Moldavian Platform, and by extension, from Eastern Europe.

Joniak, P., & de Bruijn, H., 2015. Rodents from the Upper Miocene Tuğlu Formation (Çankırı Basin, Central Anatolia, Turkey). *Paläontologische Zeitschrift 89*, 1039–1056.

Rummel, M., 1998. Die Cricetiden aus dem Mittel- und Obermiozän der Türkei. *Documenta Naturae 123*, 1–300.

Săndulescu, M., 1984. Geotectonica României. *Ed. Tehnică, București*, 329 pp.

Ünay, E., 1980. The Cricetodontini (Rodentia) from the Bayraktepe section (Çanakkale, Turkey). *Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen B 83*, 399–418.

Dumitru-Daniel Badea [badeadaniel.i13@gmail.com], Bogdan-Gabriel Ratoi [bog21rat@gmail.com], and Mihai Branzila [mib@uaic.ro], Faculty of Geography and Geology, "Alexandru Ioan Cuza" University, Bulevard "Carol I", Nr.11, 707006, Iași, Romania.

Preservation and palaeoenvironmental insights from fossiliferous Allaru Mudstone concretions

Luke Brosnan*, Stephen F. Poropat, William D. Rickard, and Kliti Grice

Carbonate concretion nodules offer an excellent opportunity to examine ancient life and modes of exceptional fossil preservation by preserving biomolecules from the time of deposition, either intact or as recognisable diagenetic products. In the literature, greater than 80% abundance of intact cholesterol and associated diagenetic products were reported in a *ca* 380 Ma invertebrate within a concretion from the Gogo Formation, classifying the organism as a crustacean. Sterols including coprostanol have been reported in coprolites preserved in siderite nodules (Mazon Creek, 311–306 Ma) representing a carnivorous diet of the producer organism.

The Allaru Mudstone (central Queensland, Australia; 105 Ma) was deposited at a time of increasing sedimentation rate and benthic fauna recovery following the oceanic anoxic event during which the underlying Toolebuc Formation was deposited. Biomarker and stable isotope analyses of Allaru Mudstone concretions provide further insights on the organisms and palaeoenvironment from the last inland sea of Cretaceous Australia. In this study, a range of invertebrates encased within carbonate nodules have been imaged by X-ray computed tomography. Specimens include ammonites (*Myloceras* sp.), crabs (*Torynomma quadrata*), and a belemnite guard. Biomarkers and intact sterols have been extracted and analysed from the matrix and fossil to indicate a range of preservation and/or weathering. The kerogen has been subjected to hydropyrolysis to selectively cleave biomarkers representative of the original composition without organic matter overprinting. Mineral phases have been characterised by X-ray diffraction, and the elemental composition was determined by ICP-MS. A summary of these findings will contribute to the understanding of the Allaru Mudstone through a combined palaeontological and geochemical approach.

Luke Brosnan [Luke.Brosnan@postgrad.curtin.edu.au], Stephen F. Poropat [Steve.Poropat@curtin.edu.au], and Kliti Grice [K.Grice@curtin.edu.au], Western Australian Organic and Isotope Geochemistry Centre (WA-OIGC), School of Earth and Planetary Science, Curtin University, Kent St, Bentley, WA 6102, Australia; William D. Rickard [W.Rickard@curtin.edu.au], John de Laeter Centre, Curtin University, Kent St, Bentley, WA 6102, Australia.

Remarkable mouldic preservation of a mid-Proterozoic benthic eukaryote assemblage: implications for 'Darwin's Dilemma'

Wendi Bulfin and Peter McGoldrick*

It can be argued that 'Darwin's Dilemma', in essence the paucity of fossils in rocks older than the Cambrian, is still a problem today. Possibly more so, given the research focus on the early Earth system over the last few decades. The mid-Proterozoic Laan fossil site in northwestern Tasmania includes many examples of exceptionally preserved casts and moulds of *Horodyskia* and other purported large eukaryotes (see Van Stall *et al.* poster, this meeting). These fossils are hosted by rhythmically laminated mudstones and fine sandstones. Why such seemingly mundane rocks should contain well-preserved fossils will be the focus of this poster. We will discuss the local environmental setting, taphonomic processes and subsequent deformation history of the host sequence. All three likely played a role in fossil preservation. Microbial textures and rhythmic graded beds indicate a sea floor where distal storm effects periodically disrupted the established microbial-mat substrate. We suggest microchemical environments resulting from the decomposition of organic matter, together with contrasting rheology of fine sand and mud layers facilitated textural preservation. This is analogous to some types of Ediacaran fossil preservation (e.g. Gehling 1999, Bobrovskiy *et al.* 2019). Some implications for the search for other large delicate fossils will be discussed.

Bobrovskiy, I., Krasnova, A., Ivantsov, A., Luzhnaya (Serezhnikova), E. & Brocks, J.J., 2019. Simple sediment rheology explains the Ediacara biota preservation. *Nature Ecology & Evolution 3*, 582–589.

Gehling, J.G., 1999. Microbial mats in terminal Proterozoic siliciclastics: Ediacaran death masks. *Palaios 14*, 40–57.

Wendy Bulfin [danyan11@bigpond.com], and Peter McGoldrick [p.mcgoldrick@utas.edu.au], CODES, University of Tasmania, Locked Bag 66, Hobart, TAS 7001, Australia.

Marine avian diversity in the Paleocene of New Zealand

Vanesa L. De Pietri*, Erica Crouch, Leigh Love, Al Mannering, Gerald Mayr, Catherine M. Reid, and R. Paul Scofield

Understanding the evolutionary processes that drove the diversification of modern birds after the Cretaceous/Paleogene mass extinction event 66 million years ago (Ma) has long been hampered by a sparse Paleocene (66–56 Ma) global fossil record. Cretaceous–Paleogene marine sediments exposed in the Waipara River, North Canterbury, have held regional and global scientific importance since the 1800s. In the 1980s, complete and well-preserved fossil penguins were recovered from the *ca* 62.5 – 56 Ma Waipara Greensand. More recently, discoveries of giant penguins, tropicbirds and bony-toothed birds, have further underscored the role of Zealandia as a hub for seabird evolution, and have begun to reshape our understanding of ancient marine-bird faunas and their significance in assessing the impact of changing environmental conditions during the early Paleogene on vertebrate faunas. Here we provide an overview of our research, in which we aim to develop a comprehensive fossil record of marine birds from the Waipara Greensand to enhance our understanding of their taxonomic diversity and palaeobiology. Improving stratigraphic control of the collected specimens is essential for deciphering key evolutionary relationships and revealing the extent and timing of early diversification events in different seabird lineages. Analyses of microfossils in samples of the surrounding matrix associated with these bird fossils not only allow us to refine the age of the sediments but also facilitate palaeoenvironmental reconstructions. This way, we can further explore how ecological and environmental changes during the Paleocene, at regional and global scales, have influenced the composition and diversity of these early vertebrate faunas.

Vanesa L. De Pietri [vanesa.depietri@canterbury.ac.nz], Leigh Love [lvlove@xtra.co.nz], Al Mannering [alman@slingshot.co.nz], and Catherine M. Reid [catherine.reid@canterbury.ac.nz], School of Earth and Environment, University of Canterbury, Private Bag 4800, Christchurch 8140, New Zealand; Erica Crouch [e.crouch@gns.cri.nz], GNS Science, 1 Fairway Drive, Lower Hutt 5040, New Zealand; Gerald Mayr [Gerald.Mayr@senckenberg.de], Senckenberg Research Institute and Natural History Museum Frankfurt, Ornithological Section, Senckenberganlage 25, D-60325 Frankfurt am Main, Germany; R. Paul Scofield [pscofield@canterburymuseum.com], Canterbury Museum, 11 Rolleston Ave, Christchurch 8013 and School of Earth and Environment, University of Canterbury, Private Bag 4800, Christchurch 8140, New Zealand.

Putting a name to a face: assessing the utility of geometric morphometrics on classifying the fossil varanids of Naracoorte Caves World Heritage Area

Isabella Donato*, Alessandro Palci, Mark Hutchinson, and Elizabeth Reed

Pleistocene fossil sites like those in the Naracoorte Caves World Heritage Area offer unique insights into past biodiversity. The turnover of vertebrate species over time, both living and extinct, provides insights into past ecological responses to changing climate, with implications for our understanding of the impact of present-day climate change. At Naracoorte, palaeoecological research has focused primarily on the mammalian fauna. However, a diverse range of herpetofaunal species are preserved in the cave deposits and, by virtue of their sensitivity to changes in temperature and precipitation, may provide detailed information on palaeoenvironmental change at Naracoorte. Monitor lizards (Varanidae) are an ecologically important component of the Australian fauna and are abundant in the Naracoorte deposits, particularly the middle Pleistocene Fossil Chamber in Victoria Fossil Cave. However, obstacles in reptile identification, due to their relatively low morphological variation, must be overcome to include them in palaeoecological research. Here we explore the use of geometric morphometrics to assess the taxonomic affinity of five varanid fossils, represented by three dentaries and two parietals. The fossils were compared to modern species that are currently found in the area: *Varanus gouldii* (n=12), *Varanus rosenbergi* (n=9) and *Varanus varius* (n=12). The specimens were CT scanned to obtain digital 3D models for analysis using three-dimensional geometric morphometrics. To represent the shape of each element, we placed 54 landmarks (12 fixed and 42 semi-landmarks) on homologous points of the parietals and 30 landmarks (7 fixed and 23 semi-landmarks) on the dentaries. Dentaries and parietals belonging to *Varanus gouldii*, *Varanus rosenbergi* and *Varanus varius* could all be separated based on their morphology; fossil parietals and dentaries were confidently assigned to *Varanus varius*. The presence of *Varanus varius* just after the peak of the interglacial periods (notably MIS 7) is consistent with the warm, wet conditions and forested environment preferred by this species.

Isabella Donato [isabelladonato25@gmail.com], Alessandro Palci [alessandro.palci@adelaide.edu.au], and Elizabeth Reed [liz.reed@adelaide.edu.au], School of Biological Sciences, Faculty of Sciences, Engineering and Technology, University of Adelaide, North Terrace, Adelaide, SA 5000, Australia; Mark Hutchinson [mark.hutchinson@samuseum.sa.gov.au], Herpetology Section, South Australian Museum, North Terrace, Adelaide, SA 5000, Australia.

Mid-Miocene marine macroinvertebrates at 45° South: palaeoclimate change and ecological impacts

Michelle Gray*, Elizabeth. A. Weldon, and Mark. T. Warne

Climate change is known to force migration, promote generic range expansion, and reduce faunal diversity (Jablonski *et al*. 2013, Hastings *et al*. 2020) the impact of which may be evident over extended periods (Heim 2008, Jablonski *et al*. 2013, Mathes *et al*. 2021). This research investigated 254 marine macroinvertebrate genera across six phyla and aimed to understand how present-day latitudinal distribution of marine faunas has been impacted by palaeoclimate change documented for the mid-Miocene. Diversity shifts from just prior to the onset of the mid-Miocene Climatic Optimum (MMCO) (*ca* 17 Ma) through to the onset of the mid-Miocene Climatic Transition (*ca* 13 Ma) were investigated using literature-based sampling of four Miocene-aged lithofacies (shallow-shelf limestone, shallow-shelf sandy/clay, mid-shelf clay/marl and outer-shelf clay) located across the Port Philip Bay coastline in Victoria. In the Miocene, Port Phillip Bay sat at latitude 45º South. Modern distribution patterns obtained from existing records (Atlas of Living Australia 2022) were utilised to determine the average maximum latitude shift of relict genera (n=125) no longer in Port Phillip Bay but remaining in Australia since the Miocene. Here, generic diversity increases in Port Philip Bay during the mid-Miocene is demonstrated. This was driven by a reduction in north–south sea-surface temperature gradients and eustatic change which culminated in the dominance of genera with wide-ranging latitudinal affinities (cosmopolitan genera). The ability to track preferred temperature ranges northwards was likely facilitated by Australia's northward drift and warm northbound east coast currents (Edgar 2014, Holbourn *et al*. 2013, McGowran *et al*. 1997, Warne *et al*. 2003). An average latitude shift of 20–30º equatorially was recorded for relict genera. Temperate-affiliated relicts shifted 20º equatorially, whereas cosmopolitan and Indo-Pacific tropical-affiliated relicts recorded shifts of up to 40º northwards, suggesting a return to latitudes representative of their biogeographic affinities. The extinction of 51% of Port Philip Bay's endemic genera and successful range expansion of 125 relicts dominated by cosmopolitan genera, signals a long-term trend toward the homogenisation of marine macroinvertebrates in Australian benthic environments seen after the mid-Miocene Climatic Optimum.

Atlas Of Living Australia, 2022. *Occurrence records. Veneridae*, https://spatial.ala.org.au/ (accessed 2022).

Edgar, G., 2014. Geological history and climate change in southern Australia. In *Ecology of Australian Temperate Reefs*, Shepherd, S. & Edgar, G., eds, CSIRO Publishing, Collingwood, 21–40.

Hastings, R.A., Rutterford, L.A., Freer, J.J., Collins, R.A., Simpson, S.D. & Genner, M.J., 2020. Climate Change Drives Poleward Increases and Equatorward Declines in Marine Species. *Current Biology 30*(8), 1572–1577, e1572.

Heim, N., 2008. A null biogeographic model for quantifying the role of migration in shaping patterns of global taxonomic richness and differentiation diversity, with implications for Ordovician biogeography. *Paleobiology 34*, 195–209.

Holbourn, A., Kuhnt, W., Frank, M. & Haley, B.A., 2013. Changes in Pacific Ocean circulation following the Miocene onset of permanent Antarctic ice cover. *Earth and Planetary Science Letters 365*, 38–50.

Jablonski, D., Belanger, C.L., Berke, S.K., Huang, S., Krug, A.Z., Roy, K., Tomasovych, A. & Valentine, J.W., 2013. Out of the tropics, but how? Fossils, bridge species, and thermal ranges in the dynamics of the marine latitudinal diversity gradient. *Proceedings of the National Academy of Sciences 110*(26), 10487–10494.

Mathes, G.H., Kiessling, W. & Steinbauer, M.J., 2021. Deep-time climate legacies affect origination rates of marine genera. *Proceedings of the National Academy of Sciences 118*(36), e2105769118.

McGowran, B., Li, Q., Cann, J., Padley, D., McKirdy, D.M. & Shafik, S., 1997. Biogeographic impact of the Leeuwin Current in southern Australia since the late middle Eocene. *Palaeogeography Palaeoclimatology Palaeoecology 136*, 19–40.

Warne, M., Archbold, N., Bock, P., Darragh, T., Dettmann, M., Douglas, J., Gratsianova, R.T., Grover, M., Holloway, D., Holmes, F., Irwin, R., Jell, P., Long, J., Mawson, R., Partridge, A., Picket, J., Rich, T., Richardson, J., Simpson, A. & Vandenberg, A., 2003. Palaeontology: the biogeohistory of Victoria. In *Geology of Victoria*, Birch, W., ed., Geological Society of Australia, Victoria Division, Melbourne, Victoria, 605–652.

Michelle Gray [m.gray@research.deakin.edu.au], Elizabeth A. Weldon [l.weldon@deakin.edu.au], and Mark. T. Warne [mark.warne@deakin.edu.au], School of Life and Environmental Sciences, Deakin University, Geelong, VIC 3216, Australia.

The first lamniform sharks described from the late Albian – early Cenomanian Griman Creek Formation

Emil B. Herbert*, Nicolás E. Campione, Phil R. Bell, Timothy Frauenfelder, and Elizabeth T. Smith

In the middle Cretaceous, a large portion of Australia was covered by the shallow inland Eromanga Sea. Lamniform sharks were common during this time, with known fossil occurrences across Australia. However, of the eastern occurrences, very few have been formally described, and even less is known about the sharks from the Surat Basin. Here, we report on the first shark teeth found from the late Albian – early Cenomanian Griman Creek Formation (GCF). The teeth are from two distinct regions putatively containing outcrops of the GCF: Bymount, near Surat, southern Queensland; and various opal mines near Lightning Ridge, northern New South Wales. We report on four teeth collected from Bymount and one tooth from Lightning Ridge. Within this small sample, several lamniform families are represented including Paraisuridae, Pseudoscapanorhynchidae, and Odontaspididae from Surat and Archaeolamnidae from Lightning Ridge. The paraisurid is an anterolateral tooth with strong mesio-distal compression, salient lingual protuberance, and an absence of lateral cusplets, assigned to *Paraisurus* aff. *compressus*, representing the youngest material of this genus in Australia. Two pseudoscapanorhychid taxa are interpreted based on their small size and prominent labial crown bulge. Finally, the first *Archeolamna* material from eastern Australia inferred by the lack of nutritive groove, single pair of triangular lateral cusplets, and a distinct lingual neck basal to the crown. Lamniforms are a strictly marine clade, making their discovery in the GCF unexpected. As the formation was interpreted as a largely freshwater palaeoenvironment, the occurrence of lamniforms may be explained by periodic inundations by the Eromanga Sea, despite its hypothesised regression during this time. Alternatively, the shark teeth could have been reworked from the underlying marine sediments of the Wallumbilla Formation. Continued work on the shark diversity in this formation will serve to test these hypotheses and shed light on the palaeoenvironment of the Griman Creek Formation.

Emil Herbert [eherber4@myune.edu.au], Nicolás E. Campione [ncampion@une.edu.au], Phil R. Bell [pbell23@une.edu.au], and Timothy Frauenfelder [timothy.frauenfelder@gmail.com], Palaeoscience Research Centre, School of Environmental and Rural Science, University of New England, Armidale, NSW 2351, Australia; Elizabeth T. Smith [elizabethtsmith@exemail.com.au], Australian Opal Centre, 3/11 Morilla Street, Lightning Ridge, NSW 2834, Australia.

Morphometrics and function of the ornithischian femur and fourth trochanter

Justin L. Kitchener*, Phil R. Bell, and Nicolás E. Campione

Early ornithischians were small-bodied bipeds that possessed characteristic femoral morphology, including a bowed shaft and 'pendant' shaped fourth trochanter (4tr). The form of the 4tr may have functional significance, as it provides attachment sites for the powerful caudofemoralis muscles, and femoral curvature may improve distal load resistance during retraction. Although the variation present in the ornithischian femur and 4tr has long been recognised, a broad quantitative study that considers phylogeny and function has been lacking. We assembled a dataset of 8 linear measurements from femora of 51 ornithischian taxa, and for 41 of these, we recorded the two-dimensional, lateral shape of the 4tr using geometric landmarks.

Principal component analysis (PCA) of the linear measurements shows that they are driven primarily by size (~90% along PC1), followed by femoral curvature (~7% on PC2). Principal component analysis of the 4tr shape shows that variation largely relates to an increasingly more proximal position of the 4tr tip (~77% along PC1), while PC2 (~11% of the variance) correlates with an increasingly more posterior projection of the tip. A two-block partial least squares test (r-pls = 0.613, p-value = 0.001, Z = 3.038) of the geometric and linear datasets demonstrates a significant association between body size and 4tr shape. Functionally, a distally extended 4tr tip increases mechanical advantage during femur retraction. Several small-bodied taxa, including the burrowing *Oryctodromeus*, and proposed burrowers *Koreanosaurus*, *Nanosaurus*, and *Psittacosaurus*, exhibit a high distal extension of the 4tr tip, suggesting that the shape of the 4tr evolved as a possible adaptation to burrowing or digging behaviours, analogous to the enlarged third trochanter of contemporary mammalian femur-driven diggers (e.g. the Aardvark and xenarthrans).

Justin L. Kitchener [jkitche3@myune.edu.au], Phil R. Bell [pbell23@une.edu.au], and Nicolás E. Campione [ncampion@une.edu.au], School of Environmental and Rural Science, University of New England, Armidale, NSW 2351, Australia.

The end-Permian extinction event of eastern Gondwana — a song of slime and fire

Chris Mays*, Vivi Vajda, Tracy D. Frank, Christopher R. Fielding, Sam M. Slater, and Stephen McLoughlin

The threat of wildfires and harmful microbial blooms to land and freshwater ecosystems is increasing today, exacerbated by CO_2-driven warming. Similarly, the end-Permian event (EPE; *ca* 252.2 Ma), the most severe of all mass extinctions, has been consistently linked to a rapid increase in CO_2, an attendant temperature spike and, as our recent findings show, a peak in wildfire activity and freshwater microbial blooms. Our recent study of the charcoal records from Permian–Triassic strata of eastern Australia and the Lambert Graben (East Antarctica) reveal increasing fire activity in the wetland *Glossopteris* Biome during the late Permian, reaching a maximum at the onset of the EPE. This end-Permian 'burn-out' was followed by a depressed fire regime for >3 million years (at least until the Smithian–Spathian Event, SSE; *ca* 249.3 Ma). Fire spread and frequency during this interval was likely limited by a major shift in vegetation during the EPE from dense peat-forming broadleaf floras to sparse, open forests dominated by sclerophyllous corystosperms, peltasperms and conifers. In contrast to the low post-EPE abundances of charcoal, fossil freshwater algae and bacterial remains have their greatest abundances immediately above the fossil-poor 'dead zone' following the EPE horizon. These reached concentrations typical of modern toxic microbial blooms, remaining intermittently high until the SSE. Collating the regional charcoal and algal fossil records from eastern Australia, these data indicate that the EPE collapses in land and freshwater ecosystems were heralded, and likely driven in part, by these ecological stressors.

Chris Mays [cmays@ucc.ie], School of Biological, Earth and Environmental Sciences, Environmental Research Institute, University College Cork, Distillery Fields, Cork T23 N73K, Ireland; Vivi Vajda [vivi.vajda@nrm.se], Sam M. Slater [sam.slater@nrm.se], and Stephen McLoughlin [steve.mcloughlin@nrm.se], Swedish Museum of Natural History, Svante Arrhenius v. 9, SE-104 05, Stockholm, Sweden; Tracy D. Frank [tracy.frank@uconn.edu], and Christopher R. Fielding [christopher.fielding@uconn.edu], Department of Earth Sciences, University of Connecticut, Beach Hall, 354 Mansfield Road (Unit 1045), Storrs, CT 06269, USA.

Riders on the storm: the palaeoenvironmental setting of the Tasmanian 'string of beads' fossils

Peter McGoldrick*, Sean Johnson, Clive Calver, John Everard, Grace Cumming, Alan Chester, Carolyn Scott, Stuart Bull, and Torsten Jensen

At a disused quarry in northwestern Tasmania (the Laan fossil site: see Van Stall et al. poster, this meeting) rhythmically laminated mudstones and fine sandstones of the Lower Rocky Cape Group display an array of well-preserved bedding surface textures. These include *Horodyskia williamsii* and other features that can be interpreted as Microbially Induced Sedimentary Structures. However, several megascopic features may be casts and moulds of large eukaryotes. Regional mapping by the Geological Survey of Tasmania, and student projects along the coast and at the Laan site, reveals a complex mosaic of near-shore – mid-shelf – outer-shelf sedimentary facies. This poster will describe examples of each of these and argue that the broad setting for the Lower Rocky Cape Group was a tide- and storm-influenced continental margin. Specifically, the Laan site rocks were deposited in a marine outer-shelf setting periodically affected by storms, but mostly below storm-wave base. We will use new geochemical data (element proxies and iron speciation) to argue for a ventilated (oxygenated) water column in the local environment of the fossil site. However, ubiquitous disseminated pyrite in mudstones from the site may indicate a transition to anoxia at, or near, the sediment-water interface (see Bulfin & McGoldrick poster, this meeting). Elsewhere in the Lower Rocky Cape Group highly pyritic and carbonaceous facies yield data consistent with water-column anoxia and euxinia. If this patchwork of coeval oxic–ferruginous–sulfidic environments in the mid-outer shelf is a response to major storm events, then stormy shelf settings of the mid-Proterozoic may have presented a unique set of selection pressures for early eukaryotes.

Peter McGoldrick [p.mcgoldrick@utas.edu.au], Sean Johnson [johnsongeoserv@gmail.com], Clive Calver [clive.calver@utas.edu.au], Alan Chester [achester@live.com.au], Carolyn Scott [carolyn.scott@utas.edu.au], Stuart Bull [sbull@utas.edu.au], and Torsten Jensen [torsten_lund_jensen@hotmail.com], CODES, University of Tasmania, Locked Bag 66, Hobart, TAS 7001, Australia; John Everard [John.Everard@stategrowth.tas.gov.au] and Grace Cumming [Grace.Cumming@stategrowth.tas.gov.au], Geological Survey of Tasmania, Department of State Growth, 30 Gordons Hill Road, Rosny Park, TAS 7018, Australia.

Ophthalmosaurian remains from the mid-Cretaceous 'upper' Gearle Siltstone of Western Australia represent the youngest record of ichthyosaurs from the Southern Hemisphere

Rhys D. Meyerkort*, Mikael Siversson, and Benjamin P. Kear

Ichthyosaurs maintained relatively high species diversity throughout the Early Cretaceous yet experienced a profound decrease in both abundance and diversity at the beginning of the Cenomanian. Reliable records of ichthyosaurs in the middle and upper Cenomanian are extremely scarce, with only one previous confirmed record from the upper Cenomanian. Here we describe isolated ichthyosaur remains recovered from the uppermost Albian – Cenomanian 'upper' Gearle Siltstone of the Murchison River area, near Kalbarri, Western Australia. These specimens are too fragmentary for specific classification but can confidently be assigned to the recently coined Brachypterygiidae family. An isolated phalanx from the uppermost part of the 'upper' Gearle Siltstone is of upper middle or upper Cenomanian age and represents the youngest record of ichthyosaurs in the Southern Hemisphere.

Bardet, N., Wellnhofer, P. & Herm, D.,1994. Discovery of Ichthyosaur Remains (Reptilia) in the Upper Cenomanian of Bavaria. *Mitteilungen der Bayerischen Staatssammlung für Paläontologie und Historische Geologie 34*, 213–220.

Fischer, V., Bardet, N., Benson, R.B., Arkhangelsky, M.S. & Friedman, M., 2016. Extinction of fish-shaped marine reptiles associated with reduced evolutionary rates and global environmental volatility. *Nature Communications 7*(1), 10825.

Siversson, M., Cook, T.D., Ryan, H.E., Watkins, D.K., Tatarnic, N.J., Downes, P.J. & Newbrey, M.G., 2019. Anacoracid sharks and calcareous nannofossil stratigraphy of the mid-Cretaceous 'upper' Gearle Siltstone and Haycock Marl in the lower Murchison River area, Western Australia. *Alcheringa 43*(1), 85–113.

Rhys D. Meyerkort [meyerkortr@gmail.com], University of Western Australia, 35 Stirling Hwy, Crawley WA 6009, Australia; Mikael Siversson [mikael.siversson@museum.wa.gov.au], Department of Earth and Planetary Sciences, Western Australian Museum, 49 Kew Street, Welshpool, WA 6106, Australia; Benjamin P. Kear [benjamin.kear@em.uu.se], Museum of Evolution, Uppsala University, Norbyvägen 18, SE-752 36 Uppsala, Sweden.

Microbial mats and microbialites of the Indian Archean successions: characteristics and contrasts in global perspective

Yogmaya Shukla*, Mukund Sharma, and Arif H. Ansari

Of the five Archean cratons in India, the Singhbhum Craton in eastern India and the Dharwar Craton in the south possess relatively less metamorphosed rocks in reasonable abundances, therefore holding promise for microfossil investigations and targeted palaeobiological studies. After almost three decades, palaeobiological studies in Indian Archean successions are now gaining momentum, and new fossil localities have been identified in these two cratons. In addition to microbialites/stromatolites, microbial mats (sedimentary structures caused by microbiological activity) are also recorded in clastic deposits within both cratons. These microbially induced sedimentary structures (MISS) include a wealth of microscopic textures i.e. 'Microbially Induced Sedimentary Textures' (MIST).

Newly discovered Neoarchean 'egg carton-shaped' stromatolites from the Dharwar Craton are the second record of such stromatolites in the world after those in the Strelley Pool Formation, Western Australia. MISTs are also preserved in thin-sections of chert from the Neoarchean Banded Iron Formations in the Dharwar Supergroup.

At the Kasia locality, stratiform, tiny cumulate, domical, pseudo-columnar, and columnar stromatolites are recorded in the Singhbhum Craton. The newly recorded stromatolites are part of the Mesoarchean Iron Ore Group (IOG) exposed in the Keonjhar district, Odisha, India. The biogenicity of these stromatolites is corroborated by $\delta^{13}C$-organic carbon signatures (-39.4 to -28.0 ‰) obtained from distinct layers, indicating the role of microbial communities including anoxygenic photo-synthesisers and methanotrophs as stromatolite builders.

Apart from conventional approaches of describing palaeobiological signatures (lithological suitability of samples and simple morphological descriptions) to prove biogenicity, investigations on the Indian early life fossils are also undertaken with new analytical techniques (biochemical methodology, biomarker studies, and isotopic fractionation values).

Yogmaya Shukla [yogmayashukla@bsip.res.in; yogmayashukla@gmail.com], Mukund Sharma [mukund_sharma@bsip.res.in], and Arif H. Ansari [a.h.ansari@bsip.res.in], Birbal Sahni Institute of Palaeosciences, Lucknow-226007, India.

New Eocene Araucariaceae fossils from the high southern latitudes of Australia: systematics and phylogenetic analyses

Miriam Slodownik*, Ignacio Escapa, Chris Mays, Greg Jordan, Raymond Carpenter, and Robert S. Hill

The fossil assemblage of the Macquarie Harbour Formation in Tasmania, Australia, represents a near-polar forest during the Early Eocene Climatic Optimum (*ca* 53–50 Ma) just before the final breakup of Gondwana. The new specimens of the extinct *Araucarioides linearis* (Araucariaceae) presented here include near-complete leaves, female cone scales, a seed and abundant associated araucariaceous pollen (*Dilwynites tuberculatus*). Thus, we present the first reproductive organs of this genus. The new characters reveal the close relationship to the extant, monotypic *Wollemia*. The generic diagnosis of *Araucarioides* is emended, adding important characters to differentiate the genus from *Wollemia*. Furthermore, the phylogenetic placement is assessed through parsimony analyses. The palaeogeographical distribution of *Araucarioides* is restricted to the polar and subpolar regions in southern New Zealand in the Late Cretaceous and southeastern Australia in the early Eocene. Adaptations to seasonal environments likely facilitated the survival of *A. linearis* through the end-Cretaceous impact winter and photosynthetic crisis, whereas the continuing northwards movement of the continental plates of Australia and New Zealand likely caused its extinction.

Miriam Slodownik [miriam.slodownik@adelaide.edu.au], Raymond Carpenter [raymond.carpenter@adelaide.edu.au], and Robert S. Hill [bob.hill@adelaide.edu.au], School of Biological Sciences, University of Adelaide, North Terrace, SA 5005, Australia; Ignacio Escapa [iescapa@mef.org.ar], Museo Paleontológico Egidio Feruglio, Consejo Nacional de Investigaciones Científicas y Técnicas, Trelew 9100, Chubut, Argentina; Chris Mays [cmays@ucc.ie], School of Biological, Earth and Environmental Sciences, Environmental Research Institute, University College Cork, Distillery Fields, Cork T23 N73K, Ireland; Greg Jordan [Greg.Jordan@utas.edu.au], School of Natural Sciences, University of Tasmania, 209 Life Sciences Building, Sandy Bay, TAS 7005, Australia.

Laan fossil site, northwest Tasmania: world's oldest konservat-lagerstätte?

Jessica Van Spall, Peter McGoldrick*, Donna Satterthwait, and Indrani Mukherjee

The third documented occurrence of the mid-Proterozoic 'string of beads' fossils was discovered in a disused quarry in a remote part of northwestern Tasmania (Calver *et al.* 2010). Based on a small collection now archived at the Tasmanian Museum and Art Gallery, the fossils were assigned to the same species as 'string of beads' from the Bangemall Supergroup in Western Australia (*Horodyskia williamsii* Grey, Yochelson, Fedonkin and Martin, 2010). The Tasmanian site is now a State Fossil Reserve and, in recognition of the beads' discoverer Martin Laan, is referred to as the 'Laan fossil site' by the FrOTH ('Friends of Tasmanian *Horodyskia'*) group at the University of Tasmania. From 2011 to 2020, a limited amount of additional material from the Laan site had been collected in an ad hoc fashion. This material included examples of enigmatic 'non-bead' bedding surface textures. In November 2021, the FrOTHies spent two days at the Laan site systematically collecting several hundred kilograms of new material. This collection yielded more than a hundred new specimens with a wide variety of textured bedding surfaces. The samples range in size from a few centimetres to individual large slabs weighing more than 25 kg. This poster will discuss the bedding surface features present at the Laan fossil site, and provide a depiction of macroscopic and megascopic features. These include 'classic' MISS (microbial induced sedimentary structures) features as well as several large 'morphotypes' (including *Horodyskia williamsii*). The MISS and larger morphotypes occur as casts and moulds, and sometimes as delicate flattened impressions, on tops and soles of beds. We will argue that, together with the *Horodyskia*, they represent a remarkably well-preserved, likely in situ, benthic association of micro- and macro-organisms. As such, they would be the oldest known example of a konservat-lagerstätte.

Calver, C.R., Grey, K. & Laan, M., 2010. The "string of beads" fossil (*Horodyskia*) in the mid-Proterozoic of Tasmania. *Precambrian Research 180*, 18–25.

Grey, K., Yochelson, E.L., Fedonkin, M.A. & Martin, D.M., 2010. *Horodyskia williamsii* new species, a Mesoproterozoic macrofossil from Western Australia. *Precambrian Research 180*, 1–17.

Jessica Van Spall [jvan0@utas.edu.au], Peter McGoldrick [p.mcgoldrick@utas.edu.au], and Donna Satterthwait [Donna.Satterthwait@utas.edu.au], CODES, University of Tasmania, Locked Bag 66, Hobart, TAS 7001, Australia; Indrani Mukherjee [indrani.mukherjee@unsw.edu.au], School of Biological, Earth and Environmental Sciences, University of New South Wales, Dalton Building, Kensington, NSW 2052, Australia.

Ordovician–Devonian fossils and biostratigraphy of the southern Cobar Superbasin, New South Wales

Yong Yi Zhen, Patrick M. Smith*, Yuandong Zhang, Desmond Strusz, Ian G. Percival, Carole J. Burrow, Jodie Rutledge, and Steven Trigg

This study re-examines more than 2000 fossil samples from 51 stratigraphic units spanning the Ordovician to Devonian sedimentary successions of the Cargelligo and Nymagee 1:250 000 geological map sheets in central New South Wales. It provides a comprehensive review of all published and unpublished reports available on the palaeontology and biostratigraphy of this region, which encompasses the southern Cobar Superbasin and its underlying Ordovician turbidites and associated siliciclastic sequences. Conodonts in chert and graptolites in shale are useful in dating and subdividing the Ordovician turbiditic sequences that are largely restricted to the eastern and southeastern portions of the study area. Age-diagnostic conodonts indicating Floian and Darriwilian ages are recovered from the Wagga Group (=Adaminaby Group). Distinctive Late Ordovician graptolite assemblages are also recorded from the Bendoc and Margules groups. The Cobar Supergroup of late Silurian to Early Devonian age unconformably overlies deformed and metamorphosed Ordovician basement rocks and Silurian granitic rocks. Fossils have been recorded from various lithofacies representing shallow-marine shelf settings on the Kopyje, Mouramba, Winduck and Walters Range shelves to deeper water turbiditic deposition in the Cobar Basin, as well as in the Mount Hope and Rast troughs. They include conodonts, trilobites, corals, brachiopods, stromatoporoids, molluscs and other invertebrates, fish scales and plates, trace fossils, and plant fossils. These are from 11 groups and their 27 constituent formations or members of the Supergroup and the overlying Mulga Downs Group. Biostratigraphic reappraisals presented in this report underpin a better understanding of the formation and evolution of the Cobar Superbasin and provide more precise stratigraphic controls on the distribution of known and potential mineral deposits hosted in these sedimentary sequences (Zhen *et al.* 2023).

Zhen, Y.Y., Smith, P., Zhang, Y.D., Strusz, D., Percival, I.G., Burrow, C.J., Rutledge, J. & Trigg, T., 2023. Field guide and catalogue of Ordovician–Devonian fossils from the Cargelligo and Nymagee 1:250 000 geological mapping area, central New South Wales. *Quarterly Notes of the Geological Survey of New South Wales 157*, in press.

Yong Yi Zhen [yong-yi.zhen@regional.nsw.gov.au], Ian G. Percival [ianpercival1952@gmail.com], and Jodie Rutledge [jodie.rutledge@regional.nsw.gov.au], Geological Survey of New South Wales, 947–953 Londonderry Road, Londonderry, NSW 2753, Australia; Patrick M. Smith [Patrick.Smith@Australian.Museum], Palaeontology Department, Australian Museum Research Institute, Sydney, NSW 2010, and Department of Biological Sciences, Macquarie University, Sydney, NSW 2109, Australia; Yuandong Zhang [ydzhang@nigpas.ac.cn], Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, Nanjing 210008, People's Republic of China; Desmond Strusz [desmond-strusz@homemail.com.au], Palaeontology Department, Australian Museum Research Institute, Sydney, NSW 2010, Australia; Carole J. Burrow [carole.burrow@gmail.com], Geosciences, Queensland Museum, 122 Gerler Road, Hendra, QLD 4011, Australia; Steven Trigg [steven.trigg@regional.nsw.gov.au], Geological Survey of New South Wales, 105 Prince Street, Orange, NSW 2800, Australia.

New specimens, localities and provenance for the Quaternary vertebrate palaeontology of the East Gippsland Karst

Tim Ziegler*, Tom Aberdeen, Wayne R. Gerdtz, Phil McGuinn, Wayne Revell, Douglass R. Rovinsky, and Elen Shute

Quaternary vertebrate fossils have been retrieved from the Paleozoic limestone East Gippsland Karst (EGK) near the townships of Buchan and Murrindal, East Gippsland, Victoria, since at least 1889. Early accessions to the Victorian State Palaeontology Collection from the EGK are characterised by imprecise or dissociated provenance, impeding scientific utility and development of a proper scientific history. Archive research involving newspaper articles, historical correspondence, museum ephemera and family history has confirmed the earliest local reports of megafaunal remains occurred in December 1906, initiating a short period of intensive scientific field surveys directed or led by the National Museum of Victoria (NMV). The earliest substantiated photograph of a vertebrate fossil from Buchan is newly presented. Curation of EGK localities in the State Collection also disclosed an unrecognised rostrum of the tachyglossid *Megalibgwilia owenii* collected in 1907 at Foul Air Cave (ASF Karst Code 3B-27), Buchan. This is the first record of *Megalibgwilia* in Victoria, and indicates a more continuous distribution across southeastern Australia than otherwise established. Field surveys are currently ongoing under a Parks Victoria Access Agreement with the assistance of the Victorian Speleological Association. At Nightshade Cave (3M-152), Murrindal, an exceptional specimen of the sthenurine kangaroo *Simosthenurus occidentalis* was retrieved. It is the most complete fossil skeleton retrieved from a Victorian cave, comprising a near-complete skull and axial skeleton plus extensive appendicular material. Other taxa identified in Nightshade Cave include a megapodiid bird (*Latagallina* sp.), marsupials *Dasyurus viverrinus* and *Perameles* sp., and *Canis dingo*. A donation of historically collected fossils from a cave nearby disclosed a yet undocumented pitfall assemblage including a large thylacine, another megapodiid (*Progura* sp.), *Zygomaturus trilobus*, and other taxa. These are together the first fossil record of megapodiids in Victoria. This project has enhanced the EGK's palaeontological importance, and further field surveys and retrievals are planned.

Tim Ziegler [tziegler@museum.vic.gov.au], and Wayne R. Gerdtz [wgerdtz@museum.vic.gov.au], Museums Victoria Research Institute, GPO Box 666, Melbourne, VIC 3001, Australia; Tom Aberdeen [tom.aberdeen@gmail.com] and Wayne Revell [wayne.revell@gmail.com], Victorian Speleological Association, GPO Box 5425, Melbourne VIC 3001, Australia; Phil McGuinn [phil.mcguinn@parks.vic.gov.au], Parks Victoria, 98 Caves Rd, Buchan, VIC 3885, Australia; Douglass R. Rovinsky [rovinsky.d@gmail.com], no current affiliation; Elen Shute [elen.shute@flinders.edu.au], Flinders University, GPO Box 2100, Adelaide, SA 5100, Australia.


AUSTRALASIAN PALAEONTOLOGISTS