This year, Progressive Palaeontology revisits the University of Bristol, which last hosted the conference in 2010. The Palaeobiology Research Group has recently been relocated from the Wills Memorial Building to the new Life Sciences Building with the School of Biology, which is where the icebreaker reception will be held. This state-of-the-art building was built to meet the demands of modern research, and does so while showcasing this in an open-plan layout, and to high levels of energy efficiency and sustainability. On the roof of the Life Sciences Building is the Sky Lounge, a large communal area, glass-walled and with an open terrace, giving panoramic views over Bristol, and towards Bath, Dundry, and Lansdown. It is here that we will hold the icebreaker reception. The talks and poster sessions will be held in the nearby Chemistry Building, lecture theatre 1. Here is a large auditorium, and an area to display posters and for coffee breaks.

Both of these locations are accessible from the heart of the University of Bristol campus. They will be signposted around the University, and volunteers will be able to guide you. The address of the Life Sciences Building is: 24 Tyndall Avenue, BS8 1TQ; the Chemistry Building is at: Cantock’s Close, BS8 1TS.

**LINKS**

Life Sciences Building: [http://www.bristol.ac.uk/biology/newbuilding/](http://www.bristol.ac.uk/biology/newbuilding/)
Palaeobiology Research Group: [http://palaeo.gly.bris.ac.uk](http://palaeo.gly.bris.ac.uk)
University of Bristol Homepage: [http://www.bristol.ac.uk](http://www.bristol.ac.uk); Campus Map: [http://www.bris.ac.uk/maps/google/](http://www.bris.ac.uk/maps/google/)

**LOGISTICS**

**TRAVEL**

**Road**  Bristol is at the junction of the M4 and M5 motorways. From the motorway, the best route is to leave the M4 at Junction 19, onto the M32, which will bring you straight into the heart of Bristol. From the south-west, you can leave the M5 at Junction 18, onto the A4, which will also take you to the centre. From the south-east, follow the A36 or A37 until these join the A4 at Totterdown and Keynsham respectively, then follow the A4 into Bristol. Be aware that routes into and around Bristol can become severely congested during rush hours.

Parking cannot be provided at the University, and the roads around are part of a residents’ parking scheme: during the day there is no free parking on-street nearby. Multi-storey car parks are located on Jacob’s Wells Road (BS8 1EH), Trenchard Street (BS1 5AN), and Rupert Street (BS1 2PY); all are within short walking distance of the University.

**Bus**  National Express runs frequent services between Bristol and various cities around the UK, including Gatwick and Heathrow airports. Coaches stop at the Bus Station (BS1 3NU). Megabus also serves Bristol, stopping in the centre, opposite Colston Hall (BS1 5AR), and at Temple Meads Station (BS1 6QF).

Bristol has an extensive local bus network, largely run by First and Wessex. Services 8 and 9 provide frequent (up to every six minutes) connections
between Temple Meads, the centre, and the University Campus – stopping close the conference centre – on St Michael's Hill and Queen's Road. Single journeys cost £1.50, with unlimited travel day passes costing £4.40. Student tickets require a First Student TravelCard.

**Rail**  Bristol has two main railway stations: Bristol Temple Meads, located near the city centre, and Bristol Parkway, on the north-east outskirts. Both are served by frequent trains from London Paddington, Birmingham, and Plymouth, and connecting trains between them. Connections are available from London Paddington to St Pancras International for the Eurostar continental services. From Temple Meads (BS1 6QF), buses 8 and 9 connect to the city centre and the University.

**Air**  Bristol Airport is the closest airport, 10 miles from the centre of Bristol, with direct flights from many locations in the UK and Europe, and connecting flights internationally. An airport bus, the Bristol Flyer, service A1, provides quick and frequent transport to Bristol Bus Station (BS1 3NU). This costs £7 for a single ticket or £11 for an open return. From London Gatwick and Heathrow airports, National Express and Megabus coaches provide the best connections into Bristol.

**ACCOMMODATION**

We cannot provide accommodation for the conference. However, there are many hotels and B&Bs in the city centre, close to the University, and farther afield. Reasonable prices can be found at the Premier Inn, Holiday Inn, or Ibis hotels, each of which is a 10–30 mins walk, or short bus journey, to the University. Other places are available.

**LINKS**

BRISTOL AIRPORT [http://www.bristolairport.co.uk](http://www.bristolairport.co.uk); BRISTOL FLYER: [http://flyer.bristolairport.co.uk](http://flyer.bristolairport.co.uk)
CAR PARKING [http://www.travelwest.info/car_parking](http://www.travelwest.info/car_parking)
CONFERENCE

REGISTRATION
Registration will be alongside the icebreaker reception at the Life Sciences Building from 17:30 on 9 April, and from 08:00 outside the lecture theatre 1 in Chemistry on 10 April. Delegates will be given a pack that includes a name badge and a printed copy of the final version of this booklet with the programme. There is no need to print a copy of the booklet beforehand.

ICEBREAKER
The icebreaker will be held in the Life Sciences Building’s Sky Lounge (BS8 1TQ) from 17:30 on 9 April. Light refreshments will be provided to stimulate conversation. Organisers and volunteers will be on hand should you have any questions. Afterwards, we shall visit pubs of the Clifton and Redland areas, but shall not travel too far from the conference centre.

LOGO
The logo was designed by Al Tanner. It has a clean and simple design, featuring several of the research areas that the group here at the University of Bristol cover: a spiral for micropalaeontology and climate evolution, a DNA strand for molecular evolution and phylogenetics, and the skull of Diplodocus for morphological and vertebrate evolution and function.

PRESENTATIONS

Oral sessions There will be four oral sessions on the 10 April. Like at last year’s ProgPal in Southampton, these will be divided into three sessions of standard talks, with the last session comprising shorter ‘lightning’ presentations. Each session will be chaired by members of the organising committee. In standard talks, presenters will be given 15 minutes, with the recommended allowance of 12 mins talk and three minutes for questions and switching. ‘Lightning’ talks will be five minutes each: four minutes plus one minute for questions. It is polite to keep talks relevant, and to time.

PowerPoint 2013 for Windows, PowerPoint 2011 for Mac, and Keynote ’09 for Mac will be available for slide presentations. Limited time will be available to upload and test presentations only on 10 April; because of this, it is advisable to keep presentations simple. Videos should be either embedded, or copied alongside the presentation file; link fidelity cannot be guaranteed. Specialist fonts should be embedded in the file, but note that this is not available in PowerPoint 2011 for Mac or Keynote. Those wishing to ensure reliability may

Delegates may submit a talk and poster abstract on different topics, but abstracts must be submitted on two forms. Talk submissions may be for either full or lightning talks. Submissions should not exceed 250 words, and follow the style guide of Andrade 2011 (http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3136827/). Abstracts may be submitted at http://www.palass.org/modules.php?name=propal&page=102, deadline is 6th March 2015. Abstract selection for lightning talks and posters will be an open competition between all submissions. Full length talk abstract submissions will be divided into two subsets: subset A will contain all undergraduate, MSc/MSci, and 1st year PhD submissions; subset B will contain 2nd–4th year PhD submissions. The best abstracts from subset A will make up 50% of the available full talk slots (exact proportion dependent on number of submissions). The best abstracts from subset B will make up the remaining percentage. Abstracts will be selected based on the following criteria: background (10 marks), methods (10 marks), results (10 marks), conclusions (10 marks).
wish to save their presentation as a PDF file, and present from that. Presentations may be submitted in advance to progpal15@palass.org, noting the author and title.

**Poster session** Posters should be available throughout the day on 10 April, therefore, we ask that you bring them to registration. The standard poster size is A0 in either portrait or landscape orientation, printed in advance. We will provide adhesion to hang posters. The designated poster session is after the lightning talk session (15:05–16:00), but posters may be viewed at any time. Those presenting posters are asked to stand beside their poster during this time. After the poster session, please remove your poster and take it with you, or we may store it overnight for those on the field trip.

**TRAVEL GRANTS**

The Paleontological Society and Society of Vertebrate Palaeontology have each generously provide a travel fund for member-delegates from Europe or the USA. Details about these and application instructions can be found at http://www.palass.org/modules.php?name=propal&page=103. Deadline for applications is 1st MARCH 2015. Direct enquiries to progpal15@palass.org.

**WI-FI**

Wi-Fi is available in the Sky Lounge and lecture theatre. The University of Bristol uses the eduroam security protocols, so should be available for automatic connection by those from participation institutions. Otherwise, temporary access credentials will be available.

**LIVE STREAMING**

Live streaming will again be provided by the Palaeocast team, available at http://palaeocast.com/. Please do advertise this beforehand. If you do not wish to have your talk recorded or streamed, please inform the committee in advance – during abstract submission – and notify at the beginning of your talk.

**SOCIAL NETWORKS**

Announcements and updates will be posted to the ProgPal 2015 Facebook page, which can be found by searching ‘Progressive Palaeontology 2015’. We also encourage tweeting about the conference using the handle #ProgPal15. However, when tweeting, do be mindful of the sensitivity of some data, particularly if sharing photographs of presentations. Some speakers may wish for their talk not to be broadcast, this will be notified at the beginning of such talks.

**STALLS**

We are happy to have stalls with representatives from the Geological Society of London at the conference, who will be around to talk about membership benefits, publishing, and answer other questions you may have. Also, two local palaeoartists, Robert Nicholls and Luis Rey, will also be there to show, talk about, and sell their artwork, and add much colour to the surroundings.
REFRESHMENTS
Coffee and tea will be available outside the lecture theatre during the morning and afternoon breaks. Lunch is not provided, but there are many supermarkets, bakeries, sandwich shops, and restaurants close to the conference centre. The volunteers will be happy to point you in the right direction, and make suggestions.

ANNUAL DINNER
This year, the annual dinner will be held at the award winning №4 Clifton village on 10 April, after the poster session. This is about 25 minutes walk from the lecture theatre – the committee and volunteers will direct delegates. The dinner will be £17 each for two courses, payable during registration online.

PRIZES
At the annual dinner, we will announce prize winners for both best talk and best poster. These will be decided by the committee and staff of the University of Bristol. In particular, they will look for novelty of method and results, quality of presentation, and handling of questions. All presentations and poster are automatically included for consideration.

AUCTION
After the annual dinner, we plan to instigate an auction of lots to raise money for a Progressive Palaeontology travel fund that will aid delegates to attend future Progressive Palaeontology conferences. Donations for this are very welcome, and will be received at registration. The auction will be hosted by the inimitable David Button, Esq.

FIELD TRIP
The field trip will take in three localities near to Bristol, and along the Welsh Marches: Aust, Usk, and Hay-on-Wye. These well-known localities have produced a wide range of invertebrate and vertebrate fossils from the Silurian through to the Jurassic. A more detailed briefing will be given to attendees after the oral presentations.

FIELD GUIDE
A field guide to the localities is on page 24 of this booklet.

TRAVEL & LUNCH
Transport will be provided, but lunch and drinks will not. We plan to leave early to cover the distance and get as much time at the localities as possible. The field trip will leave from outside The Hawthorns (BS8 1UQ) at 08:30 on 11 April. It is your responsibility to be at the meeting point on time. We will have lunch at a pub in Aust after the first locality, before moving on. This serves excellent food, with a good selection of local ales. The day will be long, so please bring snacks and refreshments.
SAFETY

This field trip is being run as part of the University of Bristol, so we ask that you represent us fairly. The localities are varied, and take in beaches and quarries, each with their own safety concerns. Hammers are permitted at all localities, but remember that these are scientifically important, so should not be reaped of all their treasures. Hard hats will be provided. The weather is uncertain, so warm and waterproof clothing, and/or sun protection may be required. Stout, waterproof, and supportive footwear will be important, especially for the beach at Aust. Do take care under cliffs and rock faces. Trip leaders have been trained in First Aid, and will have First Aid kits.

LINKS

AUST FOSSILS http://www.austfossils.co.uk/index.asp

VISITING BRISTOL

For those that are staying in Bristol before or after the conference, there are numerous attractions and activities that make this city one of the most exciting in the UK. Bristol is well known for its ample pubs and architecture, and there are many of both, and more, within a short walk of the University campus and conference centre. Many details of events and places to go can be found on the Visit Bristol website.

BUILDINGS & MUSEUMS

Bristol is home to many of Isambard Kingdom Brunel’s great engineering landmarks, including both the Clifton Suspension Bridge, and the ss Great Britain. Auspiciously, 9 April is the 199th anniversary of Brunel's birth. There are several museums that exhibit local and natural history. The palaeontology of the local area is covered by Bristol Museum & Art Gallery, next door to the Wills Memorial Building (BS8 1RL). The museums hold several exhibitions throughout the year covering many varied topics. For nature lovers there is Bristol Zoo Gardens, featuring Asiatic lions, Panthera leo persicus; African penguins, Spheniscus demursus; and monkey puzzle, Araucaria araucana; and is the only place in the UK that you can see paddlefish, Polyodon spathula. Near the centre is the Aquarium. Slightly further afield are Blaise Castle Estate and Tyntesfield House.

CULTURE & NIGHTLIFE

For those looking to spend an evening somewhere, Bristol has several theatres, cinemas, restaurant areas, bars, and clubs. Many of these are located around the city centre, including the Hippodrome, Colston Hall, and many bars and clubs along Park Street. Also, the Broadmead shopping quarter has just that, with further bars, restaurants, and cinema in Cabot Circus.
SHOPPING
Bristol is a great place to shop. There are three main areas around the city: Broadmead shopping quarter is near the city centre, and incorporates Cabot Circus; Whiteladies Road and Clifton Village features many more local shops and boutiques; and The Mall at Cribbs Causeway, near the M4/M5 junction, is a large out of town shopping centre.

GREEN SPACES
In 2015, Bristol is the European Green Capital. The city also has many open and green areas that are open to the public. Brandon Hill Nature Reserve is close to the conference centre, and the University, with great views towards the harbour and beyond. Near the centre is Castle park, beside Broadmead shopping centre. A short walk away are Clifton and Durdham downs, an open area of common land, with views down to gorge, goats in the gully, and a short walk from the suspension bridge. Across the suspension bridge are Leigh Woods and Ashton Court Estate, with a deer park.

LINKS
BRISTOL MUSEUMS http://www.bristolmuseums.org.uk
CABOT CIRCUS http://www.cabotcircus.com
THE MALL https://www.mallcribbs.com
UNIVERSITY OF BRISTOL TOUR http://www.bris.ac.uk/university/visit/walking-tour.html
VISIT BRISTOL http://visitbristol.co.uk

COMMITTEE & VOLUNTEERS
This year’s committee are:

- Joseph Keating  CHAIR
- JJ Hill  ANNUAL DINNER
- Benjamin Moon  EDITOR
- Chris Rogers  SECRETARY
- Mark Puttick  RECEPTION
- Luke Parry  FIELD TRIP
- Max Stockdale  FIELD TRIP
- Al Tanner  LOGO & SELECTION
- Fiona Walker  RECEPTION

The organisers would also like to thank the numerous volunteers who have helped in the organisation of the conference.
ACKNOWLEDGEMENTS

We wish to thank the following for their generous support:


The Paleontological Society and the Society of Vertebrate Paleontology have provided funds for travel grants.

Cambridge University Press and Siri Scientific Press have donated prizes.

Many thanks also to the University of Bristol for hosting this event.
09:00 Announcements
09:05 Welcome Prof. Michael J. Benton

Session 1 – Diversity & ecology
Chair Mark Puttick

09:15 An examination of differences in feeding ecology between successive fossil proboscidean faunas from south China as revealed by dental microwear texture analysis (DMTA)
S. Zhang

09:30 ‘Horns, hooves & hounds’ – mandibular morphometrics & the macroevolution of North American mammals through the Cenozoic
S. Singh, M. Stockdale, C. Janis, M. Benton

09:45 Extinction geography and sampling of marine invertebrates at the K–Pg boundary
M. Topham

10:00 Environmental drivers of crocodyliform extinction and diversity
J. Tennant

10:15 Terrestrial tetrapods of the Triassic
C. Kinsella

10:30 Unearthing the roots of mammalian diversity: the equality of the cynodont fossil record
K. Ludwig

10:45 Coffee break

Session 2 – Early vertebrate evolution
Chair Joe Keating

11:15 Don’t hold your breath: new constraints on atmospheric pO² during Romer’s Gap

11:30 Digital dissection of suction-feeding and biting fish
R. Brocklehurst, L. B. Porro, E. J. Rayfield

11:45 Revised relationships of fossil Aulopiformes: implications for habitat shifts over the Cretaceous-Palaeogene boundary
H. Beckett, M. Friedman

12:00 First report of a paraplenoid in Petalichthyida (Placodermi) and its phylogenetic implications
M. Castiello, M. D. Brazeau

12:15 Assessing evolutionary tempo and mode across vertebrate evolution
R. P. Dearden, J. N. Keating, P. C. J. Donoghue

12:30 Nothing but skin and bones – early vertebrate fossils unveil the developmental history of the dermal skeleton
Y. H. Park, M. Rücklin

12:45 Lunch

Session 3 – Lightning session & posters
Chair Benjamin Moon

14:15 Announcements

14:20 Quantifying the environmental context of the Cambrian metazoan radiation: a geochemical approach
T. Hearing, T. Harvey, M. Williams, S. Gabbott, P. Wilby, M. Leng

14:25 Putting the Burgess Shale through the washing machine O. Bath Enright

14:30 The eye of the beholder: the evolution of vision in the ecdysozoa
J. F. Fleming

14:35 Assembling the Early Palaeozoic terranes of Japan
C. P. Stocker, M. Williams

14:40 New Palaeogene and Neogene hydrocarbon seep molluscs from the Caribbean
J. Bestwick, C. T. S. Little, F. L. Gill, S. Kiel

14:45 Crocodilians of the Hell Creek Formation of north-west South Dakota USA: an investigation into niche partitioning
E. Wallace

14:50 Dental character analysis and evolution of hadrosaurid dinosaurs
E. Strickson

14:55 Lesothosaurus diagnosticus and Stormbergia dangershoeki: anatomy, ontogeny, and synonymy
M. G. Baron, D. B. Norman, P. M. Barrett
<table>
<thead>
<tr>
<th>Time</th>
<th>Session 4 – Taphonomy, taxonomy &amp; morphology</th>
<th>Chair</th>
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<tbody>
<tr>
<td>15:00</td>
<td>An investigation into taphonomy, taxonomy, and historical biodiversity in cave systems in Cayman Brac (Cayman Islands)</td>
<td>V. L. Harvey</td>
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<tr>
<td>15:05</td>
<td>Posters &amp; coffee</td>
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<tr>
<td>16:00</td>
<td>Chemically characterising the diagenetic alteration of melanin in soft-bodied vertebrate fossils</td>
<td>C. Colleary, J. Vinther</td>
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<td>16:15</td>
<td>Exploring phosphatisation: evidence from Lebanese fossil polychaetes</td>
<td>P. Wilson, L. Parry, G. Edgecombe</td>
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<tr>
<td>16:30</td>
<td>Lophotrochozoans from the Transantarctic Mountains</td>
<td>L. Bassett-Butt, L. Holmer, C. Skovsted</td>
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<td>16:45</td>
<td>Tiny acritarchs with porous vesicle from the Early Cambrian of Estonia and the implications for the fossil record of picoplankton</td>
<td>H. Agić</td>
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<tr>
<td>17:00</td>
<td>Why does <em>Globicetus</em> (fossil beaked-whale) have a bony sphere inside the head?</td>
<td>J. Muchagata, O. Mateus</td>
</tr>
<tr>
<td>17:15</td>
<td>The cranial biomechanics of <em>Effigia okeeffeae</em> and its convergence with Ornithomimosauridae</td>
<td>A. Jones, D. Button, A. Cuff, E. Rayfield</td>
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<td>17:30</td>
<td>Conference photo</td>
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The following abstracts are ordered alphabetically by surname of the first author. Abstracts for full talks (§), lightning talks (†), and posters (¶) are indicated after the title.

Tiny acritarchs with porous vesicle from the Early Cambrian of Estonia and the implications for the fossil record of picoplankton

H. Agić¹

1 Department of Earth Sciences, Uppsala University, Villavägen 16, 752 36 Uppsala, Sweden

The Proterozoic–Phanerozoic transition records a general trend of decrease in the phytoplankton cell size, in contrast to the earlier large Ediacaran acritarchs (ECAP).

Particularly minute, unornamented organic-walled microfossils (4–9 µm in diameter) have been uncovered from the Early Cambrian Lükati Formation in northern Estonia via acid (HF) maceration. The formation consists of fine siliciclastics and has been deposited in shallow marine environment. Lack of any thermal alteration in the Baltic Syncline successions allows for excellent preservation, evident in the fine scale structures observed on the microfossils.

Among the rich palynomorph assemblage in Lükati, a new species of tiny, spheroidal, and aggregated eukaryotic microfossils is recorded. It is characterised by a corrugated and flexible vesicle wall perforated by dense nano-scale pores. Despite its unique morphology, the new species shares some diagnostic characters with other fossil and extant taxa, mainly among prasinophyte algae.

This new species is among the smallest microfossils with eukaryotic morphology (wall sculpture). Habib & Knap (1982) coined the term ‘small acritarchs’ for exceptionally minute microfossils in the Cretaceous assemblages. This group was long neglected due to tiny specimens becoming lost in the standard palynological extraction techniques or difficult to observe with light microscopy. SEM studies on the Lükati assemblage show that ‘small acritarchs’ have appeared already in the Cambrian. Size, abundance, prasinophyte affinity, and eukaryotic wall sculpture make the new species a likely member of the eukaryotic picoplankton. This group significantly contributes to the overall primary productivity in the present oceans, and this trend likely arose in the Cambrian.

An X-ray look at the loss of morphological disparity during mass extinction events using planktic foraminifera

A. Ball¹, D. Schmidt¹, A. Caromel¹, E. Rayfield¹

1 School of Earth Sciences, University of Bristol, Wills Memorial Building, Queens Road, Bristol, BS8 1RJ, UK

Mass extinctions and their associated loss in morphological disparity offer up valuable insights into the operation of evolutionary processes. Developmental influences on disparity are rarely investigated due to the lack of intact ontogenetic stages preserved in the fossil record. Planktic foraminifers retain all developmental stages in their final tests, thereby providing an invaluable repository for exploring developmental disparity. For the first time we employ synchrotron radiation X-ray tomographic microscopy to reconstruct the ontogeny of four extinct planktic foraminifers from pre-extinction and extinction-recovery assemblages. Results suggest that fast generation times and ontogenetic morphological simplification are advantageous in recovering from ecological crises.

Differences in ontogenetic morphological complexity observed between the dominant Paleocene and Oligocene post-extinction morphotypes indicates that the relative timeframes of extinction events, i.e. abrupt vs. gradual, determines the survival of complex morphotypes.

Despite variable adult morphologies, both modern and fossil juveniles show conservative growth trajectories and testmorphologies, demonstrating the operation of early developmental morphological constraints. These findings emphasise the importance of utilising entire ontogenetic sequences to gain insights into evolutionary processes.

Lesothosaurus diagnosticus and Stormbergia dangershoeki: anatomy, ontogeny, and synonymy

M. G. Baron¹,², D. B. Norman¹, P. M. Barrett²

1 Department of Earth Science, University of Cambridge, Cambridge, CB2 3EQ, UK
2 Department of Earth Sciences, Natural History Museum, London, SW7 5BD, UK

The early evolution of the ornithischian dinosaurs in the Triassic and Lower Jurassic is still poorly understood when compared with the sauropods. Lesothosaurus diagnosticus represents one of the earliest known ecosystems ornithischians, and is found in the Upper Elliot Formation of South Africa and Lesotho (Hettangian–Sinemurian). Although it has been described in a number of works previously, the postcranial anatomy of this taxon has been almost overlooked, and the literature is still lacking a detailed description of the postcranial material. This study has attempted to create the first comprehensive postcranial redescription of L. diagnosticus, as well as other ‘fabrosaurids’ material from the same area, using collections in London and South Africa. This study has found a large ornithischian specimen from the Lower Jurassic to be an adult form of L. diagnosticus, altering our interpretation of the syntype material, which we now consider to be juvenile. With this larger, mature specimen being attributed to L. diagnosticus, the character states of these ‘fabrosaurs’ can be reassessed and the validity of another taxon, Stormbergia dangershoeki, can be called into question. Based upon the presence of a single autapomorphy, as well as a lack of any other clear discriminating characters, this study finds S. dangershoeki to represent an adult form of L. diagnosticus. We therefore propose S. dangershoeki should be considered a junior subjective synonym of L. diagnosticus and therefore not a valid taxon. With this new information we can now reassess the anatomy, relationships, and evolution of the early ornithischians.

Lophotrochozoans from the Transantarctic Mountains

L. Bassett-Butt¹,², L. Holmer³, G. Brock³, C. Skovsted¹

1 Palaeobiology Department, Naturhistoriska Riksmuseet, Frescativägen 40, 114 18 Stockholm, Sweden
2 Department of Earth Sciences, Geological Survey of Iceland, Villavägen 16, 752 36 Uppsala, Sweden

The Cambrian East Gondwanan margin, consisting of Antarctica, Australia, and India, is suggested to represent the cradle of lophotrochozoan evolution. Few studies have examined the fauna of Antarctica in detail, due to the remoteness of the location and difficulties associated with sampling. Herein, we describe the results of two studies from the Transantarctic Mountains, which has shed light on the development of Cambrian bilaterians. The Middle
Cambridge Nelson Limestone Formation fauna is described and includes a variety of brachiopods and other small shelly fossils. The brachiopod species are very similar to Australian and Indian forms, but are substantially younger in Antarctica. A redescription of tommotiids from the Early Cambrian Shackleton Limestone suggests that the diversity of Antarctic forms has been underestimated. In addition, a possible new tommotid specimen from the Nelson Limestone extends the record of the group into the Drumian.

Putting the Burgess Shale through the washing machine†
O. Bath Enright¹

1 School of Earth & Environmental Sciences, Burnaby Building, Burnaby Road, Portsmouth, PO1 3QJ, UK

The Burgess Shale is a world-famous Middle Cambrian fossil Lagerstätte; renowned for its exceptional preservation of soft-bodied organisms. The deposit was traditionally interpreted as the product of dilute turbidity currents with transport from one environment to another, but more recent analysis on the degree of disarticulation of the fossils argue that transport was minimal. The sedimentology of the Burgess Shale has received far less attention compared to the fossils, despite the obvious significance that this aspect has on the process that led to their entombment. With the deposit holding important insights into the Cambrian explosion and evolutionary biology, it is crucial to understand the effects of different sediment-density regime durations and the disarticulation of different body plans of the Burgess Shale biota. It is important to determine if these assemblages represent true palaeocommunities or not, and if organisms were capable or incapable of surviving transport. These experiments will use analogue organisms of the polychaete Nereis virens and shrimp Crangon crangon to represent a large proportion of animals in the deposit; using annular flume tank experiments will systematically investigate the survivorship of the animals of staying intact or not, when subjected to prolonged transport depending on laminar, turbulent, or transitional flow regimes. Preliminary results from initial experiments involving the analogue organisms and seawater are presented here.

Revised relationships of fossil Aulopiformes: implications for habitat shifts over the Cretaceous-Paleogene boundary †
H. Beckett¹, M. Friedman¹

1 Department of Earth Sciences, University of Oxford, South Parks Road, Oxford, OX1 3AN, UK

Aulopiformes (lizardfishes and kin) is a globally distributed order of marine eutelost fishes, associated with deepsea or bentopelagic environments. Shallow-water Cretaceous deposits like the English Chalk yield a great diversity of pelagic predatory aulopiforms, while Palaeogene representatives in similar settings appear to be benthic. Many fossils assigned to Aulopiformes have not been subjected to modern analyses designed to extract more detail from these specimens or infer placement in a phylogenetic tree. Computed tomography permits detailed morphological analysis of these fossils, and resulting anatomical information can be used in phylogenetic analyses. Twelve fossil aulopiforms were modelled using computed tomography and included in an existing matrix of morphological and molecular genetic characters for extant aulopiform taxa. Bayesian ‘tip-dating’ analysis was used to estimate divergence times for the order, and major divisions within it. †Argilichthys, †Aulopopsis, and †Sardinoideis illustrans are shown to be basal members of Synodontidae. †Sardinoideis illustrans, previously assigned to Myctophiformes, is an aulopiform and requires a new generic assignment. †Labrophagus is a basal member of the Ipnapoidea, and the remaining taxa from the English Chalk form a clade of uncertain phylogenetic placement, falling either within Alepisauroidea, or as clade at the base of the order. Divergence times for Aulopiformes are older than previously estimated. These results can shed light on inferred habitat shifts seen in Aulopiformes over the Cretaceous-Paleogene boundary, with implications for the Paleogene origin and diversification of modern predatory pelagic groups like Scombroidae.

Identifying proxies for ecology in mesozoic mammals †
G. Benevento¹, O. Bath Enright¹

1 Department of Earth Sciences, University of Oxford, South Parks Road, Oxford, OX1 3AN, UK

Extant mammals include over 5000 species and exhibit a tremendous variety of ecologies. Mammals, however, have not always shown this much disparity of form and function. They evolved during the Late Triassic, and are widely thought to have remained relatively conservative in their morphologies and body sizes for the remainder of the Mesozoic, although notable exceptions do exist. After the Cretaceous-Paleogene (K-Pg) extinction, mammals underwent an explosive adaptive radiation, hypothesised to be the result of niche clearing, and a release of constraint caused by the extinction of the dinosaurs.

This adaptive radiation has not been well quantified. Previous research has relied on body mass as a proxy for ecological niche. I aim to use a more informative suite of morphological traits including feeding and locomotor characters, such as jaw and limb measurements.

Grossnickle & Polly (2013) performed a morphometric analysis to compare Mesozoic mammal jaws with extant species in order to infer diet type. Here, I use their principle component 1, which they report as the most indicative of diet type, to test for a correlation between jaw shape and jaw mechanical advantage. Preliminary results show that there is no correlation between these two datasets, echoing results by Anderson (2009).

This indicates that overall jaw morphology and functional measurements may not be closely linked, and also stresses the importance of using multiple functional measurements when trying to infer feeding ecology from fossils jaws.

New Paleogene and Neogene hydrocarbon seep molluscs from the Caribbean †
J. Bestwick¹, C. T. S. Little¹, F. L. Gill¹, S. Kiel¹

1 School of Biology, University of Leeds, Leeds, LS2 9JT, UK
2 School of Earth and Environment, University of Leeds, Leeds, LS2 9JT, UK
3 Georg-August Universität Göttingen, Geoscience Center, Geobiology Group, Goldschmidtstraße 3, 37077 Göttingen, Germany

Hydrocarbon seeps are sites along continental margins where hydrocarbon-rich fluids flow onto the seafloor. Modern seep communities are dominated by bacteria-grazing gastropods and bivalves hosting chemosymbiotic bacteria in their gills. The fossil record of seep communities dates back to the Devonian with increasing numbers of records in the Mesozoic and Cenozoic. Ancient Caribbean seeps are Late Eocene–Miocene in age, whose taxa were originally described in 2005. Recent discoveries have warranted a taxonomic re-investigation of this fauna, offering new insights into the evolution of Cenozoic seep communities.

In total 500+ mollusc specimens were described from seep limestone blocks from Barbados and Trinidad, comprising 21 bivalve and 17 gastropod species, of which 10 and 14 respectively are new. Of particular note are tall-spired gastropods, previously identified as zygopleurids, now reassigned to two genera within the Hokkaidoconchidae. This family has only been recorded from
Mesozoic seeps, so its occurrence in the Cenozoic raises the possibility of other ‘relic’ taxa in Caribbean fossil seeps. There are differences between faunas in Barbados and Trinidad as the former contains over twice as many mollusc species. Differences are also present between localities in Barbados, indicating complex faunal associations and/or unrecognised temporal differences.

Many modern seep mollusc families are also found in the Miocene, such as lucinid and vesicomyid bivalves. However, many genera disappear after the Late Miocene, with modern genera lacking pre-Pliocene fossil records. These changes roughly coincide with the closure of the Isthmus of Panama, indicating this phenomenon may have contributed in shaping Caribbean seep communities.

**The functional morphology of ichthyosaurs**

A. Brimacombe¹, B. Moon¹, S. Lautenschlager¹, I. Rahman¹, M.J. Benton¹

1 School of Earth Sciences, University of Bristol, Wills Memorial Building, Queens Road, Bristol, BS8 1RJ, UK

Biomechanical analyses for behavioural characteristics, such as the mode of locomotion of an animal, are especially challenging when studying extinct species. The assessment of the swimming mode of ichthyosaurs has previously focussed on anatomy, muscle reconstruction, and overall body shape transformation, with previous studies using statistical techniques to calculate swimming speed. However, though the initial analyses have been refined, there is still significant uncertainty regarding the margin of error (with the calculations of swimming speed variable by a factor of 1.5). This investigation therefore introduces innovative computational approaches to evaluate the magnitude of fluctuations in the fluid dynamics of ichthyosaur species depending on alterations to their body shape.

Using photographic sampling of specimens originating from the Triassic to the Cretaceous (Ophthalmosaurus, Ichthyosaurus, Stenopterygius, and Mixosaurus), supported by measurements of aspects such as skull length, three-dimensional models of ichthyosaur species are constructed using Blender. These models are then imported into COMSOL to produce the fluid dynamics evaluations. This combination of novel techniques allows for the manipulation of the models to assess the influence of anatomical changes such as the reduction of appendages, as well as the potential for additional analyses by altering parameters such as swimming velocity and fluid viscosity. Preliminary results of the study on Ophthalmosaurus using these methods are presented here. This study also lends itself to further analysis such as the sampling of additional specimens, assessing variations in ontogenetic stage, and correlations using geometric morphometric analysis.

**Feeding biomechanics of biting & suction-feeding fish**

R. J. Brocklehurst¹, L. B. Porro¹, E. J. Rayfield¹

1 School of Earth Sciences, University of Bristol, Wills Memorial Building, 24 Tyndall Avenue, Bristol, BS8 1TQ, UK

Across the fish-tetrapod transition, major changes occurred in the feeding system as vertebrates moved from aquatic suction-feeding to terrestrial biting. However, there currently is a lack of data on feeding biomechanics in modern analogues of early tetrapods. Sarcopterygian fishes and amphibians are the closest bracketing taxa, but these groups are highly secondarily modified. Instead, we will use the Northern Pike (Esox lucius, a suction feeder) and the European eel (Anguilla anguilla, a biter).

Detailed, three-dimensional finite element models, with individually segmented bones and sutures will be reconstructed from CT data. These models will then be loaded with realistic muscle forces, assigned accurate species-specific material properties, and analysed. Models will be corrected for size, to compare principal strains (tension and compression) and Von Mises stress (a function of principal strains, and indicator of failure in bone).

We predict that Anguilla will generate higher bite forces and experience lower mandibular stresses than Esox, when corrected for size. We also predict that incorporation of more accurate material properties information will improve model accuracy. These results will provide valuable information on mechanical function of the jaws in living fish, and the differences in function between biters and suction-feeders. They will also allow comparisons with predictions of mechanical behaviour from models of extinct stem tetrapods, to better understand changes feeding across the fish-tetrapod transition.

**Don’t hold your breath: new constraints on atmospheric \( \rho \text{O}_2 \) during Romer’s Gap**

D. K. Carpenter¹, J. E. A. Marshall², D. J. Beerling³, C. H. Wellman²

1 School of Ocean and Earth Science, University of Southampton, European Way, Southampton, SO14 3ZB, UK

Following the End Devonian Mass Extinction, tetrapods disappear almost completely from the fossil record for some 15 million years – a phenomenon known as Romer’s Gap. Latest Devonian tetrapods were aquatic and equipped with a variable number of digits,
The vast morphological differences between extant jawless and vertebrates have been a focal point of research as they possess unusual characters otherwise seen only in fossil jawless fishes. Here we investigate the endocranial morphology of Shearsbyaspis, an exceptionally preserved petalichthyid placoderm from the Early Devonian of Australia, using x-ray computed microtomography. We demonstrate the presence of a parasphenoid bone in the palate, reported for the first time in a petalichthyid. It is broad in shape, densely denticulated, with an undivided and posteriorly placed buccohypophysial foramen. This differs from the morphology present in most arthrodire placoderms, and resembles instead that of early crown gnathostomes. A parasphenoid has previously been recorded only in arthrodiran placoderms, possibly linking them to crown gnathostomes. Our finding shows that parasphenoids were instead more broadly distributed in stem gnathostomes and possibly plesiomorphic for a more inclusive set of the gnathostome total group. This raises questions about the currently prevailing hypothesis of placoderm paraphyly. Finally, we explore competing phylogenetic hypotheses for placoderms and crown gnathostomes in light of the new parasphenoid data, and suggest avenues for future research on the problem of cranial conditions for crown gnathostomes.

The cause of the hiatus is unclear. One hypothesis, in part based on Palaeozoic atmosphere models, is that oxygen levels were abnormally low at this time, falling beneath a critical threshold below which a terrestrial mode of life became untenable. However, such models are highly complex and require a number of assumptions which are difficult to test; disagreement over how to incorporate these into the models in a realistic way has led to widely diverging outputs that are difficult to reconcile. An alternative interpretation is that Romer’s Gap is an artefact of collection failure or taphonomic bias; proponents of this view note that rare finds of tetrapod material have progressively narrowed the gap over the last 50 years.

A high-resolution Famennian–Viséan record of wildfire frequency and intensity, based on the relative abundance of microscopic charcoal (inertinite) amongst dispersed organic matter in sedimentary rocks, is providing new insights into biosphere flammability and hence an independent constraint on $\rho$O$_2$ during this critical interval. Results thus far indicate no significant suppression of wildfire activity, suggesting that reduced atmospheric $\rho$O$_2$ is not a viable explanation for Romer’s Gap.

First report of a parasphenoid in Petalichthyida (Placodermi) and its phylogenetic implications

M. Castiello¹, M. D. Brazeau¹

1 Department of Life Sciences, Imperial College London, Silwood Park Campus, Buckhurst Road, Ascot, SL5 7PY, UK

The vast morphological differences between extant jawless and jawed vertebrates represents an obstacle in our reconstruction of the evolution of the gnathostome body plan. Placoderms are the only known jaw-bearing stem gnathostomes, providing critical evidence on the early evolution of primitive cranial architecture of early jawed vertebrates. Among placoderms, the petalichthyids have become a focal point of research as they possess unusual characters otherwise seen only in fossil jawless fishes. Here we investigate the endocranial morphology of Shearsbyaspis, an exceptionally preserved petalichthyid placoderm from the Early Devonian of Australia, using x-ray computed microtomography. We demonstrate the presence of a parasphenoid bone in the palate, reported for the first time in a petalichthyid. It is broad in shape, densely denticulated, with an undivided and posteriorly placed buccohypophysial foramen. This differs from the morphology present in most arthrodire placoderms, and resembles instead that of early crown gnathostomes. A parasphenoid has previously been recorded only in arthrodiran placoderms, possibly linking them to crown gnathostomes. Our finding shows that parasphenoids were instead more broadly distributed in stem gnathostomes and possibly plesiomorphic for a more inclusive set of the gnathostome total group. This raises questions about the currently prevailing hypothesis of placoderm paraphyly. Finally, we explore competing phylogenetic hypotheses for placoderms and crown gnathostomes in light of the new parasphenoid data, and suggest avenues for future research on the problem of cranial conditions for crown gnathostomes.

Faunal composition of the Rhaetic beds of Hampstead Farm, Gloucestershire, UK

G. Coleman¹, E. MacDonald¹, H. Thiel¹, E. Mears²

1 School of Earth Sciences, University of Bristol, Life Sciences Building, 24 Tyndall Avenue, Bristol, BS8 1TH, UK
2 The University of Edinburgh, Grant Institute, The King’s Buildings, James Hutton Road, Edinburgh, EH9 3FE, UK

The Late Triassic was a time of biotic and environmental change, which led to a mass extinction that affected terrestrial and marine organisms. The mass extinction has been linked to mass volcanism that occurred at the same time (Schoene et al. 2010). The Bristol region experienced environmental change in the Late Triassic, which created a fluctuating environment (Mackeau et al. 1994). Such changes are expected to have had an impact on the local fauna. This study used material from Hampstead Farm Quarry near Bristol to analyse the fauna that inhabited the area at the end of the Rhaetian. The faunal composition of Hampstead Farm Quarry was found to be skewed, and differed significantly in composition and diversity to the Aust bone bed from the early Rhaetian. Changes to the fauna in the Bristol area therefore occurred during the Rhaetian, which may be a result of local environmental fluctuations and indicative of wider changes occurring at the end-Triassic that led to the Triassic–Jurassic mass extinction.

Chemically characterising the diagenetic alteration of melanin in soft-bodied vertebrate fossils

C. Colley¹,², J. Vinther³

1 Department of Geosciences, Virginia Tech, Blacksburg, VA 24060, USA
2 School of Earth Sciences, University of Bristol, Wills Memorial Building, Queen’s Road, Bristol, BS8 1RJ, UK
3 Department of Earth Sciences, University of Cambridge, Cambridge, CB2 3EQ, UK

The study of organic preservation in deep time has advanced greatly in the last few decades as new technologies have been incorporated into studies of ancient life. Microscopic analyses of carbonaceous structures found in organic residues in a diversity of fossil taxa have recently been described as fossil melanin-bearing granules and melanosomes. However, the fossilisation of melanin and the chemical characteristics of fossil melanosomes are poorly understood. Here, we use time-of-flight secondary ion mass spectrometry (ToF–sims) to study the preservation and alteration of melanin, the most common source of pigment in living organisms. We have identified melanosomes in a wide range of fossil taxa including bird feathers, mammalian hair, amphibian skin, and cephalopod ink sacs. Incorporating artificial maturation experiments on fresh melanin samples, we find that the mass spectra derived from fossil melanosomes are best interpreted as diagenetically altered melanin. By analysing a chemical fingerprint for each modern, matured, and fossil sample, we are able to make predictions regarding the degradation behaviour of melanin. Using principal component analysis to visualise the variation between samples, we are able to discern between taxa and the two different types of melanin, demonstrating the great potential this combination of methods has for identifying organic compounds in fossils, and understanding how they are altered during diagenesis.
New insights on ontogeny of Bagaceratops rozhdestvenskii (Dinosauria: Ceratopsia) from the Late Cretaceous of the Gobi Desert (Mongolia)

L. Czepeński⁴

Department of Palaeobiology and Evolution, Faculty of Biology, University of Warsaw, Żwirki i Wigury 101, 02-089 Warszawa, Poland

Bagaceratops rozhdestvenskii is a species of medium-sized basal coronosaur (derived neoceratopsian dinosaur) closely related to Protoceratops. This taxon was established by Teresa Maryańska & Halszka Osmólska in 1975 based on material collected from the Late Cretaceous of the Gobi Desert (Barun Goyot Formation, Mongolia). Several well-preserved skulls that were referred to Bagaceratops demonstrate quite a wide range of variation. The most prominent of characteristics that vary within collections include: overall morphology, size, and proportions of skull; shape, angle of inclination and of widening of the frill; shape and size of nasal horn core; details of maxillary teeth morphology; possible presence of premaxillary teeth; and fenestration of frill. These features were interpreted by later authors as evidence for different ontogenetic, sexual, intraspecific, or interspecific variation. Re-examination of skull collections, which contain individuals at different stages of growth, with reconstruction of each specimen, and with comparison to recently described, closely-related taxa from nearly contemporary sediments of the Gobi Desert, may allow us to recognize the real nature of variability within this taxon. In addition, it may shed new light on diversity of neoceratopsian dinosaurs from the Late Cretaceous of Asia, and the validity of other “bagaceratopid” taxa.

The preservation potential of polychaete jaws

J. Daniell¹

1 6 St James Place, 8–10 Bond Street, Bristol BS1 3LU, UK

Scolecodonts, the fossilised jaws of polychaete worms, are enigmatic microfossils that allow a rare glimpse into the natural history of the polychaetes, a highly diverse yet understudied group. Specimens are common in Ordovician and Silurian sediments, representing the earliest crown group appearances for the group. However, in sediments from the Devonian onwards, scolecodonts become increasingly rare, and many of the modern groups are unrepresented or completely absent. This has been attributed to changes within jaw composition within the polychaete families, causing them to ‘evolve out’ of the fossil record. Modern polychaetes possess jaws that incorporate minerals (Eunicidae), transition metals (Glycera and Nereis), and uniquely, melanin (Glycera). This is supported by evidence from modern sediments, of which jaw numbers does not correlate with species abundance. However no direct study on the preservation potential of the jaws exists.

We propose to use a combination of chemical analysis techniques including Pyrolysis-GC-MS and ToF-SIMS on matured jaws to explore how jaw chemistry may affect preservation. These will be compared with data from fossil jaw specimens and visualised using a principal component analysis. It is expected that the jaws of Glycera will show a comparably high preservation potential, as is reflected by the fossil record. The influence of the melanin content will be explored, highlighting its aptitude to preserve in fossils. We hope to elucidate some of the taphonomic biases within the polychaete fossil record, while also furthering knowledge of the preservation potential of different biologic structures.

Assessing evolutionary tempo and mode across vertebrate evolution

R. P. Dearden¹, J. N. Keating³, P. C. J. Donoghue¹

1 School of Earth Sciences, University of Bristol, Life Sciences Building, 24 Tyndall Avenue, Bristol, BS8 1TQ, UK
2 Department of Life Sciences, Imperial College London, Silwood Park Campus, Buckhurst Road, Ascot, Berkshire, SL5 7PY, UK

Living vertebrates are divided into two clades: those with jaws, the gnathostomes, and those without, the cyclostomes. A suite of other morphological differences further separate the gnathostomes from their jawless brethren, including a mineralised dermo- and endocranium, paired nostrils, and paired appendages. Furthermore, molecular evidence suggests that, since separating from that of the cyclostomes, the gnathostome genome has undergone one or two whole genome duplications (wGDs). Thus understanding the tempo and mode of gnathostome evolution is of great interest to evolutionary biologists. Due to the morphological gulf between the two groups, the study of extant taxa alone is uninformative in exploring the nature of this transition. The fossil record, however, reveals the morphologies of an array of Palaeozoic stem-gnathostome fishes, chronicling the acquisition of jawed-vertebrate characters as the gnathostomes arose from their jawless forbears. In an attempt to gain insight into gnathostome evolution, we assembled a generic-level supermatrix from the literature, comprising 254 taxa and 626 characters, and including all major stem-gnathostome groups. Parsimony and Bayesian approaches were both used to assess phylogeny, and these trees were used in a series of character acquisition rate analyses to evaluate evolutionary tempo. Morphological disparity was also assessed using NMDs analysis. The gnathostome stem was recovered as a series of plesions, constituting the traditional ‘cyclostom’ groups. It displays some heterogeneity in rate, although no specific area that might directly correspond to a wGD. In future we plan to integrate molecular data by using tip dating molecular clock dating to estimate node ages.

Constructing a synapomorphic hierarchy as a means of better understanding chondrichthyan evolution

R. P. Dearden¹, M. D. Brazeau¹

1 Department of Life Sciences, Imperial College London, Silwood Park Campus, Buckhurst Road, Ascot, SL5 7PY, UK

Modern chondrichthians, the cartilaginous fishes, are the sister group to the osteichthyans (bony fishes), and themselves comprise the familiar elasmobranchs (sharks and rays), and the far less specialised holocelophans (rat-, rabbit-, and elephant-fishes). While this phylogenetic framework is secure, uncertainty about the placement of the earliest fossil taxa from the Palaeozoic Era clouds our understanding of early chondrichthyan evolution. This, in turn, hinders our understanding of the process of character assembly that led to the modern gnathostome body plan. Here, consensus methods are employed to illustrate these areas of uncertainty in chondrichthyan phylogeny, using phylogenetic datasets from the literature. Putative synapomorphies for total-group Chondrichthyes and its constituent clades are then reviewed and a synapomorphic hierarchy constructed from these characters using an outgroup-based approach. The placement of problematic groups is then assessed against this hierarchy. Despite recent analyses which have placed Palaeozoic ‘sharks’, stethacanths and symmoriids, on the chondrichthyan stem, our character set shows that they share synapomorphies with holocelophans, providing evidence that they in fact lie somewhere on the holocelophan stem. Members of the probable ‘acanthodian’ grade share certain chondrichthyan characters consistent with their living on the chondrichthyan stem. This synapomorphic hierarchy provides a framework
Ec dysis in the fossil record

H. B. D rage

1 Department of Zoology, University of Oxford, South Parks Road, Oxford, OX1 3PS, UK
2 Oxford University Museum of Natural History, Parks Road, Oxford, OX1 3PZ, UK

Ec dysis is the process of exoskeleton moulting. Periodic ec dysis is necessary for development, growth, and repair in organisms with a restrictive exoskeleton, but represents a time of extreme vulnerability to predation. This life history strategy unites the most taxonomically diverse group of animals, the Ecdysozoa (first identified using molecular data by Aguilardo et al. 1997).

Within- and between-group variations in trilobite ec dysial methods have been sporadically described in the literature. Tentative explorations of preserved moulting habits have also been published for Loricifera, Lobopodia, and various other arthropods, including Euryperida. For the most part these are descriptive works, with little broad-scale relevance for understanding the evolutionary history and ecologies of these animals. Notable exceptions include papers on ec dysial habit as related to survivorship through geological time, morphological constraint, and behaviour.

I will explore how patterns of ec dysis have evolved in the fossil record, how this relates to phylogeny, and has influenced long-term ecosystems. Substantial collections of crown and stem ecdysozoan fossil exuviae housed in the UK, Europe, and North America have yet to be examined in the context of ec dysis. Preliminary work suggests trilobite ec dysial mode may be linked to development, including body size and instar phase. Trends in ec dysial mode between families and through geological time are also being explored.

As the key uniting factor for Ec dysosoa, the evolution of ec dysial characteristics must have been central to shaping their extinct and extant diversity, morphology, development, and ecology. This warrants extensive further research into ec dysis in the fossil record.

Manus of the aetosaur Stagonolepis olenkae from the early Late Triassic of Poland

D. Drózdz

1 University of Warsaw, Department of Paleobiology and Evolution, 101 Żwirki i Wigury St., building of CNBCh, 02-089 Warsaw, Poland

Aetosaura is a clad of Late Triassic heavily armoured omnivorous pseudosuchians. Although widely occurring and studied for more than a century, the anatomy of their manus remains poorly known, being restored only in Stagonolepis robertsoni by Walker (1961), and Longosuchus meadei by Sawin (1947). New material of three semiautoclated manus associated with forearm bones (ZPAL AbII 2407, 3049, 3050) of Stagonolepis olenkae from Krasiejów in Upper Silesia has enabled reconstruction of its structure in one more species. The specimens were mechanically cleaned and bones were partially separated. Probable phalangeal formula in S. olenkae is 2-3-4-5-3, the same as in S. robertsoni. Metacarpals are well fitted to each other and they partially overlap. The carpus consists of four carpal bones positioned in two rows. The first row consists of radial fused with intermedium and ulnae; the second row is built of two distal carpals. Fusion of radiale and intermedium has been already observed in S. robertsoni, L. meadei, and Aetosaurus ferratus, which suggests that this feature is typical for all aetosaurs. In L. meadei, the same number of carpal bones were recognised, but they were differently positioned. The whole manus was covered by osteoderms with variable shapes, ranging from subrectangular in the area of metacarpals to more rounded in the area of carpals and distal phalanges. S. olenkae is the first known aetosaur with osteoderms covering the manus.

The eye of the beholder: the evolution of vision in the ecdysozoa

J. F. Fleming

1 School of Earth Sciences, University of Bristol, Life Sciences Building, 24 Tyndall Avenue, Bristol, BS8 1TQ, UK

The ecdysozoa – the moulting invertebrates – are a clad that contains the majority of named animal life. Despite this, most of the work performed on opsins – the protein family that regulates photoreceptive processes – has been focused on the vertebrates. This study aims to determine the timing of the development of sight and colour vision within the superphylum, and use this to characterise the visual systems of extinct members of the clad. Transcriptome sequences were assembled de novo using Trinity, and then subjected to a BLAST search against a set of known opsins. Final trees were then constructed in Phylobayes, and compared to a Dayhoff recoded tree to remove structural bias. New opsins have been discovered in a number of extant species previously thought to lack them entirely. This places the evolution of photoreception at the base of the Ecdysozoa, and has a number of implications regarding the development of colour vision, and thereby the condition of colour vision in extinct taxa. The trees suggest a basal arthropod origin of colour vision, with at least one other origin event in the superphylum, which could date the origin of ecdysozoan colour vision back as far as the Precambrian, raising interesting questions about the visual ecology of extinct Ecdysozoa.

Carboniferous fish communities from New Brunswick (Canada) and their implications for understanding the marine to freshwater ecological transition

A. Ó. Gogáin, M. J. Benton, D. Carpenter, H. J. Falcon-Lang, R. Miller

1 Department of Earth Sciences, University of Bristol, Wills Memorial Building, Queen's Road, Bristol, BS8 1RJ, UK
2 School of Ocean and Earth Science, National Oceanography Centre, Southampton, European Way, Southampton, S014 2ZH, UK
3 Department of Earth Sciences, Royal Holloway University of London, Egham Hill, Surrey, TW20 0EX, UK
4 New Brunswick Museum, Saint John, E2L 4Z6, New Brunswick, Canada

Fish began to invade freshwater environments in mid-Palaeozoic times, yet exactly how this key transition occurred remains poorly understood, because, today, fish are either exclusively freshwater or marine, with very few examples of euryhaline taxa. Empirical palaeontological evidence is limited because there are relatively few studies of the biodiversity, endemism, and salinity tolerances of fossil fish communities at key time intervals. Here we look at systematics and Sr-isotope geochemistry of a new collection of mid-Carboniferous fish from the Coal Measures of New Brunswick (Canada) to determine what fish taxa were present. In doing so, a major comparative database of mid-Carboniferous taxa has been compiled allowing for the assessment of whether particular fish species were endemic to certain coal swamp basins (suggestive of a freshwater mode of life), or more globally widespread (suggestive of a euryhaline habit, capable of migrating between freshwater basins via intervening seaways). These findings will improve knowledge of prevalence of euryhalinity (an unusual ecolo-
The origin of life is one of the most challenging and discussed topics of evolutionary biology, and is fundamental to our understanding of ancient living systems. The Last Universal Common Ancestor (LUCA) is the ancestor of all current life on Earth today, and with no preserved fossils in the geological record, our only evidence for its existence lies in the two descent lineages: Archaea and Bacteria.

LUCA’s thermal and ecological preferences have been widely debated, although the use of tree-based approaches in all studies are deeply flawed, as their application to deep time exposes them to phylogenetic inaccuracies caused by gene transfer.

The accumulation of diverse, complete genome sequences in the last decade has enabled us to use an innovative, model-free approach, which is both judicious and timely. By analysing LUCA’s ‘genomic fossils’ in the form of invariable sites of universally distributed amino acids, we are able to glimpse the ecological nature of LUCA.

Scripting language Perl was used to partition and count the amino acids of Bacteria, Archaea, and Eukaryota, and variable sites were eliminated using PAUP. The amino acid compositions of both the completed genomes and the universally distributed proteins were characterised according to the Dayhoff matrix, and plotted to depict the last common ancestor of Bacteria, Archaea, Eukaryota, Vertebrata, and ultimately LUCA.

Preliminary results have shown LUCA to be a hyperthermophile, with a proportion of excess polar to charged amino acids. This suggests a ‘hot’ environment, potentially a black smoker hydrothermal vent.

Investigating macroevolutionary patterns in Early Cambrian olenellid trilobites

E. Hambling¹, D. Pisani¹, K. Davis²

1 School of Earth Sciences, University of Bristol, Life Sciences Building, 24 Tyndall Avenue, Bristol, BS8 1TQ, UK
2 University of Bath, Claverton Down Road, Bath, Somerset, BA2 7AY, UK

Supertrees are frequently used as frameworks for investigating macroevolutionary patterns throughout the history of life. Here, both MRPT and Bayesian supertree methods have been used to construct an updated consensus of the relationships within the Early Cambrian trilobite suborder Olenellina. The new supertrees have then been used to investigate evolution, extinction, and diversification through time, and specifically, whether the cryptic early radiation of Pancrustacea may have had an effect on the evolutionary history of the olenellids. Results demonstrate that the olenellids were severely affected by the Early Botomian mass extinction event at 517 Ma with both diversification and the number of lineages dropping substantially at the time, alongside peaks in the rate of extinction. After integrating a molecular phylogeny to the new olenellid supertrees, results suggest increased rates of extinction within the olenellids at the time of the Pancrustacean radiation at 513 Ma. This suggests that the olenellid taxa that survived the mass extinction may have lacked the resilience for recovery and were subsequently outcompeted by the rapidly radiating Pancrustacea.

An investigation into taphonomy, taxonomy, and historical biodiversity in cave systems in Cayman Brac (Cayman Islands)

V. L. Harvey¹

1 School of Earth, Atmospheric and Environmental Sciences, University of Manchester, Williamson Building, Oxford Road, Manchester, M13 9PL, UK

It is well documented, and an unfortunate and common theme, that many species have become extinct following historic European expansion throughout the Caribbean Sea. The Cayman Islands had been untouched by human colonisation until European discovery (Columbus, 1503), offering a unique opportunity to better understand human impact on island paleobiodiversity, and one that has not yet been undertaken using the powerful technologies available in the 21st Century.

The pristine cave systems of Cayman Brac shelter large assemblages of faunal remains that provide a natural longitudinal study into taxonomic diversity on the island through time (>130 000 years before present). Notably, all terrestrial endemic mammals from the Cayman Islands have become extinct, and many have done so since the arrival of humans. Remains of extinct mammals on Cayman Brac include rodents Capromys and Geocapromys, and two new species of the shrew-like Nesrophantes (Harvey et al., in press).

An analysis of sub-fossil bone has been undertaken to assess faunal assemblages indicative of taxonomic diversity throughout the period spanning human colonisation of the region. This research deploys: (1) Synchrotron Rapid Scanning X-Ray Fluorescence (SRS-XRF) to understand taphonomic processes on Cayman Brac, and preservation of organic remains in caves in the tropics; and (2) Zooarchaeology by Mass Spectrometry (ZooMS) to identify morphologically unidentifiable bone fragments through collagen ‘fingerprinting.’

This on-going research provides insight into: (i) the evolution of ecosystems, (ii) changes in biodiversity, (iii) radiation of vertebrates on Cayman Brac, and (iv) the impact of an invasive species (humans) upon endemic island fauna.

Quantifying the environmental context of the Cambrian metazoan radiation: a geochemical approach

T. Hearing¹, T. Harvey¹, M. Williams¹, S. Gabbott¹, P. Wilby³, M. Leng³

1 Department of Geology, University of Leicester, University Road, Leicester, LE1 7RH, UK
2 British Geological Survey, Environmental Science Centre, Nicker Hill, Keyworth, Nottingham, NG12 5GG, UK
3 NERC Isotope Geoscience Laboratory, British Geological Survey, Keyworth, Nottingham, NG12 5GG, UK

The rapid appearance and diversification of metazoan body plans in the fossil record is perhaps the most significant interval in the evolution of Phanerozoic ecosystems. However, very little is quantitatively known about the marine environment of the ‘Cambrian explosion.’ Temperatures, latitudinal temperature gradients, and dissolved oxygen content of Cambrian seas are quantitatively unconstrained but have all been invoked as important factors in
radiation and extinction events through this period. Investigations utilising conodont bioapatite stable oxygen isotope data have reconstructed ocean temperatures from the Ordovician Period, but euconodonts are not known below the uppermost Cambrian. Phosphatic ‘small shelly fossils’ (SSFs) are proposed as an alternative repository of palaeoenvironmental data from the Lower and Middle Cambrian, and could address this gap. However, diagenetic alteration can obliterate original palaeoenvironmental signals. Fossil material analysed for proxy data must therefore be demonstrably unaltered. SSFs from the Lower Comley Limestone, Lower Cambrian, Shropshire, were investigated by optical and scanning electron microscopy following a protocol devised to test preservation of biophosphate. Preliminary chemical data was also collected using energy dispersive X-ray spectroscopy. External morphology and internal ultrastructure were examined for primary (biogenic) features. Both biological and alteration ultrastructural textures were observed, with primary textures dominant and alteration mostly highly localised. Phosphatic SSFs occur alongside (recrystallised) calcareous fossils, indicating that pervasive phosphahtatisation has not occurred. A subset of microfossils from the Lower Comley Limestone are therefore considered to be suitable repositories of palaeoenvironmental data and will be further examined for the first quantitative constraints on Cambrian marine environments.

The body size of planktic foraminifera is a product of multiple biological processes, including metabolism and nutrition as well as abiotic factors. Maximum body sizes are reached during periods of climatic optima with smaller sizes (dwarfing) seen during episodes of climatic stress. Body size fluctuations are thus likely to be a feature of environmental perturbations in the past, present, and future. One such perturbation is the Middle Eocene Climatic Optimum (MEO) ~40 Ma, a short-lived global warming event triggered by an influx of carbon to the global carbon system, which resulted in surface and deep ocean temperatures rising by ~3–6°C. Constraining the effects of the MEO is imperative due to its relevance for predicting the consequences of anthropogenic driven climate change on marine ecosystems in the future.

Here we use samples from Ocean Drilling Program Sites 702 (South Atlantic, 50° 57’S, 26° 22’W) and 865 (Equatorial Pacific, 18° 26’N, 179° 33’W) to conduct biometric analysis of planktic foraminifera assemblages across the MEO using an automated microscope, which can rapidly measure the maximum diameter of thousands of foraminifer tests. The aim of this investigation is to identify the magnitude, rate and direction of any planktic foraminifera body size response to the MEO, and any differences in this response between high versus low latitude communities. It is hypothesised that foraminiferal body size initially increased as the oceans warmed and approached optimum conditions for many taxa, but exhibited reduced sizes due to environmental stress at the peak of the MEO.

Evolutionary trends in testudines: a phyloclimatic study

L. Holloway

1 School of Earth Sciences, University of Bristol, Wills Memorial Building, Queen’s Road, Bristol, BS8 1RJ, UK

In the modern world, Cryptodira (hidden-necked turtles) are much more species-rich than Pleurodira (side-necked turtles). Cryptodira also have a wider geographical range and occur in a greater number of habitats. In this study a large set of molecular data for extant turtles was concatenated and used to reconstruct a phylogeny for all Testudines. This was used to investigate whether or not the two lineages arose concurrently, and whether Cryptodira has always been more successful than Pleurodira. Fossil data was then integrated into the phylogeny and ancestral nodes were dated. Multiple approaches were used to reconstruct the phylogeny, including maximum likelihood and Bayesian approaches. Programs such as PhyloBayes and MrBayes were used. Occurrence data for extant species was collected and compared to modern climate observations to determine habitat preferences for living turtles. Ancestral states were reconstructed for key nodes in the phylogeny, using a variety of statistical frameworks and evolutionary models, to infer environmental preferences for ancestral species. Particular focus was given to precipitation and minimum temperature tolerances as these variables are known to limit distribution of extant turtles. Palaeoclimatic data was then compared to the dated phylogeny to determine whether there is a significant correlation between known periods of climate change in the past and significant lineage splitting events in the evolutionary history of Testudines. Analysis of the impact that past climate change has had on turtle evolution allows predictions to be made about the future evolutionary responses of turtles to current climate change.

Post-cranial anatomy and palaeopathologies of an Upper Jurassic Pliosaur from Westbury, Wiltshire, UK

R. J. Jalili, J. Sassoon, M. J. Benton

1 School of Earth Sciences, University of Bristol, Wills Memorial Building, Queen’s Road, Bristol, BS8 1RJ, UK

Specimens of the genus *Pliosaurus*, and pliosauromorphs in general, are rare and significant in the study of giant marine reptiles and apex predators. The previously described skull of *Pliosaurus brachyaspidsus*, now referred to as *P. carpenteri*, from the Kimmeridge Clay Formation (Kimmeridgian) of Westbury, Wiltshire, UK, is thought to have belonged to an ageing individual, with a suite of palaeopathologies that may be involved in its death. New descriptions of the post-cranial elements of the same individual, provide important insights into the size and anatomy of the species. Along with the ~1.8 m long skull, an incomplete vertebral column, pectoral and pelvic elements, as well as a partial paddle, are used to estimate the total length of the individual. In addition to the pathologies described in the cranium and mandibles, there are unique, *in vivo* fusions of the gastralia, and also three phalanges from digits I and II, possibly implicated in the lifestyle of the marine predator. A bite mark on one metapodial also fits the puncture wound made by a tooth of the same individual, indicating aggressive behaviour between individuals.

The cranial biomechanics of *Effigia okeeffeae* and its convergence with Ornithomimosauridae

A. Jones, D. Button, A. Cuff, E. Rayfield

1 School of Geography, Earth and Environmental Sciences, University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK
2 School of Earth Sciences, University of Bristol, Life Sciences Building, 24 Tyndall Avenue, Bristol, BS8 1TQ, UK
3 Department of Genetics, Evolution and Environment, University College London, Darwin Building 218A, Gower Street, London, WC1E 6BT, UK

Extreme convergences in food processing morphology provide an opportunity to test hypotheses of repeated evolution into palaeobiological niches. Using their convergent cranial morphology and edentulism as a comparative tool, this study assesses the
previously speculated functional and palaeobiological similarity between *Effigia okeeffeae* (Archosauromorpha: Pseudosuchia) and ornithomimosaurid dinosaurs (Archosauromorpha: Avemetatarsalia). The crushed skull of *Effigia* was CT scanned, digitally separated from the attached matrix, and retrodeformed, producing a 3D model. Adductor and temporal musculature was reconstructed using attachment scars, extant phylogenetic bracketing, and osteological constraints; muscular force was subsequently calculated from cross-sectional areas. The cranial model was converted into a finite element (FE) mesh and bite forces were simulated separately at three positions, with resulting von Mises stresses displayed on the skull as a rainbow plot. The retrodeformed skull differed from previous hypothetical drawings by possessing a dorsally concave ventral edge of the cranium and an anterodorsally convex cutting edge of the dentaries. FE analysis showed *Effigia* to possess a rostral bite force comparable to ornithomimosaurs, but a cranium poorly equipped for the resulting stresses. Conversely, stresses induced from a posterior bite were lower despite the greater mechanical advantage afforded by a more posterior position. *Effigia* appears to be functionally and ecologically distinct from ornithomimosaurs, being comparatively poorly adapted to rostral biting. Instead of a rostral bite, preceding a ‘catch and throw’ swallow, as suggested in ornithomimosaurs, *Effigia* is here suggested to have used its strongly downturned dentaries and overlapping premaxillae as a shearing mechanism to slice through fibrous vegetation.

**Terrestrial tetrapods of the Triassic**

C. Kinsella¹, M. J. Benton¹

¹ School of Earth Sciences, University of Bristol, Life Sciences Building, 24 Tyndall Avenue, Bristol BS8 1TQ, UK

The Triassic was a highly significant period for terrestrial tetrapod macroevolution, with recovery from the end-Permian mass extinction dramatically restructuring ecosystems, and the origin of several new groups, including dinosaurs. The ecological patterns among terrestrial tetrapods throughout the Triassic and into the Jurassic are relatively understudied, despite their implications on Mesozoic and modern ecosystems. Presented here is the preliminary analysis of a new global specimen level dataset of terrestrial tetrapod occurrences covering the Triassic and Early Jurassic. Generic richness corrected for sample size using rarefaction and shareholder quorum subsampling, evenness, relative abundance, and body size trends of key groups are examined through time. A dramatic decline in synapsids in the late Carnian (~230 Ma) is coincident with the earliest appearance of dinosaurs, which subsequently radiate in the Norian. In addition to this success, dinosaurs appear to be unaffected numerically by a large drop in evenness and diapsid generic richness in the latest Triassic, instead rising to peak relative abundance at the expense of other groups. The results contribute to the ongoing debate regarding the nature of the origin of dinosaurs, with the evidence apparently supporting opportunistic replacement during a period of global warming (Carnian Pluvial Event) and extinction. Their adaptability appears to have solidified their dominance during further upheaval in the latest Triassic.

Using Bayesian phylogenetics to reveal the interplay between squamate and rhynchocephalian diversity

C. G. Klein¹, D. Pisani¹, J. Voithner¹, N. Longrich³, A. Tanner¹

¹ School of Earth Sciences, University of Bristol, Wills Memorial Building, Queen's Road, Bristol, BS8 1RJ, UK
² Department of Biology and Biochemistry, University of Bath, Bath, Claverton Down, BA2 7AY, UK

The clade Lepidosauria arose about 250 Ma, and consists of two orders: the rhynchocephalians were relatively diverse from the Late Triassic to the Cretaceous, but are now only represented by one species, the tuataras of New Zealand. The squamates are presently represented by almost 10,000 species, but only started reaching higher diversity levels in the Cretaceous. The interplay between rhynchocephalian and squamate diversity, as well as what drove the sudden diversification of squamates, are both poorly understood. Competitive replacement of rhynchocephalians by squamates has been proposed to explain this faunal turnover. However, the fossil record is too poor to directly test this using case studies, and no large scale study has yet been undertaken. Here we look at diversity through time and changes in diversification rates for both clades to try to identify any patterns of changes in diversity between the two orders, and between the orders, and biotic and abiotic Mesozoic events. A dataset of 110 squamate taxa coded for 12 nuclear and mitochondrial genes is used to construct a molecular-based timescale for the squamates, which we contrast against the rhynchocephalian fossil record. Analyses of the change in rate of diversification reveal that more ancestral squamate divergences date to the Jurassic, however, divergences of modern families commonly occur in the Cretaceous. Morphological phylogenies reveal that rhynchocephalians remain diverse into the Late Cretaceous in Gondwana. The faunal turnover thus had a spatial aspect to it, as has been alluded to in the literature.

Unearthing the roots of mammalian diversity: the equality of the cynodont fossil record

K. Ludwig¹²³

¹ Department of Earth and Environmental Sciences, University of Pennsylvania, Philadelphia, PA 19104, USA
² School of Earth Sciences, University of Bristol, Wills Memorial Building, Queen’s Road, Bristol, BS8 1RJ, UK

Debate persists over the quality of the fossil record. At the core of the debate are how well the fossil record represents past biodiversity, the effects of biasing factors, and the validity of sampling correction methods. However, few studies explore how complete the fossil record is in terms of the fossils themselves – whether there are correlations between times of high or low specimen quality and measured biodiversity. To explore this question, we performed a literature-based study on cynodonts, a diverse clade that originated in the Late Permian and gave rise to mammals during the Late Triassic. We utilised two metrics for determining skeletal completeness – quantifying individual specimen completeness and composite species completeness – as well as a metric for cladistic character completeness. These were compared to measures of taphonomic and sampling bias, and temporal trends in species diversity. No significant correlations were found between measures of completeness and these sampling metrics. However, there were significant correlations between the different sampling metrics (such as terrestrial formation and collection counts), which indicates that cynodont diversity is not tied to these sampling metrics or to completeness measures. Specimen completeness does seem to be affected by lithology and ecological factors. These results suggest that using sampling proxies globally and across taxonomic groups may be relatively meaningless when...
exploring the cranial and endocranial anatomy of a Jurassic ichthyosaur using digital techniques

R. D. Marek¹, B. C. Moon¹, M. J. Benton¹, M. Williams²

¹ School of Earth Sciences, University of Bristol, Life Sciences Building, 24 Tyndall Avenue, Bristol, BS8 1TQ, UK
² Bath Royal Literary and Scientific Institution, 16–18 Queen Square, Bath, BA1 2HN, UK

Even after 200 years of study, some details of the cranial anatomy of ichthyosaurs, one of the most successful groups of marine vertebrates in the Mesozoic, are still unclear. New information on the braincase, palate, and occiput are provided from three-dimensional scans of an exceptionally preserved ichthyosaur (Haastipteryx typicus) skull from the Toarcian of Strawberry Bank, England. This ichthyosaur has unusual, hollow, tubular hind bars. The occipital and braincase region is fully reconstructed, creating the first digital cranial endocast of an ichthyosaur. Enlarged optic lobes and an enlarged cerebellum suggest neuroanatomical adaptations that allowed it to be a highly mobile, visual predator. The olfactory region also appears to be enlarged, suggesting that olfaction was more important for ichthyosaurs than had been assumed. These results further our knowledge of ichthyosaur cranial anatomy in three dimensions, and provide a platform in which to study the anatomical adaptations that allowed ichthyosaurs to dominate the marine realm during the Mesozoic. Contrary to previous published results, phylogenetic analysis suggests the ichthyosaur is a leptonectid.

The Rhaetian vertebrates of Hampstead Farm Quarry, Gloucestershire, UK

E. M. Mears¹,², M. J. Benton³

¹ School of Earth and Environment, University of Leeds, Maths/Earth and Environment Building, Leeds, LS2 9JT, UK
² School of GeoSciences, University of Edinburgh, Grant Institute, The King’s Buildings, James Hutton Road, Edinburgh EH9 3FE, UK
³ School of Earth Sciences, University of Bristol, Wills Memorial Building, Queen’s Road, Bristol, BS8 1RJ, UK

The Late Triassic was a time of faunal turnover, with sudden climate change and a major transgression putting a strain on ecological communities. An archipelago existed in south-west Britain at this time, and these deposits have been well-studied thanks to the exceptionally preserved terrestrial vertebrate fauna. Marine fauna of the same area, meanwhile, have been less studied. The rocks at Hampstead Farm Quarry, Gloucestershire, are part of the Westbury Formation and preserve a Rhaetian palaeocommunity in a normal-bedded marine sequence. This study focuses on a single vertebrate-rich bed (bed 9). Fossils recovered from this bed were classified and counted to determine the faunal composition represented. A total of 2862 individual teeth were examined, along with numerous tooth fragments. From this sample, 22 morphotypes were identified, 13 of which were referable to established taxa. The fossil fauna was dominated by two species, Glyptothorax albertii (60% of all fossils examined) and Saurichthys acuminatus (30%). As these results show, osteichthyan fish comprised the largest portion of the sample, followed by chondrichthyan fish. ‘Other vertebrates’ were a minimal component. On the other hand, Chondrichthyes were the most diverse group in the sample, with a total of 10 morphotypes compared to osteichthyans (eight morphotypes) and ‘other vertebrates’ (four morphotypes). These results show a highly skewed fauna, different to that found in slightly older bone beds in south-west Britain. The fauna recovered from Hampstead Farm Quarry provides a snapshot of a marine ecosystem from quiet, shallow waters that surrounded the south-western British archipelago during the latest Triassic.

Why does Globicetus (fossil beaked-whale) have a bony sphere inside the head?

J. Muchagata¹,², O. Mateus³

¹ Faculdade de Ciências e Tecnologia/Universidade Nova de Lisboa, 2829-516 Caparica, Portugal
² Departamento de Geociências, Universidade de Évora, Largo dos Colegiãos 2, 7000 Évora, Portugal
³ Museu da Lourinhã, Rua João Luís de Moura, 95 2530-158 Lourinhã, Portugal

Ziphiids or beaked-whales are deep-diving, echolocation-user odontocetes. Recently, a new fossil taxon, Globicetus hiberus Bi- anucci et al., 2013, was described from the Atlantic Ocean floor phosphatised deposits from the Upper Early Miocene–Middle Miocene offshore of central Portugal and Galicia. The most peculiar feature of the holotype skull (ML1361) is the large spherical prominence in a medial position of the rostrum, which justified the generic name: the species has fused premaxillae that form a sphere, and a premaxillary shelf in a posterior position. The origin of this structure is mysterious but one can advance some hypothesis: 1) malformation, disease, or deformity; 2) head-butting during mating rituals; 3) ballast in deep-diving; 4) increase of the velocity of the sound waves; 5) reflective and directional aim of the sound beam; 6) sound barrier between the emitted sound waves from the phonic lips into the sound-reception tooth row in the lower jaw; 7) secondary sexual organ (‘inside antlers hypothesis’). Ongoing research using computer simulation based in 3D models and images may shed some insight on the whale’s behaviour, and determine the soft tissue and sound propagation in Globicetus. The whale might recognise and visualise ultradense bones in a body of another as distinctive echoic images and detect the shape of the compact spheroid through the soft tissue (due to high density contrast) using high frequency sounds. Therefore the spheroid may not be a sound transmitter, but a visual display object. The understanding of how these animals communicated may help to further the knowledge in extinct species.

Correlates between calcaneal morphology and locomotion in extant and extinct carnivorous mammals: a feline case study

E. Panciroli¹, C. Janis¹

¹ School of Earth Sciences, University of Bristol, Wills Memorial Building, Queen’s Road, Bristol BS8 1RJ, UK

Determining locomotion and ecology in fossil taxa can be challenging, particularly when there is limited skeletal material preserved for study. In order to make informed assertions on the locomotion and habits of fossil taxa, it is necessary to gather empirical data from extant taxa for which locomotion and lifestyle can be reliably documented. The calcaneum is known to be informative in terms of locomotion and ecology for several mammal groups, but there is a paucity of empirical study for carnivorans. As the calcaneum is also frequently preserved in the fossil record, it is an excellent structure for study. In order to make informed assertions on the locomotion and lifestyle of fossil carnivorans, we determined their probability of locomotion and ecology.
We were able to distinguish distinct groupings related to locomotor behaviour, particularly arboreal and cursorial species. The proposed extinct cursor *Miracinonyx* (the Pleistocene American 'cheetah') showed important distinctions from *Acinonyx* (the extant African cheetah), showing that detailed anatomical comparisons may yield different interpretations from more superficial observations. This type of analysis has the potential to reveal previously unanticipated ecologies in fossil taxa.

Nothing but skin and bones – early vertebrate fossils unveil the developmental history of the dermal skeleton §

Y. H. Park¹, M. Rücklin¹

1 Naturalis Biodiversity Centre, Darwinweg 5, 2333 CR, Leiden, The Netherlands
2 Institute of Biology Leiden, Leiden University, Sylviusweg 72, 2333 BE, Leiden, The Netherlands

To the untrained eye they may be mistaken for an ordinary piece of gravel, but even the tiniest remains from early jawed vertebrates (gnathostomes) can give invaluable insight into the developmental history of the dermal skeleton. We are focusing on dermal skeleton fossils of two groups. First is the Upper Silurian acanthodians, a well-established group of stem chondrichthyans. The basal state of acanthodians would thus provide insight also into the basal state of chondrichthyans. Secondly, the enigmatic Ordovician *Skiichthys halsteadi* is a possible contender for the oldest jawed vertebrate. However, due to the sparsity of its remains *Skiichthys* is characterised entirely based on its few dermal scale remains. New strategies to characterise these minuscule fossil fragments have been developed in the recent decades. Replacing the destructive sectioning and grinding process for the SEM is a less invasive approach using 3-dimensional synchrotron tomographic data. Using this technology, we characterised acanthodian scales, spines, and a skull plate. The acanthodian skull plate differs in the growth pattern and tissue organisation compared to the body scales. Through digital segmentation, a 3-dimensional model of the development is achieved. We identified at least two different types of *Skiichthys* scales by differences in growth arrest line patterns and tissue compositions. A thorough understanding of the histology of acanthodian skull plates will help to solidify the debated phylogenetic hypotheses and re-evaluate the identification of *Skichthys* as the oldest jawed vertebrate.

‘Horns, hooves, & hounds’ – mandibular morphometrics & the macroevolution of North American mammals through the Cenozoic §

S. Singh¹, M. Stockdale⁴, C. Janis³, M. Benton¹

1 School of Earth Sciences, University of Bristol, Life Sciences Building, 24 Tyndall Avenue, Bristol, BS8 1TQ, UK
2 School of Earth Sciences, University of Bristol, Wills Memorial Building, Queen’s Road, Bristol, BS8 1RJ, UK

Understanding the driving forces behind macroevolutionary patterns has been the subject of much study, with great attention focused on Cenozoic mammals. The debate over whether intrinsic variation or extrinsic selection pressures takes precedence in influencing macroevolution is on-going and remains highly contentious. The high resolution of the Cenozoic geological record provides a detailed narrative of these extrinsic & intrinsic events, capturing their impacts on mammalian faunas, enabling us to closely study these events and their effects. Here, we use landmark-based geometric morphometric methods to investigate the influence of changing climate & flora on North American mammalian macroevolution; focusing on the ecological changes associated with the decline of forested habitats and rise of open habitats such as grasslands. By analysing mandibular disparity, we can achieve a more complete understanding of how environmental pressures can influence feeding ecology, and ultimately direct macroevolution. Using morphospace plots, we chart the mandibular morphometric transitions of North American, perissodactyl assemblages through the ecological changes of the Cenozoic, with additional regression analyses against floral diversity. Furthermore, we include a complementary morphometric analysis of the Canidae, as a contrasting outlook on the extent to which floral/environmental changes can influence wider mammalian macroevolution. Our study provides a new eco-morphological perspective to traditional, phylogenetic analyses, illustrating how utilisation of novel, quantitative methods can advance our understanding of palaeobiology.

Ontogenetic modifications of the pelvic girdle and hindlimb revealed by an subadult specimen of *Protoceratops andrewsi* ¶

J. Słowik¹

1 University of Warsaw, Department of Paleobiology and Evolution, ul. Zwirki i Wigury 101, 02-089, Warszawa, Poland

A nearly complete articulated skeleton ZPAL MG D-11/3 of subadult early ceratopid dinosaur *Protoceratops andrewsi* from the Dinosaur Formation of the Gobi Desert provides new evidence on postcranial variability. Reconstruction of the pelvis shows the dorsal margin of the ilium is typical for *P. andrewsi* in its erect pose, and straight, long, and slender ischium with expanded distal end. However, the pubis differs in shape in comparison with adult *P. andrewsi* – postpubis is oriented backward, not downward and then backward, so there is no obturator notch, also the shape of the prepubis is different. The right femur with a very large fourth trochanter is poorly preserved. Articulated tibia and fibula are long and slender, the proximal, as well as distal, ends are poorly preserved. Most probably they were broken before the specimen was buried. The pes lacks tarsus and the metatarsus is compact, long, and slender. Most phalanges are present, and the finger’s formula is typical for *Ceratopsia* (2,3,4,5,0), although the unguals are pointed, not rounded. It appears that anatomical modifications remained in *P. andrewsi* until its subadult ontogenetic stage.

The transition of the Actinopterygii through the end-Triassic extinction event ¶

F. M. Smithwick¹

1 School of Earth Sciences, University of Bristol, Wills Memorial Building, Queen’s Road, Bristol, BS8 1RJ, UK

The end-Triassic extinction event (ETE) represents one of the least understood major biotic crises in Earth history. Although we are beginning to appreciate the causes and abiotic consequences of the event, little work has been undertaken into interpreting the effects on the biosphere. No work has yet attempted to quantify the transition of one of the most important and successful groups of the Phanerozoic, the Actinopterygii, through the ETE. Using proven landmark morphometrics and functional morphometrics from published photographs and museum specimens, the transition of the Actinopterygii is quantified in a morphological context, from the Early Triassic to the Late Jurassic. A detailed study of the feeding mechanics of a major genus of actinopterygian, *Dapedium*, is also undertaken using mathematical models to ascertain reasons for the group’s radiation in the earliest Jurassic. Initial results suggest that actinopterygian diversity drops significantly between the latest Triassic and earliest Jurassic, along with morphological disparity. *Dapedium* is shown to be a generalist durophage, an ecological mode known to do well post-mass extinction, and thus the
radiation of *Dapedium* may show a freeing up of ecospace in the after
term of the end-Triassic extinction event. Data from the most
diverse vertebrate clade therefore appears to show that the ETE
had a wider effect on the marine realm than previously thought.
Further study of major clades through the ETE will help to further
elucidate the event’s role in shaping vertebrate evolution.

**Assembling the Early Palaeozoic terranes of Japan**

_C. P. Stocker¹, M. Williams¹_

¹ University of Leicester, Department of Geology, University Road, Leicester, LE1 7RH, UK

The Lower Palaeozoic fossils of Japan are widely documented and
have been collected for over 100 years. They include extensive
faunas of trilobites, brachiopods, corals, ostracods, and conodonts,
but their palaeontological significance outside of Japan is largely
unknown. Despite Japan’s rich geological heritage, the use of its
fossils for reconstructing the Early Palaeozoic biogeography of
East Asia have been under-utilised, partly because the materials
are in need of extensive taxonomic revision. Here, we review the
geographical distribution of the Japanese Lower Palaeozoic and its
fossil content. We identify key fossil faunas and methods by which
we can help assemble the Early Palaeozoic terranes of Japan.

**Dental character analysis and evolution of hadrosaurid dinosau-
s**

_E. Strickson¹_

¹ 28 Russell Road, Westbury Park, Bristol, BS6 7UB, UK

Hadrosaurids dominated the herbivorous niches of five continents
in the Late Cretaceous. Their success has often been attributed
to their feeding abilities, namely their complex dental batteries and
ability to continuously masticate. Using data collected from
museums from around the world, dental characters of hadrosaur-
ids and other ornithopods were analysed in an attempt to estab-
lish how directly tooth morphology led to their success. Through
phylogenetic studies and through principal component analysis
with morphospaces, the disparity and diversity of hadrosaurs was
compared and their evolution analysed in light of their feeding
mechanisms and dietary change.

**Cranial musculoskeletal anatomy of *Psittacosaurus lujia-
tunensis***

_A. C. Taylor¹, S. Lautenschlager³, E. J. Rayfield¹_

¹ School of Earth Sciences, University of Bristol, Life Sciences Building,
24 Tyndall Avenue, Bristol, BS8 1TQ, UK

The pseudomusser is a novel jaw closing muscle developed in
some species of parrots, which forms a muscular cheek superfi-
cially similar to the mammalian masseter muscle. The presence of
a pseudomusser-like muscle was hypothesised (in a previous
study) in a group of dinosaurs called psittacosauras as a result of
the evolution of psittacosaurus (Ornithischia: Ceratopsia) was originally named for the resemblance of
their skull shape to that of psittaciform birds (parrots); however,
there is a lack of evidence for any form-function correlation, or
the evolutionary transformation leading to a de novo muscle. Evi-
dence for a de novo muscle currently only relies on tentative muscle
scars. Here, a three-dimensional, digital model of the jaw adductor
anatomy of *Psittacosaurus lujianensis* has been created, using a
detailed and stepwise approach. This revised musculature model
reveals the extent of hypothesised convergence between two evol-
utionary disparate organisms, and will be well suited to further
quantitative functional analysis. Moreover, study of the skulls of
various other basal ceratopsians reveals whether the muscle at-

**Environmental drivers of crocodyliform extinction and di-
versity**

_M. Topham¹_

¹ Department of Earth Science and Engineering, Royal School of Mines,
Prince Consort Road, Imperial College London, SW7 2BP, UK

Crocodyliforms are a major group of extant pseudosuchian arch-
osaurians. However, their diversity patterns through time are poorly
known in the context of our current understanding of sampling
biases. The Jurassic–Cretaceous interval witnessed the extinction
and radiation of numerous major clades, punctuated by multiple
catastrophic events and long-term environmental perturbations.

Shareholder Quorum Subsampling (sqs) was applied to a
newly compiled dataset of global crocodyliform fossil occurrences,
combined with the use of a new supertree to estimate phylogenetic
diversity through this time. Three-tiered and boundary-crosser
origination and extinction rates were calculated, to see if there
is evidence for a consistent trend using independent datasets.
Finally, we fitted maximum likelihood models to this range of
diversity and extinction estimates using a suite of environmental
data to infer the drivers of these patterns.

We find strong evidence for a major diversity crash through
the J/K boundary, from which marine crocodyliforms never
recovered. Terrestrial crocodyliforms, including semi-aquatic
forms, recover rapidly to achieve pre-Jurassic–Cretaceous extinc-
tion levels. A combination of geochemical cycling and sea-level
changes drove these long-term macroevolutionary patterns in
crocodyliforms.

**Extinction geography and sampling of marine invertebrates at
the K–Pg boundary**

_M. Topham¹_

¹ University of Bath, Claverton Down, Bath, BA2 7AY, UK

The Cretaceous–Palaeogene (K–Pg) event is the most recent of the
Big Five mass extinctions, occurring about 66.0 Ma. Thought to
have been caused by the impact of an asteroid, the huge changes to
the environment and climate caused the extinction of about 80%
of all species including, famously, the non-avian dinosaurs. How-
ever, it isn’t well known how sampling affects extinction rates, or
how extinctions vary geographically.

To study these problems, data was collated from the Paleobi-
ology Database. It covers the Maastrichtian and Danian ages, and
contains 30,514 occurrences and 1,422 genera from seven marine
invertebrate taxa: Bivalvia, Gastropoda, Echinodermata, Brachio-
poda, Cephalopoda, Bryozoa, and Polychaeta. _R, past, and Es-
timateS_ were used to analyse the data using Chi-squared tests, res-
mapping simulations, and logistic regression.

The results show that there is a significant hemispherical dif-
ference in the probability of survival of marine invertebrates across
the K–Pg boundary for all but one taxon group – Bivalvia. Res-
mapping simulations indicate that higher levels of sampling in the
Maastrichtian makes the extinction appear to be more severe,
whereas in the Danian the more sampling there is, the less severe
the extinction appears.

Geographic distribution has an effect on chances of survival.
Sampling bias has an impact on what data appears to show. These
results could have applications in understanding areas that are vulnerable to extinction in present day climate change, and it is important to be aware of the effects of sampling so as to avoid drawing false conclusions from data.

Crocodilians of the Hell Creek Formation of north-west South Dakota USA: an investigation into niche partitioning

E. Wallace

1 School of Earth, Atmospheric and Environmental Sciences, University of Manchester, Oxford Road, Manchester, M13 9PL, UK

Fossilised crocodilian teeth are common within the Hell Creek Formation of north-west South Dakota, but have hitherto not undergone detailed study. The three species formerly described are: Thoracosaurus neocesariensis, Borealosuchus sternbergii, and Brachychampsa montana. This study aims to identify crocodilian teeth collected in the Hell Creek Formation, determine if there are any significant differences in the sizes and curvatures of teeth between species, and establish how they were able to coexist. Ninety-six isolated teeth have been collected from a single locality in north-west South Dakota. The height, labial-lingual depth, proximal-distal width, and curvatures (labial, lingual, and curvature at the carina) were measured for each tooth. Linear regressions and ternary diagrams were used to analyse size and curvature measurements within and amongst the taxa. The teeth were identified as Borealosuchus sp., Thoracosaurus sp., and Brachychampsa sp. Results show a relationship between tooth proportion (height, depth, and width) and species with regards to Borealosuchus and Brachychampsa, but not Thoracosaurus, and there is no correlation between curvature and species. However, the general skull and dental morphologies of these taxa suggest different feeding habits and thus potential niche partitioning. Brachychampsa had short, broad, and flat teeth towards the posterior end of the dentary, capable of shell crushing, whereas the snout morphology of Thoracosaurus and Borealosuchus suggest Thoracosaurus was piscivorous, whereas Borealosuchus was carnivorous. Dietary resource partitioning enabled the coexistence of these three species. Further analysis using 3D morphometrics and histology may explicate the species of crocodilian that once resided in the Hell Creek Formation.

Exploring phosphatisation: evidence from Lebanese fossil polychaetes

P. Wilson1, L. Parry1,2, J. Vinther2, G. Edgecombe3

1 School of Earth Sciences, University of Manchester, Oxford Road, Manchester, M13 9PL, UK

2 Department of Earth Sciences, Natural History Museum, Cromwell Road, London, SW7 5BD, UK

The preservation of soft-tissue is extremely rare within the fossil record, but where preserved, yields unprecedented insights. Among the processes responsible for the permineralisation of labile tissues, phosphatisation is key, often replicating muscle tissue and digestive tracts in high fidelity, three-dimensional calcium phosphates. While recent efforts have elucidated the broad triggers of this process, understanding of the fine-scale geochemical and diagenetic controls that bring about phosphatisation is poor, due to the limited extent to which such tissues are normally preserved. However, the discovery of a small number of polychaetes (n = 9) showing full-body phosphatisation, from the Cretaceous (Cenomanian) Lebanese Lagerstätten of Haqel and Hjoula have allowed a unique opportunity to explore this territory and elucidate the triggers that are responsible for extensive phosphatisation, especially considering their unique taphonomic condition among fossil polychaetes worldwide. In order to explore this theme, we attempted to diagnose the animal based solely upon the musculature preserved using myoanatomical mapping and SEM, comparing these reconstructions with extant CT-scanned polychaetes. This revealed a common taxonomic affinity among these fossil polychaetes, belonging to a new species within the Amphinomidae (fireworms). Also revealed are three prominent biases that influence the process of phosphatisation: 1) a taxon bias limited to this specific amphinomid; 2) a tissue bias, where certain tissues are replicated to higher fidelity; and 3) a locational bias, where different body regions have varying fidelities. A robust explanation for this phenomenon is, however, lacking, highlighting a need for further investigation of phosphatisation biases.

An examination of differences in feeding ecology between successive fossil proboscidean faunas from south China as revealed by dental microwear texture analysis (dmta)

S. Zhang

1 School of Earth Sciences, University of Bristol, Wills Memorial Building, Queen’s Road, Bristol, BS8 1RJ, UK

Recently, geochronologically well-constrained successions of Pleistocene fossil mammal faunas have been reported from the karst caves around Chongzuo, Guangxi Zhuang Autonomous Region in south China: the early Pleistocene Gigantopithecus-Synomastodon fauna, the middle Pleistocene Ailuropoda-Stegodon fauna, and the late Pleistocene Homo-Elephas fauna. Overriding trends through these fossil successions include decline and extinction of Neogene relict taxa among large mammals, and reduction of forest- and bamboo forest-dwelling taxa among small mammals. The succession of fossil proboscidean genera in a confined area, coupled with high sensitivity of newly-devised 3D dental microwear texture analysis (dmta) as strongly independent proxy for dietary differences, enable testing of the role of feeding preference in macroevolutionary faunal successions. High-resolution epoxy casts of dental wear facets from Sinomastodon, Stegodon, and Elephas from the Chongzuo area were analysed under an Alicona Infinite Focus microscope using International Organisation for Standardisation (ISO) roughness parameters. Preliminary analyses of 3D image outputs from Sinomastodon and Stegodon already reveal statistically significant differences in wear facet texture, as previously predicted from dental morphology and other lines of inference described in the literature. Following the null-hypothesis that changes in vegetation driven by a continuous Pleistocene drying trend drove the proboscidean succession in south China, the resultant principal coordinate analysis (pco) of dental wear facet roughness parameters should place Sinomastodon and Elephas in highly distinct morphospace, with Stegodon as intermediate. Occupation of very similar morphospace by more than one genus would indicate some mechanism of competitive displacement at work.

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Introduction  The Usk inlier is a classic Silurian locality located in south-east Wales. The rocks range in age from Wenlock to Pridoli (~433 Ma to ~419 Ma). The Silurian rocks occur in a domed fold (pericline), surrounded by the Devonian Old Red Sandstone. The localities that we will be visiting are composed of the Ludlow Upper Bringewood Formation on the western side of the Llandegveth reservoir and the Wenlock Limestone at the disused Cilwrgi Quarry. The fossils are a classic Silurian shelly fauna, composed of abundant brachiopods, bivalves, gastropods, fragmentary trilobites, tabulate and solitary corals, and bryozoans.

Geological Setting  The rocks of Usk were deposited in a shallow marine environment and are approximately 600 m thick and exposed over an elliptical area approximately 15 km long and 8 km wide. The geology of the area is described in detail by Walmsley (1958). The rocks at Usk were deformed in the Carboniferous, during the Hercynian Orogeny, resulting in the plunging anticline in which the Silurian rocks are exposed. Fossils are typically preserved as casts and moulds in the Bringewood Formation, although original shell material is present but rare at the Llandegveth locality.

Biota  Upper Bringewood Formation.

Brachiopods
Articulate  
*Sphairirynchia wilsoni*  
*Isorthis orbicularis*  
*Gypidula lata*  
*Atrypa reticularis*  

*Strophonella euglypha*  
*Leptaena depressa*  

Location of the Usk locality and general stratigraphy of the rocks. From Walmsley (1958) and Haslett (2012).
Illustrations of fossils from the Usk area. From Haslett (2012).

Inarticulates
   *Lingula* sp.

Tabulate corals
   *Favosites*

Trilobites
   *Dalmanites* sp.
Introduction
The rocks exposed in numerous quarries around Craswall belong to the Early Devonian St Maughans Formation. This unit comprises red-green–grey sandstones and mudstones, interbedded with calcrete and conglomerate layers (Allen & Tarlo 1963; Allen 1964). It is around 400–700 m thick. The base of the unit is delimitated by the Bishop’s Frome Limestone member of the Raglan Mudstone Formation, while the Senni beds, which are relatively more sand dominated, demarcate the top of the formation (Brandon et al. 1989). The sediments of the St Maughans Formation contain disarticulate and fragmentary remains of jawless and jawed vertebrates, as well as arthropods and early vascular plants. In rare siltstone lenses, however, vertebrate taxa are preserved as articulated death assemblages (Dineley & Metcalf 1999).

Geological setting
The sediments of the St Maughans Formation were deposited in a braided stream system, close to the shoreline of the arid Euramerican continent (Allen & Tarlo 1963). This formation is characterised by vertically repeating cyclothem sequences comprising a scoured surface – typically with associated conglomerate lenses – with an overlying cross-bedded sandstone facies that grades upwards into a siltstone facies (Allen 1964). These facies are thought to represent erosive channel base, channel infill and floodplain deposits respectively. Discontinuous green siltstone lenses with articulated fish remains likely represent cut off channels in which the fauna becomes trapped, dies, and is subsequently buried during flooding events (Dineley & Metcalf 1999).

Biota
The vertebrate fauna is dominated by ostracoderms, particularly pteraspis heterostracans such as Rhinopteraspis crouchi (White 1935). The osteostracans, thelodonts and acanthodians of nearby Wayne Herbert Quarry have been described by Miles (1973), Turner (1982), and Keating et al. (2012). A diverse early vascular plant fauna from Craswall has recently been described by Morris & Edwards (2014).

Vertebrates

Osteostracans
- Diademaspis janvieri
- Janaspis punctata
- Janaspis newtonensis
- Zenaspis waynensis

Heterostracans
- Rhinopteraspis crouchi

Errivaspis waynensis
Poraspis sericea
Weigeltaias sp.
Thelodonts
Nikolivia milesi

Tabulate corals
Favosites

Trilobites
Calymene sp.
Dalmanites sp.
Generali
sed cyclothem sequence
typical of the St Maughans Formation from nearby Abergavenny. From Allen (1964).

Block diagram depicting river depositional facies typical of the St Maughans Formation. From Allen (1964).
Taxa from the St Maughans Formation. A, Rhinopteraspis crouchi; B, pteraspid plate section; C, etched pteraspid plate, showing histological layers; D, Errivaspis waynensis; E, Janaspis newtonensis; F, Ptomacanthus anglicus; G, Zenaspis waynensis; H, Monnowella bennettii; I, Craswallia haegensis; J, Zosterophyllum strobili

“Acanthodii”

Ptomacanthus anglicus
Vernicomacanthus waynensis
Uraniacanthus spinosus

Arthropods
Pterygotus anglicus?
Preacturas gigas

Plants
Monnowella bennettii
Cooksonia hemisphaerica
Aberlemnia sp.
Salopella allenii
Zosterophyllum strobili
Craswallia haegensis
**LOCALITY 3: AUST CLIFF  ELEANOR HOLDER**

**Grid reference: ST 566895**

**Introduction**  Aust Cliff is located below the Severn Bridge on the shores of the Severn Estuary, and is Britain’s best locality for Rhaetic fossil fish. Exposures of Upper Triassic and Lower Jurassic strata lie unconformably upon a Carboniferous limestone basement, blocks of which can sometimes be found along the shore (Dineley & Metcalf 1999). The lower portions of the cliff belong to the non-fossiliferous Mercia Mudstone Group, but are overlain by the fossil-rich Penarth Group, which includes the Rhaetiac bone bed. Aust Cliff is noted for numerous fish remains as well as marine and terrestrial reptile fossils (Dineley & Metcalf 1999).

**Geological setting**  The Mercia Mudstone Group exposure at Aust cliff consists of the Red (Keuper) Marls and the Tea Green Marls (together the Blue Anchor Formation), and comprises a majority of the cliff section (~37 m). These are interpreted as wind blown deposits and evaporite sequences deposited in Triassic deserts (Dreghorn 1967; Dineley & Metcalf 1999). These variably-coloured units are largely non-fossiliferous.

The Rhaetiac, including the highly fossiliferous ‘Rheatic bone bed’, is represented by the Penarth Group, thought to have been deposited within 1–2 Ma (Benton et al. 2002). This is further broken into the Westbury Formation and the Lilstock Formation, the latter of which is composed of the Langport and Cotham members (Swift & Martill 1999). The Penarth Group represents shallow lagoon deposits formed during a period of marine transgression ~190 Ma and comprises dark grey and black shales, and argillaceous limestones (Dreghorn 1967; Dineley & Metcalf 1999). Sedimentary structures, such as ripple marks, can be seen on the surface of the limestone layers (Swift & Martill 1999). The bone beds are locally discontinuous (Swift & Martill 1999), and composed of grits and conglomerate that contain clasts of the underlying Blue Anchor Formation (Dreghorn 1967; Swift & Martill 1999; Benton et al. 2002). This, combined with the worn nature of the vertebrate fossils and the presence of terrestrial and marine vertebrate material within the unit, suggests a reworked deposit or storm event deposits in shallow marine waters (Swift & Martill 1999; Benton et al. 2002).

At the top of the cliff section is the very base of the Lower Lias, representing the earliest Jurassic, and a fully marine palaeoenvironment. The lower part of the Jurassic is also denoted by the occurrence of the *Psiloceras planorbis* Ammonite Biozone (Simms et al. 2004).

**Biota**  Aust Cliff is known for its fish remains and is the type locality for the actinopterygian *Severnichthys acuminatus*, the hybodont shark *Lissodus minimus*, and the lungfish *Ceratodus latissimus* and *Synectodus rhaeticus* (Dineley & Metcalf 1999). Other vertebrate remains include ichthyosaur, plesiosaur, and terrestrial material from dinosaurs, such as the prosauropod *Camelotia borealis* (Swift & Martill 1999).

Fish remains are the most common fossils at Aust Cliff, from both the Actinopterygii (e.g. Teleostei: *Pholidophorus higginsi*; Halcostomi: *Legnonotus cothamensis* and Sarcopterygii (e.g. Ceradontidae: *Ceratodus latissimus*). Condrichthyan material, such as scales and teeth, are also common. It is also possible to find fish and shark coprolites, which sometimes contain crustacean and other fish material (Dineley & Metcalf 1999).
Invertebrate fossils can also be found at Aust including bivalves, gastropods (although rare), and insects (Swift & Martill 1999). An in depth description of all the Penarth group biota can be found in Swift & Martill (1999).

References


