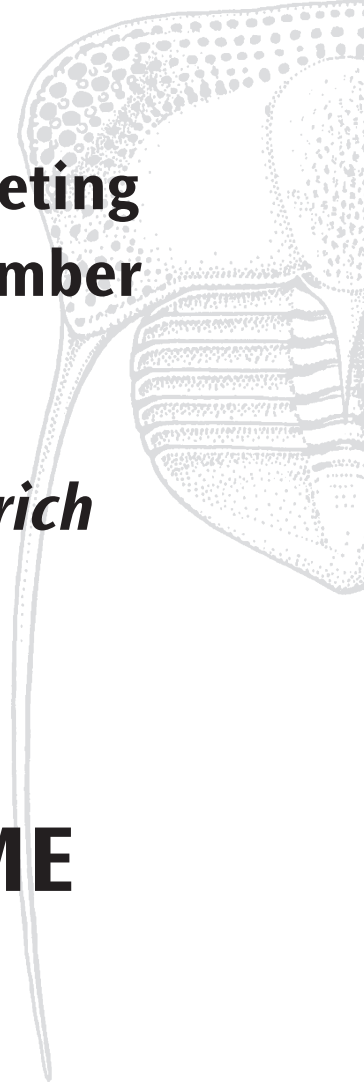


**The
Palaeontological
Association**

**57th Annual Meeting
13th–16th December
2013**

***University of Zurich
Switzerland***

**PROGRAMME
and
ABSTRACTS**





The Palaeontological Association

57th Annual Meeting

13th–16th December 2013

University of Zurich, Switzerland

The programme and abstracts for the 57th Annual Meeting of the Palaeontological Association are provided after the following summary of the meeting.

Venue

The Conference will take place at the Universitaet Zentrum (see directions map), University of Zurich, which is a ten-minute walk uphill from the main station (HB = Hauptbahnhof). Accommodation we have reserved is nearby, so no further public transport will be needed to get to the lecture halls from your hotel (only if you stay in places further away, obviously). However we will use public transport to get to the Conference dinner. Tickets will be provided and we will guide you there in small groups.

Maps

Four maps have been prepared to assist delegates in navigation in Zurich. A map is available for each of the following categories: hotels; directions; pubs/bars; conference dinner. The maps can be downloaded as jpg files from the Annual Meeting website.

Registration and booking

Registration, abstract submission and booking (including payment by credit card) commenced on Monday 1st July 2013. The final deadline for registration is Friday 15th November 2013. Registrations and bookings will be taken on a strictly first-come-first-served basis. No refunds will be available after the final deadline.

Registration, abstract submission, booking and payment (by credit card) is through online forms available on the Palaeontological Association website (<<http://www.palass.org/>>). Please note that all transactions will be in sterling (£:GBP). Accommodation must be booked separately (see below).

The cost of registration is the same as last year. Early registration is €110.00 (approximately £90.00, US\$140.00) for ordinary and retired members; €75.00 (approximately £60.00, US\$95.00) for students; and €145.00 (approximately £120.00, US\$185.00) for non-members. Registration costs include sandwich lunches on Saturday and Sunday, the reception on Friday evening, full registration package and tea/coffee breaks.

The Annual Dinner event costs €60.00 (approximately £50.00; US\$75.00). It will be held in the Uto Kulm Restaurant on the Uetliberg (<<http://www.utokulm.ch/en/restaurant/>>), a mountain next to Zurich (see conference dinner map). The evening's festivities will include a drinks reception, a salad



buffet and a classical Swiss cheese fondue. To get to the restaurant, we will guide you to the train and will travel to the highest mountain of Zurich, the Üetliberg (870 m). From the train station, it will still be a short walk of 500 m (60 m in altitude). The last train from the mountain is at 0.03am, so the restaurant closes around 11.45pm.

If you are not able to walk a short distance, please contact <annualmeeting@palass.org> to arrange a shuttle.

Oral contributors

All speakers (apart from the symposium speakers) have been allocated 15 minutes. You should therefore prepare a 12 minute talk to allow time for questions and switching between presenters. We are using a limited number of parallel sessions in adjacent theatres so this is especially important. A single A/V projector linked to two screens (*i.e.* displaying the same image) is available; the system is both Mac- and PC-based and PowerPoint is installed. We will try to accommodate anyone who requires other platforms/hardware, provided they bring these with them. Your presentation should be submitted and checked the day before it is scheduled. If this is not possible, then please contact me.

Poster contributors

Poster boards are *c.* 2m tall and 1m wide; they will not be supplied with power sockets. Each will accommodate an A0-sized poster presented in PORTRAIT format. The board will *not* be suitable for posters of this size in landscape format.

Should I bring materials to fix the poster to the board?

You can, but you don't have to.

May I ship my poster to you in advance to avoid baggage charges?

Of course: ship it to me (allowing time for Christmas post) at Christian Klug, Paläontologisches Institut und Museum, Karl Schmid-Strasse 4, CH-8006 Zürich. E-mail me at <annualmeeting@palass.org> to advise that you have done so. You can collect your poster upon arrival. (You may wish to bring the poster on a USB stick in case it is lost or damaged in the post, but we do not have access to an A0-printer here, so you would have to go to a shop nearby to get it printed in the worst case.)

Friday 13th: Symposium and Icebreaker reception

The meeting will begin on Friday afternoon with the Symposium followed by the icebreaker reception.

Please note that this scheduling is different from previous years.

The **Symposium** is on 'Fossilised ontogenies and evolution'. We are extremely grateful to the Palaeontological Association for their sponsorship of the Symposium and the Annual Address.

The **Icebreaker reception** will be held at the Zoological Museum. Many thanks to the city of Zurich for sponsoring this event!

Saturday 14th to Sunday 15th: Conference, and Association AGM

The Conference itself will commence on Saturday 14th December with a full day of talks and posters and the Association AGM. The lectures will be mainly in the large lecture hall **KOL2-F-180**, which is suspended above the Zoological Museum (see directions map), and parallel sessions might be held in the afternoons in lecture hall **KOL-F-118 E 5029**. In the evening there will be the Annual Dinner. After the Dinner, everybody is free to go to bed or find a pub or bar (see pub map).



Sunday 15th December will comprise a dedicated poster session and talks. The time allocated to each talk will be 15 minutes; we will try to avoid parallel sessions, however they will be organised for part of each day if really required to accommodate as many speakers as possible.

Monday 16th: Fieldtrips

Field trip A (Dinosaur museum Aathal): £40.00

[without lunch]

We will take public transport (included) from the main station of Zurich to the village of Aathal. After a ten-minute walk we will be at the Museum. We will be guided either by the director Dr H.C. Hans-Jakob Siber or by the vice-director Dr Thomas Bolliger. The Sauriermuseum Aathal was founded by Dr Hans-Jakob Siber and has become world-renowned for its world-class dinosaur skeletons, which were excavated by Siber's team. Lunch will be either at the Italian restaurant next door or in the Museum. The tour will end around 3pm (back in Zurich around 3.30pm), making it possible – for those who wish to travel home the same day – to catch a late flight.

Fieldtrip B (Ticino, Monte San Giorgio, Museum Meride): £110.00

[including one night in a hotel (shared rooms) from Sunday to Monday, breakfast, museum fee, transport; dinner + lunch will have to be paid individually]

Directly after the last talk, we will take three VW-buses to Ticino. We will have lunch directly south of the St. Gotthard-tunnel and will arrive at our hotel around 10pm. On Monday, Dr Heinz Furrer (Curator of the Palaeontological Museum of the University of Zurich) will guide us to two localities in the Monte San Giorgio area (it might be cold, but usually there is not a lot of snow) and we will visit the new and excellent museum in Meride, which exhibits fossils from the Triassic of Monte San Giorgio as well as spectacular models of the animals of Monte San Giorgio made by Beat Scheffold (Collection assistant, producer of palaeontological reconstructions). We will head back to Zurich around 3pm and will be at Zurich around 7pm (the time of arrival might vary significantly depending on weather conditions and traffic).

The number of participants is limited to 24.

Getting to Zurich

For those who wish to avoid flying, Zurich can be reached by combining rail (*e.g.* via Paris, TGV usually takes about 4–5 hours to Zurich) or bus links, which might be more or less cheap but obviously time consuming. For the majority, flying will be the best option.

Plane

Zurich is served by Zurich Airport Kloten (ZRH), which is located north of Zurich City Centre. There are currently direct air links (including EasyJet from London) into Zurich from a large number of airports globally, and, in particular, from Britain, continental Europe and North America. Early booking is recommended if you want to get a good bargain. It is usually worthwhile consulting search engines such as, *e.g.*, <<http://www.jetcost.co.uk/>> or <<http://www.ebookers.com/>>, which search several providers and airlines.

Another option is flying to Basel/Mulhouse airport. From there, a bus takes you to the main station in Basel city. There are fast trains to Zurich, which take about one hour. So in total, the journey Basel airport – Zurich would take about 1h 30min.



Transferring from the airport

There are frequent connecting “S-Bahn” (city trains) and regular trains from the airport to the city centre (main station = Hauptbahnhof). You can use all of those where Zurich HB is indicated (some are faster, some slower) with the same ticket from the vending machine in the airport (around £2 to £3; you can pay in Euros, Swiss Francs, Maestro, Postbank card, etc.). The transfer takes 10 to 15 minutes.

Getting to the Universitaet Zentrum-building (University of Zurich)

Once you’ve reached the main station (Zurich HB), leave the building towards the River Limmat. Be careful, because there is also the River Sihl, which is also close to the train station (see directions map). You can always ask because most of the locals speak English well and are very helpful. Cross the Limmat and continue to a large roundabout with a bus stop and a tram stop (“Central”). From there, you can:

- walk up the stairs: <<http://www.plaene.uzh.ch/KO2#ankermap>>
- take tram 6 or 10 to the stop ETH/Universitaetsspital then follow the directions map; you can find a map of all connections within the city with this link: <http://www.zvv.ch/opencms/export/sites/default/common-images/content-image-gallery/linien-zonen-pdfs/Liniennetzplan_Stadt_Zuerich_2012.pdf>
- take the cable car (Polybahn; see directions map). The entrance is next door to Starbucks at Central (across the river from the main station). It costs 1 CHF (it is included when you have a valid ticket for Zone 110); there is a vending machine at the entry of the Polybahn. It is a short romantic ride, which takes you to the Polyterrasse, which is a large terrace providing a nice view over the town. Cross the terrace and turn left into the Karl Schmid-Strasse. The entrance is between the two fishponds.

As always, we will put up signs to guide you, once you are close to the lecture halls.

Train

Zurich is served by one main railway station: Zurich HB (main station = Hauptbahnhof). There are TGVs from Brussels and Paris, ICs from Frankfurt, Stuttgart and Berlin, and the Cisalpino from Milano. They are all rather comfortable and fast. Make sure to check whether you need reservations or not.

Local public transport: Tram and bus

Public transport is excellently organised in Switzerland and the costs are reasonable. In Zurich, there is a tram stop or a bus stop roughly every 300 m. You can get short-distance tickets (“Kurzstrecke”; only valid to the destinations listed on the vending machine), one-hour tickets (in Zurich for Zone 110, which is the majority of the city) and 24-hour tickets for Zone 110. Zurich is not a very big town, so many places can easily be reached on foot. Bear in mind, however, that there are many hills and walking through Zurich might involve climbing many stairs.

Taxi

There are usually abundant taxis in operation in the city centre at any given time. Zurich taxis are among the most expensive taxis in the world, so I recommend using them only if you are rich or lack another choice. It is possible to hail a taxi from the street, but convenient taxi ranks in the city centre are located on the Hauptbahnhof and around other bigger train or tram stations. You may also call one at +41 (0) 44 4444444 or +41 (0) 43 4555885 or +41 (0) 44 4504242.



Accommodation

Rooms in a variety of hotels, hostels and guest-houses at a range of prices are available in Zurich city centre and can be reserved through the usual channels. In addition, we have organised discount rates at some hotels close to University.

Accommodation must be booked separately. Bookings can be made individually (for students: why not try couch-surfing?) or via the following link (for hotels where we made reservations and where we obtained a cheaper rate, BOOK EARLY: these rates are available only until **6th November**):

<<http://www.zuerich.com/en/kongresslandingpages/kongress31.html>>

Zürich Tourismus, Hotelreservation
Im Hauptbahnhof
Postfach
CH-8021 Zürich
Tel.: +41 44 215 40 40
Fax: +41 44 215 40 44
E-Mail: <hotel@zuerich.com>

A credit card number is required at the time of booking as a guarantee for your room.

These are the included hotels (see Hotels map):

Hotel St. Georges, Weberstrasse 11, 8004 Zürich,
single room 129.50 CHF **double** room 166 CHF

Hotel Limmathof, Limmatquai 142, 8001 Zürich,
single room 145 CHF **double** room 178 CHF

Hotel Scheuble, Mühlegasse 17, 8001 Zürich,
single room 150 CHF

Hotel Astor, Weinbergstrasse 44, 8006 Zürich,
single room 155 CHF **double** room 185 CHF

City Hotel, Löwenstrasse 34, 8021 Zürich,
single room 165 CHF **double** room 230 CHF

Comfort Hotel Royal, Leonhardstrasse 6, 8001 Zürich,
single room 175 CHF

Hotel Alexander, Niederdorfstrasse 40, 8001 Zürich,
single room 180 CHF **double** room 240 CHF

Hotel Adler, Rosengasse 10, 8001 Zürich,
single room 195 CHF **double** room 275 CHF

Rütli, Sorell Hotel, Zähringerstrasse 43, 8001 Zürich,
single room 200 CHF **double** room 230 CHF

Leonardo Boutique Hotel Righihof, Universitätstrasse 101, 8006 Zürich,
single room 300 CHF **double** room 310 CHF

Think about sharing a room to save costs, if necessary!



The hotel costs are not so different from British towns. Nevertheless, we are still working on an option to offer cheaper rates to PhD and other students (see also below).

PhD and Masters students might prefer to stay at the Youth Hostel:

Jugendherberge Zürich, Mutschellenstrasse 114, 8038 Zürich

Tel: +41 43 399 78 00,

E-mail: <zuerich@youthhostel.ch>

Web: <<http://www.youthhostel.ch/zuerich>>

There are several other hotels (some indicated on the Hotels map), which are at a reasonable distance and *not* in this list (Hotel Sunnehus, Design Hotel Plattenhof, Hotel Foyer Hottingen).

Students without funding who are looking for a private place to stay may contact Christian Klug (e-mail <chklug@pim.uzh.ch>).

Travel grants to student members

The Palaeontological Association runs a programme of travel grants to assist student members (doctoral and earlier) to attend the Annual Meeting in order to present a talk or poster. For the Zurich 2013 meeting, grants of less than £100 (or the € equivalent) will be available to student presenters who are travelling from outside Europe. The actual amount available will depend on the number of applicants and the distance travelled. Payment of these awards is given as a disbursement at the Meeting, not as an advance payment. Students interested in applying for a PalAss travel grant should contact the Executive Officer, Dr Tim Palmer (e-mail <palass@palass.org>) once the organisers have confirmed that their presentation is accepted, and before **1st December 2013**. Entitle the e-mail "Travel Grant Request". No awards can be made to those who have not followed this procedure.

Any increase in the granted amount depends on the amount of money that will come in from sponsors.

Why not make a stay of it?!

Switzerland at any time of the year is an excellent destination for a short break; why not come a few days early and see what the country has to offer? Alternatively, if anyone travelling with you is not enthralled by the idea of three days at a PalAss Conference there is plenty to do.

<<http://www.myswitzerland.com/en/home.html>>

<<http://www.zuerich.com/en/Visitor.html>>



The organisers of the Annual Meeting gratefully acknowledge the support of these sponsors:



**University of
Zurich** ^{UZH}

Mathematisch-naturwissenschaftliche Fakultät

**paläontologisches
museum**

der Universität Zürich

**zoologisches
museum**

der Universität Zürich

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Swiss Academy of Sciences
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TREATISE

on Invertebrate Paleontology



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Schedule of events and timetable of presentations

Friday, 13th December 2013

Thematic Symposium *“Fossilised ontogenies and evolution”*

Lecture Hall SOD-1-102, Schönberggasse 2

- 13.45–14.00 **Welcome and introductory remarks**
- 14.00–14.30 **Reproduction and early development of two plants from the Early Devonian Rhynie chert**
Prof. Hans Kerp, Patricia Kearney & Hagen Hass (Universitaet Muenster)
- 14.30–15.00 **Larval ecology in fossil gastropods**
Dr Alex Nuetzel (Bayerische Staatssammlung fuer Palaeontologie und Geologie Munich)
- 15.00–15.30 **Trilobites – the development and evolution of the trilobite trunk region**
Prof. Nigel Hughes (University of California Riverside)
- 15.30–16.00 coffee break
- 16.00–16.30 **Fossilized ontogenies: Gogo placoderms reveal embryonic development in 370 million year old early vertebrates**
Dr Zerina Johanson (Natural History Museum London) and Kate Trinajstic (Curtin University)
- 16.30–17.00 **Life histories of early tetrapods: a diversity of ontogenies**
Dr Rainer Schoch (Staatliches Museum fuer Naturkunde Stuttgart)
- 17.00–17.30 **Gradualism, punctuated equilibria, and missing links in developing teeth**
Prof. Jukka Jernvall (University of Helsinki)

Annual Address

- 17.30–19.00 **Sharks and the deep origin of modern jawed vertebrates**
Prof. Michael Coates (Department of Organismal Biology and Anatomy, University of Chicago)

Reception

- 19.00–23.30 Icebreaker reception at the Zoological Museum.



Saturday 14th December 2013: Conference and Association AGM

Oral Presentations

* Candidates for the President's Award are marked with an asterisk.

+ denotes speaker other than the first author.

08.45 **Welcome**

Session 1: Proterozoic

KO2-F-180: <http://www.plaene.uzh.ch/floormaps/KOL_D.png>

09.00 **Microbial life after the Great Oxidation Event**

* Bettina E. Schirrmester, Martin Brasier and Philip C. J. Donoghue

09.15 **Ancient microbial life on the Indian subcontinent**

* Therese Sallstedt

09.30 **Establishing a Fossil Record of Euglenoids from the 1.1 Ga Nonesuch Formation to the Recent**

Charles H. Wellman, Wilson A. Taylor, Bas van de Schootbrugge, Andreas Koutsodendris and Paul K. Strother

09.45 **Early animals from the Ediacaran Doushantuo Formation?**

* John A. Cunningham, Philip C. J. Donoghue and Stefan Bengtson

10.00–10.30 Coffee

Session 2: Proterozoic, Cambrian

KO2-F-180: <http://www.plaene.uzh.ch/floormaps/KOL_D.png>

10.30 **A Doushantuo-type acritarch assemblage from phosphorite pebbles of the Ediacaran Biskopås Formation of southern Norway**

* Peter W. Adamson and Nicholas J. Butterfield

10.45 **Mathematical models of the morphology of Ediacaran fronds: implications for phylogeny, disparity and the evolution of architectural complexity in an extinct fractal clade**

* Jennifer Hoyal Cuthill

11.00 **Dumbbells, Discs and Inundation: palaeoecological insights from the Ediacaran of Charnwood Forest, UK and Newfoundland, Canada**

* Charlotte G. Kenchington

11.15 **The lateral continuity of Ediacaran fossil surfaces: Implications for taphonomy and palaeoecology**

* Jack J. Matthews, Alexander G. Liu and Martin D. Brasier



- 11.30 **French contribution to the understanding of the emergence of the phoronids–brachiopods total group: Early Cambrian tomotiids and earliest mickwitziid from Montagne Noire, southern France**
* Lea Devaere, Sebastien Clausen, Lars E. Holmer and Daniel Vachard
- 11.45 **Chemical variability of apatite in the shells of Cambrian lingulate brachiopod *Ungula ingraca* (Eichwald)**
* Liisa Lang, Kalle Kirsimäe and Signe Vahur
- 12.00–13.00 Lunch

Session 3A: Palaeozoic arthropods

K02-F-180: <http://www.plaene.uzh.ch/floorplans/KOL_D.png>

- 13.00 **Functional morphology of leanchoilid megacheirans: not sluggish scavengers but agile predators**
* Joachim T. Haug, Derek E. G. Briggs and Carolin Haug
- 13.15 **Neural characters support chelicerate affinities for Cambrian great appendage arthropods**
* Xioaya Ma, Gregory D. Edgecombe, Gengo Tanaka, Hou Xianguang and Nicholas J. Strausfeld
- 13.30 **Taphonomy, morphology and evolutionary significance of fuxianhuiid euarthropods from the Early Cambrian Xiaoshiba biota, South China**
* Javier Ortega-Hernández, Jie Yang, Nicholas J. Butterfield and Xi-guang Zhang
- 13.45 **The phylogeny of ptychopariid trilobites and their derivatives, and the importance of ontogenetic data in analyses of trilobite relationships**
* James C. Lamsdell and Paul A. Selden
- 14.00 **Extraordinary End-Ordovician ostracod association from Kętrzyn IG-1 borehole, NE Poland**
* Karin Truuver and Tõnu Meidla
- 14.15 **A new lobopodian from the Silurian of Canada – a case study in decay-informed palaeontology**
* Duncan J. E. Murdock, Sarah E. Gabbott and Mark A. Purnell
- 14.30 **The mode of life of pterygotid eurypterids: insights from their visual system**
* Ross P. Anderson, Victoria E. McCoy, Maria E. McNamara, and Derek E. G. Briggs
- 14.45 **A new calmanostracan (Arthropoda: Branchiopoda) from the Upper Devonian Strud Lagerstätte, Belgium**
* Linda Løgebro, Pierre Gueriau, Thomas A. Hegna, Nicholas Rabet and Graham E. Budd
- 15.00–15.30 Coffee



Session 3B: Evolution

KO2-F-118: <http://www.plaene.uzh.ch/floormaps/KOL_F.png>

- 13.00 The phylogeny of the Coleoidea – the major ‘constructing areas’
Dirk Fuchs
- 13.15 **Visualizing developmental constraints and the anisotropy of phenotype space**
Sylvain Gerber
- 13.30 **Development of tooth plates in the earliest jawed vertebrates**
Martin Rücklin, Martin D. Brazeau, Philip C. J. Donoghue, Kate Trinajstić and
Zerina Johanson
- 13.45 **Do ‘living fossil’ fishes exist? And does it matter?**
Lionel Cavin and Guillaume Guinot
- 14.00 **Tooth development in batoids (skates and rays)**
Charlie J. Underwood, Moya M. Smith and Zerina Johanson
- 14.15 **The dinosaur–bird evolutionary transition: phylogeny and patterns of
morphological evolution**
Stephen L. Brusatte, Graeme T. Lloyd, Steve C. Wang and Mark A. Norell
- 14.30 **Are there rules underlying body shape evolution in ray-finned fishes? Regionalization
of the axial skeleton in the ambush predator guild**
Erin E. Maxwell, Laura A. B. Wilson and Marcelo Sanchez-Villagra
- 14.45 **Discordance between evolutionary rates and disparity in carnivoran cranial evolution**
Anjali Goswami, Jeroen Smaers, Christophe Soligo and P. David Polly
- 15.00–15.30 Coffee

Session 4A: Devonian, Carboniferous etc.

KO2-F-180: <http://www.plaene.uzh.ch/floormaps/KOL_D.png>

- 15.30 **Root traces and plant–soil interactions of two Middle Devonian trees, New York State**
* Jennifer L. Morris, David J. Beerling, William E. Stein, Chris M. Berry, John E. A. Marshall,
Charles H. Wellman and Jonathan R. Leake
- 15.45 **Body organisation of euchelicerates: developmental clues from fossil and extant
horseshoe ‘crabs’**
* Carolin Haug, Peter Van Roy and Joachim T. Haug
- 16.00 **The impact of fossil data on arthropod phylogeny**
* David A. Legg
- 16.15 **Quantification of volumetric growth and Buoyancy of some Palaeozoic ammonoids**
* Carole Naglik and Christian Klug
- 16.30 **New ammonoid-bearing horizons in the Carboniferous Shannon Basin, Ireland:
further evidence for normal salinities in late Mississippian and Pennsylvanian basins
of north-west Europe**
* Anthea R. Lacchia, Colm Pierce, John R. Graham, George D. Sevestopulo and
Peter Haughton



- 16.45 **Finite element, occlusal, and microstructural analyses indicate that conodont ‘enamel’ microstructure is adapted to dental function**
* Carlos Martínez-Pérez, Emily J. Rayfield, Mark A. Purnell and Philip C. J. Donoghue
- 17.00 **Cranial endocast morphology of ancient ray-finned fishes**
* Sam Giles and Matt Friedman
- 17.15 **Palaeoneurology in Devonian lungfish: addressing morphological diversity or conservatism in the neurological system?**
* Tom Challands
- 17.30 **A new look at the enigmatic *Scaumenella mesacanthi*: Immature stages of two acanthodiform acanthodians from the Late Devonian Miguasha Fossil-Fish Lagerstätte (Canada)**
* Marion Chevrinai and Richard Cloutier

ANNUAL GENERAL MEETING

Session 4B: Palaeozoic

K02-F-118: <http://www.plaene.uzh.ch/floormaps/KOL_F.png>

- 15.30 **On the edge: early land plants and marine algae from the Lower Silurian Kalana Lagerstätte, Estonia**
Oive Tinn, Viirika Mastik, Leho Ainsaar and Tõnu Meidla
- 15.45 **Cambrian–Ordovician plankton diversification: patterns, macroecological significance and limitations**
Taniel Danelian, Thomas Servais, Lauren Pouille, Hendrik Nowak and Jörg Maletz
- 16.00 **A suspension feeding anomalocaridid from the Early Cambrian Sirius Passet, North Greenland**
Jakob Vinther, Martin Stein and David A. T. Harper
- 16.15 **Anomalocaridids had two sets of lateral flaps**
Peter Van Roy, Allison C. Daley and Derek E. G. Briggs
- 16.30 **Origins and early evolution of nacre**
Michael J. Vondrasco and Antonio G. Checa
- 16.45 **Ordovician–Silurian Chileida – first post-Cambrian records of an enigmatic group of Brachiopoda**
Lars E. Holmer, Leonid Popov and Michael G. Bassett
- 17.00 **Biodiversity, biogeography and phylogeography of Ordovician rhynchonelliform Brachiopoda**
David A. T. Harper, Christian M. Ø. Rasmussen, Maria Liljeroth, Richard B. Blodgett, Yves Candela, Jisuo Jin, Ian G. Percival, Jiayu Rong, Enrique Villas and Renbin Zhan
- 17.15 **The third-dimension of the puzzle: morphofunctional and phylogenetic applications of X-ray scanning of Cambrian stemmed-echinoderms**
Sebastien Clausen, Elise Porez, Claude Monnet and Laurence Debeauvais



- 17.30 **Soft-part preservation in a solutan echinoderm from the Fezouata Biota (Lower Ordovician, Morocco)**
Bertrand Lefebvre, Thomas E. Guensburg, Emmanuel Martin, Claire H. Milne, Rich Mooi, Fleur Noailles, and Jean Vannier
- ca. 18.00 Public Transport to the Uto Kulm
- 19.00 Drinks reception at the Uto Kulm
- 19.30 **Annual Dinner**
- Fondue on the Üetliberg in the Hotel Uto Kulm
- 00.03 Last train into town. Don't miss it, it's a long and steep walk!

Sunday 15th: Conference

Oral Presentations

- * Candidates for the President's Award are marked with an asterisk.
+ denotes speaker other than the first author.

Session 5: Poster session

- 08.45–10.00 Lichthof: <http://www.plaene.uzh.ch/floormaps/KOL_D.png>
Coffee

Session 6: Triassic, Jurassic

- KO2-F-180: <http://www.plaene.uzh.ch/floormaps/KOL_D.png>
- 10.00 **High resolution biostratigraphy and biodiversity dynamics of Dienerian (Early Triassic) ammonoids from the Northern Indian Margin**
* David Ware and Hugo Bucher
- 10.15 **New conodonts from the Griesbachian microbialite in South China: implications for an improved definition of the base of the Triassic**
* Morgane Brosse, Nicolas Goudemand, Åsa M. Frisk, Aymon Baud, Borhan Bagherpour and Hugo Bucher
- 10.30 **New evidence for a lamprey-like motion of the grasping elements of ozarkodinid conodonts**
* Nicolas Goudemand, Guido Roghi, Manuel Rigo, Morgane Brosse, Maximiliano Meier, Paul Tafforeau and Severine Urdy
- 10.45 **Evidence for an intra-Early Triassic crisis of benthic ecosystems**
* Richard Hofmann, Michael Hautmann, Elke Schneebeli-Herman and Hugo Bucher



- 11.00 **Systematics, origins and palaeoecology of placodont marine reptiles (Sauropterygia, Placodontiformes)**
* James M. Neenan and Torsten M. Scheyer
- 11.15 **The developmental basis of 200 million year old mammal teeth**
* Ian Corfe, Andy Smith, Teemu Hakkinen, Laura Lammi, Pekka Nieminen, Aki Kallonen, Keijo Hamalainen, Pam Gill and Jukka Jernvall
- 11.30 **Taphonomy and palaeoecology of a Jurassic ichthyosaur: similarities and differences to modern whale falls**
* Silvia Danise, Katie Matts and Richard J. Twitchett
- 11.45 **Large scale environmental gradients as a control on the skeletal taphonomy of Ichthyopterygia**
* Susan R. Beardmore, Patrick J. Orr and Heinz Furrer
- 12.00–13.00 Lunch

Session 7A: Jurassic to Cenozoic

KO2-F-180: <http://www.plaene.uzh.ch/floormaps/KOL_D.png>

- 13.00 **Rhodoliths on a Miocene volcanic island**
* A. Cristina Rebelo, Michael W. Rasser and Sérgio P. Ávila
- 13.15 **High diversity in the polychelidan lobsters community from the La Voulte Lagerstätte (France, Middle Jurassic)**
* Denis Audo, Sylvain Charbonnier, Jean-Paul Saint Martin and Bruno Caze
- 13.30 **Latest Cretaceous Antarctic cephalopods; evolution, extinction, and biogeography**
* James D. Witts, Paul B. Wignall, Jane E. Francis, Rob J. Newton and J. Alistair Crame
- 13.45 **150 million years of morphological evolution in half of all vertebrates: there's something special about teleosts**
* John Clarke, Graeme T. Lloyd and Matt Friedman
- 14.00 **Micro-CT scan-based reconstructions of the inner ear in fossil and extant hedgehogs and gymnures (Erinaceomorpha, Mammalia): phylogenetic implications and perspectives**
* Olivier Maridet, Loïc Costeur, Cathrin Schwarz, Marc Furió, F. M. Van Glabbeek, and Lars W. Van den Hoek Ostende
- 14.15 **Histomorphometry on the postcranium of *Thalassocnus*, the aquatic sloth**
* Eli Amson
- 14.30 **New Zealand Early Miocene dolphins unfold global distribution and early origins of kentriodontids**
* Gabriel Aguirre-Fernandez and R. Ewan Fordyce
- 14.45 **The evolution of seabirds in the Humboldt Current: New clues from the Pliocene of central Chile**
* Martin Chavez Hoffmeister, Briceño Carrillo, D. Jorge and Sven N. Nielsen

15.00–15.30 Coffee



Session 7B: Silurian to Triassic

K02-F-118: <http://www.plaene.uzh.ch/floormaps/KOL_F.png>

- 13.00 **Colonisation of the water column by ostracods in the late Silurian**
Vincent Perrier, Mark Williams and David J. Siveter
- 13.15 **Devonian lycopod forests in Svalbard**
Christopher M. Berry and John E. A. Marshall
- 13.30 **Tabulate corals on crinoids: unusual biocoenosis from the Lower Devonian of Morocco**
Błażej Berkowski and Mikołaj K. Zapalski
- 13.45 **Diversity among new Tournaisian tetrapods from Scotland**
Jennifer Clack and Timothy R. Smithson
- 14.00 **Romer's Gap: a surprisingly productive period in vertebrate evolution**
Timothy R. Smithson and Jennifer Clack
- 14.15 **The Lilliput Effect in the latest Permian ammonoids from Iran**
Dieter Korn, Lucyna Leda, Abbas Ghaderi, Vachik Hairapetian and Martin Schobben
- 14.30 **Permian–Triassic fishes: extinction and recovery**
Carlo Romano and Martha B. Koot
- 14.45 **Diversification and diversity partitioning in Early Triassic benthic ecosystems**
Michael Hautmann, Richard Hofmann, Åsa M. Frisk, Morgane Brosse and Hugo Bucher
- 15.00–15.30 Coffee

Session 8A: Methods, varia

K02-F-180: <http://www.plaene.uzh.ch/floormaps/KOL_D.png>

- 15.30 **Experimental decay and disarticulation of phyllocarids, and the implications for the arthropod fossil record**
* Oliver J. Kneivt, Mark A. Purnell and Sarah E. Gabbott
- 15.45 **The taphonomy of tooth wear – quantifying the impact of post-mortem abrasion on tooth surface microtextures**
* Laura McLennan and Mark A. Purnell
- 16.00 **Trace elemental imaging of well-preserved fossils: a new tool for palaeontological and taphonomical studies**
* Pierre Gueriau, Cristian Mocuta, Didier B. Dutheil, Serge X. Cohen, Dominique Thiaudière, Sylvain Charbonnier, Gaël Clément and Loïc Bertrand
- 16.15 **A new R package for automating cladistic ordination and the effects of phylogenetic signal on disparity measures**
* Graeme T. Lloyd
- 16.30 **Stable isotope compositions in shark dental tissues as a proxy to seawater chemistry**
* Živila Žigaitė, Ivan Sansom, Martin Whitehouse and Michael Joachimski



- 16.45 **The earliest pearls in the mollusc fossil record: clues for complex parasite life cycles or collection biases?**
* Kenneth De Baets and Aleksandra Skawina
- 17.00 **Morphological and functional diversity in therizinosaur claws**
* Stephan Lautenschlager
- 17.15 Announcement of prize winners and close of meeting

Session 8B: Varia

K02-F-118: <http://www.plaene.uzh.ch/floormaps/KOL_F.png>

- 15.30 **Acritarchs?**
Thomas Servais, Stewart G. Molyneux, Paul K. Strother and Gerard J. M. Versteegh
- 15.45 **A bridge over troubled water – The continuous record of terrestrial vertebrates from the Oxfordian to the Berriasian in the Jura Mountains**
Daniel Marty and Christian A. Meyer
- 16.00 **Extreme warming of tropical waters during the Paleocene – Eocene Thermal Maximum**
Tracy Aze, Paul N. Pearson, Alex J. Dickson, Marcus P. S. Badger, Paul R. Bown, Richard D. Pancost, Samantha J., Gibbs, Brian T. Huber, Melanie J. Leng, Angela L. Coe, Anthony S. Cohen and Gavin Foster
- 16.15 **Miocene bryozoans on a remote volcanic island – long-distance dispersal with short-lived larvae**
Björn Berning and Sérgio P. Ávila
- 16.30 **Exceptional preservation in a high-energy sandwave facies environment: Fe-mummification of bryozoans from the Plio–Pleistocene Red Crag Formation**
Consuelo Sendino, Paul D. Taylor and Javier Cuadros
- 16.45 **Cenozoic record of catshark egg capsules from methane seeps**
Crispin T. S. Little, Steffen Kiel, Kazutaka Amano and Kathleen A. Campbell
- 17.00 **Fungal symbionts in the fossil deep biosphere**
Stefan Bengtson and Magnus Ivarsson

Please move to the lecture hall K02-F-118 for the Announcement of prize winners and close of meeting.



Abstract of Annual Address

Sharks and the deep origin of modern jawed vertebrates

Michael Coates

Department of Organismal Biology & Anatomy, University of Chicago, Chicago, USA

New specimens, methods and trees are transforming our understanding of early shark-like fishes and the early evolution of gnathostomes. Chondrichthyes (sharks, rays and ratfishes) tend to be characterized as primitive, but supporting evidence is elusive: living outgroups (agnathans) are phylogenetically remote, and the fossil record of early sharks is well known to be fragmentary. Changes have been triggered by phylogenies assembled in response to discoveries of remarkable Silurian and early Devonian fishes, revealing new sets of primitive conditions for modern clades. Importantly, such analyses are dismembering long accepted groups of early jawed vertebrates: acanthodians are emerging as primitive chondrichthyans, and placoderms as stem lineage gnathostomes. Such studies have benefited significantly from the particular value of CT technology for investigations of early chondrichthyan morphology. Implications of these new trees and data are still being assessed. The latest branching patterns are far from stable, but they seem to provide a more balanced view of extant clades: the specializations of sharks *vs.* the primitive retentions of bony fishes. New perspectives are opened on the origins of innovations such as jaws, internal gill skeletons and paired fins, and on the likely influence of Palaeozoic extinctions, re-shaping the roots of the modern vertebrate biota.



Abstracts of symposium presentations: Fossilised Ontogenies and Evolution

Evo-devo on a roll: the development and evolution of the trilobite trunk region

Nigel Hughes and Mathew Knauss

Dept. of Earth Sciences, University of California, Riverside, USA

The good record of postembryonic development of the trunk region of some trilobite species permits investigation of how mature body form was constructed. The trunk was built progressively via the expression of new exoskeletal segments in a subterminal generative zone, and by their growth and development in subsequent instars. This permits insight into the relationship between the ontogenies of individual taxa and clade history. The controls of trunk segment growth may be explored in order to understand how segment differentiation was determined in early arthropods. Trilobite trunk segments varied from one another in size, shape, and articulation state, and clade evolutionary history suggests a repeated tendency towards greater morphological differentiation within the trunk, along with allocation of a larger proportion of trunk segments to the mature pygidium. This was paralleled by the evolution of secured, encapsulated enrollment. Enrollment in those individuals with small numbers of articulating segments accommodated considerable flexure at each joint, which show differences in form from those joints within segment-rich thoraces. While the developmental evolution of trilobites retains rich research possibilities, we posit that both biomineralization and encapsulated enrollment enhanced protective capability, and that adaptive response to predation pressure was an important driver of trilobite evolution.

Gradualism, punctuated equilibria, and missing links in developing teeth*

Jukka Jernvall

Institute of Biotechnology, University of Helsinki, Helsinki, Finland

The tempo of evolution continues to be one of the central questions of evolutionary biology. Better sampling of both the fossil record and genomic information has shown that evolutionary rates vary through time, among species, and among traits. Yet, evolutionary transitions, whether fast or slow, should generally result from small alterations of development. Contributions from experimental developmental biology have had a limited role in capturing the gradual aspects of evolutionary change. A limitation of experimental manipulations of development is the preponderance of large alterations in the phenotype. For example, experiments affecting gene expression through a loss or gain of function produce changes that at the level of gene regulation and the phenotype typically provide information about saltational but not about gradual changes. Teeth, however, provide a useful model system to link advances in evolution and development. First, especially mammalian cheek tooth evolution shows many examples of evolutionary transitions. Second, understanding of the basics of mammalian tooth development has reached the point where we can experimentally alter tooth morphology in a quantitative fashion. Taken together, it is now becoming possible to show when, and how, developmental biology can contribute to palaeontological studies.



Fossilized ontogenies and evolution: Gogo placoderms reveal embryonic development in 370 million year old early vertebrates

Zerina Johanson¹ and Kate Trinajstić^{2,3}

¹Department of Earth Sciences, The Natural History Museum, London, UK

²Western Australian Organic and Isotope Geochemistry Centre, Department of Chemistry, Curtin University, Perth, Australia

³Earth and Planetary Sciences, Western Australian Museum, Perth, Australia

Placoderms are phylogenetically basal jawed vertebrates and are resolved as successive sister taxa to crown-group gnathostomes (Osteichthyes, Chondrichthyes). As such, placoderms are critical to understanding the polarity of character transitions within the crown-group. Early ontogenetic stages of placoderms are surprisingly well-known, including ‘fish nurseries’ from the Miguasha Formation, Canada, Lode Formation, Latvia and Catskill Formation, USA. We focus on the exquisitely preserved placoderm specimens from the Gogo Formation, Australia, including embryonic material. These embryos have only recently been discovered in newly prepared specimens and by careful study of existing museum collections; new non-destructive methods such as CT- and synchrotron scanning show great promise for future discoveries. Gogo placoderm embryos provide information about the ontogenetic development of skeletal elements such as head and trunkshield plates, dentitions, and vertebral elements, but also about placoderm reproduction. Information is preserved in the major placoderm groups Pycnodontida and Arthrodira, including multiple embryos in pregnant females, embryos of differing sizes, and of different sexes (*e.g.*, male claspers preserved in certain embryos). By comparison to well-studied chondrichthyans, we can make inferences as to the nature of vertebrate reproduction at the evolutionary transition from jawless to jawed vertebrates.

Reproduction and development of land plants from the Lower Devonian Rhynie chert

Hans Kerp, Hagen Hass and Patricia Kearney

Forschungsstelle für Paläobotanik, Institut für Geologie und Paläontologie, Westfälische Wilhelms-Universität Münster, Münster, Germany

The Rhynie Chert is a hot-spring deposit that contains a broad spectrum of excellently preserved fungi, plants and animals. This Pragian (Early Devonian) Lagerstätte is the oldest, completely preserved fossil terrestrial ecosystem. Six land plant species are known from the Rhynie Chert and an additional one has been described from another nearby occurrence. Of four species both the sporophyte and gametophyte generations are known in exquisite detail. *Aglaophyton major* and *Rhynia gwymne-vaughanii* had leafless, bifurcated upright axes terminally bearing spindle-shaped sporangia. These plants did not have underground parts, but they rested directly on the substrate. Spores are found *in situ* but also dispersed. Germinating spores are often associated with microbial mats. A series of developmental stages of *Aglaophyton*, ranging from germinating spores to full-grown gametophytes with antheridia and archegonia, can be documented. Gametangia are standing on top of flattened or in slightly bowl-shaped axis apices and/or laterally just below the apex. The alternation of generations can also be demonstrated for *Rhynia*. It is remarkable that sporophytes and gametophytes are very similar in having both a vascular strand and stomata, however, they differ in size. Apart from clonal reproduction, a feature shared with all Rhynie Chert plants, *Rhynia* apparently had another mode of asexual reproduction. *Rhynia* formed small axial propagules with rhizoids, stomata



and vascular tissue. Several ontogenetic stages of these propagules have been found and the developmental pattern resembles that of somatic embryogenesis, a form of asexual reproduction known from various modern pteridophytes and angiosperms.

Larval ecology in fossil gastropods

Alexander Nützel

SNSB-Bayerische Staatssammlung für Paläontologie und Geologie, Department of Earth and Environmental Sciences, Palaeontology & Geobiology, GeoBio-Center LMU, Munich, Germany

The shell of marine gastropods conserves and reflects ontogeny to a high degree when compared with other invertebrates. The function of larvae is to transform a small embryo or hatchling into a larger juvenile. Planktotrophy is indicated by a small embryonic shell (size is also related to systematic placement) with little yolk followed by a multi-whorled shell formed by a free-swimming veliger larva. Basal gastropod clades (e.g., Vetigastropoda) lack planktotrophic larval development. The great majority of Late Palaeozoic and Mesozoic “advanced” gastropods with known protoconch had planktotrophic larval development. Dimensions of internal moulds of protoconchs suggest that planktotrophy was largely absent in the Cambrian and evolved at the Cambrian/Ordovician transition mainly due to increasing benthic predation. Early gastropod larval shells were openly coiled and poorly sculptured. During the Middle and Late Palaeozoic, modern tightly coiled larval shells (commonly with strong sculpture) evolved due to increasing predation pressure in the plankton. The presence of numerous Late Palaeozoic and Triassic gastropod species with planktotrophic larval development suggests sufficient primary production although direct evidence for phytoplankton is scarce in this period. Contrary to previous suggestion, it seems unlikely that the end-Permian mass extinction selected against planktotrophic species.

The evolution of life cycles in temnospondyls

Rainer R. Schoch

Staatliches Museum für Naturkunde, Stuttgart, Germany

In the largest early tetrapod clade, the temnospondyls, ontogenies were diverse and quite distinct from the life cycles of extant amphibians. Three well-studied genera exemplify the diversity of these long-extinct ontogenies, here analyzed with respect to their bearing on the evolution of important life history traits (plasticity, reaction norm, metamorphosis). The basalmost taxon *Sclerocephalus* had an especially flexible ontogeny that was readily adjusted by means of developmental evolution to variable lake environments. Plasticity and changes in the reaction norm also played a major role, which is apparent both morphologically and in altered developmental traits. In the branchiosaurid *Apateon*, a biphasic life cycle was established, with metamorphosis producing a terrestrial morph; truncation of the ontogenetic trajectory produced a sexually mature larva as an alternative morph (neoteny). Plasticity was high only in the larval morphs, permitting the neotenes to adjust to harsh lake conditions. In the non-metamorphosing Triassic *Gerrothorax*, morphology was extremely conserved, but histology revealed much plasticity at the microscopical level, correlating with environmental fluctuations. This pioneer taxon coped well with changing levels of salinity. Despite their differences, the three temnospondyls were similar in responding to environmental fluctuations by enhanced plasticity, permitting them to populate lakes inhabitable to other taxa, particularly fishes.



Abstracts of oral presentations

* Candidates for the President's Prize are marked with an asterisk.

+ denotes speaker other than first author.

A Doushantuo-type acritarch assemblage from phosphorite pebbles of the Ediacaran Biskopås Formation of southern Norway

* **Peter W. Adamson and Nicholas J. Butterfield**

Department of Earth Sciences, University of Cambridge, Cambridge, UK

The Early Ediacaran saw the appearance of remarkably large microfossils succeeding the Cryogenian glaciations. This new microfossil biota, best known from the Doushantuo Formation of South China, includes a diverse assemblage of large (20–800 µm diameter) acanthomorphic acritarchs with potential for biostratigraphically resolving Early Ediacaran time.

Doushantuo-type acritarchs have been described from Australia, China, Eastern Europe, India, Siberia, Svalbard, and the Urals, but were first described from phosphorite pebbles in the Biskopås Formation, Southern Norway. Re-study of the Biskopås phosphorites has revealed eleven species of acanthomorphic acritarch, numerous colonial and solitary acritarchs, microbial filaments and microbial mats, all in close association. Significantly, the assemblage of Biskopås acritarchs is duplicated in Biozone 2 (Member III) of the Doushantuo Formation in Yangtze Gorges, illustrating close biostratigraphic correlation with South China. The absence of *Tianzhushania* in the Biskopås, which dominates Biozone 1 in the Doushantuo Formation, is consistent with this observation.

New Zealand Early Miocene dolphins unfold global distribution and early origins of kentriodontids

* **Gabriel Aguirre-Fernandez and R. Ewan Fordyce**

Department of Geology, University of Otago, Dunedin, New Zealand

The extinct family Kentriodontidae has been implicated in the origins of the most diverse living clade of cetaceans – the Delphinidae, Monodontidae and Phocoenidae. New kentriodontids from New Zealand expand the reported Northern Hemisphere record, and imply an early (probably Late Oligocene) origin for the group. Three New Zealand skulls of *Kentriodon* new species are from Caversham Sandstone, Karitane (OU 22375 and OU 22172, 22–20 Ma) and Mount Harris Formation, Kakahu (ZMT 114, 19–17 Ma). The fossils overlap in age with type and referred specimens of *Kentriodon permix* from the Calvert Formation of Maryland, NW Atlantic. These and other *Kentriodon* records indicate a wide temperate-water distribution in the Early to Middle Miocene, similar to the distribution of living *Delphinus* spp. A fourth New Zealand kentriodontid (AUGD V9; Port Waikato, Te Akatea Formation, ca. 25–23 Ma, latest Oligocene) differs from *Kentriodon* spp. in autapomorphies of the skull and periotic. Phylogenetic analysis puts this fossil in stem-Delphinoidea. The New Zealand kentriodontids add to diversity and geographic range, and indicate an early origin for the family, with implications for molecular clock studies of modern dolphins.



Histomorphometry on the postcranium of *Thalassocnus*, the aquatic sloth

* **Eli Amson**

Muséum national d'Histoire naturelle, CR2P – UMR 7207 CNRS, Univ Paris 06, France

The aquatic sloth *Thalassocnus* (Pilosa, Tardigrada) is represented by five species in the Neogene deposits of the Pisco Formation, Peru. Comparison with other pilosans reveals that *Thalassocnus* displays osteosclerosis in ribs and long bones, an adaptation to buoyancy and trim control well known in extant and extinct sirenians for instance. The histological study, which includes the characterization of two ontogenetic stages, suggests that the mechanism responsible for this specialized structure of bones is likely to be imbalanced remodelling. While extreme osteosclerosis is found in the ribs of some sirenians, the occurrence of well-characterized osteosclerosis in normally developed long bones, as observed in *Thalassocnus*, was hitherto not reported. Moreover, the osteosclerotic condition in *Thalassocnus* progressively increases from the geologically earliest species (*T. antiquus*) to the latest one (*T. carolomartini*), i.e. in a time span of ca. 3 million years. Similar conclusions can be drawn about the incipient pachyostotic condition found in the ribs of the latest species of *Thalassocnus*. These observations allow a precise calibration through time of the structural changes that occurred in the skeleton of a terrestrial mammal during the initial stages of its adaptation to aquatic life.

The mode of life of pterygotid eurypterids: insights from their visual system

* **Ross P. Anderson¹, Victoria E. McCoy¹, Maria E. McNamara² and Derek E. G. Briggs¹**

¹Department of Geology and Geophysics, Yale University, New Haven, USA

²School of Biological, Earth, and Environmental Sciences, University College Cork, Cork, Ireland

The large chelicerae of the pterygotid eurypterids has been marshalled as evidence that they were high-level predators in Palaeozoic oceans. This interpretation has been questioned on the basis that the chelicerae were biomechanically unable to process armoured prey (Laub *et al.* 2010 *Bull. Buffalo Soc. Nat. Sci.*39:29).

We investigated specimens of the pterygotid *Acutiramus cummingsi* from the Bertie Formation, Ontario (423–419 Ma). Each specimen is around 20 centimetres from anterior to posterior and possesses crescent shaped eyes composed of about 1,300 lenses. Like the modern *Limulus* a cuticular cornea varies in thickness on lenses across the eye. The lenses reach 330 micrometres in maximum dimension with each lens having six immediate neighbours. Calculations show that the angles between the optical axes of adjacent lenses are on the order of 1.50 to 2.00 degrees, indicating a visual acuity comparable to that of many modern arthropods.

A comparison of the visual system of *Acutiramus* with that of various living arthropods suggests that it lacked the precise and efficient visual system required for high-level predation. This conclusion is consistent with the biomechanics of the chelicerae.



High diversity in the polychelidan lobsters community from the La Voulte Lagerstätte (France, Middle Jurassic)

* **Denis Audo¹, Sylvain Charbonnier¹, Jean-Paul Saint Martin¹ and Bruno Caze²**

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² Mairie de La Voulte-sur-Rhône, La-Voulte-sur-Rhône, France

The Callovian La Voulte Lagerstätte is celebrated for its diverse and exceptionally preserved fauna including arthropods, cephalopods, echinoderms, marine worms and vertebrates. Two types of preservation occur: fossils are flattened on marly beds or included into nodules, which preserve fine details such as ommatidia. Comparisons with the adjacent outcrops and study of the fauna suggest a rather deep water environment making La Voulte one of the rare windows on Jurassic deep-sea fauna. The present study focuses on polychelidan lobsters, a clade that diversified during the Jurassic whose extant members are blind and restricted to deep-waters. The reinvestigation of polychelidans has led to the discovery of numerous new species. Contrary to other localities, where multiple polychelidan lobster taxa occur, species at La Voulte are not closely related to each other, but correspond either to taxa occurring in other Lagerstätten, or very divergent species. The significance of this exceptional diversity is still difficult to assess, but proves the importance of studying deep-water palaeoenvironments such as La Voulte. In that view, the MNHN Paris and the La Voulte municipality are collaborating to accommodate scientists and organize palaeontological excavations in the near future, which will eventually lead to a better understanding of this deep-sea palaeocommunity.

Extreme warming of tropical waters during the Paleocene–Eocene Thermal Maximum

Tracy Aze^{1*}, Paul N. Pearson¹, Alex J. Dickson^{2}, Marcus P. S. Badger³, Paul R. Bown⁴, Richard D. Pancost³, Samantha J., Gibbs⁵, Brian T. Huber⁶, Melanie J. Leng⁷, Angela L. Coe², Anthony S. Cohen² and Gavin Foster⁵**

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³ Organic Geochemistry Unit, Bristol Biogeochemistry Research Centre and the Cabot Institute, School of Chemistry, University of Bristol, UK

⁴ Department of Earth Sciences, University College London, London, UK

⁵ Ocean and Earth Science, National Oceanography Centre, University of Southampton, Southampton, UK

⁶ Smithsonian Institution, Department of Paleobiology, Washington, USA

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The Paleocene–Eocene Thermal Maximum (PETM), approximately 56 million years ago, was a major carbon-led global environmental perturbation. Records of PETM tropical sea surface temperatures (SST) are rare and are commonly affected by diagenesis, reworking



and stratigraphic gaps. New single specimen isotope analyses of exceptionally well-preserved planktonic foraminifera from the PETM in Tanzania (*ca.* 19°S palaeolatitude) generate extremely low oxygen isotope values. The accompanying carbon isotope excursion displays a negative shift of *ca.* 3.7° over the same period. Accounting for changes in pH and sea water chemistry we estimate that during the PETM tropical SST near the study site rose by at least 3°C and could have been as high as 43°C. The absence of calcareous plankton from a large part of the Tanzania PETM record suggests that extreme environmental change, such as high temperatures and possibly low pH, may have temporarily exceeded their tolerance limits, indicating that still more extreme conditions may have occurred.

Large scale environmental gradients as a control on the skeletal taphonomy of Ichthyopterygia

* **Susan R. Beardmore¹, Patrick J. Orr¹ and Heinz Furrer²**

¹*School of Geological Sciences, University College Dublin, Belfield Campus, Dublin, Ireland*

²*Paläontologisches Institut und Museum der Universität Zürich, Zürich, Switzerland*

Taphonomic studies using datasets with large *n* often neglect to resolve palaeogeographic and stratigraphic contexts of specimens, preventing temporal and/or spatial variation in preservation from being tested. We illustrate this via analysis of the taphonomy of Ichthyopterygia (*n*=173) from the Besano (Middle Triassic), Posidonienschiefer (Lower Jurassic) and Blue Lias (Lower Jurassic) formations of Europe. A semi-quantitative methodology was used to confirm a general taphonomic pathway for the clade that was also apparent at locality level. A division between trends in peripheral and medial regions, and a tendency for the shoulder/pelvic joint to disarticulate first but loss of completeness to initiate in the distal part of each limb, implies carcasses routinely sank quickly after death. The ‘floating’ phase within the water column was limited, and ‘residence’ at the sediment relatively extended; this model contradicts those proposed previously. Overall, loss of articulation and completeness is highest for the Besano, and lowest for the Blue Lias, Formation. As ichthyopterygian morphology is generally conservative, this primarily reflects a depositional context, specifically variation in current activity, with the fidelity of preservation decreasing from the edge of an epicontinental basin (Blue Lias), across its centre (Posidonienschiefer) to an intra-platform basin on a carbonate shelf (Besano).

Fungal symbionts in the fossil deep biosphere

Stefan Bengtson and Magnus Ivarsson

Department of Palaeobiology, Swedish Museum of Natural History, Stockholm, Sweden

The presence of fungi in the deep biosphere, hundreds of meters below the ocean floor, has only recently been established. Their ecological role is still unknown, owing to the difficulties of obtaining and culturing organisms from sub-seafloor settings. Natural fixation through fossilization provides means of observing morphological characteristics and deducing life conditions of these elusive organisms. Synchrotron-based X-ray tomographic microscopy (SRXTM) of fungi from Eocene basalts in the Emperor Seamount chain (northern Pacific Ocean) revealed the three-dimensional organization of the organisms and their spatial relationship to the surroundings. The fossils occur in veins and cracks in the basalt, and are preserved both through embedding in hydrothermally precipitated minerals and as montmorillonite replacements within voids. Complex mycelial networks with anastomosing septate hyphae occur with clusters of cell-like objects, suggesting that both hyphal and



yeast-like organisation is represented. The organisms were able to bore into mineral substrates (calcite and zeolites), forming galleries. Morphological features suggest symbiotic relationships between organisms having close and specific spatial relationships. These fossil environments present a means to study the evolution of the deep biosphere in deep time, in particular the participation of eukaryotes in what was long considered a prokaryotic reclus.

Tabulate corals on crinoids: unusual biocoenosis from the Lower Devonian of Morocco

Błażej Berkowski¹ and Mikołaj K. Zapalski²

¹ *Institute of Geology, Adam Mickiewicz University, Poznań, Poland*

² *Faculty of Geology, University of Warsaw, Warsaw, Poland*

Hamarilopora minima is a favositid tabulate coral occurring in the Lower Devonian (Pragian) of Hamar Laghdad (SE Morocco). These corals commonly encrust crinoid stalks belonging to the crinoid genera: *Amurocrinus*, *Cylocharax* (?) and *Schyschcatocrinus*. Most of the hosts belong to *S. breviatus*. Encrustation of long pluricolumnals (up to 30 elements) evidences *in vivo* encrustation.

Most coral-hypobiont associations show signs of interactions, such as anatomical changes and deformations. In the described case crinoid hosts do not display any evident anatomical changes of the skeleton. As coral epibionts were changing mechanical properties of the crinoid stalk it can be inferred that the coral influence on the crinoid was negative. On the other hand, the coral was elevated over the seafloor and benefited from nutrient-bearing water currents. Therefore the interaction can be classified as faint parasitism. Recent crinoids possess a variety of epibionts, but the majority of them are crustaceans; no analogous association is known from Recent seas.

Miocene bryozoans on a remote volcanic island – long-distance dispersal with short-lived larvae

Björn Berning¹ and Sérgio P. Ávila^{2,3,4}

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A Late Miocene, storm-induced coquina preserved on Santa Maria Island (Azores, central North Atlantic) yielded numerous taxa with planktotrophic larvae such as bivalves, balanids and echinoids, which are likely to have reached the island via their larval stage. Surprisingly, however, the single most speciose taxon within the fossil assemblage on this remote island was the Bryozoa. Almost all of the present bryozoan species brood their embryos, resulting in a very restricted range of larval dispersal measuring centimetres to few kilometres given that a suitable substratum is available. Therefore, passive, long-distance dispersal by means of rafting of adult colonies growing on floating substrata can be regarded as the only possible way of reaching the island. This finding highlights the importance of analysing patterns and processes of dispersal when studying the geographic distribution of shallow-water, epibenthic taxa in general, and emphasises the function of



remote volcanic islands as stepping-stones in cross-oceanic dispersal, even of taxa with non-planktotrophic larvae, in particular. More elusive is the problem of explaining the distribution of exclusively bathyal bryozoans on deep seamounts that did not reach the sea surface during glacial sea-level lowstands.

Devonian lycopod forests in Svalbard

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The presence of Devonian *in situ* lycopoid trees (as *Archaeosigillaria*) is highlighted on the Geological Excursion Map of Billefjorden, Central Spitsbergen. These occur in the Plantekløfta conglomerate and are currently dated as Famennian (late Late Devonian). New palynological data shows that they are, in fact, Mid Devonian to earliest Late Devonian in age and the oldest-known record of *in situ* arborescent lycopoids showing the spatial structure of the vegetation.

The standing lycopoid tree fossils are internal mudstone to sandstone casts, buried by mudstones, sandstones or cobble conglomerates. They are spaced on the order of 10–20 cm apart. New observations show the trees to have bulbous, cormose bases up to 20 cm wide and narrow roots. Incomplete trunks were up to 133 cm in length. The trunks are predominantly preserved as internal casts, and the surfaces show a pattern of diamond-shaped leaf bases and can be referred to *Protolepidodendropsis pulchra*. In comparison with the cladoxylopid–aneurophytalean progymnosperm forests at Gilboa, New York, the Svalbard lycopoids grew much closer together, and were monospecific at least locally. The *in situ* microspore and megaspore have been identified and enable us to map the global distribution of these lycopoid forests in both time and space.

New conodonts from the Griesbachian microbialite in South China: implications for an improved definition of the base of the Triassic

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High resolution sampling in the base of the Luolou Formation in Wuzhuan (Nanpanjiang Basin, Guangxi) provides diverse Griesbachian conodont faunas and allows construction of a well-resolved conodont distribution for this crucial interval. The occurrence of the foraminifera *Paraglobivalvulina mira* (Reitlinger) and *Dagmarita chanakchiensis* (Reitlinger) within the calcarenite underlying the microbialite indicate a Late Permian age. Based on conodonts, we recognize two residual maximal horizons (RMH). The lowest RMH, four metres above the base of the microbialite, is defined by *Neogondolella taylorae* (Orchard) and *Neogondolella n. sp. A*. The upper RMH corresponds to the calcarenite that caps the microbialite and is defined by the co-occurrence of *Isarcicella staeschei* (Dai and Zhang) and *Isarcicella isarcica* (Huckriede). The lowest RMH overlaps with the *N. taylorae* interval zone established in sections without microbialite (*e.g.* Meishan) but is



here reported for the first time from a microbialite-bearing section in the Yangtze platform or Nanpanjiang basin. The second RMH overlaps with the *Isarcicella isarcica* interval zone recorded above the microbialite in other sections. In Wuthuan, the most appropriate conodont taxa for constraining the base of the microbialite are *Neogondolella taylorae* and *N. n. sp. A*, which, at least locally, define the earliest Triassic RMH.

The dinosaur-bird evolutionary transition: phylogeny and patterns of morphological evolution

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The evolution of birds from theropod dinosaurs was one of the great evolutionary transitions in the history of life. Although there has been much recent work on avian origins, there remains little consensus on the phylogenetic relationships of birds and their closest relatives (coelurosaurian theropods), which hinders work on large-scale macroevolutionary patterns during the dinosaur–bird transition. We present a new comprehensive species-level phylogenetic analysis of Mesozoic coelurosaurs (150 taxa, 853 discrete characters), which is the latest iteration of the Theropod Working Group dataset. The character dataset was used to study trends in morphological disparity (anatomical variability) and the phylogeny was used as a framework to assess rates of character change across the dinosaur–bird transition. Basal avialans (birds) overlap in morphospace with their closest non-avialan relatives, without any significant statistical separation between them. This indicates that, in their overall anatomy, birds were merely part of a continuum of coelurosaurian morphological evolution and not a highly distinctive group. However, Avialae and proximal nodes and branches on the phylogeny are associated with significantly elevated rates of character change, suggesting that the origin of major groups such as birds may involve a burst in the pace of morphological change.

Do ‘living fossil’ fishes exist? And does it matter?

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A strict ‘tree-thinking’ approach led some neontologists to reject the concept of ‘living fossils’. Here we present three case-studies of piscine vertebrates, and we show why they deserve the epithet ‘living fossils’.

- 1: Morphological disparity observed in the coelacanth lineage since the Devonian, expressed in number of osteological transformations, is more reduced than the morphological disparity observed in any vertebrate clades during the same time interval.
- 2: Based on a phylogeny of dipnoans including fossil taxa, the extant Australian lungfish lies at the tip of the longest temporal isolated branch of the vertebrate tree of life and gets the highest “Evolutionary Distinctiveness” value for all vertebrates.
- 3: The discovery of teeth from a Palaeozoic shark lineage in the Early Cretaceous of Southern France represents the longest gap in the fossil record of a marine vertebrate lineage and provides evidence for deep-sea refugia during biotic crises.



Although 'living fossils' is not etymologically satisfactory (a fossil cannot be alive), the expression is suitable to define a group of organisms with specific evolutionary characteristics. Recognition of their particularisms is essential for understanding episodes in the history of life that could not be otherwise detected by a time-free 'pattern reconstruction' approach.

Palaeoneurology in Devonian lungfish: addressing morphological diversity or conservatism in the neurological system?

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Lungfishes (Dipnoi) serve a critical comparative role in our understanding of tetrapod evolution. As the sister group of tetrapods, lungfishes represent the closest extant divergent line in the evolution of the tetrapod neurosensory system. Examination of the neurological system in fossil lungfish is vital to establish if living lungfish retain the same neurological characters as primitive lungfish. In the absence of numerous endocasts of extinct primitive tetrapods and tetrapodomorphs, this will have a direct bearing on how suitable extant lungfishes are as a model for primitive tetrapod neurology. However, we do not know what neurosensory characters were present in Devonian Dipnoi and how they varied. New digital endocasts of Devonian Dipnoi are presented here, refining previous interpretations of the neurosensory system of taxa based only on observations of the endocranium. In *Chirodipterus* the olfactory bulb is contiguous with the telencephalon, seen only in the African lungfish *Protopterus annectens*. The pineal organ is located antero-dorsally on the diencephalon which possesses a postero-ventrally expanded hypophysis to the hypothalamus as seen in *Protopterus annectens*. Further to these observations, the present study reveals that the dipnoan brain contains numerous characters that are potentially important in contributing to resolving the phylogeny of Devonian Dipnoi.

The evolution of seabirds in the Humboldt Current: New clues from the Pliocene of central Chile

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New Neogene fossil assemblages in South America have revealed important clues about the evolution of seabird faunas in one of the major upwelling systems of the world: the Humboldt Current. However, most of this record comes from Northern Chile and Southern Peru. In consequence, our knowledge for the temperate transitional zone is negligible. A new Late Pliocene assemblage of fossil birds from the locality of Horcon in Central Chile offers a unique opportunity to fill this gap. Morphological and cladistic analyses of a medium-sized penguin reveal that these specimens represent a new species of crested penguin. Additionally, a partial skeleton of a small cormorant and a partial tarsometatarsus of a sooty shearwater have been identified. The Horcon fossils suggest the existence of a mixed avifauna in central Chile during the Pliocene, resembling the current assemblages from the transitional zone, with the presence of species shared with Northern



Chile and Southern Peru and a previously unrecorded genus of penguin currently absent from the Humboldt System but present in the Magellanic region. Comparison of Pliocene seabird diversity across the Pacific coast of South America shows that the Horcon avifauna represents a distinctive assemblage linking the living faunas with the Late Miocene ones.

A new look at the enigmatic *Scaumenella mesacanthi*: Immature stages of two acanthodiform acanthodians from the Late Devonian Miguasha Fossil-Fish Lagerstätte (Canada)

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In 1935, Graham-Smith described *Scaumenella mesacanthi* as a Late Devonian “chordate and probably a vertebrate” from the Escuminac Formation (Quebec, Canada). Since the original description, *Scaumenella* has been re-interpreted as a prochordate, a larval ostracoderm or a larval-juvenile acanthodian. However, the widely-accepted interpretation considers these minute specimens as decay stages of the acanthodian *Triazeugacanthus affinis* through presumably an early diagenetic process called “scaumenellization.” Among the *Scaumenella* specimens, we identified immatures of *T. affinis* and *Homalacanthus concinnus* based on species-specific otolith characteristics even in the smallest specimens (*Triazeugacanthus*: 3.91 mm; *Homalacanthus*: 15.55 mm). A sample of 197 specimens of *Triazeugacanthus* (larvae: 3.91–17.22 mm; juveniles: 17.55–31.47 mm; adults: 26.52–52.72 mm) constitutes a size series. Larvae show no squamation but a progressive appearance of various skeletal structures (e.g., cranial plates, otoliths, vertebral elements), whereas juveniles progress in terms of osteological development and squamation. Developmental patterning is identified for some of these structures: distal accretion of odontodes on spines, antero-posterior and proximodistal directions of squamation in fin webs, and a postero-anterior direction of squamation on the body. These results are interpreted considering the recent phylogenetic remodelling of the acanthodian grade and the close relationship of acanthodiforms with osteichthyans.

Diversity among new Tournaisian tetrapods from Scotland

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New discoveries from the earliest Carboniferous have the potential to change our understanding of the evolution of terrestrial tetrapods. Two specimens from Burnmouth and another from Willie’s Hole variously include skull and postcranial material. One Burnmouth specimen shows a jugal with a long posterior extension and a shallowly embayed orbital margin (primitive). A presumed tabular with a posterior ‘horn-like’ process bears overlap surfaces for two more medial bones. They suggest a tabular-parietal contact (derived). The postcranium includes a lozenge-shaped interclavicle (?primitive), both cleithra, clavicles and humeri, a radius, scapulocoracoid, ribs, notochordal centra and neural arches. The other specimen consists of a disarticulated skull with a broad, denticulated pterygoid (primitive), a jugal with a deeply excavated orbital margin (derived), a distinctive lower jaw, teeth with folded enamel, and a parasphenoid with posterior wings (derived). The specimens differ greatly from one another; neither resembles any previously known taxon. The Willie’s Hole skull superficially resembles that of a temnospondyl in outline, although key features cannot be seen. The pterygoid appears broad, suggesting



small or absent interpterygoid vacuities (primitive). Newly assigned postcrania include limb and girdle elements. These specimens illustrate conflicting character combinations, unsuspected diversity, and possible explosive radiation of tetrapods in the Tournaisian.

150 million years of morphological evolution in half of all vertebrates: there's something special about teleosts

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Neopterygian fishes represent over half of all extant vertebrate species, and comprise the diverse teleost lineage with *ca.* 29,000 species and their holostean sister group with a mere eight species. The stark contrast between these two clades has provided the basis for assertions of teleost 'superiority' and fuelled a series of evolutionary scenarios, many of which make explicit – and therefore testable – morphological predictions.

We quantified morphological diversity for 370 neopterygian species across 150 million years of the Mesozoic and constructed a supertree of fossil neopterygians to test two hypotheses: (i) genome duplication in the teleost stem was responsible for elevated rates of morphological change in the group relative to holosteans; and (ii) low holostean diversity today accurately reflects historical patterns.

As predicted by the hypothesis that genome duplication drove teleost diversification, we find elevated rates of morphological evolution in teleosts compared with holosteans, a result driven by rate increases in both the teleost crown group and crownward portions of the teleost stem. We reject that holosteans were always irrelevant; they show comparable morphological diversity to teleosts for nearly 150 million years and are not characterised by low rates of morphological change, contrary to their 'living fossil' stereotype.

The third-dimension of the puzzle: morphofunctional and phylogenetic applications of X-ray scanning of Cambrian stemmed-echinoderms

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Echinoderms challenge the understanding of body-plan appearance and evolution. The emergence and relationships of Palaeozoic taxa with stalk and food-gathering appendages used for filter feeding, traditionally classified within the Pelmatozoa, have been particularly debated during the last decades. The monophyly of this group has been strongly questioned and it is generally split into two sub-phyyla based on important differences in structure and insertion of their feeding-appendages: Blastozoa (former cystoids) and Crinozoa (crinoids). For some authors, crinozoans are not rooted in blastozoans but in edrioasteroids, as suggested by the Ordovician protocrinoids. For others, crinoids may have emerged from a blastozoan body-plan, as suggested by 'chimeric' taxa. Recent discoveries are controversial and, instead of resolving this phylogenetic jigsaw, brought new disconnected pieces in the puzzle. This study was aimed at analyzing microanatomical structures of some Mid- to Late Cambrian debated taxa and remains with exceptional preservation by means of CT-scanning and synchrotron radiation. The 3D reconstruction of internal microstructures of feeding-appendages enabled testing possible relationships or convergences within pelmatozoan-echinoderms. It shows that a blastozoan rooting of crinoids cannot be



rejected, although a high plasticity of blastozoan appendages complicate the phylogenetic enigma and raised questions about homologies used to define the different sub-phyla.

The developmental basis of 200 million year old mammal teeth

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The limited preservation of genetic data and evidence of development in the fossil record make applying insights from molecules and developmental genetics to extinct animals difficult. Fossils however provide information about variation, which can be examined from a developmental perspective. We tested whether variation in fossil mammal tooth morphology can be used to identify the molecular and developmental origins of said variation. To examine the developmental potential of teeth at the base of mammalian evolution, we quantified developmentally informative morphological variation in the 200Ma old early mammal *Morganucodon watsoni*. Comparing results with dentally similar extant ringed seal, lynx, marten, and raccoon dog dentitions shows *Morganucodon* has an intermediate degree of variation between seals and other carnivorians. Seals have evolutionarily lost well-defined occlusion of the teeth in shifting to a piscivorous diet; we interpret that *Morganucodon* had not yet evolved the developmental control for precise occlusion. Next we used a gene-network-based computational model of tooth development, and data from a human mutation with a dental phenotype, to infer likely changes underlying the evolution of modern mammalian occlusion. This study shows how fossils can provide data for, and help to direct, molecular studies into the underpinnings of morphological diversity.

Early animals from the Ediacaran Doushantuo Formation?

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Among the fossils recovered from the Ediacaran Doushantuo biota are a number of forms that have been interpreted as animal remains. Reports have been published of stem-metazoans, poriferans, cnidarians, ctenophores and a diversity of bilaterians. However, all of these claims are contentious, with alternative explanations having been proposed in each case. As a result, some of the most widely accepted animal candidates in the biota are a suite of tubular fossils including the genera *Sinocyclocyclicus*, *Ramitubus*, *Quadratitubus* and *Crassitubus*. These taxa have been interpreted as eumetazoans and compared to cnidarians such as tabulate corals. As this is based largely on comparisons of simple branching patterns and cross-wall structures, more detailed morphological information is needed to test this hypothesis rigorously. Here we present new Synchrotron Radiation X-Ray Tomographic Microscopy (SRXTM) data on Doushantuo tubular fossils, including new taxa. The new data allow detailed anatomical characterization of the fossils at a cellular level, which illuminates the life cycle of the organisms.



Cambrian–Ordovician plankton diversification: patterns, macroecological significance and limitations

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The Early Ordovician is characterized by a number of fundamental macroecological changes in the oceanic trophic chain, best illustrated by the introduction of planktonic graptolites and planktotrophic gastropods to the water column. What is the biotic record of Cambrian planktonic groups throughout this macroevolutionary event? The radiolarian and acritarch fossil record during the critical Cambrian/Ordovician transitional interval provides valuable insights.

Revision of the Early Palaeozoic literature suggests that after their appearance in the Proterozoic, acritarchs were only moderately diverse during the Early Cambrian. Their diversity continuously increased during the Cambrian, with a significant increase in the Late Cambrian and Early Ordovician and highest values in the Middle Ordovician. Polycystine radiolarians, known since the Early Cambrian, appear to have followed an overall similar trend with continuous increase of species diversity over the Cambrian–Ordovician interval. However, recent results on the radiolarian record from western Newfoundland attest to a more complex history in the overall biotic changes during the Cambrian/Ordovician transition. These are represented by genus-level selective extinctions, as well as within-clade species faunal turnover and species extinction that occurred during two steps in the Upper Cambrian Stage 10. They were then followed by intra-clade species diversification.

Taphonomy and palaeoecology of a Jurassic ichthyosaur: similarities and differences to modern whale falls

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Bones of an ichthyosaur (*Ophthalmosaurus* sp.) from the Oxfordian (Upper Jurassic) Sandsfoot Formation and the associated invertebrate fauna were investigated to test the hypothesis that carcasses of Mesozoic marine reptiles hosted similar communities to modern and fossil whale falls. Bite marks on the bone surfaces indicate initial scavenging by fishes. Echinoid grazing traces (*Gnathichnus pentax*) indicate colonisation of the defleshed bones by algal or microbial mats. This is confirmed by the presence of microborings in the bones and microbially induced carbonates on the bone surface (clotted micrite). Pyrite framboids and peloidal fabrics within the bone spaces possibly indicate microbial decay of the bone organic compounds by sulphate reduction. Finally, numerous suspension-feeding macro-invertebrates, free living close by or directly attached to the bones, indicate prolonged exposure and colonization of the carcass on the sea floor prior to final burial. In this marine reptile fall, as in whale falls, we recognise an initial “mobile scavenger” and a final “reef stage”. The microbial signatures (clotted micrite, pyrite framboids and peloids) may indicate development of a “sulphophilic stage”, as in modern whale falls, even though no direct evidence for a chemosynthetic-based ecosystem (e.g. chemosynthetic bivalves such as lucinids and thyasirids) was found.



The earliest pearls in the mollusc fossil record: clues for complex parasite life cycles or collection biases?

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Recent molecular studies have suggested that the basal parasitic flatworms (Neodermata) had a simple life cycle, while more derived parasitic flatworms (Cestoda, Trematoda) developed complex life cycles. The intermediate stages of the latter have often been implicated in the formation of bivalve pearls. Blisters and free pearls of fossil mollusks (bivalves, cephalopods, nautiloids) have therefore often been used as an indication for the presence of complex parasite life cycles. We investigated the occurrence of pearls and putative flatworm fossils through geological time in an up-to-date ecological and phylogenetic framework. Their fossil record proves to be extremely patchy and biased towards the Recent. Furthermore, the occurrence of pearls in distantly related orders as well as various other mollusk phyla suggests an ancient origin of the potential to form pearl-like structures in the earliest shelled mollusks. Although the flatworm body fossil record is very poor, it does agree with the idea that these parasites co-evolved with their vertebrate hosts. Nevertheless, the use of the host fossil record to test the hypothesis of coevolution leads to circularity (in the absence of reliable parasite fossils), which might be resolved by calibrating parasite molecular clocks with biogeographic events instead.

French contribution to the understanding of the emergence of the phoronids–brachiopods total group: Early Cambrian tommotiids and earliest mickwitziid from Montagne Noire, southern France

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The brachiopods and phoronids have been shown to constitute a monophyletic group. Recent palaeontological discoveries have dramatically improved our conception of the emergence of this major clade. Many recent studies indicate that tommotiids (metazoans bearing an external, multiplated phosphatic scleritome) and mickwitziids (inequivalved organisms with punctate bilaterally symmetrical shell) represent basal to more derived members of the phoronids–brachiopods total group, and can shed light on the emergence of their peculiar body-plans. To date, the exact phylogenetic relationships within this group and the emergence of the different brachiopods from the basal tommotiids along with its timing are still debated. The study of Lower Cambrian limestones from the Montagne Noire, Southern France, led to the discovery of a new, and oldest (Terreneuvian), representative of the mickwitziids, n. gen. et sp., from the Avène-Mendic slice, along with an abundant assemblage of sclerites of the camenellan tommotiid *Kelanella altaica* from the Cambrian Stages 3 to 4 (Minervois nappe). Among the camenellans, *Kelanella* is interpreted to occupy a transitional position between the Lapworthellidae, characterized by unspecialized conical sclerites, and the Kennardidae and Tommotidae, whose scleritome is constituted of three and two types of sclerites, respectively. Implications for the character evolution along the tommotiids–phoronids–brachiopods lineages are further discussed.



The phylogeny of the Coleoidea – the major ‘constructing areas’

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Many conflicting ideas about the higher-level phylogeny of the Coleoidea are currently circulating in the literature. This is considered to be mainly due to numerous new discoveries in the past few years. Apart from taxonomical and terminological inconsistencies, this disagreement largely arose from real homology problems, which are mainly based on shell characteristics.

It is the aim of the present talk to summarize the most important conflicts, to differ between terminological confusions and ambiguous character polarizations, and to perform different phylogenetic scenarios. In doing so, evolution-relevant questions such as ‘Is Recent *Vampyroteuthis* a living fossil?’, ‘Are belemnites really extinct?’, or ‘How conservative is Recent *Spirula*?’ will be considered.

Visualizing developmental constraints and the anisotropy of phenotype space

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Morphological spaces (morphospaces) are quantitative representations of phenotype space that have proved particularly useful in the broad field of evolutionary morphology. Yet, do current conceptualizations and uses of morphospaces appropriately echo the evolutionary dynamics of organisms depicted in such spaces? Many studies implicitly assume that the phenotype space is an isotropic state-space, but two main lines of evidence suggest that such a view is inadequate: First, large-scale palaeontological analyses have shown that order and discontinuity are distinctive features of morphospace occupation; Second, advances in evolutionary developmental biology have shed light on the statistical properties of the genotype–phenotype map and their consequences for the structure of variation and patterns of evolutionary change. Here, I use a well-understood trilobite case study to illustrate the effect of developmental constraints on the directionality of evolutionary transitions and on the accessibility structure of phenotype space. The morphospace obtained is strongly anisotropic and reveals the discordance between the apparent range of possible phenotypes in the geometric neighbourhood of an evolving lineage and their actual accessibility. It is advised that geometric measures of distance in morphospace should be taken with caution and if possible replaced or complemented with more realistic and developmentally meaningful measures of evolutionary accessibility.

Cranial endocast morphology of ancient ray-finned fishes

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The endocranial cavity of vertebrates houses the brain and associated soft tissues. An infilling of this cavity – an endocast – can be used as a proxy for studying brain morphology. The rarity of natural fossil endocasts, and destructive techniques often necessitate the making of artificial ones, means that we have a poor understanding of endocranial morphology in many taxa. Computed tomography (CT) techniques allow non-destructive study of virtual endocasts, and can be applied to rare and delicate



specimens. We used CT to examine the crania of two early ray-finned fishes: *Mimipiscis* (ca. 382 Ma), from Western Australia; and *Kentuckia* (ca. 347 Ma), from Kentucky. Despite being key taxa in analyses of early ray fin relationships, their endocasts have never been fully described. Our models reveal new morphological features, for example the presence in *Mimipiscis* of small optic lobes and a high-sitting labyrinth. These features are seen elsewhere in ray fin outgroups, in particular the lobe-finned fishes, and confirm the placement of *Mimipiscis* as a primitive member of the group. *Kentuckia*, in contrast, shares many features with stratigraphically younger taxa. As well as revealing new morphological data, our findings have implications for when key innovations arose in the brains of early ray-finned fishes.

Discordance between evolutionary rates and disparity in carnivoran cranial evolution

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Rapid morphological evolution is often thought to contribute to the generation of organismal diversity, but increased evolutionary rates are not necessarily correlated with increased disparity. We analysed evolutionary rates and disparity for a 3-D morphometric dataset of cranial landmarks representing a sample of living and extinct carnivorans (Mammalia, Placentalia). Evolutionary rates were reconstructed along phylogenetic branches of a fully resolved tree using an adaptive peak model. Disparity was estimated as landmark variance, and rates and disparity were compared across the cranium and within previously identified modules. Results indicate that evolutionary rates and disparity are not significantly correlated (Spearman's $r = 0.23$, $p = 0.09$) across the entire skull. Modules that display the greatest disparity in carnivorans (orbit and zygomatic regions) do not display significantly higher rates of evolution than other modules. The basicranial module shows strong integration and low disparity, but one of the highest rates of evolution, suggesting that integration does not necessarily constrain rate of morphological evolution, although it may constrain morphological diversity. Discordance between evolutionary rates and morphological disparity suggests that carnivorans evolve rapidly but within a relative limited area of morphospace, consistent with previous qualitative and quantitative assessment of repeated convergences in morphology across distantly-related carnivorans.



New evidence for a lamprey-like motion of the grasping elements of ozarkodinid conodonts

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Goudemand *et al.* (2011, PNAS) re-interpreted some uncommon bedding-plane natural assemblages of conodont elements as potentially recording rare but alternative living configurations, and proposed an animated reconstruction of the feeding apparatus of ozarkodinid conodonts at work. The reconstructed movements suggested the presence of a lingual cartilage about which the elements were rotated by pairs of antagonistic muscles, *i.e.* a pulley-like mechanism also present in extant cyclostomes (hagfishes and lampreys).

One of the predictions of this feeding model is that the unpaired S_0 element and the pair of anterior and obliquely pointed M elements performed a synchronized pinching movement. The record of this infrequent configuration was equivocal in previous assemblages.

We have recently imaged some newly discovered and exceptionally preserved fused clusters of elements of the Norian *Mockina* Kozur using propagation phase-contrast X-ray synchrotron microtomography. The analysis of these almost complete clusters lends further support to the revised hypothesis of S_1 and S_2 element morphology and to the proposed model. In particular, the recorded positions of the M elements relative to the S elements add new constraints that are compatible with the model and one cluster even shows direct evidence of the predicted pinching configuration.

Trace elemental imaging of well-preserved fossils: a new tool for palaeontological and taphonomical studies

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Using synchrotron X-ray fluorescence spectral raster-scanning coupled to spectral decomposition or statistical analysis, we imaged a broad range of well-preserved fossils focusing on trace elemental distributions, particularly strontium, yttrium and other rare earth elements, all known to be present in significant quantities in fossil bones, teeth and sedimentary apatite. The observed contrasting elemental distributions provide discrimination of hard tissues (bones, carapaces or cuticles) from both the sedimentary matrix and fossilized soft tissues. Such an improved discrimination is particularly interesting for the interpretation of flattened fossils, as it allows visualizing anatomical features that are hidden under well-preserved, decay prone tissues or a non-preparable sedimentary matrix. In addition, insights on trace element amounts open new ways



for palaeoenvironmental and taphonomical studies, as they simultaneously reflect the connectivity of the environmental water network, local redox, the specific surface area of the bioapatite nanocrystals and physico-chemical conditions and properties of substituted apatite. Contrasted elemental signatures therefore evidence differences in initial compositions, concentrations, sorption and/or substitution rates, providing relevant information on the fossilization processes.

Biodiversity, biogeography and phylogeography of Ordovician rhynchonelliform Brachiopoda

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Phylogeographic evolution and changing distribution and diversity of rhynchonelliforms through the Ordovician are linked to its dynamic palaeogeography. Early Ordovician (Tremadocian and Floian) low-diversity faunas were punctuated by local species pumps, notably on the South China Palaeoplate. During the Early to Mid-Ordovician (Dapingian–Darrwilian), marine life experienced an unprecedented hike in diversity at species, genus and family levels, firmly installing suspension-feeding benthos as the main component of the Palaeozoic fauna. The continents were widely dispersed together with a large number of microcontinents and volcanic arcs related to intense magmatic and tectonic activities. Climates were warm and sea levels high. Pivotal to the diversification is the role of gamma (inter-provincial) diversity and by implication the spread of continents and frequency of island arcs and microcontinents. Provincial patterns were disrupted during the Sandbian and early Katian with the migration of elements of the benthos into deeper-water regimes, enjoying more cosmopolitan distributions. Later Katian faunas exhibit partition between carbonate and clastic environments. During the latest Katian, patterns were disrupted by poleward migrations of warm-water taxa in response to changing climate, facilitating low-latitude species pumps in carbonate settings. The Hirnantian was marked by severe extinctions across orthide–strophomenide clades within few, but well-defined, climatically-controlled provinces.



Body organisation of euchelicerates: developmental clues from fossil and extant horseshoe ‘crabs’

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We studied the morphological changes of embryonic and postembryonic stages of fossil and extant horseshoe crabs with different imaging methods, e.g., polarised white-light and fluorescence microscopy, microCT, or stereo imaging. Although horseshoe crabs and other euchelicerates are considered to be direct developers (no significant changes during post-embryonic development), our results show that morphology changes considerably during post-embryonic development in extant and fossil xiphosurids, especially affecting the opisthosoma. While the euchelicerate body is considered to be clearly divided into prosomal and opisthosomal regions, the segmental composition is still a matter of debate. The seventh appendage-bearing segment is classically regarded as originally belonging to the opisthosoma, becoming incorporated into the prosoma during ontogeny in xiphosurids. However, while our data indicate that the ventral part of the seventh appendage-bearing segment is incorporated into the xiphosurid prosoma, the dorsal fate of this segment is less simple to identify. Although the first opisthosomal tergite is generally thought to be completely lost in xiphosurids, early representatives of the group actually show this tergite to be fully expressed in the opisthosoma. In conclusion, common knowledge of body organisation and developmental patterns of xiphosurids, and with this, reconstructions of the stem-species of euchelicerates are, at best, oversimplified.

Functional morphology of leanchoiliid megacheirans: not sluggish scavengers but agile predators

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Leanchoiliid megacheirans are Cambrian centimetre-sized arthropods, most famously known from the Burgess Shale, British Columbia, Canada. Leanchoiliids have been mostly interpreted as rather slow, scavenging organisms, or even mud eaters. Our re-investigation of several leanchoiliid species, including the iconic *Leanchoilia superlata*, indicates a more active life habit of these species. The body of leanchoiliids is significantly more slender than previously reconstructed, thus inducing a much lower drag; the broad appearance results from the elongate wing-like tergo-pleurae. The trunk limbs possess a special joint connecting basipod, endopod and bipartite exopod. This special joint stabilises the exopod during the power stroke, and allows a passive flapping back during recovery stroke, further reducing drag forces. The limbs are furthermore equipped with numerous spines, and the body-appendage joint allows movements comparable to a mandible; possible prey items can be perfectly processed with these appendages. The second appendage, which had been previously overlooked, appears to be specialised as a kind of mouthpart. With this small appendage the head comprises four appendage-bearing segments rather than three. This aspect and other characters support that megacheirans, including leanchoiliids, are not only an ingroup of euarthropods, but also chelicerates in the wide sense.



Diversification and diversity partitioning in Early Triassic benthic ecosystems

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New field data in combination with exhaustive taxonomic revisions allow analysis of benthic recovery from the end-Permian mass extinction at an unprecedented level of temporal, spatial, and taxonomic resolution. Diversity increased relatively quickly during the Griesbachian, reaching a first acme at the end of the substage, but then remained stagnant to slightly retrograde during the Dienerian. The Smithian witnessed resumption of recovery but the most profound increase in global diversity occurred at the beginning of the Spathian. Remarkably, however, diversity at the local level (*i.e.*, alpha- and beta-diversity) is largely decoupled from the global trend. Whereas beta-diversity remained constantly low, the highest alpha diversity in the entire Early Triassic occurred already 0.5 Ma after the extinction, within the Luolou Formation of South China. Maximum association richness is 31 species, which is unmatched, even by the richest associations from the Spathian (maximum association richness 18 species) that lived >1.5 Ma later. The taxonomic composition of the Luolou fauna suggests that the high diversity is an effect of exceptional preservation, rather than locally favourable environmental conditions. The new data highlight the problem of a Griesbachian preservational bias and the inadequacy of global diversity as a sole indicator of recovery.

Evidence for an intra-Early Triassic crisis of benthic ecosystems

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The recovery from the end-Permian mass extinction is traditionally described as highly protracted. However, recent studies have shown that, in addition to nektonic groups such as ammonoids and conodonts, benthic ecosystems also show a remarkably volatile recovery pattern. Based on quantitative palaeoecological analysis of Pangean shelf settings of the Palaeotropics, we show that benthic ecosystems experienced incipient recovery and a subsequent decline within the first million years of the Early Triassic. The evidence includes: (i) comparatively diverse associations around the Griesbachian–Dienerian transition, (ii) decreasing diversity and evenness towards the end of the Dienerian, and (iii) notable turnover and extinction around the Dienerian–Smithian boundary. The integration of these results with published geochemical data from the eastern Panthalassa margin and palynofacies data of the eastern Tethys suggests that this demise correlates with widespread oxygen-depletion. The inter-regional recovery of benthos during the Griesbachian contradicts the long held hypothesis of persistent shallow marine anoxia in the aftermath of the end-Permian mass extinction as a main driver of the delayed recovery. Our data rather suggest that a subsequent diversity setback during the Dienerian mimics a sluggish recovery of benthic ecosystems after the greatest crisis in the Phanerozoic history of life.

Ordovician–Silurian Chileida – first post-Cambrian records of an enigmatic group of Brachiopoda

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Brachiopods of the order Chileida have been recorded previously only from rocks of Early to Mid-Cambrian age (Botomian – Amgaian). They are typified by having a calcareous



strophic shell with a delthyrium and colleplax, and these characters are shown to be present in species of the two new genera n. gen. 1 and n. gen. 2, from the Late Ordovician of Kazakhstan and the Silurian of Sweden and Britain, respectively. In specimens of n. gen. 2, the triangular colleplax is phosphatized secondarily by bacterial activity. It is suggested that the phosphatized colleplax represents an organic pad that served as the original attachment structure of n. gen. 2 by encrustation. N. gen. 1 and n. gen. 2 represent the first post-Cambrian record of chileids from the Ordovician and Silurian; the new family forms the first phylogenetic link between Cambrian chileids and Carboniferous–Permian isogrammids.

Mathematical models of the morphology of Ediacaran fronds: implications for phylogeny, disparity and the evolution of architectural complexity in an extinct fractal clade

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The morphology of Ediacaran rangeomorph fronds is characterised by self-similar fractal branching iterated over decreasing size scales. The mathematical rules (or descriptions) for such fractal branching appear to be convergent across a wide range of biological structures and clades (such as plant leaves and vertebrate lungs). This offers an opportunity to apply general mathematical systems for fractal branching (originally developed to describe plant growth and development), to model precisely the morphology of the Ediacaran fronds. I will present a new project that aims to develop a unified mathematical scheme for frond morphology. This will allow computer modelling and visualisation of three-dimensional frond morphology and provide new data for phylogenetic and disparity analyses. Preliminary results support a diversification of space-filling strategies and provide new detail regarding changes in body organisation needed to produce such morphologies. Interestingly, there appear to have been several different space-filling derivations that require changes to the fundamental axiom for fractal branching, while others can be modelled by modifications of shallower operations. Implications for the evolution of architectural complexity via modification of self-similarity will be discussed.

Dumbbells, Discs and Inundation: palaeoecological insights from the Ediacaran of Charnwood Forest, UK and Newfoundland, Canada

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The Avalon Assemblage of Charnwood Forest (UK) and Newfoundland (Canada) collectively comprise the oldest known occurrence of Ediacaran macrofossils. Although long considered the poor cousin of the Newfoundland succession, recent cleaning and silicone rubber moulding of bedding surfaces in Charnwood Forest has revealed a diverse and well-preserved biota, including at least seven previously undescribed taxa. All are preserved as low-relief impressions on upper bedding plane surfaces. One of the new taxa, the colloquially named ‘Dumbbell’, has an unusually large holdfast disc, long stalk and dense, bushy frond.

Detailed sedimentological and petrographical analysis of several fossiliferous localities in Newfoundland and Charnwood Forest has revealed a strong correlation between the nature of the beds directly underlying the fossiliferous horizons and the composition of the



hosted biota, particularly in terms of their functional morphology. Stalked forms such as the ‘Dumbbell’ preferentially occur on beds characterized by very thin parallel to wispy lamination, indicating more frequent inundation. In contrast, flat-lying forms such as *Fractofusus* are dominant on beds with a homogenous, massive character. These subtle differences demonstrate a clear link between functional morphology and palaeoecology in the Ediacaran.

Experimental decay and disarticulation of phyllocarids and the implications for the arthropod fossil record

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The study of soft-bodied fossils is fraught with difficulties. Decay can transform the remains of organisms such that phylogenetic characters are modified or even lost, yet signs of decay in fossils are difficult to recognize, potentially leading to systematic error in fossil interpretation. In vertebrates, for example, more derived characters are systematically lost to decay first, leading to the process known as ‘stem-ward slippage’. In arthropods, though decay has been shown to strongly affect the style of disarticulation, the phylogenetic implications of this have not been investigated. Here, we present a character-based study of decay and disarticulation of the extant phyllocarid crustacean, *Nebalia bipes*, to evaluate biases in the extensive fossil record of both phyllocarids and the wider malacostracan group. We combined systematic sampling and documentation of soft tissue decay with tumbling of decayed specimens to simulate post-mortem transport. Our results have a direct bearing on phyllocarid phylogenies, but also reveal counter-intuitive patterns with broader implications for the preservation potential of arthropods.

The Lilliput Effect in the latest Permian ammonoids from Iran

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We studied the classical Permian–Triassic (P–Tr) boundary sections in the vicinity of Julfa (NW Iran) and in the Baghuk Mountain area (Central Iran). The youngest Permian ammonoid-bearing carbonate formation is the *Paratirolites* Limestone (four metres of red nodular limestone), which represents about the upper half (*ca.* 1.2 Ma) of the Changhsingian stage. A temporal development of the Late Permian ammonoid faunas is observed. In contrast to earlier studies, the *Paratirolites* Limestone is not uniform in its ammonoid faunas but shows some distinct patterns:

- (1) A morphological development from complex sutures with strongly frilled external lobes towards simpler suture lines.
- (2) A general simplification of the conch geometry from trapezoidal to compressed whorl cross-sections.
- (3) A smoothing of the shell ornament (loss of coarse sculpture such as ventrolateral nodes with a development to faint ribs).
- (4) A conspicuous size decrease of the ammonoid conchs (from up to 250 mm diameter to 25 mm), meaning a body mass reduction of three orders of magnitude.



These data indicate that the evolution of the ammonoids has severely been affected already within the Changhsingian stage. These data demonstrate the complex morphological evolution of the latest Permian ammonoids prior to the mass extinction event.

New ammonoid-bearing horizons in the Carboniferous Shannon Basin, Ireland: further evidence for normal salinities in late Mississippian and Pennsylvanian basins of north-west Europe

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The basin fill of the Carboniferous Shannon Basin, Western Ireland, during the late Mississippian and Pennsylvanian consisted of deep-water shales succeeded in turn by basin floor turbidite sandstones, and slope and delta deposits. Ammonoids and thin-shelled bivalves have long been known from widespread, black, carbonaceous shales known as marine bands. These faunas were previously thought to be restricted to these intervals of sediment starvation in the Shannon Basin and elsewhere in NW Europe. Their stratigraphical distribution has been interpreted as reflecting highstands when salinities were of normal marine values, with intervening barren strata corresponding to periods of low salinity.

Recent fieldwork in the Shannon Basin has revealed that ammonoids are not restricted to the highly-condensed shale sections (marine bands), but are also preserved in less carbon-rich shale horizons, that probably reflect higher sedimentation rates, in silty mudstones and as bounce casts at the base of sandstones. The occurrence of ammonoids in the Shannon Basin is thought to be primarily controlled by sedimentation rate. The presence of normal marine faunas outside the traditional marine bands suggests that salinity values of the Shannon Basin and, by implication, of other deep-water basins during the Carboniferous were normal in between periods of sediment starvation.

A new calmanostracan (Arthropoda: Branchiopoda) from the Upper Devonian Strud Lagerstätte, Belgium

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The Upper Devonian locality of Strud, Namur Province, Belgium, was rediscovered in 2004, and has since then yielded a substantial number of vertebrates, invertebrates and plants. The locality is mostly known for its tetrapod abundance, but it also shows remarkable preservation of arthropods, mostly crustaceans such as malacostracans and branchiopods. Here we present a new member of the Calmanostraca (Notostraca + Kazacharthra +/- *Castracollis*), which bears close resemblance to modern notostracans in possessing a large simple head-shield covering almost half of the trunk, eleven phyllopodous



thoracic appendages and a legless posterior abdomen with a spine-bearing telson ending in a caudal furca. It differs by the unornamented head-shield, and by the undifferentiated thoracic appendages. The habitus resembles modern juvenile notostracans, but the differentiation and relative size of mouthparts and limbs suggest that these specimens are all adults. These fossils change our understanding of the basal radiation of calmanostracans and challenge our facile understanding of what it means to be a notostracan.

The phylogeny of ptychopariid trilobites and their derivatives, and the importance of ontogenetic data in analyses of trilobite relationships

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In recent years great advances have been made in our understanding of the intra-relationships of the Trilobita, moving beyond a purely subjective phenetic approach to their taxonomy towards an integrated, phylogenetic-based taxonomic framework. One of the major revisions this has brought about is the conclusion that ptychopariid trilobites are likely paraphyletic, with a number of other groups (including major clades such as asaphids, phacopids, harpetids and proetids) being derived from a –ptychopariid– lineage. It is still unclear, however, whether ptychopariids as currently defined are truly paraphyletic, with the descendent trilobite orders being derived from a single common ancestor, or whether ptychopariids are polyphyletic with the other orders evolving independently as offshoots from within the lineage. Here, we present a novel analysis of 114 characters coded for 52 taxa comprising representatives of Ptychopariida, Asaphida, Phacopida, Harpetida, and Proetida. Ptychopariids are shown to be polyphyletic, while proetids form a monophylum contra the views of some earlier researchers. The importance of including ontogenetic character data in trilobite analyses is emphasized; resolution is greater when including characteristics exhibited only in the protaspid and meraspid stages of development, and some clades can only be retrieved when taking such data into account.

Chemical variability of apatite in the shells of Cambrian lingulate brachiopod *Ungula ingraca* (Eichwald)

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Skeletal apatite is known to have a very variable nature, with biochemical, environmental and diagenetic signatures merged in the shell composition. Several investigations have demonstrated the existence of two discrete apatite phases in lingulate shells that are thought to be related with different types of lamellae in the shell structure. We show for the first time using combined infrared (ATR FT-IR) and energy dispersive spectroscopic (EDS) mapping of the cross sections of *Ungula ingraca* shells the compositional variation of apatite that follows the lamination of brachiopod shell. The compact laminae are rich in PO₄³⁻, Na, Mg and poor in F and Ca, the less compact (baculate) laminae are rich in carbonate, F and Ca, but contain relatively less Na and Mg. The differences in chemical composition of the apatite in different types of laminae suggest different origin of the apatite phases that can be interpreted as the original skeletal apatite and secondary apatite, respectively. It is



likely that the compact laminae have the highest preservation potential, and are composed of original apatite secreted by the organism, whilst the less compact laminae are mostly composed of secondary apatite.

Morphological and functional diversity in therizinosaur claws

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Therizinosauria is a group of enigmatic theropod dinosaurs from the Cretaceous of North America and Asia. Although they exhibit numerous unusual anatomical features in the cranial and postcranial skeleton, they are best-known for the presence of exceptionally elongate and enlarged claws on the fore limbs. In spite of these particular cases of hypertrophied specialisation, there exists a general trend towards an increase in size and the lengthening of the unguals in Therizinosauria, whereas the morphology of the manual unguals among the individual taxa is highly variable and diverse.

Here, we use three-dimensional finite element analysis (FEA) to investigate the biomechanical function and implications of the morphological variation of the manual unguals of different therizinosaurian taxa. Employing Fast Fourier Transform (FFT) shape analysis, the distribution of manual ungual morphologies across theropods is elucidated.

Results of the different functional and morphological analyses provide evidence that therizinosaurian claws occupied a large morphospace. This diversity is reflected in the functional performance of the different claw shapes, most likely indicating different ecological strategies. While small, robust claws are better equipped to withstand high stress and strain resulting from a fossorial usage, large and elongate unguals appear to have been more prone to damage and fracturing.

Soft-part preservation in a solutan echinoderm from the Fezouata Biota (Lower Ordovician, Morocco)

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In the Zagora area (central Anti-Atlas, Morocco), the Fezouata Shales have yielded successive highly diverse assemblages of marine invertebrates comprising both abundant remains of skeletonized taxa typical of the Great Ordovician Biodiversification Event (*e.g.*, articulate brachiopods, bivalves, cephalopods, crinoids, gastropods, graptolites, ostracods, starfish), and numerous exquisitely preserved remains of lightly sclerotized or soft-bodied organisms (*e.g.*, aglaspidids, anomalocaridids, machaeridians, marrellomorphs). Solutans constitute a small clade of controversial, asymmetric Palaeozoic echinoderms (Middle Cambrian – Lower Devonian). They have been interpreted either as basal deuterosomes (“callichordates”), as hemichordate-like, pre-radiate echinoderms (“carpoids”), or as highly derived blastozoan echinoderms (“cystoids” *s.l.*). The



morphology of solutans invariably consists of a single feeding appendage (brachiole), a flattened body (theca), and a bipartite, stem-like appendage (homoiostele). However, their soft-part anatomy remained completely unknown. A single specimen from the Fezouata Biota (Late Tremadocian) partly bridges this gap, and provides the first evidence of soft-part preservation (hind-gut) in this long extinct class of echinoderms.

The impact of fossil data on arthropod phylogeny

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The arthropods are the most diverse, abundant and ubiquitous phylum on Earth. Five main extant groups (subphyla) can be recognized: the Pycnogonida, Euchelicerata, Myriapoda, Hexapoda, and Crustacea. Each group displays a distinctive body plan and a suite of autapomorphies that makes determining their inter-relationships difficult. Although a variety of hypotheses have been proposed regarding their inter-relationships, just three have frequently been recovered in recent phylogenetic analyses. Rather than representing incongruent topologies these hypotheses represent variations of the rooting position on the same parent topology.

300 fossil and 120 extant taxa were coded into an extensive phylogenetic dataset of 1,025 characters. Results of the phylogenetic analysis and additional perturbation tests confirm the utility of fossil taxa for polarizing relationships within Euarthropoda and reducing long-branch artefacts. For example, the hexapods were recovered within a paraphyletic Crustacea, a result anticipated by molecular phylogenetic analyses but until now elusive in morphological phylogenies. Perturbation tests indicate that close affinities of myriapods and hexapods, a result common in morphological analyses, is the result of a long-branch artefact caused by the convergent adaptation to a terrestrial habit, which is broken by the addition of fossil material.

Cenozoic record of catshark egg capsules from methane seeps

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Elasmobranch egg capsules are rare in the fossil record. They include Palaeozoic and Mesozoic spirally coiled capsules of the *Palaeoxyris* group found mainly in freshwater deposits, occasional occurrences of chimaeroid egg capsules (*Chimaerotheca*) ranging back to the Triassic, and rare skate egg capsule specimens (*Rajitheca*) from the Oligocene of central Europe. All these records represent internal or external moulds, many are flattened, and a capsule wall has never been reported. Here we report newly discovered catshark egg capsules from deep-water methane seeps from the modern Eastern Mediterranean, the Miocene of New Zealand, and Late Eocene of Washington State, USA (*Scyliorhinotheca goederti*). All the specimens are closely associated with tube worm bushes, suggesting that cold-seep ecosystems have served as nurseries for predatory elasmobranch fishes for at least 35 million years. The fossil capsules are preserved three-dimensionally and some show mineralized remnants of capsule walls, now replaced by carbonates resulting from the anaerobic oxidation of methane biogeochemical process.



A new R package for automating cladistic ordination and the effects of phylogenetic signal on disparity measures

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Palaeontology has adopted cladistic measures of disparity with increasing frequency in recent years as a means of tackling a broad range of macroevolutionary questions. However, there has been comparatively little innovation in terms of both methodology and implementation, with many workers stringing together different software packages in order to achieve their aims. Here I present a novel R package that attempts to automate the entire process of taking a cladistic dataset, converting it into a distance matrix, performing an ordination, and extracting disparity measures. In addition I implement some novel methodological improvements, primarily to deal with the missing data problem. These include re-scaling techniques (Gower dissimilarity and a new method based upon maximum possible observable distances) and a likelihood method for estimating both ancestral and terminal character states. By using a large (114 taxa, 555 characters) recent dataset of the theropod dinosaurs I show:

- 1) that Gower dissimilarity has undesirable properties that make it unsuitable for ordination, and
- 2) use of phylogeny to fill gaps in cladistic matrices can significantly bias resulting ordination and disparity measures.

Neural characters support chelicerate affinities for Cambrian great appendage arthropods

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Comparative study of nervous systems is fundamental for understanding the evolutionary relationships between major arthropod groups. Exceptionally well-preserved Cambrian arthropod fossils provide a rich and under-exploited source of data on neuroanatomy during the early stages of the arthropod radiation. Following the recent report of a malacostracan-like brain from the Chengjiang arthropod *Fuxianhuia protensa*, we here document the most complete neuroanatomical profile known from a Cambrian animal from the head and trunk of a 'great appendage' arthropod, *Alalcomenaeus* sp. (Chengjiang Lagerstätte). Micro-computed tomography and elemental analyses reveal one optic neuropil separate from a protocerebrum that is contiguous with four head ganglia, succeeded by eight contiguous ganglia in an eleven-segment trunk. This arrangement of optic neuropils, brain and ganglia corresponds most closely to the nervous system of Chelicerata, and direct evidence is provided for deutocerebral innervation of the great appendage. The fossil neuroanatomy and neural cladistics together support the assignment of 'great appendage' arthropods to the chelicerate total group and corroborate segmental and structural homology between the great appendage and chelicera. *Alalcomenaeus* and *Fuxianhuia protensa* demonstrate that the two main configurations of the brain observed



in modern arthropods, those of Chelicerata and Mandibulata, respectively, had diverged by the Early Cambrian.

Micro-CT scan-based reconstructions of the inner ear in fossil and extant hedgehogs and gymnures (Erinaceomorpha, Mammalia): phylogenetic implications and perspectives

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The Erinaceidae comprises the spiny (Erinaceinae) and hairy hedgehogs (Galericinae). Although the extant members of this family are well-known, their phylogenetic relationships and their position among the phylogeny of mammals remain controversial. The fossil representatives are rarely taken into account in phylogenies. The study of fossils mainly focuses on the dentition, but dental morphology is strongly influenced by ecology and dietary habits.

The bony labyrinth of mammals is known to bear meaningful systematic and phylogenetic information. Thanks to high-resolution computed tomography it is now possible to reconstruct inner structures without damaging the skulls. We reconstruct here for the first time the inner ear of three European fossil hedgehogs: *Neurogymnurus cayluxi* Filhol, 1877 (Galericinae, Early Oligocene), *Amphechinus edwardsi* (Filhol, 1879) (Erinaceinae, Early Miocene), and *Galerix exilis* (Blainville, 1840) (Galericinae, Middle Miocene). We compare them to the extant European hedgehog (Erinaceinae) and moonrat (Galericinae).

Among Galericinae, *Neurogymnurus*, *Galerix* and the moonrat share many common features, but surprisingly the bony labyrinth of the erinaceine *Amphechinus* looks more similar to *Galerix* than to the European hedgehog, suggesting a more complex evolutionary history than previously proposed. Further phylogenetic analyses including inner structures data will allow better understanding of the differentiation process between the two subfamilies.

Finite element, occlusal, and microstructural analyses indicate that conodont 'enamel' microstructure is adapted to dental function

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Conodonts are an extinct group of jawless vertebrates, the first in our evolutionary lineage to develop a biomineralized skeleton. However, the origin of this skeleton and their homology with the rest of vertebrate skeletal tissues remain extremely controversial. Specifically, it has been argued that the enamel-like tissues of conodonts cannot be homologous to vertebrate enamel because they are too complex for such a primitive vertebrate. Using Finite Element analysis, informed by occlusal and microwear analyses, we



tested the hypothesis that this incongruence occurs because the microstructure of conodont crown tissue is adapted to the complex dental functions that the elements performed. Our study shows a close topological co-variation in the patterns of compressive and tensile stress distribution with different crystallite orientation. In regions of high stress, such as the apex of the basal cavity and inner parts of the platform, the crown tissue shows a complex crystallite arrangement formed by interwoven prisms, discontinuities between which would have acted to decussate cracks, preventing propagation. These results corroborate the hypothesis that variations in conodont crown tissue are functional adaptations due to the complex tooth-like function that the elements performed.

A bridge over troubled water – The continuous record of terrestrial vertebrates from the Oxfordian to the Berriasian in the Jura Mountains

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Until the first European dinosaur mega-tracksite was reported in 1990, the Late Jurassic carbonates of the Jura Mountains, deposited at the northern Tethyan margin, were thought to be marine. However, meanwhile, numerous terrestrial fossils and sedimentological features – including over 50 dinosaur tracksites from many different stratigraphic levels, dinosaur bones and teeth, pterosaur and plant remains, charophytes and limnic ostracods – have been found spanning from the Oxfordian to the Berriasian. Here, we report dinosaur tracks preserved in charophyte-bearing stromatolites of the Vorbourg and Röschenz members. These are so far the oldest stratigraphic levels (SB OX5; Middle Oxfordian) with dinosaur tracks in the Jura Mountains and considerably extend the *in situ* terrestrial record. They are important for palaeogeographical reconstructions and prove the coeval presence of freshwater and dinosaurs on the Jura carbonate platform. The repeated terrestrial evidence shows that these “bridges over troubled water” were most of the time connected landmasses, and not islands, that linked the northeastern Massif Central with the southwestern London Brabant Massif. These emergent areas were able to host large populations of dinosaurs and repeatedly served as migration corridors open at least every 400,000 years, linked to changes in sea-level due to eccentric orbital cycles.

The lateral continuity of Ediacaran fossil surfaces: Implications for taphonomy and palaeoecology

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The Mistaken Point Ecological Reserve (MPER) in Newfoundland records abundant macrofossils of Late Ediacaran age, documenting the initial evolution of complex multicellular communities within a marine siliciclastic succession. Detailed sedimentological and stratigraphic mapping within the MPER demonstrates that several important fossil surfaces outcrop at multiple locations. The lateral extent of these surfaces, in excess of nine km, indicates that deep marine Ediacaran macrofossil communities were not geographically restricted to localised habitats, as was predicted by some previous ecological models.



Importantly, the observed palaeontological assemblages at each locality can show considerable variation in taxonomic composition and fossil densities. We explain the extent to which these differences result from original ecological variability, and later taphonomic processes. The insights gained from this study reveal several critical biases that influence interpretation of Ediacaran fossil assemblages. Consideration of these factors will lead to more rigorous and robust interpretation of palaeobiology in the important Ediacaran–Cambrian transition.

Are there rules underlying body shape evolution in ray-finned fishes? Regionalization of the axial skeleton in the ambush predator guild

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Elongation in fishes is strongly correlated with increased numbers of vertebrae. The addition of vertebrae can occur in the abdominal region, the caudal region, or both, and suggests that these axial regions are evolving independently. We tested whether unrelated groups of fishes in the elongate ‘ambush predator’ guild are characterized by the preferential addition of vertebrae to the abdominal region, predicted based on the posterior displacement of the median fins in this ecomorphotype. We examined changes in regional vertebral counts related to elongation in fossil and living representatives of seven clades of teleost and non-teleost fishes [Saurichthyidae, Lepisosteidae (gars), Belontiidae (needlefish), Esocidae (pikes), Sphyrnaeidae (barracudas), Fistulariidae (cornetfishes), Aulostomidae (trumpetfishes)], using weighted squared change parsimony reconstruction and phylogenetic independent contrasts. We observed a preferential addition of vertebrae to the abdominal region in five of the seven clades surveyed. The two clades not characterized by preferential lengthening of the abdominal region, Saurichthyidae and Aulostomidae, showed a novel vertebral region anterior to the anal fin, distinct from both the abdominal and more posterior caudal vertebrae. Based on these results, it appears that regional changes in the axial skeleton of ray-finned fishes can be predicted from changes in median fin position.

The taphonomy of tooth wear – quantifying the impact of post-mortem abrasion on tooth surface microtextures

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Analysis of diet in extinct organisms is difficult. Stomach contents rarely fossilise, and fossil evidence of predation is even rarer. As a result alternative methods for dietary discrimination have been developed. Microwear analysis of tooth surfaces has been used extensively to determine diet and to separate dietary ecotypes in a wide range of extinct animals. Application of microwear analysis to fossil material requires an understanding of how taphonomic processes, such as sediment abrasion, affect the microwear signal. Yet aside from a few qualitative observations this has never been studied.

Here we present the first quantitative analysis of the impact of post-mortem abrasion on 3D microtextures of teeth. Our analysis, based on a series of experiments tumbling teeth of different sizes and shapes in sediments representing a range of compositions and grain sizes,



allows us to recognise the effects of abrasion on surface textures. This information will enable future microwear studies to select fossil samples which are most likely to preserve original dietary microwear, leading to more accurate interpretation of dietary signals, and more realistic insights into past ecosystems.

Root traces and plant-soil interactions of two Middle Devonian trees, New York State

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The evolution of trees and forest ecosystems in the Devonian is hypothesised to have intensified plant–soil interactions via increasingly deep roots, which was a major driver in increasing rates of mineral weathering, leading to perturbations of global biogeochemical cycles. We provide the first study to investigate this hypothesis, by linking rarely preserved *in situ* root moulds to palaeosol features at depth from a Middle Devonian (Givetian) fossil forest floor from New York State. The palaeosol surface has been mapped by Stein and Berry, who identified the two root types as likely belonging to archaeopteridalean progymnosperms and cladoxylopsid pseudosporochaleans. We report the depth and morphology of rooting structures and assess the nature and degree of plant–soil interactions from detailed sedimentological and geochemical studies of the palaeosols.

Eighteen cores, up to 3m in depth, were drilled through the palaeosols, half under each of the two types of tree. The cores penetrated through a series of stacked red palaeo-vertisols, which are capped in places by a siltstone rich in fish fragments. We present data on the two kinds of roots and their relationships to the distributions of elements throughout the palaeosol profile and across individual roots.

A new lobopodian from the Silurian of Canada – a case study in decay-informed palaeontology

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The evidence for the assembly of the panarthropod body plan relies on the exceptionally preserved faunas of the Palaeozoic. The lobopodians are integral to this story, with proposed affinities across the panarthropod tree. However, their largely soft-bodied anatomy is subject to the processes of decay and preservation; both potentially obscuring and modifying our interpretation of lobopodian characters. Here we describe a new lobopodian taxon, known from 80 individuals from the Eramosa Lagerstätte, Middle Silurian, Ontario, Canada. Their morphology and preservation is varied, and yet – through comparison with the anatomy of onychophorans decayed in the laboratory – we can confidently assign all specimens to the same taxon. We demonstrate that significant morphological differences between fossil lobopodian specimens may be accounted for by decay-induced modification. This underscores the importance of experimental decay in the investigation of non-biomineralized fossils. Furthermore, as the first Silurian lobopodian,



this taxon bridges the stratigraphic gap between those from Cambro–Ordovician Lagerstätten and the Carboniferous Mazon Creek. The Eramosa lobopodian lacks the plates characteristic of many Cambrian forms (e.g. *Microdictyon*), and isolated plates are not found within Silurian sediments as they are in the Cambrian. This may reflect the post-Cambrian extinction of biomineralizing forms and a shift in lobopodian ecology.

Quantification of volumetric growth and buoyancy of some Palaeozoic ammonoids

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For the first time, we can provide accurate empirical datasets of chamber and septum volumes through ontogeny for Palaeozoic ammonoid species. Most of the investigations in ammonoid palaeobiological studies have been performed using 2D parameters, volumes being usually neglected or extrapolated from 2D measurements. Such studies concern and document more Mesozoic than Palaeozoic ammonoids. Here, we present new data of three Palaeozoic specimens, which were subjected to physical-optical tomography and virtually reconstructed in 3D. In spite of specimen loss, detailed reconstructions were achieved for the direct calculation of volumetric growth. The material consists of *Fidelites clariondi*, *Diallagites lenticulifer* (Devonian, Morocco), and *Goniatites multiliratus* (Carboniferous, USA). In addition to volumetric growth trajectories, these data allow for the first time the empirical testing of existing numerical buoyancy models. Geomagic makes it possible to reconstruct gravity centres for all parts constituting the animal, and we are now able to calculate the coordinates of the gravity and buoyancy centres of the entire animal and thus its *syn vivo* orientation. Based on these data on shell orientation, we can draw conclusions on their mode of life and perhaps also aspects of the evolution of buoyancy control in ammonoids.

Systematics, origins and palaeoecology of placodont marine reptiles (Sauropterygia, Placodontiformes)

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Placodonts are a plesiomorphic clade of durophagous sauropterygians from the eastern and western Tethys of the Middle to Late Triassic. The evolutionary relationships and origins of the Placodontia remain unclear, particularly in the light of new taxa from China. In order to resolve this, micro-computed tomography was used on crania from all valid taxa and, for the first time, a comprehensive phylogeny including all eastern and western placodonts is presented. Among the Chinese forms, *Placodus inexpectatus* clusters with European unarmoured ‘placodontoids’, *Sinocyamodus* within Cyamodontida, while *Glyphoderma* and *Psephochelys* fall within the highly nested Placochelyidae, thus pulling this node back into the late Middle Triassic. This indicates that all placodont clades originated during a period of intense speciation during the Middle Triassic, with armoured cyamodontoid taxa diversifying into the Late Triassic on both sides of the Tethys.

Additionally, a skull of a new sauropterygian from Winterswijk, the Netherlands – *Palatodonta bleekeri* – has provided evidence concerning both the palaeogeographic and evolutionary origins of Placodontia. Characters such as a single row of conical palatine



teeth place *Palatodonta* as sister taxon to Placodontia, indicating an origin of the clade in the western Tethys and suggesting their characteristic palatine dentition did not initially evolve for durophagy.

Taphonomy, morphology and evolutionary significance of fuxianhuiid euarthropods from the Early Cambrian Xiaoshiba biota, South China

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The study of new exceptionally-preserved species belonging to a recently discovered Konservat-Lagerstätte from the Early Cambrian (Series 2, Stage 3 global stage; lower Canglangpuan local stage) of Yunnan Province in SW China – the Xiaoshiba biota – offers a fresh perspective of fuxianhuiid diversity and evolution. The results lead to the recognition of a unique style of preservation in the Xiaoshiba fuxianhuiids *Chengjiangocaris kunmingensis* and *Fuxianhuia xiaoshibaensis*, consisting of the ‘taphonomic dissection’ of the antero-dorsal shield that covers the head region prior to final burial. A major outcome is the unambiguous identification of a pair of specialized post-antennal appendages in the fuxianhuiid head, previously interpreted as a pair of gut diverticula. These findings carry important implications for understanding the segmental organization of the head in fuxianhuiids, along with other stem-group euarthropods such as *Branchiocaris pretiosa*, and suggest that a deutocerebral antenniform first appendage is sympleiomorphic for Euarthropoda. The new data on the morphology and overall body organization of fuxianhuiids lead us to reconsider their phylogenetic position as the most basal stem-euarthropods, as well as their significance for understanding the early evolutionary origins of the most successful animal phylum on the planet.

Colonisation of the water column by ostracods in the Late Silurian

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Ostracods are the most prolific arthropods in the fossil record, ranging from at least the Ordovician onward. They are present in a wide range of ecosystems, mostly as part of the (nekto)benthos. They are also an important component of modern marine zooplankton, from near surface to abyssal depths. Often very abundant in sub-thermocline ocean waters, most ostracod zooplankton are micro-predators or detritus feeders. Ostracods made the ecological shift from the benthos during the Silurian, as evidenced by a comprehensive fossil record of their environmental distribution and details of their soft anatomy. Coupled with information on Recent ostracods, there is an extensive dataset by which to assess ‘when’ (temporally), ‘how’ (physiology and functional anatomy), and ‘why’ (environmental and biological feedback) ostracods colonized the water column, a major event in the ecological radiation of the group and a model for the study of benthic to zooplanktonic ecological shifts.

A case study of the supposed pelagic entomozoid *Richteria migrans* from the Ludlow Series will be detailed in the light of new discoveries in the Russian Arctic and Central Asia. Its morphology, palaeogeographic distribution, facial and environmental range, and relationship to water chemistry and climate will be assessed to evaluate its mode of life.



Rhodoliths on a Miocene volcanic island

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The Azores are a volcanic archipelago in the central North Atlantic. Santa Maria is the oldest and eastern-most island of this archipelago, and the only one that bears fossil deposits, which contain a variety of nodules composed of coralline algae (Corallinales, Rhodophyta), which are known as rhodoliths. Rhodoliths and autochthonous coralline algal crusts occur in various volcanogenic settings of Late Neogene age. At Malbusca, pillow lavas formed a structural relief filled by sediments composed of rhodoliths in rock-forming quantities. Rhodoliths of different growth-forms are mainly composed of coralline algae, bryozoans and barnacles. Bioclasts or volcanic pebbles act as nuclei. The sedimentary matrix between rhodoliths is composed of bioclastic remains, comprising fragments of molluscs, sea urchins, foraminifera, rhodolith constituents and volcanic clasts. Rhodolith beds show a gradual transition into several metres of cross-bedded sands, which are again overlain by volcanic rocks. Today, these sediments are situated *ca.* 20 metres above sea level and show a lateral extension of *ca.* 250 m. Rhodoliths and autochthonous crusts are studied with respect to taxonomy, crustose algal sequences, growth-forms, and microfacies of the sedimentary matrix. The aim of this study is the palaeoenvironmental reconstruction of rhodolith formation within a volcanic setting.

Permian–Triassic fishes: extinction and recovery

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Mass extinction events near the Palaeozoic/Mesozoic boundary had a major impact on life on Earth. Here we present an updated analysis of the diversity dynamics and size changes of Chondrichthyes and Osteichthyes during the Permian/Triassic. We show that chondrichthyan genus diversity declined during the Middle–Late Permian. Many Palaeozoic groups (*e.g.* Petalodontiformes) were largely replaced by hybodonts and modern sharks (Neoselachii). A significant overall decrease in tooth size and body length observed across the Permian/Triassic boundary suggests a selective loss of large-sized chondrichthyans. The largest extinction occurred amongst marine groups, with benthic and pelagic groups suffering most, but selectivity for these palaeoecological traits is not evident. Osteichthyes show a general pattern of low diversity during the Permian to higher levels in the Triassic, leading to increased diversity among the modern ray-finned fishes (Neopterygii). Palaeopterygii experienced a significant increase in body size across the Middle/Late Permian boundary and remain among the larger fishes during the Triassic.



Neopterygians mostly remained smaller and, thus, mostly occupied lower positions within aquatic food webs. Our data indicates an important evolutionary turnover among fishes, changing from chondrichthyan-dominated communities of the Carboniferous–Permian to osteichthyan (actinopterygian)-dominated associations of the Meso- and Cenozoic.

Development of tooth plates in the earliest jawed vertebrates

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The first jawed vertebrates, the “placoderms”, exhibit an immense variety of jaw and dental morphologies including both teeth and tooth plates. Tooth plates of ptyctodont “placoderms” have been compared with dental structures in crown-group gnathostomes including the holocephalan chondrichthyans, but interpreted to have evolved in parallel with gnathostome teeth. Little is known about the internal morphology of these plates both in terms of the tissues from which they are comprised and their mode of development.

We examine the dental structures and development in the ptyctodont “placoderm” *Kimbryanodus williamburyensis* from the Upper Devonian of Australia. Synchrotron tomography revealed primary mineralised structures building a framework and pleromic dentine infilling primary spaces, but also cutting primary growth lines, evidencing remodelling.

Our data support an interpretation of sequential growth of the primary structure away from the oral surface of the tooth plate. Secondarily initial structures are infilled and partially remodelled with pleromic hard tissues. In spite of their outward differences, teeth and tooth plates of “placoderms” and tooth plates of holocephalan chondrichthyans share developmental processes like infill of primary structures with dentine and sequential growth.

Ancient microbial life on the Indian subcontinent

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The Aravalli and Vindhyan Supergroups represent two major phosphorite deposits on the Indian subcontinent. While the Aravalli has been thought to be part of an early global phosphogenic event around 2 Ga, there is still some controversy with respect to the exact age. The Vindhyan Supergroup comprises one of a small number of voluminous 1.6 Ga phosphate deposits. Both the Vindhyan and the Aravalli contain stromatolites that consist of alternating phosphatic and carbonatic laminae. These were examined with petrographic microscopy and synchrotron X-ray tomographic microscopy (SRXTM), to compare phosphatized microbial fabrics from the two locations. Vindhyan stromatolites contain



well-preserved coccooid and filamentous cyanobacteria. Vertical sections show differently sized microbial filaments that display alternating prostrate and erect growth positions, similar to fabrics from modern hot springs. The spatial distribution of phosphate from both sites is often constrained to the laminae or to cappings around columnar microbialites, which indicates a correlation between phosphate and the stromatolite-building microbes.

Microbial life after the Great Oxidation Event

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The origin of life dates back 3.45 billion years. Among the few bacterial phyla that have been identified from the Precambrian are Cyanobacteria, photosynthesizing prokaryotes responsible for the 'Great Oxidation Event' (GOE) over 2.3 billion years ago. Nevertheless, early occurrences of Cyanobacteria are highly debated and far from being resolved. The 1.88 billion year old Gunflint Chert (Canada) depicts one of those locations where presumable cyanobacterial microfossils have been found. But not only have those fossils been questioned, also the ecological context – stromatolite builders – of the Gunflint fossils has been debated. Given the immense importance of the Gunflint Formation, with a microfossil abundance and diversity rarely seen in deposits of this age, resolving the life history of those microfossils will give insights into the level of evolutionary complexity shortly after the GOE. Using different resolutions we have scanned 180 Gunflint samples, applying Synchrotron radiation X-ray tomographic microscopy at the Swiss Light Source, Switzerland. So far, we have been able to identify over eight distinct morphotypes. Comparisons of morphotype abundance and distribution to modern mat and planktonic environments, suggest that fossils of the Gunflint Chert have been part of planktonic microbial communities. Furthermore, several morphotypes do strongly resemble modern cyanobacterial taxa.

Exceptional preservation in a high-energy sandwave facies environment: Fe-mummification of bryozoans from the Plio-Pleistocene Red Crag Formation

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The Red Crag Formation of Suffolk and Essex (SE England) is a Plio-Pleistocene marine deposit of medium- to coarse-grained, shelly, quartzose sands. It contains cross-bedded sets up to 5 m high. As the name indicates, it is red at outcrop and strongly oxidized. However, unweathered samples from the subsurface are known to have a greenish colour.

Colonies of cyclostome and cheilostomes bryozoans are commonly found encrusting shells that are locally abundant in the Red Crag. They can be exquisitely preserved, with delicate articulated spines and calcified opercula. The cryptic microhabitats on the undersides of the bivalve shells gave physical protection to the bryozoans. But this cannot fully explain their exceptional condition. Remarkably, the calcified skeletons of the bryozoans are normally absent, and fine details of the colonies are preserved by thin coatings of rusty red-coloured goethite. Coatings must have formed very early in diagenesis. Its original mineralogy is unknown but may have been the same green mineral (glauconite and/or chlorite) that gives unweathered Red Crag. Conversion of this mineral to goethite was apparently accompanied by dissolution of the calcitic skeletons of the cyclostome and most of the cheilostome bryozoans.



Acritarchs?

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The term 'acritarchs' is widely used and many different definitions have been proposed. It was introduced by Bill Evitt in 1963 to classify all the former 'hystrichosphaerids' that could not be identified as dinoflagellate cysts. Evitt defined the acritarchs as a group that included all organic-walled microfossils with unknown biological affinities. Subsequently, other authors have redefined the group by adding an interpretation of biological affinity to the original definition, maintaining that the acritarchs were unicellular, marine, of algal origin and/or belonging to the microphytoplankton. This has led to the present-day confusion between the definition and the biological interpretation of the acritarchs. Several alternatives to the term acritarch have been proposed in the literature, but none have been widely adopted following their introduction. As the exact biological affinity of most individual morphotypes remains unknown, the informal grouping of the acritarchs is still valuable and Evitt's original definition should be retained. Therefore, we advocate continued use of the term 'acritarch' as an informal category in Botanical Nomenclature.

Romer's Gap: a surprisingly productive period in vertebrate evolution

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Carboniferous tetrapod fossils have generally been found in economically important deposits of coal, oil shale and limestone. The absence of such deposits in the Tournaisian has limited the likelihood of chance finds in Romer's Gap. Recently, tetrapods, fishes and terrestrial arthropods have been found in the Ballagan Formation of the Tweed and Northumberland Basins. We present the results of discoveries at several new localities in that formation, from which vertebrate fossils have been found in a variety of sediments. Localities include Burnmouth on the Berwickshire coast, where the entire Tournaisian is exposed. In total, vertebrate remains have so far been found at 21 horizons. These discoveries reveal a rich variety of taxa, suggesting an explosive radiation of tetrapods and fishes following the End Devonian Mass Extinction. The first Carboniferous xenacanth sharks and holocephalans are reported. Lungfishes, which suffered a significant reduction in diversity following the Hangenberg event, are represented by at least three new taxa. Our finds support the hypothesis that Romer's Gap is due largely to collection failure. From the palaeogeographical context of our discoveries and the nature of the depositional environment, we are providing clues as to where new earliest Carboniferous localities may now be found.

On the edge: early land plants and marine algae from the Lower Silurian Kalana Lagerstätte, Estonia

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The Kalana Lagerstätte, of Llandovery (Aeronian) age, is located in Central Estonia. The fossils and rocks of the locality refer to a nearshore environment, where normal marine



carbonates with rhynchonelliform brachiopods, tabulate corals and bryozoans alternate with laminated lagoonal carbonates with leperditid arthropods and rare eurypterids. The succession contains numerous coquina lenses with abundant gastropods or brachiopods.

Most impressive fossils in Kalana are the non-mineralized algae, which occasionally cover surfaces with remarkable floral patterns. While the Rhodophyte species *Leveilleites bartnageli* is the most common among fossilized algae, a number of chlorophyte species, mostly dasyclades, demonstrate the diversity of the Silurian marine flora.

Unexpectedly, these marine beds have also revealed a number of early land plants with new lycophte species of *Drepanophycus* and *Zosterophyllum*, both the oldest known members of the genus. A couple of inconspicuous fragments resemble *Baragwanathia* but the stem and microphylls of these specimens are an order of magnitude smaller than in the previously described species. The locality has also yielded some dichotomously branching sterile axes tentatively assigned to the form genus *Hostinella*.

While occasional algal fossils of comparable age have been found in few other places, the early land plants from Kalana predate all known vascular plant macrofossils, including the earliest *Cooksonia*.

Extraordinary End-Ordovician ostracod association from KŁtrzyn IG-1 borehole, NE Poland

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The KŁtrzyn IG-1 borehole in north-eastern Poland is situated in the southern part of the Central Baltoscandian Confacies belt area and exposes mostly argillaceous limestones deposited in distal ramp situation. The Ordovician–Silurian boundary interval was studied for ostracods. The species composition consists mostly of binodicopes and resembles the *Harpabollia harparum* association known from South Estonia, Latvia, Scandinavia and Carnic Alps. In addition to the species typical of the *Harpabollia harparum* association, Polish material also contains some metacopes and eridostracans that are sparse or absent in the Hirnantian Stage in Estonia and Latvia. Genera characteristic to North Estonian *Medianella intecta* association (*Steusloffina*, *Medianella*, *Microcheilimella*) are nearly absent in KŁtrzyn. The faunal differences of these can possibly be explained by the different positions of the studied areas in the Ordovician palaeobasin, which deepened in the south-western direction. This is the first occasion where likely depth differences are recorded in the composition of the cool-water Hirnantian ostracod assemblage.

Tooth development in batoids (skates and rays)

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The batoids – including the skates, stingrays, sawfish and guitarfish – are a diverse group today, comprising over half of all living chondrichthyan species. They form a sister group to all living sharks, although their origins are still poorly known. Like sharks and many



extinct shark-like groups, rays produce teeth continuously throughout their life, teeth forming lingually, in association with a dental lamina, before moving labially and being shed at the outer margins of the jaws. Teeth in each sequential row are added to even, then odd, alternate positions on the jaw; in every other row a tooth is at the jaw symphysis. Study of embryos of several species of modern batoids has revealed that there are several modes of structural pattern within the group. In some taxa, the first formed teeth are present along the length of the jaw with little or no subsequent increase in tooth numbers during ontogeny. In others, only two teeth are present in the first row with additional teeth added further from the symphysis with each new row. Unravelling the phylogenetic and evolutionary significance of these patterns is necessary for a better understanding of batoid origins among the chondrichthyans.

Anomalocaridids had two sets of lateral flaps

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While our understanding of anomalocaridids has made great strides over the past decades, several aspects of their morphology remain poorly understood. Their lateral flaps have been considered as derived from the flaps of taxa like *Kerygmachela*, *Pambdelurion* and *Opabinia*, making them potentially homologous to the exopods of euarthropods, but the arrangement of the flaps and apparent absence of any trunk limbs in anomalocaridids remains problematic. A newly discovered complete, three-dimensionally preserved anomalocaridid specimen from the Early Ordovician Fezouata Biota of Morocco reveals that it possessed two sets of lateral flaps, a feature that can also be identified in at least one other anomalocaridid fossil from the Middle Cambrian Burgess Shale of Canada. The lower, largest set of flaps is ventral in origin while the second, smaller set arises dorsally, completely separate from the ventral set. The dorsal flaps are closely associated with the setal blades. These findings indicate that the dorsal flaps are homologous to the flaps of ‘gilled lobopodians’ and the exopods of euarthropods, while the ventral flaps correlate to lobopodian limbs and euarthropod endopods. Hence, anomalocaridids represent a stage preceding the fusion of endo- and exopod into the euarthropod biramous limb, securing their position within the arthropod stem.

Origins and early evolution of naacre

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Evidence from modern animals and the fossil record indicates that naacre originated independently in different groups of molluscs. There are plentiful data on original inner shell microstructures of molluscs from the Early and Middle Cambrian, but naacre is absent. We have confirmed that this shell microstructure is preserved in cephalopods



– and probably also occurs in bivalves and gastropods – from the Ordovician of the Midwestern USA, and thus we infer that nacre originated during the Great Ordovician Biodiversification Event or just prior to it. We show that the preservation of this earliest known nacre is unique and the original texture was diagenetically replicated, but the structure can nevertheless be reliably inferred to have been mother-of-pearl. By the Middle to Late Palaeozoic, nacre was common in bivalves, gastropods, and especially cephalopods, correlating with increasing predation pressure through that interval. Our current work has revealed that nacre in these cases appears modern to a great degree, and in some instances shows ultrastructural details important in understanding the origins of this shell microstructure.

A suspension feeding anomalocaridid from the Early Cambrian Sirius Passet, North Greenland

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Anomalocaridids, with their lateral flaps interpreted as swimming devices, were the largest nektonic organisms in the Early Palaeozoic. Other than the flaps, the only appendages known are a pair of large frontal appendages. Recent studies of material from the iconic Burgess Shale, Chengjiang and Emu Bay Shale Lagerstätten have demonstrated morphological diversity in these appendages, hinting at an as yet under-appreciated ecological diversity in the group. We here present new specimens of *Tamisiocaris borealis* from the Lower Cambrian Sirius Passet Lagerstätte of North Greenland. We dispel doubts about anomalocaridid affinities of the taxon and present new morphological detail. We show that the appendage possessed delicate spines, with dense rows of fine bristles, analogous to the appendages of modern suspension-feeding arthropods. The presence of a large microphagous suspension feeder in the Early Cambrian together with evidence of the introduction of phytoplankton and mesozooplankton to the water column at this time implies that the pelagic food web was quite complex and that primary productivity was relatively high. It seems to be a trend that microphagous nektonic suspension feeders evolve from microphagous nektonic ancestors during periods of high productivity. This trend can be extended to the anomalocaridids, generally portrayed as the first large nektonic predators.

High resolution biostratigraphy and biodiversity dynamics of Dienerian (Early Triassic) ammonoids from the Northern Indian Margin

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Extensive new collections of ammonoids from the Dienerian of the Salt Range (Pakistan) and Spiti Valley (Himashal Pradesh, India) allowed us to thoroughly revise their taxonomy and propose a new, high-resolution biostratigraphical scheme. A total of 48 species were collected, allowing the differentiation of 12 ammonoid zones, grouped into three intervals (early, middle and late Dienerian). This contrasts strongly with the previously established two-zone biostratigraphical scheme. This very high resolution permits a detailed study of biodiversity changes throughout this interval, which is crucial for a better understanding of



the recovery following the end-Permian mass extinction. Ammonoid biodiversity first peaks in the early Dienerian. An extinction occurred at the early/middle Dienerian boundary, and diversity remains low during the rest of the Dienerian. Biodiversity increased slowly in the earliest Smithian and a pronounced radiation occurred at the end of the early Smithian. Species turnover rates were high over the whole period, with generally more than 50% turnover, sometimes reaching 100%. The low diversity in the middle and late Dienerian can be correlated with an anoxic event associated with high temperatures. These results contradict the widely held hypothesis of a slow progressive recovery of ammonoids during the Dienerian.

Establishing a Fossil Record of Euglenoids from the 1.1 Ga Nonesuch Formation to the Recent

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The euglenoids are largely freshwater, flagellated protists belonging to the excavate branch of the eukaryotic supertree. Euglenoid cells are covered by a pellicle composed of distinctive, interlocking longitudinal strips of protein-rich heteropolymers. A few workers have noted a similarity between the encysted forms of extant euglenoids and the fossil palynomorph *Pseudoschizaea*. Similar discoidal palynomorphs marked with concentric striae may represent a Phanerozoic series of euglenoid fossil cysts. The Ordovician–Silurian microfossil, *Moyeria cabottii*, was previously interpreted as euglenoid based on morphological criteria. We extracted *M. cabottii* from the Fish Bed Formation (Silurian of Scotland). Its wall ultrastructure shows distinctive frames consisting of π -shaped plateaus and shallow U-shaped heels, which are fused to form the pellicle wall. This structure is consistent with the extant euglenoid pellicle. *Moyeria cabottii* and *Moyeria* sp. occur in lacustrine shales of the 1.078 ± 24 Ga Nonesuch Formation (USA). This extends back considerably the first occurrence of euglenoids, and is consistent with molecular phylogenetic studies that posit their basal position near the root of the eukaryotic supertree. *Moyeria* now joins a handful of Precambrian fossils with well-established ties to crown groups in the eukaryotic supertree, and provides a useful minimum constraint calibration for molecular clock analyses.

Latest Cretaceous Antarctic cephalopods; evolution, extinction, and biogeography

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The final demise of ammonoid cephalopods at the end of the Cretaceous has provided crucial evidence of the rate of extinction in this accelerated crisis, the nature of which is



still debated. Maastrichtian (72–66 Ma) cephalopod faunas are found globally, although many faunas have been difficult to correlate to the international timescale due to lack of biostratigraphic or chronostratigraphic control. This has led to continued debate about the nature of ammonoid extinction during the Cretaceous/Paleogene (K/Pg) transition, as well as diversity changes throughout the Maastrichtian, a stage known to contain climatic and oceanographic oscillations.

Here we present data based on new collections of a Maastrichtian cephalopod fauna from the López de Bertodano Formation on Seymour Island, Antarctica (65°S). The expanded nature of this sequence together with the abundant and well-preserved macrofossil fauna make this a key locality for assessing biotic changes during the Maastrichtian and across the K/Pg boundary at high southern latitudes. We review and re-evaluate the taxonomy, record of evolution and extinction of the fauna in comparison to updated age models, and discuss subsequent implications for the palaeobiogeography of latest Cretaceous cephalopod faunas using a variety of statistical methods and a global database of Maastrichtian ammonoid occurrences.

Stable isotope compositions in shark dental tissues as a proxy to seawater chemistry

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Oxygen isotope composition of shark dental tissue biominerals have been studied in three modern species from monitored environment (temperature and salinity) of the tropical ocean tank at the Blackpool Sea Life Centre. Teeth of *Carcharhinus plumbeus*, *Carcharhinus melanopterus* and *Carcharias taurus* were collected from deceased specimens *in situ*, and from the substrate. Two geochemical methods were applied to obtain the ¹⁸O / ¹⁶O ratios: (1) the *in situ* δ¹⁸O measurements of the entire fluorapatite oxygen components within separate layers of enameloid and dentine were carried out using Cameca 1280 secondary ion microprobe (NORDSIM), and (2) conventional IRMS analyses of the δ¹⁸O of chemically separated phosphatic component were performed in parallel on tissue-selective bulk samples. The resulting δ¹⁸O values showed intra-tissue uniformity (parallel-bundled enameloid in particular) of each species within the sub-permil precision of the measurements, but gave average 2‰ (1σ = ± 0.35) inter-specific variation, comparable to previously reported 2.5‰ and 2.9‰ taxonomic offsets in fossil vertebrate bioapatite. The ¹⁸O variation within and between species have both histological and mineralogical explanations, and allow us to estimate the extent of ‘vital effects’ as part of the oxygen isotopic fractionation in modern aquatic vertebrate fluorapatite, as well as species-specific biomineralization patterns in sharks.



Abstracts of poster presentations

* indicates a poster eligible for the Council Poster Prize.

Decapod crustaceans of Monte Fallano, a new Lagerstätte from the Bajocian–Bathonian of southern Italy

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Quite recently, a new Plattenkalk was discovered near Monte Fallano (Campania, southern Italy). This Plattenkalk, dated to the Bathonian–Bajocian by microfossils, yields an exceptionally preserved and diverse marine fauna of osteichthyan fish, decapod and isopod crustaceans. Terrestrial insects and plants have also been recovered. The Monte Fallano Plattenkalk is a typical Konservat-Lagerstätte: fossils are compressed on laminated limestone plates, with delicate elements such as eyes and antennae preserved. Our work focuses on decapod crustaceans and their significance. In Monte Fallano most of them belong to well-known Mesozoic groups: aegerid shrimps, erymid and eryonid lobsters. One new shrimp species, ascribed to Sergestidae, is the earliest occurrence of this family, which is otherwise rare in the Late Cretaceous and diversified in modern fauna. Each species is known from multiple specimens and their anatomy can be precisely described. This allowed the first description of an eryonid's ontogenetic series. The Monte Fallano Lagerstätte fills gaps in decapod crustaceans' fossil record. Faunal and preservation similarities with the Kimmeridgian–Tithonian localities of southern Germany and the Cenomanian of Lebanon are probably linked to relatively similar palaeoenvironmental conditions. Further investigations are planned in Monte Fallano and will undoubtedly expand our knowledge of this Middle Jurassic fauna.

The nature of Ordovician limestone-mudstone alternations in the Oslo-Asker area (Norway): primary or diagenetic rhythms?

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The Ordovician eustatic sea level curve for Baltica, to some extent based on lithological evidence from the Oslo-Asker area in Norway, indicates a number of lowstands of Mid and Late Ordovician age, interpreted as glacioeustatic. Limestone-mudstone alternations were



deposited during the lowstands, potentially recording short-term palaeoclimatological fluctuations. However, alternatively, these could also be the result of differential diagenesis. In our project, we revisit some Oslo–Asker sections to test both hypotheses, and to obtain additional data on Ordovician climate change.

Our methodology consists of a bed-by-bed sampling of the rhythmites, for an integrated palynological (chitinozoans) and geochemical (XRF) study. An original cyclic signal should be reflected in the chitinozoan microfauna, sensitive to climatic and environmental changes, whilst a uniform distribution would point toward a diagenetic origin of the rhythmites. The XRF analyses allow us to assess if there has been a diagenetic redistribution of elements. Preliminary palynological data indicate well-preserved and relatively abundant palynomorphs that at first glance do not show any major difference between the assemblages from the mudstones and limestones, at the species level. Based on these first results, the palaeontological data seem to be in agreement with the geochemical data that do not identify an original cyclic signal.

The NHMUK rescue dig at Woodeaton quarry, Oxfordshire

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A disused quarry at Woodeaton, Oxfordshire, designated as a geological SSSI, exposes one of the most complete sections of Middle and Late Bathonian (Middle Jurassic) in southern England. The exposure displays a continuous and accessible section from beneath the Taynton Stone to the base of the Forest Marble.

The quarry is scheduled for landfill and will be turned into a nature park. Although some sections will be preserved, exposures of the Rutland Formation, Hampen Marly Beds and White Limestone will be lost.

In 2013 and following exploratory collecting trips, the Department of Earth Sciences at the Natural History Museum (NHMUK), London, decided to mount a rescue dig to gather representative macrofossils, micropalaeo and microvertebrate samples.

In June 2013, a multidisciplinary team of palaeontologists spent a week logging sections and collecting samples. A total of 1.6 tonnes of sediment was collected. The samples were dried and sieved to 500 micrometres. Remains of sharks, rays, brachiopods, molluscs, fragments of bony fish and small tetrapod bones are among the most abundant. It is estimated that it will take several years to sort the samples completely. The samples are available for scientific research. Studies are currently under way, focusing on the biostratigraphy and palaeoenvironments.

Analyzing the shape variability and evolution inside Basiliolidae (Brachiopoda)

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Within the framework of a wider project focused on the investigation of the palaeoecological changes which have determined and regulated the evolutionary history



of brachiopods and their survival until recent times, a multidisciplinary study (combined statistical analyses considering occurrences, biometry and geometric morphometry, coupled to isotopic analyses values) will be presented here regarding the long lineage family Basiliolidae (Brachiopoda).

The main part of the database for this study was recorded during a visit to the Hungarian Natural History Museum in Budapest financed by a SYNTHESYS grant. In this collection, there are more than 1,000 specimens belonging to 7 genera and at least 19 species (*Apringia*, *Serratapringia*, *Megapringia*, *Jakubirhynchia*, *Mondegia*, *Basiliocostella*, *Aphelesia*) from Sinemurian to recent of Central-Southern Europe (Hungary, Austria, Italy, Malta). Additional data coming from several populations of *Soaresirhynchia* (Toarcian of Italy, Portugal and UK) plus data coming from the literature will be included.

The preliminary results presented here are focused on the specimens from Hungary and the use of geometric morphometry to test statistically the intra-generic and intra-specific variation, and to record the ontogenetic shape variations. (At present, the first author is solely responsible for these preliminary results.)

New information about a Triassic brachiopod association from Oman

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Some years ago we reported a brachiopods association (rhynchonellids and spiriferids) from the Lower Triassic (Lower Induan, *Isarcica-carinata* zones) Al Jil Formation in the Wadi Wasit area of Oman. The brachiopods were assigned to *Orbicoelia extima* (Grant) and ?*Lissorhynchia* n.sp.

Recently we obtained new information through the use of X-ray computed tomography (CT scanning) carried out at the University of Bonn. This will permit a noticeable improvement in the taxonomical description of the taxa, especially regarding the internal structures. The previous description based on serial sections was quite incomplete because of bad preservation of internal structure after the serial sectioning process (probably because of the complete silicification of the specimens).

The re-description will provide a much more detailed photographic documentation thanks to the LEICA microscope facility hosted at the University of Tartu, which allow a 3D reconstruction through a 'composite multi-stack image' (*i.e.* a composite image derived from many pictures of the specimen taken with different exposures). (At present, the first author is solely responsible for these preliminary results.)

Biomechanical insight into sauropodomorph craniodental evolution

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The sauropodomorph dinosaurs represented a significant and global radiation during the Mesozoic. Crucial to this success was the adoption of high-fibre herbivory early in



the history of the clade. Whilst basal ('prosauropod') forms are generally considered to have remained conservative, Sauropoda is marked by numerous craniodental character complexes hypothesized to have been associated with greater bite forces and cranial robustness correlated with a shift towards bulk-feeding, with more derived taxa then showing the convergent development of morphologies potentially associated with greater dietary specialization. However, the functional variance and biomechanical significance of many of the characters cited in these hypotheses remain untested. We address this deficit through measurement of disparity in craniodental functional characters and finite-element modelling of exemplar taxa.

Results demonstrate that 'prosauropod' and sauropod taxa do indeed occupy highly distinct regions of functionspace. Surprisingly, the 'prosauropods' show a greater level of functional disparity than the basal 'broad-crowned' sauropods, the latter specialized towards the production and accommodation of greater bite forces. The greatest levels of functional disparity are seen in the 'narrow-crowned' diplodocoid and titanosauriform lineages, which demonstrate phylogenetic trends into unique regions of functionspace, potentially correlated with the expansion of 'narrow-crowned' versus decline of 'broad-crowned' sauropods during the Cretaceous.

Shell damage and repair in recent cockles *Cerastoderma edule*

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During a storm in early May 2013, thousands of second-year cockles were eroded from the tidal flats of the Wadden Sea near the Royal Netherlands Institute for Sea Research at the Island of Texel. They were deposited still alive near the High Water line on the adjoining sandy margin. Burrowing in the shell-rich sand high on the shore proved difficult for the cockles. In the following months, some were consumed by oystercatchers, some became fastened by the byssal threads of mussels. Those that remained loose were rolling in the waves at high tide. This caused abrasion and finally holes just below the umbo in articulated shells of the still-living cockles. Careful searching showed later a couple of cockles that had been able to repair these holes. This shows that shell repair does not always indicate failed predation.

Giant rodent diversity in the northern neotropics: The Late Miocene cranial remains from Urumaco, Venezuela

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Caviomorphs constitute a large evolutionary radiation of South America rodents, exhibiting a wide range of body size and ecomorphological disparity. The geological history of caviomorphs has been recorded mainly from high latitudes, besides isolated discoveries from the northern Neotropics. The Late Miocene fauna from Urumaco, Venezuela, is noteworthy for its location and for preserving the giant rodent *Phoberomys patersoni*, known based on an almost complete skeleton, with body mass estimates ranging from 220 to 450 kg. Previous studies of isolated postcranial remains suggested that the giant rodent diversity from Urumaco was higher than is currently recognized. Based on new dental and cranial remains we document ontogenetic and taxonomic variation that



indicates the presence of at least four rodent species in Urumaco, including *Neopiblema*. The morphological and size variation in euhyposodont caviomorphs from Urumaco is evaluated taxonomically based on reference to analogous living and extinct species from South America.

Late Neogene chondrichthyan assemblages from the Eastern Pacific and Caribbean region: Diversity, Palaeoenvironments and Palaeogeographic implications

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We report three chondrichthyan assemblages from Tropical America, including the Eastern Pacific of Ecuador (Angostura, Onzole, Canoa and Jama formations: Late Miocene–Pliocene) and the Caribbean region of Panama (Chagres formation: Late Miocene) and Venezuela (Urumaco Formation: Late Miocene). These assemblages contain shallow and deep-water chondrichthyans, with a diversity of at least 60 taxa including the families Chlamydoselachidae, Hexanchidae, Squalidae, Centrophoridae, Etmopteridae, Dalatiidae, Pristiophoridae, Squatinidae, Heterodontidae, Ginglymostomatidae, Odontaspidae, Lamnidae, Otodontidae, Alopiidae, Scyliorhinidae, Hemigaleidae, Triakidae, Carcharhinidae, Sphyrnidae, Rhynchobatidae, Pristidae, Dasyatidae, Myliobatidae and Rhinopteridae. The assemblage from the Urumaco Formation is related with neritic-coastal habits. In contrast, the abundance of sharks typical of deep-water such as *Chlamydoselachus*, *Centrophorus* sp., *Isistius* cf. *triangulus* from the Angostura and Jama formations in Ecuador and *Heptranchias perlo*, *Squalus* sp., *Centrophorus* cf. *granulosus*, *Trigonognathus* sp., *Dalatis licha*, *Isistius* cf. *triangulus* from the Chagres formation Panama, indicate palaeoenvironments associated with a short platform shelf bordering a deep margin. There is much taxonomic commonality between faunas from the Eastern Pacific and Western Atlantic, and the Chagres formation fauna indicates the existence of a marine Caribbean–Pacific connection during the latest Miocene.

A redescription of *Pentlandia macroptera* Traquair 1889

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The Mid-Devonian dipnoan *Pentlandia macroptera* was erected by Traquair well over a century ago but is still very poorly understood. Previous descriptions have described only in the briefest detail how this genus differs from other contemporary dipnoan taxa. More recent studies alluding to *P. macroptera* have gone into some detail about elements of the post-cranial skeleton but a detailed reconstruction of the cranium has not been attempted. This is, in part, due to the poor preservation of the skull. Still, attempts to place this taxon phylogenetically have been made but all from a limited number of specimens. As such the phylogenetic position of *P. macroptera* is equivocal. New observations indicate that



P. macroptera is polymorphic and may possess a D bone. The palatal region is described for the first time, revealing dentition on the. Details of the structure of the pectoral girdle are presented with observations of the anocleithrum and cranial ribs, previously unknown in *P. macroptera*. This wealth of new data has allowed the phylogenetic position of *P. macroptera* to be resolved to a higher degree than ever before, thus improving the phylogeny of the diverse Mid-Devonian Dipnoi.

***Tealliocaris*: a decapod crustacean from the Carboniferous of Scotland**

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Newly observed structures of *Tealliocaris woodwardi* (Etheridge, 1877) help to resolve the taxonomy of Scottish Carboniferous eumalacostracan crustaceans referred to the genus *Pseudotealliocaris* Brooks, 1962. The holotype of *Pseudotealliocaris caudafimbriata*, which is also the type for the genus *Pseudotealliocaris*, is considered here to be a species of *Tealliocaris*, thus making it necessary to re-examine in detail other species assigned to the genus *Pseudotealliocaris*. The diagnostic structures used to identify *Tealliocaris* are also common to those species ascribed to *Pseudotealliocaris*. The different species previously referred to *T. etheridgii*, *T. robusta* and *T. woodwardi* can be differentiated on the basis of minor differences, including the number of anterolateral spines on the antennal scale and carapace, the rugosity of the carinae on the carapace, and the presence or absence of transverse grooves on the pleonal tergites. In addition, the expanded second pleonal pleurae and the enlarged third pleonal tergite, the achelate thoracopods, flagelliform pereopodal exopods, pediform third maxilliped and the presence of phyllobranchiate gills all indicate a closer relationship to decapod crustaceans, in particular Astacida, Homarida and Glypheoidea, than to any other crustacean group.

Taphonomic biases in the preservation of coleoid cephalopod soft-tissues in Mesozoic Lagerstätten

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Crown coleoids have an enigmatic fossil record. Despite low preservation potential, exquisite examples of phosphatised soft tissues are known from several Mesozoic Lagerstätten formations. Recent work demonstrates that all of these fossils appear to be members of the Vampyropoda (octopods and Vampire squids), suggesting a complete lack of crown decabrachians, except for supposed stem forms, such as belemnoids. Recent molecular clock studies clearly indicate that squid and other Decabrachia co-existed with the Vampyropods in the later parts of the Mesozoic. This study investigates whether a potential taphonomic bias could explain this apparent discrepancy by conducting controlled decay experiments of extant squid and octopods. We demonstrate that buoyancy related ammonia-rich fluids found in decabrachian tissues buffer the pH of decaying ten-armed coleoid carcasses. Phosphatisation of soft tissues is closely tied to the pH, which preferentially precipitates below pH 6.38. Ammonia therefore appears to be an important factor in limiting the fossilisation of decabrachians, which are thus excluded from Lagerstätten deposits. A hitherto unknown taphonomic phenomenon is identified that may explain the preservational bias seen in the fossil record.



A statistical and mass spectrometric characterization of the molecular preservation of melanin

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Melanin is the most common source of pigment in the integuments of vertebrates, and has various functions including display, camouflage, UV protection, and structural support. Melanosomes, the organelles that contain melanin, have been discovered in fossil specimens of various taxa, yet it is poorly understood how these structures are preserved or affected by diagenesis. Identification has been primarily based on melanosome morphology, with more recent studies seeking to identify key chemical constituents that are representative of melanin. However, methods that identify metals chelated to organic molecules are not specific to melanin, whilst conventional methods for identifying molecular signatures – such as mass spectroscopy – are too destructive. We have utilized time-of-flight secondary ion mass spectrometry (ToF-SIMS), a minimally destructive technique, which allows intact fossil specimens or small samples to be analyzed, yielding molecular fragments from the sample surface. The complex spectrum of secondary ions obtained presents an analytical challenge, which we show can be characterized in a principal component space. We hereby demonstrate that molecular signatures of melanin are preserved across a number of avian and non-avian taxa in deep time.

Environmental controls on microevolution in Miocene sticklebacks

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Fossil sticklebacks from the Miocene of Nevada provide a unique and important example of directional microevolutionary change in a model vertebrate organism (*e.g.* Hunt *et al.* 2008, Evolution). The sticklebacks (*Gasterosteus doryssus*) are preserved in laminated diatomites of the Truckee Formation, and whilst research on these fish is often cited as a textbook case study of microevolution in fossils, the nature of the diatomite – crucial in establishing both the environmental context and the timescale of evolutionary change – has received scant study. Here we use a combination of micropalaeontological and isotopic analyses of diatomite samples (containing sticklebacks for which morphological data has been recorded) to investigate variation in the palaeoenvironment of the lake during the period of most marked evolutionary change in the sticklebacks. Our results – including a number of previously unreported diatom genera – provide new evidence, allowing us to tease apart biotic and abiotic drivers of environmental change in the lake, enhancing our understanding of this classic example of microevolution.

Late Oligocene brachiopod – crinoid association in Antigua: Expanding the record of deeper-water benthos in the Caribbean

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Extant brachiopods and stalked crinoids flourish together in the deeper waters of the Caribbean Sea. Similar brachiopod and crinoid associations have been reported from the diverse palaeoenvironments in the Neogene of the region, including the Pleistocene of Jamaica (deeper-water forereef), and the Miocene of Jamaica (island slope chalks), Barbados (accretionary prism) and Carriacou (turbiditic siliciclastic shelf). Comparison with analogous modern environments indicates deposition in water depths over 150 m.

The occurrence of this distinctive benthic association has now been extended back into the Upper Oligocene of the Caribbean basin. Weiss (1994, *Caribbean Journal of Science*, vol. 30, p. 22) reported that crinoids and brachiopods both occur in the Antigua Formation of Antigua; the latter occur high in the formation, implying deeper water in this retrograde succession. Moreover, Cooper (1979, *Smithsonian Contributions to Paleobiology*, no. 37) recorded *Argyrotheca dubia* (Cooper) and *Tichosina foresti* Cooper from the Antigua Formation. Here we report columnals of isocrinid crinoids (cf. *Isocrinus* sp.) associated with rare brachiopods (*Terebratulina* sp.) from Half Moon Bay in southeast Antigua, high in the Antigua Formation. These taxa provide independent evidence for the deeper-water aspect of this part of the Antigua Formation, in beds that also yield large, thin-walled fossil sponges.

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A dearth of diplobathrids from the type Devonian

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The diverse biota from the marine deposits of the type area of the Devonian was monographed by the Reverend George Ferris Whidborne, MA, FGS (1846–1910) between 1889 and 1907. Most well preserved specimens of crinoids are cladids or monobathrids. The camerate crinoids are dominated by the monobathrid *Hexacrinites* spp., known from many thecae and several nominal species from the Middle Devonian Torquay Limestone Group. The dicyclic diplobathrid camerates are less speciose and commonly poorly preserved. Diplobathrids include *Rhodocrinites?* sp. (poor crown); *Acanthocrinus?* sp. (spinose thecal plate); *Gilbertocrinus* sp. (columnals); non *Rhipidocrinus crenatus* (Goldfuss) (possibly a monobathrid crown); *Thylacrinus?* sp. (fragment of theca); and rhodocrinitid? sp. indet. This is in stark contrast to the five genera and nine nominal species known from the Silurian, and three genera and 14 nominal species in the Mississippian of the British Isles. The potential reasons for this disparity are many, but must include lack of effort by collectors over more than 100 years, limited exposures, and poor preservation due to tectonic deformation.

Modern Foraminiferal Diversity of Raja Ampat (New Guinea)

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In Indonesia's West Papua Province lies an area already known for its tremendous coral reef biodiversity, the Raja Ampat Archipelago. This constellation of more than 1,500 islands remains largely unexplored due to its remote location and difficult access conditions. Our study is the first analysis of a comprehensive set of sediment samples identifying the composition, structure and diversity of benthic shallow-water foraminifera assemblages



present in this region. The sample material covers the full range of existing macrohabitats and a depth range of 1 – 50 metres. All taxa were identified to species level and a new set of species was recorded. The foraminiferal assemblages exhibit an extraordinarily high species richness of both smaller and larger benthic taxa. Specific diversity was compared to other Indo-Pacific reefal sites to assess the significance of Raja Ampat as a hotspot for foraminiferal diversity and to shed new light on the processes generating species richness in the Coral Reef triangle. Our findings suggest that Raja Ampat constitutes a unique hotspot of marine diversity and one of the world's biologically richest locations among reefs in modern oceans.

Functional Diversity across the Permian/Triassic boundary

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The Late Permian extinction event was the largest biotic crisis of the Phanerozoic with up to 74% of benthic marine invertebrate genera becoming extinct. However, our analyses of the occurrence and range-through data of 1,770 genera demonstrate that at the global scale functional diversity was little affected, despite the magnitude of the extinction event, and only one mode of life was eliminated globally. As shown by previous studies, the extinction was nevertheless selective against sessile, suspension feeding lifestyles and in the extinction aftermath there was a radiation of mobile lifestyles within the marine benthos. Using occurrence data alone results in an overestimate of global extinction magnitude and loss of ecospace, due to sampling biases and the Lazarus effect. At local and regional scales, functional richness was dramatically reduced in tropical ecosystems, but those at higher latitudes suffered less change, at least initially. Recovery of functional richness varied between regions, occurring sooner in Panthalassa than in Palaeotethys. These differences further highlight the complexity of ecosystem response to the Late Permian extinction crisis and through the recovery period. Our results also highlight where gaps in knowledge of certain depositional settings or regions are biasing our understanding of key intervals in the recovery.

Diversity and palaeoecology of Early Devonian invertebrate associations in the Tafilalt (Anti-Atlas, Morocco)

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The Moroccan Anti-Atlas is famous for its highly fossiliferous and well-exposed Palaeozoic rocks. The superb exposures and local abundance of fossils provide the possibility of studying Early Devonian faunal associations in their stratigraphical context in the Tafilalt.

We examined five faunules of Early Devonian age (early Lochkovian – early Emsian) of the Jebel Ououfilal in the Tafilalt for alpha diversity and ecospace utilization. Therefore,



all macrofossils were identified and grouped according to ecological categories of tiering, motility and feeding behaviour. The analyses reveal a strong increase in species richness and an extension of ecospace use during the Early Devonian of the Taouz area. These findings reflect a regional environmental change during the Early Devonian of the Tafilat. In particular, the increase in benthic species leads to the supposition that a steady rise of oxygen content near the seafloor occurred in combination with a sea-level fall.

The rediscovery of Madeira Island Palaeobotany: The case of S. Jorge and Porto da Cruz leaf beds and collections

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The occurrence of plant fossils in Madeira Island has been known since the mid-19th century. Lyell and Hartung discovered in 1854, in São Jorge (SJ), a leaf-bed rich in lauraceae and fern fossils. The results of this discovery were published in two papers: Heer (1857) and Bunbury (1859). Specimens from these publications are currently housed in the ETH-Z-DERDW, NHM and SMC, respectively; a third collection gathered by Hartung is missing. In 1859, Johnson discovered the leaf-bed of Porto da Cruz (PC). From this site we relocated three small collections. Recent inspection of the old sites re-identified the PC outcrop. The SJ site is no longer available, buried by a landslide. Our study of SJ macrofossils revealed the presence of 19 morphotypes, contrasting with the 37 originally proposed, 14 of which are attributable to modern genera. The floristic composition of the SJ fossils closely matches the current floristic association of Temperate stink laurel (*Ocotea foetens*) forest. In the PC macroflora, four morphotypes were recognized. This species-poor macroflora may be associated with opportunistic colonisations of the surface of successive flood deposits inside a naturally dammed fluvial valley.

Investigating the form-function relationship and trophic niche separation in cichlids using 3D microtextural analysis of tooth wear

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Lake Victoria cichlids represent a perfect group for the study of dietary variation and functional morphology due to the well-established link between trophic ecology, morphological evolution and speciation. Their fused Lower Pharyngeal Jaw (LPJ) has been interpreted as a key morphological innovation allowing high levels of adaptive radiation, linked to dietary specialisation for many species (Liem 1973, Systematic Zoology). LPJ with molariform dentitions are thought to suggest shell-crushing diets, however, recent work hypothesises the diet of the supposedly shell-crushing cichlid species *Astatoreochromis alluaudi* is more generalised than previously thought. Therefore, apparently specialized trophic morphology may not be a good predictor of diet, thus invoking “Liem’s Paradox” (Binning *et al.* 2009, *Journal of Fish Biology*). This suggests



that basing dietary analyses on tooth morphology presents a potential problem in fossils. Quantitative 3D microtextural analysis of tooth wear may offer a solution. Using LPJ teeth from populations with known diets, we test whether microtextural analysis allows a determination of dietary specialisation and discrimination between ecotypes. Our results provide insights into the use of 3D microtextural analysis as a tool for dietary differentiation in aquatic vertebrates and new evidence for the effect of Liem's Paradox on cichlid diet.

A continental decapod crustacean from the Late Devonian period

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Terrestrialization stands as one of the most significant evolutionary events in the history of life on Earth. It started in the Ordovician by the invasion of land by plants, and the Late Devonian knew the rise of major new groups of animals, such as tetrapods, insects and other continental invertebrates. We collected a new species of the Carboniferous shrimp *Tealliocaris* in the Famennian (Late Devonian) of Strud, Belgium. Found both in the Devonian and the Carboniferous, this genus was a rare survivor of the end-Devonian mass extinction that strongly affected the evolutionary history of vertebrates, but also crustaceans. A cladistic analysis on the external morphology carried out on extant decapod crustaceans and incorporating fossils indicates a phylogenetic position for *Tealliocaris* as the sister-taxa of *Palaeopalaemon*, a rather derived decapod crustacean from the same period, confirming an origin of Decapoda long before the Late Devonian. Found in the continental (floodplain and pond) deposits of Strud, a unique snapshot of the terrestrialization process, our fossils therefore document the earliest occurrence of a continental decapod crustacean, and may indicate that decapods already composed continental ecosystems since the first steps of terrestrialization.

Testing for time-specific facies: Lower Palaeozoic iron ooids from the Podlasie Basin, E-Poland

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Iron ooids have been reported from several specific stratigraphic levels in the Lower Palaeozoic, e.g. the Darriwilian, Hirnantian, Llandovery. We have observed an iron ooid-bearing interval in a core (Narew IG2) from East Poland. The studied core succession represents outer shelf setting of the Baltic platform, which can be traced from Norway across Sweden and Estonia to Russia. The facies is bioturbated, ferruginous marl with bottom-dweller fauna including trilobites, brachiopods, and crinoids. The iron ooids were deposited in a low energy milieu. To characterize the ooids, which consist mainly of goethite, geochemically we employed the GADDS, EDX and microfacies analysis.



To specify the age of this oolitic interval we processed the samples for microfossils and recovered conodonts, scolecodonts and chitinozoans. The lower part of the studied core fragment yielded chitinozoans belonging to the Mid-Ordovician to basal Silurian *Cyathochitina campanulaeformis* – *kuckersiana* group. Preliminary data from the upper part suggest a correlation to the *A. longicollis* chitinozoan Biozone (Upper Telychian–Middle Wenlock). The Early Silurian age of the iron-enriched interval is also supported by pterospathodid conodonts closely above the oolitic level.

The recovery of Cambrian crustaceans and other small carbonaceous fossils (SCFs) using conventional palynological processing

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The maceration of mudrocks in hydrofluoric acid (HF) is a standard step in conventional palynological processing, where the focus is on recovering very small or robust carbonaceous microfossils such as spores, pollen, acritarchs, chitinozoans and scolecodonts. However, the application of a simplified laboratory procedure, with a single HF treatment and minimal physical manipulation, sometimes reveals a diversity of more delicate small carbonaceous fossils (SCFs). Here we compare the two techniques directly, using samples from the Earlie/Deadwood succession of Saskatchewan and the Nolichucky Shale of Tennessee (both Cambrian Series 3 to Furongian). Although the largest and most intact SCFs were recovered using the simplified procedure, more fragmentary specimens were able to survive successive applications of hydrochloric, hydrofluoric and nitric acids, plus sieving and centrifugation. Most notably, we have identified a suite of Nolichucky palynomorphs as fragmentary copepod mandibles, through comparison with more intact Deadwood SCFs. Clearly, a gentle procedure is necessary to recover the most informative specimens, and to provide a search image for more fragmentary material. On the other hand, standard palynological processing can recover very small and/or rare specimens, increasing the chances of extracting palaeobiological and biostratigraphic signal from rocks with sub-optimal preservation. Overall, we advocate a combined approach.

Synchronised moulting in arthropods from the Middle Cambrian Burgess Shale (Yoho National Park, Canada)

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Behavioural biology of extinct organisms is more challenging to infer than that of extant organisms. In few cases behaviour of extinct organisms is indirectly accessible, e.g., through functional morphological reconstructions, from predator–prey or parasite–host interactions. We present possible fossilised examples of interactions on population level between conspecific individuals. Arthropods grow by moulting. Among extant group-living arthropods, several examples are known in which some individuals or the entire group synchronise the timing of their moulting. Such an interaction at population level



can also be found in the fossil record. Examples of synchronised moulting have been reported for fossil crustaceans, trilobites and sea scorpions. Especially for trilobites and sea scorpions this behaviour has been interpreted as being coupled to mass mating. We report cases of synchronised moulting in two species of arthropods from the Middle Cambrian Burgess Shale fauna (Series 3, Stage 5). In one case, the moulted organisms clearly represent juveniles, contradicting a mating-related explanation. We discuss possible different interpretations of these and other fossil mass occurrences of even-sized exuviae, such as reduction of predatory pressure and cannibalism. Also possible mechanisms for triggering the synchronised moults are discussed. Most plausibly, a pheromone communicating system was present in these putatively “primitive” organisms.

Larvae of Mesozoic lobsters and the evolution of metamorphosis

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Metamorphosis is a short phase during post-embryonic ontogeny in which a rapid and drastic change of morphology occurs. In arthropods this involves a morphological change within one or two moults. Numerous groups of modern arthropods develop through metamorphosis; most notable examples are holometabolous insects, but also achelatan lobsters. Achelatan lobsters offer a special chance to study the evolution of metamorphosis and its deep time aspects, as larval, juvenile and adult representatives have been found repeatedly in the fossil record. Among the fossils are certain forms that resemble their modern counterparts, yet also forms without a correspondence in the modern fauna are known. The latter are specimens with a mixture of larva-specific and juvenile-specific characters. These forms might represent:

- 1) Intermediate stages between true larval and juvenile stages, indicating that the metamorphosis in Mesozoic forms occurred in more moults than in modern forms.
- 2) Less highly specialised larvae compared to their modern counterparts, *i.e.* still lacking certain apomorphies of the modern species.
- 3) Paedomorphic species, *i.e.* species that retain larval characters into the adult phase.

All three cases appear to be represented among the known fossils, also indicating a greater diversity of developmental patterns in Mesozoic forms than today.

The power of tooth morphology in reconstructing cervid evolution (Ruminantia, Artiodactyla, Mammalia)

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Tooth morphology has been a strong tool for identification, taxonomic classification and dietary indication in mammals. However, it has not been used for a comprehensive classification of extant cervids so far. Systematics in fossil cervids are traditionally



reconstructed based on antler morphology and other skeletal features, whereas in extant cervids it is reconstructed using molecular data.

In this study, an overview of the diversity in tooth morphology for 20 fossil and most extant species of cervids, ranging from the Miocene until today, is compiled for the first time. A detailed comparative analysis of the occlusal morphology of the upper and lower postcanine dentition allows for identification of indicative characters for each genus, applicable to questions concerning the evolutionary history of cervids (*e.g.* phylogeny, palaeobiogeography). Trends of character evolution can be tracked throughout the fossil record. Different morphotypes of living cervids based on the morphology of selected tooth positions (*e.g.* p4) could be classified and applied to fossil representatives. An overlap of classifications based on the different tooth positions together with a non-overlap of dietary classifications supports the phylogenetic signal in tooth morphology. This confirms the power of mammalian tooth morphology, providing a more conclusive picture of evolution of Cervidae.

The deep time aspect of brood care evolution – dictyopteran insects as an example

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Dictyoptera is a group of insects, represented by three morphotypes: cockroaches, mantids and termites. Early roachoid dictyopterans were dominant faunal elements in Carboniferous forests, but dictyopterans can also be found in younger deposits, *e.g.*, in the Cretaceous Crato Formation, Brazil, or in Baltic amber. Modern dictyopterans exhibit a wide range of brood care adaptations: carrying an ootheca ('egg packages'), ovovivipary (retraction of oothecae into brood pouch until hatching), feeding of young, sub-social and even eu-social behaviour. While the fossil record readily provides important additional data for reconstructing the evolution of morphological traits, it rarely does so for the evolution of behavioural aspects.

We present examples of cases in which fossils provide direct and/or indirect evidence of brood care in Dictyoptera:

- 1) Early representatives of Mantodea, that provide a phylogenetic signal for the occurrence of ootheca formation;
- 2) Earliest known direct evidences of ootheca-carrying cockroaches from the Cretaceous Crato Formation;
- 3) Cockroach nymphs preserved in Eocene amber indicating further-reaching brood care behaviour, *i.e.* aggregations of blind hatchlings demonstrating a parental dependence in early stages.

These, and other, examples are being integrated into a more holistic approach for understanding the evolution of brood care within Dictyoptera.



Revision of *Patagosaurus fariasi* and the early evolution of basal eusauropods

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Sauropod dinosaurs represent an important component of Mesozoic terrestrial vertebrate faunas, yet their early evolution and diversification in the Jurassic is still poorly understood.

Most records of basal Jurassic sauropods are from eastern Asia. The only abundant basal sauropod material reported from the Western Hemisphere is from the Middle Jurassic Cañadón Asfalto Formation of Chubut province, Argentina, which yielded two described species, *Patagosaurus fariasi* and *Volkheimeria chubutensis*. *Patagosaurus* in particular has figured prominently in basal sauropod phylogenies.

However, recent analysis of tooth morphology of the material recovered from several localities that have yielded material referred to *Patagosaurus* suggests that several taxa are represented. Likewise, significant differences are found in the anatomy of dorsal neural arches and ilia in several specimens referred to this taxon. This suggests that this material includes more than one taxon. Furthermore, recent fieldwork in the area has recovered a wealth of new material that indicates a higher sauropod diversity than currently recognized.

These preliminary results demonstrate that the genus *Patagosaurus* is in need of revision, and data from this taxon should currently be used with caution.

The reinvestigated postcranium of *Henkelotherium guimarotae* (Cladotheria, Mammalia) from the Late Jurassic of Portugal using X-ray computed tomography

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The dryolestid *Henkelotherium guimarotae* from the Late Jurassic of the Guimarota coal mine (Portugal) is known by a largely complete skeleton. The postcranial skeleton has been described earlier. However, since the specimen was transferred to a plastic matrix during preparation, several details were previously inaccessible. Here we present new insights in the postcranial skeleton using x-ray computed tomography (μ CT) and virtual image rendering (Avizo). Contrary to earlier description, *Henkelotherium* has a rather plesiomorphic humerus similar to that of *Dryolestes leiriensis*, with clearly separated radial and ulnar condyles on the anterior side. An inchoate trochlea is present on the posterior aspect of the humerus, with the ulnar condyle spiralling posteriorly to some extent. The scapula is also more plesiomorphic than previously assumed, with an inferior crest on the posterior border of the scapula. In this regard it shows similarities to the scapula of such symmetrodontans such as *Zhangbeotherium*; however it is more derived than symmetrodontans in having a larger supraspinous fossa. The caudal vertebrae show a length/width ratio similar to those of extant arboreal mammals without grasping tails. Our new study corroborates a previous hypothesis that *Henkelotherium* had an arboreal lifestyle.



Axes of Evolution: uncovering the truth about early land plant development

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The PLANTORIGINS-ITN Project is an international research network bringing together developmental geneticists and palaeontologists with the aim of tackling the major outstanding questions regarding the evolution of plant tissues and organs, and their genetic regulation. Within this project, research on the 411 million-year-old Rhynie Chert, consisting of permineralised plant remains, is focusing on three chert organisms, the Charophycean algae, the primitive vascular plant *Rhynia gwynne-vaughanii*, and the more complex lycopod, *Asteroxylon mackiei*. Characterisation of the Charophycean algae life cycle and morphology may illuminate our understanding of the earliest phases in land plant evolution. Analysis of asexual propagules of *Rhynia gwynne-vaughanii* has revealed detailed information on the ontogeny of the organs and tissues of this sporophyte. Research on the stomata of the early fossil lycopod *Asteroxylon mackiei* shows possibly the earliest record of polyploidy in plants. Advanced microscopy techniques like confocal microscopy and x-ray tomographic microscopy (synchrotron) are crucial to the optimal imaging of these fossils. We have also used phylogenetic and comparative studies with extant algae, bryophytes and lycopods to help interpret the evolution of the algae and plants of the Rhynie chert. This work, combined with new genetic data, is successfully beginning to realise the objectives of the project.

Fossil coleoids from the Lagerstätte of Sahel Aalma (Upper Cretaceous, Lebanon)

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The study of 17 specimens of coleoid cephalopods from the Santonian chalky limestones of Sahel Aalma, from the Dubertret collection stored at the MNHN of Paris, reveals a diversity much higher than previously assumed for this Lagerstätte. Five species can be identified: *Dorateuthis syriaca* and *Palaeoctopus newboldi* (already reported from this site), as well as three species previously unknown in Sahel Aalma: *Glyphiteuthis libanotica*, *Glyphiteuthis* n. sp. and *Rachiteuthis* n. sp. Consequently, we document the first unambiguous Santonian occurrence of the genera *Rachiteuthis* and *Glyphiteuthis*. We agree with previous authors in that the diagnostic characters for *D. syriaca* have yet to be clarified. In addition, morphological differences are so tenuous between *D. syriaca* and the Jurassic *Senefeldriteuthis tricarinata* and *Plesiototeuthis prisca* that we suggest they might be seen as a single species.

The 17 studied specimens show numerous well-preserved soft-part characters. Some of them were previously unknown and have a major phylogenetic significance. For example, we document for the first time two transverse rows of sessile suckers in *D. syriaca*.

Finally, the soft-part anatomy of the studied gladius-bearing coleoids (*i.e.* absence of tentacles, transverse pairs of suckers, sessile suckers, crop) strongly suggests that they are closely related to modern vampyropods.



Early Vertebrate Skeletogenesis

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The skeleton is one of the most important vertebrate characters, yet surprisingly little is known about its early evolution. Crucially, we lack ontogenetic data for the earliest ossifying vertebrates. The Heterostraci are among the most primitive vertebrates with an extensive skeleton and hence greater understanding of their ontogeny can inform the pleisiomorphic condition of vertebrate skeletogenesis. Heterostracan dermal plates often show a concentric arrangement of superficial tubercles interpreted as 'growth lines', while internally these plates show no evidence of growth. Several competing growth hypotheses have previously attempted to rationalise the incongruence between internal and external skeletal architecture. To this end, a palaeohistological study was devised to test these hypotheses and provide a skeletogenic model for the Heterostraci. Data have been collected from an ontogenetic sequence of corresponding dermal plates, permitting a generative model of the dermoskeleton to be conceived. This model has subsequently been verified using a comparable ontogenetic sequence of body scales analysed using synchrotron X-ray tomography. Preliminary results suggest that the internal architecture is more dynamic than has been previously proposed. The middle layer invasively expands through ontogeny, and cancellae are subdivided by trabecular cross-walls. These results suggest that the skeleton was systematically remodelled in response to growth.

Composition and significance of the Weeks Formation Fauna (Guzhangian; Utah, USA)

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Cambrian Lagerstätten offer extraordinary insight into the composition and evolution of early metazoan communities. Recent discoveries in the Ordovician question the view of an abrupt transition between the Cambrian and Palaeozoic Evolutionary Faunas. This stresses the need for more data on Late Cambrian non-biomineralized animals. Here we present some preliminary results of our investigations on the Guzhangian Weeks Formation fauna of Utah, USA. The Weeks Formation comprises a 300-m-thick sequence of thin-bedded lime mudstones, wackestones and grainstones with variable amounts of shale. It represents an open-shelf marine environment. Two types of exceptional preservation are recognized: 1, pyritization of major morphological details with subsequent oxidization to iron oxides and coating of chlorite; and 2, phosphatization of arthropod guts. The shelly fauna is dominated by trilobites and brachiopods, while non- or weakly biomineralized organisms



are predominantly arthropods and priapulids. The arthropod fauna is rich in aglaspidids, a group best known from Guzhangian–Furongian deposits. However, animals characteristic of Cambrian Series 2–3 (*Anomalocaris*, leañoiliids) and Ordovician (*Tremaglaspis*) biotas are also present, along with several species of uncertain affinities. Accordingly, the Weeks Formation fauna may be regarded as transitional, which supports the hypothesis of more gradual evolution of metazoans during the Early Palaeozoic.

Quantitative analysis of the Late Ordovician coral–stromatoporoid reefs in the Xiazhen Formation at Zhuzhai, southeast China

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Various Late Ordovician (late Katian) reef complexes are reported from the border area between Jiangxi and Zhejiang provinces of southeast China. One of the most well-known examples of the low-relief coral–stromatoporoid reefs is exposed in Zhuzhai, Yushan County. They comprise two main reefal units (~ 7.4 m thick altogether), occurring in the lower part of the Xiazhen Formation. However, most previous interpretations of these are based on qualitative descriptive data. We first describe the quantitative relationship among the framebuilders in these metazoan–dominated reefs by using line transects on the outcrop combined with point counting for thin sections. The result shows that the major skeletal builders, including stromatoporoids, tabulate and rugose corals, are mainly preserved in growth position and account for 44–53% of sampled framework. Abundant and diverse stromatoporoids, taking up 22.4–31.2% in volume, play a key role in the lower reefal unit. With a vertical succession, tabulate corals turn into the dominant group (reaching up to 49.4%) in the second unit, and stromatoporoids are relatively rare (< 2%) there. The two reefal units represent different ecological stages that are characterized by *Plasmoporella*–*Clathrodictyon* community and *Agetolities*–*Catenipora* community one after the other.

New occurrences of palaeoscolecid worms in the Lower Palaeozoic of Morocco and the USA

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Palaeoscolecids are long cylindrical annulated vermiform ecdysozoans with an eversible proboscis comparable with that of priapulids. Their most conspicuous external features are aligned knob-like sclerites of assumed primary phosphatic origin associated to the annulations of their moulting cuticle. Recent cladistic analyses indicate that palaeoscolecids probably belong to the stem lineage Priapulida. Their fossil record ranges from the Early Cambrian to the Late Silurian, but only isolated sclerites or small clusters of sclerites are usually found in sediments as SSF or SCF. By contrast, complete animals are relatively rare except in some Early Cambrian Lagerstätten such as in Chengjiang. Here, virtually complete specimens are reported from several localities of Utah and Morocco, which give important information on the anatomy, ecology and distribution of Palaeoscolecida throughout the Cambrian–Ordovician transition. Two specimens were recovered from the



Issafen Formation (Cambrian Series 2, Stage 3) near Timkit township, Morocco. Three others were found in the Weeks Formation (Cambrian Series 3, Guzhangian), central House Range, Utah (USA). The Fezouata Formations (Early Ordovician, Late Tremadocian) in the Zagora area, Morocco, have yielded the largest collection (around a dozen specimens). Lastly, four specimens were collected at Bou Nemrou, in the Izegguirene Formation (Late Ordovician, Sandbian) near Rissani, Morocco.

Late Ordovician (Katian) spores in Sweden – oldest land plant remains from Baltica

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A palynological investigation of Late Ordovician (Katian) successions within the Röstånga-1 core, southern Sweden has been performed. The lithology constitutes mudstone and graptolitic shales, with subordinate limestone, formed in the deeper marine halo of southern Baltica. The palynological assemblages are dominated by marine microfossils, mainly chitinozoans and acritarchs. Interestingly, a sparse but well preserved record of cryptospores was encountered including *Tetrahedraletes medinensis*, *T. grayii* and *Pseudodyadospora* sp. identified within the Lindegård Formation (late Katian – early Hirnantian). This possibly represents the earliest record of early land plant spores from Baltica and definitely the oldest spore record of Sweden.

The cryptospores of this study were recovered from the Lindegård Mudstone with the oldest record of spores just above the FAD of the graptolite taxa *D. complanatus*. The presence of cryptospores in sediments of this study shows that land plants had migrated to the palaeocontinent Baltica by at least the Late Ordovician.

Palaeobiogeography of ammonoids (cephalopods) during the Cenomanian global warming

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Moderate extinction (26% of marine genera) and several abiotic events (high sea level, positive carbon isotope excursion, and the global oceanic anoxic event OAE-2) marked the Cenomanian/Turonian boundary (Cretaceous). Although this event is used often to illustrate the impact of anoxia, it does not hold for ammonoids, which underwent profound changes before. Besides, a long-term global warming, which peaked in the Early Turonian, is another characteristic of this period. Thus, quantifying and elucidating the biogeographic changes, structures and dynamics of ammonoids during the Cenomanian is a critical step towards the understanding of biodiversity drivers and dynamics. To this purpose, this study focuses on standard and also more recent quantitative approaches (rarefaction and extrapolation curves, occurrence ratio profiles, bootstrap spanning networks). The study relies on an exhaustive compendium of ammonoid occurrences extracted from the literature and with homogenized taxonomy. It includes more than 350 species and 110 genera. Preliminary results indicate a high proportion of endemic taxa that nevertheless decreased during the Cenomanian. Several palaeobiogeographic provinces can be distinguished, although they overlap. The evolution of the properties and relationships between these ammonoid provinces accurately captures changes in climate and oceanic circulation (especially the opening of the South Atlantic).



Mapping global patterns in Cretaceous nautiloid distribution

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The distribution of extant nautiloid cephalopods is restricted to the Indo-Pacific, typically between 40 degrees south and 20 degrees north, centred on the equator. Post-mortem drift of shells floating on ocean currents extends their occurrence well beyond their respective home ranges. During the Late Cretaceous nautiloids reached their maximum post-Palaeozoic generic diversity, with twelve genera representing three families, namely the Eutrephoceratidae, Hercoglossidae and Nautilidae, with peak origination of genera during the Early Cretaceous. Plotting the occurrence of nautiloids onto palaeogeographical reconstructions of the Cretaceous world reveals diversity hotspots in the North American Seaway, western Tethys, and the east coast of Africa with Madagascar and the Indian continent. Distributions range between 30 and 50 degrees north and south, markedly away from the equator. In common with extant forms they occupied continental shelf archipelagos with numerous islands and channels.

The origin of conodonts and of vertebrate mineralized skeletons

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The earliest vertebrates to possess mineralized skeletons are the conodonts, the phosphatic feeding elements of which have inspired the 'inside out' hypothesis that teeth evolved independently of the vertebrate dermal skeleton and before the origin of jaws. However, little is known of the early evolution of the conodont element, and much of the evidence marshalled in support of this hypothesis is drawn from highly derived euconodonts. By using synchrotron radiation X-ray tomographic microscopy we are able to characterize fully the internal structure of morphologically similar euconodont and paraconodont elements. Paraconodont elements demonstrate a clear spectrum of grades of structural differentiation, including patterns of growth common to basal bodies of euconodont elements, which affirms a stepwise acquisition of euconodont characters culminating in the evolution of crown tissue – a euconodont apomorphy, and therefore not homologous to vertebrate enamel. This demonstrates that euconodonts derive from within a paraphyletic Paraconodontia, and that the precise similarities in ontogeny, tissue structure and topology between conodont elements and vertebrate odontodes is a remarkable instance of convergence. The last common ancestor of jawed vertebrates and the conodonts likely lacked a mineralized skeleton. Furthermore, another plank is removed from the hypothesis that teeth evolved before jaws.



A biased view on the diversity of Cambrian acritarchs

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Acritarchs are the main source of information about phytoplankton in the Cambrian. Studies on Cambrian acritarchs abound, but for a convincing reconstruction of diversity and evolutionary trends they need to be combined. Diversity can be measured and presented in different ways, and for the Cambrian acritarchs a number of biases and difficulties exist, the results need therefore to be critically assessed. Here we use the available data and various methods to approximate Cambrian acritarch diversity on specific and generic levels and on regional and global scales. The global total diversity curve obtained shows a gradual increase throughout the Lower Cambrian, a drastic decline in the early Middle Cambrian and a considerable new rise during the Upper Cambrian. The curve is conspicuously following the sampling distribution, which does not make it invalid. Regional patterns, while based on a comparatively restricted data pool, do not always exactly mirror global trends and are potentially better indicators for the actual diversity at a given time and locality.

Interdependence of diversity and specialisation in Phanerozoic marine invertebrates

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Analyses of the fossil record have repeatedly demonstrated that ecological traits predict extinction risk in marine invertebrates, but the relationship between autecology and patterns of preferential origination is less well explored. Both selective origination and extinction determine the dynamics of biodiversity and its ecological composition. Using sampling-standardised data from the Paleobiology Database, we studied habitat breadth of marine genera as a proxy for their specialisation in three major marine invertebrate groups (brachiopods, gastropods and bivalves) over the Phanerozoic. In particular, we examined how the varying level of ecological specialisation in these groups is related to diversity and its fluctuations. Specialisation of a genus is defined as a function of its realised ranges in water depth, substrate mineralogy, and grain-size. Sampling-standardisation is performed using shareholder quorum sub-sampling. Our time series consists of 83 intervals, most of which are equivalent to geological stages. We found that the proportion of specialists is positively correlated with diversity. Intervals of increasing diversity are characterised by the preferential origination of specialists, whereas diversity decrease is linked to their selective extinction. These findings provide strong evidence that the overall level of specialisation of marine invertebrates and its fluctuations through time are controlled by diversity-dependent processes.

Humble origins for a successful strategy: complete enrolment in Early Cambrian olenellid trilobites

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Trilobites are typified by the behavioural and morphological ability to enrol their bodies, most likely as a defence mechanism against adverse environmental conditions or predators.



Enrolment generally required a combination of complex morphological adaptations (e.g. caudalized body, coaptative devices), and it has been argued that the palaeoecological pressure to enrol was an important driving force in the evolution of the major trilobite groups. Although most trilobites could enrol at least partially, there is uncertainty on whether Olenellidae (Redlichiida) – among the most phylogenetically and stratigraphically basal representatives – could engage in this behaviour due to their poorly caudalized trunk and scarcity of coaptative devices. Here we report complete – but not fully encapsulating – enrolment in *Mummaspis*, an olenellid from the Early Cambrian (lower Dyeran) Mural Formation of Alberta. The Mural specimens exhibit simple coaptative devices that stabilized the enrolled configuration in life, but without mechanical locks capable of preserving the behaviour in the absence of rapid pre-mortem burial. Complete enrolment in olenellids was achieved through a combination of sympleiomorphic characters, and thus provides new information on the character polarity associated with this key trilobite adaptation. These are the oldest documented occurrences of enrolment in polymerid (*i.e.* non-eodiscoid) trilobites in the fossil record.

Identifying chemosymbiosis through geological time by stable isotope analysis of shell-bound organic matter

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Chemosynthesis-based ecosystems use energy from bacterial oxidation of inorganic molecules to fix carbon. Living in symbiosis with chemosynthetic bacteria allows marine invertebrates to dominate reducing environments. Chemosymbiosis is the dominant nutritional strategy in modern seep and vent communities, but its origin and evolutionary history are poorly understood. Evidence for chemosymbiosis in the fossil record is extremely scarce, as soft tissues containing symbiotic bacteria are not preserved. Our aim is to identify and trace chemosymbiosis through geological time using carbon, sulphur and nitrogen stable isotopic signatures of organic matter preserved within shells. Shell-bound organic matter (SBOM), within and between shell minerals, has similar isotopic values to soft tissues. If preserved in fossils, SBOM will allow us to investigate the relationship between chemosymbiosis and the evolution of Phanerozoic seep and vent fauna. Here we present stable isotope data on the relation between SBOM and soft tissues for modern seep and non-seep bivalves and brachiopods. This work forms the basis for future analyses including a wide variety of species from fossil cold seeps and control localities. Moreover, for the first time the possibility of chemosymbiosis in ancient brachiopods will be tested, having disappeared from seeps after taxonomic domination in the Palaeozoic and Mesozoic.

Benthic ecosystem dynamics following the Late Triassic mass extinction event

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A major extinction event will disrupt benthic ecosystems, resulting in the collapse and subsequent recovery of marine communities. In order to investigate benthic ecosystem recovery after the Late Triassic extinction event, the well-exposed sedimentary succession between Pinhay Bay and Lyme Regis, southern UK, was studied. Quantitative data were collected from 19 limestone beds of the Rhaetian–Sinemurian Blue Lias Formation. For



each sampled bed, two 50 x 50 cm quadrats were randomly placed on the bedding plane surface and all macroinvertebrate fossil remains found within the quadrats were counted and identified. Palaeoecological changes were assessed through analyses of diversity, richness, evenness, abundance and occupation of ecospace. Although there is a general trend from palaeocommunities with lower diversity, richness, abundance and evenness around the Triassic/Jurassic boundary to those with higher diversity, richness, abundance and evenness by the late Hettangian, there are significant shifts within biozones and even between adjacent beds. Most of the palaeocommunities are characterized by low-level, surficial, suspension feeders, but higher tier organisms and an increase in motility and feeding styles characterise the later stages of recovery. The Hettangian trends recorded in this study are comparable to those recorded from other UK sites despite differences in sampling methodology.

Exploding the Myth: Can Carcasses Explode?

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In the palaeontological and archaeological literature of the past almost four decades, we encounter a non-uniformitarian taphonomic scenario not recognized by veterinary and human medicine, that of the “exploding carcass”, an explosive bursting of a body in an advanced state of decomposition (postulated for a great taxonomic variety of vertebrates). We are convinced that the hypothesis of subaquatic carcass explosion is not tenable. The maximum values of intra-abdominal pressure measured on Recent vertebrates filled with putrefaction gases is lower by several orders of magnitude than the hydrostatic pressures that according to bathymetric calculations were assumed to have prevailed at the depositional sites of the fossils (*e.g.*, fossil sites at Holzmaden, Messel, Solnhofen, and Monte San Giorgio). In the calculated bathymetries of the depositional sites in question, the main components of the putrefaction gases (CO₂, N₂, O₂ [sic!]) would be dissolved in the bodily fluids and putrefaction fluids of the carcass. The potential transport mechanisms for skeletal elements in low-energy and life-hostile aquatic depositional environments are: bottom currents (induced, *e.g.*, by storms or internal waves); turbidites; disarticulation and gravitational settling within an intact yet putrefaction-fluid-filled body cavity; current-induced transport by the discharge of putrefaction fluids from a ruptured integument.

The Miocene land snails of Southern Germany: taxonomy, palaeobiogeography and palaeoecology

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Miocene fossil sites in Southern Germany harbour a very diverse land snail fauna. The molluscs from these sites started being studied and described in the first half of the 19th century, but many remain unstudied to this day. The intention of the present work is to build a palaeobiogeographic history of the land snails in Central Europe through the Miocene. As such, a large database is being built based mainly on literature data. Of course, the fossils from many sites have either never been properly described or are in dire



need of a revision. Since unreliable data would harm a biogeographic analysis, some of these molluscan faunas are currently being revised, namely the Early and Middle Miocene faunas of Southern Germany: Sandelzhausen, Oggenhausen, Randeck Maar and Gündlkofen (for now, but others, like Biberach, will be added soon). Moreover, it is a good opportunity to study other aspects of these faunas, such as palaeoecology and palaeoenvironment. Sandelzhausen, for instance, dates from the Miocene Climatic Optimum, and systematic collection of its snails allows a precise study of faunal and environmental changes, which is being further complemented by isotopic (C, O and Sr) analyses.

Distinguishing absence from loss: Phylogenetic analysis of exceptionally preserved fossils requires very few errors to be made

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Exceptional preservation of soft-bodied fossils provides unique insight into many important evolutionary events, foremost being the Cambrian explosion. Use of these fossils in evolutionary contexts requires robust placement in phylogenetic frameworks. The complex taphonomic processes of decay and preservation underlying the formation of these fossils make it difficult, however, to distinguish phylogenetic absence from taphonomic loss. Is a particular morphological character (*e.g.* appendage, tentacle or nerve cord) missing from a fossil because it was never there, or just happened not to be preserved? Here, we demonstrate that the introduction of only a few miscoded absences to simulated and real phylogenetic datasets ('0's rather than '?') causes taxa to drift down trees, toward the root. This low threshold for errors may cause fossil organisms to be erroneously interpreted as more primitive than they were in life. It therefore presents a problem for all evolutionary studies that attempt to use exceptionally preserved soft-bodied fossils to reconstruct rates of evolution (molecular clocks) or unlock sequences of morphological change (evolutionary transitions). Stem-ward slippage, whereby taphonomic processes cause organisms to appear artificially primitive, therefore appears to be a ubiquitous and problematic phenomenon, even when no decay biases exist.

Leaf galling during the transition from the Palaeozoic to Modern Insect Fauna

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Gall-inducing insects cause plants to form a growth around nymphs. In modern ecosystems, insects belonging to many lineages induce galls; overwhelmingly, they attack angiosperms. Some gall-inducing insect lineages, especially Sternorrhyncha (Hemiptera) and Thysanoptera, are twice as old as angiosperms. Three lines of evidence suggest that leaf-galling by insects began when these lineages originated, during the Permian Period: damage on leaves, insect body fossils, and palaeoclimate trends. The Permian was a time of increased aridity. Recently, numerous fossil gall types have been found on Permian leaves. In particular, two floras from the Early Permian of Texas demonstrate that gall induction on leaves became widespread during the Kungurian Stage. Permian insects from several lineages, including Sternorrhyncha and Thysanoptera, became smaller, and small size is the principal prerequisite for gall induction of a plant host by an arthropod. All potential



gall-inducers of this time interval were members of the Modern Insect Fauna, which incrementally replaced the Palaeozoic Insect Fauna throughout the Permian. Because gall-inducers invest less energy in feeding and protecting themselves, and therefore devote more energy to reproduction, the evolution of gall induction may have been a key development during the only time interval wherein the two global assemblages of insects overlapped.

Chaetetids from the Upper Carboniferous Buckhorn Asphalt Quarry Lagerstätte, Oklahoma

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Chaetetid sponges from the Desmoinesian Buckhorn Asphalt Quarry Lagerstätte represent the largest benthic organisms in this outcrop (max. diameter: 21 cm, max. height: 8.3 cm). Deposition of the chaetetid-bearing sediments occurred in a shallow (euphotic zone II-III) marine setting near the palaeo-equator. The siliciclastic-carbonatic sediments from the Lagerstätte were impregnated by migrating hydrocarbons during or shortly after deposition; hence, fossil preservation is generally outstanding.

Chaetetid skeletons from the quarry originally consisted of high Mg-calcite. Two morphotypes are present, comprising domical and laminar growth, which indicates genetic rather than environmental control. Internal skeletal features comprise tabulae, spine-like projections, pseudoseptae, growth disturbances, and greyish structures. Tubule diameter and length is variable, and spicules are absent. Skeletal fragmentation is common and indicates complex taphonomic mechanisms. Some specimens display large incisions indicating physical impact. The skeletal surface is also often covered by microbial mats associated with Mn-carbonatic cements.

The Toploje Member chert: A terrestrial Permian Lagerstätte from East Antarctica

* **Ben J. Slater¹, Stephen McLoughlin² and Jason Hilton¹**

¹*School of Geography, Earth and Environmental Sciences, University of Birmingham, Birmingham, UK*

²*Department of Paleobotany, Swedish Museum of Natural History, Stockholm, Sweden*

The Toploje Member chert is an extensive deposit of silicified peat remains which preserves a diverse array of Roadian to Wordian aged terrestrial life from high-latitude Gondwana. The peat consists primarily of glossopterid and cordaitalean gymnosperm organs alongside smaller proportions of herbaceous lycophytes, ferns and other gymnosperms. Also preserved are a diverse collection of fungi, Peronosporomycetes, various coprolite morphotypes and rare arthropod remains. Studies of the microcoprolites allow detailed assessment of patterns of food consumption, the presence of discrete feeding guilds and levels of trophic complexity. The invertebrate-plant-fungal interactions associated with all organs of the *Glossopteris* whole-plant reveal a 'component community' of invertebrate herbivores and fungal saprotrophs centred around the *Glossopteris* organism, and demonstrate that a multitude of ecological interactions were well developed by the Middle



Permian in high-latitude peat-forming mires. Quantitative analyses of the constituents preserved in the Toploje Member chert are compared to data from coal macerals of co-occurring coal seams, revealing that while silicified peats preserve an unparalleled sample of the palaeocommunity, they do not necessarily accurately reflect the constituents that ultimately go on to dominate the coal maceral volume.

Micro vs. Macro: A quantitative comparison of palynological and plant macrofossil data from a Jurassic plant bed

* **Sam Slater and Charles H. Wellman**

Department of Animal and Plant Sciences, University of Sheffield, Sheffield, UK

Palynomorphs from Middle Jurassic terrestrial deposits of the Ravenscar Group from the Cleveland Basin in northeast Yorkshire are used to reconstruct palaeoenvironmental conditions at this time. Assemblages of abundant, diverse and well-preserved palynomorphs have been recovered from numerous horizons throughout the sequence. A five metre section through a plant bed from Hasty Bank, North Yorkshire has been sampled at 10 cm intervals for high resolution analysis of spore/pollen and palynofacies assemblages. The macrofossil palaeobotany of this section was assessed in detail by Spicer and Hill (1979) by analysing quantitative palaeobotanical count data using multivariate plots. Quantitative palynological data are compared with previous palaeobotanical data by assigning spores/pollen to parent plant taxa. This enables integration of dispersed spore and pollen studies with palaeofloristic reconstructions. Correspondence and principal components analysis in conjunction with absolute abundance data shows lithology is the dominant factor controlling spore/pollen assemblages and palynofacies compositions. Palynological assemblages display evidence of larger catchment areas than palaeobotanical macrofossil data. Despite this, palynological data in this section are considered to be more representative of the true palaeoflora due to the preferential preservation of more durable plant taxa such as *Equisetum*, which artificially inflates relative abundances of many species in macrofossil assemblages.

A new view on lobopodian sclerites: implications for the affinity, distribution and diversity of Cambrian ‘onychophorans’

* **Martin R. Smith¹, Thomas H. P. Harvey^{1,2} and Jean-Bernard Caron^{3,4}**

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⁴*Department of Ecology and Evolutionary Biology, University of Toronto, Toronto, ON, Canada*

Lobopodian worms are widely recognized as having an important role in the elucidation of early panarthropod evolution – even if their exact implications for the origins of tardigrades, arthropods and onychophorans remain unclear. Of primary concern is the shortage of characters that are unique to any individual panarthropod phylum. Here we describe previously unappreciated synapomorphies from onychophoran claws. These distinctive morphological features have exact parallels in the claws and armature of *Hallucigenia* specimens from the Burgess Shale, identifying this taxon – but not its compatriot *Aysheaia* – as a stem-group onychophoran. A disparate suite of Early to Middle



Cambrian microfossils can now be recognized as onychophoran sclerites, greatly expanding the diversity and distribution of the group. Taken together, these fossils provide new constraint on the establishment of the onychophoran body plan.

Redescription and phylogenetic position of the archosauriform *Dorosuchus neoetus* from the Middle Triassic of Russia

* **Roland B. Sookias**^{1,2}, **Andrey G. Sennikov**³, **Richard J. Butler**^{1,2} and **David J. Gower**⁴

¹*School of Geography, Earth and Environmental Sciences, University of Birmingham, Birmingham, UK*

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³*Borissiak Paleontological Institute RAS, Moscow, Russia*

⁴*Natural History Museum, London, UK*

The Middle Triassic (Early Anisian) basal archosauriform *Euparkeria capensis* from South Africa is central to our understanding of archosauriform evolution as it may approach the ancestral archosaur body plan, and is the sister to crown Archosauria in most cladistic phylogenies. *Dorosuchus neoetus* from the Anisian of Russia has been assigned as a member of the family Euparkeriidae. The holotype (right ilium, femur, and tibia of a single individual) and other specimens including a braincase were referred to *Dorosuchus* on original description. A partial pterygoid and left posterior mandible from the same locality but from a different block were subsequently referred. We present a new diagnosis of the taxon. A phylogenetic analysis using all referred specimens places *Dorosuchus* immediately outside Archosauria+Phytosauria, one node more crownward than *Euparkeria*. An analysis excluding the mandible and pterygoid yields a similar result, whilst the mandible and pterygoid alone are placed in the crown. *Dorosuchus* can be considered a taxon close to the base of Archosauria, approaching – like *Euparkeria* – the morphology of the ancestral archosaur, though referral of the mandible and pterygoid to the taxon remains tentative. There is no strong evidence for a monophyletic Euparkeriidae including *Dorosuchus*.

Preserving Cambrian bodies in Sirius Passet, North Greenland: a unique Lagerstätte

* **Katie M. Strang**

University of Durham, Department of Earth Sciences, Durham, UK

The Sirius Passet Lagerstätte of Peary Land, North Greenland, occurs in marine mudstones and represents the oldest Cambrian exceptional preservation of soft tissues, pre-dating the Burgess Shale by ~10 million years. The Lagerstätte contains a weakly to non-mineralised largely arthropod fauna that is characterised by three main types of fossil preservation: films, moulds and permineralised guts. Thin section, SEM, BSE and SEM-EDAX analysis have been carried out on the films and preliminary results show these are composed mainly of silica, with a noticeable depletion in clay minerals. Permineralised, microbial mats are associated with the fossils and scattered through the thin sections. It is postulated that the films were formed during an early phase of silicification that may be associated with the growth of coccoid cyanobacteria. Further work continues to try and constrain the timing of silicification. Initial results show there is no clay over printing in the films, indicating that the Sirius Passet is not only the oldest of the Cambrian Lagerstätte, but also unique.



Mycorrhizas in *Horneophyton lignieri* from the Rhynie Chert, Scotland (*ca.* 407 Ma) most closely resemble associations in extant lycophytes, hornworts and early divergent liverworts: a reappraisal of the nature of Palaeozoic fungal associations

Christine Strullu-Derrien¹, Paul Kenrick¹, Silvia Pressel² and Jeffrey G. Duckett²

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²Department of Life Sciences, Natural History Museum, London, UK

Fungi form close associations with plants. The evolution of these symbioses is considered a key event that drove plant terrestrialisation 460 MYA. Arbuscular mycorrhizas involving fungi in the Glomeromycota have been widely assumed to be the ancestral symbiotic condition in both bryophytes and tracheophytes.

We studied thin sections of exceptionally well-preserved permineralized plants from the Rhynie Chert, Scotland (*ca.* - 407 Ma). We document mycorrhizas in *Horneophyton lignieri*, a small plant with bifurcating stems that developed from a corm-like base bearing rhizoids.

A Glomeromycota-like fungus colonized the aerial stems of the plant in a discontinuous zone of the outer cortex forming vesicles, arbuscule-like structures and spores. However the presence of hyphae in intercellular spaces and fungus-free rhizoids in the corm more closely resemble the associations previously described in lycophytes, hornworts and the earliest divergent liverworts. These have been recently identified as belonging to the Mucoromycota, an earlier fungal lineage than the Glomeromycota.

In the context of current research demonstrating that Glomeromycota and Mucoromycota can form symbioses in liverworts, hornworts, and lycophytes, sometimes simultaneously, our discovery indicates that dual colonization also occurred in *Horneophyton*. Our result strengthens the notion that early land plants relied on a wider symbiotic repertoire than previously thought.

The adaptive radiation of Triassic marine reptiles

* Tom Stubbs and Michael J. Benton

School of Earth Sciences, University of Bristol, Bristol, UK

The diversification of Mesozoic marine reptiles in the Triassic represents an exemplary evolutionary radiation. Fossil evidence suggests that Triassic marine reptiles evolved a great range of feeding ecologies, morphological innovations and body sizes as early as the Anisian; rapidly establishing trophically diverse marine communities. In this study we quantify and explore the proliferation of ecological variation during the early stages of Mesozoic marine reptile evolution, by examining variation in feeding ecology and body size. To assess feeding ecology we analyse morphological and biomechanical variation (disparity) in lower jaw elements. Calculating morphological and biomechanical disparity through time reveals that Triassic marine reptiles became very disparate by the Anisian, and this level of variation was maintained until the Triassic–Jurassic boundary, despite faunal turnovers and a large decline in species diversity during the Late Triassic. In contrast, although the Anisian is associated with the largest range of body sizes, the evolution of greatest body size is delayed until the Late Triassic. Overall, this study quantitatively supports the notion that Triassic marine reptiles became ecologically diverse early in their history, and reveals that marine reptiles persisting into the Late Triassic remained trophically diverse and achieved greater overall body sizes.



Bryozoan skeletal mineralogy across the Eocene–Oligocene boundary: stasis in the face of global oceanographical changes

Paul D. Taylor¹, Noel P. James² and George Phillips³

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²*Department of Geological Sciences and Geological Engineering, Queens University, Kingston, Ontario, Canada*

³*Museum of Natural Science, Jackson, Mississippi, USA*

An increasing number of cheilostome bryozoan clades since the Late Cretaceous have evolved the ability to make aragonitic skeletons. Here we provide a first test of whether changing bryozoan biomineralogy correlated with the switchover from a calcite to an aragonite sea by comparing the mineralogical compositions of bryozoan assemblages from the Late Eocene with those from the Early Oligocene, a time believed to mark the transition. XRD analyses of skeletal mineralogy were undertaken of bryozoans from deposits in Mississippi and western Alabama preserving skeletal aragonite (as indicated by the occurrence of aragonitic molluscs). The hypothesis that the proportion of species employing aragonite increases from the Eocene into the Oligocene at the probable transition to aragonite seas is not supported by our data. Among 23 Eocene species, 14 (61%) were found to be calcitic, 7 (30%) aragonitic, and 2 (9%) bimineralic, whereas among 28 Oligocene species 19 (68%) were calcitic, 5 (18%) aragonitic and 4 (14%) bimineralic. Possible reasons why the expected mineralogical change is lacking include incorrect dating of the calcite to aragonite sea switchover, the compensating effects of cooling at this time favouring calcite over aragonite biomineralization, and overriding biological control of skeletal mineralogy by the bryozoans.

Paleocene forests and climates of Antarctica: signals from fossil wood

Laura Tilley¹, Jane Francis¹, Vanessa Bowman² and J. Alistair Crame²

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²*British Antarctic Survey, Cambridge, UK*

During the greenhouse world of the Paleocene, Antarctica was covered in forests, even though the continent was situated over the South Pole. Fossil wood is abundant in marine sequences of Seymour Island, Antarctica. The wood originated from forests that once grew on the volcanic arc now represented by the Antarctic Peninsula and then floated as driftwood on the ocean before eventually sinking into the ocean sediments and becoming permineralised. Fossil wood has been systematically collected from Paleocene marine sequences of Seymour Island and has been studied in order to reconstruct the forest composition and evolution of the vegetation throughout the Paleocene. Results indicate that trees of southern beech (*Nothofagus*), monkey puzzle trees (*Araucaria*), Cunoniaceae and podocarp conifers lived in the forests. These tree types can be found in cool temperate forests in Chile and New Zealand. Analysis of tree rings and angiosperm anatomy has been conducted in order to reconstruct the climate in which the forests grew during the Paleocene; here we present preliminary results and their implications.



Life reconstruction of *Kaatedocus siberi*

* Emanuel Tschopp^{1,2}, Davide Bonadonna³ and Andrea Píroncini⁴

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A life reconstruction of the recently described diplodocid sauropod *Kaatedocus siberi* from the historic Howe Quarry in the vicinity of Shell, Wyoming (Upper Jurassic Morrison Formation) is proposed. The skull and neck are reconstructed based on the holotype material (SMA 0004) and remaining body proportions were based on closely related taxa like *Diplodocus* and *Apatosaurus*. Special attention has been paid to two aspects of soft tissue reconstruction: a palpebral element, as suggested in the initial description, and the dermal spines reported from the Howe Quarry. The palpebral element is interpreted to protect the eye anterodorsally, possibly during feeding in dense vegetation. Following this interpretation, we reconstructed this element as covered by a keratinous layer. The dermal spines are shown in several parallel rows along the neck, back and tail, reaching nearly the tip of the tail. This arrangement is based on their association with distal caudal vertebrae in the Howe Quarry, and on comparisons with preserved skin from other dinosaur taxa, where rosette-like structures appear to be arranged in horizontal lines, often restricted to the dorsal portion of the body. The spines possibly functioned in thermoregulation, as they increase the body surface area, or as display structures.

Nektaspidid arthropods from the Early Ordovician Fezouata Biota of Morocco

Peter Van Roy^{1,2}

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²Department of Geology and Soil Science, Ghent University, Ghent, Belgium

The lamellipedian Order Nektaspidida includes the Families Naraoiidae, Liwiidae and Emucarididae. While the appendages of several naraoiid taxa are known in considerable detail, understanding of the appendage morphology of emucaridids and liwiids is limited. As a result, Nektaspidida is essentially united on potentially plesiomorphic similarities in dorsal exoskeletal morphology. Although often regarded as “soft-bodied trilobites”, nektaspidids consistently fail to resolve within Trilobita in cladistic analyses and their exact relationship to this clade currently remains unresolved. In fact, considering the lack of robust synapomorphies uniting Nektaspidida, the possibility that the group itself may not represent a monophyletic clade currently cannot be excluded. Nektaspidids are a rare component of the exceptionally preserved Fezouata Biota from the Early Ordovician of Morocco. A small liwiid with an elongate cephalic shield overlapping the first of three trunk tergites and a tail shield of comparable shape but smaller size is known from three different instars. Naraoiids are represented by a single, poorly preserved and incomplete specimen. These new finds add to the Ordovician record of Nektaspidida, which hitherto was limited to the Middle Ordovician naraoiid *Pseudonaraoia hammani* from the Czech Republic and the Late Ordovician liwiids *Tariccoia arrusensis* from Sardinia and *Soomaspis splendida* from South Africa.



The ontogenetic development of conch opening surface areas in the Ammonoidea: exploring the interface between the external environment and the inner body chamber

* **Sonny A. Walton and Dieter Korn**

Museum für Naturkunde, Leibniz Institute for Research on Evolution and Biodiversity, Berlin, Germany

The authors propose new methods for the measurement of ammonoid conchs and their parameters. The new empirical measurements pertain to the surface area of the opening of the conch and the perimeter length of the conch opening. Estimated heights of the buccal mass and hyponome are also used based on their ratios with the aperture height obtained from *Nautilus pompilius*. The new measurements are: Conch Opening Surface Area (COSA), Conch Opening Perimeter Length (COPL), Buccal Mass Height (BMH), Buccal Mass Area (BMA), Hyponome Height (HypH), and Hyponome Area (HypA). The new parameters are: Conch Opening Perimeter Length Index (COPLI), Conch Opening Surface Area Index (COSAI), and Buccal Mass Area Index (BMAI). The aforementioned measurements and parameters have been obtained from over 60 ammonoid species from the Devonian through to the Jurassic representing a wide range of morphotypes. The authors suggest that these new methods will help to reveal more information about the palaeobiology of the Ammonoidea.

Articulated rays from the Late Cretaceous of Morocco and the affinities of the genus *Ptychotrygon*

David J. Ward¹ and Charlie J. Underwood²

¹*Department of Earth Sciences, The Natural History Museum, London, UK*

²*School of Earth Sciences, Birkbeck College, London, UK*

The Moroccan Turonian (Late Cretaceous) locality of Goulmima is well known for its ammonites, teleost fishes and marine reptiles preserved in calcareous nodules. Recently a number of batoids have been recognised which preserve their hard part anatomy in three dimensions.

Articulated fossil batoids are typically known as compression fossils, such as those from the Late Cretaceous Lebanese plattenkalks. Whilst often well preserved, their detailed anatomy and structural relationships are difficult to interpret. Articulated batoids preserved in three dimensions are very rare and largely restricted to two described species from the Mid Cretaceous Santana Formation of Brazil.

A single specimen of a recently described batoid, *Tingitanius tenuimandibularis*, is the earliest known platyrhinid. The majority of the remaining specimens are unidentified sclerorhynchid sawfishes usually referred to as "*Libanopristis*". However, preliminary studies confirm the presence of *Micropristis* based on its dental and rostral peg morphology, with tooth morphology suggesting that this is congeneric with *Texatrygon*. Other, typically larger specimens, very similar in shape to *Libanopristis* display articulated dentitions referable to *Ptychotrygon*, a batoid with a global distribution, unknown affinities and previously known only from isolated teeth. This raises the intriguing possibility that the Lebanese specimens of *Libanopristis* may be juvenile or small specimens of *Ptychotrygon*.



Size of *Asteroxylon mackiei* stomata guard cells as a ploidy level indicator

* **Zuzanna Wawrzyniak**^{1,2} and **Paul Kenrick**¹

¹*Department of Earth Science, The Natural History Museum in London, London, UK*

²*Department of Palaeontology and Stratigraphy, Faculty of Earth Science, University of Silesia, Poland*

Asteroxylon mackiei is the largest and the most complex plant found in the Early Devonian Rhynie Chert. Our overall goal was to document the gametophyte generation that remains unknown.

We used the size of stomata as an indicator of ploidy level in a novel approach to recognizing diploid and haploid generations. This method is based on a well-established correlation between genome size and cell size in living plants.

We measured guard cell length, which remains constant in open or closed stomata. The gametophyte/sporophyte status of our specimens was unknown except for some that had attached sporangia.

A bimodal distribution of guard cell lengths was anticipated if two ploidy states (haploid, diploid) were present. Furthermore, we expected known sporophytes to cluster with the peak of larger guard cells.

Contrary to expectations, results showed a more or less normal distribution, but with a very broad range of values that exceeded what would be expected from a single ploidy grouping.

Our preliminary interpretation of the results is that the data do not show haploid/diploid phases, but that they may reflect a polyploid series, which would represent the earliest direct evidence of polyploidy in plants.

New Triassic floras from Southern Poland

* **Zuzanna Wawrzyniak**^{1,2}, **Paweł Filipiak**² and **Paul Kenrick**¹

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²*Department of Palaeontology and Stratigraphy, Faculty of Earth Science, University of Silesia, Poland*

The overall aims of this PhD project are to assess the nature and potential of the plant macrofossil record in the Triassic terrestrial sediments of southern Poland and to document floral change through the Triassic, focusing initially on remains at five sites in the Olenekian, Anisian, Norian and Rhaetian Stages. New discoveries based on recent fieldwork include abundant preserved leaf cuticles and seeds in sediments exposed in an outcrop in Palegi (latest Olenekian–Early Anisian; Holy Cross Mountains); tree trunks, leaves cuticles and clusters of plant debris in Zawiercie–Marciszow site (Norian), and three Rhaetian sites: in Poreba outcrop (plant debris, cuticles and large tree trunks), in Lipie Slaskie brickyard (leaves and seeds cuticles, cones, stems and debris) and in Czerwone Zlebki in Tatra Mountains.

Except for the Czerwone Zlebki site, plant remains are well-preserved and diverse. Cuticles at several sites are exceptionally abundant and thick, with details of the epidermal cell patterns and stomatal apparatus clearly visible. The new data will be used to develop more accurate palaeoecological and palaeoenvironmental interpretation of Triassic environments in this region.



Late Jurassic to Early Cretaceous Dinoflagellate Cysts from the Eastern Gulf of Mexico: Facilitating future exploration and development activities in the basin

* **Stephanie Wood¹, Charles H. Wellman¹ and Iain Prince²**

¹*Department of Animal and Plant Sciences, University of Sheffield, Sheffield, UK*

²*Shell Exploration and Production, Woodcreek Research Facility, Houston, Texas, USA*

The Mesozoic deposits of the Eastern Gulf of Mexico (EGoM) are one of the world's major hydrocarbon reserves. However, there is a distinct lack of published studies on dinoflagellate cysts from these strata. This research aims to produce a dinoflagellate cyst biostratigraphy from data collected from three wells around the EGoM.

The Gulf of Mexico is a structurally complex area in terms of its tectonic setting. The unusual tectonic setting of this basin therefore requires a well age-constrained stratigraphy to be established to elucidate structure and correlate formations.

Preliminary studies demonstrate that well-preserved dinoflagellate cysts dominate in these deposits. The samples are being analysed using light and scanning electron microscopy. The dinoflagellate cysts will be systematically described and quantitative data concerning their occurrence/abundance collected. These data will then be utilised in a detailed analysis of the biostratigraphy, palaeoecology, palaeoenvironments and palaeogeography of the deposits. The count data will then be analysed using the statistical package PAST, and will be presented using STRATABUGS.

Further hydrocarbon exploration and development are a priority to ensure energy security. Development of a robust biostratigraphic model for the EGoM basin will greatly facilitate future exploration and development activities in this basin.

Tabulate corals in the Devonian of Afghanistan

Mikołaj K. Zapalski¹, Emilie Pinte² and Bruno Mistiaen²

¹*Faculty of Geology, University of Warsaw, Warsaw, Poland*

²*Groupe ISA, Université catholique de Lille, Lille-Cedex, France*

The Devonian reefal environments of Afghanistan were studied mostly in the Central Mountains (Hazarajat); a few studies deal also with faunas from the Band-e Bayan Zone. As in other Devonian settings, main bioconstructors are stromatoporoids, as well as rugose and tabulate corals; bryozoans are locally important framework builders. Stromatoporoids, as main bioconstructing organisms, were studied in detail, while rugose corals were the subject of very few studies. Tabulates formed a significant part of Devonian reefal ecosystems, yet did not make the object of published studies, except reports of few genera or species.

Our preliminary study shows that overall diversity on a generic level is high compared to other coeval faunas, and these faunas contain 17 genera, belonging to Favositida (14 genera), Syringoporida (*Roemerolites* and *Thecostegites*) and Heliolitida (*Heliolites*). Besides common, widespread favositid genera (*Favosites*, *Pachyfavosites*, *Thamnopora*, *Alveolites*, *Scoliopora*) the assemblage contains rare *Plicatomurus*. Favositids contain endobionts similar to *Chaetosalpinx*. Early Devonian tabulates are rare and occur in mud-mounds of Bokan Formation; conversely, Givetian and Frasnian settings yielded abundant tabulate faunas.

**The
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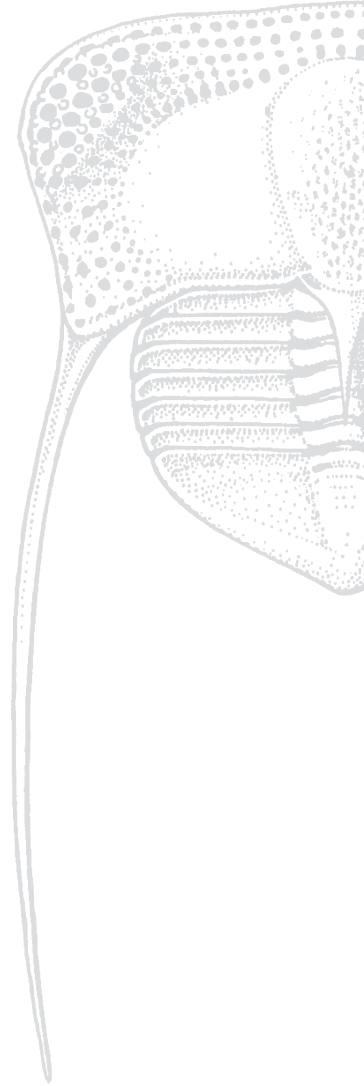
**Annual
General
Meeting**

17.45

Saturday

14th December

Papers





Annual Meeting 2013

Notification is given of the 57th Annual General Meeting

This will be held at the University of Zurich, Switzerland, on 14th December 2013, following the scientific sessions.

AGENDA

1. Apologies for absence
2. Minutes of the 56th AGM, University College Dublin
3. Trustees Annual Report for 2012
4. Accounts and Balance Sheet for 2012
5. Proposed amendments to the Constitution
6. Proposed changes to subscriptions
7. Election of Council and vote of thanks to retiring members
8. Report on Council Awards
9. Annual address

NOMINATIONS FOR COUNCIL

At the AGM, the following vacancies will occur on Council: President elect, Vice-President, Editor-in-Chief, two Editor Trustees, Internet Officer, Publicity Officer, Outreach Officer, Education Officer, three Ordinary Members.

The following nominations were received by the deadline:

President elect:	Prof. David A. T. Harper
Vice President:	Dr Mark Sutton
Editor-in-Chief:	Dr Andrew B. Smith
Editor Trustees (two posts):	Prof. Charles H. Wellman Dr Marcello Ruta
Internet Officer:	Mr Alan Spencer
Publicity Officer:	Dr Liam Herringshaw
Outreach Officer:	Dr Fiona Gill
Education Officer:	Dr Caroline Buttler
Ordinary members (three posts):	Dr Richard Butler Dr Cris Little Dr Martin Munt



DRAFT AGM MINUTES 2012

Minutes of the Annual General Meeting held on Sunday 18th December 2012 at University College Dublin.

1. **Apologies for absence:** Dr C. Jeffery-Abt, Prof. P.C.J. Donoghue, Dr R. Owens, Mr P. Winrow.
2. **Minutes:** proposed by Prof. M.P. Smith and seconded by Mr D. Ward, the minutes were agreed a correct record by unanimous vote of the meeting.
3. **Trustees Annual Report for 2011:** Proposed by Dr A. McGowan and seconded by Dr C. Klug, the report was agreed by unanimous vote of the meeting.
4. **Accounts and Balance Sheet for 2011:** Proposed by Dr H.A. Armstrong and seconded by Prof. J.W. Cope, the accounts were agreed by unanimous vote of the meeting.

5. Election of Council and vote of thanks to retiring members

Prof. J.E. Francis extended a vote of thanks to the following members of Council who were retiring from their positions this year: Prof. J.W. Cope and Prof. M.P. Smith. The following members were elected to serve on Council. *President:* Prof. M.J. Benton; *Vice Presidents:* Dr H.A. Armstrong and Dr A.B. Smith; *Treasurer:* Mr P. Winrow; *Secretary:* Prof. R.J. Twitchett; *Chair of Publications Board:* Dr P. Orr; *Editor Trustees:* Prof. P.C.J. Donoghue, Dr H.A. Armstrong; *Newsletter Editor:* Dr A. McGowan; *Book Review Editor:* Dr C. Jeffrey-Abt; *Newsletter Reporter:* Dr L. Herringshaw; *Internet Officer:* Dr M. Sutton; *Meetings Coordinator:* Dr T. Vandenbroucke; *Ordinary Members:* Dr C. Klug, Dr R. Owens, Dr P. Upchurch, Dr W. Renema and Mr D. Ward. Dr F. Gill and Dr C. Buttler were co-opted to assist with outreach, and Prof. M.A. Purnell was co-opted to assist with publicity. Dr Klug will organise the annual meeting in 2013 at the University of Zurich, Switzerland.

6. Association Awards

The following awards were made: Lapworth Medal to Prof. E.N.K. Clarkson (University of Edinburgh); President's Medal to Dr H. Dowsett (USGS); Hodson Award to Dr J. Vinther (University of Bristol); and the Mary Anning award to A. Rasmussen (Denmark). Under the Small Grants Scheme, the following awards were announced: Sylvester-Bradley Awards to S.M. Ferrari, P. Jardine, V. McCoy, R. Nawrot, M. Smith, and M.L. Raveloson; Callomon Award to Dr J. Hooker; and Whittington Award to J. Clarke. Research Grants were awarded to Dr E. Cadena (North Carolina State University), Dr M.-E. Clémence (Plymouth University), and Prof. M.A. Purnell (University of Leicester). The President's Award was made to Dr N. Longrich (Peabody Museum of Natural History, Yale) and the Council Poster Prize was presented to E. Locatelli (Yale University).

The Annual Address entitled "New views on the origin of our species" was given by Prof. C. Stringer (Natural History Museum, London).

Trustees Annual Report 2012

Nature of the Association. The Palaeontological Association is a Charity registered in England and Wales, Charity Number 276369. Its Governing Instrument is the Constitution adopted on 27th February 1957, amended on subsequent occasions as recorded in the Council Minutes. The aim of the Association is to promote research in Palaeontology and its allied sciences by (a) holding



public meetings for the reading of original papers and the delivery of lectures, (b) demonstration and publication, and (c) by such other means as the Council may determine. Trustees (Council Members) are elected by vote of the Membership at the Annual General Meeting. The contact address of the Association is c/o The Executive Officer, Dr T. J. Palmer, Institute of Geography and Earth Sciences, University of Aberystwyth, Aberystwyth SY23 3DB, Wales, UK.

Trustees. The following members were elected to serve as trustees at the AGM on 18th December 2011: *President:* Prof. J. E. Francis; *Vice Presidents:* Prof. J. C. W. Cope and Dr H. A. Armstrong; *Treasurer:* Mr P. Winrow; *Secretary:* Dr R. J. Twitchett; *Chair of Publications Board:* Dr P. Orr; *Editor Trustee:* Dr P. C. J. Donoghue; *Book Review Editor:* Dr C. Jeffrey-Abt; *Publicity Officer:* Dr E. Rayfield; *Newsletter Reporter:* Dr L. Herringshaw; *Newsletter Editor:* Dr A. McGowan; *Web Officer:* Dr M. Sutton; *Meetings Coordinator:* Dr T. Vandenbroucke; *Ordinary Members:* Dr C. Klug, Dr R. Owens, Dr W. Renema, Prof. M. P. Smith, Dr P. Upchurch, Mr D. Ward. *The Executive Officer:* Dr T. J. Palmer and *Editor-in-Chief:* Dr S. Stouge continued to serve Council but are not Trustees. Dr C. Buttler, Dr F. Gill and Prof. M. A. Purnell were co-opted onto Council but are not Trustees.

Membership. Membership on 31st December 2012 totalled 1,182 (1,167 at end 2011). Of these, 692 were Ordinary Members, 148 Retired Members, 18 Honorary Members, 268 Student Members and 56 Institutional Members. There were 80 institutional subscribers to *Special Papers in Palaeontology*. Wiley-Blackwell also separately manage further Institutional subscribers and distribute publications to these Institutional Members on behalf of the Association.

Professional Services. The Association's Bankers are NatWest Bank, 42 High Street, Sheffield S1 1QF. The Association's Independent Examiner is G. R. Powell BSc FCA, Nether House, Great Bowden, Market Harborough, Leicestershire LE16 7HF. The Association's investment portfolio was managed by Quilter, St Helen's, 1 Undershaft, London EC3A 8BB.

Reserves. The Association holds reserves of £709,878 in General Funds, which enable the Association to generate additional revenue through investments, and thus to keep subscriptions to individuals at a low level, whilst still permitting a full programme of meetings to be held, publications produced and the award of research grants and grants-in-aid. They also act as a buffer to enable the normal programme to be followed in years in which expenditure exceeds income, and new initiatives to be pursued. The Association holds £72,337 in Designated Funds which contribute interest towards the funding of the Sylvester-Bradley, Hodson Fund and Jones Fenleigh awards, and which will contribute interest towards the funding of the Callomon and Whittington awards. Funds carried forward to 2013 totalled £782,215.

Finance. Total charitable expenditure, through grants to support research, scientific meetings and workshops in 2012, was £248,423. Governance costs were £15,555. Total resources expended were £294,969. The Association continues its membership of the International Palaeontological Association and remains a Tier 1 sponsor of *Palaeontologia Electronica*, and the *Treatise on Invertebrate Paleontology*.

Risk. The Association is in a sound financial position. Succession planning for executive officers remains a concern and will be considered as part of the Annual Review of Officers in 2013.

Charitable Activities. The Association continues to increase its range and investment in charitable activities. We have continued to provide funds to support student and speaker attendance at our own and international meetings.



Research Grants. Palaeontological Association Research Grants were awarded to Dr Edwin Cadena (North Carolina State University) “A new fossil turtle from the Early Cretaceous (Barremian–Aptian) of Colombia (South America); revealing the early stages of marine turtle evolution”; Dr Marie-Emilie Clémence (Plymouth University) “The impact of climate change on carbonate production, across the Triassic–Jurassic Boundary”; and Prof. Mark Purnell (University of Leicester) “Microstructures of body parts and homology in non-biomineralised vertebrates”.

Grants-in-aid. The Association provided funds to support the following meetings: The evolution of biomineralization (GSA Annual Meeting session T137, Charlotte, NC, USA); Virtual Paleontology: computer-aided analysis of fossil form and function (GSA Annual Meeting session T144, Charlotte, NC, USA); International Palynological Congress (IPC) XIII and International Organization of Palaeobotany Conference (IOPC) IX (Tokyo, Japan); The Anthropocene: Confronting the Prospects of a +4°C World (AGU meeting session, San Francisco, CA, USA).

Small Grants Scheme. The scheme received seventeen applications. Eight were recommended for funding in 2013, totalling £9,973. Sylvester-Bradley Awards were made to Silvia Mariel Ferrari, Phillip Jardine, Victoria McCoy, Rafal Nawrot, Martin Smith and Miky Lova Raveloson. The Callomon Award was made to Jeremy Hooker, and the Whittington Award to John Clarke.

Online activities. The online activities of the Association continue to expand. A grant was provided to support the *Palaeocast* website initiative. The Association continues to host mirror sites for the Paleodbase, *Palaeontologia Electronica*, the EDNA fossil insect database, the Palaeontographical Society website, and a database of fossils from Kent produced by the Kent RIGS Group.

Public meetings. Four public meetings were held in 2012, and the Association extends its thanks to the organisers and host institutions of these meetings.

56th Annual Meeting. This was held on 16–18 December at University College Dublin. Dr Orr with local support from colleagues and PhD students organised the meeting which included a symposium on “Taphonomy and the fidelity of the fossil record” and comprised a programme of internationally recognised speakers. There were 268 attendees. The Annual Address entitled “New views on the origin of our species” was given by Prof. Chris Stringer (Natural History Museum, London). The President’s Award for best oral presentation from a member under 35 was made to Nicholas Longrich (Peabody Museum of Natural History, Yale). The Council Poster Prize was presented to Emma Locatelli (Yale University). There was no post-conference field trip.

British Science Festival, Palaeontological Association Symposium. This is an annual forum for presentations to the public and general scientists. The Symposium “Our fossil-fuelled future” was organised by Dr L. Herringshaw (University of Durham) and funds were provided in support of four internationally renowned speakers.

Progressive Palaeontology. The annual open meeting for presentations by research students was organised by J. Ortega-Hernandez and a team of eight other colleagues, and was held at the University of Cambridge.

Lyell Meeting. The Lyell Meeting in 2012 was held in London on the topic of “Big Palaeontology”, organised by Dr T. Dunkley-Jones (Imperial College).



Publications. Publication of *Palaeontology* and *Special Papers in Palaeontology* is managed by Wiley Blackwell. Volume 55 of *Palaeontology*, comprising six issues, was published. *Special Papers in Palaeontology* 87, “Tabulate corals from the Givetian and Frasnian of the southern region of the Holy Cross Mountains (Poland),” by M. K. Zapalski; and *Special Papers in Palaeontology* 88, “Smithian (Early Triassic) ammonoids from the Salt Range, Pakistan,” by T. Brühwiler *et al.*, and “Middle and late Smithian (Early Triassic) ammonoids from Spiti, India” by T. Brühwiler *et al.*, were also published during the year. The Association is grateful to the National Museum of Wales and the Lapworth Museum (University of Birmingham) for providing storage facilities for publication back-stock and archives. Council is indebted to Meg and Nick Stroud for assistance with the publication and distribution of *Palaeontology Newsletter*.

Publicity. The Association continues to promote palaeontology and its allied sciences through press releases to the national media, radio and television. For the first time, the Association had a stand at the Lyme Regis Fossil Festival, which was staffed by members of Council, the Executive Officer and volunteers.

Awards. The Lapworth Medal, awarded to people who have made a significant contribution to the science by means of a substantial body of research, was presented to Prof. E. N. K. Clarkson (University of Edinburgh). The President’s Medal for a palaeontologist in recognition of outstanding contributions in his/her earlier career, coupled with an expectation that they will continue to contribute significantly to the subject in their further work, was awarded to Dr H. Dowsett (USGS). The Hodson Award, for a palaeontologist under the age of 35 who has made an outstanding achievement in contributing to the science through a portfolio of original published research, was awarded to Dr J. Vinther (University of Bristol). The Mary Anning award, for an outstanding contribution by an amateur palaeontologist, was made to Alice Rasmussen (Denmark). Council also awards an undergraduate prize to each university department in which palaeontology is taught beyond Level 1.

Governance. The Association continues to improve its administration, with further improvements to the *Newsletter* and website. Trustees were members of the Joint Committee for Palaeontology; Prof. Francis (Chair) and Dr Twitchett represented the Association. During the year the Association responded to requests for information from HEFCE concerning the Research Excellence Framework.

Forthcoming plans. Council will continue to make substantial donations, from both General and Designated funds, to permit individuals to promote the charitable aims of the Association. Resources will be made available from General Funds to support the Association Research Grant, Grants-in-Aid, provided to carry out research into palaeontological subjects, to disseminate findings in print and at conferences, and to support the provision of palaeontological workshops. The Association will continue to recognise the contribution individuals have made to palaeontology and associated sciences through its awards. In 2013, a similar programme of public meetings and publications will be carried out. Funds will be made available to further develop the website aimed at encouraging outreach and to support other outreach initiatives. The Association plans to set up a new undergraduate research bursary scheme. The 57th Annual Meeting will be held at the University of Zurich. Progressive Palaeontology will be held at the University of Leeds. The Association will sponsor a symposium at the British Science Festival, “Bodies of evidence,” and provide travel grants for the Congress of the European Geosciences Union.



THE PALAEOLOGICAL ASSOCIATION Registered Charity No. 276369
STATEMENT OF FINANCIAL ACTIVITIES for the YEAR ENDED 31st DECEMBER 2012

	Note	General Funds	Designated Funds	TOTAL 2012	TOTAL 2011
Incoming Resources					
Generated Funds					
Voluntary income	Subscriptions	58,627		58,627	61,916
	Donations	<u>175</u>	<u>2,566</u>	<u>2,741</u>	<u>1,250</u>
		58,802	2,566	61,368	63,166
Charitable activities					
Sales	Palaeontology	206,951			
	Special Papers	9,573			
	Offprints	90			
	Newsletter	450			
	Field Guides	11,954			
	Distribution	<u>1,032</u>			
		230,050		230,050	228,715
Investment income		<u>14,970</u>	<u>80</u>	<u>15,050</u>	<u>13,323</u>
TOTAL INCOMING RESOURCES		<u>303,822</u>	<u>2,646</u>	<u>306,468</u>	<u>305,204</u>
Resources expended					
Costs of generating funds					
for voluntary income	Admin.	27,805			23,640
Investment mgt.	Stockbroker fees	<u>3,186</u>			<u>3,215</u>
		30,991	0	30,991	26,855
Charitable activities					
Publications	Palaeontology	70,730			
	Special Papers	6,247			
	Offprints	1,022			
	Field Guides	16			
	Newsletters	16,046			
	Distribution	2,575			
	Marketing	2,379			
	Editorial costs	<u>59,443</u>			
Total Publications		158,458		158,458	184,026
Scientific Meetings & Costs		6,946		6,946	29,060
Grants and Awards		20,761	11,299	32,060	9,987
Research Grants		16,197		16,197	14,358
Administration of charitable activities		<u>34,756</u>		<u>34,756</u>	<u>29,551</u>
		237,118		248,417	266,982
Governance costs	Examiner's fee	450			
	Trustee expenses	4 8,154			
	Administration	<u>6,951</u>			
		15,555	0	15,555	16,481
TOTAL RESOURCES EXPENDED	2	<u>283,664</u>	<u>11,299</u>	<u>294,963</u>	<u>310,318</u>
NET INCOMING RESOURCES		20,158	-8,653	11,505	-5,114
INVESTMENT GAINS/LOSSES					
	Realised gain	1,298			
	Unrealised gain	<u>26,327</u>			
		27,625		27,625	-12,217
DEFICIT/(SURPLUS) FOR THE YEAR		47,783	-8,653	39,130	-17,331
FUNDS BROUGHT FORWARD		<u>662,101</u>	<u>80,990</u>	<u>743,091</u>	<u>760,422</u>
FUNDS CARRIED FORWARD		<u>709,884</u>	<u>72,337</u>	<u>782,221</u>	<u>743,091</u>



THE PALAEOLOGICAL ASSOCIATION Registered Charity No. 276369
BALANCE SHEET as at 31st DECEMBER 2012

<u>2011</u>		Note	<u>2012</u>
£			£
	INVESTMENTS		
520,606	At market value	1.6	546,214
	CURRENT ASSETS		
199,212	Cash at Banks	166,901	
<u>111,900</u>	Sundry Debtors	6	<u>119,767</u>
<u>311,112</u>	Total Current Assets		286,668
	CURRENT LIABILITIES		
23,500	Subscriptions in Advance	19,681	
<u>65,127</u>	Sundry Creditors	7	<u>30,980</u>
<u>88,627</u>	Total Current Liabilities		50,661
<u>222,485</u>	NET CURRENT ASSETS		<u>236,007</u>
<u>743,091</u>	TOTAL ASSETS		<u>782,221</u>
	Represented by:		
662,101	GENERAL FUNDS		709,884
	DESIGNATED FUNDS	8	
17,218	Sylvester-Bradley Fund		11,230
21,914	Jones-Fenleigh Fund		23,286
11,828	Hodson Fund		10,386
10,010	Callomon Fund		8,599
<u>20,020</u>	Whittington Fund		<u>18,836</u>
<u>80,990</u>			<u>72,337</u>
<u>743,091</u>			<u>782,221</u>

THE PALAEOLOGICAL ASSOCIATION Registered Charity No. 276369
DESIGNATED FUNDS for the YEAR ENDED 31st DECEMBER 2012. Note 8 to the Accounts

	Sylvester- Bradley	Jones- Fenleigh	Hodson	Callomon	Whittington	TOTAL 2012	TOTAL 2011
Donations	513	1,949	0	53	53	2,566	1,250
Interest Received	<u>17</u>	<u>22</u>	<u>12</u>	<u>10</u>	<u>20</u>	<u>80</u>	<u>85</u>
TOTAL INCOMING RESOURCES	530	1,970	12	62	72	2,646	1,335
Grants made	<u>6,518</u>	<u>598</u>	<u>1,454</u>	<u>1,473</u>	<u>1,256</u>	<u>11,299</u>	<u>6,896</u>
SURPLUS/(DEFICIT) FOR THE YEAR	-5,988	1,372	-1,442	-1,411	-1,184	-8,652	-5,561
FUNDS BROUGHT FORWARD	<u>17,218</u>	<u>21,914</u>	<u>11,828</u>	<u>10,010</u>	<u>20,020</u>	<u>80,990</u>	<u>86,551</u>
FUNDS CARRIED FORWARD	<u>11,230</u>	<u>23,286</u>	<u>10,386</u>	<u>8,599</u>	<u>18,836</u>	<u>72,337</u>	<u>80,990</u>



Note 9 to the Accounts

Nominal	Holding	Cost (bought pre 2012)	Value end 2011
£18,000	UK 4.75% Stock 07/03/20 GBP 100	£ 18,145.87	£ 22,469.00
£20,000	UK 4.5% Gilt 07/03/19 GBP 0.01	£ 20,092.99	£ 24,370.00
£64,176.46	COIF Charities Fixed Interest Fund	£ 85,000.00	£ 85,669.16
804	Royal Dutch Shell B shares	£ 12,432.00	£ 19,730.00
1,425	BP Ord 25c shares	£ 5,047.35	£ 6,562.00
600	BHP Billiton \$0.5 shares	£ 4,341.48	£ 11,265.00
500	BG Group Ordinary 10p shares	£ 3,977.95	£ 6,883.00
1,465	HSBC Holdings Ordinary 0.5 US Dollar shares	£ 4,425.44	£ 7,194.15
360	HSBC Holdings Ordinary 0.5 US Dollar shares	£ 1,087.47	£ 1,767.85
6,800	Lloyds TSB Ordinary 25p shares	£ 10,169.91	£ 1,762.00
1,800	Barclays 25p Ord shares		
875	BAE Systems Ord 2.5 P shares	£ 3,542.00	£ 2,495.00
230	Weir Group 12.5p shares		
1,000	3I Group Ordinary £0.738636 shares	£ 3,058.76	£ 1,810.00
1,150	Tesco Ord GBP 0.05	£ 4,583.22	£ 4,640.00
1,550	Kingfisher Ord GBP 0.157142857	£ 3,554.45	£ 3,886.00
500	IMI Ord 25p shares		
175	Carnival Plc Ord USD 1.66	£ 3,996.49	£ 3,721.00
650	Glaxo Smithkline Ordinary 25p shares	£ 10,232.42	£ 9,565.00
220	Shire Ord 5p shares		
2,499	Bluecrest Allblue Ord Npv GBP shares	£ 3,020.28	£ 4,176.00
550	Amec ord 50P	£ 6,133.62	£ 4,991.00
7,000	Ing Global Real Estate Securities Ord NVP shares	£ 7,084.00	£ 5,705.00
4,175	Vodafone Group Ord USD 0.11428571	£ 6,034.20	£ 7,469.00
2,150	BT Group Ordinary 5p shares	£ 7,787.53	£ 4,104.00
225	Brit Amer Tobacco Ord GBP 0.25	£ 4,991.81	£ 6,875.00
300	Unilever PLC Ord GBP 0.031111	£ 4,326.21	£ 6,489.00
460	Pearson Ordinary 25p shares	£ 8,069.00	£ 5,566.00
490	Serco Group Ord 2P	£ 3,005.01	£ 2,323.00
700	National Grid Ord GBP 0.113953	£ 3,648.26	£ 4,375.00
420	Experian Ord 10C	£ 3,444.95	£ 3,677.00
670	Blackrock World Mi Ord 5P	£ 4,019.09	£ 4,231.00
315	Standard Chartered Ord USD 0.50	£ 5,514.48	£ 4,438.00
650	RIT Capital Partners Ordinary £1 shares	£ 4,903.90	£ 7,956.00
4,400	TR Property Ord 25p shares		
1,000	Balfour Beatty 50P	£ 2,913.17	£ 2,648.00
20	Schroder Alt Solut Agriculture C GBP Dis Hdg	£ 2,987.22	£ 2,338.00
1,225	Brown Advisory US Equity Value £B		
1,500	British Empire Sec & Gen Trust Ordinary 10p shares	£ 5,005.61	£ 6,211.00
425	Findlay Park Partners US Smaller Companies	£ 6,158.47	£ 12,891.00
2,825	Ishares S&P 500 GBP	£ 20,319.63	£ 23,031.00
900	JPMorgan Am UK Ltd Emerging Markets I Instl	£ 5,043.10	£ 4,649.00
8,000	Bny Mellon Glb Fds Erg Mkts Debt Loc Crr C	£ 10,776.59	£ 9,957.00
425	Fidelity EUR Value Ordinary 25P shares	£ 4,059.07	£ 4,263.00
3,900	Edinburgh Dragon Trust Ordinary £0.20 shares	£ 4,478.10	£ 8,463.00
160	GLG Japan Corealpha Equity IT Acc	£ 11,330.79	£ 10,569.00
5,200	Scottish Widows Property Trust B	£ 4,669.49	£ 4,673.00
26	Veritas Asset Mgmt Veritas Asian A GBP	£ 8,182.27	£ 6,663.00
1,320	Goldman Sachs Fund US Equity I GBP Inc Nav	£ 14,640.81	£ 14,045.00
65	Roche Hldgs Ag Genusscheine Nvp	£ 7,226.55	£ 7,119.00
6,600	Henderson Gbl Invs European Special Sits I Inc	£ 7,037.91	£ 6,917.00
55	Shd Umbrella Funds Paragon Capp App Ire B	£ 9,894.52	£ 9,510.00
1,283.80	COIF Charities Investment Fund Acc Units	£ 75,000.00	£ 100,494.71
	Total	£ 465,393.44	£ 520,605.87



Investment Portfolio 2012

Proceeds (sold in 2012)	Cost (bought in 2012)	Gain realised during 2012	Value end 2012	Gain unrealised during 2012
			£ 22,498.00	£ 29.00
			£ 24,352.00	£ (18.00)
			£ 86,477.78	£ 808.62
			£ 17,487.00	£ (2,243.00)
			£ 6,053.00	£ (509.00)
			£ 12,777.00	£ 1,512.00
			£ 5,063.00	£ (1,820.00)
			£ 9,477.00	£ 2,282.85
£ 1,981.56		£ 213.71		
£ 2,075.99		£ 313.99		
	£ 4,034.84		£ 4,723.00	£ 688.16
£ 2,506.19		£ 11.19		
	£ 5,064.75		£ 4,322.00	£ (742.75)
			£ 2,172.00	£ 362.00
			£ 3,864.00	£ (776.00)
			£ 4,404.00	£ 518.00
	£ 4,905.57		£ 5,485.00	£ 579.43
			£ 4,127.00	£ 406.00
			£ 8,678.00	£ (887.00)
	£ 4,986.29		£ 4,151.00	£ (835.29)
			£ 4,251.00	£ 75.00
			£ 5,517.00	£ 526.00
£ 7,071.61		£ 1,366.61		
			£ 6,448.00	£ (1,021.00)
			£ 4,969.00	£ 865.00
			£ 7,022.00	£ 147.00
			£ 7,098.00	£ 609.00
			£ 5,465.00	£ (101.00)
			£ 2,622.00	£ 299.00
			£ 4,921.00	£ 546.00
			£ 4,116.00	£ 439.00
			£ 3,930.00	£ (301.00)
£ 3,722.08		£ (715.92)		
	£ 7,560.85		£ 7,352.00	£ (604.00)
			£ 7,612.00	£ 51.15
			£ 2,737.00	£ 89.00
£ 2,298.88		£ (39.12)		
	£ 14,789.62		£ 14,945.00	£ 155.38
			£ 7,110.00	£ 899.00
			£ 14,336.00	£ 1,445.00
			£ 24,263.00	£ 1,232.00
			£ 5,257.00	£ 608.00
			£ 10,434.00	£ 477.00
			£ 5,470.00	£ 1,207.00
			£ 10,452.00	£ 1,989.00
			£ 10,629.00	£ 60.00
			£ 4,451.00	£ (222.00)
			£ 7,671.00	£ 1,008.00
£ 14,606.59		£ 561.59		
			£ 8,040.00	£ 921.00
			£ 8,210.00	£ 1,293.00
£ 9,397.00		£ (113.00)		
			£ 114,775.57	£ 14,280.86
£ 43,659.90	£ 41,341.92	£ 1,599.05	£ 546,214.35	£ 26,327.41



Notes to the Financial Statements for the year ended 31st December 2012

1. Accounting Policies

The principal accounting policies adopted in the preparation of the financial statements are set out below and have remained unchanged from the previous year and also have been consistently applied within the same financial statements.

1.1 Basis of preparation of financial statements

The accounts have been prepared in accordance with the Statement of Recommended Practice issued by the Charity Commission in 2011 and cover all the charity's operations, all of which are continuing.

The effect of events relating to the year ended 2012 which occurred before the date of approval of the statements by Council have been included to the extent required to show a true and fair state of affairs at 31st December 2012 and the results for the year ended on that date.

1.2 Fund Accounting

General Funds are unrestricted funds which are available for use at the discretion of the Council in furtherance of the general objectives of the charity and which have not been designated for other purposes.

Designated funds comprise unrestricted funds that have been set aside by Council for particular purposes. The aim of each designated fund is as follows:

Sylvester-Bradley Fund: Grants made to permit palaeontological research.

Jones-Fenleigh Fund: Grants to permit one or more students annually to attend the meeting of the Society of Vertebrate Palaeontology and Comparative Anatomy (SVPCA).

Hodson Fund: Awards made in recognition of the palaeontological achievements of a worker under the age of 35.

Callomon Fund: Grants made to permit palaeontological research with a fieldwork element.

Whittington Fund: Grants made to permit palaeontological research with an element of study in museum collections.

1.3 Incoming Resources

The charity's income principally comprises subscriptions from individuals and institutions which relate to the period under review, and sales of scientific publications which are brought into account when due.

1.4 Resources Expended

All expenditure is accounted for on an accruals basis and has been classified under the appropriate headings.

Charitable expenditure is that which is incurred in furtherance of the charity's objectives.

Administrative costs have been allocated to the various cost headings based on estimates of the time and costs spent thereon.

1.5 Investments

Investments are stated at market value at the balance sheet date. The statement of financial activities includes net gains and losses arising on revaluations and disposals throughout the year both of investments and foreign cash balances.

1.6 SCHEDULE OF INVESTMENTS (per analysis sheet)



2. Analysis of Financial Resources Expended

	Staff costs £	Other costs £	Total 2012 £	Total 2011 £
Generating Funds	18,520	12,471	30,991	26,855
Charitable activities	62,354	186,063	248,417	266,982
Governance	<u>4,630</u>	<u>10,925</u>	<u>15,555</u>	<u>16,481</u>
	<u>85,504</u>	<u>209,459</u>	<u>294,963</u>	<u>310,318</u>

3. Staff Costs

	Salary £	National Insurance £	Pension Contributions £	Total 2012 £	Total 2011 £
Publications: 1 employee (2011 – 1)	32,918	0	6,069	38,987	39,125
Administration: 1 employee (2011 – 1)	<u>32,167</u>	<u>3,420</u>	<u>10,713</u>	<u>46,300</u>	<u>42,648</u>
	<u>65,085</u>	<u>3,420</u>	<u>16,782</u>	<u>85,287</u>	<u>81,773</u>

4. Trustees Remuneration and Expenses

Members of Council neither received nor waived any emoluments during the year (2011 – nil).

The total travelling expenses reimbursed to 19 Members of Council was £8,154 (2011 – £10,086).

5. Costs of Independent Examiner

	2012 (£)	2011 (£)
Examination of the accounts	450	400
Accountancy and payroll services	<u>1,450</u>	<u>1,450</u>
	<u>1,900</u>	<u>1,850</u>

6. Debtors

	2012 (£)	2011 (£)
Accrued income – receivable within one year	119,767	111,900

7. Creditors – falling due within one year

	2012 (£)	2011 (£)
Social Services costs	3,196	3,303
Accrued expenditure	<u>27,784</u>	<u>61,824</u>
	<u>30,980</u>	<u>65,127</u>

8. Designated Funds

(See page 103.)

9. Schedule of Investments

(See pages 104–105.)



**Independent Examiner's Report
on the Accounts of The Palaeontological Association
for the year ended 31st December 2012**

Respective responsibilities of trustees and examiner

The charity's trustees are responsible for the preparation of the accounts. The charity's trustees consider that an audit is not required for this year under section 144 of the Charities Act 2011 (the Charities Act) and that an independent examination is needed.

It is my responsibility to:

examine the accounts under section 145 of the Charities Act,

follow the procedures laid down in the general Directions given by the Charity Commissioners (under section 145(5)(b) of the Charities Act, and

to state whether particular matters have come to my attention

Basis of independent examiner's statement

My examination was carried out in accordance with the general Directions given by the Charity Commissioners. An examination includes a review of the accounting records kept by the charity and a comparison of the accounts presented with those records. It also includes consideration of any unusual items or disclosures in the accounts and seeking explanations from the trustees concerning such matters. The procedures undertaken do not provide all the evidence that would be required in an audit, and consequently no opinion is given as to whether the accounts present a "true and fair" view and the report is limited to those matters set out in the statement below.

Independent examiner's statement

In connection with my examination, no matter has come to my attention:

(1) which gives me reasonable cause to believe that in any material respect the requirements:

to keep accounting records in accordance with section 130 of the Charities Act;

to prepare accounts which accord with the accounting records and comply with the accounting requirements of the Charities Act

have not been met; or

(2) to which, in my opinion, attention should be drawn in order to enable a proper understanding of the accounts to be reached.

Dated: 25th April 2013

G R Powell F.C.A.

Nether House, Nether Green,
Great Bowden,
Market Harborough
Leicestershire
LE16 7HF



Proposed changes to the Constitution

Council is recommending certain changes to the Constitution, and members will be asked to approve these at the AGM. The proposed changes are:

1. To modify the list of officers of the Association in line with changes that have been made to streamline the structure of the Publications Board and the Editorial Board of *Palaeontology*. A new, paid Publications Officer has been appointed and the duties and responsibilities of the 'Editor-in-Chief' have been substantially revised. The duties and responsibilities of the 'Chair of the Publications Board' are now included within those of the new 'Editor-in-Chief' and it is proposed to modify the wording of the Constitution to reflect this.
2. In order to maintain flexibility within Council, it is proposed to modify the permitted duration of maximum service as an Officer of the Association.

The wordings of the existing and proposed new Constitutions are given below:

Existing Constitution

1. *Name*: The name of the Association shall be '*The Palaeontological Association*'.
2. *Nature of the Association*. The Palaeontological Association is a Charity registered in England, Charity Number 276369. Its Governing Instrument is the Constitution adopted on 27 February 1957, amended on subsequent occasions as recorded in the Council Minutes. Trustees (Council Members) are elected by vote of the Membership at the Annual General Meeting. The contact address of the Association is that of The Executive Officer.
3. *Aims*: The aim of the Association is to promote research in Palaeontology and its allied sciences by (a) holding public meetings for the reading of original papers and the delivery of lectures, (b) demonstration and publication, and (c) by such other means as the Council may determine.
4. *Membership*: Ordinary, Student, Retired and Honorary members shall be considered full members of the Association and eligible to take part in the government of the Association, but Institutional Members shall not be eligible to take part in the government of the Association.
5. *Subscriptions*: The annual subscriptions for individuals shall be determined by the members in General Meeting. The annual subscriptions for institutions shall be determined by Council.
6. The business of the Association shall be undertaken by a Council and by committees of the Council. The Council shall consist of a maximum of twenty members. The Officers shall consist of a President, and, at least, two Vice-Presidents, a Treasurer, a Secretary, a Chair of the Publications Board and such other Officers as the Council may from time to time determine. At any meetings of the Council six members shall form a quorum which shall always include the President, or a Vice-President or the Secretary. The committees of the Council may co-opt members of the Association as non-voting committee members. Committees of Council shall be open to all members of Council.



7. Periods of service for Officers shall be flexible but should normally not exceed two years for President and Vice-Presidents, and five years for Secretary, Editors, and Treasurer. Total consecutive service as an Officer (excluding service as President) shall not exceed ten years. Other members of the Council shall be elected for a period of three years. All members of Council are Trustees of the Association in accordance with charity law.
8. Elections shall be held annually to fill vacancies on Council. The results of elections shall be announced at the Annual General Meeting. If nominations exceed vacancies a ballot shall be conducted at the meeting and provision shall be made for a postal ballot for members unable to attend the meeting. Nominations should be received by the Secretary not later than the Wednesday of the first full week in October preceding the Annual General Meeting.
9. The Annual General Meeting shall be held within 12 months of the end of the Association year. Other meetings shall be held as determined by Council.
10. The annual report and accounts of the Association shall be made up to 31st December in each year and shall be examined in accordance with the requirements of the relevant Charity Acts. Examined accounts and the annual report shall be submitted to the Annual General Meeting.
11. No member is entitled to any distinct or separate share in the property or effects of the Association, and in the event of a dissolution of the Association such property or effects shall be disposed of by gift to one or more other charitable Societies or Associations which have for their objects the furtherance of palaeontology or its allied sciences, as shall be decided by a vote of a meeting called for the purpose.
12. No alteration of these rules shall be made except by a majority vote at a meeting of the Association held after one month notice of the proposed alterations has been given by the Secretary to the Ordinary, Student and Retired Members.
13. Council may, as resources allow, employ the services of one or more paid officers, to be known as Executive Officers, to carry out a proportion of the tasks involved in the running of the Association. Paid officers will normally attend meetings of Council but shall not be entitled to vote and will not be Trustees. The appointments of all paid officers will be reviewed on an annual basis.

Proposed New Constitution (changes in bold)

1. *Name*: The name of the Association shall be '*The Palaeontological Association*'.
2. *Nature of the Association*. The Palaeontological Association is a Charity registered in England, Charity Number 276369. Its Governing Instrument is the Constitution adopted on 27 February 1957, amended on subsequent occasions as recorded in the Council Minutes. Trustees (Council Members) are elected by vote of the Membership at the Annual General Meeting. The contact address of the Association is that of The Executive Officer.
3. *Aims*: The aim of the Association is to promote research in Palaeontology and its allied sciences by (a) holding public meetings for the reading of original papers and the delivery of lectures, (b) demonstration and publication, and (c) by such other means as the Council may determine.
4. *Membership*: Ordinary, Student, Retired and Honorary members shall be considered full members of the Association and eligible to take part in the government of the Association,



but Institutional Members shall not be eligible to take part in the government of the Association.

5. *Subscriptions*: The annual subscriptions for individuals shall be determined by the members in General Meeting. The annual subscriptions for institutions shall be determined by Council.
6. The business of the Association shall be undertaken by a Council and by committees of the Council. The Council shall consist of a maximum of twenty members. The Officers shall consist of a President, and, at least, two Vice-Presidents, a Treasurer, a Secretary, **an Editor-in-Chief** and such other Officers as the Council may from time to time determine. At any meetings of the Council six members shall form a quorum which shall always include the President, or a Vice-President or the Secretary. The committees of the Council may co-opt members of the Association as non-voting committee members. Committees of Council shall be open to all members of Council.
7. Periods of service for Officers shall be flexible but should normally not exceed two years for President and Vice-Presidents, and five years for Secretary, Editors, and Treasurer. Total consecutive service as an Officer (excluding service as President) **should normally** not exceed ten years. Other members of the Council shall be elected for a period of three years. All members of Council are Trustees of the Association in accordance with charity law.
8. Elections shall be held annually to fill vacancies on Council. The results of elections shall be announced at the Annual General Meeting. If nominations exceed vacancies a ballot shall be conducted at the meeting and provision shall be made for a postal ballot for members unable to attend the meeting. Nominations should be received by the Secretary not later than the Wednesday of the first full week in October preceding the Annual General Meeting.
9. The Annual General Meeting shall be held within 12 months of the end of the Association year. Other meetings shall be held as determined by Council.
10. The annual report and accounts of the Association shall be made up to 31st December in each year and shall be examined in accordance with the requirements of the relevant Charity Acts. Examined accounts and the annual report shall be submitted to the Annual General Meeting.
11. No member is entitled to any distinct or separate share in the property or effects of the Association, and in the event of a dissolution of the Association such property or effects shall be disposed of by gift to one or more other charitable Societies or Associations which have for their objects the furtherance of palaeontology or its allied sciences, as shall be decided by a vote of a meeting called for the purpose.
12. No alteration of these rules shall be made except by a majority vote at a meeting of the Association held after one month notice of the proposed alterations has been given by the Secretary to the Ordinary, Student and Retired Members.
13. Council may, as resources allow, employ the services of one or more paid officers, to be known as Executive Officers, to carry out a proportion of the tasks involved in the running of the Association. Paid officers will normally attend meetings of Council but shall not be entitled to vote and will not be Trustees. The appointments of all paid officers will be reviewed on an annual basis.



Proposed changes to Subscriptions

Council is recommending changes to the subscriptions, detailed below, and members will be asked to approve these at the AGM. The proposed changes follow Council's consideration of the distribution costs of paper copies of *Palaeontology*, and a desire that members should pay less for online-only subscriptions to *Palaeontology*.

Membership Categories

All members receive *Palaeontology* and the *Newsletter*.

Ordinary Member – The principal category.

Retired Member – Retired members are over 60 and not in full-time employment. Currently their subscription is defined as being half that of Ordinary Members.

Student Member – Student members are registered members of a school, college, or university. Study towards a formal educational qualification is their full-time or principal occupation.

Undergraduate Member – These are recipients of the Association's Undergraduate Prize for best performance in palaeontology by a penultimate year undergraduate from an eligible university department. Their membership is free, lasts for two years, and is not affected by these proposals.

Honorary Member – These are individuals who have been significant benefactors and/or supporters of the Association. Their membership is free and is not affected by these proposals.

Current and proposed changes to subscriptions:

Membership Category	Subscription (£)	
	Current	Proposed
Ordinary Member; online access to <i>Palaeontology</i> only	36.00	30.00
Ordinary Member; print and online access to <i>Palaeontology</i>	36.00	45.00
Retired Member; online access to <i>Palaeontology</i> only	18.00	15.00
Retired Member; print and online access to <i>Palaeontology</i>	18.00	36.00
Student Member (UK); online access to <i>Palaeontology</i> only	10.00	15.00
Student Member (UK); print and online access to <i>Palaeontology</i>	10.00	36.00
Student Member (overseas); online access to <i>Palaeontology</i> only	15.00	15.00
Student Member (overseas); print and online access to <i>Palaeontology</i>	15.00	36.00