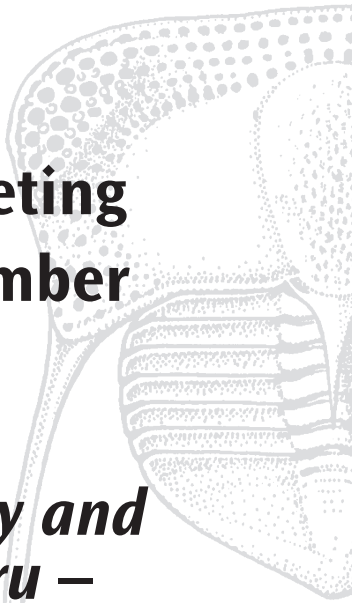
The Palaeontological Association

59th Annual Meeting

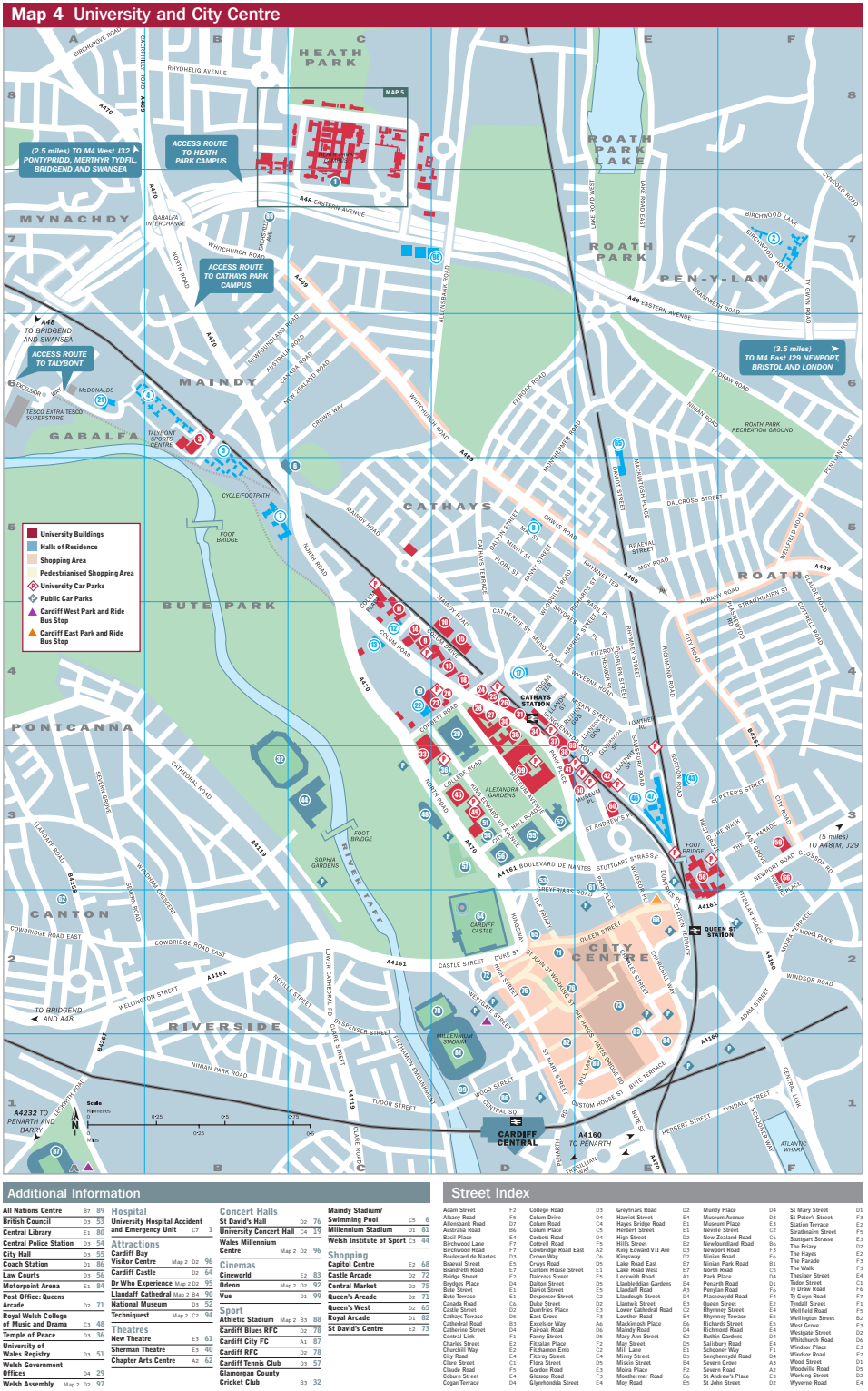
14th–17th December 2015

Cardiff University and Amgueddfa Cymru – National Museum Wales



PROGRAMME, ABSTRACTS and AGM papers

Map 4 University and City Centre



Cathays Park Campus (Map 4)

Tel: 029 2087 4000

Aberconway Building	C4	11
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Development and Alumni Relations	E3	60
Earth and Ocean Sciences	D3	39
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Engineering	E3	58
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Estates	F3	66
Eye Clinic	D4	15
Finance	F3	66
Glamorgan Building	D3	49
Global Opportunity Centre	D3	41
Graduate Centre	D3	38
Hadyn Ellis Building	D4	10
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Music	D4, D4*	20 23*
Optometry and Vision Sciences	D4	15
Pharmacy and Pharmaceutical Sciences	C3	33
Physics and Astronomy	E3	58
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* Indicates main site

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Aberconway	C4	11
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Bridge Street E2
Brydges Place D4
Bute Street E1
Bute Terrace E1
Canada Road C6
Castle Street D2
Cathays Terrace D5
Cathedral Road B3
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Charles Street E2
Churchill Way E2
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Clare Street C1
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Flora Street D5
Garden Road E3
Glossop Road F3
Glyntorridda Street E4
Greyfriars Road D2
Harriet Street E5
Hayes Bridge Road E1
Herbert Street D2
High Street D2
Hill's Street E2
King Edward VII Ave D3
Kingsway D2
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Senghennydd Hall E3 46
Talybont Court B5 7
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University Hall and Conference Centre F7 2

Map of conference venues

The Palaeontological Association

59th Annual Meeting 14th–17th December 2015

Cardiff University and Amgueddfa Cymru – National Museum Wales

The programme and abstracts for the 59th Annual Meeting of the Palaeontological Association are provided after the following information and summary of the Meeting.

Venue

The Conference takes place at **Amgueddfa Cymru – National Museum Wales** and **Cardiff University**, which are both located at Cathays Park in the City Centre. All conference venues, including the Annual Dinner, are within a 5-10 minute walk of each other. Cardiff Central train station is a *c.* 20 minute walk.

Oral presentations

All speakers (apart from the symposium speakers) have been allocated 15 minutes. You should therefore present for only 12 minutes to allow time for questions and switching between speakers. We have a number of parallel sessions in adjacent theatres so timing is especially important. All of the lecture theatres have a single A/V projector linked to a large screen. All presentations should be submitted and checked the day before they are scheduled. This is particularly relevant for Mac-based presentations as Cardiff is PC-based.

Poster presentations

Poster boards will accommodate an A0-sized poster presented in **portrait** format only. Materials to fix the poster to the boards are available at the meeting.

Travel grants to student members

Students who have been awarded a PalAss travel grant should see the Executive Officer, Dr Tim Palmer (e-mail <**palass@palass.org**>), to receive their reimbursement.

Cardiff

Cardiff is the capital city of Wales with many cultural and entertainment attractions (see <**http://www.visitcardiff.com/**>). During the Conference, there will be a Christmas market in the centre of the city and ice-skating outside City Hall. There are many restaurants and bars in the city centre.

Schedule

Monday 14th December: Symposium and reception
In the morning (09.00–12.00) prior to the start of the meeting, there will be a training workshop (funded by the Software Sustainability Institute) on the *SPIERS* software suite for tomographic reconstruction, led by Russell Garwood, Mark Sutton and Imran Rahman, in the **Main Building, Cardiff University, Palaeontology Lab. 2.14**.

The meeting will begin with a Symposium in the afternoon (at 13.00) in the **Reardon Smith Lecture Theatre** at **Amgueddfa Cymru – National Museum Wales**. Registration will be available from 12.00–18.00 at the entrance to the lecture theatre.

The theme of the Annual Symposium is 'Palaeobiotic interactions'.

Following the Symposium there will be an icebreaker reception at 18.00 in the Main Hall of **Amgueddfa Cymru – National Museum Wales**, with the opportunity to look around the **Evolution of Wales Galleries** and the **Reading the Rocks: the Remarkable Maps of William Smith** exhibition.

Tuesday 15th December: Conference, AGM, Annual Address and Dinner
The Conference will commence at **Cardiff University** at 08.45 with a full day of talks and posters, followed by the Association AGM (at 16.45) and the Annual Address (at 17.15) given by Prof. John Hutchinson (The Royal Veterinary College). The first, second and final sessions will be in Shared Lecture Theatre, E1.21 Sir Martin Evans Building. The parallel middle sessions will be in Large Shandon Lecture Theatre, -1.64 Main Building and Large Chemistry Lecture Theatre, 1.123 Main Building. Posters will be on display throughout the meeting in the VJ Gallery/Council Chamber, where tea breaks will be held.

In the evening there will be a reception (at 19.00) and the Annual Dinner (at 20.00) at **Cardiff City Hall.**

Wednesday 16th December: Conference
The day will begin with a poster session (08.45–09.45) in the VJ Gallery/Council Chamber where tea, coffee and Welsh cakes will be served. Lectures will commence at 09.45 with parallel sessions in Large Shandon Lecture Theatre, -1.64 Main Building and Large Chemistry Lecture Theatre, 1.123 Main Building. The final session will be held in Large Shandon Lecture Theatre, -1.64 Main Building.

Thursday 17th December: Field-trip

Price **£30** including transport and lunch.

The field-trip starts at 09.00 from the front steps of the **Amgueddfa Cymru – National Museum of Wales**, returning to Cardiff by 17.30 with stops at the Museum and main railway station. The number of participants is limited to **45**.

In the morning, the field-trip will visit classic Silurian carbonates of the Usk Inlier, and we will then take you to Blaenavon, a World Heritage Site. Lunch will be at Big Pit National Coal Museum with the opportunity to go 300 feet (91 m) underground with a miner-guide.

Schedule of events and timetable of presentations

Monday 14th December

SPIERS Training Workshop *(funded by the Software Sustainability Institute)*

Russell Garwood, Mark Sutton and Imran Rahman.

N.B. Pre-register to participate – for details see <**http://www.palass.org/modules.php?name=annual_meeting&page=40**>.

09.00–12.00 Main Building, Cardiff University, Palaeontology Lab. 2.14

Thematic Symposium: "Palaeobiotic interactions"

Reardon Smith Lecture Theatre, National Museum Cardiff

12.00–18.00 Registration

Underlined author denotes designated speaker

13.00–13.15 **Welcome from Dr Richard Bevins (Keeper of Natural Sciences) followed by logistical information**

13.15–13.55 **Competition and symbiosis on marine hard substrates in the fossil record**
Paul D. Taylor

13.55–14.35 **Leaving no stone unturned: the feedback between biotic diversity and early diagenesis**
V. Paul Wright and Lesley Cherns

14.35–15.15 **Fossil lichens**
Rosmarie Honegger, Dianne Edwards and Lindsey Axe

15.15–15.45 Tea/coffee break

15.45–16.25 **Something ate my fossil: from anecdote to testing hypotheses**
Elizabeth M. Harper

16.25–17.05 **Rooted in Earth history: the Devonian transition to a forested planet**
Christopher M. Berry, William E. Stein, Peter Giesen, John E. A. Marshall and Honghe Xu

17.05–17.45 **Animal–animal and animal–microbial ecological interactions in ancient methane seep communities**
Crispin T. S. Little

Reception

Main Hall, National Museum Cardiff

18:00–20:00 **Icebreaker reception**

Tuesday 15th December

Conference, Association AGM, and Annual Dinner

Underlined author denotes designated speaker.

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

⁺Posters in Viriamu Jones (VJ) Gallery/Council Chamber, Main Building, Cardiff University.

08.00–08.40 Put up posters

Session 1 (Shared Lecture Theatre, E1.21 Sir Martin Evans Building, Cardiff University)

08.15–11.00 **Registration**

08:45–09:00 **Opening of the Annual Meeting** by Professor Hywel Thomas (Pro Vice-Chancellor Research, Innovation and Engagement) followed by logistical information.

09:00–09:15 **The Anthropocene biosphere**
Mark Williams, Jan Zalasiewicz, Peter K. Haff, Christian Schwägerl, Anthony D. Barnosky and Erle C. Ellis

09:15–09:30 **The grapes among the apes: implications of a new fossil record of the Vitaceae from the African Miocene**
*Neil F. Adams, Margaret E. Collinson, Selena Y. Smith, Marion K. Bamford, Félix Forest, Panagiota Malakasi, Federica Marone and Dan Sykes

09:30–09:45 **Evidence for sexual dimorphism in the plated dinosaur *Stegosaurus mjosi* (Ornithischia, Stegosauria) from the Morrison Formation (Upper Jurassic) of Western USA**
*Evan T. Saitta

09:45–10:00 **Tetrapodophis amplectus, a four-legged snake from the Early Cretaceous of Gondwana, and implications for the origins of snakes**
Nicholas R. Longrich, David M. Martill and Helmut Tischlinger

10:00–10:15 **Ancient spiders and salt lakes**
Paul A. Selden and Matt R. Downen

10:15–10:30 **"MISS" conceptions and misconceptions: microbial, abiotic and problematic sedimentary surface textures from the Archaean to the present**
Neil S. Davies, Alexander G. Liu and Martin Gibling

10:30–11:00 **Tea/coffee break and posters**⁺ (VJ Gallery, Main Building, Cardiff University)

Session 2 (Shared Lecture Theatre, E1.21 Sir Martin Evans Building, Cardiff University)

11:00–11:15 **How big is a genus?**
Julia D. Sigwart, Keith D. Bennett and Mark Sutton

11:15–11:30 **A stable isotopic investigation of chemosymbiosis through geological time**
*Edine Pape, Fiona L. Gill, Crispin T. S. Little and Robert J. Newton

11:30–11:45 **Silicified molluscs from the Vikinghøgda Formation, central Spitsbergen: systematic and palaeoecological significance**
*William Foster, Silvia Danise and Richard Twitchett

11:45–12:00 **The radiation of plankton during the Bajocian: a Mesozoic pelagic revolution**
*Nickolas J. Wiggan, James B. Riding and Nicholas J. Butterfield

12:00–12:15 **When fossils and living taxa agree on patterns of morphological evolution: a case study with Afrotheria**
*Mark N. Puttick and Gavin H. Thomas

12:15–12:30 **The Strawberry Bank Lagerstätte reveals insights into Early Jurassic life**
Michael J. Benton, Matt Williams, Andrew Ross and Matt Friedman

VJ Gallery, Main Building, Cardiff University

12:30–13:30 **Lunch and posters**+
[Registration]

Session 3a (Large Shandon Lecture Theatre, -1.64 Main Building, Cardiff University; in parallel with Session 3b)

13:30–13:45 **Conodont-based, high-resolution, quantitative biochronology of the end-Permian mass extinction in South China**
*Morgane Brosse, Hugo Bucher and Nicolas Goudemand

13:45–14:00 **Phylogenetic relationships of Heterostraci, agnthans on the gnathostome stem**
*Emma L. Randle and Robert S. Sansom

14:00–14:15 **The 100 million year journey to teleost supremacy**
*John Clarke, Lauren Sallan and Matt Friedman

14:15–14:30 **The ecomorphological diversifications of Mesozoic marine reptiles**
*Thomas L. Stubbs and Michael J. Benton

14:30–14:45 **Phylogeny and macroevolution of crocodylomorphs**
*Max T. Stockdale, Michael J. Benton, Mario Bronzati, Marco B. de Andrade and Gavin H. Thomas

14:45–15:00 **Evolutionary rates reveal mechanisms of axial body plan evolution in Sauropterygia**
*Laura C. Soul and Roger B. J. Benson

Session 3b (Large Chemistry Lecture Theatre, 1.123 Main Building, Cardiff University; in parallel with Session 3a)

13:30–13:45 **Experimental taphonomy and the role of decay and preservation in determining the anatomy and diversity of Cambrian vertebrates**
Mark A. Purnell, Sarah E. Gabbott, Duncan J. E. Murdock and Peiyun Cong

13:45–14:00 **Unlocking the preservation pathways of Cambrian neural tissue**
Xiaoya Ma, Gregory D. Edgecombe, Xianggang Hou, Tomasz Goral and Nicholas J. Strausfeld

14:00–14:15 **The role of framboidal pyrite and sulfur cycling in Ediacaran taphonomy**
Alexander G. Liu

14:15–14:30 **Clay-microbe interactions and implications for exceptional preservation**
Sean H. McMahon and Derek E. G. Briggs

14:30–14:45 **Phosphatisation of soft-tissues: an integrated palaeontological and geochemical analysis of the Christian Malford Lagerstätte (Callovian, Middle Jurassic)**
Phil R. Wilby, Mark A. Woods, Keith L. Duff, Greg D. Price, Mike J. Norry, John D. Hudson, Kevin N. Page, Roy G. Clements and Malcolm B. Hart

14:45–15:00 **How do marine microfossils get trapped in amber?**
Leyla J. Seyfullah, Dennis Grabow and Alexander R. Schmidt

VJ Gallery, Main Building, Cardiff University

15:00–15:30 **Tea/coffee break and posters**[+]

Session 4 (Shared Lecture Theatre, E1.21 Sir Martin Evans Building, Cardiff University)

15:30–15:45 **A Cambrian greening of the terrestrial landscape**
Paul K. Strother

15:45–16:00 **Cryptogamic ground covers as modern analogues of early terrestrial ecosystems**
Ria L. Mitchell and Paul Kenrick

16:00–16:15 **Variations in wildfire activity driven by atmospheric oxygen changes across the Toarcian OAE**
[*]Sarah J. Baker, Claire M. Belcher, Stephen P. Hesselbo and Tim M. Lenton

16:15–16:30 **Hot and fiery or just hot? A global record of early Palaeogene wildfire**
[*]Brittany E. Robson, Margaret E. Collinson, Walter Riegel, Volker Wilde, Andrew C. Scott, Erica M. Crouch, Elizabeth M. Kennedy, J. Ian Raine, Christian Dupuis, Carlos Jaramillo and Richard D. Pancost

16:30–16:45 **Break**

16.45–17.15 **Annual General Meeting (AGM)**

Annual Address

Shared Lecture Theatre, E1.21 Sir Martin Evans Building, Cardiff University

17:15–18:15 **Computer modelling and simulation of extinct organisms: its utility and limitations for reconstructing the evolution of locomotor behaviour**
John R. Hutchinson

Reception & Annual Dinner

City Hall

19:00–20.00 **Reception**

20.00–23.00 **Annual Dinner**

Wednesday 16th December

Conference & Poster session

Session 5 (VJ Gallery/Council Chamber, Main Building, Cardiff University)

08:45–09:45 **POSTER SESSION⁺ with tea/coffee & Welsh cakes**
Sponsored by The Paleontological Institute & Frontiers in Earth Science

Session 6a (Large Shandon Lecture Theatre, -1.64 Main Building, Cardiff University; in parallel with Session 6b)

09:45–10:00 **The Mesoproterozoic Ruyang Group, China – a hotspot of early eukaryote biodiversity**
*Heda Agić, Małgorzata Moczydłowska and Leiming Yin

10:00–10:15 **New windows into the ecology and taphonomy of Ediacaran acanthomorphs**
*Peter W. Adamson and Nicholas J. Butterfield

10:15–10:30 **A record of small carbonaceous fossils (SCFs) from the Ediacaran–Cambrian of Baltica: expanding the Burgess Shale-type taphonomic window**
*Ben J. Slater, Thomas H. P. Harvey, Romain Guilbaud and Nicholas J. Butterfield

10:30–10:45 **Ontogeny, preservation, and systematics of Palaeoscolecida (stem-Priapulida?) – is the diversity of the group drastically overestimated?**
*Emmanuel L. O. Martin, Rudy Lerosey-Aubril and Peter Van Roy

10:45–11:00 **Annelid fossil data reconcile morphological and molecular phylogenies**
*Luke Parry, Gregory D. Edgecombe and Jakob Vinther

11:00–11:15 **The curious case of *Rollinschaeta myoplena*: reconstruction of extensively phosphatized myoanatomy in extinct taxa**
*Paul Wilson, Luke Parry, Dan Sykes, Gregory Edgecombe and Jakob Vinther

Session 6b (Large Chemistry Lecture Theatre, 1.123 Main Building, Cardiff University; in parallel with Session 6a)

09:45–10:00 **Morphology of the jaw adductor complex across the cynodont–mammaliaform transition**
Stephan Lautenschlager, Pamela Gill, Michael Fagan and Emily J. Rayfield

10:00–10:15 **On the difficulty of reconstructing hybodont dentitions based on isolated teeth**
Gilles Cuny and Stanislas Rigal

10:15–10:30 **Near-stasis in the long-term diversification of Mesozoic tetrapods**
Roger B. J. Benson, Richard J. Butler, John Alroy, Philip D. Mannion, Matthew T. Carrano and Graeme T. Lloyd

10:30–10:45 **Dinosaur biogeographic structure and Mesozoic continental fragmentation: a network-based approach**
Alexander M. Dunhill, Jordan Bestwick, Holly Narey and James Sciberras

10:45–11:00 **Remarkably preserved brain tissue ultrastructure in an Early Cretaceous iguanodontian dinosaur**
David B. Norman, Martin D. Brasier, Alexander G. Liu, Laura Cotton, Jamie Hiscocks, Russell Garwood and David Wacey

11:00–11:15 **Camouflage patterns in an ornithischian dinosaur**
Jakob Vinther, Robert Nicholls, Stephan Lautenschlager, Gerald Mayr, Emily Rayfield and Innes Cuthill

VJ Gallery, Main Building, Cardiff University

11:15–11:45 **Tea/coffee break and posters**[+]

Session 7a (Large Shandon Lecture Theatre, -1.64 Main Building, Cardiff University; in parallel with Session 7b)

11:45–12:00 **An outstanding upper Katian (Upper Ordovician) fossil assemblage from Portugal (Buçaco, Central Iberian Zone): biostratigraphical and palaeobiogeographical significance**
[*]Jorge Colmenar, Sofia Pereira, Artur A. Sá and Carlos M. da Silva

12:00–12:15 **Biostratigraphical review and palaeobiogeographical remarks on the trilobite genus *Lichas* Dalman, 1827**
[*]Sofia Pereira, Artur A. Sá, M. Pires and Carlos M. da Silva

12:15–12:30 **Chitinozoan biozonation in the Arenig Series (Floian–lower Darriwilian stages) of Wales**
[*]Chloé E. A. Amberg, Thijs R. A. Vandenbroucke, Stewart G. Molyneux, Jean-François Ghienne and Philippe Razin

12:30–12:45 **Using fossils and phylogenies to date the timing of key gene regulatory network innovations in echinoids**
[*]Jeffrey R. Thompson, Elizabeth Petsios and David J. Bottjer

12:45–13:00 **Reconstructing Miocene neotropical palaeoenvironments: a case study from the palaeosols and ichnofossils of Cerdas, Bolivia**
[*]Angeline M. Catena, Daniel I. Hembree, Beverly Z. Saylor and Darin A. Croft

Session 7b (Large Chemistry Lecture Theatre, 1.123 Main Building, Cardiff University; in parallel with Session 7a)

11:45–12:00 **On the origin of animals and biologically mediated flow**
Nicholas J. Butterfield

12:00–12:15 **How easy was the Ediacaran transition to large body size? Rangeomorph growth, development and complexity**
Jennifer Hoyal Cuthill

12:15–12:30 **Depositional and preservational environments of the Ediacara Member, Rawnsley Quartzite (South Australia): assessing the timing of 'ferruginization'**
Lidya G. Tarhan, Noah J. Planavsky, Mary L. Droser and James G. Gehling

12:30–12:45 **TRiPS, SQS, ACE and Chaos; evaluating the accuracy and precision of species richness estimators in palaeobiology**
Jostein Starrfelt

12:45–13:00 **Differential speciation and extinction rates across space and through time: implications for the generation of latitudinal diversity gradients**
Erin E. Saupe, Huijie Qiao, Corinne E. Myers, Jorge M. Soberón, A. Townsend Petersen, Stephen J. Hunter, Joy S. Singarayer and Paul J. Valdes

VJ Gallery, Main Building, Cardiff University

13:00–14:00 **Lunch and posters**[+]

Session 8a (Large Shandon Lecture Theatre, -1.64 Main Building, Cardiff University; in parallel with Session 8b)

14:00–14:15 **A new use for old pollen: reconstructing past solar irradiance using pollen chemistry**
Phillip E. Jardine, Wesley T. Fraser, Barry H. Lomax and William D. Gosling

14:15–14:30 **Estimation of taxonomic richness variation through geological times: a simulation approach**
[*]Corentin Gibert and Gilles Escarguel

14:30–14:45 **What limits the morphological disparity of clades?**
[*]Jack W. Oyston, Martin Hughes, Peter J. Wagner, Sylvain Gerber and Matthew A. Wills

14:45–15:00 **Ontogenetic stages in the basal Gondwanan eusauropod *Patagosaurus***
[*]Femke M. Holwerda, Oliver W. M. Rauhut and Diego Pol

15:00–15:15 **The monophyly of Euparkeriidae and its implications for the rise of crown Archosauria**
[*]Roland B. Sookias

15:15–15:30 **Earliest members of a 'living fossil' lineage indicate a late origin of modern ray-finned fish diversity**
[*]Sam Giles, Guang-Hui Xu and Matt Friedman

Session 8b (Large Chemistry Lecture Theatre, 1.123 Main Building, Cardiff University; in parallel with Session 8a)

14:00–14:15 **The eldonids: cryptic éminences grises of the Palaeozoic oceans**
Breandán A. MacGabhann and John Murray

14:15–14:30 **The morphology and affinity of the Cambrian "muscle worm"**
Allison C. Daley, Emily M. C. Tilby, John P. Paterson, Diego C. Garcia-Bellido, Gregory D. Edgecombe and James B. Jago

14:30–14:45 **Recent advances in lobopodian palaeobiology and evolution**
Javier Ortega-Hernández

14:45–15:00 **The Ordovician explosion in the designs of trilobite eyes**
Brigitte Schoenemann and Euan N. K. Clarkson

15:00–15:15 **Are solemyoids and ctenodontids related?**
John C. W. Cope

15:15–15:30 ***Evactinostella crucialis* – another weird and wonderful bryozoan**
Eckart Håkansson, Marcus Key and Andrej Ernst

VJ Gallery, Main Building, Cardiff University

15:30–16.00 **Tea/coffee break** (take down posters)

Session 9 (Large Shandon Lecture Theatre, -1.64 Main Building, Cardiff University)

16:00–16:15 **Conservation palaeobiology of Chesapeake Bay oysters**
Rowan Lockwood and Kristopher M. Kusnerik

16:15–16:30 ***Kalania pusilla*, an exceptionally preserved non-calcified alga with oldest documented gametophores from the lower Silurian (Aeronian, Llandovery) of Estonia**
Oive Tinn, Viirika Mastik, Leho Ainsaar and Tonu Meidla

16:30–16:45 **Five new Tournaisian tetrapods: their sedimentology and palaeoenvironments**
Carys E. Bennett, Jennifer A. Clack, Timothy Kearsey, Sarah J. Davies, David Millward, Tim R. Smithson, Marcello Ruta, Ben Otoo, John E. A. Marshall, Emma Reeves and Andrew Ross

16:45–17:00 **Latitudinal diversity gradients in Mesozoic non-marine turtles**
David B. Nicholson, Paul M. Barrett and Patricia A. Holroyd

17:00–17:15 **Presentation by Lyon 2016 organising committee**

17:15–17:30 **Presentation of President's awards to oral and poster presenters: followed by closing remarks**

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Abstracts of symposium presentations:

Palaeobiotic interactions

Rooted in Earth history: the Devonian transition to a forested planet

Christopher M. Berry[1], William E. Stein[2], Peter Giesen[3], John E. A. Marshall[4] and Honghe Xu[5]

[1]*Cardiff University, UK*

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[4]*University of Southampton, UK*

[5]*Nanjing Institute of Geology and Palaeontology, China*

Modern forests lie at the centre of a web of interactions from which influence spreads far beyond the terrestrial realm into the wider Earth System, including atmospheric composition and marine geochemistry. The 'transition to a forested planet' during the Mid and early Late Devonian (393–372 Ma) must therefore have been a time of profound global change, the predicted effects of plant growth and plant-enhanced weathering being incorporated into, for example, models of atmospheric CO_2 through time. Supporting knowledge of vegetation during this interval has, however, been very sketchy until recently. This talk will highlight the recent dramatic changes in concepts of the morphology, anatomy and growth of tree-sized plants which appeared and evolved during this time (aneurophytaleans, archaeopteridaleans, pseudosporochnaleans, lycopsids) with an emphasis on leaves, roots and wood. Definitive and spectacular evidence of plant community structure and ecology is available from the study of *in situ* tree bases, roots and rhizomes from New York and Svalbard, and allows interpretation of macrofossil assemblages further afield. Study of *in situ* and dispersed spore assemblages allows better sampling and stratigraphic resolution of the global migration of tree groups. Total evidence will allow better understanding and modelling of the environmental impact of early forests.

Something ate my fossil: from anecdote to testing hypotheses

Elizabeth M. Harper

University of Cambridge, UK

Predation, along with competition, is thought to play a major role in structuring modern marine communities. It has frequently been cited as a driving force in evolution, for example in explaining the rise of particular traits (*e.g.* life habits, morphologies or behaviours) perceived as defensive adaptations. But these familiar tales may be difficult to test in the fossil record. Palaeoecologists are familiar with recognizing particular trace fossils as evidence of predation in the fossil record. But how can we turn interesting fossils with an interesting story to tell into a source of plentiful robust data with which to test evolutionary hypotheses and to generate new ones? How can we dove-tail palaeontological data with those produced by neontological studies? How can we capture the wide variability in predation intensity seen in modern environments but routinely destroyed by taphonomy?

talks

Fossil lichens

Rosmarie Honegger[1], Dianne Edwards[2] and Lindsey Axe[2]
[1]*University of Zürich, Switzerland*
[2]*Cardiff University, UK*

Before focusing on lichens and lichen-like organisms from Cenozoic amber to the Neoproterozoic Doushantuo fossils, a short overview on the phylogeny, morphology and anatomy, especially on mycobiont–photobiont interactions in extant lichens and on their fungal and bacterial cohabitants will be presented. Well-preserved Mesozoic lichens are rare. In the few Palaeozoic lichens known until now with well-preserved fungal partners, the cyanobacterial or green algal photobiont often did not fossilize. Dorsiventral thallus organization with internal stratification, *i.e.* optimal light exposure of the photobiont cell population, a characteristic of extant foliose and squamulose lichens, occurs in *Cyanolichenomycites devonicus* with cyanobacterial (*Nostoc* sp., mainly gelatinous sheaths being preserved) and *Chlorolichenomycites salopensis* with presumed green algal photobiont (preserved as pyrite framboids). These charcoalified fragments, resulting from wildfires, fossilized *ex situ* in marine sediments (siltstone) in the Lower Devonian (Lochkovian) of the Welsh Borderland. The microbiome of *C. salopensis* was ultrastructurally resolved: bacterial colonies on the cortical surface, endolichenic fungi between and actinobacterial filaments in close contact with medullary hyphae of the mycobiont, the same situation being found in extant lichens. Horizontal gene transfer (*e.g.* polyketide synthase genes) from bacteria to ancestors of extant lichens and non-lichenized ascomycetes with lichenized ancestors (*Penicillium*, *etc.*) occurred.

Animal–animal and animal–microbial ecological interactions in ancient methane seep communities

Crispin T. S. Little
University of Leeds, UK

Modern methane seeps were only discovered in 1984, but are now known to be a very common feature of continental margins, both in shallow and deep water settings. Seep communities are ecologically complex and mirror coral reefs in that the bulk of the biomass in the ecosystem is formed of animals that have symbiotic relationships with bacteria, although these are chemosymbionts in the case of methane seeps (utilizing geochemical energy sources), rather than photosymbionts in coral reefs (utilizing sunlight). Chemosymbiosis at seeps includes relationships between microbial organisms (methanotrophic archaea and sulfide oxidizing bacteria), and vestimentiferan tubeworms and bivalve molluscs. Diversity in seep communities is relatively low, and a few taxa (all chemosymbiotic) dominate each site, these being vestimentiferans, bathymodiolin mussels and vesicomyid clams. The tubes and shells of these animals form the structural 'framework' of seep communities, projecting above the sediment–water interface, and in turn act as hard substrates for secondary communities of boring, grazing and filter-feeding animals. In this talk I will explore the fossil record of seep communities to show how a variety of traditional and more modern analytical techniques have been used recently to elucidate many similar animal–animal and animal–microbial palaeoecological interactions at ancient methane seeps.

Competition and symbiosis on marine hard substrates in the fossil record

Paul D. Taylor
Natural History Museum, London, UK

Many animals and plants that colonize hard surfaces in the sea are sessile and either bore into or cement permanently to the substrate surface. Because they retain their life positions after fossilization, these sclerobionts offer scope for studying biotic interactions in the fossil record. Encrusting sclerobionts compete actively for living space, with dominant competitors overgrowing the edges of subordinates. An alternative mode of spatial competition is fouling, whereby larvae recruit directly onto the living surfaces of sclerobionts. Spatial competition has been studied extensively in modern marine communities but there has been little research on competition between encrusters in ancient communities. This reflects poor knowledge of the taxonomy of the sclerobionts involved, as well as perceived difficulties in distinguishing between overgrowth *in vivo* and post-mortem. Whereas sclerobionts enter into a wide range of diffuse symbioses with other organisms cohabiting the same substrate, more specific fossil symbioses occur between pairs of sclerobiont species that become intergrown, sometimes with one of the symbionts being soft-bodied and preserved through bioclaustration within a skeletonized host. Here the *in vivo* nature of the association is unequivocal. The fossil record of sclerobionts is a largely untapped resource for studying the long-term dynamics of competition and symbiosis.

Leaving no stone unturned: the feedback between biotic diversity and early diagenesis

V. Paul Wright[1] and Lesley Cherns[2]
[1]*Amgueddfa Cymru – National Museum of Wales, UK*
[2]*Cardiff University, UK*

The Early Palaeozoic diversification of infauna led to increases in the depth of burrowing that affected the depth at which secondary carbonates precipitated in the sediment column. This resulted in changes in the mechanical behaviour of the shallow buried sediments, that in lower-mid Ordovician, low energy, subtidal settings led to the most extensive phase of submarine hardground formation during the Palaeozoic. These hard seafloor substrates promoted the diversification of a rich and diverse encrusting and boring biota. Thus diversification of the infauna fed back to changes in early diagenesis that triggered changes in the epifaunal community. Prior to this interval the zone of carbonate precipitation lay at a shallower depth in the sediment, subject to frequent current reworking. The thin sheets of the cemented layers became reworked to produce the well-documented Upper Cambrian–Lower Ordovician "flat pebble breccias". By late Ordovician times, burrowing depth had increased further so that the depth of secondary carbonate precipitation was sufficiently great (>300mm) that scouring of the seafloor rarely exhumed the secondary carbonate horizons; hardgrounds became less common, but thick successions of diagenetic limestone-marl alternations formed in subtidal settings.

Abstract of Annual Address

The Annual Address will be given on Tuesday 15th December.

Computer modelling and simulation of extinct organisms: its utility and limitations for reconstructing the evolution of locomotor behaviour

John R. Hutchinson
The Royal Veterinary College, London, UK

Considering that we cannot observe the behaviour of extinct organisms, and yet their derived or ancestral traits make them attractive scientific subjects, how can we test how certain behaviours evolved? Computational methods are maturing as an approach that complements classical methods such as anatomy, ichnology, morphometrics or analogies with living animals. With the rapid advance of 3D imaging technologies, it is easy to build realistic digital organisms and estimate biological parameters such as body mass. Once a computational model is made, it opens up opportunities for more sophisticated techniques from estimating joint ranges of motion to predictive dynamic simulations that generate novel behaviours. I discuss examples from our research on the evolutionary biomechanics of locomotion in vertebrates, including simple modelling approaches of how tetrapods first walked, more complex biomechanical modelling of how fast giant dinosaurs like *Tyrannosaurus* could move, and simulations that test how the form and function of the limb muscles of tetrapods evolved into major locomotor adaptations such as avian bipedalism. A recurrent theme is the importance of the experimental validation of computational models, and the sensitivity analysis of parameters entered into models to test how much unknowns matter for the questions we ask using them in palaeobiology.

Abstracts of oral presentations

* Candidates for the President's Prize are marked with an asterisk.
Underlined author denotes designated speaker.

The grapes among the apes: implications of a new fossil record of the Vitaceae from the African Miocene

***Neil F. Adams[1], Margaret E. Collinson[1,2], Selena Y. Smith[3], Marion K. Bamford[4], Félix Forest[5], Panagiota Malakasi[5], Federica Marone[6] and Dan Sykes[2]**
[1]*Royal Holloway, University of London, UK*
[2]*Natural History Museum, London, UK*
[3]*University of Michigan, USA*
[4]*University of the Witwatersrand, South Africa*
[5]*Royal Botanic Gardens, Kew, UK*
[6]*Paul Scherrer Institute, Villigen, Switzerland*

The early Miocene Hiwegi Formation on Rusinga Island in Kenya has yielded a rich flora and fauna, including the early hominoid Proconsul. The flora is important because it provides rare evidence for habitats directly inhabited by early hominoids in the transition between arboreal primates and later hominids, and because tropical palaeolatitude records are uncommon. A comparative study of fossil and modern seeds using micro-computed tomography (μCT) and synchrotron radiation X-ray tomographic microscopy (SRXTM) shows that some fossils belong to four new Cissus species and represent the first African fossil record of the grape family (Vitaceae). Virtual taphonomy explains how key features of the fossils were obscured during fossilization leading to previous misidentification of some specimens to the moonseed family (Menispermaceae). Phylogenetic relationships within modern Cissus were reconstructed using previously obtained DNA sequences, as well as newly generated sequences for African species. Modern species most similar to the fossils belong to at least three clades, in early diverging lineages, currently widespread across Africa and southeast Asia. The fossils are interpreted to represent moist forest and arid-adapted taxa and add previously unrecognized diversity of lianas and shrubs to a Miocene mosaic of woodland and forest habitats: the setting for early hominoid evolution.

New windows into the ecology and taphonomy of Ediacaran acanthomorphs

***Peter W. Adamson[1,2] and Nicholas J. Butterfield[1]**
[1]*University of Cambridge, UK*
[2]*British Geological Survey, UK*

The Ediacaran is marked by a distinctive assemblage of large acanthomorphic acritarchs, best known from the Doushantuo Formation in South China. These fossils offer the only reasonable prospect for biostratigraphic subdivision of the early Ediacaran, although such potential seems compromised by their restriction to localized low-energy environments, primarily chert and phosphorite facies. Our study of the interstices of a debris-flow conglomerate in the Ediacaran Biskopås Formation (Norway) substantially expands the known palaeoenvironmental and taphonomic range of Doushantuo-type acanthomorphs.

In some cases the spaces were filled with fossiliferous micrite (now microsparite) – the first documented occurrence of Doushantuo-type acritarchs preserved in carbonate. Elsewhere the interstices include the remains of phosphatized, boulder-encrusting microbial mats with incorporated acanthomorphs – the first documented occurrence of Doushantuo-type phosphatization outside of South China. Given these two distinct taphonomic pathways, and the contemporaneous growth of microbial mats, it is clear that the acanthomorph-forming organisms were living in direct proximity to the actively prograding conglomerate, either within the interstices or on locally quiescent palaeosurfaces. The discovery of acanthomorphs in both high-energy environments and carbonates presents an important new search image for such fossils, and substantially increases their potential for biostratigraphically partitioning the early Ediacaran.

The Mesoproterozoic Ruyang Group, China – a hotspot of early eukaryote biodiversity

***Heda Agić[1], Małgorzata Moczydłowska[1] and Leiming Yin[2]**

[1]*Uppsala University, Sweden*

[2]*Nanjing Institute of Geology and Palaeontology, China*

The Mesoproterozoic Era was a critical time for the diversification of Eukaryota and the appearance of the first complex morphologies. Earliest eukaryotic fossils with ornamentation and sculpture occur in the 1.8–1.6 Ga successions worldwide. The Ruyang Group, China, records a high diversity (26 taxa) of such organic-walled microfossils. Studied samples derive from organic-rich shale intervals through Baicaoping and Beidajian formations, deposited in shallow marine environments. Acetolysis-resistant palynomorphs were extracted from the rock via HF-maceration and studied using light and scanning microscopy. Depositional age of Ruyang successions has been constrained to 1.75–1.40 Ga via zircon U-Pb dating, extending the first appearance of complex eukaryotic characters back in the fossil record. Novel morphologies among this unicellular biota include a variety of processes, spongy membranes, and specimens with internal bodies of varying sizes, up to 87% of the vesicle diameter. Fossil diversity is highest in the middle Baicaoping and the uppermost Beidajian Formation. Key characters displayed by the Ruyang biota are consistent with reproductive structures (cysts) among modern protists. A significant degree of intracellular complexity would have been required to produce such intricate morphologies. Size, morphology and wall ultrastructure support the position of some Ruyang microfossils in the crown-group Eukarya.

Chitinozoan biozonation in the Arenig Series (Floian–lower Darriwilian stages) of Wales

***Chloé E. A. Amberg[1], Thijs R. A. Vandenbroucke[2], Stewart G. Molyneux[3], Jean-François Ghienne[4] and Philippe Razin[5]**

[1]*Université Lille 1, France*

[2]*Ghent University, Belgium*

[3]*British Geological Survey, UK*

[4]*Institut de Physique du Globe de Strasbourg, France*

[5]*Université de Bordeaux, France*

The Early-Middle Ordovician has long been considered a super-greenhouse world. However, emerging evidence suggests that global cooling towards the Late Ordovician glaciations may have started earlier than previously thought, perhaps even during the Early Ordovician. Our research project further investigates this hypothesis, testing the following predictions: 1) if low-stand sedimentary features (such as unconformities) in the near field (Anti Atlas of Morocco) are of glacio-eustatic origin, they ought to correlate with other, distant, indications of lowstand; and 2) if the climate changed, this ought be reflected in the distribution patterns of Early–Middle Ordovician chitinozoans. Both approaches are challenged by the lack of chitinozoan data from the Anglo-Welsh basin, needed to correlate the Moroccan sections (without graptolites) into the classic Anglo-Welsh area. Here, we present a chitinozoan biostratigraphy for the historical type Arenig Series in Wales. Our results indicate that the Avalonian chitinozoan fauna, containing assemblages of *Lagenochitina* aff. *esthonica*, differs from that of Gondwana in the lower and middle Arenig. The upper Arenig Avalonian fauna correlates with the *Desmochitina bulla* Biozone from Gondwana. This new framework and the absence of several key Gondwana taxa is here used to make inferences about the Early Ordovician climate.

Variations in wildfire activity driven by atmospheric oxygen changes across the Toarcian OAE

***Sarah J. Baker, Claire M. Belcher, Stephen P. Hesselbo and Tim M. Lenton**

University of Exeter, UK

Oceanic anoxic events (OAEs) represent periods in Earth's history of major disruption to the global carbon cycle. During an OAE, organic carbon burial rates increase due to abundant primary productivity within surface waters leading to anoxic bottom waters and enhanced organic preservation. Over geological timescales organic carbon burial serves as a major source of atmospheric oxygen. Small changes in atmospheric oxygen concentrations have been shown to greatly influence wildfire activity, yet no one has considered studying fossil evidence postulated changes to atmospheric oxygen driven by OAEs before. Here we show variations in charcoal abundance as a proxy for wildfire activity across the Toarcian OAE, from three sites. Our results show significant changes in wildfire activity that we suggest may be able to resolve the potential timescale over which atmospheric oxygen can change across an OAE. Increased charcoal abundance coincides with the onset of the Toarcian OAE and remains high throughout its duration, diminishing only during a negative carbon isotope excursion period due to elevated precipitation levels that likely dampened wildfire activity. Our results provide physical evidence from the fossil record that changes in atmospheric oxygen concentrations, driven by increased organic carbon burial during an OAE, were possible across this relatively short geologic timescale.

talks

Five new Tournaisian tetrapods: their sedimentology and palaeoenvironments

***Carys E. Bennett[1], Jennifer A. Clack[2], Timothy Kearsey[3], Sarah J. Davies[4], David Millward[3], Tim R. Smithson[2], Marcello Ruta[5], Ben Otoo[2], John E. A. Marshall[6], Emma Reeves[6] and Andrew Ross[7]**

[1]*University of Leicester, UK*
[2]*University of Cambridge, UK*
[3]*British Geological Survey, UK*
[4]*University of Leicester, UK*
[5]*University of Lincoln, UK*
[6]*University of Southampton, UK*
[7]*National Museums Scotland, UK*

Far from being a depauperate interval for fossil tetrapods, the Tournaisian has recently yielded an unprecedented diversity of taxa. A cladistic analysis of five new tetrapod species places three taxa below the origin of the tetrapod crown group. The remaining two taxa are part of the amphibian stem group. The fossils occur spaced through the Ballagan Formation at the Burnmouth and Willie's Hole sites. Despite their stratigraphic and geographic separation, four of the five tetrapods occur in the same lithology, a microconglomerate: matrix-supported grey siltstones with clasts of 1-2 mm in size derived from floodplain sediments. Microconglomerates are common (140 beds in a 490 metre succession), often (71% of beds) overlying desiccation cracks, and are one of the richest fossil deposits in this formation; plant fossils and megaspores are abundant as are the remains of actinopterygians, rhizodonts, ostracods, eurypterids, myriapods and non-marine bivalves. Tetrapods, lungfish and chondrichthyans are rarer. Deposition occurred in seasonal flooding events, likely due to monsoonal rainfall. Varied palaeosols and palynology indicate a mosaic of environments including forests, scrubland, wetlands and desiccating pools. Fossil specimens are often articulated and indicate minimal transportation and rapid burial. These under-recognized deposits record early diversification of tetrapods into newly-appearing habitats.

Near-stasis in the long-term diversification of Mesozoic tetrapods

Roger B. J. Benson[1], Richard J. Butler[2], John Alroy[3], Philip D. Mannion[4], Matthew T. Carrano[5] and Graeme T. Lloyd[3]

[1]*University of Oxford, UK*
[2]*University of Birmingham, UK*
[3]*Monash University, Australia*
[4]*Imperial College London, UK*
[5]*Smithsonian Institution, USA*

How did evolution generate the extraordinary diversity of vertebrates on land? Zero species are known prior to ~380 million years ago, and more than 30,000 are present today. The widely-held expansionist model suggests that this was achieved by large and unbounded increases, leading to substantially greater diversity in the Recent than at any time in the geological past. However, only a small amount of empirical data have been used to test this hypothesis. We quantify patterns of vertebrate standing diversity on land during the Mesozoic–early Palaeogene interval, applying sample-standardization to a global fossil dataset containing 27,260 occurrences of 4,898 non-marine tetrapod species. Our results

show a highly stable pattern of Mesozoic tetrapod diversity, underpinned by a weakly positive, but near-zero, long-term net diversification rate over 190 million years. Diversity of non-flying terrestrial tetrapods less than doubled over this interval, despite the origins of exceptionally diverse extant groups within mammals, squamates, amphibians and dinosaurs. Therefore, although major groups of modern tetrapods have Mesozoic origins, rates of Mesozoic diversification inferred from the fossil record are slow. Apparently multiplicative diversity increases over the K/Pg boundary suggest that the gradualistic evolutionary diversification of tetrapods was punctuated by brief but dramatic episodes of radiation.

The Strawberry Bank Lagerstätte reveals insights into Early Jurassic life

Michael J. Benton[1], Matt Williams[2], Andrew Ross[3] and Matt Friedman[4]

[1]*University of Bristol, UK*

[2]*Bath Royal Literary and Scientific Institution, UK*

[3]*National Museums Scotland, UK*

[4]*University of Oxford, UK*

The Strawberry Bank Lagerstätte from the Early Jurassic (early Toarcian) of Ilminster, Somerset, provides a rich insight into Early Jurassic marine vertebrate life, revealing exquisite anatomical detail of marine reptiles and large pachycormid fishes thanks to exceptional preservation, and especially the uncrushed, 3D nature of the fossils. The site documents a fauna of Early Jurassic nektonic marine animals (five species of fishes, one species of marine crocodilian, two species of ichthyosaurs, cephalopods and crustaceans), but also over 20 species of insects. Unlike other fossil sites of similar age, the 3D preservation at Strawberry Bank provides unique evidence on palatal and braincase structures in the fishes and reptiles. The age of the site is important, documenting a marine ecosystem during recovery from the end-Triassic mass extinction, but also exactly coincident with the height of the Toarcian oceanic anoxic event, a further time of turmoil in evolution. Initial digital reconstructions show the great potential of the site, and a new, funded project aims to extract full information from this long-forgotten Lagerstätte.

Conodont-based, high-resolution, quantitative biochronology of the end-Permian mass extinction in South China

***Morgane Brosse[1], Hugo Bucher[1] and Nicolas Goudemand[1,2]**

[1]*University of Zurich, Switzerland*

[2]*École normale supérieure de Lyon, France*

The construction of a high-resolution zonation across the Permian–Triassic Boundary (PTB) is of paramount importance for elucidating the mechanisms at play before, during and after the end-Permian mass extinction because it provides a time frame for reconstructing the global sequence of abiotic and biotic events that occurred during that critical interval. We propose a new conodont-based regional biozonation of the PTB interval for the Chinese Nanpanjiang basin, including the reference-setting GSSP section of Meishan. This discrete zonation comprises six Unitary Association Zones (UAZs). UAZs are preferred to the traditional, continuous interval zones, because they enable the detection and solving of biostratigraphical contradictions, hence lead to more robust and more accurate biozonations. We standardized the high-resolution conodont data from six well-documented sections. The resulting zonation is largely compatible with the conodont data

of five additional sections and enables intra-basinal correlations, including between sections displaying drastically different facies. Combining these results with published carbon isotopic data and radiometric absolute ages, we show that the deposition in South China during the earliest Triassic of microbialites lasted no more than 0.55 Ma.

On the origin of animals and biologically mediated flow

Nicholas J. Butterfield
University of Cambridge, UK

The evolution of multicellular metazoans was one of the most revolutionary transitions in the history of life on Earth. Explanations for its conspicuously-late appearance (in the mid-Neoproterozoic) have focused largely on atmospheric evolution, reasoning that multicellular organisms require fundamentally higher levels of oxygen than corresponding unicells. This isn't true. Whereas unicells live in viscous flow regimes and exchange oxygen and CO_2 solely by diffusion, the collectivized activity of flagellated cells in sponge-grade organisms gives rise to turbulent flow (advection) and, as a consequence, access to fundamentally greater levels of gas exchange. Given the presence of single-celled aerobic eukaryotes a billion years prior to the earliest estimated appearance of sponges, oxygen availability can be dismissed as a viable hypothesis for the delayed appearance of animals. By the same token, the primary impetus for multicellularity was likely to have been feeding rather than gas exchange. Even so, the invention of this new fluid dynamic technology was a prerequisite for advancing to more complex grades of organization. In turn, the increasingly sophisticated means of diploblastic and triploblastic animals to bioturbate their aqueous medium revolutionized Phanerozoic ocean structure and dynamics – with local returns to Proterozoic conditions during mass extinction.

Reconstructing Miocene neotropical palaeoenvironments: a case study from the palaeosols and ichnofossils of Cerdas, Bolivia

***Angeline M. Catena[1], Daniel I. Hembree[2], Beverly Z. Saylor[1] and Darin A. Croft[1]**
[1]*Case Western Reserve University, USA*
[2]*Ohio University, USA*

Bolivia is one of the few countries in South America that preserves a rich fossil record of middle Miocene Neotropical mammals. Nevertheless, little is known about the palaeoenvironments that fostered the development of this ancient mammalian diversity. Cerdas, an early Middle Miocene (16–15 Ma) locality has produced remains of 15 mammal species in seven orders and nine families. In this study, we use palaeopedology and ichnology to investigate its palaeoenvironment. The palaeosols of Cerdas are weakly to moderately developed, occur in compound profiles, and are primarily composed of red-to-brown silty sandstone. The molecular weathering ratios are characterized by low oxidation and lessivage values and moderate calcification and leaching values. The palaeosols are interpreted as eutric Inceptisols that formed proximal to braided streams. Rhizohaloes and linear to J-shaped, lined and unlined, horizontally to subvertically oriented burrows are common in the palaeosols. The rhizohaloes are interpreted as roots of small- to medium-sized plants that grew in imperfectly drained soils, and the burrows are interpreted as dwelling and feeding structures of various soil invertebrates. Based on the characteristics of the palaeosols and ichnofossils, the palaeoenvironment of Cerdas is interpreted as a humid to subhumid shrubland located proximal to an alluvial system.

The 100 million year journey to teleost supremacy

***John Clarke[1], Lauren Sallan[1] and Matt Friedman[2]**
[1]*University of Pennsylvania, USA*
[2]*University of Oxford, UK*

Teleost fishes, with ~29,000 species and a bewildering array of morphologies, represent the dominant group of aquatic vertebrates today. In dramatic contrast, their holostean sister group consists of just eight species and two body plans, restricted to the freshwaters of North America. However, the pattern by which teleosts achieved this dominance is unclear. This is because a Mesozoic 'golden age'of holostean diversity, described in classic palaeontological accounts, has not been quantified, preventing any reasoned comparison with teleosts. We quantified disparity for >350 neopterygian species across the first 150 million years of the Mesozoic. Holosteans show greater disparity than teleosts across the Triassic and Early Jurassic. Teleosts approach holostean levels of disparity in the Middle Jurassic, before achieving and maintaining higher disparity than holosteans from the Late Jurassic onwards. Although the period of teleost supremacy coincides with the origin and subsequent diversification of crown teleosts, crown taxa were not responsible for the initial teleost takeover in the Late Jurassic. Instead, it was the presence of early diverging stem teleost clades, such as Aspidorhynchids and Pycnodonts, that drove the initial teleost takeover, clades that remained important contributors to teleost disparity throughout the Lower Cretaceous, even when outnumbered by crown taxa.

An outstanding upper Katian (Upper Ordovician) fossil assemblage from Portugal (Buçaco, Central Iberian Zone): biostratigraphical and palaeobiogeographical significance

***Jorge Colmenar[1], Sofia Pereira[2,3,4], Artur A. Sá[3,4] and Carlos M. da Silva[2]**
[1]*University of Copenhagen, Denmark*
[2]*Universidade de Lisboa, Portugal*
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The *Nicolella* Community was the most typical brachiopod-dominated assemblage throughout high-latitude Gondwanan shelves during mid to late Katian times. It is widely represented in the Upper Ordovician rocks of the Porto de Santa Anna Formation (Central Iberian Zone, Portugal). The present study focuses on the rich fossiliferous silicified rocks of the upper half of this formation in the Cabeço Pedrogão locality (Espinheira, Buçaco). The fossil assemblage is dominated by echinoderms, followed by brachiopods and bryozoans, but trilobites and algae are fairly common too. The re-study of the classical fossil collections from these beds housed at the Museu Geológico (Lisbon), supplemented by several sampling campaigns, revealed the presence, among others, of previously unregistered brachiopod and trilobite taxa in Portugal: *Kjaerina* (*Villasina*) *meloui*, a brachiopod recorded previously only in the uppermost Rosan Formation (Armorican Massif, France); *Ceraurinus*? *meridianus* and "*Bumastus*" aff. *commodus*, trilobites only known from the Cystoid Limestone (Iberian Chains, Spain). These records are important additions to the knowledge of the Portuguese Upper Ordovician benthic marine communities, providing crucial new data to constrain the biostratigraphy of the upper half of the Porto de Santa Anna Formation and the palaeogeographical setting of this region during the Late Ordovician.

talks

Are solemyoids and ctenodontids related?

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The chemoautotrophic solemyoids are one of the most primitive living bivalve groups; they have protobranch gills and are therefore often compared with the other extant protobranch group, the nuculoids, and most authorities suggest that the solemyoids were derived from the nuculoids. Unlike most bivalves, solemyoids are distinctly elongated anteriorly, and this anterior elongation has caused them to be linked with a group of Ordovician anteriorly-elongated nuculoids, the ctenodontids, although ctenodontids possess a taxodont dentition, whilst solemyoids are edentulous. Studies have been published suggesting putative intermediate forms between the two groups. However, all this has been thrown into disarray, following the discovery of a seemingly fully-fledged solemyoid in the Early Ordovician. In spite of this, however, the latest cladistic analyses link the two groups closely. But is this suggested relationship spurious?

On the difficulty of reconstructing hybodont dentitions based on isolated teeth

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Hybodont sharks represent the sister-group of modern elasmobranchs. They appeared in the Devonian and disappeared at the end of the Cretaceous. Like for all cartilaginous fishes, complete fossils are very rare in the fossil record and these animals are known mainly through isolated teeth. However, to reconstruct the complete dentition from only isolated teeth is almost impossible, which could make their phylogenetic relationships very difficult to decipher as the following two examples demonstrate. *Asteracanthus magnus*, hitherto known only from isolated teeth, was considered close to *A. medius*, of which a complete dentition is known. However, a partial dentition of *A. magnus* recently found in the Middle Jurassic (Bathonian) of Normandy (France) shows that teeth usually identified as anterior of *A. magnus* represent in fact teeth of the first lateral file and that it possessed high-crowned anterior teeth. As a result, *A. magnus* appears closer to *A. smithwoodwardi* than to *A. medius*. *Isanodus paladeji* is a heterodont hybodont described from the Lower Cretaceous (Barremian) of Thailand. Its dentition was reconstructed using *Lissodus nodosus* as a proxy, but new discoveries do not fit the current reconstruction and it seems that this species could encompass teeth belonging to at least two separate genera.

The morphology and affinity of the Cambrian "muscle worm"

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Myoscolex is an enigmatic animal with prominent musculature from the Cambrian Emu Bay Shale in Australia. Its affinities are widely debated, having been compared to annelids,

arthropods, *Opabinia*, and chordates. *Myoscolex* has some of the oldest and best-preserved phosphatised muscle tissue in the fossil record, so it is important for understanding the evolution of this morphological feature. Hundreds of recently collected specimens of *Myoscolex* have been examined and described to give a more complete overview of its anatomy. The elongated body is segmented and shows longitudinal and dorsal-ventral muscles, the latter arranged in opposing pairs on each segment. SEM examination reveals details on the size and arrangement of the muscle fibres. The new material shows that each body segment had a pair of rigid, rod-like structures to which setae arranged in a cross-hatch pattern were attached. The external cuticle was smooth and adorned with triangular plates along the ventral margin. There is no evidence for *Opabinia*-like flaps or a proboscis. A possible cephalic region consists of three round carapaces with tiny, paired sclerite structures. Identifying the affinity of *Myoscolex* requires careful consideration of the ontogeny and preservation of exceptionally preserved specimens of this abundant Emu Bay Shale animal.

"MISS" conceptions and misconceptions: microbial, abiotic and problematic sedimentary surface textures from the Archaean to the present

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In recent years, an increasing number of sedimentary surface textures in the rock record have been suggested to document the presence of microbial mats, resulting in their classification as microbially induced sedimentary structures, or "MISS". The rapid rate at which this understanding has developed has led to repeated misconceptions arising in the literature, with implications for understanding aspects of evolution and extinction in the fossil record. Commonly repeated claims include: 1) MISS are more common prior to the evolution of, or during post-extinction lulls in, bioturbation, and 2) MISS are predominantly shallow marine features produced by cyanobacteria. Combining a meta-survey of literature with original observations from multiple Precambrian and Phanerozoic formations, we demonstrate that both of these claims are unfounded. MISS are in fact more common in Phanerozoic than Precambrian strata, and have a continuous pan-environmental, post-Archaean record. The perception that they are restricted to exceptional intervals of Earth history likely arises from a sampling and publication bias. We also address the decreasing appreciation of abiotic sedimentary processes that may create morphologically similar features to MISS. By introducing the umbrella term 'sedimentary surface textures', of which MISS are one subset, we suggest a practical, non-sensational methodology for classifying these features.

talks

Dinosaur biogeographic structure and Mesozoic continental fragmentation: a network-based approach

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Dinosaur macro-biogeographic structure is influenced by continental fragmentation, although some intercontinental exchange of dinosaur faunas continued up to the end of the Cretaceous. Macro-biogeographic patterns are obscured by uneven geographic sampling through time and a residual earlier Mesozoic distribution which is sustained up to the end of the Cretaceous. Here, we use a novel network-based approach to reconstruct dinosaur macro-biogeographic patterns through the Mesozoic Era and test how continental fragmentation affected dinosaur macro-biogeographic structure and evolutionary rates. Geographic connectedness declines through time, from peak aggregation in the Triassic–Jurassic to complete separation in the latest Cretaceous. Biogeographic connectedness shows no trend in the raw and novel connection networks, but decreases through time whilst showing some correlation with continental fragmentation in the first-step networks. Despite continental isolation and high sea levels, intercontinental faunal exchange continued right up to the end of the Cretaceous. Continental fragmentation and dinosaurian macro-biogeographic structure do not share a common pattern with dinosaurian evolutionary rates, although there is some evidence that increased continental isolation resulted in increased origination rates in some lineages. Spatiotemporal sampling biases and early Mesozoic establishment of family-level distribution patterns are important drivers of apparent dinosaur macro-biogeographic structure.

Silicified molluscs from the Vikinghøgda Formation, central Spitsbergen: systematic and palaeoecological significance

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Understanding how the marine biosphere recovered from the late Permian mass extinction event is a major question in the evolutionary history of life on Earth. The quality of the global fossil record of this interval is, however, somewhat poor, due to problems with preservation. Here we report on a new early Induan marine fauna from the Vikinghøgda Formation, Svalbard, which are all silicified and represent the oldest silicified fauna known from the Triassic. Excellent preservation of the internal characteristics of bivalve shells, gastropod apertures and protoconchs provides critical new systematic data. For its age, the assemblage is exceptionally diverse with 12 species belonging to 10 genera of bivalves and gastropods. Although this richness is due largely to the excellent preservation, the assemblage provides further evidence that the mid-palaeolatitude Boreal Ocean housed significant biodiversity during the Early Triassic. Four species are new, and several taxa are recorded in the Early Triassic for the first time. These new data support taxonomic reassignment of some of these taxa, which has important implications for their inferred palaeoecology and our understanding of the composition and function of benthic marine communities in the wake of the late Permian mass extinction.

Estimation of taxonomic richness variation through geological times: a simulation approach

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Estimating taxonomic richness and its variations through geological time is a notoriously difficult task, due to several taphonomical and methodological reasons making the reconstructed signal potentially distinct from the real (but unknown!) one. Through a simulation approach, we examine the effect of a major, while surprisingly still understudied, source of potential disturbance: the effect of time discretization through biochronological construction, generating spurious coexistences of taxa within biozones, and thus ultimately making continuous- and discrete-time taxonomic richness curves very different. Our approach relies on continuous-time simulated biodiversity curves, then time-discretized to estimate the actual loss of information generated by this manipulation. A broad spectrum of dataset parameters (*e.g.*, average biozone duration, total number of taxa, average taxonomic longevity) are tested through sensitivity analysis, showing that the worsening effect of time-discretization on the biodiversity signal highly depends on such parameters. Based on these simulation results, we propose a simple algorithm allowing the back-transformation of a discrete-time taxonomic richness dataset as customarily constructed by palaeontologists into a virtually continuous-time dataset. We show that the new biodiversity curve obtained this way fits the original signal much more closely, even when the initial dataset conditions are particularly hostile to an accurate time-discretized reconstruction.

Earliest members of a 'living fossil' lineage indicate a late origin of modern ray-finned fish diversity

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Actinopterygians account for over half of living vertebrate diversity. Difficulty lies in unravelling how modern actinopterygian lineages, particularly polypterids, emerged from a 'haze' of inadequately known fossil taxa, leading to problems when ascertaining the age of the living radiation. Recent cladistic analyses that incorporate extant actinopterygians in addition to a range of Palaeozoic and Mesozoic taxa typically recover a Middle Devonian age for the actinopterygian crown. This is seemingly incongruous with the Cretaceous age of the earliest known polypterid fossils and molecular evidence suggesting that the living polypterid radiation is Neogene in origin. Here we use CT scanning to describe previously unknown aspects of the braincase, jaws and gill skeleton of *Fukangichthys*, a scanilepid from the Triassic of China, revealing a stem-polypterid affinity for the Scanlepiformes and exposing many of the supposedly primitive features of modern polypterids as reversals. This discovery shifts all Palaeozoic and some Mesozoic taxa onto the actinopterygian stem and suggests a much younger age for the actinopterygian crown, bringing it more into line with estimates indicated by the earliest fossil members of other extant actinopterygian lineages. This fundamental shift in the age of the crown has major implications for the accuracy of current molecular clock models.

talks

Evactinostella crucialis – another weird and wonderful bryozoan

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The Lower Permian Callytharra Formation in Western Australia has yielded a rich bryozoan fauna dominated by cystoporate and fenestrate bryozoans. Variation in the faunal composition reflects a pronounced cyclic depositional environment, with shale-carbonate para-sequences bundled into para-sequence sets. Bed planes in the homogeneous carbonate sands terminating most of the para-sequence sets are exceptional in exposing large colonies in life position, with the cystoporate *E. crucialis* and the fenestrate *Lyroporella erkosoides* as the most prominent. While *L. erkosoides* appears directly adapted to the shallow water, storm wave-generated deposition interpreted from the sediment supporting these colonies, the mode of life of *E. crucialis* remains somewhat ambiguous. Investigation of well-preserved colonies in life position – including internal as well as external colony architecture in combination with branch geometry – allows detailed interpretations regarding 'mode of life' of *E. crucialis*. These colonies typically comprise four symmetrically arranged, vertical branches reaching up to 25 cm in length, rising from a base partially submersed in the sediment surface, but not otherwise attached; evenly distributed, prominent maculae indicate the presence of well-controlled, colony-wide feeding currents. Both of these observations appear at odds with the ambient, storm wave-dominated environment.

Ontogenetic stages in the basal Gondwanan eusauropod Patagosaurus

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Patagosaurus is the best-represented eusauropod from the Middle Jurassic of South America; several specimens are known from two contemporaneous bonebeds from the Cañadón Asfálto Formation, Patagonia, Argentina. Among these are individuals representing different ontogenetic stages. The material consists mostly of axial elements, but appendicular elements such as femora and scapulae were also recovered, as well as two dentaries. Osteological redescriptions of the holotype and referable material reveal three distinct ontogenetic stages within this taxon; one juvenile, two subadults (including the holotype) and one fully-grown adult. Major morphological differences between ontogenetic stages lie mainly in the vertebrae; increasing stage of fusion between the neural arch and the vertebral body, increasing depth of the pleurocoels, expression of laminae, absence/presence of centrodiapophyseal fossae, increasing height of neural arch, diagonal/horizontal projection of transverse processes. Lastly, tooth count and dentary symphysis depth increase with ontogeny. Appendicular elements seem to grow isometrically. Apart from the North African genus *Tazoudasaurus*, and possibly *Lapparentosaurus* from Madagascar, there are no well-known Gondwanan eusauropods with ontogenetic stages preserved, leaving a gap between basal sauropodomorphs, such as *Massospondylus*, and more derived sauropods (mostly diplodocids). *Patagosaurus* thus represents an important data point in studying ontogeny in more basal sauropods.

How easy was the Ediacaran transition to large body size? Rangeomorph growth, development and complexity.

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The Ediacaran fossil record captures one of the most dramatic events in the history of life, the evolution of large body size. The rangeomorphs had already achieved impressive sizes of up to two metres at their first appearance (580 Ma). Yet we know little about the evolutionary-developmental mechanisms underlying this transition, or how rapidly it could have occurred. We lack direct knowledge of the genetic and developmental underpinnings of the extinct rangeomorph body plan. However, the iterative branching structure of the rangeomorph frond offers an opportunity to infer fine-scale patterns and rates of growth through ontogeny. I will present the findings of such a study and discuss the implications for the complexity and evolution of early macro-morphology.

A new use for old pollen: reconstructing past solar irradiance using pollen chemistry

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Despite the importance of solar irradiance as a dominant control on Earth's energy budget, no proxy has been developed that can provide total solar irradiance (TSI) reconstructions prior to the Holocene. Here, we present a novel proxy based on the chemical composition of sporopollenin, the primary component of the outer walls of pollen and spores (sporomorphs). Sporopollenin chemistry is responsive to levels of ultraviolet-B (UV-B) radiation exposure, which offers the possibility of using fossil sporomorph chemistry as a proxy for past UV-B flux and, by extension, TSI. The high preservation potential of sporomorphs means that this new proxy has the potential to reconstruct UV-B and TSI flux over much longer timescales than has previously been possible. Furthermore, Fourier Transform Infrared (FTIR) spectroscopy allows sporopollenin chemistry to be rapidly and non-destructively assessed on small sample sizes (≤10 sporomorphs/sample). We demonstrate the utility of this proxy using grass pollen chemistry data from the late Pleistocene of Ghana, and relate this to modelled TSI. This proxy provides a new approach for quantifying UV-B flux and TSI through time, and therefore offers the potential to determine how changes in solar irradiance have contributed to climatic and biotic change in the past.

Morphology of the jaw adductor complex across the cynodont–mammaliaform transition

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The evolution of the mammalian jaw is characterized by the gradual reduction of its individual bones into a single element and the incorporation of the post-dentary bones into the middle-ear complex. This osteological transformation is accompanied by a modification of the jaw adductor musculature, which is thought to have allowed the evolution of a more efficient masticatory system. Here we use digital techniques to reconstruct the jaw adductor musculature of different non-mammalian cynodonts and mammaliaforms (including *Thrinaxodon*, *Probainognathus*, *Diademodon*, *Morganucodon*, *Hadrocodium*). Three-dimensional digital models of the adductor muscles were created on the basis of osteological correlates, homological criteria and spatial constraints. Different hypothesized arrangements were tested, taking into account maximum muscle stretch factors and comparative data from contrast-enhanced CT scans of an extant taxon (*Monodelphis*). The resulting models show a trend in the arrangement of the neomorphic masseter muscle, shifting from an originally vertical position in basal taxa to an anteroposteriorly diagonal position in *Morganucodon*, thus avoiding interference with the post-canine teeth. At the same time, the temporalis muscle increased in absolute and relative size in mammaliaforms. These digital models confirm existing assumptions, but also provide new data and quantitative assessments on the musculoskeletal evolution of the mammalian masticatory system.

The role of framboidal pyrite and sulfur cycling in Ediacaran taphonomy

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Late Ediacaran mouldic preservation of soft-bodied organisms, in diverse lithologies, contrasts markedly with the often temporally- and spatially-restricted preservation of soft tissues in Phanerozoic deposits. Preservation of Ediacaran macrofossils in coarse sandstones has been explained by the "death mask" hypothesis of Gehling (1999), whereby early diagenetic (microbially-induced) pyrite mineralization cast the exterior morphology of organisms prior to soft-tissue decay and lithification of the sediment. However, a paucity of evidence for pyrite has previously prevented extension of this taphonomic pathway to other Ediacaran facies. New petrological and compositional data from Newfoundland (Canada) demonstrate that framboidal pyrite played an integral role in macrofossil preservation in Ediacaran deep-marine settings. Pyrite framboids or their oxidation products form laterally extensive sub-millimetre-thick surface veneers on all studied fossil-bearing bedding planes, and occur in association with a variety of smothering substrates. When combined with increasing recognition of pyrite in association with macrofossils at other global Ediacaran localities, the "death mask" model is here proposed to offer a universal explanation for mouldic Ediacaran preservation. The Ediacaran taphonomic window may thus be an artefact of global marine sulfur cycling and the activity of sulfate reducers, rather than reflecting true evolutionary signals.

Conservation palaeobiology of Chesapeake Bay oysters

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Populations of the eastern oyster (*Crassostrea virginica*) in Chesapeake Bay (USA) are declining precipitously due to overharvesting, sediment influx and disease. Although ecological records are limited to the past century, the Pleistocene record stretches back 500,000 years and may provide a baseline for ecological restoration. The focus of this research was to reconstruct the size distribution, growth rates and population densities of Pleistocene oyster deposits in the mid-Atlantic region. Bulk samples were collected from 10 localities, ranging from early to late Pleistocene and yielding 21 to 2,400 oysters per locality. Shell height was measured for 3,500 left valves and population density was quantified at the only intact field locality. Age was estimated by: 1) counting lines on bisected hinges; and 2) counting bumps on the medial surface of the hinge. Late Pleistocene oysters are significantly larger than colonial or modern oysters and population density for Pleistocene reefs is an order of magnitude larger than modern estimates. Aging techniques yield correlated age estimates, but additional sclerochronology is required for ground-truthing. This study suggests that, although restoration efforts focus on the raising and seeding of oyster larvae, priorities need to shift to protecting large, disease-resistant oysters.

Tetrapodophis amplectus, a four-legged snake from the Early Cretaceous of Gondwana, and implications for the origins of snakes

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Snakes are a diverse and successful group of squamates, with over 3,000 known species, but the origins of this remarkable diversity are poorly understood. Two-legged snakes have previously been described, but four-limbed have remained unknown – until now. *Tetrapodophis amplectus* from the Early Cretaceous (Aptian) Crato Formation of Brazil represents the oldest definitive snake and the first with four limbs. *Tetrapodophis* shows numerous snake apomorphies, including hooked teeth implanting into sockets, an intramandibular joint, zygosphene-zygantrum articulations between vertebrae, >150 presacral vertebrae, and transverse belly scales. Although snake-like in most features, *Tetrapodophis* retains short but well-developed arms and legs. Adaptations for aquatic life are absent. Instead, *Tetrapodophis* exhibits burrowing specializations, consistent with a subterranean origin for snakes. Surprisingly, the limbs are not vestigial, but are specialized for grasping. Along with a highly flexible spine, here interpreted as an adaptation for constriction, recurved teeth, and the presence of a vertebrate in the gut, this suggests that early snakes were carnivores. Finally, *Tetrapodophis* provides insight into the geographic origin of snakes. *Tetrapodophis*, together with a high diversity of basal lineages from Africa and South America, both extinct and extant, indicates that crown Serpentes originated and radiated in Gondwana during the Early Cretaceous.

talks

Unlocking the preservation pathways of Cambrian neural tissue

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Exceptionally preserved Cambrian fossils provide a rich source of data regarding neural organization during the early stages of the animal radiation. Recent reports of neural structures in Cambrian panarthropods significantly contributed to our understanding of the early evolution of panarthropod nervous systems and controversies about segmental homologies. However, scarcity of fossilized neural tissue means that most studies to date are based on single specimens, hindering tests of the fidelity of those structures and the diagenetic processes that led to their exceptional preservation. This study describes newly-discovered specimens of *Fuxianhuia protensa* with fossilized brains revealing matching morphological profiles, which allow rigorous testing of their reproducibility. The new specimens support a recent interpretation of a tripartite brain in this species but revise the trajectory of its optic nerves as confluent with the anterior protocerebrum. Geochemical analyses provide crucial insight into neural tissue preservation, revealing that the neural tissue was initially preserved as carbonaceous film and subsequently pyritized. This mode of preservation is consistent with the taphonomic pathways of gross anatomy, indicating that no special mode is required for the fossilization of labile neural tissue. Preliminary decay experiments also support the preservation potential of neural structures and their morphological interpretation after compression.

The eldonids: cryptic éminences grises of the Palaeozoic oceans

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The eldonids are an extinct group of asymmetrical unmineralized discoidal organisms ranging from the early Cambrian to the late Devonian. First described in 1847, they remain little known and poorly understood, even with thousands of specimens from multiple Palaeozoic Lagerstätten including the Burgess Shale and Chengjiang. Based on a combination of newly-acquired fossil material, older curated specimens and published descriptions, the taxonomy of the entire eldonid group has been revised. At least eight genera and ten species are divided across three families, one order, and one class, placed within the deuterostome stem group Cambroernids. The eldonids remained quite anatomically conservative throughout their record. All possessed a dextrally coiled sac (containing the alimentary canal) with circumoral tentacles, and radiating bifurcating lobes within the body cavity. The proposed taxonomic groupings are distinguished on variations of these morphological features and the nature of the dorsal integument. Eldonids often occurred in large gregarious swarms, with a remarkably cosmopolitan palaeoenvironmental and palaeogeographic distribution – known from shallow- to deep-marine environments from tropics to poles. Their general restriction to Lagerstätten is essentially a taphonomic artefact, and belies the fact that they were likely a ubiquitous and significant component – the éminences grises – of the Palaeozoic oceans.

Ontogeny, preservation and systematics of Palaeoscolecida (stem-Priapulida?) – is the diversity of the group drastically overestimated?

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Palaeoscolecids are a diverse group of Early Palaeozoic marine worms. First assigned to annelids, they are now regarded as phylogenetically close to priapulids (Cycloneuralia). However, their long annulated trunk is covered by (primarily?) phosphatic sclerites, which are sometimes found isolated. 61 species (45 genera) have been described from body fragments, either preserved as compression fossils (CF) or secondarily phosphatised (Orsten-type fossils; OF). CF are usually more complete, occasionally displaying the proboscis, but OF exhibit much better preservation of sclerites. In this contribution, we argue that this difference in preservational styles profoundly impacts the systematics of Palaeoscolecida. Actually, not a single genus is known from both types of materials. Besides, the maximum body width of CF species is *c.* 6 mm on average (occasionally >10 mm), whereas it rarely exceeds 1.5 mm in OF species (mean: 1.3 mm). This suggests that 39% of palaeoscolecid species may actually be defined on immature specimens. Using 68 CF (maximum body width 0.51–3.33 mm) of a new species from the Fezouata Shales (Lower Ordovician, Morocco), we show that growth was discontinuous in palaeoscolecids. We also demonstrate that many characters used to discriminate taxa significantly change during ontogeny, which further questions the validity of OF species.

Clay-microbe interactions and implications for exceptional preservation

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Exceptionally preserved fossils are produced by multifarious interactions between tissues, autolytic enzymes, minerals and other substrates, oxidants and other nutrients, and a diverse, shifting community of microorganisms. Experimental taphonomy aims to tease apart these interactions and isolate their individual significance. Our work explores the role of microbes, which mediate essential steps in the fossilization of a carcass, from initial decay to the alteration of carbonaceous compounds and replication in minerals. Clay minerals and bacteria are of similar particle size. A number of studies have shown that particular clay minerals promote or inhibit the growth of specific types of bacteria via an array of physical and chemical interactions. This has profound implications for the distribution of taphonomic biases in the fossil record. While interactions between certain clay minerals and animal tissues or enzymes have been implicated in Burgess-Shale type preservation, we suggest that clay–microbe interactions may be critical. Preliminary experimental data indicate that glauconite, for example, to a greater extent than many other clays, may inhibit the growth of specific bacteria involved in the decay of marine animals. Such results have the potential to explain relationships between marine sediment composition and exceptional preservation in the Palaeozoic record.

Cryptogamic ground covers as modern analogues of early terrestrial ecosystems

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Cryptogamic ground covers (CGCs, *i.e.*, communities of bryophytes, lichens, algae, fungi and bacteria) are the early colonizers of fresh and potentially nutrient-poor ground surfaces. A growing body of data from both the fossil record and molecular phylogenetics indicates that comparable associations were components of the first extensive terrestrial biosphere in the Early Palaeozoic. Our goal is to understand how cryptogamic organisms contribute towards the development of soils by mineral weathering, with a view to using them as modern analogues of early soil ecosystems. We employed a variety of micro-analytical techniques to bryophyte and lichen dominated primeval volcanic substrates from Iceland and New Zealand. X-ray micro-CT imaging of substrate cores suggests complex physical interactions between the organic and mineralogical components. SEM and EDX reveals an assortment of biotic/mineral attachment methods (mucilage secretion sticking, rhizoid sticking, symbiotic fungal entwining) showing physical and chemical micro-features from a bio-weathering origin. XRD data suggest that smectite clays are also from a biological origin. These features could assist in distinguishing between biotic and chemical weathering markers in the sedimentological record, and ultimately assist in recognising ancient CGCs and their respective soils during the first substantial colonisation of the land during the Early Palaeozoic.

Latitudinal diversity gradients in Mesozoic non-marine turtles

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The latitudinal gradient in diversity is a first-order pattern of taxic richness today and is important in the evolutionary history of climate-sensitive ectothermic organisms like reptiles. We explore the importance of the latitudinal diversity gradient in Mesozoic turtles, which first appear in the Triassic and are represented by at least 17 families and 75 genera by the end of the Cretaceous. Recent area-corrected species richness is highest at 25°N, but area-corrected genus richness is even from 30°N to 5°S, with a notable drop in richness outside the tropics and subtropics at *c.* 30°N and 30°S. In the Mesozoic, raw genus richness is greatest at 30–45°N and is lowest in the tropics and above 60°N and 60°S. This is partly a reflection of sampling bias, as tropical regions are under-represented in the tetrapod fossil record. However, the absence of turtles at well-sampled high latitude tetrapod localities suggests that low richness above 60°N/S is genuine and shareholder quorum subsampled data bear out this general pattern. Comparisons between generalized least squares regression models indicate that sampling intensity is a better predictor of latitudinal genus richness in the fossil record than either palaeo-land area or sampling plus land area.

Remarkably preserved brain tissue ultrastructure in an Early Cretaceous iguanodontian dinosaur

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We report high-fidelity mineralization of soft tissues within a natural cranial endocast of an iguanodont dinosaur from fluvial sediments of the Wealden (Hastings Group) in Sussex. Moulding of the braincase wall and adjacent brain tissues by phosphates and carbonates allows direct examination of fossilized brain tissue, arguably for the first time in the fossil record. SEM imaging and CT-scanning reveal ultrastructural preservation of the membranes that surrounded the brain itself (meninges) and larger blood vessels are preserved in collophane (calcium phosphate), and the vessels are either lined by, or infilled with, microcrystalline siderite (iron carbonate). Meninges of the cerebellum preserved in this specimen exhibit ultrastructural similarities with those seen in living archosaurs. In addition, some of the fabric of the outer cortical layers of the brain and associated smaller blood vessels are also preserved in phosphate and carbonate. The structure of these membranes and associated tissues has some bearing on the extent to which the brain filled the endocranial cavity and therefore upon estimates of encephalization quotients (EQs) in these dinosaurs. Implied behavioural repertoires derived from functional and biological inferences drawn from trace fossils among iguanodontian ornithopods are compared and contrasted with brain volume observations based upon this new specimen.

Recent advances in lobopodian palaeobiology and evolution

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The lobopodians comprise more than 30 species of soft-bodied animals with a worm-like appearance that are known from several Palaeozoic Konservat-Lagerstätten, although most representatives have been described from Early and Middle Cambrian deposits worldwide. Lobopodian evolution is widely recognized as critical for understanding the deep origins of the megadiverse clade Panarthropoda, whose extant representatives include Euarthropoda (arachnids, millipedes, crustaceans, hexapods), Tardigrada (water bears) and Onychophora (velvet worms). New fossil discoveries and the input of developmental data have helped to clarify some of the more controversial issues in lobopodian evolution, such as their affinities relative to extant groups. Recent analyses indicate that armoured forms – which encompass most of lobopodian diversity – occupy a position within stem-group Onychophora, whereas forms with spinose 'frontal appendages' and gut diverticulae belong to stem-group Euarthropoda. The recovery of stable phylogenies also allows the study of broad evolutionary patterns, such as the recognition of bottom-heavy disparity and ecological complexity within the onychophoran stem lineage. It is now possible to tackle more contentious issues such as the enigmatic origins of tardigrades, whose depauperate fossil

record and miniaturized body size in extant representatives has led to much disagreement regarding their early evolution and phylogenetic relationships with other groups.

What limits the morphological disparity of clades?

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Variation in form within clades is decoupled from estimates of diversity. Specifically, groups tend to reach maximum levels of morphological disparity relatively early in their evolutionary histories, even if diversity is low. This pattern is found in many clades of both animals and plants, suggesting it may represent a universal evolutionary phenomenon. This suggests a 'restricted morphospace', consistent with an observed decrease in the rate of origination of novel bodyplans and higher taxa over time. It has also been demonstrated that the rate of evolution of new character states decreases up the phylogenies of most clades. We used a sample dataset of published phylogenies of 93 clades of animals to test whether character exhaustion is widespread among animal clades. We also investigated the possibility that character exhaustion can account for early high disparity by testing whether a simple relationship exists between the level or rate of exhaustion in character states up a phylogeny and the shape of a clade's disparity profile. The result has profound implications not only for the link between the evolution of novel characters and overall morphological disparity but also suggests that while evolution is shaped by constraint, some constraints have a greater importance than others.

A stable isotopic investigation of chemosymbiosis through geological time

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Biomineralizing organisms use organic templates during shell formation, and this shell-bound organic matter (SBOM) records the isotopic composition of an animal's diet. By analysing the isotopic signature of SBOM the nutritional strategies of fossil bivalves and brachiopods can potentially be directly reconstructed. We aim to investigate the occurrence of chemosymbiosis through geological time. Chemosymbiosis is an unusual nutritional strategy whereby invertebrate animals obtain their nutrition from symbiotic bacteria, which oxidize sulfur (thiotrophy), methane (methanotrophy) or both (dual symbiosis). This allows bivalves to thrive in inhospitable ecosystems of the deep sea (cold seeps and hydrothermal vents), but whether or not ancient seep dwellers were chemosymbiotic is unknown. In modern bivalve and brachiopod taxa, nutritional strategies can be distinguished using SBOM nitrogen, sulfur and carbon stable isotope values. SBOM has successfully been isolated from ancient cold seep specimens, and results allow positive identification of thiotrophy in fossil seep clams and seep mussels (Cretaceous–Pleistocene). Data will be presented for pre-Cretaceous fossils seeps, where we find extinct bivalve taxa and mono-specific brachiopod assemblages. This will test the possibility of chemosymbiosis in seep dwelling brachiopods, which disappeared from cold seeps after taxonomic domination in the Palaeozoic and Mesozoic.

Annelid fossil data reconcile morphological and molecular phylogenies

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Despite transcriptomic data becoming more available, hypotheses of annelid relationships based on morphological and molecular data have remained incongruent. Morphological analyses have typically recovered a monophyletic Polychaeta, with the simple-bodied polychaetes forming an early diverging clade or grade. This is in stark contrast to molecular trees, in which polychaetes are paraphyletic and include clitellates, echiurans and sipunculans. The oldest stem group annelid body fossils are complex-bodied polychaetes that possess well-developed parapodia and head appendages (palps), suggesting that the root of annelids is misplaced in morphological trees. We present a reinvestigation of the morphology of key fossil taxa and include them in a comprehensive phylogenetic analysis of annelids. Cambrian taxa present several unusual characters, including the occurrence of palps on a limb-bearing, segment-like head, which contrasts with the presegmental head of extant annelids. We present the most taxonomically inclusive phylogenetic analysis of annelid morphology to date, containing a representative sample of extant and fossil annelids from the Palaeozoic, analysed using implied weights parsimony and Bayesian inference. We find that the inclusion of fossil taxa polarizes morphological characters in a manner that is compatible with current molecular hypotheses, with echiurans and clitellates recovered within polychaetes.

Namapoikia: a modular, calcareous probable sponge from the Ediacaran

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The earliest calcified metazoans appeared during the latest Ediacaran (~550-541Ma). Of these, *Namapoikia*, found exclusively in the Driedoornvlagte reef complex of the Nama Group of southern Namibia (~548 – ~547Ma), is unique in having a robust, modular carbonate skeleton and attaining large diameters of up to a metre. *Namapoikia* was initially described as a possible cnidarian or poriferan, but here we confirm likely affinity with the Porifera and clarify growth style and strategy. *Namapoikia* colonised the walls of fissures in thrombolitic reefs, or occasionally open surfaces. Serial image stacks show that *Namapoikia* contains irregular tubular voids which range from columnar to labyrinthine in shape, and are disrupted by transverse partitions. In places, the skeleton shows synchronized banding, which may reflect episodic seasonal or annual growth. *Namapoikia* also shows two substrate-specific attachment strategies: encrusting onto lithified microbialite, but using arrays of holdfasts to attach to living microbial substrates. The large size and modular body plan of *Namapoikia* suggest that it grew over longer time periods than the co-occurring, smaller metazoans *Cloudina* and *Namacalathus*. *Namapoikia* may have required a stable, persistently oxygenated habitat, which was comparatively uncommon in the variable redox conditions of the Ediacaran ocean as represented by the Nama Group.

talks

Biostratigraphical review and palaeobiogeographical remarks on the trilobite genus *Lichas* Dalman, 1827

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The trilobite genus *Lichas* is currently known from Upper Ordovician (uppermost Sandbian/Katian) to Silurian (Wenlock-Ludlow? Series) sequences. Originally described from the upper Katian of Sweden, the genus presently includes 11 valid species reported from Portugal, Spain, Italy, the United Kingdom, Sweden, Morocco, UEA and probably also Japan and Mongolia. *Lichas keisleyensis* Reed, 1896 is considered a junior synonym of *L. subpropinquus* McCoy, 1851. New data from the Upper Ordovician of Portugal led to the definition of two new species from the Porto de Santa Anna Formation (Katian) of Buçaco. The presence of *Lichas* sp. in the Chão do Amieiral and Cabeço do Peão formations (uppermost Sandbian/Katian) of Portugal constitutes the oldest records of this genus. From a phylogenetic point of view, the occurrence of *Lichas* in the Portuguese Upper Ordovician and the presence of a posteromedian spine in the pygidium of the oldest known species of the genus indicate a closer relationship between the monogeneric tribe Lichini and Dicranopeltini Phleger, 1936. Biostratigraphical and palaeobiogeographical analysis suggest that *Lichas* originated in high-latitude Gondwana, where it has its older record and numerous Sandbian/Katian species, and not in Baltica as previously considered.

Experimental taphonomy and the role of decay and preservation in determining the anatomy and diversity of Cambrian vertebrates

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The Lower Cambrian Chengjiang biota of China contains four genera of early vertebrates: *Haikouichthys*, *Myllokunmingia*, *Zhongjianichthys* and *Zhongxiniscus*. These are the oldest fossil vertebrates known and they play key roles in calibrating molecular clocks and informing our view of the anatomy of animals, potentially including transitional forms, close to the origin of vertebrates. Despite the evident importance of these fossils the degree to which taphonomic processes have affected their anatomical completeness has not been investigated. For example, some or all might have been affected by stemward slippage – the pattern observed in experimental decay of non-biomineralized chordates in which preferential decay of synapomorphies and retention of plesiomorphic characters would cause fossil taxa to erroneously occupy more basal positions than they should. We have expanded this analysis to include a broader range of potentially significant environmental variables and, by comparing and combining the results of different experiments from several taxa, we have identified general patterns. Applying our results to the Chengjiang vertebrates demonstrates that experimentally-derived models of phylogenetic bias are applicable to fossils. Anatomical and phylogenetic interpretations of early vertebrates that do not take these biases into account risk overestimating diversity and the evolutionary significance of differences between fossil specimens.

When fossils and living taxa agree on patterns of morphological evolution: a case study with Afrotheria

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There is an ongoing debate about the limits of inferring past change based solely on extant taxa. Here we test the effects of fossil inclusion and exclusion when investigating patterns of body mass evolution in the placental clade Afrotheria – a clade that includes elephants, sea cows and elephant shrews. We find a general congruence when fossils are included and excluded from analyses: in both cases we find a small afrotherian ancestral size (~100 grams) and a rate increase on the branch leading to the larger-bodied Paenungulata and Tubulidentata. The inclusion of cladistics morphological data and fossils does change phylogenetic topology, but these differences also have little impact upon patterns of body mass evolution, and these results are congruent with the fossil record generally. Surprisingly, the largest differences between analyses result from model selection, not the addition of fossils. Models that allow for variation in rate on the phylogeny produce a ~tenfold smaller ancestral size compared to homogeneous-rate models. The inclusion of fossils will always increase confidence in reconstructed patterns even in cases where patterns agree. However, in addition to including fossils, careful selection between models is necessary when reconstructing patterns of morphological evolution.

Phylogenetic relationships of Heterostraci, agnathans on the gnathostome stem

***Emma L. Randle and Robert S. Sansom**

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Inter- and intra-evolutionary relationships of jawless fish are fundamental to our understanding of patterns of vertebrate evolution. Key amongst these are the ostracoderms, a paraphyletic group of stem gnathostomes. The largest and most diverse group, the heterostracans, are currently lacking a reliable phylogenetic framework, thus limiting understanding of ostracoderm diversification. Using the Pteraspidiformes as a case-study (47 taxa), we investigated different coding strategies incorporating continuous characters to build phylogenies within the group. This framework enabled expansion to include broader heterostracan taxa (*i.e.* Cyathaspididae and Psammosteidae). Here we show that some 'classic' clades hold true, but the Psammosteidae are well nested within the Pteraspidiformes in all iterations. Analysis with discrete and continuous characters yields the best resolved trees, whilst gap coding performs poorly given its sensitivity to missing data. The results serve as a framework to consider the intra- and inter-relationships of the group more broadly. Only once this is achieved can inferences about the early evolution of vertebrates be made, including ancestral morphotypes, character transitions and the timing and tempo of these innovations.

talks

Hot and fiery or just hot? A global record of early Palaeogene wildfire

***Brittany E. Robson[1], Margaret E. Collinson[1], Walter Riegel[2,3], Volker Wilde[3], Andrew C. Scott[1], Erica M. Crouch[4], Elizabeth M. Kennedy[4], J. Ian Raine[4], Christian Dupuis[5], Carlos Jaramillo[6] and Richard D. Pancost[7]**

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Modern wildfire is predicted to increase dramatically due to global warming (Liu *et al*. 2010). Our documentation of higher-than-modern levels of wildfire in the early Palaeogene greenhouse at a German site supports this prediction (Robson *et al*. 2015). Here we examine global early Palaeogene fire activity using literature from India and China and new data on charcoal (inertinite) in lignites from Australasia, Europe, North America and South America. Typically, the latest Paleocene (Thanetian) had higher levels of wildfire activity than the Early Eocene (Ypresian). Through the latest Paleocene and much of the Early Eocene, wildfire activity was very variable both within and between sites. Within sites, charcoal can comprise 0–44% of the lignite. Examples of wildfire activity considerably higher than modern levels (*c*. 4.3%) are present in all sites studied. In most sites where both Thanetian and Ypresian could be compared the highest charcoal values (22–44%) occur in the Thanetian. Some Ypresian sites contain intervals characterized by low charcoal amounts similar to modern, but others contain only infrequent low values. These charcoal data from the early Palaeogene greenhouse suggest that wildfire activity may increase and become more variable in future warm climates.

Evidence for sexual dimorphism in the plated dinosaur *Stegosaurus mjosi* (Ornithischia, Stegosauria) from the Morrison Formation (Upper Jurassic) of Western USA

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Dimorphism in the shape of *Stegosaurus mjosi* dermal plates (*n*=40) does not result from non-sex-related individual, interspecific, or ontogenetic variation and is most likely a sexually dimorphic feature. One morph possessed wide, oval plates 45% larger in surface area than the tall, narrow plates of the other morph. Intermediate morphologies are lacking. Principal component analysis supports marked size- and shape-based dimorphism. In contrast, non-sex-related individual variations often show intermediate morphologies. A new quarry in Montana shows at least five individuals buried in a single horizon that were not brought together by water transportation. This site demonstrates co-existence, and possibly suggests sociality, between two morphs that only show dimorphism in their plates. Without evidence for niche partitioning, it is unlikely that the two morphs represent different species. Histology of the new specimens in combination with studies on previous specimens indicates that both morphs occur in fully-grown individuals. The dimorphism is not a result of ontogenetic change. The two morphs of plates do not come from different

positions on the back of a single individual. Plates from all positions on the body can be classified as one of the two morphs, and previously discovered, isolated specimens possess only one morph of plates.

Differential speciation and extinction rates across space and through time: implications for the generation of latitudinal diversity gradients

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Biodiversity is unevenly distributed across the surface of the Earth. The tropics harbour greater numbers of species than temperate zones, a pattern seen in both ancient and modern times. The causal mechanism(s) responsible for these latitudinal gradients still remain debated, although centuries have passed since their initial discovery. It is still unknown whether rates of speciation and extinction directly follow a latitudinal gradient, or whether secondary dispersal contributes to higher species diversity in the tropics. We introduce a cellular automaton algorithm designed to simulate processes of extinction, allopatric speciation, and dispersal within the evolving climate system of the Pleistocene. We test whether differential rates of speciation and extinction in tropical versus temperate climates can alone produce diversity gradients. We additionally test whether the magnitude of the diversity gradient on a continental scale depends on the degree of environmental heterogeneity observed across continents through time. Preliminary results suggest that speciation rates are elevated in tropical regions and depressed at higher latitudes. Interestingly, diversity hot spots developed without invoking higher extinction rates at higher latitudes. This work provides a null model for spatial patterns of biodiversity dependent solely on the contributions of species' physiological tolerances, dispersal, and the evolving climate system.

The Ordovician explosion in the designs of trilobite eyes

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The eyes of Cambrian trilobites are poorly known, apart from those of the eodiscids and the Furongian to upper Ordovician Order Olenidae, though more are being discovered. Most are reniform 'slit-eyes' and all are holochroal. Schizochroal eyes arose in the early Ordovician by paedomorphosis from a holochroal ancestor, but in addition the 'explosion' in trilobite diversity during the Ordovician is matched by a striking increase in different kinds of holochroal eyes. The range in holochroal eye morphology correlates well with the habitat of the Ordovician trilobites; thus thin-shelled trilobites living in quiet conditions normally have thin biconvex lenses, while robust-bodied trilobites living in high-energy

environments have thick, and sometimes prismatic lenses. The optics of trilobite eyes can be studied using tools developed for the analysis of living arthropod eyes, which facilitate an understanding of habitat. Special attention here is given to the eyes of asaphid and cheirurid trilobites, which raise some interesting problems.

Ancient spiders and salt lakes

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The Green River Formation crops out over 64,000 square kilometres of Wyoming, Colorado and Utah, averages 600 m in thickness, and represents one of the world's longest-lived Great Lakes systems, lasting approximately 17 million years. Spider fossils are abundant in some horizons but, until recently, only a single specimen (*Linyphia byrami* Cockerell, 1925) had been described. In the first part of this talk, a sample of spiders from the families Uloboridae, Hersiliidae, Selenopidae and Thomisidae are described. Such diversity represents a variety of life modes and habitats; it is suggested that storms and flash flooding were the likely mechanisms for transporting the spiders into the lake. In the second part of this talk, we compare the spider fauna of Green River with those of two other palaeolake deposits, and demonstrate how spider leg flexure can serve as a proxy for the palaeosalinity of ancient lakes.

How do marine microfossils get trapped in amber?

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Amber is well-known for entrapping terrestrial organisms (inclusions), like arthropods, plants and fungi, and preserving them. Rarely, amber also preserves limnetic organisms like water beetles, together with terrestrial taxa. Marine organisms are usually only found as surface or fissure contaminants on amber found on the coast. However, three amber deposits from the Cretaceous of France (*c.* 100 Ma) have several amber pieces with marine inclusions (diatoms, radiolarians, sponge spicules, foraminiferans, larval echinoderm remains), alongside terrestrial ones. This implies the proximity of a resinous forest to the Atlantic coast, but the exact conditions necessary to produce amber pieces that contain terrestrial and marine inclusions are debated: were these mangrove forests or the result of rare high-energy conditions like a cyclone or tsunami flooding the low-lying forest, or the results of normal coastal conditions? We set up experiments along the highly resinous low-lying coastal *Araucaria columnaris* forests in New Caledonia to test this. Using fresh resin applied to slides we showed that normal coastal conditions allow some marine microorganisms to become embedded in resin, so seawater did not have to make contact with the resinous trees, but the diversity found in French amber suggests that a much more energetic event occurred.

How big is a genus?

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Genera are units that contain variable numbers of species, from one (monotypic) to thousands. The largest proportion of genera, usually over 30%, contain only a single species and a very small proportion contain large numbers of species. Past observations of this phenomenon have invoked taxonomic 'splitting', and implied this skewed distribution is in conflict with strict tree-thinking or true phylogenetic systematics. We show the predominance of monotypic genera is a strongly consistent pattern across Metazoa, so empirical evidence suggests it may be a 'real' result of speciation processes. We compared empirical data (real taxonomy of real organisms) with simulations that provide omniscient or ideal genus-size frequencies (simulated taxonomic sorting on simulated trees). We generated hypothetical trees using birth–death models with known and constant probabilities of speciation (birth) or extinction (death) at each generation. We imposed a taxonomic sorting on the set of species that were non-extinct after 500 generations, based on phylogenetic topology and/or character attributes of surviving lineages. Observed taxonomy of living animals in fact closely match an idealized hypothetical taxonomy of monophyletic units, especially when defined by character similarities. Monotypic genera are, as should be expected, very frequent, and large genera very rare (splitters 1, lumpers 0).

A record of small carbonaceous fossils (SCFs) from the Ediacaran–Cambrian of Baltica: expanding the Burgess Shale-type taphonomic window

***Ben J. Slater[1], Thomas H. P. Harvey[2], Romain Guilbaud[1] and Nicholas J. Butterfield[1]**
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Given the spatiotemporal rarity of Burgess Shale-type Lagerstätten, attention has recently turned to small carbonaceous fossils (SCFs) as a cosmopolitan tool for investigating early metazoan evolution. Efforts have predominantly focused on middle-late Cambrian sediments of North America. Here we push back the record into the early Cambrian and Ediacaran of the Baltoscandian Basin, sampling a continuous collection of drillcores for SCF-yielding mudstones. The basin-wide approach employed in this study is the largest-scale spatiotemporal investigation of SCF assemblages to date. A clear temporal trend has emerged; early Cambrian (Stage 4) sediments contain high metazoan diversity including exquisitely-preserved priapulid microstructures, a variety of wiwaxiid sclerites, palaeoscolecids, trilobites, fragments of arthropod cuticle and organisms previously known only from the Burgess Shale (*e.g. Burgessochaeta*-like annelids). Older (Stage 3–Fortunian) assemblages are characterized by lower metazoan diversity and exhibit greater regional homogeneity, principally being composed of numerous protoconodont/chaetognath grasping spines alongside assorted macroscopic algae. Ediacaran SCFs are dominated by bizarre enigmatic forms, comprising 'vendotaenids', tubular and sheet-like structures, but conspicuously lack recognizably metazoan-derived elements. The SCF record in Baltica reveals a previously unrecognized cryptic diversity of organic-walled Ediacaran fossils and fundamentally expands the biogeographic and temporal distribution of earliest Phanerozoic metazoans otherwise restricted to Burgess Shale-type Lagerstätten.

The monophyly of Euparkeriidae and its implications for the rise of crown Archosauria

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Euparkeria capensis has been considered to approach the ancestral archosaur in its morphology, and is the sister taxon to crown Archosauria in many phylogenetic analyses. Several other taxa have been assigned to Euparkeriidae, but recent work has found only one valid taxon – *Halazhaisuchus qiaoensis* from China – to form a clade with *Euparkeria*. However, no phylogenetic analyses to date have included more than two putative euparkeriids. For the first time, a phylogenetic analysis including all putative euparkeriid taxa is undertaken, using a large matrix of stem and crown archosaurs, analysed with maximum parsimony and Bayesian methods. Using both methods, the putative Russian euparkeriid *Dorosuchus neoetus* is found to be the sister taxon to Archosauria+Phytosauria, whilst *Euparkeria capensis* forms a euparkeriid clade with *Halazhaisuchus qiaoensis* and the Polish taxon *Osmolskina czatkowicensis*, one node stemwards of *Dorosuchus neoetus*. *Osmolskina* and *Halazhaisuchus* are sister taxa. Support for the euparkeriid clade recovered is low, and uncertainty regarding assignment of material to *Osmolskina* and *Dorosuchus* means that conclusions remain tentative. However, the broad phylogenetic position of putative euparkeriids close to the base of Archosauria is confirmed, and the euparkeriid *Bauplan* can be considered the antecedent of the cursorial, upright locomotion underlying the rise of crown Archosauria.

Evolutionary rates reveal mechanisms of axial body plan evolution in Sauropterygia

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Sauropterygians were highly successful Mesozoic marine reptiles that had a broad range of body plans, including the highest cervical vertebral count and range of any clade (5 to 76). They therefore provide a model system for studying the evolution of vertebral counts and axial regionalization in tetrapods. We present a dataset of axial body plan measurements from 120 sauropterygian taxa spanning 180 million years. Using various phylogenetic comparative methods we test three explicit hypotheses about sauropterygian evolution: 1) neck length evolved via changing somitogenesis (vertebral number) and homeotic effects (axial regionalisation) rather than by differential somitic growth; 2) somitogenesis and homeotic effects were decoupled; 3) somitogenetic change was the dominant mechanism of axial body plan evolution. Our results show that differential somitic growth was not an important driver of macroevolutionary change in sauropterygian body plans, unlike in mammals. In line with previous studies of tetrapods, background patterns of somitogenetic and homeotic change were decoupled. However, the establishment of higher-level taxa with novel body plans involved rare, correlated, high-magnitude changes to both somitogenesis and homeotic effects. Our results demonstrate the importance of heterogeneous statistical models in uncovering the links between hypothesised developmental drivers of macroevolutionary change in vertebrate body plans.

TRiPS, SQS, ACE and Chaos; evaluating the accuracy and precision of species richness estimators in palaeobiology

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To accurately portray the dynamics of species richness in deep time using fossil data we need ways to account for the non-random deterioration of biological signals that occurs in the heterogeneous processes of fossilization, preservation, detection and publication. There are a multitude of different estimators of species richness ranging from simple and intuitive subsampling techniques to complex and computer-power-demanding models. I have recently proposed a new approach called TRiPS (True Richness estimation using a Poisson Sampling model) that not only reconstructs species richness, but also estimates the bias itself (*i.e.* the differential preservation and detection of fossils among geological intervals). I will here detail this new approach and compare its accuracy and precision with other richness estimators commonly used in palaeobiology, among them SQS (shareholder quorum subsampling), ACE (abundance coverage estimator), Chao1 and Chao2 using simulations. Finally, I'll apply these richness estimators to the observations on Mesozoic dinosaurs from the Paleobiology Database and discuss drawbacks and benefits of the various estimators.

Phylogeny and macroevolution of crocodylomorphs

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The Crocodylomorpha present a unique dichotomy in their diversity and morphological disparity through time. The stem group is limited to the Mesozoic, but is represented by a highly disparate range of ecomorphologies. Conversely the crown group is limited to amphibious ambush predators, but is represented by a much greater species richness than the stem group. Despite the abundance of the crown group, the crown-group Crocodylomorpha are represented by just 23 extant species. Does this pattern represent a true decline in disparity and diversity through time, or a more complex sequence of shifts within the group? Here we present a comparison of evolutionary rates among crown- and stem-group Crocodylomorpha in relation to morphospace occupation. The phylogenetic framework of these analyses is a new phylogeny of the Crocodylomorpha assembled using the matrix representation parsimony (MRP) method. This study finds support for extreme evolutionary stasis in several crocodylomorph clades. Diversity among the Crocodylomorpha appears to be closely linked with temperature, with decreasing diversity in the Cenozoic closely matching global cooling. Additional morphospace occupation by stem-group Crocodylomorpha relative to the crown group is occupied by taxa originating from two discrete adaptive radiations in the Mesozoic, with disparity otherwise remaining constant throughout the Mesozoic and Cenozoic.

A Cambrian greening of the terrestrial landscape

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Although studies of living plants and green algae have generated a robust phylogeny that encompasses the origin of the land plants (embryophytes), the evolutionary pathway that tracks the algal–plant transition remains largely unknown. Bower originally proposed that the plant sporophyte evolved in response to selection in subaerial settings, and that spores preceded embryophytic development in evolutionary time. This general framework is supported both by extant studies in bryophyte sporogenesis and by the fossil record which shows laminated cryptospore dyads by the middle Cambrian and embryophytic spore tetrads occurring in the middle Ordovician, some 40 million years prior to the first upright axial plant mesofossils. Organic debris from shallow marine deposits from the Cambrian of Laurentia includes dispersed spores and spore dyads, spore clusters, patterned spore clusters, cuticular remains and possible protonematal remains. These spores and fragments document the remains of organic structures adapted to subaerial settings prior to the first occurrence of true land plants. They add support to Bower's theory of the antithetic origin of the plant sporophyte. It is likely that an evolving complex of aeroterrestrial charophytic algae were contributing to a greening of the terrestrial surface well in advance of the evolutionary origin of the plant embryo.

The ecomorphological diversifications of Mesozoic marine reptiles

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Mesozoic marine ecosystems were dominated by reptiles, including sauropterygians, ichthyosaurs, crocodylomorphs, turtles and mosasaurs. Previous research has shown that early marine reptiles achieved great taxonomic diversity in the Middle Triassic, as they broadly diversified into many feeding modes following the Permo–Triassic mass extinction. However, it is not known whether this initial phase of evolution was exceptional in the context of the entire Mesozoic. I explore this by quantifying trends of morphological disparity, focusing on functional variation in the jaws and dentition and skull size diversity. Results show that the Middle to early Late Triassic represented a time of pronounced phenotypic diversification in marine reptile evolution, with rapid attainment of maximum functional disparity in the jaws and dentition, and a disparate range of skull sizes. Following Late Triassic extinctions, it took over 100 million years to recover comparable variation in the Campanian and Maastrichtian. Clades that diversified during the Triassic biotic recovery, the sauropterygians and ichthyosauromorphs, show early diversifications, early high disparity and early burst trends, while less support for these trends is found in thalattosuchian crocodylomorphs and mosasaurs. Overall, the Triassic represented a special interval in marine reptile evolution, as numerous groups radiated in new adaptive zones.

Depositional and preservational environments of the Ediacara Member, Rawnsley Quartzite (South Australia): assessing the timing of 'ferruginization'

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The palaeoenvironmental setting in which the Ediacara Biota lived, died and was preserved in the eponymous Ediacara Member of the Rawnsley Quartzite of South Australia is an issue of longstanding interest and recent debate. Over the past few decades, interpretations have ranged from deep marine to shallow marine to terrestrial. We examine the evidence in support of and against various palaeoenvironmental interpretations of the fossiliferous Ediacara Member, and focus particularly upon the history of ferruginization of these rocks. Ferric oxides, previously mooted as evidence for a terrestrial palaeoenvironment, consist largely of surficial, non-bedform-parallel staining and irregular patches and thus strongly reflect late-stage processes. Moreover, uranium isotope analysis of iron oxides associated with Ediacara fossiliferous beds indicates that these oxides record recent, post-depositional oxidation. Sedimentological and geochemical evidence indicates that Ediacara iron oxides cannot be used to invoke a terrestrial palaeoenvironmental setting for the Ediacara Biota. Conversely, independent sedimentological, palaeoecological and geochemical evidence lends strong support for a shallow marine depositional environment. These findings demonstrate that careful assessment of palaeoenvironmental parameters is essential to the reconstruction of the depositional and early diagenetic history of the Ediacara Biota and the factors that led to the fossilization of these early complex ecosystems.

Using fossils and phylogenies to date the timing of key gene regulatory network innovations in echinoids

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Molecular developmental biology lends the ability to understand the genetic underpinning behind the origin of evolutionary novelties through the study of Gene Regulatory networks (GRNs). GRNs are the system of genetic interactions responsible for the development and formation of body plans and morphologies. The resultant products of the interactions of GRNs are visible in the rock record in the form of fossil morphologies. Because fossils show us direct evidence for the outcome of genetic interactions taking place in GRNs, they allow us to infer the activity of portions of GRN topologies in the fossil record, and thus date the timing of these genetic evolutionary innovations. Using paired fossil data and phylogenetic analyses, we have been able to date the appearance of a novel piece of GRN circuitry essential for skeletogenesis in larval echinoids, the double-negative gate. The double-negative gate has been demonstrated to be present in a number of phylogenetically distant euechinoid echinoids; however, it is absent in their sister clade, the cidaroids. Using well-dated fossil taxa and a robust phylogeny for echinoids, we are able to date the appearance of this innovation to at least the Lower Jurassic, coincident with the first appearance of irregular echinoids in the fossil record.

Kalania pusilla, an exceptionally preserved non-calcified alga with the oldest documented gametophores from the lower Silurian (Aeronian, Llandovery) of Estonia

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Dasycladacean algae are an order of unicellular organisms within the Division Chlorophyta. Having been in existence since the Cambrian period, they constitute a substantial component of algal geological history. A significant proportion of dasyclads develop a calcium carbonate skeleton, the main characteristics of the order are the radially symmetrical thallus architecture and the siphonous body plan of the cell. A working quarry in Kalana, Estonia, has revealed rich exceptionally-preserved flora and fauna of Early Silurian (Aeronian, Llandovery) age with algae, especially dasyclads, as the most diverse and abundant fossil group. Here we present a new dasycladacean species *Kalania pusilla*. The fossils of the siphonous unicellular algae occur as black or dark brown carbonaceous compressions on surfaces; many of them reveal three-dimensional preservation together with finely preserved details. The algal fossils are non-calcified and do not show any traces of possible carbonate skeleton. *K. pusilla* is characterized by a cylindrical uniaxial thallus, two orders of lateral segments – perpendicularly arranged whorls of short bulbous primary laterals, which bear clusters of ovate gametophores in their mature stage, and fine hairy secondary laterals. The reproductive structures of the fertile specimens represent the oldest documented evidence of gametophores in the fossil record.

Camouflage patterns in an ornithischian dinosaur

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Countershading is one of the most widespread forms of camouflage. A dark dorsum and light ventrum counteract the gradient created by illumination from above, obliterating cues to 3D shape. Because the optimal countershading varies strongly with light environment, pigmentation patterns give clues to an animal's habitat. Melanosomes are preserved in feathered dinosaurs and aspects of original colour patterns can be reconstructed from these. Here we present a study of an exceptionally well-preserved specimen of *Psittacosaurus* from the Chinese Jehol biota, at the Senckenberg Museum. This *Psittacosaurus* was countershaded with a light underbelly and tail, while the chest is relatively more pigmented. Other pigmentary patterns resemble disruptive camouflage, while the chins and lateral horns on the face appear heavily pigmented. SEM analyses show that the impressions preserve small, spheroidal melanosomes, suggesting a brownish colour to the body. We have projected the colour patterns onto an anatomically correct lifesize model of *Psittacosaurus* in order to assess their function experimentally. These are compared to the predicted optimal countershading from the measured radiance patterns generated on an identical grey-scale model in direct versus diffuse illumination. These studies suggest that *Psittacosaurus* inhabited a closed habitat such as a forested area with a relatively dense canopy.

The radiation of plankton during the Bajocian: a Mesozoic pelagic revolution

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The Bajocian (Middle Jurassic, 170–168 Ma) was a critical interval in the evolution of modern marine plankton. Dinoflagellates underwent a major radiation, whilst coccolithophores diversified and became significantly more abundant, and planktonic foraminifera appeared for the first time. In the Early Bajocian, dinoflagellate cyst diversity was limited and dominated by species of *Dissiliodinium*. It was during this interval that the coccolithophore genus *Watznaueria* diversified and dramatically increased in abundance, which marks the transition to ecological dominance of this genus for the remainder of the Mesozoic. Cyst-forming dinoflagellates radiated rapidly through the middle to Late Bajocian, with over 50 species appearing by the earliest Bathonian. This diversification was accompanied by significant experimentation in the archaeopyle (excystment aperture) formation of cyst-forming dinoflagellates. The coincidence of this phytoplankton radiation with the appearance of planktonic foraminifera reflects a fundamental shift in contemporaneous marine plankton, with important biogeochemical, ecological and evolutionary implications. Given the coincident radiations of marine nekton, most notably ammonites, there would appear to be major innovations in pelagic ecosystems as a whole, with the connecting links provided by mesozooplankton. Viewed in this light, the primary impetus for the middle Bajocian radiation was ecological – a Mesozoic Pelagic Revolution.

Phosphatisation of soft-tissues: an integrated palaeontological and geochemical analysis of the Christian Malford Lagerstätte (Callovian, Middle Jurassic)

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Phosphatised soft-tissues are comparatively widespread and routinely preserve sub-cellular details. Thus, they constitute the richest source of data available to palaeobiologists. Nevertheless, the fundamental depositional drivers remain unclear. Phosphatised soft-tissues are abundantly preserved in a variety of organisms (fish, coleoids, crustaceans) in the Oxford Clay at Christian Malford, Wiltshire (UK). Systematic collecting reveals that these are confined to particular horizons that differ subtly from the 'background' sediment. In particular, they coincide with significant peaks in P, Mo and TOC, and the horizons preserve more substantial evidence (*e.g.* foraminifera-floods, burrowing) for the benthic environment having switched repeatedly between anoxic and oxic states. The sum of data supports a model in which the necessary P was sourced from disseminated organics and was concentrated by scavenging Fe-oxyhydroxides in surficial layers during oxic interludes. Subsequent release of P for phosphatisation was triggered by the development of decay halos around carcasses that entered at this time. Because all of the horizons yielding phosphatised soft tissues lie at the top of minor fining-upward cycles (parasequences) and are clustered within a highstand interval, there exists, for the first time, the very real possibility of prospecting for such preservation based on an understanding of global- and basin-scale dynamics.

talks

The Anthropocene biosphere

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The geological record preserves evidence for fundamental changes in Earth's biosphere. A 'metazoist' might posit the most significant change during the late Precambrian and early Cambrian, culminating in the Cambrian adaptive radiation of animals. A 'microbialist' view, on the other hand, might point to the evolution of oxygenic photosynthesis or of the Eukarya as most significant. We suggest that the modern biosphere shows early signs of entering a new stage of evolution characterized by: 1) global homogenization of flora and fauna; 2) a single species (*Homo sapiens*) commandeering 25–40% of net primary production and also mining fossil net primary production (fossil fuels) to break through the photosynthetic energy barrier; 3) human-directed evolution of other species; and (4) increasing interaction of the biosphere with the technosphere (the global emergent system that includes humans, technological artefacts, and associated social and technological networks). These unique features of today's biosphere represent a major new phase in our planet's history with effects that may persist, and amplify, over geological timescales.

The curious case of Rollinschaeta myoplena: reconstruction of extensively phosphatized myoanatomy in extinct taxa

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Phosphatization, the permineralization and replacement of organic materials and structures, is a taphonomic process that frequently results in the preservation of labile tissues and other diagnostic features that normally fail to survive the process of diagenesis. As a result, phosphatized remains often elucidate key windows into the depths of the fossil record which have helped to characterize the history of life, although the volume of material preserved is generally limited. *Rollinschaeta myoplena*, a phosphatized polychaete from the Cretaceous Lagerstätten of Lebanon, is unique among its co-occurring taxa in that it preserves the vast majority of its muscle tissue in three dimensions while lacking almost all of its recalcitrant components, allowing the novel diagnosis of this animal based upon soft-tissues only. Extensive camera lucida mapping and comparison to extant annelids using micro-CT scanning reveals an affinity with the Amphinomidae ('fireworms') based upon the presence of two dorsal longitudinal muscle band pairs, a single ventral pair of longitudinal muscle bands, dorsal and ventral circular muscle tissue and a number of readily identifiable body features. This discovery has yielded important insights into the process of phosphatization and its mode of preservation is unprecedented.

Abstracts of poster presentations

* indicates a poster eligible for the Council Poster Prize.
Underlined author denotes designated presenter.

Acanthomorphic acritarch pseudofossils in Ediacaran chert nodules from Oman

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Chert permineralization provides an important taphonomic window into the diversity, ecology, and the spatial and temporal distribution of large acanthomorphic acritarchs in the Ediacaran. It is therefore important to critically assess diagenesis in chert-forming environments in order to identify diagenetic artefacts masquerading as biological characters. The occurrence of genuine acanthomorphs in the Ediacaran of Oman would have important implications for the understanding of Huqf stratigraphy, and Ediacaran biostratigraphy in general. Here we present an in-depth taphonomic analysis of a shallow marine carbonate environment with large, apparently acanthomorphic, acritarchs bearing long cylindrical or conical processes, preserved in chert nodules from the Khufai Formation (Huqf Supergroup) in Oman. However, petrographic analysis reveals that the apparently acanthomorphic features of the acritarchs are the result of early diagenetic precipitation of bladed and dog-tooth isopachous calcite cements on sphaeromorphic acritarch vesicles. Coating of these crystals by remobilized organic matter creates the illusion of acanthomorphic processes. These cements can generally be distinguished from acanthomorphic processes by their morphological inconsistency. This means partially or poorly preserved acritarchs – those most likely to experience diagenetic overgrowths – are also the most difficult to distinguish from pseudofossils. Understanding diagenesis in chert-permineralizing environments is therefore crucial for a robust Ediacaran microfossil record.

Prasinophyte world: biodiversity of organic-walled microfossils from the Tonian Visingsö Group, Lake Vättern, Sweden

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Diversification of eukaryotic, single-celled, organic-walled microorganisms reached its peak in the early Neoproterozoic. The Tonian Visingsö Group, southern Sweden, has yielded exceptionally-preserved palynomorphs, including fossils of characteristic prasinophyte morphologies. Microfossils were recovered from a drill core through the Visingsö Group, exposed on Visingsö island and the coast of Lake Vättern. Biostratigraphic correlation with isotopically-dated successions suggests the Visingsö strata were deposited ~740–800 Ma. The upper formation contains well-laminated, micaceous shales and is particularly fossiliferous. Microfossils were extracted by a standard palynological method, studied using light and scanning-electron microscopy, and compared to extant protists. Diversity increases upwards through the Visingsö succession, from spheroidal

to ornamented morphotypes. The assemblage contains *Pterospermopsimorpha*, *Simia*, *Tasmanites*, *Cerebrosphaera*, *Vandalosphaeridium*, *Trachysphaeridium*, *Chuaria*, *Kildinella*, leiosphaerids and unnamed acanthomorphs. Certain microfossils share morphological characters with extant prasinophytes *Pterosperma* and *Pachysphaera*. Furthermore, presence of an envelope around a central body in some taxa is indicative of a phycoma: a resilient reproductive structure produced by present-day prasinophytes. Prasinophycean algae have a long evolutionary history, appearing in the Mesoproterozoic, and are poorly resolved. However, the order represented in the fossil record, Pyramimonadales, is monophyletic. Visingsö microfossils provide a detailed insight into the early evolution of this ancient algal group.

Extinction-related body size trends in Early Jurassic bivalves and brachiopods of northeastern Spain

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The Pliensbachian–Toarcian extinction event, attributed to global warming and associated environmental changes such as expanding oceanic anoxia, is recorded in marine assemblages worldwide. Published data indicate that marine molluscs underwent significant size changes during this event, including a temporary reduction in body size in some surviving taxa during the immediate post-extinction interval (*i.e.* the Lilliput effect). Such studies are, however, based on single locations and recorded size trends may simply reflect local depth- or facies-related changes. To address this, the body sizes of 763 individuals of 17 Pliensbachian–Toarcian benthic genera, collected by bulk sampling two different localities in northeastern Spain, were studied. Where possible, three linear dimensions were measured on each specimen, which were then used to calculate geometric mean size. Significant differences were found between the two localities, with larger body sizes in the shallower, better-oxygenated site. Body size trends within some individual taxa through the same interval of time recorded differences in direction or amplitude at the two localities. Interspecific differences in response were also recorded. These results suggest that even during major global change, differences in the local environment and ecology govern the biotic responses of marine organisms resulting in site-specific body size trends through time.

Microfossil communities preserved in Ediacaran cherts of the Shuurgat Formation, Zavkhan Terrane, southwestern Mongolia

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Abundant microfossils are preserved within Cryogenian strata of the Taishir Formation (*c.* 660–635 Ma), southwestern Mongolia. Here we assess changes in microbial communities across the Marinoan snowball Earth ice age by analysing microfossils preserved in early diagenetic chert nodules from the overlying Ediacaran strata of the Shuurgat Formation. The Shuurgat Formation was deposited during early Ediacaran time:

it conformably overlies a Marinoan cap carbonate in the basal Ol Formation and is overlain unconformably by the Zunne Arts Formation, which includes the Precambrian–Cambrian boundary. The fossiliferous chert nodules occur in subsidiary intraclast conglomerate horizons within the laminated micrite and calcisiltite upper portion of the Formation. Abundant fragments of organic material, which contain carbonaceous microfossils and may represent pieces of microbial mat, are preserved within the chert nodules. Spheroids, 5–20 μm in maximum dimension, some of which possess thick walls with internal detail, dominate the microfossil assemblage. Filaments are also well represented with morphologies including branched, unbranched, and septate forms. A vase-shaped microfossil (VSM), ~100 μm in maximum dimension, hints at the presence of unicellular eukaryotes. VSMs have previously only been reported in *c*. 850–720 Ma strata, and if confirmed, the new Shuurgat Formation VSMs represent the youngest Neoproterozoic occurrences yet discovered.

Two new odd Notosuchians from the Upper Cretaceous Bauru Group, Southeastern Brazil

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Notosuchian crocodylomorphs are a key element in South American Mesozoic fossil assemblages, particularly in the Upper Cretaceous fossil record of Bauru Group, where crocodylomorphs currently comprise over 15 taxa, most of them belonging to Sphagesauridae, Baurusuchidae and Peirosauridae. Undescribed specimens from the vicinity of Marilia, Brazil indicate the existence of two new notosuchian taxa. The first one – a small fragment of maxilla with teeth – comes from the Araçatuba/Adamantina Formations (Campanian) and represents a new species of the small-sized *Adamantinasuchus*, characterized by the presence of an antorbital fenestra. The second specimen – a partial skull and mandible – comes from the Marilia Formation (Maastrichtian). It represents a medium-sized sphagesaurid, displaying the typical dentition and morphology of this family, alongside unexpected bizarre characteristics of the rostrum, narial opening and orbital region. Most of the notosuchian fauna of Bauru Group contrasts with other South American and African crocodylomorphs, with dentition and skull morphology dedicated to process food rather than to capture prey. The continual increase of diversity and disparity of Brazilian fossil crocodylomorphs in recent decades suggests that the collection effort carried out since the 1940s has so far only provided a glimpse of the exquisite past faunal assemblages, particularly in the Bauru sediments.

Palynological analysis of the Middle Devonian of northern Spain: hunting for the Kačák event

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Northern Spain contains one of the most complete Devonian sequences in Western Europe chronicling widely varying depositional environments in a Peri-Gondwana setting. We describe palynomorph assemblages from the Eifelian and Givetian age Huergas, Naranco and Gustalapiedra Formations from Asturias, Castilla y León and Palencia provinces, respectively.

These laterally equivalent formations represent a transect from shallow nearshore marine, across the shelf, to deep offshore shelf deposits. They are comprised of large sandstone bodies interspersed with black shales that are sandwiched between thick limestone sequences. Samples have been collected from long stratigraphic sections and yield rich assemblages of land-derived spores and marine palynomorphs (acritarchs, chitinozoans and occasional scolecodonts). The palynological assemblages have been quantitatively analysed to reveal changes in the terrestrial flora and marine biota through time and space. The Kačák event is a widely occurring anoxic event that occurs around the Eifelian/Givetian boundary and is associated with extinctions in the marine realm. This event is not well characterized in the Iberian Peninsula but is believed to be represented in the upper part of the Huergas, Naranco and Gustalapiedra Formations. We aim to identify the Kačák event in northern Spain and document its effect on both the marine phytoplankton and terrestrial biota.

Drifters, floaters or swimmers? Morphological evidence for functionally selective extinction in the Ammonoidea

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Of the major extinction events that the Ammonoidea survived, the Devonian/Carboniferous was arguably the most severe. The Ammonoidea had already been greatly winnowed by the mid-Frasnian Kellwasser event, which saw the near-extinction of most major lineages. Despite the rapid diversification of the Family Tornoceratidae and the Order Clymeniida in the 30 million years before the end of the Devonian, the Hangenberg bio-event brought the entire Subclass Ammonoidea to the brink of total extinction. The survival and radiation of a single Goniatite lineage subsequently saw much of the previous morphological diversity replaced by convergent forms. Here we utilize multiple approaches to elucidate possible morphological and functional factors that may have affected a lineage's susceptibility and ability to recover from extinction events. We present a geometric morphometric methodology that enables us to describe detailed shape change trends in ammonoid conchs, and to do this throughout their ontogeny. These data, alongside three-dimensional scanning and printing technology, allow us to assess the hydrodynamic properties of different ammonite species at different ontogenetic stages, and for the first time, to make information-based inferences regarding their ontogeny, ecology and functional biology.

Testing biotic recovery from the early Toarcian (Lower Jurassic) extinction event

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The Toarcian oceanic anoxic event (TOAE) and associated marine mass extinction have attracted a great deal of research effort, focusing primarily on the causal mechanisms. In contrast, there is less known of the patterns of biotic recovery following this mass extinction (and others). Yet such recoveries are of interest as they record how surviving organisms radiate into newly vacated ecospace. The Cleveland Basin, North Yorkshire, has one of the most expanded Toarcian rock sections. Previous studies have presented a limited

view of the recovery interval as the upper Toarcian sequence across much of the basin was truncated by a period of erosion during the Middle Jurassic. However, the Ravenscar coastal section preserves all of the upper Toarcian stratigraphy. We sampled 44m of this section and recorded 25,412 benthic and nektic macrofossils, giving us new range data, and allowing, for the first time, a full evaluation of the biotic recovery from the TOAE. Results show that the recovery interval was overprinted by a regressive marine sequence with pre-extinction levels of diversity attained and exceeded around 5 million years after the extinction horizon.

The overlooked crustaceans from Mount Lebanon

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In the Middle Ages, when Louis IX of France went to crusades, fossil fishes were discovered in Lebanon. Almost eight hundred years later, the very same outcrops continue to yield an impressive fauna and flora dated into the Cenomanian and Santonian. Among the animals, crustaceans are extremely diversified, yet still poorly studied. To address this problem, we propose the first comprehensive revision of all crustaceans from Lebanon. In this study, we describe or redescribe over 60 species of crustaceans: mantis shrimps, glass shrimps, diverse dendrobranchiate and caridean shrimps, glypheid lobsters, slipper lobsters, erymid lobsters, squat lobsters, crustacean larvae – including those of slipper, achelate and polychelidan lobsters. Most of these species are the first or last fossil occurrence of their respective group. The Lebanese outcrops also yield the last members of the enigmatic thylacocephalan arthropods, which affinities are still not resolved. Our study shows for the first time that Lebanese outcrops rival in terms of palaeobiodiversity all other Mesozoic outcrops. They offer a unique view to the palaeobiodiversity of crustaceans and will help to better understand the evolution of crustacean clades and the timing of their apparition.

Rock and roll: assessing the damage of turbulent flows on soft-bodied organisms

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In the past, experimental taphonomy on exceptional preservation of soft-bodied organisms mostly focused on post-depositional factors, such as decay in static bodies of water. However, an underdeveloped aspect of this field of research is the sedimentological processes leading up to the entombment of fossil organisms in the first instance. This is especially significant for those from fossil Lagerstätten where organisms may be allochthonous, such as the Burgess Shale. This has important implications for interpreting the palaeoecology of these assemblages. It is therefore crucial to understand the effects of different sediment-density flow regimes on soft-bodied organisms. Here, through experimentation, we analyse the exact variables of turbulent flows that may have a

detrimental effect on the polychaete, *Alitta virens*. Variables studied include the angularity of the grains, transport distance, and concentration of a flow in an annular flume tank. An index of 'increasing state of damage' has been devised to classify the amount of destruction each organism exhibits after the experimental procedure. Results of these experiments are discussed here.

Reconstructing the evolutionary history of the clade Pelagia

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Pelagia is a disparate clade of open-ocean fishes recently identified through molecular studies. This group includes the economically important Scombridae (tunas and mackerels), which are characterized by exceptional anatomical innovations for efficient high-speed swimming. The ecologically distinct lineages of Pelagia appear to have diverged rapidly early in the group's history. This conforms to concepts of 'adaptive radiation', but differs from classic examples like cichlids and *Anolis* lizards in both age and geographic scale. Although numerous well-preserved fossils have been aligned with Pelagia, these have not been integrated into a modern phylogenetic framework. Consequently, there is great uncertainty in the age of this radiation (molecular estimates disagree by 50 Ma) and the specific relationships between major sub-clades. Excellently preserved material from the UK, Angola and other sites provides an opportunity to investigate the evolutionary history of the group. We applied computed tomography (CT) to three-dimensionally preserved fossils historically attributed to this clade, including putative scombrids (*Landanichthys*, *Scombrinus*), gempylids and trichiurids (*Eutrichiurides*, *Progempylus*). Preliminary results suggest unexpected levels of trophic diversity in the earliest scombrids, as well as a need to re-examine the systematics of the diverse London Clay scombroid fauna. This will inform a larger morphological review of this clade.

Lamniform shark tooth morphometrics show a shift in community structure over the Cretaceous–Palaeogene mass extinction event

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Extinct lamniform shark teeth are abundant in the fossil record, but the significance of these to the study of the broader ecosystem is overlooked in the literature. In this study, shark tooth morphology, which in modern taxa corresponds to feeding behaviour and prey choice, is used as a proxy in fossil assemblages to suggest the feeding guilds and community structure present. Tooth morphology was quantified from two lamniform (mackerel shark) assemblages from Morocco, one from each side of the K/Pg boundary, as well as for a selection of morphologically diverse extant taxa. Principal component analysis (PCA) shows a dramatic shift in morphospace: the pre-extinction (Maastrichtian) morphospace has a range smaller than, but comparable to, that of the extant taxa, while the post-extinction (Danian) morphospace is much reduced. Across the K/Pg boundary there is a loss of tooth morphology extremes, including large, robust teeth, and broad serrated teeth. These data suggest that this marine ecosystem was highly impacted on an ecological basis, at apex-predator level, by the K/Pg extinction event. A loss of large, cutting-form and robust teeth suggests both a decrease in shark size, and the loss of large prey items.

Changes in mammal disparity across two fossil Lagerstätten sites from the Mesozoic and Cenozoic

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Extant mammals exhibit a remarkable variety of forms and functions; however, they have not always shown such high levels of ecomorphological disparity. Mesozoic mammals are stereotyped as small 'generalists' or 'insectivores', only evolving novel forms as a result of an adaptive radiation at the K/Pg boundary. Shifts in the disparity of phenotypic traits in mammals from the Mesozoic to Cenozoic are not well quantified. Complicating matters is an emerging picture of surprisingly high levels of morphological disparity in Mesozoic mammals. In an attempt to better constrain patterns of mammal diversification, we quantified ecomorphological disparity in two Lagerstätten with a common lacustrine setting stratigraphically flanking the K/Pg boundary: the Cretaceous Jehol Biota and the Eocene Messel Pit. With a relative abundance of specimens yielding information on anatomical systems beyond dentition, functionally relevant continuous measurements for limbs and jaws, representing locomotor and feeding type respectively, can be collected. Preliminary results show mammals from these two sites do not show substantial differences in disparity in traits related to feeding ecology. Elevated locomotor disparity in Messel mammals can be attributed to a handful of groups with locomotor ecologies unknown from the Cretaceous: bats, early horses, and the genus *Leptictidium*, which may have been semi-bipedal.

Assessment of the Creswell Crags fossil material in the Nottingham Natural History Museum, Wollaton Hall, UK

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The Creswell Crags gorge on the Nottinghamshire–Derbyshire border contains a series of caves in which Holocene and Late Pleistocene deposits accumulated. The palaeontological significance of Creswell Crags was first recognized in the 1870s when a diverse fossil mammalian fauna was excavated from the cave deposits. This led to a large number of fossils being donated, sold or bequeathed to the Nottingham Natural History Museum, Wollaton Hall (NOTNH). This study provides the first investigation of the entire NOTNH Creswell Crags collection with respect to faunal abundances, how these proportions compare to historical excavations, and a review of the provenance data. Overall, the NOTNH contains 274 fossil specimens from Creswell Crags consisting of 466 individual elements, of which 61% have been identified to genus level. 17 genera have been identified from six orders: Carnivora, Artiodactyla, Perissodactyla, Proboscidea, Lagomorpha and Primata. The NOTNH collection contains proportionately more woolly rhino (*Coelodonta*) elements than the 1870s excavations but fewer hyaena (*Crocuta*), reindeer (*Rangifer*), and woolly mammoth (*Mammuthus*). We attribute these discrepancies to a possible 'donation bias'. Only 10.1% of elements can be attributed to specific caves and none retain any detailed stratigraphic data. This compromises the overall scientific value of the collection.

What were they thinking? Exploring the potential of neurocranial anatomical studies throughout Ceratopsia

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The neurocranial anatomy of extinct organisms has always excited the palaeontological community. Since the 19th century, palaeontologists have been examining whether endocasts can provide a good resolution of brain size and morphology and, if so, what this can tell us about the sensory capacity of these long dead organisms. Ceratopsians were one of the most diverse dinosaurian clades of the Late Cretaceous and have a fantastic fossil record of basal forms in Asia. Ceratopsian palaeontology is currently lacking in comprehensive neuroanatomical studies. Analysis of ceratopsian neurological evolution will ultimately show how neurology likely affects behaviour, assumed through previous studies. This investigation offers the rare chance to study both basal Asian and North American taxa to enable analysis in a morphological and macroevolutionary context whilst creating an accessible set of braincase 3D PDFs. I present the preliminary study indicating what the palaeoneurology of *Psittacosaurus lujiatunensis* can tell us, and how this can be expanded to incorporate every major clade within Ceratopsia.

Traces on living slipper limpets *Crepidula fornicata* (L.)

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Slipper limpets were imported to the UK in ~1880 and invaded the Netherlands in ~1930. They are now abundant in the Wadden Sea, especially between the Pacific oysters flourishing here since ~1990. Slipper limpets are sessile suspension feeders living in chains. Herring gulls crush slippers by dropping them on the Wadden Sea dyke. On these the attachment scar of the limpet on top is easily visible. They hardly move after attachment, which leaves the area outside the attachment available for boring organisms. In the Wadden Sea this is mainly the boring polychaete *Polydora*. This drives the slipper to produce extra shell material (blisters) on the inside of its shell. These are well known in *Polydora*-infested mussels. Fossil attachment scars of *Crepidula* and the related *Capulus* were described as *Lacrimichnos*. Fossilization potential of these attachment traces is low, they are not mentioned amongst the many bioerosion traces on fossil *Crepidula* by Richiano *et al*. 2015.

Reconstructing the Middle Miocene palaeoenvironment of Quebrada Honda, Bolivia, using ichnology and palaeopedology

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The Neotropics contain exceptional levels of mammalian diversity, but few fossil-producing localities document the history of this fauna. La Venta, Colombia (LV), and Quebrada Honda, Bolivia (QH) are contemporaneous (13–12 Ma) sites that preserve the remains of many extinct Neotropical mammals. Almost no genera are shared between

these localities, which could reflect habitat differences. Here we use palaeopedology and ichnology to elucidate the habitat of QH and test this hypothesis. The palaeosols of QH are weakly to moderately developed and composed of brown-to-red mudstones; they are interpreted as Entisols and Inceptisols. The ichnofossils include burrows with chambers, and horizons of *Celliforma* and *Coprinisphaera*; they are interpreted as breeding structures of solitary insects and dwelling structures of small mammals, respectively. Rhizoliths include rhizohaloes that are interpreted as roots of grasses and other small plants, and rhizocretions that are interpreted as taproots of medium to large plants such as shrubs and trees. The palaeosol and ichnofossil data from QH suggest a mixture of grasslands and savannahs located proximal to alluvial systems. This interpretation contrasts with published palaeoenvironmental interpretations for LV (river-associated tropical forests) and indicates that dissimilar habitats could account for many of the differences between the mammal faunas of these two fossil sites.

The Tournaisian: a sarcopterygian incubator?

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Once considered to be nearly devoid of vertebrates, Romer's Gap is now being bridged as new material from the Tournaisian of northern England and the Scottish Borders reveals higher than anticipated diversity of fish and tetrapods from this period. New material from Tantallon, East Lothian, Scotland, from the upper Ballagan Formation (late Tournaisian) provides evidence of continued radiation throughout the Tournaisian. In particular, sarcopterygian taxa (represented predominantly by teeth), especially lungfish and rhizodonts, are abundant and diverse. The Tantallon material is, however, unusual in one very important aspect: most of it is very small. Recent bulk acid preparation and subsequent sorting has revealed a rich variety of micro fossils including lungfish tooth plates, rhizodont teeth and chondrichthyan teeth and scales, including forms not previously seen in the Ballagan Formation. This new material, along with other Tournaisian sites in the region, is beginning to dispel the myth that the post-Hangenberg world was a desolate sparsely-inhabited dystopia but rather one of rapid diversification in the Sarcopterygii that rapidly occupied newly available niches.

Lepidosaurian diversity through time: an exploratory look at the data

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Lepidosauria comprises Rhynchocephalia (tuatara and extinct relatives) and Squamata (lizards, snakes and amphisbaenia). In the past both were geographically widespread, with a complicated history of radiation and extinction. While their diversity in certain periods

has been examined, long-term patterns have not. Here I study the diversity of terrestrial lepidosaurs from the Triassic–Palaeogene (252–23 Ma) on genus-level occurrence data (1,418 specimens representing 332 genera) from the Paleobiology Database. Shareholder quorum subsampling is used to alleviate biases associated with raw diversity counts. At substantial quorum levels (>0.5), low diversity in the Late Triassic further declines across the Jurassic boundary. High diversity in the Late Cretaceous plummets between the Campanian and Maastrichtian, prior to the K/Pg extinction. A rise post-K/Pg represents radiation following the extinction of non-avian dinosaurs. Diversity falls again in the Late Eocene, recovering somewhat in the Oligocene; this may represent the "Grande Coupure" turnover event. Current data are highly American-centric: 41% of specimens are from the USA. Occurrences are concentrated in the Late Cretaceous and Eocene, likely representing intensive sampling; further data will be gathered to reduce these biases. More complete information can be used to examine potential drivers of diversity, and comprehensively assess bias in the lepidosaur record.

Livers, guts and gills: how decay profiles control the fossilization potential of soft tissues

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The interpretation of soft-bodied fossils is often contentious, especially in primitive or enigmatic fossil organisms where we have no modern analogues for comparative analysis. It is therefore of vital importance to understand the processes organisms undergo during the fossilization process, chief of which is decay. We have designed a series of novel experiments to investigate in real time how decay processes affect the fossilization potential of specific internal soft-tissues. Our data will allow us to unravel the timing and sequence of internal anatomical decay and what controls this crucial process. Our findings can then be applied to the fossil record to allow a greater accuracy in correctly interpreting fossils and our understanding of evolutionary relationships through deep time.

Damage and repair in Wenlock reefs: evidence of predation on Silurian corals

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Predation pressure is widely thought to have played a critical role in evolution. Most studies of predator–prey interactions described in the fossil record have focused on shelly molluscan or brachiopod prey. In particular, there are relatively few studies which have recognized predation evidence on fossil corals. Here we document damage and repair in corals from the Much Wenlock Limestone Formation (Silurian: Wenlock) of the English Midlands and Welsh Borderlands and test the hypothesis that they were caused by predators.

Counting the valid radiolarian genera in the Palaeozoic

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The first ever Palaeozoic radiolarian genus was described in 1890 from Ordovician cherts of Scotland. Not much happened for the following 60 years, until the milestone study of Deflandre, who, based on Carboniferous radiolarians from the Montagne Noir (France), established their evolutionary significance. In order to achieve taxonomic clarity and a sound appreciation of Palaeozoic radiolarian genus diversity, we have undertaken the preparation of an illustrated taxonomic catalogue for all 348 Palaeozoic genera described in the literature, including a re-illustration of the holotype of the type species of each genus. In our publication we will present a revised opinion of the status and family assignment of all Palaeozoic genera described so far, and will provide an up-to-date evaluation of their currently known age range. A taxonomic revision of the 348 generic names was conducted taking into account existing published opinion; this revision allowed us to identify 84 junior synonyms, six homonyms, one *nomen nudum* and 38 *nomina dubia*. Finally, 17 genera cannot be considered any longer as radiolarians, most of them being re-interpreted already in the literature as sponges. We intend for this atlas to serve as a useful taxonomic and biostratigraphic compendium in the palaeontological community.

Trends in trilobite moulting

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Arthropods periodically moult their exoskeletons for growth, development and repair. The methods by which they moult are consistent within clades of extant taxa, but trilobites show uniquely high levels of variation in this behaviour, both within and between species. Trilobites exhibit at least six distinct moulting behaviours, producing exoskeleton fragment configurations that are recognizable in the fossil record. Here I present results of a study exploring broad trends in trilobite ecdysial patterns through time and taxonomy. I examined collections of trilobite-moulted exoskeletons, housed in museums across the UK (London, Oxford, Birmingham) and Sweden (Uppsala), and combined this with information from the descriptive literature. These data consist of information on moulting behaviour, measures of morphology and complexity, and growth data. No clear evolutionary patterns in trilobite ecdysis have previously been identified, or interpreted in light of their admittedly poorly-constrained phylogeny. However, new data suggest the occurrence of different moulting behaviours, which vary between Orders and through time, and are associated with variation in body size. Trends in trilobite moulting behaviour

relate to phylogeny, morphology and development, and have influenced the evolution and survivorship of the group. Future research will focus on moulting behaviour within well-sampled Orders and localities.

Spatial and temporal species richness of the fossil pollen genus *Aquilapollenites* using data from the John Williams Index of Palaeopalynology

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Occurrence databases are key to deciphering patterns of evolution, diversity, and biogeography through geological time. However, these databases are typically thought of as digital entities. The John Williams Index of Palaeopalynology (JWIP) is a cross-referenced index card system detailing global pre-Quaternary palynomorph occurrences and is believed to be the most comprehensive palynological database in the world. A proof of concept study, aimed at assessing the digitization potential of the card index, was undertaken on the fossil pollen genus *Aquilapollenites*. This genus is often affiliated with the modern angiosperm family containing the mistletoes, and belongs to an eminent group of pollen called the Triprojectates. *Aquilapollenites* is commonly associated with pollen assemblages of the Late Cretaceous and also the K/Pg extinction event. The data extracted from the JWIP revealed that *Aquilapollenites* suffered a 62% loss in global species richness at the K/Pg extinction event, a significant loss leading to the extinction of the genus soon after. The JWIP, despite being non-digital, allowed an exhaustive analysis of the temporal and spatial species richness of *Aquilapollenites*, and therefore presents a unique opportunity for studies of this kind. Given the nature of the data, the potential applications of the JWIP are infinite.

A new specimen of *Othnielosaurus consors*

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Here we describe a new specimen of *Othnielosaurus consors* from the Upper Jurassic Morrison Formation. The specimen was found at the Howe Stephens Quarry (Wyoming, USA) and represents the most complete and largest single skeleton currently known for this taxon. The postcranial skeleton is virtually complete except for the forelimbs, which are only partially preserved. The specimen exhibits the most complete cranial material (including a relatively well-preserved lower jaw and a right maxilla) found in a single individual of the taxon. The preservation quality of the bones varies from relatively well preserved to heavily crushed. Slight differences between this skeleton and other specimens referred to *Othnielosaurus consors* are noted, but are explained by either individual or ontogenetic variation or the preservation quality of the specimen. Whether the size difference in comparison with other specimens is related to ontogeny or sexual dimorphism cannot be determined currently. A phylogenetic analysis recovers *Othnielosaurus consors* with the new character scorings as a member of Neornithischia and sister taxon to Cerapoda. This result differs from earlier assessments, which referred to the taxon as a 'hypsilophodontid' or basal ornithopod, and is in agreement with relatively recent phylogenetic studies.

Building a sedimentary geochemical database to understand the co-evolution of marine life and environments in a statistical framework

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After decades of intensive work, it is clear that the Neoproterozoic–Palaeozoic was an interval of considerable change in terms of marine redox conditions. Questions remain, however, about the magnitude and timing of palaeoenvironmental change, particularly in relation to significant events in the history of life and broad trends in diversity, ecology and morphology. Rigorous statistical analyses of long-term changes are hampered, in part, by insufficient data and limited data curation by the sedimentary geochemistry community. In keeping with the recent push towards improved data accessibility, aggregation, and standardization (*e.g.* Paleobiology Database, NSF IEDA, BGS OpenGeoscience, Macrostrat), here we discuss how we are bringing together new and existing datasets (in particular major and trace element concentrations, iron speciation, trace metal enrichments, and metal isotope values) in a relational database, based in part on the BGS and EarthChem data models. This allows for flexible querying across large datasets, efficient data import/export, quality control, and the establishment of good metadata standards. Ultimately, it will facilitate the analysis of redox conditions and shifts in biogeochemical cycling through time in a robust statistical framework, and enable comparison of changing palaeoenvironmental landscapes with new and existing compilations of animal body size, diversity and ecological guild occupation.

Recent benthic foraminiferal assemblages from mangrove swamps and channels of Abu Dhabi (United Arab Emirates)

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Benthic foraminifera are an excellent tool to monitor marine coastal environments and to assist in the study of coastline change. Little is known about Recent foraminifera from mangrove swamps and channels of the Arabian Gulf. Detailed sampling collection in mangal environments of Eastern Abu Dhabi (UAE) was carried out to assess the distribution of benthic foraminifera in different sedimentary facies. Samples were collected in intertidal channels, mud flats and near the roots of *Avicennia marina*, and stained with Rose Bengal to identify the living foraminifera. The water salinity at the sampling sites was between 44 and 49 ppt. The samples collected in the higher energy settings (channels) were characterized by very low abundance of foraminiferal tests, no living forms were found in the coarser facies. The fine-grain sediments collected near mangrove roots presented a high abundance of living and dead foraminiferal tests. The assemblages in these samples show very low diversity and are almost entirely constituted of small-sized opportunistic species belonging to the genera *Ammonia* and *Elphidium*. The study of the distribution of Recent benthic foraminifera from mangrove environments of the Abu Dhabi region can provide reliable analogues for understanding and interpreting the depositional environment of ancient coastline sediments.

A new large-sized temnospondyl from the Permian of southern Brazil

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Although the temnospondyl known diversity is substantial, the current knowledge of South American taxa is lacking. Remains of a large-sized temnospondyl from the Rio do Rasto Formation (Middle–Late Permian) of Southern Brazil represents a putative new taxon that may shed light on temnospondyl evolution and palaeobiogeography. The specimen MCP-4275PV is a hemimandible of ~50 cm in length, indicating that this specimen exceeded the majority of Brazilian temnospondyl taxa in size, only surpassed by the Late Permian *Prionosuchus*. Meaningful characters include a type I postglenoid area (PGA), hamate process and coronoids devoid of teeth, proportionally small but numerous dentary teeth. The short and posterodorsally-oriented retroarticular process parallels the morphology of certain Crocodylia, highlighting biomechanic similarities between these different tetrapod groups. Preliminary phylogenetic analysis (TNT, PAUP; 66 taxa, 217 characters) consistently places MCP-4275PV as the sister-group of *Parotosuchus*, a capitosaur genus currently known from Laurasian territories, South Africa and Antartica. If confirmed as a *Parotosuchus*, MCP-4275PV will expand the presence of the genus to South America. Furthermore, it will represent possibly the oldest capitosaur, a group almost entirely restricted to the Triassic. The future use of CT-scanning should provide access to new morphological data and the refinement of current results.

posters

Resolving biology and taphonomy in Cambrian small shelly fossils

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Small shelly fossils (SSFs) provide the earliest evidence of biomineralization in animals, first appearing in the latest Ediacaran (with *Cloudina*) before dramatically diversifying during the Cambrian. They represent stem group members of at least six metazoan phyla, in addition to various problematic taxa. SSFs occur as phosphatic, calcareous and siliceous microfossils, but are often preserved by secondary mineralisation. This hinders resolution of their original ultrastructure and composition which in turn obscures the phylogenetic relationships of these early animals. Richly fossiliferous horizons in the Lower Comley Limestone (Lower Cambrian, Shropshire, UK) were targeted to test biomineralogical and phylogenetic hypotheses of key SSF taxa. This unit is known for its secondarily-phosphatised preservation of micro-arthropods (phosphatocopids), but it also yields a diverse SSF assemblage. Scanning electron and optical microscopic examination revealed well-preserved biogenic ultrastructures in many of the phosphatic SSFs, including differential laminae of linguliformean brachiopod shell secondary layers and growth laminae in hyolithelminths, lapworthellids and the spinous genus *Rhombocorniculum*. These microfossils are unusually free from secondary mineralisation and can shed light on the biomineralogy and phylogenetic relationships of key early metazoan taxa. The high-fidelity preservation of these SSFs also makes them suitable candidate sources of isotopic constraints on Cambrian marine environments.

Diversity and morphological disparity of the Rhynchocephalia

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Rhynchocephalia is an order of reptiles that originated in the Triassic. Today this group is only represented by a single living species, *Sphenodon punctatus*. For many years, it was believed that the Rhynchocephalia did not change through time, because some of the fossil species and the extant *Sphenodon* showed a very similar morphological structure. This argument lies behind the common description of the extant *Sphenodon* as a living fossil. However, during the last 20 years many fossil species have been described, which have provided information about their morphological diversity in the past, and suggested that there was considerably more variation in form than previously believed. In order to explore the macroevolution of Rhynchocephalia, we performed a diversity and disparity analysis of this group. Also, we explored morphospace occupation through the Mesozoic by using landmarks of the lower jaw. This shows that the modern *Sphenodon* lies close to the centroid of the morphospace plot. Triassic and Jurassic rhynchocephalians show the greatest occupation of morphospace, and disparity has, overall, declined substantially through the Mesozoic and Cenozoic. When divided into feeding morphospaces, there has been a distinct movement in morphospace through time.

Correlation of avian wing loading and aspect ratio with track: application for estimation of extinct avian body

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Avian wings connected to locomotion of flying have possibly evolved adapting to habitat types. Modern avian wing parameters were analysed to examine if wings are grouped constrained by habitats, as tracks are morphologically divided into three groups corresponding to habitat types. Multiple regression analyses of the wing and track data reveal that the avian wing loading and aspect ratio are closely related to the track shape parameter (the primary principal component of the relative warp analysis), expressed by a simple equation that enables the quantitative estimation of the wing parameters from track shapes. These results confirm that avian wings are also divided into three groups corresponding to habitat types. Thus, habitats are closely related to avian wings as well as tracks, and seem to constrain both flight and walking, as a result of adaptation. Using the correspondence relation between wing parameters and track area found in this study, body weights were estimated for extinct avian taxa from the Cretaceous to Cenozoic periods. The estimated weights support the hypothesis that the early Cenozoic avian was larger in size than Cretaceous ones.

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

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Convergent food processing morphology may indicate functional or ecological analogy; however, form and function frequently decouple, meaning explicit testing is required to investigate such hypotheses. The edentulous cranium of *Effigia okeeffeae* (Archosauria: Pseudosuchia) is here compared functionally to those of the ornithomimosaurids *Struthiomimus altus*, *Ornithomimus edmontonicus* and *Garudimimus brevipes* (Archosauria: Dinosauria), to which it has previously been compared qualitatively. Digital retrodeformation of the holotype skull (AMNH FR 30587) of *Effigia* was performed using CT data, before conversion into a finite element (FE) mesh. Adductor and temporal musculature was digitally reconstructed using attachment scars, osteological constraints and extant phylogenetic bracketing. Bite force, estimated from cross-sectional muscle areas, was applied to the mesh simulating rostral, mid and posterior biting. Accounting for size, we estimate *Effigia* to have possessed a bite force comparable to the ornithomimosaurids, however results of FE analyses indicate *Effigia*, unlike ornithomimosaurids, was poorly adapted to rostral biting. This may be partially due to the comparatively large nares of *Effigia*, placed posterior to the rostral bite point (rather than dorsal to the bite point in ornithomimosaurids) channelling compressive rostral stresses through the thin narial septum. While similarly edentulous, minor cranial differences make *Effigia* and ornithomimosaurids unlikely as direct ecological analogues.

posters

Disturbance and diversity in the Ediacaran: integrating sedimentology and palaeontology through multivariate statistical analysis

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Rangeomorphs dominate the Ediacaran successions of Newfoundland (Canada) and Charnwood Forest (UK), and are characterized by their complex, pseudo-fractal branching architecture. Understanding of their biology is hindered by the lack of known extant counterparts, and even fundamental aspects such as taxonomy remain under revision. Despite the uncertainty surrounding these organisms, there is the potential to resolve many aspects of their ecology. Individual bedding surfaces host communities which are remarkably different in terms of their community composition and diversity. In modern ecosystems, such aspects of the community are influenced by several biological and abiological factors; many of these (predation, burrowing) would have been limited or absent in the Ediacaran, whereas physical constraints such as disturbance would still have been in effect. By correlating detailed petrographic analysis with morphological analysis over 25 fossiliferous sites (using complex multivariate statistical techniques), several palaeobiological features including fine-scale tiering, community structure and ecological succession can be elucidated. Importantly, communities with the highest diversity were those with demonstrably intermediate levels of environmental disturbance, a feature typical of modern ecosystems. This work highlights the influence of subtle, transient

environmental parameters on the composition of these ancient communities, and reveals the temporal persistence of fundamental ecological principles.

Phase changes in the microfossil assemblages during the early Toarcian (Lower Jurassic)

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The early Toarcian oceanic anoxic event (TOAE) was a period of extreme environmental change. The TOAE succession exposed in Yorkshire, UK, shows significant perturbations to geochemical proxies and macrofossil assemblages, indicating a rise in global temperature, increased extent of deoxygenation and marine invertebrate extinctions. Foraminifera and palynomorphs from samples taken every 10 cm, geochemical proxies (Kemp *et al.* 2011; Pearce *et al.* 2008) and macrofossil data (Caswell and Coe 2013), together with an improved method of foraminiferal extraction (Kennedy and Coe 2014), demonstrate a three-phase change during the TOAE. Phase 1 records a stepped deterioration in open marine assemblages and increase in terrestrial abundance, interpreted as evidence of enhanced continental runoff. One Milankovitch cycle below the onset of the TOAE *sensu stricto* foraminifera disappear. Phase 2, which represents the start of the TOAE *sensu stricto*, is defined by a shift from an open marine to restricted, sphaeromorph assemblage. Phase 3 is characterized by a substantial sphaeromorph bloom contemporaneous with a significant change in terrestrial vegetation.

Digital restoration of the cranial skeleton of *Morganucodon oehleri*

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Morganucodon oehleri is a basal mammaliaform found in Upper Triassic and Lower Jurassic deposits of Europe and China. Although the species is represented by numerous fossils, these are mostly restricted to isolated teeth and fragmentary elements. Solely a handful of articulated, albeit distorted and incomplete, cranial skeletons form the exception. While the morphology of individual elements, in particular of isolated teeth, has been studied in great detail in the past, reconstructions of the cranial skeleton have been limited to two-dimensional interpretive drawings. Based on high-resolution CT scans of a nearly complete and articulated skull of *M. oehleri* (FMNH CUP 2320), a digital restoration of the cranial skeleton was performed using a suite of virtual restoration techniques. The newly restored skull shows several distinct differences to previous reconstructions. The supraoccipital region is laterally convex and characterized by a distinct sagittal crest, suggesting the presence of a well-developed temporalis musculature. The coronoid process of the lower jaw is positioned posterior to the level of the alisphenoid and extends dorsally, almost to the level of the parietal, thus reducing the length of the temporalis muscle. In this, the hypothesized morphology provides new information on the sequence of character acquisition and morphological evolution at the cynodont–mammaliaform transition.

Stylophoran echinoderms of the Afon Gam Konservat-Lagerstätte (Lower Ordovician, Wales)

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In contrast to the Cambrian Explosion, our knowledge of the Great Ordovician Biodiversification Event (GOBE) relies primarily on shelly fossils. The Afon Gam Lagerstätte, from the early late Tremadocian (Lower Ordovician) of Bala area, North Wales, partly fills this gap. The Afon Gam Biota consists almost exclusively of Cambrian-like taxa. Contrary to the situation in the contemporaneous Fezouata Biota (Morocco), it has not yielded any representatives of groups typical of the GOBE (*e.g.*, asterozoans, crinoids, eurypterids, graptolites, ostracods, xiphosurans). The Afon Gam Biota is dominated by diverse sponges, algae and various kinds of worms, associated with inarticulate brachiopods, trilobites and occasional other arthropods (*e.g.*, bivalved forms, mollisoniid-like taxa), cnidarians, hyolithids, tergomyan molluscs and echinoderms. The composition of the Afon Gam echinoderm assemblage (eocrinoids, glyptocystitid rhombiferans and stylophorans) is strikingly similar to the low-diversity Furongian echinoderm faunas recorded worldwide (*e.g.*, Australia, China, France, Korea, USA). Stylophorans are rare and are represented by three taxa: 1) a basal chauvelicystid cornute (probably intermediate between *Chauvelicystis* and *Prochauvelicystis*); 2) a basal amygdalothecid cornute; and 3) a kirkocystid mitrate (*Anatifopsis trapeziiformis*). This stylophoran assemblage suggests relatively strong affinities with both Furongian and Tremadocian/early Floian faunas.

posters

Remarkable lophotrochozoans from the Weeks Formation Konservat-Lagerstätte (Cambrian Series 3; Utah)

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The Guzhangian Weeks Formation is the least well-known of the three Cambrian Konservat-Lagerstätten of the House Range (Utah). Yet, new collection efforts reveal that its faunal diversity (>80 species, including 30 'soft'-bodied) rivals that of both the Wheeler and Marjum Formations. Ecdysozoans, especially arthropods (57 species), are by far the most diverse components. By contrast, lophotrochozoans are only represented by a single hyolith species and two brachiopod species, despite the great abundance of the latter. Three new possible representatives of this group were recently discovered. One taxon has an elongate body with pairs of short, setae-bearing lateral lobes. It strongly resembles extant dorvilleid polychaetes and is therefore regarded as the first annelid from the Weeks Formation. Another taxon comprises a large (6 cm), three-dimensionally preserved, asymmetrical shell with growth lines and a straight hinge. These features suggest that the fossil represents a disarticulated valve of a bivalved mollusc. The last taxon has an elongate body (>5 cm)

composed of a thick peduncle and a capsule. The capsule was originally semi-rigid and has a second opening laterally. Both parts are preserved in apatite, possibly reflecting the original mineralogy of the capsule. Lophophorate affinities of this taxon are discussed.

Empirical and simulation approaches to detecting barriers to dispersal in extinct terrestrial organisms: testing the effects of Pangaean breakup and avian flight on Mesozoic dinosaurs

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A terrestrial organism's ability to disperse can be restricted by major barriers such as oceans, or enhanced by an enabling trait such as powered flight. However, most currently adopted palaeobiogeographical methods require *a priori* designation of discrete areas, thus making prior assumptions regarding dispersal barriers. Here, by contrast, we use the raw continuous data of palaeocoordinates of latitude and longitude as input, and combine this with phylogenetic data as a means of inferring the existence or breakdown of barriers to dispersal without defining discrete areas. As a case study, we use Mesozoic dinosaurs, a group that spans the breakup of Pangaea and the origin of a major dispersal-enhancing trait (powered flight). Palaeocoordinate data were sourced from the Paleobiology Database and phylogenetic data come from a probabilistically time-scaled 1000-taxon supertree. Initial results suggest that there is little or no evidence for barriers to dispersal when Pangaea was intact, but this changes in the Middle Jurassic. Similarly, early birds do not differ from non-avian dinosaurs until the Late Cretaceous where apparent intercontinental dispersal is observed. A simulation approach under two simple models (an intact and a rifting-apart Pangaea) broadly support our empirical interpretations. We conclude by suggesting ways in which our simulation model could be extended, for example to investigate marine organisms.

Community ecology of Cambrian deep-marine scratch circles

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The early Cambrian witnessed not only the rise of biomineralized organisms, but also a fundamental change in marine ecology, including the evolution of widespread bioturbation and a shift from Neoproterozoic-style microbial matground seafloors to more typical Phanerozoic-style bioturbated mixgrounds. However, this latter shift was delayed in deep-water settings, and the ecology of deep-marine Cambrian communities is not well-known. We investigated the palaeoecology of the deep-marine Middle Cambrian Booley Bay Formation (southeast Ireland), which contains bedding sole surfaces covered by numerous millimetre-scale scratch circles (arcuate scratches made in the substrate by the current-forced rotation of tethered epibenthic organisms) with distributional concentrations reaching 30,000 individuals per square metre. Surfaces were photographed at high-resolution, with position and morphological data (*e.g.* size, number of rings, presence of a central tubercle, orientation) recorded using image processing software and exported into R for in-depth

spatial analysis. Spatial distribution is described by pair correlation functions (PCF) calculated from the position data, with spatial models fitted to the PCFs to distinguish environmental from biological causes, mark correlation functions and PCF models of the circle sizes used to investigate growth and reproduction strategies, and random labelling analysis of morphological features used to consider scratch circle taphonomy.

The role of shifting salinity in soft tissue preservation in concretions

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Shifting salinity is characteristic of the coastal deltaic deposits that comprise the majority of exceptional fossil sites, such as the Mazon Creek concretion site, from the Carboniferous to Triassic. Shifting salinities are hypothesized to influence exceptional preservation by inhibiting decay. This project investigated: 1) the effect of shifting salinities on decay by measuring decay (using weight change and infrared gas analysis) in experiments that simulate environments with and without salinity fluxes; and 2) the role of shifting salinities in soft tissue preservation at the Mazon Creek fossil site by strontium isotope analysis of concretions with and without fossils. The experiments using weight change as a measure of decay suggest that increasing salinity inhibits decay. The experiments using infrared gas analysis as a measure of decay suggest that a flux of meteoric water into seawater inhibits decay, but a flux of seawater into freshwater promotes decay. The strontium isotope analysis of Mazon Creek concretions does not suggest that the concretions containing exceptional fossils developed during times of salinity fluxes. Therefore, these experiments and analyses do not support the idea that shifting salinities promote exceptional fossilization.

A revision of tetrapod tracks from the Late Carboniferous of Hamstead, West Midlands

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The Late Carboniferous to Early Permian was an interval of major global environmental change, with increasing aridity leading to the collapse of the previously widespread humid, tropical rainforests (the 'Coal Forests'). This environmental transition is hypothesized to have driven major changes in terrestrial tetrapod communities, with the amphibians that dominated Carboniferous ecosystems being replaced by early amniotes ('reptiles'). A set of red sandstone slabs from Hamstead, West Midlands, UK, preserve a collection of tetrapod trackways and individual tracks from the Late Carboniferous. This material has received limited previous study, despite being one of the few British sites to preserve Carboniferous tetrapod footprints. We restudied, documented and revised the taxonomy of this material using 3D photogrammetric models and rendered images highlighting coloured contour intervals and areas of changing gradient. The assemblage is dominated by large tracks assigned to *Limnopus* isp. (made by early amphibians) with a series of smaller yet similar tracks being assigned to *Batrachichnus salamandroides* (also made by early amphibians). *Dromopus lacertoides* (made by the lizard-like araeoscelids) and *Dimetropus leisnerianus* (made by early synapsids) were also identified. This ichnofauna contrasts with the slightly older and better-studied assemblage from Alveley (Shropshire, UK), which is dominated by small amphibians and reptilomorphs.

A review of the Danian vertebrate fauna of southern Scandinavia

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Vertebrate remains are widely distributed, but uncommon in the early to middle Danian limestone deposits of eastern Denmark and southern Sweden, and are mostly represented by bony fishes and Chondrichthyans. The lowermost Danian Fishclay at Stevns Klint can include substantial quantities of shark teeth and fragments of bony fishes. Although articulated specimens of osteichthyans are known from the Fiskeler and the Limhamn quarry, there are no known body fossils of elasmobranchs from the Danian of Denmark or Sweden. Reptile and bird remains are very rare. The gavialoid crocodylian *Thoracosaurus* is represented by a complete skull and associated postcranial material and an additional jaw fragment from Limhamn quarry, Sweden. Further remains of a crocodilian skull, a cervical vertebra, a limb bone and a few teeth have been found in Faxe Quarry, and a single possibly alligatorid tooth are known from the basal conglomerate of the Lellinge Greensand Formation of Copenhagen. Fragmentary turtle material has been found in Faxe and Limhamn quarries and in the late Danian København Limestone of Copenhagen. Bird remains are exclusively known from Limhamn quarry. Together this gives a picture of a diverse vertebrate fauna from the Danian of southern Scandinavia.

Early burst in the colonization of continental ecospace and the evolution of behaviour

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The colonization of land was a major evolutionary transition. Ichnological evidence suggests that this process may have begun at the end of the Ediacaran, with incursions into very shallow, marginal-marine settings. Animals made their first unequivocal amphibious terrestrial forays during the Cambrian and had managed to establish themselves in truly alluvial environments by the Late Ordovician. The remainder of the Palaeozoic is characterized by an explosion of diversity and a progressive expansion from coastal settings inland into rivers, floodplains, deserts and lakes; as well as increasing colonization of infaunal ecospace and the creation of new niches. A framework is presented for analysing ecospace occupation and ecosystem engineering through the use of trace fossil data. The colonization of each new continental environment may be viewed as a series of repeated experiments in ecospace filling and niche creation. A pattern emerges in which colonization of a new environment is followed by rapid filling of ecospace, after which animals establish new behavioural programmes represented initially by the appearance of original trace fossil architectural designs, and subsequently by a proliferation of ichnogenera representing variation upon these established themes. This pattern is consistent with the early burst model of diversification.

Impact of spatial heterogeneities on Ediacaran communities from Mistaken Point, Newfoundland

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Bedding-plane assemblages of Ediacaran fossils at Mistaken Point, Newfoundland, Canada (~565 Ma), are among the oldest known examples of macroscopic communities. The constituent organisms have few similarities with living forms, making their relationship with their environment difficult to assess. Their preservation in large *in situ* bedding plane populations allows original spatial distributions to be analysed, shedding light on the interactions between taxa and their environment. The most fossiliferous 'E' surface was mapped using differentiated GPS to millimetre accuracy. Spatial correlations between taxa were identified using Bayesian network inference, then described and analysed using pair correlation functions. Of the eight inter-taxa relationships found, five were the result of impact by four different environmental heterogeneities, and three the result of interactions between living and dead organisms. For two interactions, the presence of small-scale environmental aggregations with large-scale segregations shows that these taxa were competing over environmental resources. The spatial distributions of these competitive interactions were found to mirror extant communities where taxa reduced inter-specific competition by niche differentiation instead of trading off competitive advantages over colonization ability. Thus, while over ten times smaller than individual taxa interactions, these environmental impacts were still sufficient to drive competition and likely niche differentiation.

posters

An enigmatic large discoidal fossil from the Pennsylvanian of County Clare, Ireland

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A rare and unusual, large solitary discoidal fossil, *c*. 130–135 mm in diameter, has been discovered on a paving slab quarried from the cyclothemic Central Clare Group (Kinderscoutian, Pennsylvanian, Carboniferous) of western Ireland. The fossil impression consists of a smooth raised inner discoidal area, *c*. 80 mm across, surrounded by a slightly lower-relief outer ring with eight prominent equidistant ovoid raised nodes towards the outermost margin. The specimen is surrounded by a shallow groove. Classification of this enigmatic fossil remains unclear, although the octoradially symmetrical body plan suggests possible cnidarian affinities. The specimen is palaeoecologically interesting: it occurs within the world-renowned Liscannor Flagstone, which consists of thinly bedded, fine-grained sandstones which are extensively covered by prominent, sinuous to meandering *Psammichnites* [= *Olivellites*] horizontal feeding trails (*c*. 10–20 mm in width). This sedimentary facies is generally interpreted as representing mouth bar sedimentation in a delta front succession. The organism responsible for the discoidal impression was clearly too large to have made the *Psammichnites* trails and it occurs on a portion of the slab where these burrows are scarce. Either the *Psammichnites* trace-makers deliberately

avoided this larger solitary organism, or this is merely chance preservation, with intensive bioturbation routinely obliterating other impressions of similar discoidal organisms.

Testing hypotheses of niche partitioning in isolated fossil mammal teeth based on quantitative 3D dental microwear texture analysis

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The earliest, most basal mammals are widely considered to be generalized insectivores. Accumulating evidence indicates that slightly later mammals have greater ecomorphological diversity than previously suspected, but testing for dietary differences between the earliest taxa, known primarily from teeth alone, is problematic. This study tests the hypothesis that tooth microwear varies between extant insectivores which are known to exhibit partitioning of the dietary niche, and that analysis of tooth microwear textures can be used to detect subtle dietary differences between fossil taxa. Our analysis extends recent work on insectivorous bats by incorporating data from four species of sympatric ground-feeding and semi-aquatic shrews, and other mammal insectivores. The results elucidate the pattern of tooth textural differences among small mammal insectivores and provide new insights into differences between aerial and ground-based feeding. Application to fossil mammals provides further support for the hypothesis that 3D textural microwear analysis can be used for subtle, within-guild dietary discrimination in taxa known only from teeth.

Far offshore depositional conditions and animal behaviour as indicated by trace fossils in the Eocene Lillebælt Clay Formation, Denmark

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The major Ypresian transgression is evident in earliest Eocene strata of northwestern Europe. The Eocene strata of Denmark comprise mostly regionally distributed deposits of the Røsnæs Clay, Lillebælt Clay and Søvind Marl formations. The Lillebælt Clay Formation was formed during late Ypresian to early Lutetian, laterally equivalent to an interval of the Horda Formation in the North Sea Central Trough. It consists mostly of greyish to greenish, non-calcareous clay. In western Zealand, the Lillebælt Clay Formation contains a diverse trace-fossil assemblage, formally described for the first time. The preservation of the trace fossils is predominantly related to early diagenetic enhancement. The trace-fossil assemblage is characterized by a combination of dwelling and feeding burrows representative of the distal Cruziana ichnofacies and comprises *Atollites zitteli*?, *Bichordites* isp., *Chondrites* isp., *Dreginozoum beckumensis*, *Ophiomorpha nodosa*, *Phymatoderma melvillensis*, ?*Rhizocorallium* isp., *Spongeliomorpha* isp., and unnamed clusters of small burrows. The bioturbation took place in hemipelagic clay of a shelf setting far from the palaeocoast. At least periodically, the oxygen levels were high enough to enable tracemakers to colonize the sea bottom.

Exceptionally preserved arthropodan microfossils from the Winneshiek Lagerstätte

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The Middle Ordovician Winneshiek Shale (Darriwilian; Winneshiek County, Iowa, USA), hosts a Konservat-Lagerstätte that has yielded a diverse fauna including eurypterids, phyllocarids, ostracods, bromalites, linguloids, giant conodonts, mollusks, acritarchs and algal cells, and possible jawless fish. The shale is rich in organic content, including fragmentary cuticular remains. Palynological acid treatment enables the extraction of these small carbonaceous fossils (SCFs) from the matrix, allowing a more detailed view of their morphology. In addition to abundant eurypterid material, this method has yielded exceptionally well-preserved crustacean-type setae and a population of distinctive microfossils that we tentatively identify as the mandibles of a small-bodied crustacean. The Winneshiek mandibles share some important features with those of branchiopod crustaceans, including the apparent lack of a mandibular palp, but they are unusual in having a curved gnathal edge with no division into incisor and molar processes. The abundance of the mandibles points to a previously cryptic organism of importance in the Winneshiek biota or a nearby ecosystem. By comparison to previously described crustacean SCFs from the Cambrian of Canada, the Winneshiek fossils both extend the range of this taphonomic window, and imply an ecological expansion of small-bodied crustaceans into restricted, marginal marine environments by the Middle Ordovician.

posters

Testing functional hypotheses in cinctans (middle Cambrian Echinodermata) using computational fluid dynamics

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Cinctans are a clade of non-radial echinoderms restricted to the middle Cambrian of Gondwana (including Avalonia) and Siberia. They comprise a flattened body (theca) with an anterior mouth and a stiff posterior appendage (stele). The theca shows considerable variation in shape among species, ranging from strongly asymmetrical to almost bilaterally symmetrical; the functional significance of this morphological variation is unclear. To explore this, three-dimensional models of six cinctan taxa were constructed using the open-source 3D creation suite Blender. These taxa were chosen to represent a range of morphologies from across cinctan phylogeny. The models were then subjected to computational fluid dynamics simulations using the modelling software COMSOL. The results show that drag and lift were elevated in taxa with a more strongly asymmetrical theca, suggesting that these species were more prone to dislodgement in life. This study will shed light on the ecology of this unique clade, contributing to our understanding of the selection pressures acting on echinoderms during the Cambrian.

Plant macrofossils from the Homerian (Wenlock, Silurian) of Stonehaven, Scotland

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The Cowie Harbour fish bed is exposed at an offshore locality north of Stonehaven, Aberdeenshire, UK, and preserves a diverse fossil biota including jawless fish and euarthropods. This locality is best known for producing the earliest evidence of animals inhabiting an aerial terrestrial environment, in the form of a fragmentary millipede with preserved orifices for air-breathing. Although the age of the Cowie fish bed has been regarded as Homerian (late Wenlock) based on the preserved sporomorph diversity, the section has not yielded plant macrofossils to date. A recent collection effort at this locality produced an assemblage of well-preserved plant macrofossils. In addition to simple forms with dichotomous branching similar to the early land plant *Cooksonia*, new discoveries include a large (> 5 cm in length) lycophyte-like taxon characterized by helically arranged scaly leaflets and an absence of ramifications. Aspects of the morphology of the 'Cowie lycophyte' resemble stratigraphically younger vascular plants, such as the Gorstian (Ludlow, Silurian) *Baragwanathia* from Australia, and the Pragian (Lower Devonian) *Asteroxylon* from the Rhynie Chert in Scotland. Pending further study, these findings tentatively push back the earliest occurrence of complex vascular plants in the fossil record, and suggest a cryptic diversification of this group during the early Silurian.

Semuridia dorsetensis (Bivalvia, Pergamidiidae): new chronostratigraphy, palaeobiogeography and palaeoautoecology data from the Pliensbachian (Lower Jurassic) of Iberia

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The pterioid bivalve *Semuridia dorsetensis* was first described by Cox in 1926 as a new inoceramid species and later assigned to Melville´s genus *Semuridia* in 1969. There are some similitudes with inoceramids due to the external mytiliform outline. Nevertheless, the hinge details and a small anterior auricle distinguish them. Only a few individuals are known: the holotype and three paratype specimens held at the Natural History Museum, London. They were also referred as "unusual bivalves". A large sample of individuals was collected from Basque-Cantabrian and Asturias Basins sections (northern Iberia). The newly-collected material is chronostratigraphically well-constrained as Jamesoni Chronozone (Brevispina Subchronozone) to Ibex Chronozone intervals in those basins. The type material comes from Obtusum Chronozone (Obtusum Subchronozone) on the Dorset coast, UK (Wessex basin). It might be interpreted that the populations of southern England were later represented (~4.5 Ma) in the northern Iberian basins. Those migrations seem to be related to sedimentary facies changes as all occurrences relate them with organic-rich mudstones. The inferred benthic, epifaunal suspensivorous autoecology of these species does not exclude the facultative pseudoplanktonic habit due to the presence of a byssal notch. Alternatively they could be regarded as capable of surviving in low-oxygenated bottom waters.

Confirming the validity of late Ediacaran bioturbation via study of 3D morphology, taphonomy, and petrology

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Molecular clocks predict the origin of the clade Metazoa tens of millions of years prior to the Cambrian Explosion. However, existing body fossil evidence for their presence in the preceding Neoproterozoic Era is equivocal. Trace fossils provide an alternative record of metazoan morphological and behavioural evolution. Material from the late Ediacaran Khatyspyt Formation (~553Ma) of Arctic Siberia has been suggested to record evidence of abundant bioturbation, but this interpretation has been disputed. Here we combine X-ray tomography, SEM, and petrological analyses to investigate the three-dimensional morphology and taphonomy of this important material. The material is demonstrated to comprise of randomly-oriented series of bowl-shaped structures within a sedimentary 'halo', while taphonomic studies indicate that the structures have diffuse, silicic mineralogical boundaries. These results refute the suggestion that the Siberian material preserves body fossils of tubular organisms similar to *Cloudina*, and instead confirm an ichnological origin. We propose meniscate backfill as a mechanism to explain the morphology and mineralogy of these structures, implying that triploblastic Eumetazoan burrowers were present more than ten million years before the Cambrian Explosion.

Macroevolutionary trends through the Lower Jurassic in Bulgaria

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The Lower Jurassic (201–174 Ma) was a time of global environmental change. At the beginning of the Lower Jurassic, ecosystems were recovering from the late Triassic mass extinction event and subsequently, in the early Toarcian, there was a benthic crisis. Despite the importance of tracking the long-term faunal trends of ecosystem recovery, stability and collapse through this critical 27 myr time period, relatively few studies have documented in detail the ecological changes between the two extinction events. We will present a quantitative palaeoecological analysis of invertebrate macrofauna from the upper Hettangian–upper Toarcian sedimentary successions in northwest Bulgaria. Bulgaria provides a unique opportunity to investigate effects of changing sea-level and resulting facies variation on ecosystem stability from the eastern margin of the Tethyan epicontinental platform. This location has a more direct link with the open ocean and is therefore more likely to be representative of worldwide biotic changes, than the better studied Lower Jurassic sections in northwest Europe. Differences include a lack of black shales and variability in faunal turnover leading up to and during the early Toarcian, showing this extinction event and associated environmental changes differed between Bulgaria and northwest Europe.

A new fauna of early Carboniferous Chondrichthyans from the Scottish Borders

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Chondrichthyan teeth from a new locality in the Scottish Borders expand evidence of early Carboniferous chondrichthyans in the UK. The interbedded dolostones and siltstones of the Ballagan Formation exposed along Whitrope Burn are interpreted as a restricted lagoonal environment with fluvial input. This site is dated to the Late Tournaisian – Early Viséan by palynological evidence. The diverse dental fauna documented here is dominated by large crushing holocephalan toothplates, with very few, small non-crushing chondrichthyan teeth. Our samples are consistent with worldwide evidence that chondrichthyan crushing faunas are common following the Hangenburg extinction event. The lagoonal habitat represented by Whitrope Burn may represent a temporary refugium which is host to a near-relict fauna dominated by large crushing holocephalan chondrichthyans. Many of these had already become scarce in other localities by the Viséan and became extinct later in the Carboniferous. This fauna provides early evidence of endemism or niche separation within western European chondrichthyans at this time. This evidence points to a complex picture in which crushing chondrichthyan diversity is controlled by narrow spatial shifts in niche availability over time.

Adaptive radiation of marine crocodylians following the end-Cretaceous extinction

***Polly Russell and Nick Longrich**

University of Bath, UK

The Gavialoidea, including Gavialidae and Tomistominae, are crocodilians typically recognized by their specialized snout morphology. The long, tubular (longirostrine) snout is a derived adaptation for piscivory, observed convergently in multiple crocodilian lineages. Existing fossils show this morphology to be highly conserved amongst Gavialoidea. Here we present new fossil material from the Paleocene deposits of Morocco that reveals unprecedented levels of disparity in skull shape, indicating that the gavialoid taxa staged a major opportunistic radiation in the aftermath of the K/Pg extinction. The new material includes four species. The first, a new *Maroccosuchus* species, exhibits robust bullet-shaped teeth and broad, blunt snout, seemingly suited for durophagy. The second, a new species of *Argochampsa*, shows a uniquely shortened snout and a reduced tooth count. The third is a new genus of small gharial. The fourth has a tooth count at least 50% greater than any known gharial species, with laterally projecting teeth and a hyper-elongate snout. This high disparity in the aftermath of the K/Pg extinction is mirrored in another clade of longirostrine, marine crocodilians – the Dyrosauridae. This suggests a more widespread opportunistic radiation of marine reptiles in the Paleocene, exploiting niches vacated by mosasaurs and plesiosaurs after the K/Pg extinction.

Taphonomy of keratin in archosaurs

***Evan T. Saitta, Jakob Vinther and Chris Rogers**
University of Bristol, UK

Keratinous structures are common and diverse. Despite interest in feather evolution, little is known about keratin taphonomy. There is uncertainty as to what sorts of signatures keratin leaves in the fossil record and if keratin protein itself can even survive fossilization. Here, a series of decay and maturation experiments attempts to characterize taphonomic changes in a variety of Archosaurian feather and scale keratin types. These changes were examined from the chemical to the morphological level using scanning electron microscopy and pyrolysis gas chromatography mass spectrometry. Various keratin types appear to exhibit different taphonomic patterns and a series of unexpected results were retrieved. None of the observed keratin textures has been reported with confidence in fossil keratinous tissues, which only preserve remains of melanosomes and calcium phosphate salts from the keratin matrix. When maturing feathers (24 hours at 200 °C/250 bar and 250 °C/250 bar), we observe that the keratin becomes a smelly highly viscous fluid, supporting previous work showing that proteins have little or no long-term preservation potential as they fragment and become volatile. Some studies have assumed that keratins fossilize, which our experiments cast serious doubt on. Studies of archosaur integument evolution must consider taphonomic loss of the actual keratin.

Tetrapods from the Tournaisian of Nova Scotia and northern Britain: diversity, associated fauna and environmental setting

Tim Smithson[1], Jenny Clack[1], Jason Anderson[2] and Chris Mansky[3]
[1]*University Museum of Zoology, Cambridge, UK*
[2]*University of Calgary, Canada*
[3]*Blue Beach Fossil Museum, Hantsport, Canada*

Tetrapod trackways have been known from the Tournaisian Horton Bluff Formation at Blue Beach, Nova Scotia, for more than 150 years. Tetrapod body fossils were first found there in the 1960s. Regular walking of the beach over the past 15 years has revealed a wealth of new material in the talus from the eroding cliffs. Many isolated limb and girdle bones have been collected, representing at least four taxa. All the remains are from similar sized animals, in the range 1–1.5 m long. This contrasts with the tetrapods discovered recently from the coeval deposits of the Ballagan Formation in the Tweed Basin of northern Britain where as many as ten new taxa have been found. Here, alongside large individuals, much smaller adult forms *c*. 30 cm long are present. The associated vertebrate fauna at Blue Beach includes rhizodonts, elasmobranchs, large actinopterygians and occasional gyracanthids. Lungfish are rare. This differs from the Tweed Basin fauna where gyracanthids are common, lungfish are diverse, actinopterygians are small and elasmobranchs are almost entirely absent. The Horton Bluff Formation is thought to have been deposited in marginal marine conditions, whilst the Tweed Basin Ballagan Formation probably accumulated on extensive low-relief vegetated coastal-alluvial plains.

Cracking dinosaur endothermy: palaeophysiology unscrambled

***Max. T. Stockdale[1], Michael. J. Benton[1] and Octávio Mateus[2]**
[1]*University of Bristol, UK*
[2]*Universidade Nova de Lisboa, Portugal*

The amniote eggshell is a respiratory structure adapted for the optimal transmission of respiratory gases to and from the embryo according to its physiological requirements. Therefore amniotes with higher oxygen requirements, such as those that sustain higher metabolic rates, can be expected to have eggshells that can maintain a greater gas flux to and from the egg. Here we show a highly significant relationship between metabolic rates and eggshell porosity in extant amniotes that predicts highly endothermic metabolic rates in dinosaurs. This study finds the eggshell porosity of extant endotherms to be significantly higher than that of extant ectotherms. Dinosaur eggshells are commonly preserved in the fossil record, and porosity may be readily identified and measured. This provides a simple tool to identify metabolic rates in extinct egg-laying tetrapods whose eggs possessed a mineralized shell.

Assembling the Early Palaeozoic terranes of Japan

***Christopher P. Stocker[1], Mark Williams[1], Simon Wallis[2], Tatsuo Oji[3], Philip D. Lane[4], Thijs R. A. Vandenbroucke[5], David J. Siveter[1], Derek J. Siveter[6], Gengo Tanaka[7] and Toshifumi Komatsu[7]**
[1]*University of Leicester, UK*
[2]*Nagoya University, Japan*
[3]*Nagoya University Museum, Nagoya University, Japan*
[4]*Keele University, UK*
[5]*Ghent University, Belgium*
[6]*Oxford University Museum of Natural History, UK*
[7]*Kumamoto University, Japan*

The lower to middle Palaeozoic rock succession of Japan is replete with fossils that include trilobites, conodonts, ostracods and brachiopods. Various authors have suggested biogeographical relationships between these faunas and those of the Silurian and Devonian of the Australian segment of Gondwanaland and also the supposedly adjacent South China and North China plates, but there is no clear consensus on the palaeogeography of Japan at this time, and the published accounts of the fossil assemblages show no consistent patterns. In part, this reflects an incomplete record of the lithofacies distribution of the fauna, and of the palaeoecological analysis of the different faunas, which includes those with benthic and pelagic lifestyles. The South Kitakami Terrane of northeast Honshu, the Hida-Gaien Terrane of central Honshu, and the Kurosegawa Terrane of Shikoku and Kyushu islands, southwest Japan, are the three Lower Palaeozoic terranes of Japan. We provide a brief inventory of their stratigraphy and fossils, and show how new taxonomic, palaeoecological and stratigraphical studies provide a means of determining faunal affinities and, hence, keys to the early palaeogeographical position and evolution of the Japanese islands.

Heterochrony in the skulls of palaeognathae

*Nicola Stone
University of Bristol, UK

The palaeognathae are one of two clades (the other being the Neognathae) comprising the avian crown group. The clade comprises the secondarily flightless ratites (ostrich, emu, rhea, cassowaries, kiwis and their extinct relatives, and the extinct elephant bird and moa); and the aerial tinamous and extinct lithornids. This study explores sequence heterochrony (changes in temporal order of developmental events) of suture closure in their skulls compared with neognath species. Heterochrony, a key mechanism in dictating organismal size and shape and the evolution of organismal form, has been linked to the evolution of birds. Birds may be paedomorphic dinosaurs and many of the diagnostic characters of palaeognaths include paedomorphic features of feathers, wings, keel-less sternum, palate, cranial sutures and pectoral girdle. Over 400 museum specimens from hatchlings to adults were observed, and closure of 20 different sutures recorded in 12 species. The order of suture closure is highly conserved across species and clades, with sutures closing from the back to the front of skull. Notable exceptions may be attributable to biomechanical stress during feeding. The age of the birds at suture closure was considered with respect to altricial/precocial behaviour and size of eye cavity.

Records of terrestrial palaeoclimate and palaeoecology of Paleocene–Eocene south-central Alaska: the Chickaloon and Arkose Ridge Formations

David Sunderlin[1] and Christopher J. Williams[2]
[1]*Lafayette College, Pennsylvania, USA*
[2]*Franklin & Marshall College, Pennsylvania, USA*

Two non-marine Paleocene–Eocene units in Alaska's Matanuska Valley–Talkeetna Mountains Basin contain a rich palaeoenvironmental record at a time of hothouse climate conditions. Within the Chickaloon Formation, large cupressaceous conifer trees and coal are preserved in mire depositional environments while a suite of floodplain deposits preserve leaves, shoots of conifers and equisetaleans, angiosperm fruits, and cupressaceous cones. The generally coarser Arkose Ridge Formation preserves a similar palaeoflora in rare ponded-water facies. Recent analysis of stratigraphic successions, fossil plant and insect collections, and geochemical data suggest that these units were deposited under wet and warm temperate palaeoclimatic conditions. Leaf physiognomic estimates range between 10–14 ˚C MAT and palaeoprecipitation is high as well (120-–160 cm/yr). The occurrence of palmetto fronds (*Sabalites*) and high seasonal wood ring production support the notion of a yearly-averaged ameliorated climate. Palaeoecological interactions between insect herbivores and dicot leaves show an unexpectedly low leaf damage frequency (~7–13%) when compared to similar studies of nearly coeval assemblages from lower palaeolatitudes on North America with only marginally higher MAT estimates. We propose that this result is related to the non-analogous situation of warm climate conditions under a high-latitude seasonal light regime.

A process-based framework for interpretation of palaeontological point distributions

Andrew R. H. Swan
Kingston University, UK

The distribution of point phenomena has customarily been analysed using the nearest-neighbour statistic: this discriminates between regular, random and clustered distributions. The scheme proposed here extends this by including a second descriptor: the coefficient of variation of nearest-neighbour distances. Point distributions can then be ordinated in the parameter space defined by these two measures. Simulations can be produced according to various hypotheses about the processes underlying the distribution of palaeontological point phenomena such as trace fossils. These hypotheses include: random, deterministic/geometrical, attraction (or positive feedback), repulsion (negative feedback), paired/grouped, and multi-phase. The predicted outcomes of these processes occupy distinctive fields in the parameter space. The analysis in this framework of real trace fossil distributions reveals differences that may assist in interpreting the organisms, the ecosystem and the sedimentary dynamics.

Testing for palaeoenvironmental preference and substrate affinity in Carboniferous echinoids

***Jeffrey R. Thompson** and **David J. Bottjer**
University of Southern California, USA

Echinoids in modern oceans tend to occupy different substrates dependent upon their life mode, and many echinoids have evolved to live on or in certain substrates. Little is known about echinoid substrate affinities in the Palaeozoic, and rigorous testing of hypotheses regarding substrate affinities has never been undertaken. Five families of echinoids are abundant in the Carboniferous, the archaeocidarids, lepidocidarids, lepidesthids, proterocidarids, and palaechinids, which display a disparate array of morphologies, many of which may be adapted to specific substrates and life modes. In order to test for substrate affinities in these echinoids, a database was made of Carboniferous echinoids in museum collections comprising most of the known Carboniferous echinoid fossil record from America and Europe. Information on lithology (carbonate *vs*. siliciclastic) and grain size was recorded to test for substrate specificity in these taxa. The distribution of different clades of echinoids in the Carboniferous was then compared to the distribution of sediment types in the Carboniferous. The results show a significant affinity for carbonate sediments in all examined clades. It appears that Carboniferous echinoids preferred carbonate sediments. Additionally, specimens were scored for their taphonomic state of preservation to see how differing palaeoenvironments and depositional settings affect Palaeozoic echinoid taphonomy.

Considerations on the substitution of a type species in the case of the sauropod dinosaur *Diplodocus*

Emanuel Tschopp[1,2] and Octávio Mateus[2,3]
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[2]*Universidade Nova de Lisboa, Portugal*
[3]*Museu da Lourinhã, Portugal*

The ICZN accepts a morphologically undiagnosable type species for a genus, as long as the type species clearly belongs to the genus in question. This is the case in the sauropod dinosaur *Diplodocus*. Whereas the Code might make sense in poorly known genera, a substitution of the type species is preferable in the case of *Diplodocus*. *Diplodocus* is currently specified by *D. longus*. Only two caudal vertebrae and a chevron of its holotype remain reasonably complete. These can be referred to *Diplodocus* as generally perceived, but cannot be distinguished from other *Diplodocus* species based on autapomorphies. Thus, *Diplodocus* is specified by a nomen dubium. *Diplodocus carnegii* is known by the entire skeleton but the skull and the lower foreleg. Casts of its holotype are available in numerous museums around the world, and the species is generally used as reference for studies including *Diplodocus*. Therefore, it would make little sense to retain the fragmentary species *D. longus* as the type. In order to maintain *Diplodocus* with the generally accepted content, and provide taxonomic stability of the higher-level clades for which it is a specifier, it is preferable to substitute the current type species *D. longus* by *D. carnegii*.

posters

FossilBlitz! Extending the BioBlitz concept to deep time

Richard J. Twitchett[1], J. Alistair Crame[2], Vanessa C. Bowman[2], James R. Brown[3], Alexander M. Dunhill[4], William J. Foster[5], Crispin T. S. Little[4], Alistair J. McGowan[6], Autumn C. Pugh[4] and James D. Witts[4]
[1]*Natural History Museum, London, UK*
[2]*British Antarctic Survey, UK*
[3]*Weymouth, UK*
[4]*University of Leeds, UK*
[5]*University of Texas, USA*
[6]*BioGeoD, Edinburgh, UK*

BioBlitz events involve intense, usually time-limited, surveys of modern ecosystems undertaken by scientists and volunteers in a joint effort to document local biodiversity. Participants thus become engaged with local biodiversity issues and efficiently generate large quantities of data. As part of NERC's 50th Anniversary Summer of Science, we extended this concept to deep time. Our 'Jurassic FossilBlitz' brought together palaeontologists and members of the general public of all ages for a race against the tide to find, count and record the Early Jurassic marine fossils preserved on the rocky foreshore southwest of Lyme Regis, UK. The event targeted a short sequence through the Blue Lias Formation, spanning the Hettangian/Sinemurian interval. Each individual or family group was allocated a quadrat and simple instructions to set the quadrat down randomly and to count the different fossils within it, using an identification chart. Experts were on hand to provide assistance. Some 200 individuals participated, contributing 87 quadrats and *c.* 1,600 fossil counts. Although primarily an outreach activity that enabled the public to collect quantitative fossil data and gain an appreciation of past biodiversity change, the

data generated by FossilBlitz have some scientific value as demonstrated by comparison with published studies.

Phosphate and first principles

***Vishruth Venkataraman, Philip C. J. Donoghue and Jakob Vinther**
University of Bristol, UK

Lampreys, as the nearest extant sister group to gnathostomes, provide a crucial window into the evolution of early vertebrate body plans, including the homology of cartilaginous structures. However, the impoverished fossil record, along with poor preservation of individual specimens and poor understanding of lamprey taphonomy, aggravates the potential for character misinterpretation, particularly stem-ward slippage. We describe the first ever phosphatized putative lamprey fossils, collected from the Cenomanian of Haquel and Hadjoula in Lebanon. These fossils show preservation of myomeres and evidence of axial structures, as well as degraded sarcomeres and other cellular-level features. While phosphatization has been studied in other clades, particularly arthropods and teleost fish, preserving three-dimensional detail, our analysis, including a combination of light microscopy, UV imaging, reconstructions and SEM, reveal a novel '2½-D' preservation which preserved topology without depth. Any palaeontological work must take into account pure topology without *a priori* assumptions of phylogenetic positioning, and falsifiable, grounded claims about synapomorphies while also considering taphonomic processes. Our work helps both understand novel preservational mechanisms in early chordates, and tests the relevance of previous work on mapping decay patterns in cyclostomes.

Solving the controversy of Earth's oldest fossils using electron microscopy

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[2]*The University of Western Australia, Australia*
[3]*The University of New South Wales, Australia*
[†]*University of Oxford, UK (deceased)*

Filamentous microstructures from the 3.46 billion-year-old Apex chert of Western Australia have been interpreted as remnants of Earth's oldest cellular life, but their purported biological nature has been questioned on numerous occasions. Here we analyse new material from the original 'microfossil site' using high spatial resolution electron microscopy to decode the detailed morphology and chemistry of the Apex filaments. Light microscopy shows that the newly discovered filaments are identical to the previously described 'microfossil' holotypes and paratypes. Scanning and transmission electron microscopy data show that the filaments comprise chains of potassium- and barium-rich phyllosilicates, interleaved with quartz and iron oxides, plus a later carbon coating. Morphological features previously cited as evidence for cell compartments and dividing cells are shown to be carbon-coated stacks of phyllosilicate crystals. 3D filament reconstructions reveal non-rounded cross sections and examples of branching incompatible with a filamentous prokaryotic origin for these structures. At the nano-scale, the Apex filaments exhibit no biological morphology nor bear any resemblance to younger *bona fide* carbonaceous microfossils. Instead, it appears that these microstructures formed during fluid-flow events that facilitated the hydration, heating and exfoliation of mica flakes, plus the adsorption of barium, iron and carbon within a hydrothermal system.

A new giant species of thresher shark from the Miocene of the United States and Malta

David J. Ward[1] and Bretton Kent[2]
[1]*Natural History Museum, London, UK*
[2]*University of Maryland, USA*

In the late Early and Middle Miocene there was burst of gigantism in a number of unrelated species of shark. This event corresponded with the warmest interval of the Neogene, the so-called 'middle Miocene climatic optimum', giving high oceanic productivity. In 1942, Leriche described a large species of thresher shark from the Neogene of the USA which he named *Alopecias* (= *Alopias*) *grandis*. The holotype was from the Miocene Calvert Formation of Nomini Cliffs, Virginia. The other was reworked from the Neogene of the Charleston area. This species is poorly known and has received little attention in the subsequent literature. An undescribed species, of similar size but with a serrated cutting edge, is present in slightly younger beds in the Calvert Formation of Calvert Cliffs, Maryland. Both species are present in the Miocene of Malta. The new serrated species has now been described and is currently in press. It is unlikely that the new giant thresher shark possessed an elongated dorsal tail lobe seen in the Recent species. As the dentition is converging on that of a great white shark and its size was similar, it is reasonable to suppose that the body outline was also similar.

An examination of feeding ecology in Pleistocene proboscideans from southern China (*Sinomastodon*, *Stegodon*, *Elephas*), by means of dentral microwear texture analysis (DMTA)

***Hanwen Zhang[1], Yuan Wang[2], Christine M. Janis[1] and Mark A. Purnell[3]**
[1]*University of Bristol, UK*
[2]*Chinese Academy of Sciences, Beijing, China*
[3]*University of Leicester, UK*

Proboscideans make interesting case studies in mammalian palaeobiology, as both fossil and extant forms show a broad and flexible range of diets, which do not always go hand-in-hand with their phenotypic adaptations. Here we present a 3D dental microwear texture analysis exploring the palaeodiet of three successive genera of proboscideans inhabiting South China during the Pleistocene: *Sinomastodon*, *Stegodon* and *Elephas*. Analysis of variance and pairwise testing based on textural parameters derived from scale-sensitive fractal analysis finds significant differences between *Elephas* and the other two genera. This is borne out by a standard anisotropy-complexity plot, which suggests that *Sinomastodon* and *Stegodon* from the Early and Middle Pleistocene were committed browsers, whereas *Elephas* from the Middle and Late Pleistocene shows a broader feeding niche, possibly including both browsing and grazing. The results of this preliminary study, although based on small sample sizes, are encouraging. They support previous work indicating a complex process of Pleistocene environmental changes in South China (as opposed to a unipolar trend of cooling, drying and forest deterioration), driving the succession of three characteristic faunal assemblages: Early Pleistocene *Gigantopithecus* – *Sinomastodon* fauna, Middle Pleistocene *Ailuroposa* – *Stegodon* fauna (*sensu stricto*), and Late Pleistocene *Homo* – *Elephas* fauna.

The Palaeontological Association

Annual General Meeting

16.45

Tuesday

15th December

Papers

Annual Meeting 2015

Notification is given of the 59th Annual General Meeting

This will be held at Cardiff University, UK, on 15th December 2015, following the scientific sessions.

AGENDA

1. Apologies for absence
2. Minutes of the 58th AGM, University of Leeds
3. Trustees Annual Report for 2014
4. Accounts and Balance Sheet for 2014
5. Election of Council and vote of thanks to retiring members
6. Report on Council Awards
7. Annual address

DRAFT AGM MINUTES 2014

Minutes of the Annual General Meeting held on Wednesday, 17th December 2014 at the University of Leeds, UK.

1. **Apologies for absence.** Dr M. Sutton, Dr R. Owens, Dr M. Ruta.

2. **Minutes.** Proposed by Prof. G. Sevastopulo and seconded by Mr D. Ward, the minutes of the 2013 AGM were agreed a true record by unanimous vote.

3. **Trustees Annual Report for 2013.** Proposed by Dr A. B. Smith and seconded by Prof. D. A. T. Harper, the report was agreed by unanimous vote of the meeting. The small year-on-year decline in membership numbers was discussed and, although not considered significant at present, a small drop in the number of student members was noted.

4. **Accounts and Balance Sheet for 2013.** Proposed by Dr C. T. S. Little and seconded by Dr P. W. Skelton, the accounts were agreed by unanimous vote of the meeting. A question concerning the high spend on the Designated Funds was raised and the Treasurer confirmed that Council regularly monitors the situation and that the Designated Funds are periodically topped up from General Funds.

5. **Election of Council and vote of thanks to retiring members.** Prof. M. J. Benton extended a vote of thanks to the following members of Council who were retiring from their positions this year: Dr C. Jeffrey-Abt, Dr A. McGowan and Dr R. Owens. The following members were elected to serve on Council: President: Prof. D. A. T. Harper; Vice Presidents: Dr M. Sutton and Mr D. J. Ward; Treasurer: Mr P. Winrow; Secretary: Prof R. J. Twitchett; Editor-in-Chief: Dr A. B. Smith; Editor Trustees: Prof C. H. Wellman, Dr M. Ruta; Newsletter Editor: Dr J. Hellawell; Book Review Editor: Dr T. Challands; Publicity Officer: Dr L. Herringshaw; Education Officer: Dr C. Buttler; Outreach Officer: Dr F. Gill; Internet Officer: Mr A. R. T. Spencer; Meetings Coordinator: Dr T. Vandenbroucke;

Ordinary Members: Dr R. J. Butler, Dr C. T. S. Little, Dr M. McNamara, Dr M. Munt, and Dr I. Rahman. Dr C. Buttler will organize the Annual Meeting in 2015 at the University of Cardiff and National Museum of Wales, UK.

6. **Association Awards.** The following awards were announced:

Lapworth Medal to Prof. R. A. Fortey (The Natural History Museum, London).

President's Medal to Prof. P. C. J. Donoghue (University of Bristol).

Hodson Award to Dr. M. E. McNamara (University of Cork).

Mary Anning award to Dr Christoph Bartels.

The President's Award was made to D. Button (University of Bristol and The Natural History Museum, London).

The Council Poster Prize was presented to Jennifer Hoyal Cuthill (University of Cambridge) and Edine Pape (University of Leeds).

Undergraduate Research Bursaries were awarded to: Mr N. Adams, Royal Holloway, supervised by Prof. M. Collinson; Ms H. Betts, University of Bristol, supervised by Prof. P. Donoghue; Mr C. Bracher, Plymouth University, supervised by Dr C. Smart; Mr A. Hudson, University of Southampton, supervised by Dr I. Harding; Mr J. Bestwick, University of Leeds, supervised by Dr C. Little; Ms R. Hodge, University of Nottingham, supervised by Dr B. Lomax; Mr I. Smith, Plymouth University, supervised by Dr K. Page; Mr L. Schröer, Ghent University, supervised by Dr Thijs Vandenbroucke; Mr F. Smithwick, University of Bristol, supervised by Prof. M. Benton; and Mr J. Teoh, University of Bristol, supervised by Dr J. Vinther.

Research Grants were awarded to: Dr Adiël Klompmaker: *Comparative experimental taphonomy of marine crustaceans: clues to their fossil record*; Dr Alejandro Otero, *Phylogeny of basal sauropodomorphs: insights on the early radiation of the group and the transition to Sauropoda*; and Dr Olev Vinn, *Evolution of biofouling and bioerosion in the early Palaeozoic of Baltica*.

Under the Small Grants Scheme, the following awards were announced: Sylvester-Bradley Awards to Mr J. Huang: *Middle Triassic conodont apparatus reconstruction from China;* Dr B. MacGabhann: *Community ecology of Cambrian deep marine scratch-circles;* Ms E. Martin: *Pterosaur body mass, pneumaticity, and flight mechanics;* Mr L. Parry: *Fossil polychaetes from the Palaeozoic of North America;* and Ms N. Stone: *Biomechanical impact of skull sutures in Palaeognathae;* The Callomon Award to Mr W. Foster: *Evolution of the oldest Mesozoic platform margin reef*; Stan Wood Awards to Ms K. Richards: *Tournaisian chondrichthyans from the Scottish Borders;* and Mr D. Foffa: *Ecology and evolution of British Jurassic marine reptiles*; and The Whittington Award to Dr A. Daley: *What is the Cambrian "muscle worm"?*

9. **Annual Address:** The Annual Address entitled "Understanding ancient Earth climates and environments using models and data" was given by Prof. A. Haywood (University of Leeds).

Trustees Annual Report 2014

1. Objectives and Activities

1.1 Aims and Objectives: 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. In order to meet these objectives, the Association continues to increase its range and investment in public outreach and other charitable activities, whilst continuing to support research, publications, and student and speaker attendance at national and international meetings including our flagship Annual Meeting.

1.2 Grants–in-aid for meetings and workshops: The Association provided funds to support the following meetings and workshops: A Geological Society of America Annual Meeting 2014 symposium entitled 'Mass extinctions: volcanism, impacts and catastrophic environmental changes' (Dr. D. Bond, Hull University); a European Geosciences Union General Assembly 2015 session on Stratigraphic Palaeobiology (Dr. S. Danise, Plymouth University); the 13th meeting of Early Stage Researchers in Palaeontology (EJIP), Cercedilla, Spain (Dr S. Domingo, University of Madrid); Echinoderm Palaeobiology Conference, Zaragoza, Spain (Dr S. Zamora, Spanish Geological Survey); a meeting entitled 'Moray geology: past, present, future' (Dr S. Beardmore, Elgin Museum).

1.3 Public meetings: Four public meetings were held in 2014, and the Association extends its thanks to the organisers and host institutions of these meetings.

a. *58th Annual Meeting*. This was held on 16th–19th December at University of Leeds, UK. Dr C. T. S. Little and Dr F. Gill, with local support from colleagues and PhD students, organised the meeting, which included a symposium on 'The photosynthesis revolution: how plants and photosynthetic micro-organisms have bioengineered the planet,' and comprised a programme of internationally recognised speakers. There were 274 attendees. The Annual Address was entitled 'Understanding ancient Earth climates and environments using models and data' and was given by Prof. Alan Haywood (University of Leeds). The President's Prize for best oral presentation from an early career researcher was made to David Button (University of Bristol). The Council Poster Prize was presented to Edine Pape (University of Leeds) and Jennifer Hoyal Cuthill (University of Cambridge).

b. *British Science Festival, Palaeontological Association Symposium*. This is an annual forum for presentations to the public and general scientists. The Symposium 'Virtual Palaeontology' was held at the Lapworth Museum and organised by Dr R. J. Butler (Birmingham). Funds supported presentations by Dr R. Garwood (University of Manchester) and Dr I. Rahman (University of Bristol).

c. *Progressive Palaeontology*. The annual open meeting for presentations by research students was organised by Ms J. Lawrence and a team of colleagues, and was held at the University of Southampton.

d. *Lyell Meeting*. The Association is one of the joint co-organisers of this annual meeting. The 2014 Lyell Meeting was held in March at Burlington House, London, on the topic of 'Deep Sea Chemosynthetic Ecosystems' organised by Dr S. Danise (University of Plymouth) and Dr C. T. S. Little (University of Leeds).

1.4 Publications: Publication of *Palaeontology* and *Special Papers in Palaeontology* is managed by Wiley Blackwell. During 2014, the following volumes were published: *Palaeontology* **57**, comprising six issues; *Special Papers in Palaeontology* **91**, 'The Late Ordovician brachiopods of southern Pembrokeshire and adjacent south-western Wales', by L. R. M. Cocks; and *Special Papers in Palaeontology* **92**, 'Trilobites from Silurian reefs in North Greenland', by H. E. Hughes and A. T. Thomas. During 2014, the decision was made to cease production of *Special Papers* and to replace it with a new journal entitled *Papers in Palaeontology*. 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 thanks Meg and Nick Stroud for assistance with the publication and distribution of the Palaeontological Association *Newsletter*.

1.5 Publicity, Outreach and Engagement: The Association continues to promote palaeontology and its allied sciences through press releases to the national media, radio and television. The Association had stands at the Lyme Regis Fossil Festival and at the Yorkshire Fossil Festival, which were staffed by members of Council, the Executive Officer and volunteers. Council approved a budget of £30,000 to be spent exclusively on Outreach activities. A payment of £1,000 was made to J. McKay for artwork associated with four dioramas to be used at the fossil festivals, and during outreach visits to schools.

1.6 Research Grants: Six applications for Palaeontological Association Research Grants were received. Three were recommended for funding in 2014, totalling £14,784, and were awarded to: Dr Adiël Klompmaker, Florida Museum of Natural History, 'Comparative experimental taphonomy of marine crustaceans: clues to their fossil record'; Dr Alejandro Otero, La Plata University, 'Phylogeny of basal sauropodomorphs: insights on the early radiation of the group and the transition to Sauropoda'; Dr Olev Vinn, University of Tartu, 'Evolution of biofouling and bioerosion in the early Palaeozoic of Baltica'.

1.7 Small Grants Scheme: The scheme received 20 applications. Nine were recommended for funding in 2015, totalling £11,943. Sylvester-Bradley Awards were made to Jinyuan Huang (Chengdu Institute of Geology and Mineral Resources); Dr Breandán MacGabhann (Edge Hill University); Elizabeth Martin (University of Southampton); Luke Parry (University of Bristol), and Nicola Stone (University of Bristol). The Callomon Award was awarded to William Foster (Plymouth University); the Whittington Award to Dr Allison Daley (Oxford University); and inaugural Stan Wood awards to Kelly Richards (University of Cambridge) and Davide Foffa (University of Edinburgh).

1.8 Undergraduate Research Bursaries: In its inaugural year, the Palaeontological Association Undergraduate Research Bursary Scheme attracted 20 applications. Ten were recommended for funding in 2014, totalling £15,000, and were awarded to the following: Neil Adams, Royal Holloway, supervised by Prof. M. Collinson; Holly Betts, University of Bristol, supervised by Prof. P. C. J. Donoghue; Curtis Bracher, Plymouth University, supervised by Dr C. W. Smart; Alex Hudson, University of Southampton, supervised by Dr I. Harding; Jordan Bestwick, University of Leeds, supervised by Dr C. T. S. Little; Ruth Hodge, University of Nottingham, supervised by Dr B. Lomax; Ian Smith, Plymouth University, supervised by Dr K. N. Page; Laurenz Schröer, Ghent University, supervised by Dr T. Vandenbroucke; Fiann Smithwick, University of Bristol, supervised by Prof. M. J. Benton; James Teoh, University of Bristol, supervised by Dr J. Vinther.

1.9 Online activities: The online activities of the Association continue to expand with greater emphasis on Social Media (Facebook, Twitter). The Association continues to be the sole host for the online-only journal *Palaeontologia Electronica*, as well as continuing to host websites for other societies (The Palaeontographical Society; International Organisation of Palaeobotany), palaeontological online resources (EDNA fossil insect database; the Kent Fossil Database), and online outreach projects (Palaeontology [Online]). The Association Twitter account, **@ThePalAss**, had ~1,150 followers by the end of 2014, an increase of ~650 (130%) on the numbers at the end of 2013.

1.10 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. R. A. Fortey (Natural History Museum). The President's Medal, awarded to a palaeontologist within 15 to 25 years of their PhD in recognition of outstanding contributions in their earlier career, coupled with an expectation that they will continue to contribute significantly to the subject in their further work, was presented to Prof. P. C. J. Donoghue (University of Bristol). The Hodson Award, for a palaeontologist within ten years of award of their PhD who has made an outstanding contribution to the science through a portfolio of original published research, was awarded to Dr M. McNamara (University of Cork). The Mary Anning award, for an outstanding contribution by an amateur palaeontologist, was made to Dr Cristoph Bartels (Bochum, Germany). Council also awards an undergraduate prize to each UK and Irish university department in which palaeontology is taught beyond Level 1.

1.11 Forthcoming plans: From 2015, members will have the option of paying a lower subscription and receiving publications only online. The Association will continue to make substantial donations from General and Designated funds to promote the charitable aims of the Association. Resources will be made available to continue a similar programme of grants, meetings, outreach and public engagement activities. Funds will be made available to further develop the website with the aim of encouraging outreach and to support other outreach, education and publicity initiatives. *Special Papers in Palaeontology* will be discontinued, and will be replaced by a new journal: *Papers in Palaeontology*. Volume 58 of *Palaeontology* will be published. The 59th Annual Meeting will be held jointly at the National Museum of Wales and University of Cardiff. Progressive Palaeontology will be held at the University of Bristol.

2. Achievements and Performance

2.1 Meetings support: During 2014, the Association agreed to support a total of 11 palaeontological meetings, symposia or workshops worldwide (in UK, USA, Spain and Austria). This support enabled the worldwide dissemination of research to the benefit of the global palaeontological community.

2.2 Publications: During 2014, 110 papers were submitted to *Palaeontology*. Of these, 71 (65%) were considered suitable by the Editorial Board and 48 (44%) were subsequently accepted after peer review. Of these, 39 papers were accepted for *Palaeontology* and a further nine for *Papers in Palaeontology*. By comparison, 108 papers were submitted during 2013, of which 46 (42%) were approved for peer review by the Editorial Board, and 33 (30%) were subsequently accepted. Increases in approval and acceptance rates in 2014 are due in part to launching the new journal *Papers in Palaeontology*. For *Palaeontology*, the average production time from acceptance to first publication was 49 days in 2014, which represents a substantial reduction from an average of 84 days during the previous year. This increased efficiency in production has benefited authors and

the wider research community and is due in part to changes in ICZN rules that have allowed online publication of new taxonomic names.

2.3 Support for Research: In 2014 the Association agreed to fund the research activities of 22 individuals from six countries (UK, USA, Argentina, Estonia, Belgium and China), most of whom were early career researchers. This represents a substantial increase on previous years due to an additional ten awards made as part of the new Undergraduate Research Bursary Scheme and two awards made under the new Small Grant award in memory of Mr Stan Wood. Three of the undergraduate awardees presented their work at the 2014 Annual Meeting. Apart from directly benefiting the career development of the individuals concerned, the Association's funds enabled more palaeontological research to be undertaken worldwide than would otherwise have been the case. Compared to 2013, applications to the Research Grants scheme (6) and success rates (50%) remained the same. For the Small Grants, applications increased (from 11 to 20) and success rates fell (from 64% to 45%).

2.4 Outreach, Education and Public Engagement: During 2014, the Association supported the two major UK Fossil Festivals, at Lyme Regis and Scarborough, which attracted respectively an estimated 12,000 and 4,000 members of the general public of all ages. Secondary school students were particular beneficiaries of the Association's outreach and education activities. During 2014, we established a new, competitive Outreach and Engagement Fund to support individuals in developing new activities that promote palaeontology and its allied sciences. Continued use of social media, in particular the Association's Twitter account, has enabled the rapid and regular dissemination of research news, including of new publications, meetings and other information, to a growing audience.

3. Financial Review

3.1 Reserves: As of 31st December, The Association holds reserves of £743,997 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 to be 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 £123,797 in Designated Funds which contribute interest towards the funding of the Sylvester-Bradley, Hodson, Callomon, Whittington and Stan Wood awards and towards the Jones Fenleigh fund. £40,000 has been transferred from General Funds into the Sylvester Bradley Fund to meet demands due early in 2015. Total funds carried forward to 2015 totalled £867,774.

3.2 Summary of Expenditure: Total charitable expenditure, through grants to support research, scientific meetings and workshops in 2014, was £337,053. Governance costs were £20,115. Total resources expended were £386,799. 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*.

4. Structure, Governance and Management

4.1 Nature of the Governing document: The governing document of the Palaeontological Association is the Constitution adopted on 27th February 1957, amended on subsequent occasions as recorded in the Council and AGM Minutes.

4.2 Management: The Association is managed by a Council of up to twenty Trustees, which is led by the President. The Association employs an Executive Officer and a Publications Officer. The Trustees are elected by vote of the Membership at the Annual General Meeting, following guidelines laid down in the Constitution.

4.3 Trustees: The following members were elected at the AGM on 14th December 2013 to serve as trustees in 2014: President: Prof. M. J. Benton; Vice Presidents: Dr A. B. Smith and Dr M. Sutton; Treasurer: Mr P. Winrow; Secretary: Prof. R. J. Twitchett; Editor-in-Chief: Dr A. B. Smith; Editor Trustees: Dr M. Ruta, Prof. C. H. Wellman; Newsletter Editor: Dr A. McGowan; Book Review Editor: Dr C. Jeffrey-Abt; Internet Officer: Mr A. R. T. Spencer; Publicity Officer: Dr L. Herringshaw; Education Officer: Dr C. Buttler; Outreach Officer: Dr F. Gill; Meetings Coordinator: Dr T. Vandenbroucke; Ordinary Members: Dr R. J. Butler, Dr C. T. S. Little, Dr M. Munt, Dr R. Owens, Mr D. J. Ward. The Executive Officer Dr T. J. Palmer and the Publications Officer Dr S. Thomas serve on Council but are not Trustees. Prof. M. J. Benton and Prof. R. J. Twitchett represented the Association on the Joint Committee for Palaeontology.

4.4 Membership: Membership on 31st December 2014 totalled 1,071 (1,163 at end 2013). Of these 613 were Ordinary Members, 141 Retired Members, 16 Honorary Members, 261 Student Members and 40 Institutional Members. There were 69 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.

4.5 Risk. The Association is in a sound financial position. Succession planning for the Executive Officer will be considered as part of the Annual Review of Officers in 2015.

5. Reference and Administration

5.1 Name and Charity Number: The Palaeontological Association is a Charity registered in England and Wales, Charity Number 276369.

5.2 Address: 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.

5.3 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.

THE PALAEONTOLOGICAL ASSOCIATION Registered Charity No 276369
STATEMENT OF FINANCIAL ACTIVITIES FOR THE YEAR ENDING 31st DECEMBER 2014

				General Funds	Designated Funds	TOTAL 2014	TOTAL 2013
Incoming Resources							
Generated Funds							
Voluntary income	Subscriptions		53,841			53,841	55,744
	Donations		0		32,220	32,220	4,561
				53,841	32,220	86,061	60,305
Charitable activities							
Sales	*Palaeontology*		255,074				
	Special Papers		8,378				
	Offprints		775				
	Newsletter		250				
	Field Guides		3,933				
	Distribution		250				
				268,660		268,660	278,828
Investment income				13,413	174	13,587	14,007
TOTAL INCOMING RESOURCES				335,914	32,394	368,308	353,140
Resources expended							
Costs of generating funds							
…for voluntary income	Admin.		25,977				26,514
Investment management	S'broker fees		3,654				3,537
				29,631	0	29,631	30,051
Charitable activities							
Publications	*Palaeontology*		62,935				
	Special Papers		3,994				
	Offprints		930				
	Field Guides		27				
	Newsletters		16,100				
	Distribution		1,035				
	Marketing		2,330				
	Publication costs		64,464				
	Editorial costs		37,103				
	Total Publications		188,918			188,918	206,107
Scientific Meetings & Costs				47,141		47,141	26,591
Grants and Awards				32,398	12,843	45,241	15,409
Research Grants				14,932		14,932	5,685
Administration of charitable activities				40,821		40,821	41,664
				324,210		337,053	295,456
Governance costs	Trustee expenses		12,143				
	Administration		7,422				
	Examiner's fee		550				
				20,115	0	20,115	16,158
TOTAL RESOURCES EXPENDED				373,956	12,843	386,799	341,665
NET INCOMING RESOURCES				-38,042	19,551	-18,491	11,475
INVESTMENT GAINS/LOSSES		Realised gain	2,607				
		Unrealised gain	28,747				
				31,354		31,354	61,215
DEFICIT/(SURPLUS) FOR THE YEAR				-6,688	19,551	12,863	72,690
TRANSFERS BETWEEN FUNDS				-40,000	40,000	0	0
				-46,688	59,551	12,863	72,690
FUNDS BROUGHT FORWARD				790,665	64,246	854,911	782,221
FUNDS CARRIED FORWARD				743,977	123,797	867,774	854,911

THE PALAEONTOLOGICAL ASSOCIATION
Registered Charity No. 276369

BALANCE SHEET as at 31st DECEMBER 2014

2013 £			Note			2014 £
		INVESTMENTS				
	594,639	At market value	**1.6**			626,180
		CURRENT ASSETS				
162,483		Cash at Banks		174,448		
128,438		Sundry Debtors	**6**	132,249		
290,921		Total Current Assets			306,697	
		CURRENT LIABILITIES				
21,010		Subscriptions in Advance		25,496		
9,639		Sundry Creditors	**7**	39,607		
30,649		Total Current Liabilities			65,103	
	260,272	NET CURRENT ASSETS				241,594
	854,911	TOTAL ASSETS				867,774
		Represented by:				
	790,665	GENERAL FUNDS				743,977
		DESIGNATED FUNDS	**8**			
5,052		Sylvester-Bradley Fund			36,815	
23,720		Jones-Fenleigh Fund			24,362	
9,152		Hodson Fund			8,172	
7,573		Callomon Fund			6,500	
18,749		Whittington Fund			17,415	
0		Stan Wood Fund			30,533	
	64,246					123,797
	854,911					867,774

Approved by the Board of Trustees on 6th May 2015.

THE PALAEONTOLOGICAL ASSOCIATION Registered Charity No. 276369

DESIGNATED FUNDS, Year ended 31st December 2014. Note 8 to the Accounts

	Sylvester-Bradley	Jones-Fenleigh	Hodson	Callomon	Whittington	Stan Wood	TOTAL 2014	TOTAL 2013
Donations	210	1,090	0	210	210	30,500	32,220	1,340
Interest Received	11	52	20	17	41	33	174	75
TOTAL INCOMING RESOURCES	221	1,142	20	227	251	30,533	32,394	1,415
Grants made	8,458	500	1,000	1,300	1,585	0	12,843	9,506
NET SURPLUS/(DEFICIT)	-8,237	642	-980	-1,073	-1,334	30,533	19,551	-8,091
TRANSFERS BETWEEN FUNDS	40,000	0	0	0	0	0	40,000	0
SURPLUS/(DEFICIT) FOR THE YEAR	31,763	642	-980	-1,073	-1,334	30,533	59,551	-8,091
FUNDS BROUGHT FORWARD	5,052	23,720	9,152	7,573	18,749	0	64,246	72,337
FUNDS CARRIED FORWARD	36,815	24,362	8,172	6,500	17,415	30,533	123,797	64,246

Notes to the Financial Statements for the year ended 31st December 2014

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 2014 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 2014 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.

Stan Wood Fund: For Small Grants in the area of vertebrate palaeontology received as generous donations in memory of the Scottish fossil collector Mr Stan Wood.

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 of foreign cash balances.

1.6 SCHEDULE OF INVESTMENTS (per analysis sheet)

2. Analysis of Financial Resources Expended

	Staff costs	Other costs	Total 2014	Total 2013
	£	£	£	£
Generating Funds	17,488	12,143	29,631	30,051
Charitable activities	63,574	273,479	337,053	295,456
Governance	4,997	15,118	20,115	16,158
	86,059	300,740	386,799	341,665

3. Staff Costs

	Salary	National Insurance	Pension Contributions	Total 2014	Total 2013
	£	£	£	£	£
Publications: 1 employee (2013: 1)	30,850	2,167	3,075	36,092	34,152
Administration: 1 employee (2013: 1)	32,167	2,338	15,462	49,967	50,387
	63,017	4,505	18,537	86,059	84,539

4. Trustees Remuneration and Expenses

Members of Council neither received nor waived any emoluments during the year (2013 – nil).

The total travelling expenses reimbursed to 19 Members of Council was £12,143 (2013 – £8,083).

5. Costs of Independent Examiner

	2014 (£)	2013 (£)
Examination of the accounts	550	500
Accountancy and payroll services	1,600	1,500
	2,150	2,000

6. Debtors

	2014 (£)	2013 (£)
Accrued income – receivable within one year	132,248	128,438

7. Creditors – falling due within one year

	2014 (£)	2013 (£)
Social Services costs	1,679	1,796
Accrued expenditure	37,928	7,843
	39,607	9,639

8. Designated Funds (per analysis sheet)

Independent Examiner's Report

on the Accounts of The Palaeontological Association

for the year ended 31st December 2014

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: 4th June 2015

G R Powell F.C.A.

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

Palaeontological Association year ended 31 December 2014.

Nominal	Holding	Cost (bought pre 2014) £	Value end 2013 £
£18,000	UK 4.75% Stock 07/03/20 GBP 100	18,145.87	20,813.00
£20,000	UK 4.5% Gilt 07/03/19 GBP 0.01	20,092.99	22,688.00
804	Royal Dutch Shell B shares	12,432.00	18,331.00
1,425	BP Ord 25c shares	5,047.35	6,955.00
600	BHP Billiton $0.5 shares	4,341.48	11,214.00
500	BG Group Ordinary 10p shares	3,977.95	6,488.00
1,465	HSBC Holdings Ordinary 0.5 US Dollar shares	4,425.44	9,704.00
2,250	Barclays 25p Ord shares	4,867.00	6,119.00
1,200	Great Portland Estates Ord		
1,500	Jupiter Ord 2p		
105	Next Ord 10p shares	4,648.88	5,723.00
1,150	Tesco Ord GBP 0.05	4,583.22	3,845.00
850	Tesco Ord GBP 0.05		
437	IMI Ord 25p shares	4,267.00	6,664.00
63	IMI Ord 25p shares	638.57	961.00
175	Carnival Plc Ord USD 1.66	3,996.49	4,377.00
650	Glaxo Smithkline Ordinary 25p shares	10,232.42	10,475.00
170	Astrozeneca Ord 25c		
220	Shire Ord 5p shares	4,986.29	6,274.00
2,499	Bluecrest Allblue Ord Npv GBP shares	3,020.28	4,378.00
300	Morgan Stanley		
550	Amec ord 50P	6,133.62	5,984.00
1,861	Melrose Indust Ord 0.1p	5,936.00	5,688.00
339	Melrose Indust Ord 0.1p	1,103.88	1,037.00
2,277	Vodaphone Group Ord USD 0.11428571	3,434.00	5,397.00
109	Verizon Communications	2,600.20	4,498.00
2,150	BT Group Ordinary 5p shares	7,787.53	8,157.00
300	Diageo Ord		
300	Unilever PLC Ord GBP 0.031111	4,326.21	7,446.00
460	Pearson Ordinary 25p shares	8,069.00	6,169.00
490	Serco Group Ord 2P	3,005.01	2,446.00
700	National Grid Ord GBP 0.113953	3,648.26	5,516.00
420	Experian Ord 10C	3,444.95	4,679.00
670	Blackrock World Mining Ord 5P	4,019.09	3,116.00
400	Persimmon Ord 10p	5,035.71	4,956.00
650	RIT Capital Partners Ordinary £1 shares	4,903.90	8,190.00
4,400	TR Property Ord 25p shares	7,560.85	9,966.00
1,000	Balfour Beatty 50P	2,913.17	2,869.00
1,225	Brown Advisory US Equity Value £B	14,789.62	19,931.00
1,500	British Empire Sec & Gen Trust Ordinary 10p shares	5,005.61	7,275.00
425	Findlay Park Partners US Smaller Companies	6,158.47	18,322.00
2,825	Ishares S&P 500 GBP	20,319.63	31,358.00
900	JPMorgan Am UK Ltd Emerging Markets I Instl	5,043.10	4,946.00
425	Fidelity EUR Value Ordinary 25P shares	4,059.07	6,481.00
3,900	Edinburgh Dragon Trust Ordinary £0.20 shares	4,478.10	9,543.00
160	GLG Japan Corealpha Equity IT Acc	11,330.79	17,104.00
5,194	Aberdeen Investment Property Trust B	4,681.00	4,780.00
26	Veritas Asset Mgmt Veritas Asian A GBP	8,182.27	8,192.00
65	Roche Hldgs Ag Genusscheine Nvp	7,226.55	10,994.00
6,600	Henderson Gbl Invs European Special Sits I Inc	7,037.91	10,006.00
1,283.80	COIF Charities Investment Fund Acc Units	75,000.00	133,747.44
£64,176.46	COIF Charities Fixed Interest Fund	85,000.00	80,836.67
	Total	441,936.73	594,639.11

Schedule of Investments (Note 1.6 to the Accounts)

Proceeds (sold in 2014) £	Cost (bought in 2014) £	Gain realised during 2014 £	Gain unrealised during 2014 £	Value end 2014 £
			636.00	21,449.00
			432.00	23,120.00
			-378.00	17,953.00
			-1,098.00	5,857.00
			-2,883.00	8,331.00
			-2,163.00	4,325.00
			-788.00	8,916.00
			-640.00	5,479.00
	8,503.14		352.86	8,856.00
	6,065.93		-591.93	5,474.00
6,758.66		1,035.66		
			-1,671.50	2,173.50
	1,642.56		-36.06	1,606.50
			-1,145.00	5,519.00
1,007.75		46.75		
			731.00	5,108.00
			-1,531.00	8,944.00
	8,144.94		-400.94	7,744.00
10,445.32		4,171.32		
			275.00	4,653.00
	9,958.08		-40.08	9,918.00
5,626.91		-357.09		
			-723.00	4,965.00
1,035.64		-1.36		
			-327.00	5,070.00
4,200.77		-297.23		
			475.00	8,632.00
	5,825.54		-279.54	5,546.00
			438.00	7,884.00
			-695.00	5,474.00
843.38		-1,602.62		
			911.00	6,427.00
			-109.00	4,570.00
			-1,037.00	2,079.00
280.00			1,636.00	6,312.00
			891.00	9,081.00
			2,552.00	12,518.00
1,464.71		-1,404.29		
			2,217.00	22,148.00
7,736.04		461.04		
			3,298.00	21,620.00
			6,264.00	37,622.00
			250.00	5,196.00
			425.00	6,906.00
			1,109.00	10,652.00
			1,557.00	18,661.00
			440.00	5,220.00
			1,261.00	9,453.00
			327.00	11,321.00
			-113.00	9,893.00
			12,155.27	145,902.71
			6,764.20	87,600.87
39,399.18	40,140.19	2,052.18	28,747.28	626,179.58

Nominations for Council

At the AGM in December 2015, the following vacancies will occur on Council:

- President Elect
- Vice-President
- Treasurer

Council's nominations are as follows:

President Elect: Prof. M. Paul Smith

Vice President: Dr Emily Rayfield

Treasurer: Mr Paul Winrow (2nd term)

No other nominations were received by the deadline.