The Palaeontological Association

55th Annual Meeting

17th–20th December 2011

Plymouth University

PROGRAMME and ABSTRACTS

The Palaeontological Association

55th Annual Meeting

17th–20th December 2011

School of Geography, Earth and Environmental Sciences, Plymouth University

The programme and abstracts for the 55th Annual Meeting of the Palaeontological Association are outlined after the following summary of the meeting.

Venue

The meeting will take place on the campus of Plymouth University. Directions to the University and a campus map can be found at <**http://www.plymouth.ac.uk/location**>. The opening symposium and the main oral sessions will be held in the Sherwell Centre, located on North Hill, on the east side of campus.

Accommodation

Delegates need to make their own arrangements for accommodation. Plymouth has a large number of hotels, guesthouses and hostels at a variety of prices, most of which are within ~1km of the University campus (hotels with PL1 or PL4 postcodes are closest). More information on these can be found through the usual channels, and a useful starting point is the website <**http://www.visitplymouth.co.uk/site/where-to-stay**>. In addition, we have organised discount rates at the Jury's Inn, Exeter Street, which is located ~500m from the conference venue. A maximum of 100 rooms have been reserved, and will be allocated on a first-come-first-served basis. Further information can be found on the Association's website.

Travel

Transport into Plymouth can be achieved via a variety of means. Travel by train from London Paddington to Plymouth takes between three and four hours depending on the time of day and the number of stops. The lowest fares are available by booking in advance, *e.g.* through the First Great Western website (<**www.firstgreatwestern.co.uk**>). Flights to and from Plymouth airport have, unfortunately, recently been suspended, but many national and international airlines fly into Exeter airport or Newquay airport. Of the two, Exeter has the best public transport links to Plymouth and is one hour away from Plymouth by train. Ferries link Plymouth to France (Roscoff), Spain (Santander), and Cornwall. National Express coaches link Plymouth with all major UK cities and

London airports. Plymouth University is situated a few minutes' walk from the train station, coach/bus station, and a number of hotels, guesthouses and other accommodation. Delegates arriving by car are advised that the nearest public car parks are in Regent Street and in Drake Circus shopping centre. There will be limited free parking spaces on campus on Saturday and Sunday only. Blue badge holders will receive priority and should contact Sally Bishop-Hawes by e-mail to <**sally.bishop-hawes@plymouth.ac.uk**> to secure a place.

Registration at the conference

Registration will take place in the foyer of the Sherwell Centre, and will be open from 12.00 to 17.30 on Saturday 17th December, and from 08.00 to 17.00 on Sunday 18th December.

Symposium

The opening symposium on 'Ancient and modern biotic crises' will take place in the Sherwell Centre beginning at 13.45pm on Saturday 17th December.

Icebreaker Reception

This will commence at 18.15, following the symposium, and will take place in the Council Houses, Armada Way, PL1 2AA, located in the town centre, a 10-15 minute walk from campus. Transport will be provided for those who need it.

Oral and poster sessions

All oral presentations will take place in the Sherwell Centre, on the campus of the University. Single sessions will be held in the Lower Lecture Theatre, whereas the parallel sessions will utilise both Upper and Lower lecture theatres as indicated in the programme. The posters will be available for viewing throughout the conference in the Main Hall, where lunch will also be served on Sunday and Monday. There will be a dedicated poster session from 09.00–10.30 on Monday 19th December. Each poster will be assigned a single poster board and volunteers will be present in the Main Hall to assist contributors in putting up their posters. Each poster board is approximately 1.8m high by 0.9m wide.

Annual Address

The annual address will be given at 17.15 on Sunday 18th December by Professor Paul Pearson, on 'Climate and evolution in the Cenozoic oceans'. This will be held in the Lower Lecture Theatre of the Sherwell Centre.

Drinks Reception & Annual Dinner

There will be a drinks reception followed by the Annual Dinner in the Guildhall on Sunday 18th December. The drinks reception will commence at 19.00 and the dinner at 20.00. The Guildhall is located at the junction of Armada Way and Royal Parade, in the town centre, a 10-15 minute walk from campus. Transport will be provided for those who need it. Some free parking is available at the venue.

Field excursion

The field excursion will leave from the North Hill entrance to campus, between the Sherwell Centre and the Main Hall, at 9.00am on the morning of Tuesday 20th December. The itinerary will include examination of some of the famous, fossiliferous marine Devonian localities of the Torquay area (the English Riviera Global Geopark) in the morning, followed by lunch and an afternoon tour of Kents Cavern. At the end of the day, delegates will have the choice of returning to Plymouth or of being dropped off at Newton Abbott train station, which is on the main line to Exeter and all stations north and east. Further details will be provided to those who have registered for the fieldtrip after the final registration deadline of 18th November.

Acknowledgements

We express our appreciation to the following for providing financial assistance towards this meeting: Wiley-Blackwell, Taylor & Francis, the Geological Society of London, and the Paleontological Institute, University of Kansas.

WILEY-BLACKWELL

The Geological Society

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Schedule of events and timetable for presentations

Saturday 17th December 2011

Thematic Symposium: "Ancient and Modern Biotic Crises"

Chair: Prof. Malcolm Hart

13.45 **Introductory Remarks**

14.00 **F/F, P/T, and T/J: different initials for the same kind of event?**
Peter D. Ward

14.30 **Recurrent Jurassic anoxia following the end-Triassic mass-extinction**
Bas van de Schootbrugge, A. Bachan, S. Richoz, G. Suan and J.L. Payne

15.00 **Mesozoic oceanic anoxic events and the evolution of planktic foraminifera**
R. Mark Leckie

15.30 Coffee Break

16.00 **Half a billion years of extinction and recovery: Phanerozoic diversity patterns in fishes**
Matt Friedman, Lauren C. Sallan and Graeme T. Lloyd

16.30 **Ecological consequences of a mass extinction in the marine benthos**
Martin Solan

17.00 **Ancient mass extinctions as models for understanding modern environmental and biotic crises**
David J. Bottjer

18.15 Welcome reception at the Council Houses, Armada Way
(sponsored by the Geological Society of London)

Sunday 18th December

Oral Presentations

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

Oral presentations will take place in the Sherwell Centre on the University campus, where registration will also take place between 08:30 and 17:00. Sessions will be held in the Lower Lecture Theatre unless indicated in the schedule below. Posters will be on display in the Main Hall throughout the conference. Tea and coffee will be served in both the foyer of the Sherwell Centre and the Main Hall; lunch will be served in the Main Hall only.

8.50 Introductory Remarks

Session 1

9.00 **The Cambrian conundrum: early divergence and later ecological success in the early history of animals**
Douglas H. Erwin, Marc Laflamme, Sarah M. Tweedt, Erik A. Sperling, Davide Pisani and Kevin J. Peterson

9.15 **Macroevolutionary trends: disparity across the Phanerozoic**
Martin Hughes, Sylvain Gerber and Matthew A. Wills

9.30 **Adjusted homoplasy indices and patterns of variation**
*Jennifer Hoyal Cuthill

9.45 **Family richness in the insect fossil record**
*David B. Nicholson

10.00 **Lower Cretaceous Neuropterida (Insecta) from the Purbeck and Wealden, southern England**
*James E. Jepson

10.15 **The original colours of fossil moths**
Maria E. McNamara, Derek E. G. Briggs, Patrick J. Orr, Sonja Wedmann, Heeso Noh and Hui Cao

10.30 Coffee and Posters

Session 2

11.00 **The origin and early evolution of the arthropods**
*David A. Legg, Mark, D. Sutton, Gregory D. Edgecombe and Jean-Bernard Caron

11.15 **Differentiating arthropod segment articulation morphology and its bearing on a revised phylogeny of basal chelicerates**
*James C. Lamsdell and Martin Stein

11.30 **Skimming the surface with Burgess Shale arthropod locomotion**
*Nicholas J. Minter, M. Gabriela Mangano and Jean-Bernard Caron

11.45 **Mouthparts in the Cambrian 'molluscs' *Odontogriphus* and *Wiwaxia*: implications for ecology and affinity**
*Martin R. Smith

12.00 **The oral cone of *Anomalocaris* from the Middle Cambrian Burgess Shale**
Allison C. Daley and J. Bergström

12.15 Lunch

Session 3a (Upper Lecture Theatre; in parallel with Session 3b)

13.30 **Exploring the earliest signs of cellular life on Earth**
Martin D. Brasier and David Wacey

13.45 **The origin of sponges: examination of Precambrian metazoan diversifications**
Jonathan B. Antcliffe, R. H. T. Callow and M. D. Brasier

14.00 **New perspectives on early sponges: mineralogy, morphology and relationships**
Joseph P. Botting

14.15 **Is *Diania cactiformis* the 'missing link' between lobopodians and arthropods?**
Xiaoya Ma, Gregory D. Edgecombe, David A. Legg and Xianguang Hou

14.30 **A cryptic Cambrian radiation of crustaceans**
Thomas H. P. Harvey, M. I. Velez and N. J. Butterfield

14.45 **Up the spout? Climbing up the chelicerate stem-group**
Graham E. Budd and D. Legg

Session 3b (Lower Lecture Theatre; in parallel with Session 3a)

13.30 **Late Cenozoic history of the Southeast Asian marine biodiversity maximum: new data for old questions**
Kenneth G. Johnson, Willem Renema and the Throughflow Project

13.45 **Using zooid size variation and stable isotopes in bryozoan skeletal carbonate to reconstruct Pliocene temperature regimes**
Tanya Knowles, Melanie J. Leng, Paul D. Taylor, Mark Williams and B. Okamura

14.00 **One more whale barnacle, and the coevolution of large kings and small crowns**
Stefano Dominici and Marco Benvenuti

14.15 **Filling-in the "Palaeogene Gap": a diverse coral assemblage from the Late Oligocene of Borneo**
Laura B. McMonagle and Kenneth G. Johnson

14.30 **The dissolution of Quaternary pteropods from the Caribbean and Mediterranean Seas**
*Deborah Wall-Palmer, Christopher W. Smart, Malcolm B. Hart and A. Conversi

14.45 **First traces of *Osedax* worms from the Mediterranean**
*Nicholas D. Higgs, Crispin T. S. Little, Adrian G. Glover, Thomas G. Dahlgren, Craig R. Smith and Stefano Dominici

15.00 Coffee and Posters

Session 4

15.30 **Dinoflagellate cyst response to Oceanic Anoxic Event 2**
*Kate Olde, Ian Jarvis, Martyn Waller, Martin Pearce and Bruce Tocher

15.45 **Benthic foraminiferal change across the Cretaceous–Paleogene boundary at Brazos River, Texas**
*Andrew D. Leighton, Malcolm B. Hart, Christopher W. Smart and Richard J. Twitchett

16.00 **Bryozoan size variation across the K–T mass extinction**
*Caroline E. Sogot and Paul D. Taylor

16.15 **Definitive evidence of stem-avian mass extinction at the K–Pg boundary**
*Daniel J. Field, Nicholas R. Longrich and Tim Tokaryk

16.30 **Beyond the extinction: environmental and ecological interactions in the earliest recovery from the Cretaceous–Paleogene mass extinction**
Pincelli M. Hull, Richard D. Norris, Atreyee Bhattcharya and Sujoy Mukhopadhyay

16.50 Annual General Meeting

17.15 **Annual Address: Climate and evolution in the Cenozoic oceans**
Professor Paul Pearson

19.00 Reception and Annual Dinner at the Guild Hall

Monday 19th December

Oral Presentations

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

Oral presentations will take place in the Sherwell Centre of Plymouth University. Sessions will be held in the Upper Lecture Theatre unless indicated below. Posters will be on display in the Main Hall throughout the conference. Tea and coffee will be served in both the foyer of the Sherwell Centre and the Main Hall; lunch will be served in the Main Hall only.

Session 5: poster session (Main Hall)

Tea, coffee and pastries will be available from 9.00.

9.00 Delegates are requested to stand by their poster(s).

Session 6

10.30 **Ontogeny and microstructure of the enigmatic Cambrian tommotiid *Sunnaginia* and implications for brachiopod bodyplan evolution**
*Duncan J. E. Murdock, Philip C. J. Donoghue, Stefan Bengtson and Federica Marone

10.45 **Investigating the functional morphology of Cambrian cinctan echinoderms using computational fluid dynamics**
*Imran A. Rahman, Peter L. Falkingham, Samuel Zamora and Benedict D. Rogers

11.00 **Stars in their eyes: New sensory structure or epibiont?**
*David J. Marshall

11.15 **Functional morphometric analysis of the furcula in Mesozoic birds**
*Roger A. Close, Emily Rayfield and Patricia Vickers-Rich

11.30 **Juvenile Ediacaran organisms from the Drook Formation, Newfoundland: Insights into the ontogeny and ecology of rangeomorph palaeocommunities**
*Alexander G. Liu, Duncan McIlroy, Jack J. Matthews and Martin D. Brasier

11.45 **Spatial Analysis of Species Distributions from Mistaken Point, Newfoundland**
*Emily G. Mitchell

12.00 **Palaeoecology and taxonomic composition of the Spathian Virgin Limestone Fauna: implications for benthic recovery from the end-Permian mass extinction event**
*Richard Hofmann, Michael Hautmann, Hugo Bucher, Alistair J. McGowan and Andrew B. Smith

12.15 Lunch

Session 7a (Upper Lecture Theatre; in parallel with Session 7b)

13.15 **Cambrian Explosion and Ordovician Biodiversification or Cambrian Biodiversification and Ordovician Explosion?**
Thomas Servais, Sébastien Clausen, Taniel Danelian, David A. T. Harper, Björn Kröger, Bertrand Lefebvre, Claude Monnet, Axel Munnecke, Elise Nardin, Thijs Vandenbroucke and Jean Vannier

13.30 **New olenellid trilobites of the Digermul Peninsula, Finnmark, Northern Norway – Constraints on lower Cambrian biostratigraphy**
Anette E. S. Högström, Jan Ove R. Ebbestad, Teodoro Palacios and Sören Jensen

13.45 **Chitons without feet: new data on molluscan evolution**
Mark D. Sutton, Derek E. G. Briggs, David J. Siveter, Derek J. Siveter and Julia D. Sigwart

14.00 **A new early Ordovician lagerstätte from South China**
Lucy A. Muir, Joseph P. Botting, Peter Van Roy, Zhang Yuan-dong and Jih-pai Lin

14.15 **Impact of ash-falls on the diversity of Ordovician ostracods**
Vincent Perrier, Tõnu Meidla, Oive Tinn and Leho Ainsaar

14.30 **New observations on the earliest marine faunas of the type Devonian succession of SW England: the brachiopods of the Meadfoot Group, Torquay, Devonshire, UK**
Mena Schemm-Gregory and Kevin Page

14.45 **Small is beautiful: investigations into Early Devonian plant mesofossils from the Welsh borderland, UK**
Jennifer L. Morris, Dianne Edwards, John B. Richardson and Lindsey Axe

Session 7b (Lower Lecture Theatre; in parallel with Session 7a)

13.15 **New data on the evolution of Mesozoic freshwater hybodont sharks in Southeast Asia**
Gilles Cuny, Romain Liard, Uthumporn Deesri, Tida Liard, Suchada Khamha and Varavudh Suteethorn

13.30 **Functional disparity of the initial gnathostome radiation: stability in the face of faunal and environmental change**
Philip S. L. Anderson, Matt Friedman, Martin D. Brazeau and Emily J. Rayfield

13.45 **Interrogating dental morphospaces: an analysis of the conodont fossil record**
David Jones, Alistair R. Evans and Philip C. J. Donoghue

14.00 **Functional morphology and ontogeny of the earliest jawed vertebrates**
Martin Rücklin, Philip C. J. Donoghue, Emily Rayfield, Laurent Darras, Mark Purnell, Zerina Johanson, Kate Trinajstic, Federica Marone and Marco Stampanoni

14.15 **Bite me! Ecology of early jawed vertebrates investigated through microwear texture analysis**
*Laurent Darras, Mark Purnell, Martin Rücklin, Philip C. J. Donoghue, Emily Rayfield, Zerina Johanson, Kate Trinajstic, Federica Marone and Marco Stampanoni

14.30 **Evolution and phylogeny of Cervidae (Cetartiodactyla, Mammalia): a total evidence approach**
*Nicola S. Heckeberg, Gertrud E. Roessner and Gert Woerheide

14.45 **miRNAs and the evolution of Eutherians**
James E. Tarver, D. Pisani, P. C. J. Donoghue and K. J. Peterson

15.00 Coffee and Posters

Session 8

15.30 **Microbial zonation and cyclicity in phosphatic stromatolites from the Palaeoproterozoic Vindhyan Supergroup, India**
*Therese Sallstedt

15.45 **Animal-plant interaction in the Middle Permian of Antarctica**
*Ben J. Slater, Steven McLoughlin and Jason Hilton

16.00 **Completeness of the fossil record and the validity of sampling proxies: examples from the British Triassic and Jurassic**
*Alexander M. Dunhill, Michael J. Benton, Richard J. Twitchett and Andrew J. Newell

16.15 **A novel Carboniferous ovule elucidated through a combined methodology for three-dimensional reconstruction**
Alan R. T. Spencer, Jason Hilton and Mark D. Sutton

16.30 **Which plants constituted the amber forests? A case study of the Baltic and Bitterfeld ambers**
Leyla J. Seyfullah and Alexander R. Schmidt

16.45 **Hydrocarbon seeps from close to the Jurassic/Cretaceous boundary, Svalbard**
Oyvind Hammer, Hans A. Nakrem, Crispin T. S. Little, Krzysztof Hryniewicz, Michael R. Sandy, Jorn H. Hurum, Patrick Druckenmiller, Espen M. Knutsen and Magne Hoyberget

17.00 **Recent developments in the studies of fossil colour of birds and other dinosaurs**
Jakob Vinther, Julia A. Clarke and Matt Shawkey

17.15 Announcement of prize winners and close of meeting

Abstract of Annual Address

Climate and Evolution in the Cenozoic Oceans

Paul N. Pearson
School of Earth and Ocean Sciences, Cardiff University, Main Building, Park Place, Cardiff CF10 3YE, UK

Oceanic ecosystems were severely affected by the Cretaceous/Paleogene boundary extinctions. Recovery occurred in several phases, the longest (evolutionary recovery) lasting many millions of years. The early Cenozoic was, in general, a period of extraordinary global warmth. A long-term cooling trend in the Eocene, seemingly related to declining greenhouse gas levels caused by tectonic changes, set the stage for the formation of a large ice cap on Antarctica, and, much later, further cooling resulted in northern hemisphere ice caps. Ocean gateways opened and closed causing major changes in circulation, most notably the development of the Southern Ocean. Orbital climate cycles always existed, but their severity was enhanced by polar cooling, eventually resulting in the extreme glacial-interglacial fluctuation of the last million years.

These environmental changes form the backdrop of a rich oceanic fossil record which, for certain groups such as the mineralizing plankton, can be reconstructed in extraordinary detail. This is largely thanks to the successive international programmes of ocean coring, most recently by the Integrated Ocean Drilling Program. The record of plankton evolution is far from random: like many other fossil groups in different periods, it is characterised by waves of diversification and extinction, and highly non-random survival and speciation patterns. These fossil records allow us to formally test how much of the evolutionary pattern can be explained by external forcing and how much appears to be intrinsic to the evolution of the group in question.

Anthropogenic change is beginning to be felt in the oceans, principally through warming and ocean acidification. The rate and magnitude of future change potentially exceeds anything that has happened in the Cenozoic, threatening another mass extinction.

Abstracts of symposium presentations: Ancient and Modern Biotic Crises

Ancient mass extinctions as models for understanding modern environmental and biotic crises

David J. Bottjer

Department of Earth Sciences, University of Southern California, Los Angeles, CA 90089-0740, USA

In the next 100 years it is projected that the Earth will move from an icehouse to a greenhouse climate state. The future global warming ocean will include increases in the extent of the oxygen minimum zone and ocean acidification. Through study of the past we can predict what the Earth and its biota will be like in this new greenhouse state, and what the journey to that state will entail. The mass extinctions at the beginning and the end of the Triassic experienced significantly increased warming due to the eruption of large igneous provinces. Although climatic, palaeogeographic and geochemical conditions as well as the evolutionary state of biological systems on Earth were different then (~252 and 200 Ma) than now, results from these natural experiments on the Earth system can be observed from the fossil and stratigraphic record and potentially provide information to manage change. Much can be learned on the resistance, resilience and persistence of ecosystems, in particular the fate of metazoan reefs, the role of microbes, and the proliferation of opportunists. Although they are not a perfect analogue, early Mesozoic oceans during times of mass extinction have much to teach us about the future global warming ocean.

Half a billion years of extinction and recovery: Phanerozoic diversity patterns in fishes

Matt Friedman [1], Lauren C. Sallan [2] and Graeme T. Lloyd [1]

[1]*Department of Earth Sciences, University of Oxford, Oxford, UK*

[2]*Department of Organismal Biology and Anatomy, University of Chicago, Chicago, USA*

Fishes comprise half of all living vertebrate species, with a fossil record extending to the lower Cambrian. Compared to many other vertebrate groups, our understanding of large-scale diversity patterns in fossil fishes is limited. This is somewhat surprising, since fishes were the first vertebrate group for which patterns of palaeobiodiversity were systematically documented, in the middle 19th century by Louis Agassiz. Several factors have impeded a synoptic picture of macroevolutionary patterns in fishes from materializing: the spotty nature of record for many (but not all) fish clades, a low number of workers, and the sheer magnitude of the problem. Here we outline results from new analyses of the fish record conducted at a range of spatial and temporal scales, and their implications for our understanding of the evolutionary history of this successful assemblage. Geographically targeted investigation has allowed us to quantify the degree to which observed taxonomic patterns might be driven by the sedimentary record, revealing that fish diversity appears to be less biased by sampling than many terrestrial vertebrate groups. At broader spatial but narrower temporal scales, it is emerging that a few brief intervals of turnover and recovery have profoundly influenced the structure of modern fish biodiversity.

Mesozoic oceanic anoxic events and the evolution of planktic foraminifera

R. Mark Leckie
University of Massachusetts, Amherst, USA

The link between planktic foraminiferal evolution and environmental perturbations of the so-called Mesozoic 'Oceanic Anoxic Events' (OAEs) is compelling. Diversification and extinction are closely tied with the major OAEs, beginning in the Early Jurassic and extending through the mid-Cretaceous. Foraminifera invaded the plankton multiple times during the past 160 myr. The early Toarcian OAE may have been the first of these invasions. Innovation, such as clavate chambers, developed during the widespread OAE1a in the early Aptian (~121 Ma). Great diversification during the Aptian was squelched by the multiple events of OAE1b across the Aptian/Albian boundary (~112 Ma), a period that includes the second largest turnover in planktic forams (K/Pg boundary being the largest). The planktic forams recover, diversify, increase in size, and stratify in the upper water column during the Albian. Global tectonic influence on seawater chemistry during the mid-Cretaceous favoured calcite-producing organisms including calcareous nannoplankton. Rising global sea level and spread of epeiric seas, expanded oxygen minima, and changes in ocean circulation associated with the opening of the north-south Atlantic Ocean basin provided a backdrop for the evolution of planktic and benthic forams and other plankton groups during the Late Cretaceous. OAE2 across the Cenomanian/Turonian boundary (~94 Ma) again resulted in extinction and subsequent radiation of planktic forams.

Recurrent Jurassic anoxia following the end-Triassic mass-extinction

Bas van de Schootbrugge [1], A. Bachan [2], S. Richoz [3], G. Suan [1] and J. L. Payne [2]
[1]*Goethe University Frankfurt, Frankfurt am Main, Germany*
[2]*Stanford University, Palo Alto, USA*
[3]*University of Graz, Graz, Austria*

The Triassic–Jurassic boundary (201.6 Ma) is marked not only by a major mass-extinction, but also by a dramatic change in sedimentation style along the margins of the Tethys Ocean. Uppermost Triassic sediments are generally organic-matter poor whereas organic-matter rich black shales are prevalent in the lowermost Jurassic. New core material from Germany reveals that photic zone euxinia was common during the Hettangian and that its onset was associated with a series of both negative and positive carbon isotope excursions. Combined inorganic and organic geochemical, and micropalaeontological analyses suggest that there are strong similarities between Hettangian anoxia and the better known anoxic event of the Toarcian. The Hettangian and Toarcian anoxic events appear to be part of a series of such events that also includes poorly studied black shale intervals during the Sinemurian and Pliensbachian. Similarly to the Toarcian ocean anoxic event, questions remain regarding the cause(s) of large negative excursions in organic carbon across the Triassic–Jurassic boundary, especially where such excursions are associated with important changes in sea level and changes in organic matter composition. Long-term ocean de-oxygenation during the Early Jurassic can be attributed to greenhouse warming and consequently enhanced nutrient fluxes to the oceans triggered by flood basalt volcanism.

Ecological consequences of a mass extinction in the marine benthos

Martin Solan

Oceanlab, University of Aberdeen, Main Street, Newburgh, Aberdeenshire AB41 6AA, UK

Recognition that a reduction in the number of species within a community can negatively affect a variety of ecosystem properties has raised concern over how biodiversity loss might alter the functioning of ecosystems in the future. Much of our understanding of present day biodiversity–ecosystem functioning relations, however, is based on manipulative experiments that have altered diversity using randomly assembled communities; an approach which ignores the varying susceptibilities of species to extinction and the environmental context under which extinctions occur. By converging current perspectives of biodiversity–ecosystem function relations with longer term evolutionary patterns, much can be learnt about the ecological consequences of mass extinctions in the context of past global change. Here, using data from marine benthic invertebrate communities, I demonstrate how sediment bioturbation can be used to parameterise models that predict how specific local extinctions may affect important ecosystem processes. By applying this methodology across the trace and body fossil record of the Permian–Triassic boundary interval – where the causes and order of species extinction are well known, the nature of the ichnofabric has been documented, and fossil preservation and morphological features are sufficient to provide an indication of species traits – I will use the same methodology to estimate the likely ecological consequences of a benthic mass extinction.

F/F, P/T, and T/J: different initials for the same kind of event?

Peter D. Ward

Dept. of Biology, The University of Washington, Seattle, 98195, USA

The overriding paradigms concerning the cause(s) of the Earth's Phanerozoic mass extinctions changed from intrinsic causes (climate, atmospheric, oceanic chemistry, and sea level changes) to extrinsic (asteroid impact, and other astronomical events) during the last two decades of the Twentieth Century. However, much new research at Upper Devonian, Permian/Triassic, and Triassic/Jurassic boundary sites since that time has brought to the fore evidence that none of these particular mass extinctions were caused by extrinsic events, and that even the Cretaceous/Paleogene mass extinction was at least partially related to global warming. In this talk I will show new, unpublished evidence from Devonian sites (both Givetian/Frasnian as well was Frasnian/Famennian) in the Canning Basin, Australia; Permian sites in Alberta and South Africa; Triassic-aged sites in the Insular Belt of Western Canada; and Maastrichtian sites in Antarctica that demonstrate significant perturbations in both metals as well as sulphur and nitrogen isotopes that are consistent with global environmental changes from oceanic and atmospheric chemistry changes at these boundaries. The Upper Cretaceous sites from Antarctica show a clear pattern in the data consistent with global warming in the upper half of the Maastrichtian, at times that are correlative to pulses of the Deccan Traps Flood Basalts. Impact as a cause of mass extinction has become marginalized to the K/Pg boundary only.

Abstracts of oral presentations

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

Functional disparity of the initial gnathostome radiation: stability in the face of faunal and environmental change

Philip S. L. Anderson[1], M. Friedman[2], Martin D. Brazeau[3] and Emily J. Rayfield[1]

[1]*Department of Earth Sciences, University of Bristol, Bristol, UK*

[2]*Department of Earth Sciences, University of Oxford, Oxford, UK*

[3]*NCB Naturalis, Leiden, The Netherlands*

In the Silurian and earliest Devonian, jawed vertebrates (gnathostomes) shared ecological space with a wide range of jawless fishes (agnathans). By the end of the Devonian, a major faunal shift occurred that left younger assemblages composed almost exclusively of gnathostomes. Several qualitative scenarios have been proposed to explain the trophic radiation of the earliest gnathostomes. We present the first quantitative analysis of functional variation in early gnathostome jaws, placing constraints on our understanding of evolutionary patterns during this critical interval.

A series of biomechanically relevant morphological jaw metrics, collected from 198 Devonian gnathostome genera, were used to create a functionally informed morphospace and calculate disparity metrics. Morphospace occupancy was compared with richness data documenting the relative contribution of gnathostomes to faunal assemblages throughout the Devonian.

Functional disparity among Early Devonian gnathostomes is comparable with that seen in the Late Devonian even as taxonomic richness increases substantially. Almost half of mandibular morphospace is occupied by stem gnathostomes (placoderms) while major groups of living vertebrates (ray-finned fishes, tetrapods) show conservative morphologies. Steady levels of gnathostome functional diversity in the face of the plummeting relative richness of agnathans raises questions about the role of active displacement in this fundamental shift in vertebrate biodiversity.

The origin of sponges: examination of Precambrian metazoan diversifications

J. B. Antcliffe[1], R. H. T. Callow[2], and M. D. Brasier[3]

[1]*Department of Earth Sciences, University of Bristol, Wills Memorial Building, Queen's Road, Bristol BS8 1RJ, UK*

[2]*Department of Earth Science, Memorial University of Newfoundland, St John's, Newfoundland, A1B3X5, Canada*

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Sponges are the animal group widely considered most likely to have evolved in the Precambrian. However, in re-analysis of all fossil candidates for Precambrian sponges, we found that the oldest hitherto widely accepted, Mongolian silica hexacts from c.545 Ma, are abiogenic arsenopyrite crystals while all older material is also shown to be either an abiogenic artefact, microbial, or variants of the Ediacaran biota. There are reliable sponge remains from the basal Cambrian represented by spicules from the Soltanieh Formation,

Iran, reported in detail for the first time. Predictions of deep Precambrian divergences of Metazoa now must face an Ediacaran fossil record which is abundant in soft bodied remains and is also actively precipitating silica that has still not yielded any convincing evidence for these animals. Sponges are complex organisms that require interactions with other animals in order to survive, a result of 540 Ma of complex co-evolution with other animals. There is no reason why they should be thought more likely to be able to live outside of this context at a time before these ecosystems evolved than any other animal group. Sponges probably evolved at approximately the base of the Cambrian Period.

New perspectives on early sponges: mineralogy, morphology and relationships

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The pre-trilobite Hetang Biota of Anhui, South China, is the oldest deposit containing demonstrable, articulated spiculate sponges. Previously described as a moderately diverse assemblage of taxa including some of the largest known fossil sponges (around 1m tall), further collecting has revealed a much greater diversity. The fauna includes a range of important and unusual new taxa, combined with a suite of informative preservational styles, providing a series of unexpected and important insights into early sponges. This includes biminerallic spicules in the choiid *Lenica*, fossils showing a transitional stage between hexactine-bearing sponges and protomonaxonids (traditionally regarded as demosponges), and recognition of a group of hexactinellid-like sponges with structural tetraradial symmetry, with profound implications for early metazoan evolution. The fauna also includes micromorphic, thick-walled hexactinellids, and agglutinating sponges presumed to be ceractinomorph demosponges – the earliest examples of each. As a result of these findings the distinctions between demosponges and hexactinellids, and between Silicea and Calcarea, are breaking down in Cambrian faunas, so that class-level assignments of many taxa are now uncertain. The insights arising from the fauna demonstrate how little we know about early sponge evolution, and suggest future research directions that might begin to clarify sponge relationships.

Exploring the earliest signs of cellular life on Earth

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This talk will introduce our newly discovered ~3430 Ma assemblage of fossils closely associated with microborings into pebbles of pyrite in sandstones of the Strelley Pool Formation in Western Australia (Wacey *et al.*, 2011, *Nature Geosciences*). Arguably, these Strelley Pool fossils are the earliest cells from the fossil record for which there are multiple lines of supporting evidence. This evidence includes mapping and petrography of the habitat, at scales from kilometres to nanometres; 3D micromapping of microfossils and their metabolic pathways using NanoSIMS, FIB and Laser raman; and testing against the null hypothesis of an abiogenic origin. These approaches have allowed us to confirm the presence of hollow cell lumens, carbonaceous cell walls enriched in nitrogen, taphonomic degradation, organization into chains and clusters, and ^{13}C values ranging from δ 33 to 46 PBD. Together with directly associated microborings, and sulphur isotope fractionation patterns, these provide evidence for an early start to sulphur-metabolising bacteria along

shorelines of the early Earth. Confirmation of microbes living within pores of beach sandstones before 3400 Ma raises the potential interest of beach-like habitats for the origins of life itself within pores and pumice (Brasier *et al.*, 2011, *Astrobiology*).

Up the spout? Climbing up the chelicerate stem-group

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Whilst progress has been made in recovering a stable lower euarthropod stem group, basal stem groups systematics within the euarthropod crown remain problematic. Current concepts include an expanded 'Antennata' encompassing the mostly Cambrian arthropods possessing a single antenna. The stem group of the Chelicerata, conversely, is poorly populated, with no universally agreed members before the appearance of chasmataspid trace fossils towards the end of the Cambrian. In short, the older consensus about the 'Arachnomorpha' whereby trilobites and their allies were considered to be related to chelicerates has thoroughly broken down. A hypothesis in which the 'great appendage' arthropods were considered stem-group chelicerates based on their chelicera-like frontal appendages has in its stead gained considerable support. However, this reconstruction pays insufficient attention to older ideas of stem-group chelicerates possessing an antenniform, not cheliceriform first appendage. When the 'xenopod' taxa such as *Sidneyia* and *Emeraldella* are included in the analysis, an antennate first appendage is recovered as a chelicerate and thus euarthropod plesiomorphy. This reconstruction has significant implications for both the composition of the stems of the pancrustaceans and euarthropods more generally, as well as raising the old problem of functional transitions within arthropod frontal appendages once more.

Functional morphometric analysis of the furcula in Mesozoic birds

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The furcula displays enormous morphological and structural diversity. Acting as an important origin for flight muscles involved in the downstroke, the form of this element has been shown to vary with flight mode (Hui, 2002, *Journal of Morphology*, **251**, 284–293). This study seeks to clarify the strength of this form-function relationship through the use of eigenshape morphometric analysis coupled with recently-developed phylogenetic comparative methods, including phylogenetic Flexible Discriminant Analysis (pFDA). Additionally, the morphospace derived from the furculae of extant birds is used to shed light on possible flight adaptations of Mesozoic fossil taxa.

While broad conclusions of earlier work are supported (U-shaped furculae are associated with soaring, strong anteroposterior curvature with wing-propelled diving), correlations between form and function do not appear to be so clear-cut, likely due to the significantly larger dataset and wider spectrum of flight modes sampled here. Interclavicular angle is an even more powerful discriminator of flight mode than curvature, and is positively correlated with body size. With the exception of the close relatives of modern birds, the

ornithuromorphs, Mesozoic taxa tend to occupy unique regions of morphospace, and thus may have either evolved unfamiliar flight styles or have arrived at similar styles through divergent musculoskeletal configurations.

New data on the evolution of Mesozoic freshwater hybodont sharks in Southeast Asia

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Freshwater hybodont sharks are abundant and diverse in the Khorat Group (Upper Jurassic (?) – Lower Cretaceous) of Thailand, but so far they were well known only from the upper part of the Group, where they show a high level of endemicity. The recently discovered new shark assemblages from the lower part of the Group are less endemic at genus level. A new species of *Acrodus*, together with *Acrodus caledonicus* from the Bathonian of Scotland and *A. biscrasseplicatus* from the Middle Jurassic of Northern China, is restricted to freshwater environments, supporting Rees and Underwood's theory that this genus shifted from a marine to a non-marine environment during the Jurassic. In addition, the new Thai species represents the youngest record of the genus. We also record the oldest appearance of the genus *Heteroptychodus*, another specialized grinding freshwater hybodont. In the upper part of the Khorat Group, this genus replaces *Acrodus* as the main durophagous shark, and spreads into Japan and Mongolia. The new Thai faunas do not appear closer to the Chinese faunas than to the European ones, suggesting that the freshwater shark assemblages of the Lower Cretaceous of Southeast Asia were not directly derived from the Chinese Jurassic ones.

The oral cone of *Anomalocaris* from the Middle Cambrian Burgess Shale

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The anomalocaridids are Cambrian presumed predators that have an unusual mouthpart morphology. The oral cone consists of 32 outer plates with differentiation of four enlarged plates in perpendicular arrangement. This structure was thought to be highly consistent between Burgess Shale anomalocaridids (*Anomalocaris*, *Laggania* and *Hurdia*), and upheld as a defining feature of the anomalocaridid clade. However, re-examination of Royal Ontario Museum material has revealed that *Anomalocaris canadensis* does not have a typical "Peytoia". Its oral cone consists of three large plates separated from each other by furrows originating at the central opening and extending outwards while splitting successively into greater numbers of furrows. The large plates have clusters of asymmetric nodes on their surfaces and up to five inward-facing spines. The oral cone is irregular in both outline and central opening shape. These structures are found in association with articulated (whole-body) and disarticulated *Anomalocaris* assemblages, and the typical "Peytoia" is found only in other Burgess Shale anomalocaridid taxa, with the consequence

that *Laggania* must now be referred to as *Peytoia*. The *Anomalocaris* oral cone represents an intermediate morphology between the true 'Peytoia' of other anomalocaridids and the undifferentiated oral plates of less derived lobopodians, such as *Pambdelurion* and *Megadictyon*.

Bite me! Ecology of early jawed vertebrates investigated through microwear texture analysis

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Representatives of the clade Gnathostomata include most modern vertebrates, and form a major component of post-Silurian ecosystems. The morphology of their jaws shows a major diversification in the late Silurian and early Devonian followed by stable functional morphospace occupation. Recent works in modern ecosystems and organisms demonstrated however that morphology and ecology are not always tightly linked. Inferences of predator–prey dynamics in the fossil record could be undermined unless reliable predictors of trophic ecology are developed.

Placoderms were a major component of Devonian aquatic ecosystems. We apply modern microwear and microtexture analysis techniques to their jaws, and assess the power of the methods to answer questions of ecomorphology, ontogenetic shift in diet and predation-driven macroevolution events. Occlusion in the statodont dentition of placoderms is maintained through wear of the feeding structures, reveals dentine, bone and resets the microwear signature on a regular basis. Investigations using classical 2D microwear techniques found a less accurate ecological signal on dentine compared to enamel. Microtexture analysis does not account for features but for roughness and may thus yield unsuspected information. Differences in microtexture observed through different histologies along the jaw allow testing of hypotheses of trophic diversity between individuals among the earliest gnathostomes.

One more whale barnacle, and the coevolution of large kings and small crowns

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A large specimen of the whale barnacle *Coronula diadema* was found in early Pleistocene deposits in Tuscany. The name means "small crown", to express the form of this odd suspension-feeder, and its position on the head of large whales. Our finding suggests the species had a global distribution since the early Pleistocene. The same applies to the only other well-known fossil coronulid, *Coronula bifida*, common in the Mediterranean Pliocene and reported from Pliocene deposits of the Pacific. The known stratigraphic range of the

two shows no overlap and is next in sequence, the first in the Piacentian–Gelasian, the second from the Calabrian to the present. We hypothesize that the two are in direct descent and connected with a pronounced increase in size of the adult shell. The fossil record of large whales and the global distribution of the host, the ocean-going humpback whale, adds reliability to this. The general high host specificity of coronulid barnacles, which today include *Cetopirus complanatus*, probably dated to the Pliocene. A coevolutionary trend towards an increase in size characterizes both whales and coronulids.

talks

Completeness of the fossil record and the validity of sampling proxies: examples from the British Triassic and Jurassic

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Many studies have compared measures of the rock and fossil record, and the common pattern of covariance between sampling proxies and palaeodiversity have suggested that the fossil record is biased by the amount of rock available for sampling. However, most studies are carried out on a global or continental scale using untested sampling proxies. This raises questions about the validity and interpretation of discovered correlations between various proxies and diversity estimates. Using GIS and remote sensing techniques, we have shown that commonly used sampling proxies (*i.e.* outcrop area, number of sedimentary formations *etc.*) do not correlate well with one another, or with rock exposure area, a better estimate of the amount of rock easily accessible for sampling. Studies carried out at local and regional scales in the British Triassic and Jurassic show that strong correlations exist between worker effort and diversity, but other correlations, observed at global and continental scales, do not translate to smaller scale studies until the influences of differing facies are removed. This suggests that, although some of the diversity signal in the fossil record can be attributed to sampling biases, the influence of differing palaeoenvironments, both ecological and preservational, appears much greater.

The Cambrian conundrum: early divergence and later ecological success in the early history of animals

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Diverse bilaterian clades emerged apparently within a few million years during the early Cambrian, and various environmental, developmental, and ecological causes have been proposed to explain this abrupt appearance. A compilation of the patterns of fossil and

molecular diversification, comparative developmental data, and information on ecological feeding strategies, indicate that the major animal clades diverged many tens of millions of years before their first appearance in the fossil record, establishing a macroevolutionary lag between the establishment of their developmental toolkits during the Cryogenian (850–635 Ma), and their later ecological success during the Ediacaran and Cambrian periods. We argue that this diversification involved new forms of developmental regulation, as well as innovations in networks of ecological interaction within the context of permissive environmental circumstances.

Definitive evidence of stem-avian mass extinction at the K–Pg boundary

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The poor Late Cretaceous record of fossil birds has precluded definitive discussion of the end-Cretaceous (K–Pg) mass extinction's effects on avian evolution. In particular, it is still uncertain whether the disappearance of archaic birds occurred gradually over the course of the Cretaceous, or whether these lineages remained diverse up to the end of the Cretaceous and perished in the K–Pg mass extinction. Here, we describe a diverse avifauna from the latest Maastrichtian of western North America, which provides definitive evidence for the persistence of a range of archaic birds to within 300,000 years of the K–Pg boundary. 17 species are identified, including seven species of archaic birds, representing Enantiornithes, Ichthyornithes, Hesperornithes, and an *Apsaravis*-like bird.

None of these groups are known to survive into the Palaeogene, and their persistence into the latest Maastrichtian therefore provides strong evidence for a mass extinction of archaic birds coinciding with the Chicxulub asteroid impact. This avifauna, comprising both archaic birds as well as advanced ornithurines, is the most diverse known from the Late Cretaceous, and helps illuminate the degree to which avian radiation had proceeded by the end of the age of dinosaurs.

Hydrocarbon seeps from close to the Jurassic/Cretaceous boundary, Svalbard

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Fifteen hydrocarbon seeps bodies have been found in the Sassenfjorden area of Spitsbergen. The carbonates are found in the siltstones and mudstones of the uppermost Slottsmoya Member, in the Upper Jurassic to lowermost Cretaceous Agardhfjellet Formation. The age of the seeps ranges from the Upper Volgian (Jurassic) to lowermost Valanginian (Cretaceous). The Sassenfjorden area carbonates show complex and heterogeneous structures typical of hydrocarbon seeps. Stable isotope analyses show highly negative $\delta^{13}C$ values (down to *ca*. -43 VPDB) in the zoned carbonate cements, consistent with authigenic

precipitation in a hydrocarbon-rich environment. The species-rich, well-preserved fauna includes 15 species of small to medium sized bivalves, some of which are abundant, as well as rarer rhynchonelliform and lingulid brachiopods, gastropods, echinoderms, sponges, and serpulid and probable vestimentiferan worm tubes. Although several bivalves (solemyids, lucinids, and probably *Thyasira* and *Nucinella*) had chemosymbionts, the Sassenfjorden seep fauna contains few, if any, seep obligate taxa, consistent with formation in a relatively shallow-water palaeoenvironment. The seeps contain the earliest record of thyasirid bivalves, and a species-rich (six) brachiopod fauna including the first lingulid recorded in a seep environment. Ammonites, belemnites and large wood fragments represent *ex situ* fossils in the seep carbonate bodies.

talks

A cryptic Cambrian radiation of crustaceans

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The fossil record of crustaceans is dominated by biomineralizing, post-Cambrian groups. However, small carbonaceous fossils (SCFs) provide evidence for widespread and diverse crustaceans in the Cambrian, pointing to a largely cryptic early radiation. SCF assemblages from the middle/late Cambrian Deadwood Formation of subsurface Alberta and Saskatchewan, Canada, include a diversity of exceptionally preserved mandibles and other crustacean limbs. Together these constitute the earliest records of crown-group branchiopods and total-group copepods and ostracods. Detailed similarities with modern forms reveal a pronounced morphological stasis in various feeding adaptations. At the same time, the Deadwood fossils indicate a profound overturn in crustacean ecologies in terms of environmental distribution and body size between the Cambrian and the present day. Because predation plays a major role in structuring modern crustacean communities, these changes are plausibly interpreted as the consequence of an escalating biosphere.

Evolution and phylogeny of Cervidae (Cetartiodactyla, Mammalia): a total evidence approach

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The ruminant family Cervidae (deer) was able to occupy successfully a large number of niches in the Old and New World since their appearance in the early Neogene (20 Ma). Several adaptive radiations produced high species diversity in cervids documented in the fossil record and the extant fauna. Although numerous studies in various disciplines over the last century were undertaken to resolve the phylogeny of cervids, several discrepancies are left. These include the systematically problematic taxa Chinese Water Deer (*Hydropotes*) and Muntjac (*Muntiacus*) and the systematic position of Cervidae within Ruminantia in general. Presumably, this is a result of heterogeneous character sets. The overall exclusion of fossil species in recent phylogenetic analyses causes a tremendous gap in the character matrix, as fossil representatives provide direct information about ancestral characters and character evolution.

To solve these problems, a step towards a total evidence approach will be done; first, by compiling a data set of morphological and molecular primary data throughout extant and extinct Cervidae in a homogeneous manner and procedure, and, secondly, by using it in a phylogenetic supermatrix analysis. From this, robust results regarding the intra- and extra-familial phylogenetics of cervids are expected.

First traces of *Osedax* worms from the Mediterranean

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Osedax is a genus of unusual marine worms that subsist entirely on vertebrate skeletons on the seafloor, using root-like tissues to bore into and degrade the bones. Palaeontologists have only recently begun to appreciate the possible destructive effect that these worms may have had on the marine vertebrate fossil record and little is known of their evolutionary history. Here we present *Osedax*-like borings in a fossil whale bone from the Pliocene of Italy and show new data on the borings of extant *Osedax* worms. Using computed tomography we have characterised the morphology of these borings in detail and erected a new ichnogenus to formalise the trace fossil. This is only the second palaeogeographic occurrence of *Osedax* in the fossil record and indicates that by the Pliocene these worms had colonised a large portion of the world's oceans. This is the first evidence for *Osedax* in the Mediterranean, past or present, and suggests that more species await discovery in this region today.

Palaeoecology and taxonomic composition of the Spathian Virgin Limestone Fauna: implications for benthic recovery from the end-Permian mass extinction event

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In a comprehensive study of benthic communities from the late Early Triassic Virgin limestone in Utah, USA, we identified 30 body fossil species and 14 ichnogenera. The Virgin limestone therefore contains the most diverse benthic fauna known from the Early Triassic, challenging previous claims that deleterious environmental conditions still persisted in this region during the Spathian. Analyses of quantitative species-level data demonstrate that the ecological structure of subtidal palaeocommunities in the Virgin Limestone is not fundamentally different from that of Middle Triassic shallow-marine habitats. Simple communities are limited to locally stressed environments such as intertidal

areas and lagoons, thus providing no indication of post-extinction effects. The high proportion of newly evolved taxa, mainly heteroconch bivalves, additionally suggests that recovery was well underway during the Early Spathian. However, taxonomical differentiation between habitats was still low, indicating a time lag between increasing within-habitat diversity (alpha-diversity) and the onset of taxonomical differentiation between habitats (beta-diversity). The onset of increasing beta-diversity may be useful to distinguish two major recovery phases: the first ending with habitat saturation and the second ending with completion of ecosystem differentiation.

New olenellid trilobites of the Digermul Peninsula, Finnmark, Northern Norway: constraints on lower Cambrian biostratigraphy

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The Ediacaran to Early Ordovician succession on the Digermul Peninsula measures 1500m, mostly consisting of well-preserved siliciclastics. The Ediacaran–Cambrian transition here contains a rich suite of trace fossils comparable with that of the GSSP section in Newfoundland. New discoveries of *Treptichnus pedum* indicate that the upper part of the Manndraperelva Member is Cambrian. The first trilobites are found in the Upper member of the Doulbasgaissa Formation. Previously only a few *Kjerulfia lata* specimens were known, but fieldwork in the Summer of 2011 added new material of this species and a new *Elliptocephala* species. Both *Kjerulfia lata* and acritarchs place the trilobite-bearing level in the *Holmia kjerulfia* Assemblage Zone. The higher stratigraphic position of the Doulbasgaissa Formation suggested by Nielsen and Schovsbo (2011) is thus contradicted. With three olenellids and other shelly fauna, the *Holmia kjerulfia* Assemblage Zone in the Mjösa area shows a diversity not seen on Digermul. However, the two olenellids in Digermul are unusual in Baltoscandia, where most species are known from isolated occurrences and few or incomplete specimens. Comparison with the new material and constraints using acritarchs should provide significant improvements on the correlation of this level in Baltoscandia.

Adjusted homoplasy indices and patterns of variation

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Since the 1980s, numerous studies have attempted to isolate a biological signal in the distribution of homoplasy among phylogenies. Almost all have returned insignificant results. However, commonly used homoplasy indices are biased by statistical parameters of the phylogenetic character matrix, which may disguise the biological signal. This talk will explore adjusted homoplasy indices, which give relatively unbiased measures of homoplasy on most parsimonious trees. These indices include Archie's homoplasy excess ratio (HER) and the – new – adjusted retention index (RIadj). The character randomisation procedure, which forms the basis for these indices, will be demonstrated using PAUP. I will also describe some applications of RIadj to phylogenetic meta-analysis. The results show some of the first significant large-scale trends in the distribution of homoplasy among phylogenies, and demonstrate the usefulness of adjusted homoplasy indices.

Macroevolutionary trends: disparity across the Phanerozoic

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Indices of morphological disparity quantify differences in morphology between the taxa in a sample. Over the last 20 years they have proved invaluable for documenting and understanding large-scale patterns of morphological evolution through time, and are often used in conjunction with indices of diversity. Many published studies indicate a tendency for clades to reach their maximum disparity relatively early in their evolutionary history, although most documented examples are groups radiating in the Palaeozoic. Whether the early maximal disparity of clades is predominantly a Palaeozoic phenomenon or a generality throughout the Phanerozoic is yet to be tested. This study quantifies disparity in 99 metazoan clades described by published, discrete morphological character matrices. Using the sum of variances as a measure of disparity and a centre of gravity metric as a proxy for clade-shape, we classify disparity profiles as significantly bottom-heavy, symmetrical, or top-heavy. Results indicate the majority of profiles are symmetrical, and there are no clear trends through the Phanerozoic. However, once counts are adjusted to minimise the effects of the big five mass extinctions, bottom-heavy clades are significantly more common than top-heavy ones. The relative frequencies of clade-shape categories seem to remain unchanged when data are partitioned into Eras.

Beyond the extinction: environmental and ecological interactions in the earliest recovery from the Cretaceous–Paleogene mass extinction

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The asteroid impact onto the Yucatan Peninsula approximately 65 million years ago caused the sudden mass extinction of late Cretaceous biota. The direct effects of the impact are thought to have been short lived, with boundary-related stressors like darkness and acidification lasting on the order of hundreds of years. Interestingly, multiple lines of evidence point to prolonged environmental instability and altered ecological interactions during the first ~500,000 years of recovery. Is this instability a result of a prolonged impact effect like a global dust ring, or does it arise from the ecological dynamics of early recovery foodwebs? The first mechanism suggests that ecological instability is a result of ongoing disturbance, and the second that it is a feature of early recovery ecosystems.

Here we present multiproxy evidence from an open ocean site in the Pacific to test both possibilities. We examine records of the diversity of calcareous primary producers, consumers, and fish, helium isotope records which track terrestrial and extraterrestrial dust, carbonate stable isotope records from the surface and deep sea of climatic dynamics, and Ba/Ti proxies of organic carbon fluxes. Together, these allow us to partition the relative contribution of external, extraterrestrial forcing from internal, biogeochemical dynamics.

talks

Lower Cretaceous Neuropterida (Insecta) from the Purbeck and Wealden, southern England

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The Lower Cretaceous Purbeck and Wealden are very important fossil insect sites, and despite over 150 years of work on these deposits many of the insect groups are still in need of detailed study. One such neglected group was the superorder Neuropterida (Neuroptera, Raphidioptera and Megaloptera), which previously had only five families recorded and five species described. After a comprehensive study, an additional six families have been recorded as well as over 30 new species and 15 new genera described.

The neuropterid fauna is heavily dominated by the psychopsoid neuropterans (over 60%), in particular the family Psychopsidae. Both Neuroptera and Raphidioptera have been recorded, but as yet no Megaloptera are known. Interestingly, the fauna also shares genera with other Cretaceous deposits such as in Brazil and China. Based on the modern ancestors of these insects the neuropterids have been interpreted as living in and around wooded areas, often some distance from the site of deposition, hence their often poor state of preservation. The neuropterid fauna shows changes from the lower Purbeck to the upper Wealden, which is probably related to the change of climate and environment observed at this time.

Late Cenozoic history of the Southeast Asian marine biodiversity maximum: new data for old questions

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Southeast Asia contains the modern-day global centre of diversity for shallow marine biota, yet the timing and factors responsible for the origins and continued maintenance of this biodiversity hotspot remain obscure. Existing collections are inadequate to document the biodiversity, and more importantly the changing environmental and ecological conditions that allowed high diversity to persist. To collect the required data we have created THROUGHFLOW, a consortium of European universities, industrial partners, and the Indonesian Geological Agency funded as a Marie Curie Initial Training Network. The team includes earth systems modellers, geochemists, geologists, palaeoceanographers, palaeontologists, sedimentologists and stratigraphers. In the past year, THROUGHFLOW has deployed two field parties, totalling 1,117 researcher-days, to study the Miocene shallow marine facies of East Kalimantan, Indonesia. Over 160 exposures were studied, and eight tons of samples were collected. Preliminary results confirm high diversity in various shallow marine habitats during the Miocene. For reef facies, there was a switch from framework constructed by tabular to platy colonies to facies dominated by branching and small free-living forms. This change might coincide with rapid cooling during the Middle Miocene, or might result from regional environmental change associated with tectonic evolution of the Indonesian Throughflow.

Interrogating dental morphospaces: an analysis of the conodont fossil record

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An increasing variety of data types is being utilised for assessing morphological diversity in the fossil record, including cladistic characters, functional variables and surface metrics (*e.g.* complexity). Little attention has been focused on how results from analyses of these datasets differ, and what the differences and similarities can tell us. The conodont fossil record furnishes an excellent resource for investigating these questions, because conodont elements are abundant over a long stratigraphic range, and conodonts are ecologically important; however, quantitative information on both morphological diversity and function in their dental apparatus is largely absent. We analyse three different datasets for fifty conodont taxa across a broad phylogenetic range and compare the resulting morphospaces and disparity values. This reveals that clusters within functional morphospace partially mirror those within a cladistic morphospace, suggesting that functional innovation may have driven phylogenetic expansion. Disparity is also far lower in the cladistic dataset compared to the functional, demonstrating how the type of data used for disparity analyses may bias interpretations of morphological diversity patterns. Surface complexity appears to vary independently of both cladistic and functional morphospace occupation. In addition, we use engineering approaches to interpret morphospace in terms of functional adaptation and dietary characteristics in conodonts.

Using zooid size variation and stable isotopes in bryozoan skeletal carbonate to reconstruct Pliocene temperature regimes

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Two independent proxies are used to reconstruct the temperature regime experienced by Pliocene bryozoans from the Yorktown Formation (USA) and the Coralline Crag (UK). The first proxy is based on the observation that zooid size is inversely proportional to the temperature at the time of budding, and hence that intracolonial variation in zooid size reflects temperature range. Measurements of zooid area from SEM images were used in this way to estimate the mean annual range of temperature (MART) experienced by the colony. The second proxy is based on the isotopic analysis of skeletal carbonate; many bryozoans secrete their carbonate skeleton in isotopic equilibrium with seawater, such that $\delta^{18}O$ varies inversely with water temperature. This approach can yield meaningful data, but specimens are prone to contamination by diagenetic effects, which need to be carefully screened for using Scanning Electron Microscopy (SEM) and Cathodoluminescence (CL). Results from the Yorktown Formation suggest sea temperatures of 16.6 to 24.8°C, in agreement with studies using other taxa. Well-preserved Coralline Crag material yielded temperatures of 10.1 to 17.7°C, lower than expected, and implying that the palaeoenvironment of this deposit may require re-investigation.

talks

Differentiating arthropod segment articulation morphology and its bearing on a revised phylogeny of basal chelicerates

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Recent restudy of a number of fossil arthropods has revealed inconsistencies in the treatment of the articulation devices between their trunk segments: for example the definition of an 'articulating half-ring' is rather liberally applied. A number of different articulation morphologies are identified; an anterior axial recess with attachment to the preceding tergite via arthrodial membrane, an anterior articulating ridge or shelf constraining overlap with the preceding tergite, a posterior articulating ridge or shelf constraining overlap with the succeeding tergite, a transverse articulating boss, or an articulating half-ring and furrow, as well as telescope-like joining without obvious articulating devices other than arthrodial membrane and possibly pivot joints. The anterior articulating ridge morphology appears particularly widespread among arthropods, appearing to be part of the ground pattern for Artiopoda, Megacheira and Chelicerata. However, some synziphosurines (currently considered the paraphyletic stem-lineage to Xiphosurida) have been described as possessing articulating half-rings, and the ramifications of this are considered in light of a number of other characters. A new interpretation of basal chelicerate relationships is considered where Xiphosura is para- or even polyphyletic, with synziphosurines representing a basal grade to a clade consisting of Xiphosurida, Chasmataspidida, Eurypterida and Arachnida; further characters supporting this topology are reviewed.

The origin and early evolution of the arthropods

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With over 1,000,000 described species, arthropods are the dominant phylum on Earth today. The interrelationships between their constituent clades (subphyla) remain poorly understood however, with conflicts arising between different molecular and morphological data sources. The position of the pycnogonids (sea spiders) is particularly problematic, some analyses allying them to euchelicerates (horseshoe crabs and arachnids) and others placing them as sister-taxon to all other extant arthropods. This problem is largely the result of an uncertain root position rather than topological conflicts *per se*; phylogenetic analyses incorporating stem-group euarthropod taxa have the potential to resolve these issues. Cambrian lagerstätten contain many candidate stem-group arthropods, supplemented here by two new exceptionally-preserved taxa from the Cambrian of British Columbia: an elongate 'great-appendage arthropod' with multipodomerous trunk limbs; and a bivalved form lacking distinct tergal pleurae, a feature previously considered diagnostic of extant arthropods. A comprehensive phylogenetic analysis was undertaken incorporating these and many other fossil and Recent arthropods; this resolved the stem-lineage (including the new taxa) in some detail, documenting many steps in the sequential acquisition of euarthropod characters. Pycnogonids resolved as sister-taxon to other euarthropods, implying that their chelicerate-like characters (*e.g.* chelate first appendage) are plesiomorphies rather than synapomorphies for euchelicerates.

Juvenile Ediacaran organisms from the Drook Formation, Newfoundland: insights into the ontogeny and ecology of rangeomorph palaeocommunities

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The Ediacara biota of the Avalon terrane represents a diverse but enigmatic group of organisms. Previous discussion of the initial radiation of rangeomorph frondose organisms suggests that their appearance immediately following the Gaskiers glaciation indicates a direct causal relationship between changing palaeoenvironmental conditions, and the evolution of large and complex organisms.

The discovery of a new assemblage of juvenile rangeomorphs from the Drook Formation of Newfoundland reveals representatives of at least five different rangeomorph taxa, significantly increasing the standing diversity of the very earliest Avalonian organisms. This in turn may indicate a pre-Gaskiers origin for the Ediacara biota, independent of glacially-induced forcing factors.

The rangeomorph fronds, all smaller than three centimetres in length, provide new insights into the ontogenetic development of their respective taxa. In addition, their high fidelity preservation alongside a population of large, low fidelity ivesheadiomorphs is inferred to represent one of the earliest recorded examples of secondary community succession in the fossil record. Such an interpretation reveals the prevalence of time-averaging within Ediacaran fossil assemblages, and permits re-evaluation of the palaeobiological and taphonomic processes occurring within late Ediacaran ecosystems.

Is *Diania cactiformis* the 'missing link' between lobopodians and arthropods?

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Cambrian lobopodians have attracted much attention in that they are considered to have close affinities with the origin of arthropods. A new lobopodian species, *Diania cactiformis* Liu *et al.* 2011, was recently reported from the Chengjiang Lagerstätte. The authors suggested that this animal bears arthropod-like appendages and resolved *D. cactiformis* as sister-taxon to Arthropoda in their cladistic analysis. However, a reanalysis of the published dataset does not reproduce the phylogenetic placement of *D. cactiformis*. In our study, new observations on *D. cactiformis* are made using newly collected material, which rejects the existence of unequivocal evidence for arthropod-like articulated appendages. The criteria for defining arthropodized appendages are further discussed through comparative studies among fossil lobopodians, anomalocaridids and arthropods. Our study also challenges the previous description of antero-posterior orientation, terminal claws and trunk tagmosis. A synthesis of recent datasets for lobopodians and stem-group arthropods is used to revisit the phylogeny of stem arthropods. Irrespective of how characters are weighted, *D. cactiformis* is resolved at a much more basal position to arthropods, and is actually one of the most basal Cambrian lobopodians, indicating that the morphology of this animal's appendages does not fundamentally inform on the evolution of arthropodization.

Stars in their eyes: new sensory structure or epibiont?

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Limuloides limuloides (Arthropoda: Chelicerata) is a Late Silurian synziphosuran from the Lower Leintwardine Formation of Church Hill, Shropshire. Originally described in 1885, *L. limuloides* still represents one of the best-preserved and phylogenetically significant 'merostome' (aquatic chelicerate) specimens. Despite this, this taxon has been largely ignored, with only occasional mentions in relatively recent phylogenetic analyses and reviews. The detailed morphology of this taxon has not been re-studied since its original description and as such, unique stellate ornamentation upon the prosoma (head shield) has gone unnoticed or ignored, bar a footnote by the original author. A comparative study has shown these structures to have a consistent morphology, however the theory that they represent sensory organs is considered unlikely due to the lack of any homologous or analogous structures in any other arthropods. Modern horseshoe crabs are well known for being 'mobile substrates', hosting an array of epibionts. *L. limuloides* is recognised to be the oldest species preserved with this relationship, which also leads to the possibility that the stellar ornamentation could represent a previously unknown epibiont; however this interpretation is also contentious due to the consistent positioning of these structures. Presently the exact nature of these stellate structures remains enigmatic.

Filling-in the "Palaeogene Gap": a diverse coral assemblage from the Late Oligocene of Borneo

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A diverse fossil assemblage of stony corals has been collected from the Kinabatangan region of Sabah in Malaysian Borneo. The fossil deposits studied have been accurately dated using a combination of nannofossils, larger benthic foraminifera and strontium isotopes, placing them well within the Oligocene epoch (between 30 and 23 Ma), where previously they were thought to be of early Miocene age (between 23 and 16 Ma).

The corals have been taxonomically identified to genus-level and placed into likely species groups within each genus. There are thought to be approximately 100 species present in this collection from within (a conservative estimate of) 52 genera. This fauna has been compared to contemporary coral faunas from around the world, as well as to coral faunas collected within the Indo-West Pacific (IWP) region dating from both Miocene and Recent times. The collection presented here is one of the most taxonomically diverse assemblages of corals from the Oligocene epoch, showing that high reef-coral diversity was present in the current marine biodiversity hotspot area earlier than has been previously known, and also that some species have had a much longer residence time in the IWP than has been previously thought.

The original colours of fossil moths

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Structural colours, the brightest in nature, function primarily in communication and are widespread in nature today. The feasibility of their being fossilised, however, has received little attention, and thus the evolution of structural colouration and its functions in animals is poorly understood. Here we report the preservation of structurally coloured scales in fossil lepidopterans from the 47 million-year-old Eocene Grube Messel oil shales (Germany) and reconstruct the original colours of their wings. Specimens exhibit non-iridescent metallic hues which are generated by a multilayer reflector comprised of a stack of perforated laminae in the scale lumen; differently coloured scales differ in their ultrastructure. The original colours were altered during fossilisation but are reconstructed based upon preserved ultrastructural detail. The dorsal surface of the forewings was a yellow-green colour that probably served as a dual-purpose defensive signal, *i.e.* aposematic during feeding and cryptic at rest. This visual signal was enhanced by suppression of iridescence (change in hue with viewing angle) achieved by two different optical mechanisms: extensive perforation, and concave distortion, of the multilayer reflector. The fossils provide the first evidence for the function of structural colour in the fossil record and confirm the feasibility of reconstructing colour in non-metallic lepidopteran fossils.

Skimming the surface with Burgess Shale arthropod locomotion

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Despite being discovered over 100 years ago, the Middle Cambrian Burgess Shale Formation of Canada continues to yield important new insights into the evolution and ecology of animals during the Cambrian explosion. Burgess Shale body fossils, with their exceptional soft-tissue preservation, have traditionally been used to infer the palaeoecology of a number of species; however, direct evidence of animal behaviour, in the form of trace fossils, is a largely elusive component of the biota. Here we report the first arthropod trackways from the Burgess Shale Formation. Trackway dimensions and the requisite number of limbs are matched with the body plan of a tegopeltid. *Tegopelte* is over twice the size of all other known benthic Burgess Shale arthropods and is considered to have been a predator or scavenger. Trackway analysis demonstrates the producers were capable of very high-geared gaits, rapidly skimming across the seafloor with short propulsive backstroke phases and metachronal waves of eight limbs moving along the body. Re-examination of body fossils has also identified the presence of gut diverticulae, confirming a carnivorous mode of life. Integrated trace and body fossil evidence therefore supports previous hypotheses on the locomotory capabilities and mode of life of such arthropods.

Spatial analysis of species distributions from Mistaken Point, Newfoundland

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Bedding-plane assemblages of Ediacaran fossils at Mistaken Point, Newfoundland (565 Ma) are the oldest known examples of *in situ* macroscopic communities. The constituent organisms have few similarities with living forms, making their ecology difficult to assess. To investigate the ecology of these early communities, I analysed the spatial distributions of the fossils on two of the key bedding surfaces, building on previous work by Clapham *et al.* (2003).

Differentiated GPS was used to map out the position of fossils on bedding surfaces D and E, creating high resolution 3D data sets. These were analysed using two statistical approaches: 1) Bayesian network inference to find the key interactions within the ecosystem and 2) point pattern analysis, to calculate the strength and spatial scale of the interactions. Bedding planes D and E exhibit conspicuously different types of spatial distributions. Whereas D is characterized by limited non-random behaviour and no interspecies interactions, E has both species aggregation and interaction. This pattern is consistent with ecological succession, however further work is required to ascertain whether succession is occurring. One species – *Thectardis* – has no environmental or interspecies interactions with other taxa, which supports morphological evidence suggesting it is unrelated, both ecologically and phylogenetically, to other Ediacaran macrofossils.

Small is beautiful: investigations into Early Devonian plant mesofossils from the Welsh borderland, UK

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Much of our understanding of the anatomy of the earliest land plants comes from the study of exceptionally well preserved, charcoalified mesofossils. Despite representing only a facet of early land vegetation, they continue to make significant contributions to the understanding of biodiversity and the development of terrestrial ecosystems. Recent studies have focused on establishing the morphological, anatomical and ultrastructural characteristics, using SEM, TEM and semi-thin sectioning, of a group of mesofossils macerated from Lochkovian rocks collected from the Welsh borderland. In particular, terminal sporangia, some attached to stomatiferous branching axes, contain *in situ* spores (trilete monads or cryptospores) of which many taxa have only been recognised in the dispersed spore record. With this data it is hoped that their affinity and taxonomic relationship with the early tracheophytes and bryophytes may be elucidated. For example, based on sporangial morphology and spore wall ultrastructure, a group of discoidal sporangia containing separating dyads are thought to be closely related to the tracheophytes, the dyads possessing a similar ultrastructure to crassitate trilete monads. Conversely, a group of valvate sporangia containing permanent dyads are hypothesised as representing a separate group of early embryophytes that possessed both tracheophytic and bryophytic characteristics.

A new early Ordovician Lagerstätte from South China

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There are very few Ordovician lagerstätten known, and they usually preserve atypical faunas. The recently discovered Early Ordovician (Tremadocian–Floian) Fezouata Biota contains a typical Ordovician community, along with Burgess Shale-type elements and taxa more characteristic of modern faunas (Van Roy *et al.*, 2010, *Nature*, **465**, 215–218). However, the Fezouata formations were deposited near the south pole, and the fauna may not be typical of lower latitude communities. A new lagerstätte containing a normal marine fauna has been discovered in the early Floian Tonggao Formation of Guizhou Province, China. The deposit contains a diverse (at least 50 species) assemblage, including graptolites, algae, brachiopods, echinoderms, trilobites, gastropods, worms and unmineralised arthropods, with soft tissue preservation. The fauna is dominated by graptolites, brachiopods and arthropods. This lagerstätte is similar in preservation to the Fezouata Biota, although it formed in a shallower, semi-lagoonal environment. Many elements of the fauna are also similar, but in the material available so far, the iconic Burgess Shale-type elements are replaced by more typical Ordovician groups.

Ontogeny and microstructure of the enigmatic Cambrian tommotiid *Sunnaginia* and implications for brachiopod bodyplan evolution

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The tommotiids are a significant component of the earliest skeletal animal remains in the fossil record, occurring in large numbers in the Lower Cambrian. Sclerites of the tommotiid genus *Sunnaginia* have been implicated as integral to hypotheses regarding the evolution of the brachiopod body plan, with a morphology intermediate between the unspecialized sclerites of the tubular *Eccentrotheca* and the specialized sclerites of the tannuolinids. New microstructural data from *Sunnaginia* sclerites, of a broad ontogenetic spectrum, were collected using synchrotron radiation X-ray tomographic microscopy, revealing a microstructure for *Sunnaginia* sclerites unique among the tommotiids. These data refute the inclusion of *Eccentrotheca* within the Sunnaginiidae and highlight the need for a revision of suprageneric classification of the tommotiids. Rather, structural similarities in *Sunnaginia* sclerites suggest a close affinity to tannuolinids. In the context of recent phylogenetic schemes for the brachiopod stem, *Sunnaginia* resolves close to the node defining crown-Brachiopoda. However, the characters supporting this phylogenetic scheme cannot be consistently applied to all taxa, nor do they define a series of nested clades. We suggest therefore that a more thorough phylogenetic analysis is required in light of the data presented here and other recent descriptions.

talks

Family richness in the insect fossil record

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Insects comprise >50% of described species richness; explaining this richness is a major challenge in macroevolutionary studies. A new dataset of insect family ranges in the fossil record has been compiled from literature published up to the end of 2009. This is compared with Ross and Jarzembowski (1993, In: *The Fossil Record 2*, pp. 363–426) and Labandeira (1994, *Milwaukee Public Museum Contributions in Biology and Geology*, **88**, 1–71), showing how knowledge of the insect fossil record has developed. Origination/extinction rates are used to test hypotheses of key innovations in the evolution of insect diversity, *i.e.* wings, wing-folding and complete metamorphosis. Testing correlation between variation in family richness and environmental proxies identifies potential factors controlling diversity.

Previous studies suggest clade growth differs in marine and terrestrial taxa, supporting equilibrial and expansionist models, respectively. Fossil data for Odonatoidea (dragonflies, *etc.*) were combined with a phylogenetic supertree to infer gaps in the fossil record (Davis *et al.*, 2011, *BMC Evolutionary Biology*, **11**, 252). This analysis supports the notion that taxa, appearing to have diversified exponentially using fossil data, may have diversified logistically, suggesting that one of the major apparent differences between marine and terrestrial fossil records may be an artefact of incomplete sampling. Difficulties in assessing rock record bias in the insect record are explored, and suggestions of future directions for quantitative palaeoentomology are made.

Dinoflagellate cyst response to Oceanic Anoxic Event 2

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During the extreme greenhouse climate at the Cenomanian–Turonian boundary (CTB; 93.5 million years ago), extensive organic-rich sediments and black shales were deposited in association with Oceanic Anoxic Event 2 (OAE2). Organic-walled dinoflagellate cyst (dinocyst) records across the Cenomanian–Turonian boundary are presented for successions in Dorset (UK) and the Danish sector of the North Sea. While the Cenomanian–Turonian Boundary in Dorset is represented by a chalk-marl succession, the North Sea contains the organic-rich black shales distinctive of this horizon.

Evidence for a marine productivity peak at the onset of OAE2 in Dorset is apparent from a high absolute abundance of dinocysts, and a peak in relative and absolute abundance of the heterotrophic dinocyst *Palaeohystrichophora infusorioides*. As the OAE continues, dinocyst abundance and diversity collapse. While diversity recovers in the Turonian, dinocyst abundance remains much lower than in the Cenomanian, and the assemblage changes from one indicative of a high nutrient system to a diverse oligotrophic assemblage. The North Sea Cenomanian assemblage is less diverse and does not contain indicators of high productivity. Following a peak in dinocyst abundance and diversity in the CTB black shale, the Turonian of the North Sea is barren of dinocysts.

Impact of ash-falls on the diversity of Ordovician ostracods

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The impact of two Ordovician ash-falls of different intensities was studied in order to determine the recovery patterns of benthic ostracods (palaeocopes and 'non palaeocopes'). The studied sections are both of Sandbian age and located in NW Estonia: Põõsaspea, Kinnekulle K-bentonite (40cm) and Ristna, Grimstorp bentonite (10cm). In Põõsaspea, important faunal changes are observed: the five pre-crisis dominant species disappear above the bentonite and two species get completely extinct. The post-crisis ecosystem shows strong perturbations in terms of abundance and diversity for ~7-20ka. In Ristna the impact of the ash-fall is less dramatic: all the dominant pre-bentonite species survive, although some disturbance in abundance and diversity is observed for ~5-15ka. These results show that significant ash-falls will lead to strong faunal renewal and extinctions, while less prominent volcanic episodes only result in temporary changes in the assemblage structure. In both cases, the recovery occurs rapidly after the crisis and follows several distinct steps:

- Post-event ecosystem with 'survival faunas' (very low abundance; low diversity); one/two species (opportunistic taxa?) dominates the assemblage.
- Early stages of recolonization with 'recovery faunas' (medium abundance; medium diversity, pre-event species returning).
- Return to 'climax assemblages' with specialized taxa (high abundance; high diversity).

Investigating the functional morphology of Cambrian cinctan echinoderms using computational fluid dynamics

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Deciphering the relationship between form and function in fossil organisms is key to reconstructing their mode of life and evolutionary history, but is problematic where there is no clear modern analogue – as is the case for many Cambrian echinoderms. Modelling approaches such as computational fluid dynamics (CFD) offer a potential solution to this difficulty, as they can be used to quantitatively analyze the function of fossils without making assumptions regarding the choice of interpretive model. Taking cinctan echinoderms as an exemplar for Cambrian problematica, we used CFD to investigate the functional morphology of the group. First, complete, articulated cinctan fossils were imaged using X-ray micro-tomography and reconstructed as three-dimensional digital models. CFD simulations were then performed on these models in a variety of orientations and under a range of flow conditions. The results showed that flow was most turbulent where the current first reached the animal, suggesting that cinctans were oriented parallel

to the prevailing current direction to enhance their stability on the seafloor. Moreover, cinctans most likely faced downstream of the current, as this would permit more efficient feeding. This study demonstrates the enormous potential of computer modelling for improving our understanding of the functional morphology of fossil organisms.

Functional morphology and ontogeny of the earliest jawed vertebrates

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The evolution of jaws and teeth is thought to be the key innovation in the evolution of vertebrates. The bauplan of the first jawed vertebrates, the placoderms, is important with respect to the evolution of more derived gnathostome dentitions. We investigate the function of these first jaws and teeth and changes during ontogeny.

Applying synchrotron tomography and micro-CT we produce virtual models of growth stages of jaws of the arthrodire *Compagopiscis croucheri* from the Upper Devonian of Australia. These are used for occlusion and finite element analysis (FEA), additionally the microwear of the jaws is analysed. The occlusion- and wear-pattern of the teeth and jaws shows notable changes during ontogeny. The growth pattern of the statodont dentition prepatterns the development of the wear-pattern, this enables a functional occlusion and interlock. The biomechanical characteristics of the jaws are relatively constant during ontogeny and only a slight change in the optimization of the stress-resistance occurs. The existing morphological, histological and ontogenetic evidence argues for a basal position of the arthrodire construction in the evolution of jaws and teeth in gnathostomes. Functionally early ontogenetic stages are comparable to recent crowngroup gnathostomes, whereas later stages show a unique development of the wear pattern.

Microbial zonation and cyclicity in phosphatic stromatolites from the Palaeoproterozoic Vindhyan Supergroup, India

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Phosphatic stromatolites from the 1.6 Ga Lower Vindhyan contain abundant microbial fabrics dominated by mat-constructing filamentous microorganisms and coccoidal species. The Vindhyan Supergroup in central India comprises one of few voluminous Palaeo-Mesoproterozoic phosphorite deposits and represents a unique locality to study processes related to phosphatization, palaeoecology and taphonomy of microbial mat

associations from this time. Here we present morphological data from petrographic analysis and Synchrotron X-ray Tomographic Microscopy (SrXTM), suggesting that variations in seasonal or diurnal solar input, or recurring depositional changes, affected the growth position of motile filamentous bacteria in the Vindhyan phosphorites. Microbial fabrics studied from vertical sections cut perpendicular to bedding were characterized by alternating prostrate and erect phosphatized filaments, similar to cyclic cyanobacterial fabrics found in active hydrothermal environments (*e.g.* Konhauser *et al.* 2004, *Ambio*, **33**, 552–558). Morphological distinctions between layers in vertical sections of laminated mats appear to represent variations in community structures, and we suggest that at least two distinct epibenthic filamentous communities have played a key role in Vindhyan stromatolite morphogenesis acting as framework-builders. Further, variations in microbial growth patterns, such as the construction of tufts, are hypothesized to have greatly influenced the formation of individual laminae in the Vindhyan stromatolites.

New observations on the earliest marine faunas of the type Devonian succession of SW England: the brachiopods of the Meadfoot Group, Torquay, Devonshire, UK

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The marine faunas in Devonshire are famous for their historical contribution to the palaeontological characterization of the Devonian System. Remarkably, however, there has been little recent, systematic study of these faunas. In particular, the exact stratigraphic assignment of the shelly faunas within the Meadfoot Group is still unclear. Brachiopods are key fossils for stratigraphic assignment in neritic facies, although tectonic deformation and poor preservation can complicate their study. It has been possible to recover new material from the Torquay area of the English Riviera European and Global Geopark, which has been studied in conjunction with the type collections housed in the Natural History Museum in London as well as material in private collections. These faunas have been compared with coeval faunas from the Rhenish Slate Mountains, northern Gondwanan Terranes and the Eastern Americas Realm, and taxa revised and their systematic assignment updated. The Meadfoot Group represents a time interval from Late Pragian to Emsian, apparently becoming younger from west to east, and its brachiopod faunas show close affinities to those from the Rhenish Slate Mountains. Some taxa represent phylogenetic ancestors from the Eastern Americas Realm and confirm that there was faunal exchange between these regions in the Late Emsian.

Cambrian Explosion and Ordovician Biodiversification, or Cambrian Biodiversification and Ordovician Explosion?

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Besides the terms "Cambrian Explosion" and "Cambrian Substrate Revolution", the term "Great Ordovician Biodiversification Event" (GOBE) has more recently been introduced to designate the most important increase of biodiversity of marine life during Earth's history. While the "Cambrian Explosion" (some 545 to 530 Ma) resulted in a series of spectacular originations of "new" animals (that are mostly from the famous Fossil-Lagerstätten), the Ordovician Biodiversification resulted, some 40 to 80 myr after the "Cambrian Explosion", in an "explosion" of diversity at lower taxonomical levels, in particular during the Early and Mid-Ordovician (485 to 460 Ma). The Ordovician Biodiversification generated few new higher taxa (and no new phyla!), but a staggering increase in biodiversity at the family, genus and species ranks, documented in all diversity counts, resulting in an "Ordovician Explosion" of family, genera and species of marine organisms. Are these discrete events in the early Phanerozoic, or merely part of a predictable continuum in the history of marine life mediated by intrinsic biological constraints and the evolution of the Palaeozoic ecosystems?

Which plants constituted the amber forests? A case study of the Baltic and Bitterfeld ambers.

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Amber has been highly prized for centuries, but the value of the diversity of the organisms trapped in the amber (inclusions) is immense. Numerous studies have focused on the often exquisitely preserved zoological remains (like spiders, insects, vertebrates), with the botanical inclusions being often overlooked since they are usually fragmentary and deemed difficult to assign taxonomically. Additionally, the assumption has been that certain plant fragments do not preserve well, if at all, in particular, pollen. This study firstly documents the various preservational modes of plants that lead to differing amounts of the original biological information being retained. These taphonomic differences mean the inclusions can retain high fidelity surficial cellular details, to less well preserved specimens that have become mummified and partially to wholly replaced by pyrite growth. Our taphonomic experiments with plant remains in modern resins are trying to understand these diverse modes of preservation. Despite the nature of the plant inclusions, new information is emerging on the botanical components of the amber forests. The study's major focus compares the included flora of the Palaeogene Baltic coast and German Bitterfeld ambers with a summary of what these fossilised tree resins tell us about the plant composition of these two forests.

Animal-plant interaction in the Middle Permian of Antarctica

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A range of evidence for invertebrate feeding has been recovered from silicified peats capping a coal seam in the Middle Permian Bainmedart Coal Measures of the Prince Charles Mountains, East Antarctica. The evidence occurs in the form of coprolites, both free in the peat matrix and clustered within excavations in roots, leaves and trunk wood. Observations of coprolites in thin-sections of the peats and from scanning electron microscopy images of examples extracted from the silicified peats through bulk maceration reveal a range of coprolite morphotypes and contents that indicate a diverse range of feeding behaviours – including stem feeding, root feeding and indiscriminate feeding on sporangia, pollenivory and mycophagy. The first evidence of invertebrate feeding traces in *Vertebraria* (glossopterid) roots is also identified. These findings provide rare examples of herbivory in the Permian forest-mire ecosystems of Antarctica, and build on the range and distribution of animal-plant interactions in the Palaeozoic.

Mouthparts in the Cambrian 'molluscs' *Odontogriphus* and *Wiwaxia*: implications for ecology and affinity

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The problematic Burgess Shale (Middle Cambrian) organisms *Odontogriphus* and *Wiwaxia* have been affiliated with the molluscs, largely on the basis of their radula-like mouthparts. But these mouthparts have also been likened to the annelid jaw, bringing a molluscan affinity into question. Detailed analysis of the mouthparts shows some differences between the two taxa, but confirms a close relationship. The mouthparts bear a number of molluscan traits: teeth sit in identical uniformly-sized rows that contain a rachidian tooth, overlap but are not attached to one another, and rotate relative to their neighbours as they pass round the end of a basal 'tongue'. Annelid jaws grow and moult differently, and have different symmetry, tooth distribution and active mechanism; they provide a poor analogue for *Odontogriphus* or *Wiwaxia* mouthparts. In the context of other anatomical features, a molluscan affinity is strongly supported. The mouthparts of detritus-feeding chitons (Polyplacophora: Mollusca) are morphologically similar; notably, juveniles have very few tooth rows, suggesting an ecological overlap with *Odontogriphus* and *Wiwaxia*.

Bryozoan size variation across the K–T mass extinction

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The Lilliput Effect describes a decrease in body size through extinction events and has been investigated in several groups of organisms with respect to mass extinctions. Most Lilliput studies have focused on solitary organisms, and it is unclear whether colonial organisms

respond in a similar manner. Additionally, recent disputes about the ubiquity of the Lilliput Effect have demonstrated the need for further studies of this phenomenon.

Bryozoans have the potential to provide valuable insights into the universality and cause of the Lilliput Effect as they enable this phenomenon to be studied at two hierarchical levels: colony and zooid size. Environmental variation may be reflected in the size of living bryozoan zooids, and this information can be used to interpret past zooid size change. The K–T mass extinction is associated with a decline in primary productivity, and is likely to have had some influence on zooid size at this time.

Zooids were measured in cheilostome bryozoan taxa spanning the K–T boundary. Trends in size change across the boundary differed between taxa, and did not occur in all. This suggests a differential response of bryozoan zooid size to the K–T mass extinction, and implies that size reduction is not pervasive in all organisms.

A novel Carboniferous ovule elucidated through a combined methodology for three-dimensional reconstruction

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Plants fossilised within siderite nodules ($FeCO_3$) are often three-dimensionally preserved – such as those from the Mazon Creek Carboniferous terrestrial lagerstätte. Fossils preserved in this way have historically been studied using single-surface observation or destructive investigative methods such as serial peeling/grinding, and thin-sections. These approaches have gradually improved for over a century, but recent advances in scanning technology, matched by rises in computational power and advances in software, have opened a new and exciting set of tools for palaeobotanists. Here we report a case study of a Medullosan ovule in which a novel combination of X-Ray Micro-Tomography (XMT) and orientated precision-sectioning is used, the latter targeted using the former. This technique has allowed correlation of geometries of different layers (seen in the three-dimensional model) with histological characteristics (gathered from wafered sections). The study reveals the ovule to be unusual in displaying both radial and bilateral symmetries in different tissues and in anatomically separate parts of the seed. These previously unrecognised complexities have implications for attempts to infer systematic affinities from symmetry in fossil seeds.

Chitons without feet: new data on molluscan evolution

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The relationship between molluscan classes has long been a subject of controversy. In particular the position of the shell-less Aplacophora and their relationship to the valve-bearing Polyplacophora ('chitons') has been problematic, Aplacophora variously being treated as a paraphyletic group at the base of the Mollusca or a sister taxon to the Polyplacophora. Final resolution of this debate is required for the plesiomorphic characters of the Mollusca to be reconstructed with confidence. Recent fossil finds have supported the latter position, demonstrating that the Palaeozoic paleoloricate 'chiton' fauna included taxa, notably the exceptionally-preserved Silurian *Acaenoplax*, that combined polyplacophoran-like and aplacophoran-like characters. *Acaenoplax*, however, has a complex and highly derived morphology; its valves are not typical of Palaeozoic chitons, nor is its body unambigiuously aplacophoran-like. We describe here two species that provide almost perfect 'missing links' between the two groups; the Ordovician '*Helminthochiton*' *thraivensis*, and even more informatively, a new three-dimensionally preserved fossil from the Silurian Herefordshire Lagerstätte. These taxa preserve aplacophoran-like girdles, typical palaeoloricate 'chiton' valves, and, in the latter case, posteriorly-positioned respiratory organs. Provisional phylogenetic analyses provide further support for a sister-group relationship between extant Polyplacophora and Aplacophora, and suggest that many palaeoloricate 'polyplacophorans' may actually belong within the aplacophoran crown-group.

talks

miRNAs and the evolution of Eutherians

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microRNAs are a rare genomic character that has been used to resolve the position of some of the most troublesome nodes within the metazoan tree of life – such as the monophyly of cyclostomes and the origin of turtles and tardigrades – nodes which have long troubled both palaeontologists and neontologists alike. Here we discuss the use of microRNAs in phylogenetic analyses by considering four unique properties. Firstly, substitutions to the mature sequence are rare. Secondly, microRNAs are continuously acquired through evolutionary time. Thirdly, there is minimal secondary loss; and finally, the likelihood of convergence evolution in generating two identical miRNAs is exceedingly small. Given these characteristics, we use microRNAs to resolve the relationships amongst Eutherian mammals. The relationships between the four major clades of Eutherians (Xenarthrens, Afrotherians, Laurasiatheria and Euarchontoglires) are still contentious, with various genomic datasets suggesting that, either the Afrotherians, Xenarthrens or the Atlantogeneta (Afrotherians + Xenarthrens), are the earliest diverging lineage. However, the miRNA data suggests that the murid rodents are basal and that Rodentia itself is paraphyletic. Although this seems a radical rearrangement of Eutherian phylogenetics, the relationships on an unrooted tree are identical between datasets, suggesting, that above all else, this is a rooting problem.

Recent developments in the studies of fossil colour of birds and other dinosaurs

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The discovery of fossil melanosomes has generated much recent development in how to understand the plumage colours of non-avian dinosaurs. We currently understand how to recognize and predict melanosome morphologies that will give rise to grey, brown and black. However, since birds are not simply trichromatic, we have expanded our dataset and are now able to characterise a number of additional hues and colours, including structural colour.

The dissolution of Quaternary pteropods from the Caribbean and Mediterranean Seas

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The aragonite producing thecosome pteropods are an important planktic component of the food web in many areas of the world's oceans. In the modern ocean, experimental evidence shows that increasing atmospheric carbon dioxide and the resulting ocean acidification will negatively impact these organisms, since their aragonitic shells are highly susceptible to dissolution. In sediments which are not prone to further dissolution, pteropod shells produce a detailed time series of past aragonite dissolution and environmental conditions. Fluctuations in the preservation and abundance of pteropod shells through glacial and interglacial cycles have been found in several locations; however, these records are largely not comparable due to the use of various methodologies. Here we present and compare pteropod preservation and abundance data for two locations known for their pteropods-rich sediments. It was found that preservation increases during glacial periods and decreases during interglacial periods. Although the magnitude and rate of pH change occurring in the modern ocean is much greater than that shown in the Quaternary record, this study may be useful in predicting future effects on modern pteropod populations.

Abstracts of poster presentations

* Candidates for the Council Poster Prize are marked with an asterisk.

Revisiting Mongolepidida (Chondrichthyes): ontogenetic development and histology of the exoskeleton in some of the earliest shark-like fish

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The Order Mongolepidida is known solely from isolated polyodontode scales, restricted in stratigraphic range to the Llandovery of Mongolia and China. Mongolepids have been considered to be closely related to Chondrichthyes by previous authors. In order to test this phylogenetic hypothesis, a detailed histological and morphological investigation of *Mongolepis*, *Teslepis* and *Sodolepis* (all members of the Family Mongolepididae) has been undertaken, using non-invasive X-ray microtomography and thin-sectioned specimens studied with the aid of Nomarski-interference optics and scanning electron microscopy.

Three-dimensional renderings of the internal canal system of *Mongolepis* and *Teslepis* scales show that the horizontal canals encountered near the crown-base junction correspond to chondrichthyan-type neck canals, which open inside odontode pulp cavities. There is indication of growth in *Mongolepis* and *Sodolepis* scale crowns through deposition of secondary odontodes on the anterior of the main odontocomplex rows. This warrants a revision of mongolepid intrarelationships, as a growing-scale pattern has been regarded to be diagnostic exclusively for the Family Shiqianolepidae.

These data suggest close relationship between Mongolepidida and Chondrichthyes based on the occurrence of neck canals and absence of enamel, elasmodine, and hard tissue resorption.

Sclerobionts and bioerosion in belemnites from the Early Cretaceous Speeton Clay of Yorkshire

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The Speeton Clay, a thick (>100 m) and complex succession of Berriasian–Early Albian sediments deposited in the Cleveland Basin, is renowned for its rich marine biota. The most abundant fossils are belemnites. These were used by Lamplugh (1889) to subdivide the Speeton Clay into A, B, C and D beds. Although largely overlooked, the resistant calcite guards of the Speeton belemnites supported diverse sclerobiotic (hard substrate) communities after the death of the cephalopods. Encrusting sclerobionts are mostly foraminifera with rarer bryozoans. However, boring sclerobionts are more abundant and diverse, sometimes being present in sufficient abundance to cause significant bioerosion of the guards. Macroendoliths include brachiopod pedicle traces (ichnogenus *Podichnus*), acrothoracican barnacle borings (ichnogenus *Rogerella*), and various 'worm' borings. Among the smaller borings are the foraminiferan boring *Semidendrina* and numerous filamentous traces attributable to algal, fungal or bacterial microendoliths. Further study

of these borings should provide information about environmental parameters (*e.g.* depth) pertaining at different times during the deposition of the Speeton Clay, as well as contributing to our understanding of the evolution of sclerobionts and bioerosion.

Multidisciplinary investigation of Givetian (upper Middle Devonian) Athyrid brachiopod shells and their palaeoecological and palaeoceanographic significance

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In recent years, extensive collection of Athyrid brachiopods has been carried out from the Silica Shale of the Givetian Hamilton Group (Michigan/USA) and coeval strata from reefs situated in Northwest Africa (Morocco) which have hitherto been determined as *Athyris* '*concentrica*'. We can identify two new species belonging to the *Athyris concentrica* group with the help of serial section, and present the resulting digitized three-dimensional reconstructions of the new taxa. Regarding the fact that *Athyris* '*concentrica*' is still considered as a garbage can taxon, we used specimens of *Athyris concentrica sensu stricto* only from the type region (Eifelian, Eifel region Germany). Biometric and morphometric analyses of these three taxa have proved the identification of the new species and elucidate the differences between these species.

Brachiopod shells of the new taxa have been analyzed for stable isotopes. The use of brachiopod shells for isotopic analyses is suggested especially because the secondary layer of Recent brachiopods can be considered to be secreted in isotopic equilibrium with oceanic water. The preservation of specimens has been tested using the common techniques: thin sections, cathodoluminescence, geochemistry and shell ultrastructure. Our results will be discussed in terms of palaeoenvironmental and palaeoceanographic perspectives.

posters

Exceptional preservation of lower Cambrian mickwitziids from the Indian Springs Lagerstätte, Nevada, and implications for early brachiopod phylogeny

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The origin and early evolution of Brachiopoda can be traced back to the plethora of scleritome and brachiopod-like taxa in the Cambrian. Most conspicuous are members of Lagerstätten such as the Burgess Shale and Chengjiang faunas. We provide a comprehensive systematic reappraisal of one of these enigmatic groups, the mickwitziids, a purported stem-group of inarticulate Brachiopoda. Examination of *Mickwitzia* from the early Cambrian Indian Springs Lagerstätte (Middle Member of Poleta Formation, Montezuman Stage) with exceptionally preserved setae is our main focus. Understanding the character suites associated with these organisms is crucial to reconstructing the brachiopod stem-group, polarising character changes associated with the transition from scleritome organisms to crown-group brachiopods, and to determine the position of Brachiopoda within a wider framework of early lophotrochozoan evolution. Critical analysis of shell structure and setae from these mickwitziids with those from sites with

differing diagenetic history reveals the extent of taphonomic alteration, further informing previous taxonomic efforts. Morphometric analysis of outline and shell growth landmarks is also utilised, leading towards a revised species concept within the genus *Mickwitzia*.

A possible link to *Heliomedusa* is also investigated in light of new comparative data of mantle setae from the Nevada material.

Pipe rock ichnofabrics and microbial mats in Lower Cambrian shallow marine sandstones of western Newfoundland, Canada

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Quartz arenites of the Lower Cambrian Hawke Bay Formation were deposited on the Laurentian margin during rifting of the Iapetus Ocean. This marginal marine, wave- and tide-influenced unit has abundant arthropod grazing and resting traces (*Cruziana* and *Rusophycus*), and, in vertical section, contains complex and diverse ichnofabrics. The dominant ichnotaxa are the vertical pipes and U-shaped burrows of *Skolithos*, *Arenicolites* and *Diplocraterion*, and ichnofabrics are comparable with those of the Pipe Rock Member (Eriboll Formation) of northwest Scotland. Bioturbation intensities are highest at the base of 2–8 metre thick parasequences, in association with authigenic phosphate and glauconite at flooding surfaces. Intense bioturbation is also recorded from ripple cross-laminated, wave- and tide-influenced lower shoreface sandstones. Bioturbation is almost absent from the upper parts of parasequences, which are dominated by 2–4 m thick intervals of planar- and crinkly-laminated sandstones, with microbially induced sedimentary structures on bedding planes. This unusual facies is interpreted as having been deposited in a (non-uniformitarian) microbially-bound, upper shoreface to foreshore palaeoenvironment.

A unique new Silurian sponge (?Dictyospongioidea) from the Pentland Hills, Scotland

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A new genus and perhaps family of sponge has been collected from the North Esk Inlier of the Pentland Hills. The single specimen was collected from fossil-rich locality R82 of the Wether Law Linn Formation (upper Telychian, Llandovery, Silurian) which has yielded abundant and varied shelly faunas together with rare articulated sponges. Although sponges form only a minor part of the North Esk Inlier fauna, all species (and some genera and families) described are known only from the inlier, perhaps due to the rarity of preservation of complete sponge skeletons in similar shallow-water environments.

The specimen is superficially similar to the widespread group Choiidae, consisting of a shallow bowl with an array of large monaxons radiating from the outer part. However, it also shows areas of parallel, non-radial monaxial spicules, combined with a radial-concentric fabric. These features are reminiscent of some groups of dictyospongioid hexactinellids, but none described to date possessed projecting monaxons.

The new species cannot easily be placed into any known family, and like the co-occurring *Amphispongia oblonga*, may represent an otherwise unknown evolutionary lineage restricted to shallow-water environments. The Pentlands fauna illustrates how little we know about non-lithistid sponges from these environments in the Early Palaeozoic.

Taphonomy of the upper Kimmeridgian Wattendorf Plattenkalk of Upper Franconia (southern Germany)

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Plattenkalks offer a unique view on ancient life through their exceptional fossil preservation. This preservation required special environmental conditions often obscured by poor sedimentary characteristics. A combination of different taphonomical analyses reveals these latent palaeoenvironmental conditions. The Upper Kimmeridgian Wattendorf Plattenkalk allows quantitative taphonomic investigations because every bedding plane has been equally thoroughly searched for fossils. Through a quantitative taphonomic analysis of the plattenkalks, four different taphofacies were established by cluster analysis, comprising combinations of different biostratinomical features in fossil fishes, primarily of the genus *Tharsis*. These taphofacies indicate four energetic regimes with the transition from taphofacies A to taphofacies D marking a development from only small influences by disturbing factors to conditions of higher disturbance influencing the fish carcasses.

Qualitative taphonomic analysis has yielded two distinct modes of soft-tissue preservation in Wattendorf. The typical phosphatization as well as preservation of soft tissues through iron-oxide permineralization can be observed. Combination of the findings allows for the reconstruction of a depositional setting that exhibits stable, cyclic environmental conditions at its base. Towards the top, the environmental conditions start fluctuating, with a dominance of high-disturbance environments probably induced by bottom-water currents and mixing of the water body, perhaps initiated by strong storms.

A bivalve proxy for Neogene Antarctic and Pacific shelf marine environments

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Fossil bivalve molluscs provide a detailed record of palaeoseasonality in the chemical signature and morphology of their shells. This signal can potentially test hypotheses about the extent of sea ice in the Antarctic during Pliocene warm intervals, or the nature of the ENSO in the Pacific. Here I examine the seasonal signal of Pliocene bivalves from the eastern Pacific, the Antarctic Peninsula and the East Antarctic coastal plain as well as developing a protocol to confirm preservation. Initial analyses identify the following: 1) Neogene bivalves from James Ross Island, Antarctic Peninsula, comprise material of late Miocene through to late Pliocene age. Initial results identify warm (*ca*. 3–13 °C) early Pliocene sea temperatures, and cooler late Pliocene sea temperatures (*ca*. 0–4 °C), and flag a cooling trend which is consistent with the evolution of global climate through this interval. 2) Neogene bivalves from the Larsemann Hills, East Antarctic, identify generally warmer-than-present sea temperatures (*ca*. 0–9 °C) in the early Pliocene consistent with data from

other fossil groups of this age, including dolphins.
3) Initial analysis of material from the Mejillones Peninsula, northern Chile, of late Pliocene to earliest Pleistocene age, provide seasonality data that are more consistent with La Niña than El Niño states.

Teleost superiority: a foregone conclusion? Patterns of teleost and holostean diversification in the Mesozoic

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Teleosts are the dominant living group of aquatic vertebrates; they comprise approximately 29,000 species, assume a bewildering array of morphologies, and have come to occupy nearly every environment imaginable. In extreme contrast, their holostean sister group comprises a mere eight living species, all of which are restricted to the freshwaters of eastern North America. It is this pattern of extreme contrast, gleaned from living taxa alone, which has provided the basis for assertions of teleost 'superiority' and fuelled a series of evolutionary scenarios. However, the fossil record indicates that these groups arose in the Permian, so around 280 million years of diversification has been largely excluded from the debate. By reconstructing the historical diversity trajectories for these groups, we can establish the pattern by which teleosts came to dominate. We quantified taxonomic and morphological diversity for holosteans and teleosts from the Permian to Jurassic (spanning 50% of their joint history), with a third measure, functional diversity, to be the subject of future work. Contrary to the pattern we observe in extant taxa, our datasets suggest that across much of the Triassic and the Lower Jurassic, holosteans were in fact more diverse than teleosts, both taxonomically and morphologically. However, teleosts expanded their range of morphologies greatly in the Jurassic, and their taxonomic diversity continued to grow throughout this period. This continued teleost diversification led them to overtake holosteans during the Jurassic, signalling a 'switchover' event at this time.

The early Cenozoic roots of modern polar biotas

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The K–Pg mass extinction event, which was responsible for the eradication of at least 70% of all species, primed the phylogenetic fuse for the rise of many modern plants and animals in the Paleocene–Early Eocene. Within the marine realm we now know that some modern Southern Ocean taxa can be traced back to the Early Paleocene of Antarctica where they were components of more temperate assemblages characterised by trophic and habitat generalists. Indeed, there is some evidence to suggest that such assemblages were typical of both polar regions through the greater part of the Cenozoic era, and their presence has been taken to indicate both low rates of origination and extinction through time. Those biological taxa that managed to master the conditions in the polar regions in the post-K–Pg world in effect became ecological incumbents.

We are currently working to refine the time of origin of a number of key polar groups using a combination of palaeontological and molecular phylogenetic techniques. One interesting feature to emerge so far is a strong bipolar element which in turn suggests that evolutionary connections between the polar regions and the deep sea may date back to the early Cenozoic era.

Fossil whale falls from the Neogene of Italy

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Twenty five Neogene whales hosted in Italian museum collections were analysed to reconstruct the course of whale-fall ecological succession in shallow water settings. Degree of bone articulation, completeness of the skeleton, and lithology of the embedding sediments were used to gather information on relative water depth, water energy, sedimentation rate and overall environmental predictability around the bones. Shark teeth and invertebrate shells in close association with the bones were used as evidence of scavenging. Fossil bone bioerosion, microbially-mediated cementation and mollusc shells in the proximity of the remains informed on past biological activity around the bones.

The results are consistent with the hypothesis that shallow-water whale falls differ from their deep counterparts. Taphonomic pathways are more variable on the shelf and whale carcasses may not go through all the steps of the ecological succession recognized in the deep sea. Whilst the mobile-scavenger and the enrichment opportunistic stages are well represented, chemosynthetic taxa typical of the sulphophilic stage have been recovered only in one instance. The presence of a generalist fauna among the suspension feeding bivalves and carnivore gastropods suggests that competition rules out whale-fall specialists from shallow shelf settings.

posters

Investigating the links between taxonomy, tooth morphology and trophic ecology in pycnodont fishes

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The Mesozoic Marine Revolution constitutes a major predation-driven macroevolutionary event that resulted in the settling of modern ecological niches. The apparition of novel feeding structures triggered an arms-race between hard-shelled faunas and predators. Yet recent works have demonstrated unsuspected trophic diversity among the pycnodontid fishes, one of the 'usual suspects' in this escalation. Their apparently specialised 'shell-crushing', molariform dentition does not match their more generalistic diet evidenced through microwear texture analysis.

Toothplates from pycnodontid fishes constitute a major part of the taxonomic diversity of the group. Some species are known solely from such isolated dental remains found abundantly around the Tethys during the Mesozoic and early Cenozoic. Yet, we know that dental morphology is subject to phenotypic plasticity as in Cichlidae, where a single species can exhibit two dental morphologies on their pharyngeal jaws (thin or molariform). Also, dental ornamentation constitutes an unreliable taxonomic criterion as it is affected by tooth wear.

Application of contour-based morphometric techniques allied with dental microwear texture analysis allows us to test whether gross tooth shape can help discriminate between

Genera, Species or overall dietary preference in a range of Pycnodontidae. Results can then be applied as a test of phylogenetic and/or palaeoecological and macroevolutionary hypotheses.

Experimental formation of a microbial death mask

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Soft-bodied Ediacaran fossils from the terminal Neoproterozoic lagerstätte from South Australia have been interpreted as the result of a microbially-mediated death mask taphonomic regime. Although this model has been substantiated by the discovery of abundant microbially-induced sedimentary structures (MISS) in close association with Ediacaran fossils, it has not been tested using experimental taphonomic studies under controlled laboratory conditions. This study represents the first investigation of soft-tissue decay in association with microbial mats. Using XPS and ESEM-EDS we demonstrate the generation of iron sulphides and localized concentrations of common aluminosilicate cations (Al, K, Fe and Mg), a composition that has been frequently documented in association both with Ediacaran, and other examples of soft tissue preservation. These decay experiments involving bacterial mats are the first to provide experimental support for the microbial death mask model, and to show how the tempo and mode of preservation in the Ediacaran taphonomic window might be constrained.

Investigating the effects of taxonomic overlap in supertrees

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Supertrees are a useful method of constructing large-scale phylogenies by assembling numerous smaller phylogenies that have some, but not necessarily all, taxa in common. Supertrees have now been produced for a diverse range of taxa including dinosaurs, mammals, crocodiles and birds.

An important problem in supertree construction is the issue of taxonomic overlap. The degree of overlap can be visualised using cluster diagrams, where nodes represent source trees which are connected if they contain a specified minimum number of taxa in common. The theoretical minimum level of taxonomic overlap is two leaves in common between source trees; any source trees shown not to be connected by at least two taxa should not be included in the supertree analysis.

Pearls in bivalves and their significance for ecologists and parasitologists

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Parasitic infestations are often cited as the cause for free pearls, blister pearls and pits in the shell of bivalves and other molluscs. Such structures can, however, be caused by a variety of other irritants. In general, shelled molluscs are capable of secreting pearls. Occurrences of pearls and similar structures are exceedingly rare in the mollusc fossil record. We compiled a database of free pearls, blister pearls and pits in Recent and fossil bivalves. Blister pearls are known since the Silurian and Devonian in the Nuculoidea. Free fossil pearls first appear in various epifaunal bivalve groups of the Triassic. Such pearls are largely restricted to epifaunal taxa, which has been used to explain their absence in Palaeozoic strata as many taxa of this age were infaunal. We herein investigate the occurrence of pearls and pits in a phylogenetic and stratigraphic framework. Devonian blister pearls might form the oldest indirect fossil evidence for the addition of intermediate hosts in the life cycle of parasitic flatworms, but this is hard to prove without modern analogues.

Biostratigraphic and palaeogeographic significance of a restudied early Cambrian microfauna from Northern Montagne Noire (Southern France)

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The 'Cambrian Stage Subdivision Working Group' has recently emphasized the high potential of the early Cambrian skeletal microfossils (so-called small shelly fossils, SSFs) for the biostratigraphic subdivision of the Terreneuvian (pre-trilobitic Cambrian). At a regional scale, such biozonations have already been established for North and South China, West Avalonia and Siberia. From these, FAD of *Watsonella crosbyi* and *Aldanella attleborensis* appeared as best candidates for the definition of the base of the Cambrian Stage 2. Nevertheless, since the work of Cobbold in the 1930s, *Watsonella crosbyi* is also known from Montagne Noire (as *Heraultia varensalensis*), in well-known '*Heraultia* Limestones' considered as Cambrian Stage 3-4. However, the Montagne Noire is divided into three main structural domains: (i) the axial, metamorphic zone (ii) the southern flank, constituted of well-studied, fossiliferous rocks, and (iii) a poorly understood, complex, Northern flank arranged into imbricated tectonic units, in which Cambrian strata are poorly fossiliferous. As a consequence, '*Heraultia* Limestones' from Northern flank were dated based on lithological comparison with Pardhaillan and Lastours Formations from Southern Nappes, although formations under- and overlying the latter have never been identified in contact with the former. This study is aimed at reassessing the fossil assemblage of the '*Heraultia* Limestones' in order to test whether their age or the stratigraphic extension of *Watsonella* were wrongly evaluated. The recovered assemblage argues for a correlation with Tommotian beds of Siberia and China. The results also question the palaeogeographic and stratigraphic interpretation of the Montagne Noire.

The biostratigraphic development of a conjugate margin

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In the hydrocarbon industry, biostratigraphic data are critical for precision in stratigraphic correlation and palaeoenvironmental analysis. Despite a wealth of data in the public domain, the utility of local biostratigraphic schemes in regional-scale geological synthesis is hampered without accurate cross-calibration to standards of the International Timescale.

Here we present a study evaluating the significance of biostratigraphic data in palaeoenvironmental analysis across the conjugate margins of Africa and South America. Changes in biostratigraphic assemblages from exclusively lacustrine (fresh water ostracods), to marine fauna by the mid-Cretaceous, and progressive endemism between Brazilian and West African taxa during the Early Cretaceous, illustrate the slow separation of the two continents. Collation of a large volume of data across a range of fossil groups allows us to produce a coherent biostratigraphic synthesis, refining our understanding of the regional-scale geological evolution of the region and implications for hydrocarbon prospectivity.

A *Sowerbyella* Community from the Martinsburg Formation (Ordovician) in the Hudson Valley, southeastern New York

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During the Taconic Orogeny a basin formed off the coast of Laurentia as the Taconic Arc collided with the landmass. Rapid shallowing of the basin was the result of the Taconic Mountains shedding sediment that consisted of shales and siltstones interbedded with fine grained graywacke that formed the Martinsburg Formation in southeastern New York. The fauna shows affinities to that of Lithofacies 1 and 2 recognized in the Ordovician Reedsville Formation at Swatara Gap, Pennsylvania. Our fauna consists of *Sowerbyella* (dominant) as well as crinoids, bivalves, ostracods, corals, trilobites (*i.e. Cryptolithus*) and conulariids. Crinoids (*i.e. Ectenocrinus*) are often found articulated, indicating weak currents, a lack of significant transport, and quick burial. A more diverse fauna may have been precluded by the relatively muddy bottom. *Cryptolithus* is found in muddy, but not deep water and the absence of sessile benthic taxa such as corals and bryozoans that are intolerant of mud support the idea of a shallow water setting. Oscillation ripples also suggest a relatively shallow, subtidal environment of deposition unlike the hypothesized turbidite model that some workers attribute to the section at Swatara Gap.

Benthic foraminifera from coastline environments of the Arabian Gulf (Abu Dhabi region)

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This study shows the distribution of shallow-marine foraminifera in the off-shore coastal zone of Abu Dhabi (UAE). The 150 collected sea-floor sediment samples represent a wide-

range of shallow-marine sedimentary environments (nearshore-shelf, beach-front, channels, oolitic shoals and lagoon) proximal to the coastline.

The identified foraminifera consists mainly of porcellaneous species belonging to the genera *Quinqueloculina, Triloculina, Spiroloculina, Sigmoilinita, Miliolinella, Adelosina* and *Peneroplis*. The last one is particularly abundant in samples collected on seaweed. Hyaline foraminifera mostly belonging to the genera *Elphidium, Ammonia, Spirillina, Bolivina* and *Rosalina* are also common, together with Miliolidae in the nearshore-shelf and beach-front. Agglutinated foraminifera (*Clavulina, Textularia, Ammobaculites* and *Reophax*) occur in low percentages. Among the agglutinated foraminifera the genera *Ammobaculites* and *Reophax* are present only in the finest grain samples and have not been reported previously in the studied area.

The coarser sediments (oolith-shoal, beach-front) do not contain living foraminifera, and the dead assemblage is mostly composed of coarse sized Miliolidae with fragmented or abraded tests, probably transported.

The analysis of the foraminiferal and sedimentary facies distribution can be used in palaeoenvironmental reconstruction of Quaternary sequences from the same area. The foraminiferal record constitutes a taxonomical data bank on shallow marine benthic foraminifera from the Arabian Gulf.

Middle Miocene Planktonic Foraminifera of the Equatorial Pacific

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The middle Miocene (17–13.5 Ma) was the warmest interval of the Neogene. During the early to middle Miocene (23–11.5 Ma) the climate fluctuated greatly, with cyclic periods of Antarctic glaciation and climatic warming termed the 'mid Miocene climate optimum' characterised by a negative oxygen isotope excursion. Integrated Ocean Drilling Program Expedition 320/321 recovered lower-middle Miocene sediments with high sedimentation rates (30m/myr), continuous recovery, and orbital cyclicity from the equatorial Pacific. Previous studies of the lower interval have been hindered by the absence of biogenic carbonate (*e.g.*, Leg 199). However at Site U1338 planktonic foraminifera are abundant in the lower and middle Miocene sediments, and scanning electron microscopy has shown that foraminifera are well preserved and diverse, allowing for studies of planktonic foraminiferal stable isotopes, biostratigraphy, and biotic evolution. Here I present an overview of foraminiferal assemblages from the middle Miocene, examining the preservation and potential for future studies of foraminiferal evolution, as well as the initial results from my project, as we endeavour to produce the first orbital scaled record of $\delta^{18}O$ and $\delta^{13}C$ variability throughout 17–15Ma.

X-ray micro- and nano-tomography: An accessible tool for palaeontologists

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X-ray micro- (µCT) and nano-tomography allow the non-destructive imaging of three-dimensionally preserved fossils in their entirety. µCT in particular is becoming increasingly available to the palaeontological community, being both cheap and widely available, and allows a better understanding of fossils' anatomy, phylogeny and palaeobiology. Nano-CT, which can provide radiographs with a resolution of 250nm (and 500nm in 3D), offers a lab-based alternative to synchrotron tomography for some specimens. Here I present an introduction to both techniques, aimed at palaeontologists, describing the process from data acquisition through to reconstruction. Example studies conducted on the instruments of the Electron Microscopy and Mineral Analysis Division, The Natural History Museum, London, will be used to demonstrate the efficacy of 3D techniques when solving palaeontological problems. I also will focus on obstacles particularly pertinent to palaeontological data, and provide details of how such limitations can be overcome.

Tomographic reconstruction of Carboniferous arachnids – new results

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Recent research has demonstrated the efficacy of X-ray micro-tomography (µCT) for the study of siderite-hosted Carboniferous fossils, revealing their preserved morphology in full. This has allowed inferences regarding the mode of life and palaeobiology of a wide range of arthropods, as well as permitting fossil taxa to be scored directly into cladograms based on living species as explicit calibration points for (molecular) dating. Here we present further µCT work on Carboniferous chelicerates. Whip scorpions (Arachnida: Thelyphonida) are closely related to schizomids (Schizomida). The Carboniferous fossil *Proschizomus petrunkevitchi* Dunlop & Horrocks, 1996, is one of the earliest known whip scorpions. It is here revealed in three-dimensions with the aid of µCT, and demonstrates a mixture of thelyphonid and schizomid features; elucidating its significance as a potential schizomid forerunner. A contemporary Carboniferous arachnid, *Plesiosiro madeleyi* Pocock, 1911, is the sole representative of the extinct order Haptopoda, which has tentatively been placed among the pantetrapulmonate arachnids (spiders and their closest relatives). µCT scans reveal vital details regarding the group's palaeobiology. Furthermore, they confirm the presence of two-articled 'clasp-knife' chelicerae; an unequivocal pantetrapulmonate apomorphy, allowing the placement of this enigmatic fossil group.

Placoderm histology and the origin of the gnathostome dermal skeleton

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The evolution of the gnathostome dermal skeleton is poorly understood. Crucial within this debate is the condition in the first jawed vertebrates, the placoderms. Complications arise from conflicting phylogenetic hypotheses and the fragmentary fossil record. Using a combination of scanning electron microscopy and light microscopy we studied a range of placoderm histologies. Comparisons with outgroup taxa confirm the phylogenetic position of supposed primitive groups. We demonstrate for the first time the presence of dentinous tissues in primitive antiarchs. Dentine as a capping structure is therefore present in the bauplan for placoderms. Dermal bone is found extensively in almost every order, indicating that an osteogenic component is more important in the primitive dermal skeleton than previously thought. Mechanisms for growth and remodelling of bone are found to be widespread throughout the placoderms. The wide range of bone architectures revealed among the placoderms gives us an insight into the diversity of tissues at the dawn of the gnathostomes.

Ecomorphology and evolution of Paleogene ungulate distal femora

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Cursorial specializations of the limb skeleton occur in the earliest representatives of the modern ungulate orders. 'Condylarths', a paraphyletic group of Paleogene placental mammals thought to contain the sister taxa to the modern ungulates, do not display many of these postcranial characteristics. Comparative anatomical work has highlighted morphologies in condylarths associated with quite different modes of living. This study quantitatively examined the morphology of the distal femur in early North American ungulates. Six linear measurements were collected from the distal femora of 45 genera of extant mammals. Each genus was classified into one of six locomotor modes. Multivariate analysis of variance on four ratios found that locomotor mode was a significant predictor of variation (Wilk's λ=0.144, F(20, 624.47)=24.74, $p<0.001$). A discriminant function analysis (DFA) was used to calculate a classification function. 142 Paleogene ungulates (condylarths, artiodactyls and perissodactyls) from North American collections were measured. Classification using the DFA supports the view that certain early condylarths were tree dwelling, but does not retrieve all artiodactyls and perissodactyls as cursorial. Principal components analysis indicates ecologically significant areas where modern and fossil groups do not overlap, and that the ungulate distal femoral morphospace changed throughout the Paleogene.

Biofacies variations through the Transitional Buen Formation (lower Cambrian), Sirius Pass, North Greenland

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Field counts and identifications of thousands of *in situ* fossils through almost 13 m of strata within the Transitional Buen Formation (lower Cambrian) at the classic locality south-west of the Sirius Pass, have precisely delimited the context and extent of the Lagerstätte horizons. Some 45 species, including about five new taxa, have been related to substrate type and the presence of microbial mats and trace fossils. Although much of the succession is characterized by abundant *Buenellus* and *Isoxys* together with sponges, correspondence-relay analysis of abundance data through the middle part of the succession describes a range of biofacies dominated by varying proportions of annelids, arthropods and lobopods. Marked, too, is the correlation between the presence of large soft-bodied arthropods, microbial mats together with sub and under-mat miners. These analyses together confirm the deep-water setting of the biofacies, predominantly based on near autochthonous faunas with some allochthonous elements, mantling an older carbonate platform.

Microfossil evidence for a mid-Jurassic squid egg-laying area in association with the Christian Malford Lagerstätte

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In the 1840s, during the construction of the Great Western Railway west of Swindon, a number of beautifully preserved coleoids were found. The specimens of *Belemnoteuthis* and *Mastigophora*, as well as a number of fish, have been described as a fossil lagerstätte under the name of the "Christian Malford Squid Bed". Many of these specimens, which come from the Phaeinum Subzone (Athleta Zone, Callovian) of the Oxford Clay Formation, contain soft tissue, muscle fibres and the contents of their ink sacs. In 2007, the British Geological Survey funded an excavation some ~100 m from the original site, augmented by a drilling programme. Core No. 10 recovered clays with exceptionally large numbers of statoliths, otoliths, squid hooks and foraminifera. Jurassic statoliths have yet to be described in any detail as they have rarely been mentioned in the literature and, as yet, have no formal names.

The exceptional abundance of statoliths and squid hooks recorded in the samples from the core is thought to represent a Jurassic squid-breeding ground which existed for an extended interval of time. This is potentially the first record of such a phenomenon in the fossil record and is especially significant as it is based on one of the first reports of statoliths in Callovian strata. Alternative suggestions for the concentration all have problems, while the egg-laying model appears to fit with the known life style of modern squid.

Silicification of wood: identifying ancient and present-day processes

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Many standing fossil forest localities worldwide were preserved due to burial by silicic volcanogenic sediments. However, the time scales and processes involved in silicification of the wood are still poorly understood. The preservation of trees in volcanic settings, such as the Miocene forest of Lesvos, Greece, involves either permineralization by silica-rich water or vapour. In the laboratory in Bonn, incipient silicification has been produced experimentally using wood samples from extant trees, indicating that permineralization is potentially a relatively rapid process and that the silicification of entire tree trunks could take place on the scale of hundreds to thousands of years. In order to ground-truth our models in a natural setting, we have collected and analysed samples from silica-rich volcanic deposits around Mount St. Helens. The volcano has erupted periodically for the last 4,000 years and trees can be found in growth position within the Holocene and historic deposits there, including in debris avalanches similar to those on Lesvos. Many of these trees were exhumed by the large 1980 eruption as the landscape was transformed and drainage channels were scoured out by debris. Here we present new data and ongoing research into the taphonomic processes involved in silicification in volcanic settings.

A new approach to recognising chemosymbiosis in cold seep bivalves

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Cold seeps are sites on the sea floor where carbon and sulphur-rich compounds are emitted. Bacteria at these sites use methane and hydrogen sulphide as substrates for chemosynthesis, and live in symbiosis with macrofauna (chemosymbiosis). Chemosymbiosis in modern fauna can be identified using multiple approaches, including stable isotope analysis of soft tissues; however it is not currently possible to detect chemosymbiosis in the fossil record. Shell-bound organic matter (SOM) has a similar isotopic composition to soft tissues but can be preserved in fossil shells, therefore it has the potential to preserve an isotopic signature for chemosymbiosis in cold seep fossils.

We analysed the carbon and sulphur stable isotope composition of SOM from cold seep bivalves collected from the Gulf of Mexico. Species analysed contained methanotrophic (*Bathymodiolus childressi*) or thiotrophic (*Vesicomya cordata*) symbionts, with a heterotrophic species (*Mytilus edulis*) for comparison.

Results from this investigation provide essential baseline data on SOM isotopic signatures indicative of chemosymbiosis in bivalves at modern cold seeps. Future work will

extend this approach into the fossil record to identify methanotrophic and thiotrophic chemosymbiosis at ancient seep sites.

Investigating the effects of effacement within the trilobite Suborder Illaenina

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The furrows that plesiomorphically characterize the trilobite dorsal exoskeleton provide morphological character states that aid interpretation of the relationships between trilobite groups. The term 'effacement' is used to describe the weakening and loss of furrows, which can be accompanied by rounding of the genal angle, an increase in the width of the axis, and/or an increase in exoskeleton convexity. The loss of morphological characters presents obvious problems for phylogenetic analysis. This is particularly apparent when effacement occurs commonly within groups of closely related trilobites, as is the case within the Suborder Illaenina. Selected effaced members of the Illaenina are here analysed cladistically in order to investigate the effects of effacement on the resulting phylogenies. A clade comprising unambiguous members of the Family Illaenidae is distinguishable from those taxa which are here considered as effaced members of the Family Scutelluidae. This suggests that effacement has evolved more than once within the Illaenina. The complexity of the suite of characters affected by effacement is clear; cladistic analyses involving taxa with varying degrees of effacement are strongly influenced by the degree of effacement which taxa display.

The taphonomy of stomach contents of Lower Jurassic ichthyosaurs

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Stomach contents have been found preserved in many fossil ichthyosaur specimens, though their taphonomic mechanisms are poorly understood. This study uses a combination of Scanning Electron Microscopy and Energy Dispersive X-Ray spectrometry to analyse the preservation of phragmoteuthid hooklets within the stomach masses of Jurassic Ichthyosaurs from Lyme Regis. Elemental analyses show that the composition of preserved undigested hooklets and modern analogues are similar, however partially digested hooklets show increased calcium and decreased carbon content. The evidence suggests that soft tissue preservation is restricted to the stomach mass due to its high acid content quickly digesting the hooklets and releasing calcium that preserved the stomach mass by rapid calcium carbonate precipitation.

Biodiversity crisis and recovery during the Triassic–Jurassic greenhouse interval: testing the ocean acidification hypothesis

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The Triassic–Jurassic interval witnessed one of the major biodiversity crises of the Phanerozoic. Palaeoclimate studies have demonstrated that it was associated with a four-fold rise in atmospheric CO_2 which is hypothesised to have caused global ocean acidification. The fossil record provides long-term data from past ocean acidification events and can be used to study how marine organisms responded to periods of ocean acidification. This project examines the fossil record from Lyme Regis and St. Audrie's Bay. The lengths and widths of different bivalve taxa (*Liostrea* and *Plagiostoma*) and ostracod taxa (*Ogmoconchella*) have been measured to produce a geometric size for each specimen. These data have been compared to published estimates of atmospheric CO_2, temperature and oxygen levels. Previous authors have predicted that ocean acidification will result in a reduction in shell size through this time period. New bivalve data collected show that shell size in *Liostrea* and *Plagiostoma* increases as pCO_2 increases and preliminary *Ogmoconchella* data is indicating a similar result. Other factors may be influencing shell size through the study interval, but modern experimental studies of bivalve taxa show that shell size may continue to increase under high CO_2 conditions, but that the rate of growth may change.

Palaeogene global warming and the latitudinal diversity gradient

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Mechanisms for producing and maintaining tropical hyperdiversity play a key role in many models seeking to explain the latitudinal diversity gradient (LDG), whereby species richness declines from the tropics to the poles. Here we test the hypothesis that a latitudinal temperature gradient directly drives enhanced low-latitude speciation. We use 121 sporomorph (pollen and spore) samples from the Middle Paleocene to Middle Eocene of the US Gulf Coastal Plain (GCP), which warmed to megathermal levels during the early Palaeogene. By integrating this record with sporomorph data from the floristically distinct neotropics of Colombia, we demonstrate that (a) while neotropical species richness and first appearance rates increased concordantly with global warming, both remained stable on the GCP throughout the study interval; and (b) most first appearances on the GCP were the result of immigration, and the proportion of *in situ* speciations did not increase there during the warming episode. Our findings suggest that extra-tropical regions do not become active areas of speciation when warmed to megathermal temperatures. This in turn does not support a primary role for temperature as a direct driver of low-latitude speciation over macroevolutionary timescales.

Evolution of vertebrate bone repair

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Evidence of bone damage and repair is preserved throughout the fossil record, but most research has focused on repair of the endochondral bone of the internal skeleton. New material of dermal bone from the jawless vertebrate *Psammolepis* (Psammolepidae; Heterostraci) shows rapid repair in response to a major injury. Previously, dentine had been observed to infiltrate aspidin bone spaces in *Psammolepis* in response to bone abrasion through life. This damaged bone shows that response to injury also predominantly involves dentine, with little contribution by bone itself. There are three phases to the repair response: initially a solid layer of mineralized dentine seals the damaged surface; secondly, the injury is infilled with a mixture of pleromic dentine and coarse, woven bone. Although this second phase is disorganized, a layer of dentine tubercles forms at the surface of the repair. This upper layer is similar to the initial dentine layer, but with individual denticles more clearly present. This indicates that the main response to damage is provided by the surficial dermal denticles. Reduced response of bone in these early vertebrates may be due to the migratory ability of the odontoblasts that naturally infill abrasion spaces of the aspidin bone, at this evolutionary stage.

Palynological reworking in the Mesozoic succession of the Sverdrup Basin, Arctic Canada

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As part of ongoing Arctic studies, CASP (formerly Cambridge Arctic Shelf Programme) is investigating the eastern Sverdrup Basin, on Ellesmere and Axel Heiberg islands, Nunavut, Canada. Primary palaeontological analyses using molluscan macrofauna, palynology and micropalaeontology provide basic biostratigraphic and palaeoecological information. However, reworking – a common feature observed within the Sverdrup Basin palynomorph assemblages – provides important insights into the source of clastic detritus in the basin.

Devonian palynomorphs are common throughout the succession, but especially in strata of Jurassic and older ages. This suggests that palynomorph-bearing Devonian mudstones and shales were being eroded throughout the depositional history of the Sverdrup Basin, or that sedimentary recycling occurred throughout the Mesozoic, repeatedly reworking Devonian palynomorphs into successively younger deposits. The most significant Mesozoic reworking was during the mid-Jurassic when reworked palynomorphs comprise up to 20% of the assemblages. The age of reworked forms becomes progressively younger up-succession, which suggests that the erosional history in the hinterland is not simply that of unroofing, as if this were the case, progressively older suites of palynomorphs would be encountered up section. The next major event is in the Paleogene, when large quantities of Late Cretaceous Sverdrup Basin palynomorphs were reworked during the Eurekan Orogeny.

Comparing intraspecific variability of ammonoids

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Although uncountable articles have been published on ammonoids, intraspecific variability has been quantified rarely, especially in the Palaeozoic and/or loosely coiled ammonoids. Additionally, it is only occasionally applied to properly define species using morphological data. In a first study, we had evaluated the intraspecific variability of the earliest, still loosely coiled ammonoids from the early Emsian (Early Devonian). We discovered an intense variability but could distinguish much fewer taxa than the amount of species that had been introduced for this group. In other words: it appears to be impossible to distinguish the existing >20 species morphologically. With our current data, about one third of these species can be justified when taking their intraspecific variability into account. One of the most variable characters is the distance between subsequent whorls. This led to the hypothesis that the coiling mode might correlate with the degree of intraspecific variability to some degree. To test the relation of the degree of intraspecific variability of conch parameters with coiling, we measured another set of ammonoids from the late Emsian, the representatives of which have tightly coiled shells. We used the standard deviation as a measure of variability. Preliminary tests appear to support this hypothesis, but further data and tests are needed before drawing a conclusion.

The first Moroccan record of the peculiar tetrameric echinoderm *Tiaracrinus* (Early Devonian)

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Tiaracrinus is a pelmatozoan echinoderm with a tetrameric calyx, which is usually found without arms. Additionally, it carries eight rows of pores on the calyx. Its taxonomic assignment within the echinoderms has been repeatedly discussed, and most commonly it has been assigned to either the crinoids or the cystoids, although it also resembles blastoids. We have discovered the first two specimens from the latest Emsian of two Moroccan localities in the eastern Anti-Atlas. Morphometric analyses yielded the following results: (1) the new material differs clearly from the taxa described previously and will thus be described as a new species; (2) ontogenetic trends in, for example, the shape of the calyx and the number of pore rows became evident; (3) a phylogeny of the genus can be inferred from the morphometric differences, although with great reservation due to the low number of characters and the heterogeneous preservation of type materials.

Organic preservation of eyes in Silurian conodonts from the Eramosa Lagerstätte of Ontario, Canada

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Eyes have previously been found preserved as organic films in many vertebrate fossils, often as the only carbonaceous preservation in an otherwise biomineralized body fossil. Yet, eyes are composed of comparatively labile tissues, and hence their preservation – particularly when coupled with the concomitant absence of structures usually found to be more resistant to decay – seems to represent an alternative yet poorly understood taphonomic pathway for the preservation of non-biomineralized structures. An example of this organic eye preservation is to be found in specimens of the conodont *Wurmiella excavata* from the Eramosa Lagerstätte, which comprises the largest assemblage of articulated conodonts known from the Silurian. We reconstruct the position of the eyes on the organism, and, using infrared spectroscopy and elemental mapping, we show that the organic eyespot fossils contain remains of fatty acids with an absence of any aromatic remains, and we compare with the results of experimental decay experiments. These results suggest that a taphonomic microenvironment is developed within the eyes, and we apply this model to other examples of eye preservation across the fossil record.

Effects of the Late Permian extinction event on shark faunas

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An apparent radiation of fish families across the Permian/Triassic (P/Tr) boundary has suggested that sharks were relatively unaffected by the Late Permian mass extinction. Other evidence shows that chondrichthyan diversity may instead have followed the pattern observed in other aquatic organisms. Correlation of elasmobranch records from P–Tr oceanic basins and comparison of preservation and biodiversity are needed to ascertain true events. Faunal data are obtained from a comprehensive literature survey, with additional field data collected from the Permian–Triassic of Oman (western Neothethys), Japan (Panthalassa) and East Greenland (Boreal). The Middle Permian fauna of Oman contains *Glikmanius*, *Gunnellodus*, three new hybodontiform genera, three neoselachian genera, one unidentified hybodontiform and three unidentified euselachian taxa. The Omani Early Triassic fauna contains generically different hybodontiforms and is dominated by synechodontiforms. Japanese Permian and Triassic faunas also share no common genera, but Middle Permian faunas of Oman and Japan are similar, with *Glikmanius* in common. The East Greenland Middle Permian–Lower Triassic record is dominated by eugeneodontiforms, but also includes (undescribed) hybodontiform taxa. This new analysis expands knowledge on global distribution and diversity, and currently shows a clear divide between local Permian and Triassic communities, suggesting at least some influence of extinction on evolutionary patterns.

The eurypterid *Stoermeropterus conicus* from the lower Silurian Pentland Hills, Scotland, and sexual dimorphism in eurypterids

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Stoermeropterus conicus (Eurypterida: Eurypterina), from the Telychian (Upper Llandovery, Silurian) of Pentland Hills near Edinburgh, Scotland, is described from material originally assigned to three different species (*Nanahughmilleria conica*, *Drepanopterus bembycoides* and *Drepanopterus lobatus*). Several characters support the assignment of Stoermeropterus

to Moselopteridae, the most basal eurypterine clade, including its possession of a pediform appendage VI with a modified 'podomere' 7a and the possession of a coxal 'ear', which may represent the remains of a much-reduced exopod. *S. conicus* resolves phylogenetically as the most basal known eurypterine, and can aid in reconstructing the eurypterid ground plan. *S. conicus* also demonstrates sexual dimorphism previously undocumented in eurypterids. While all eurypterids are dimorphic in terms of possessing either a long type A (traditionally female) or short type B (male) genital appendage, *S. conicus* differs further in overall size, pretelson length and epimeron morphology. This evidence, combined with the presence of modified 'claspers' on the appendages of some other eurypterid species and observed gender ratio differences, suggests through comparison with extant arachnids and xiphosurans that the type B genital appendage should be considered the female and type A the male, supporting recent studies on the morphology of the genital structures themselves.

Fossil bivalves in the Rainbow area: new insight into the diversity and evolution of chemosynthetic communities

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Hydrothermal circulation at ultramafic-hosted sites supports a large variety of high- and low-temperature hydrothermal vents and associated ecosystems. In August 2008, numerous dead bivalve shells and associated carbonates were dredged from close to the active Rainbow vent field on the Mid-Atlantic Ridge (36°N). These fossils point to past hydrothermal activity on top of a heavily sedimented ultramafic structure, at 24 kyr, and at 112 kyr, on the slope of the same structure. The younger site has abundant shells of the vesicomyid bivalve genus *Phreagena* distributed over a large area and associated with rarer specimens of the thyasirid bivalve *Thyasira*. At the older site, specimens of the mussel *Bathymodiolus azoricus* are abundant and co-occur with a few specimens of *Phreagena* and *Thyasira*. At off-axis sites like those studied, both sediment cover and the availability of methane and sulphide, and possibly even hydrogen, as electron donors for autotrophic symbionts offer a wide variety of suitable habitats for chemosynthetic species. The spatial distribution and geochemical diversity of serpentine-hosted habitats might have favoured a more diverse fauna to colonize these habitats, and could have played a major role in the ability of chemosynthetic vent and seeps species to disperse over ocean basin scales.

Transitional patterns in the brain anatomy and evolution of therizinosaur dinosaurs

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The evolutionary transition from non-avian to avian theropods is characterised by a suite of functional and physiological specialisations. This is evident not only in a multitude of skeletal modifications, gradually appearing in the maniraptoran lineage, but also in soft tissue structures. The anatomy of the brain and associated organs closely reflects these osteological adaptations. However, information on the endocranial anatomy in theropods is rare or mostly restricted to basal taxa. In this study we describe and discuss the endocranial anatomy of therizinosaurs, an enigmatic clade of Cretaceous (Barremian–Maastrichtian) maniraptoran dinosaurs found in Asia and North America. Nested between basal coelurosaurs and derived maniraptorans, they are of special importance in terms of the evolution of anatomical and developmental patterns in the brain.

Using computed tomographic (CT) scanning, the endocranial casts and endosseous labyrinths of four therizinosaur braincases have been digitally reconstructed and visualised. Generally, the endocasts show a complex anatomy, with a mixture of plesiomorphic and derived ('avian') characters, reflecting the basal position of therizinosaurs among Maniraptora. The gradual evolution of these characters can be traced throughout the therizinosaur phylogeny – a trend that reflects the large scale transition from non-avian theropods to birds.

A high-resolution, compound-specific isotope study of the Palaeocene–Eocene Thermal Maximum in Northern Spain

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The Palaeocene/Eocene Thermal Maximum (PETM) occurred ~55Ma, initiating a period of global warming with biotic extinction and migration. It also led to fundamental changes in the carbon and hydrological cycles. Marine and terrestrial sediments record the event, however discrepancy between the carbon isotope excursion (CIE) measured in the two realms is observed. One explanation for this is the "plant community change (PCC) hypothesis", which states that the magnitude of the CIE is greater in the terrestrial realm owing to a major change in the flora during the PETM.

Presented here are total organic carbon isotope (TOC) results from six Spanish sections spanning the PETM. Also presented are preliminary n-alkane isotope results from two sections, which display a similar trend to the TOC data, but suggest that the TOC records a

lower magnitude CIE. This apparent enhancement in the magnitude of CIE is particularly significant when results for average chain length (ACL) of the n-alkanes are considered, as no change in ACL has been recorded across the PETM. This suggests that there is no appreciable reconfiguration of terrestrial higher plant matter coincident with the PETM, which would indicate that the PCC cannot explain the discrepancy between the marine and terrestrial realms.

Populations, plasticity and phenotype: the problems of continuous variation and missing links in iguanodontian dinosaurs

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There has been a resurgence of interest in basal iguanodontian dinosaurs due to the discovery of an unexpectedly diverse Cedar Mountain Formation fauna. This has led to renewed interest in historical genera such as *Camptosaurus* and *Iguanodon*, and the creation of new taxa from material formerly referred to these genera. As a result, our understanding of 'apomorphic' and 'plesiomorphic' character-states has become blurred and confused.

A clearer understanding of the ranges and styles of anatomical variation within populations of diagnosable OTUs is becoming increasingly important, because it informs the selection of features likely to be taxonomically informative. To explore this, a comprehensive review of non-hadrosaurid ankylopollexian material, collected from Europe and the United States, has been examined first hand. Particular emphasis was placed upon localities that have yielded multiple specimens.

Results demonstrate that some anatomical features are more labile, between taxa and within populations, than previously supposed. Although certain characters may be used to define anatomical 'grades' of iguanodontians, their usefulness can be altered by the discovery of new 'intermediate' taxa. Given the proliferation of singular apomorphies or unique character-combinations used to define new taxa, it is likely that they will become obsolete following the discovery of more complete material.

A diverse chasmataspidid (Arthropoda: Chelicerata) fauna from the Early Devonian (Lochkovian) of Siberia

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Examination of material from five 2" core sections held at the Palaeontological Institute, Moscow, enables the identification of a diverse chasmataspidid fauna from the Early Devonian of Siberia. *'Eurypterus' stoermeri* and *'Tylopterella' menneri* are both identified as chasmataspidids, having been dubiously described as eurypterids. *'E' stoemeri* is synonymised with *Heteroaspis novojilovi*, revoking the latter's synonymy with *Diploaspis casteri*, on the presence of preabdominal epimera, a character not present

upon *D. casteri*. The conjunction of a large paddle-shaped 6th prosomal appendage with no preabdominal epimera warrants the erection of a new chasmataspidid genus from *'T'. menneri*. Three new genera are also identified, based upon novel buckler and appendage structures and dimensions. The five core sections are of vague locality and fossils occur at varying depths, but as this fauna now represents a third of the known chasmataspidid specimens and genera, the potential for the discovery of further specimens of this poorly represented group is considerably increased.

Divergence and geography: the evolution of Upper Jurassic perisphinctids in Europe

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The Jurassic ammonite family Perisphinctidae originates in early-middle Bajocian Leptosphinctinae and ranges up through the Upper Jurassic. Its origin is assumed to be within the Pacific Realm with later subfamilies colonising Tethyan Realm and adjacent biogeographic provinces. Upper Jurassic perisphinctids originated from the late Callovian genus Alligaticeras, the stem group for the Oxfordian subfamilies Perisphinctinae and Passendorferiinae. The taxonomy of the latter subfamilies reflects the branching phylogenetic history of the family, as tectonic events, eustatic movements and climatic belts led to the creation, or disappearance, of physical barriers to dispersal and to geographic spread and/or isolation of new endemic taxa. Major tectonic events, which lead to phylogenetic branching, include early alpine rifting, opening of the North Atlantic leading to spreading of boreal derivatives (Raseniidae), and central Atlantic rifting leading to the spreading and local endemism of the Ataxioceratinae and Vinalesphinctinae. In addition, intervals of eustatic sea level rise were responsible for geographic spread and taxonomic diversification of derivative groups on shallow epicontinental platforms, including late Oxfordian–Kimmeridgian Ataxioceratinae, which originated from Tethyan Passendorferiinae. Implications for perisphinctid taxonomy of this geographical context for evolution will be discussed, including artefacts produced by both excessive 'splitting' or 'lumping' of taxa at generic and species level.

Ocean acidification overestimated?

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Culture studies have shown that planktonic foraminifera are susceptible to changes in the carbonate ion concentration (CO_3^{2-}) as they currently take place in the surface ocean. Increasing the amount of CO_2 in the ocean decreases both CO_3^{2-} and pH, more commonly known as ocean acidification. Associated morphological (decreasing test thickness) and geochemical (depletion of $\delta^{13}C$) changes are predicted from these studies. However, *in situ* and sedimentological observations indicate that this sensitivity to increasing CO_2 may

be complicated by changes associated with other biotic (*e.g.* competition) and abiotic (*e.g.* temperature, salinity) factors. Complicating this further is the potential for pre- and post-burial processes to obscure valuable information. Presented here is a coupled geochemical-morphological analysis utilising an approach that allows for accurate oxygen and carbon isotopic measurements from specimens >5µg along a core top depth transect in the North Atlantic. Contradictory to prior analysis, shell mass appears to increase with depth in some species. Sedimentation rates suggest that exposure time to corrosive water masses, rather than water depth in itself, may play an important role. Differential dissolution between populations of 'lighter' and 'heavier' tests, a bi-product of physiological and ecophenotypical processes, may also affect the average test mass.

The fate of a middle Danian (Lower Paleocene) turtle from the bryozoan limestone of Faxe Quarry, Denmark

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A piece of turtle carapace from the Middle Danian bryozoan limestone at the Faxe quarry, eastern Denmark, is identified as a partial coastal plate from the carapace of a chelonioid turtle. In addition to being the first record of turtles from the Middle Danian of Denmark, the fragment bears evidence of a dramatic taphonomic history comprising traces of three separate acts of predation and/or scavenging. Two circular bite traces measuring 4mm in diameter and situated 2.5cm apart have fractured the carapace and are interpreted as crocodylian predation traces, probably fatal to the turtle. Smaller groups of parallel scrapes, 4-5mm long and 0.5mm, wide are interpreted as bite traces from sharks, and small circular traces, only 1mm in diameter, found either solitary or in a row of three, are interpreted as scavenging traces from fish.

posters

A new genus of Acrochordiceratidae (Early Triassic) and its implications for stress-induced evolutionary jumps of ammonoids (cephalopods)

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A new genus of Acrochordiceratidae (Ammonoidea, Cephalopoda) has been discovered in Nevada (USA) and in South China, and typically ranges in the late Spathian (Early Triassic). Its plicate ribbing and subammonitic suture line are diagnostic of the family. Its large adult size, high degree of involution and subammonitic suture line stand in sharp contrast with the next younger genus of the family (*Paracrochordiceras* of early Anisian age, Middle Triassic), which is evolute and has a ceratitic suture line. Shell coiling and suture line of the new genus are closer to that of the youngest member of the family (*Acrochordiceras carolinae* of late middle Anisian age). The latter is the end-member of a long-term morphological trend of the family during the early and middle Anisian (*ca.* 4 Myr), characterized by Cope's Rule and classical increases of shell involution and sutural complexity. The abrupt morphological evolutionary jump (proteromorphosis) between the new genus and *Paracrochordiceras* at the Early/Middle Triassic boundary is

interpreted as a generalized morphological reset of long-term trends, a process which differs from usual paedomorphic transformations. A dramatic global sea-level change at the Early/Middle Triassic boundary is a likely trigger for this evolutionary jump.

Quantitative biochronology of Devonian ammonoids from Morocco

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Based on a rich dataset, we revised the biostratigraphy of the late Emsian and the Eifelian (Early–Middle Devonian) ammonoids from the Moroccan Tafilalt (Anti-Atlas). We processed this dataset (comprising 53 species from 15 sections) with the automatic and quantitative unitary association method (UAM). It led to the construction of a sequence of 17 UAs (maximal sets of actually or virtually coexisting taxa), which are grouped into ten laterally reproducible association zones. This biostratigraphical subdivision of this interval is in some parts finer than the classically used empirical stratigraphical scheme. The new zonation is also compared to a previous zonation erected using the graphic correlation method. In addition to providing supplementary biochronological subdivisions, the UAM enabled us to underline the main drawback of graphic correlation: it often artificially lengthens the stratigraphical range of species and thus creates unnecessary virtual coexistences between some species. Finally, based on the resulting species ranges of the 17 UAs from late Emsian to Eifelian, we quantified the regional ammonoid diversity of this interval in detail. This enabled us to document several regional and global diversity patterns (such as the ChoteÄ-Event), especially between anarcestids and agoniatitids.

Methods of determining cranial and postcranial character congruence using vertebrate datasets

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Tests of partition homogeneity are routinely applied to matrices amalgamating data from more than one molecular marker, or combining molecular and morphological evidence. Incongruent phylogenetic signals from different partitions are variously explicable in terms of different evolutionary histories (in the case of genes), different selective pressures, and/or different signal strengths and levels of noise. However, this approach has rarely been applied to partitions of morphological data sets. In this poster, I document the use of the incongruence length difference test to determine not only the amount of incongruence between cranial and postcranial character partitions but also its relative significance. Where significant incongruence is encountered we suggest this may be inferred as evidence for evolutionary modularity and/or a difference in the rate of evolution of these partitions.

Review of the Cretaceous non-marine Mollusca and their stratigraphical distribution in Europe

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Fifty-nine non-marine mollusc taxa have been identified from sixteen European Cretaceous deposits. These are predominantly Early Cretaceous in southern England, France and Spain. Unionid bivalves and viviparid gastropods dominate, however pulmonate gastropods are also present at some localities. Analogous modern taxa indicate that preserved Cretaceous freshwater habitats were well weeded, oxygen and nutrient-rich environments. Some taxa, notably *Margaritifera valdensis*, were widely dispersed across Europe. Major faunal changes occurred in both freshwater and marginal marine settings during the Hauterivian and Barremian. The Early Cretaceous Wealden Group of southern England is the most continuous non-marine Cretaceous sequence in Europe, its fauna linking with Las Hoyas (Spain) and Wassy (France). These three faunas along with the Jurassic–Cretaceous transitional Purbeck faunas of the French Jura and Purbeck (southern England) are considered key to understanding the European Cretaceous freshwater fauna.

Cutting the first 'teeth' – a new approach to functional analysis of conodont elements

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The diversity of form of conodont elements rivals that of the dentition of mammals or teleost fish, yet relatively little is known about their functional diversity. Conodont apparatuses are differentiated into highly disparate morphotypes, to the extent that positional homologues from distantly related taxa are more similar than different elements from a single individual. In a few derived taxa the apparatus can be divided broadly into an array of rostral food acquisition elements, and pairs of caudal occluding P-elements. Considering the high degree of morphological variation within conodont elements, comparatively 'simple' coniform elements provide the best model for understanding the most fundamental aspects of conodont functional morphology. We have generated high-resolution tomographic data for each morphotype of the coniform conodont *Panderodus unicostatus* and used virtual cross-sections to characterize changes in physical properties associated with aspects of their morphology. Subtle changes in, for example, curvature of the element or cross-sectional profile, have profound implications for the functional performance of the individual elements, and the apparatus as a whole. This technique can be applied to other coniform taxa, and the cusps and denticles of more derived elements, explaining the relationship between the morphological and functional disparity of conodont elements.

Empirical 3D-models and calculation of shell- and chamber-volumes throughout ontogeny of major subclades of Palaeozoic ammonoids

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Although ammonoids are well studied, some aspects of their palaeobiology and evolution are still unexplored. For example, empirical studies of changes in shell and chamber volume through ontogeny of the major subclades have never been performed. The aims of our study consist in documenting (1) volumetric growth in detail and (2) ontogenetic changes between major subclades throughout their early phylogeny. This is achieved by 3D-reconstructions based on specimens which were subjected to grinding tomography. Additionally, these first volumetric data provide the possibility of empirically testing the existing mathematical model for neutral buoyancy of ammonoids. Normally, CT-scans cannot be used because of the insufficient contrast between shell and matrix. Therefore four specimens have been investigated using grinding tomography: the Middle Devonian agoniatitids *Agoniatites clariondi* and *Pinacites jugleri*, the Middle Devonian anarcestid *Diallagites lenticulifer*, and the Early Carboniferous *Goniatites multiliratus*. The sections were then traced manually for each fourth slice, then processed for the 3D-reconstruction using VGstudiomax 2.1 which allows direct volume calculations. The chamber volumes are plotted versus growth, *i.e.* the shell diameter. Further specimens from both older and younger ammonoid subclades are planned to be sectioned to provide more information on volumetric changes through ontogeny and phylogeny.

The braincase and inner ear region of *Placodus* (Sauropterygia, Placodontia)

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The non-armoured placodont *Placodus gigas* Agassiz, 1833 is known from the Lower Anisian to Lower Ladinian (Middle Triassic) epicontinental deposits of Europe, and is especially well known from the German Muschelkalk. While the osteology of the skull has been thoroughly described, the braincase remains poorly understood as it is partly obscured by dermatocranial bones. In addition to this, the morphology of the sphenoid region is still controversial as it differs in each specimen. Using micro-computed tomography (µCT), two skulls of *Placodus* that exhibit well-preserved braincase and occipital regions were scanned. A new 3D reconstruction of the chondrocranium is presented, along with the first reconstruction of a sauropterygian inner ear. The osteology of the braincase has been updated, particularly with regard to the proportions that the opisthotic and prootic contribute to the lateral wall. The parabasisphenoid, which is largely obscured by the pterygoids and palatines, is relatively short, lacking a cultriform process. The ethmoid cartilage would have instead been supported by a v-shaped groove formed by the strongly raised palatines. Additionally, an unusual, ring-shaped structure is visible at the anterior-most point of the parabasisphenoid. The vestibular apparatus exhibits dorsoventrally flattened semicircular canals, a commonly-observed feature of secondarily aquatic reptiles.

Trace fossil evidence for Hirnantian soft body recovery fauna, Ceredigion, West Wales

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The end-Ordovician mass extinction is unique amongst the Phanerozoic 'Big 5' extinctions in being associated with a global 'ice-house' climate perturbation. The duration of the glaciation event, and the feedback processes that caused the climate deterioration, and subsequent amelioration, remain matters of debate in the literature. The coeval processes associated with the extinction/recovery episodes are complex, with many workers favouring a two phase 'pulsed' extinction, with global recovery linked to a post-*perculptus* climate amelioration and shelf transgression.

The rocks of the Welsh Basin record these events in the facies architecture of the Hirnantian/Llandovery rocks, and the micro-fossil, body-fossil, and trace-fossil record. Near the village of Llangrannog (Ceredigion) the Hirnantian ichnofaunal assemblage in a turbidite succession is diverse, indicating that locally the Hirnantian Avalon shelf was far from being devoid of life. The absence of significant body fossils, but very well preserved ichnofauna, suggests that the ecology was dominated by an opportunistic soft-body fauna occupying ecospace vacated during the extinction. A photographic record of the Tier 1 ichnofaunal assemblage is given, and comments offered on the associated sedimentological signatures which indicate that the ichnofaunal diversity maximum is associated with the Hirnantian glacio-eustatic sea level minimum.

posters

Reconstructing the trunk segmentation of trilobitomorph arthropods: an experimental approach

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Trilobitomorphs (trilobites and their kin) are some of the most common and abundant metazoans preserved in the fossil record, but little is known about the basic mechanisms that orchestrate the organization of their body plan. The phylogenetic position of trilobitomorphs within total-group Euarthropoda, however, allows us to infer something about the mechanisms of segment formation in these extinct taxa, as some of the fundamental genetic processes for constructing the trunk segments are remarkably conserved across all living arthropods. One example is the expression of the segment polarity gene *engrailed*, which at embryonic and early post-embryonic stages is expressed in transverse stripes that define the posterior-most part of each trunk segment. Due to its conservative segment morphology and allegedly primitive trunk tagmosis, we have utilized the centipede *Strigamia maritima* to study the correspondence between the expression of *engrailed* during ontogenetic development and the formation of dorsal exoskeletal plates (trunk tergites) similar to those preserved in trilobites. Each tergite develops from a single segmental unit, as defined by *engrailed* expression. The results allow us to infer, tentatively, the expression domains of *engrailed* in the trunk of well-preserved trilobitomorphs (*Placoparia cambriensis*, *Triarthrus eatoni*, *Misszhouia longicaudata*), and suggest the presence of segmental mismatch between the dorsal and ventral exoskeletal elements of these extinct arthropods.

Myrtaceous leaves from Cenozoic sediments in Chiapas and Nuevo Leon, Mexico

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The present work describes the presence of Myrtaceae in two Cenozoic localities from Mexico, adding important evidence to the geographic distribution of this family. Two morphotypes have been grouped based on leaf architecture features, which are shared with *Eugenia*, *Calyptranthes* and *Myrcia* (Myrtaceae). These characters include the elliptical shape of the lamina, presence of an intramarginal vein, random reticulate third vein order, acuminate apex and presence of glands over the entire lamina. The first fossil described is morphotype 1 (related to *Myrcia*), collected at the La Popa locality from the Eocene-aged La Carroza Formation in the northern province of Nuevo Leon. The second is morphotype 2 (related to *Eugenia* and *Calyptranthes*), from the Miocene-aged Ixtapa Formation in the north-west region of Chiapas Province. Morphological diversity of Myrtaceae in both localities is fairly high, consisting of more than 50 morphotypes. Their abundance, diversity and size suggest they formed part of a tropical community; material from La Popa represents a drier area compared to that of Ixtapa. Nevertheless, tectonic activity seems to be responsible for a drastic change in vegetation, climate and altitude, resulting in Mexico having dry, tropical vegetation during the Paleogene in the North and during the Neogene in the South.

Testing Silurian palaeogeography using 'European' ostracod faunas

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The distribution of representative European and eastern North American species of the three major ostracod groups present in the Silurian independently support the standard palaeogeographic reconstructions of the 'North Atlantic' region for that time period. A range of assumed benthic, biostratigraphically key palaeocope and podocope ostracods show a provincial distributional pattern that characterises a 'European' ostracod faunal province which reflects the amalgamated palaeoplates of Avalonia and Baltica. By contrast, representatives of the low-diversity, late-Silurian, supposedly pelagic myodocope ostracod fauna from the UK, France, the Czech Republic, Sardinia and other locations globally, seemingly have much wider dispersal capacity which includes, for example, trans-(Rheic) ocean locations on the Avalonia, Baltica, Armorica (West Gondwana) and Perunica palaeoplates.

That there was an apparent major barrier to the migration of supposed benthic but not pelagic ostracod faunas strongly supports the notion of the presence of the Rheic Ocean and adjacent palaeocontinents. Comparable provincial and transoceanic distributional patterns are evident amongst Recent benthic and pelagic ostracods. The ostracod faunas

of Avalonia/Baltica seemingly remained essentially distinctive, at least at species level, from those of the remainder of the Laurentian plate in the Silurian, but the reason for this is uncertain.

Transition between terrestrial-underwater walking and swimming in the Early Permian tetrapod tracks of the Southern Alps (Northern Italy)

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Nine Early Permian tetrapod trackways were recently discovered from the lowermost portion of the Pizzo del Diavolo Formation, in the Orobic Basin (Central Southern Alps, Lombardy, N Italy). They are exclusively preserved as concave epireliefs and include wide and narrow gauge trackways, sometimes with clear tail drag marks. The large variety of morphological features complicate the ichnotaxonomical identification, and a superficial analysis of the track-bearing slab could suggest a large ichnodiversity. Nevertheless the thorough examination of the studied material indicates that the different morphologies document various locomotion mechanics (terrestrial walking, underwater walking, and the transition from walking to swimming) of a single track-maker. In our interpretation the hypothetical high ichnodiversity thus reduces to gait- and substrate-related extramorphologies (such as plantigrade *vs* semiplantigrade tracks, digit elongations, curved or sinusoidal digit scratches) of a single ichnogenus, *Batrachichnus* Woodworth, 1900. The trackways were likely produced in three distinct time intervals nearby ephemeral and shallow fresh-water ponds subjected to alternating wet and dry periods as testified by the different style of preservation, mud cracks and facies associations.

posters

Foraminifera resist ocean acidification in the Wagner Basin under conditions similar to high CO_2 environments of the Cretaceous–Paleogene

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Extensive carbon dioxide vents have recently been described in the Wagner Basin (northern Gulf of California, Mexico), which cause dramatic changes in carbonate chemistry. The pHT decreased from 7.88 to 7.55 near the most active vents, where the lowest saturation states of aragonite (Ω_{Arag}) and calcite (Ω_{Calc}) were 0.95 and 1.47 respectively.

Foraminifera (unicellular protists) present in the top 2cm of the sediment (both living and dead individuals) had a range of mainly calcareous taxa (including *Bolivina acuminata*, *B. acutula*, *Bulimina marginata* and *Nonionella basispinata*). This is a normal composition for these water depths. The lack of dissolution features and the generally good preservation of the tests, even when viewed under a scanning electron microscope, were striking. With no evidence of breakage caused by transportation, it is assumed that this composition is representative in terms of numbers of individuals and taxa represented. Benthic

foraminifera from CO_2 vents around the island of Ischia (Italy) have shown dramatic long-term effects of ocean acidification. The foraminifera of the Wagner Basin appear to be surviving in high CO_2 environments comparable to those that occurred during the Cretaceous–Paleogene 'greenhouse' world where atmospheric CO_2 was much higher, but with calcareous foraminifera apparently thriving.

A 16-million year old (Middle Miocene) fossil forest from the Cucaracha Formation, Panama: wood systematics

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We describe a spectacular 16 million year old fossil forest in the Middle Miocene Cucaracha Formation of Panama. The forest is known from three sites (Contractor Hill, Centenario Bridge and Hodges Hill) spread over a distance of 3 km. The forest layer, although exposed in disjunct outcrops, is correlated by means of a distinctive welded ignimbrite unit (radiometric dates are in the process of being obtained) that entombs and preserves the forest in growth position. Based on initial assessments of the charring depth and the NNE-SSW orientation of the entrained logs and rooted stumps, the forest is interpreted as being buried and charred by a blast wave which came from the north, presumably from a volcanic plug located at a distance of 5–7km. One of the localities (Hodges Hill) also contains excellently preserved calcified woods in fluvial facies at a different stratigraphic layer. Here we describe the wood anatomy of two wood specimens from these sites. The first shows features characteristic of the Malvaceae family while the second shares most characters with the tropical genus *Celtis* (Cannabaceae).

Can fossils be placed accurately in the tree-of-life? The effect of taphonomy on phylogeny

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Fossils provide unique and important data which allow us to reconstruct historic evolutionary events such as the origins of major clades or novel anatomical features. The utility of palaeontological data in this context is predicated on our ability to reconstruct the relationships of fossil species accurately and with confidence. Fossils are, however, notoriously incomplete and the information they contain has been subject to complex filters relating to their death, burial, decay and eventual preservation. Do taphonomic filters impede our ability to reconstruct phylogenies and thereby distort our understanding of major evolutionary transitions? To investigate this issue, published cladistic matrices for a range of vertebrate and invertebrate taxa were subjected to theoretical taphonomic filters. These distinguished 'hard', more readily preservable characters from 'soft', more ephemeral characters. These character classes were then analysed using tests for partition incongruence and node recovery. Significant differences between the signal provided by hard and soft characters were detected in several cases, but not in others. Only by making this distinction is it possible to know which areas of the fossil records we can have confidence in and which are in need of revision.

New data on *Nannirhynchia pygmaea* from the Lusitanian Basin (Lower Jurassic, Portugal)

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Species of *Nannirhynchia* are distributed in North Africa, Portugal, France and England. The *Nannirhynchia* beds are characteristic of the Toarcian strata of the Lusitanian Basin and its species are used for Toarcian brachiopod biostratigraphy. Specimens of *Nannirhynchia pygmaea* from the Tenuicostatum Biozone of the Søo Giøo Formation (Lower Toarcian) occur together with other rhynchonellid, terebratulid and spiriferid brachiopods, ammonites, belemnites, bivalves, gastropods and echinoderms. Our material was collected at the classical outcrop of "Maria Pares", south of Coimbra (Central Portugal). Specimens of *Nannirhynchia pygmaea* are preserved as articulated shells and are partially pyritized as internal moulds. For the first time, we can describe the outline of the muscle field and the orientation of crura and dental plates. In addition, 3D reconstructions after serial sections were prepared to show the length and orientation of crura as well as the internal shell morphology which could not be studied on the internal moulds. Our data intends to contribute to improving the knowledge of *Nannirhynchia* and to help to create a detailed *Nannirhynchia* biostratigraphy for Lower to Middle Jurassic strata from North Africa, Western Europe and England.

A new endemic spiriferid genus from the Lower Devonian of Central Portugal

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In a recent study, the classical collection of Portuguese brachiopods by Nery Delgado stored in the LNEG Geological Museum in Lisbon is revised. If possible, new material from classical localities and new outcrops is collected. We can identify a new genus and species of delthyridoid spiriferids in the Dornes Formation within the Dornes Syncline (Central Portugal). Its assemblage fauna pleads for a Siegenian to Emsian (middle to late Early Devonian) age. Due to its capillate micro-ornamentation, the new genus belongs to the warm water northern Gondwana delthyridoid spirifer fauna, however, it resembles also *Australospirifer* from the cold water Malvinokaffric Realm. The combination of morphological features of the new genus confirms the endemicity of this taxon in Central Portugal as well as the increase of global endemism at that time. Other brachiopod taxa found together with the new genus show affinities to brachiopods from Northern Gondwanan terranes, such as *Turcispirifer* or *Ctenochonetes*. Hardly any relationship to coeval faunas from the Ardenno-Rhenish Mountais is seen. The morphological similarities to *Australospirifer* are regarded as homoplasy.

The sensory structures of (phacopid) trilobite eyes

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Trilobite eyes are among the oldest of all preserved visual systems, originating in the Lower Cambrian at about 522Ma. Their external morphology is often well preserved, and in the thick lenses of phacopid trilobite eyes sophisticated internal structures have been described correcting spherical aberration and thus forming no blurred images. Hitherto, however, nothing has been known about the sensory systems of trilobite eyes, because, as is normal in fossils, soft tissues such as nervous structures are rarely preserved. In the Devonian phacopid *Geesops*, however, using x-ray tomography, mineral films which have grown round original sublensar structures preserve the shapes of the photoreceptive organs. It has been possible to show that the sensory system of phacopid trilobite eyes resembles that of the 'living fossil' Limulus, the horseshoe crab, in structure and dimensions. An ancient optical principle has been conserved up to the present day.

A Jurassic Golden Orb-weaver spider

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Golden orb-weaver spiders (Araneae: Nephilidae: *Nephila*) are renowned for their enormous, golden-coloured orb webs, found mainly in tropical forests, and for their extreme sexual size dimorphism. Recently a large female, *Nephila jurassica*, was described from Jurassic rocks of China; but no males, so it was impossible to conclude anything about the antiquity of sexual dimorphism in nephilids. Now, a male of *N. jurassica* has been discovered in the same strata. It is as large as the female, suggesting that dimorphism had not evolved in these spiders by the Jurassic period, and that male dwarfism was the dominant selective pressure. Moreover, the species is cribellate (a plesiomorphic condition), which provides evidence on the timing of the loss of this condition among orb-weavers.

Asymmetry in an Ordovician conulariid cnidarian

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Conulariids are scyphozoan cnidarians with cone-shaped skeletons that normally show perfect tetraradial symmetry. However, in the Ordovician species *Metaconularia anomala* (Barrande, 1867) from Drabov (Czech Republic), tetraradial symmetry is compromised in three ways: (1) skeletons often show torsion; (2) the four sides may be of unequal width; and (3) one side may be missing to give a triradial skeleton. A study of almost 2,000 steinkerns showed that about 56% were torted in an anticlockwise direction (sinistral) when viewed from the apex towards the aperture, 28% untorted and 1% torted in a clockwise torsion (dextral), while the remaining 15% could not be classified. A weak

negative correlation between torsion rate and length suggests that highly torted individuals may have survived less well. Almost 5% of individuals show loss of one side for at least part of their length. Although many individuals have four sides of equal width, in some cases the widest faces are up to twice as wide as the narrowest. Asymmetry in *M. anomala* cannot be explained taphonomically. The strong preference for sinistral torsion is interpreted as a 'fixed asymmetry' that was heritable, perhaps controlled by Hox-like genes and/or the signalling protein Nodal.

An integrative approach supports a novel view on early molluscan evolution

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Molluscs are the second largest and morphologically most disparate animal phylum, they are ubiquitous, and have a formidable fossil record. Monophyly of the eight Recent molluscan classes is undisputed, but relationships between these groups and patterns of early molluscan radiation have remained elusive. We present a new molecular clock for Mollusca with implications for the early fossil record of crown group clades. Our new molecular dataset is the most comprehensive to date, and the first with multiple species from all classes (including five monoplacophorans in both living families). Our recovered topology is robust and rejects all traditional groupings such as Aculifera, Conchifera, or Testaria, but supports the monophyly of Monoplacophora and Polyplacophora (chitons) in the clade Serialia. Early diversification of molluscs started in the early Cambrian and was far more rapid and more complex than previously appreciated. Extensive evolutionary plasticity by heterochronic shifts in development and multiple convergent adaptations, as demonstrated in extant molluscs, were already within the evolutionary potential of their Cambrian forebears, and continue today. Living monoplacophorans radiated in the Cenozoic; this casts doubt on the relationships of fossil Tryblidia. Our evidence for this unexpectedly fast-paced scenario for molluscan evolution has implications for the interpretation of key fossils.

Early Eocene climate and ecology in a high-latitude floodbasin: The Chickaloon and Arkose Ridge formations, Alaska, USA

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The Chickaloon and Arkose Ridge formations in Alaska's Matanuska Valley–Talkeetna Mountains Basin contain an extraordinary palaeoenvironmental record of Early Eocene hothouse climate conditions. Coals containing large *Metasequoia* trees are preserved in mire deposits while lacustrine, floodplain, and crevasse splay deposits preserve dicot and monocot leaves, shoots of conifers and equisetaleans, angiosperm fruits, and cupressaceous cones. Recent analysis of stratigraphic successions, fossil plant and insect collections,

and sedimentary geochemistry reveal that a diverse floodbasin forest existed at sub-polar latitudes under temperate palaeoclimatic conditions.

Leaf physiognomy-based palaeoclimate estimates indicate mean annual temperatures between 10 and 14°C across various lithofacies; much higher than at present (~2°C). Estimates of annual palaeoprecipitation are high as well (120–160 cm/yr *vs*. 40–60 cm/yr in the Recent). The occurrence of palmetto fronds (*Sabalites*) and evidence of high seasonal biomass production support the notion of a yearly-averaged ameliorated climate.

Ancient interactions between insect herbivores and dicot leaves are unexpectedly rare. Leaf damage frequency (~9%) is low when compared to similar studies of coeval assemblages on North America with marginally higher palaeotemperatures. We propose that the non-analogous situation of warm climate conditions under a high-latitude light regime rather than climatic or leaf economic traits may explain these results.

Global correlation of biostratigraphic data – an industry-led workflow

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A vast quantity of biostratigraphic data exist for the Phanerozoic, transcending all fossil groups. However, the utility of these data, typically summarised in biostratigraphic schemes, requires calibration against international standards to facilitate precision in stratigraphic correlation, critical in hydrocarbon exploration workflows.

Despite standards in nomenclature and referencing, no consistent format is applied in the presentation of published biostratigraphic data. Here we outline an industry-led workflow to produce a consistent global biostratigraphic database and calibration of biostratigraphic data.

Biostratigraphic data are reviewed using current geochronological concepts as defined in the International Timescale (Ogg *et al*. 2008), while adhering to the original author's event-ordering. These data are calibrated and reviewed by consultant biostratigraphers in their areas of expertise. The data are presented in a consistent and concise format which can be interrogated and displayed using software endorsed by the International Commission of Stratigraphy, Time Scale Creator Pro.

To date, we have calibrated over 1,500 biostratigraphic charts, representative of >61,000 data points including biostratigraphic tops, bases and zones. These data provide a tool for global correlation at a high level of stratigraphic precision. We will present a demonstration of how this approach allows correlation at the global scale, focusing on a stratigraphic event.

Patterns and consequences of larval mode in Cenozoic gastropods from Southeastern Australia

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Gastropods, like many marine invertebrates, have a two-stage life cycle with planktonic larvae metamorphosing into benthic adults. Adults are slow moving and have narrow environmental tolerances, and therefore the larval stage offers the principal opportunity

for dispersal. Some species have larvae that can feed and survive for prolonged periods in the plankton (planktotrophs) whilst others have larvae that cannot feed but metamorphose after a short period of time into benthic juveniles (nonplanktotrophs). Larval mode can be inferred from the adult shell of fossil gastropods, making it possible to follow trends through geological time. It is predicted that the different larval types have fundamental effects on factors such as geographic range, species duration and speciation rate. While it is widely accepted that larval mode is closely linked with these important biogeographic and macroevolutionary correlates, these patterns have rarely been tested in the fossil record. Using the well-preserved gastropod fossils from widely outcropping Cenozoic carbonate sediments along the southeastern coast of Australia, we test the hypotheses that nonplanktotrophy is correlated with narrow geographic range, short species duration and high speciation rate, whilst planktotrophy is linked to wide geographic range, long species duration and low speciation rate.

The first record of attached secondary tiering acrotretoid brachiopods: implication for the ecological expansion of Early Cambrian brachiopods

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posters

Here we present the first account of an exceptionally preserved medium high secondary tiering (+5 to +10 cm tier) lingulate acrotretoid brachiopod from the Lower Cambrian, Chengjiang fauna (Series 2, Stage 3), Yunnan, southern China. The articulated shells of the problematic lingulate acrotreotid new genus and species are without exception still attached *in situ* to the fronds of the algae-like *Malongitubus kuangshanensis* Hu, 2005. The posterior margins of the acrotretoid shells are invariably in direct contact with the *Malongitubus* fronds, and lack all evidence of the long linguloid pedicle that is otherwise common in the Chengjiang lingulates. This indicates that the attachment of the new acrotretoid was similar to that previously known from the Middle Cambrian Burgess Shale, where the posterior margins of numerous *in situ* secondary tiering paterinates are in direct contact with spicules of erect sponges. The micromorphic acrotretoid also represents the first and oldest evidence into the enigmatic palaeoecology of the diverse micromorphic acrotretoid brachiopods that are important members of the Cambrian and Lower Palaeozoic faunas. The new record of an acrotretoid/*Malongitubus* association also demonstrates that much higher tiering levels than previously thought were reached already by the Early Cambrian.

Overlooked uncertainties in the estimation of divergence times

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Calibration is a critical step in every molecular clock analysis but is frequently overlooked. Bayesian approaches enable the degree to which fossil data approximate divergence times

to be incorporated into prior probability densities. In addition, the distribution of node ages for which fossil evidence is unavailable can be described using a speciation model. However, molecular studies rarely supply justification for the distributions used to constrain either calibrated or non-calibrated nodes. Furthermore, prior constraints can interact and become truncated in the joint estimation of divergence times. We explored the impact of these largely neglected phenomena using three empirical datasets: angiosperms, arthropods and turtles. We show that molecular clock estimates of divergence times are highly sensitive to arbitrary parameter choice. The models used to constrain calibrated nodes can affect the outcome at non-calibrated nodes and vice-versa. In some cases, the effective priors deviate substantially from the user-specified calibration priors. This issue is exacerbated with the addition of increasing numbers of taxa, increasing the number of overlapping constraints. As the calibration density decreases, the specified priors at calibrated nodes disintegrate further. These observations highlight the urgent need for further research into the way in which fossil evidence is integrated into molecular dating analysis.

Early Paleocene Recovery Fauna from Seymour Island, Antarctica

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Seymour Island, located on the Antarctic Peninsula, comprises one of the best exposed and most complete high latitude sedimentary sequences through the Cretaceous to the Eocene anywhere in the world. The section is important because the modern Antarctic fauna arose following the Cretaceous–Paleogene (K–Pg) extinction event, with biotic recovery occurring throughout the Early Cenozoic. Fossil assemblages on the island are well-preserved and include marine invertebrates, vertebrates plus terrestrial plant material washed in from the nearby Antarctic Peninsula.

In this study a new detailed stratigraphy of the Seymour Island sequence is linked with comprehensive fossil collections. The samples, which cover a 20 million year time span, will allow the scale of the K–Pg extinction plus the nature and timing of biotic recovery in the Paleocene of Antarctica to be re-assessed. Superimposed on the recovery process is a long-term basin shallowing trend within the Paleocene Sobral Formation. This new information will help us to assess large-scale patterns of Cenozoic biodiversity change in the Antarctic and their relationship to the distribution and diversity of organisms at the present day.

How were marine communities in the South Polar region affected by the Cretaceous–Paleogene mass extinction?

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The environmental catastrophe at the end of the Cretaceous is well studied in the northern hemisphere, but the effects on the southern hemisphere are relatively poorly understood. The highest southern latitude site for studying this interval is Seymour Island, Antarctica

(65°S). The Cretaceous–Paleogene (K/Pg) section is preserved within a sequence of marine siltstones and sandstones deposited in a back-arc basin, containing a rich marine fauna that records biodiversity in the southern oceans during the latest Cretaceous and across the K/Pg boundary.

New studies of the abundant marine invertebrates, in particular ammonites, bivalves and gastropods, are providing data on biodiversity and environmental change during this time interval. Ammonites show the terminal extinction at the K/Pg boundary seen worldwide; however, contrary to northern hemisphere sections, suspension-feeding bivalves do not appear to be preferentially affected by the K/Pg event. The diverse Maastrichtian community is replaced by a sparse Paleocene assemblage dominated by opportunistic taxa, such as the suspension feeding bivalve *Lahillia larseni* and predatory gastropods.

These preliminary results indicate that although the K/Pg event clearly devastated a typical Cretaceous marine community, effects on the marine biota were very different to, and perhaps less severe than, those seen in the northern hemisphere.

Semaphoronts and the phylogenetic position of fossil pancrustacean larvae

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Studies of ontogeny have a long history, but only recently have ontogenetic data been explicitly incorporated into phylogenetic analyses. However, defining homologous stages across disparate taxa remains problematic. Pancrustaceans (= crustaceans + hexapods) undergo some of the most radical ontogenetic changes seen in the Metazoa. The spectacular upper Cambrian 'Orsten' fauna preserves phosphatized fossil larvae, including putative stem- and crown-group pancrustaceans with amazingly complete developmental sequences. The putative presence and nature of adult stages remains a source of debate. We introduce a new method of coding ontogenetic data where each semaphoront (discrete larval or adult stage) is considered an OTU. This decreases the reliance on continuous timing of developmental 'events', and permits a theory-free identification of ontogenetic similarity. Characters and their states are carefully defined to identify specific putative homologies across taxa, as well as changes in morphology throughout ontogeny. Exemplar taxa covering most of Pancrustacea are included (both direct and indirect developers). We draw morphological data mainly from the rich ontogenetic and embryological literature, augmented with personal observations. Diverse early larval semaphoronts are found to group together rather than with their conspecific later stages, indicating a source of bias. To overcome this, two parsimony-based tree building methods are introduced.

Dinoflagellate distributions and Late Miocene (11.61–7.25 Ma) oceanography

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In order to understand the predictive ability of global circulation models (GCMs), it is necessary to challenge them to simulate palaeoclimates. Evaluating these simulations requires a comprehensive view of palaeoclimate from the geological record. Many present day and Quaternary studies of dinoflagellate cysts have shown that they can

be used to reconstruct palaeo sea surface parameters (SSPs). In this case we present an almost complete overview of global Tortonian dinoflagellate cyst distributions. We have constructed a comprehensive ArcGIS-MS Access database for the Tortonian, using over 80 published studies on dinoflagellate cysts. This technique allows the distribution of individual taxa to be studied and assessed for surface temperature, salinity, nutrients and upwelling.

Working within the constraints of the Tortonian (11.61–7.25 Ma) means that only a limited number of taxa are still alive today. Regardless of this the SSPs at each site have been built up by comparing the fossil dinocyst to the extant taxa and applying the same environmental tolerances of the extant taxa to that in the palaeo record. This database combined with ongoing modelling and terrestrial proxy work is furthering our understanding of the Tortonian climate.

Understanding the conodont biostratigraphy of Emeishan Large Igneous Province (South China) and its bearing on Capitanian (mid-Permian) mass extinction

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The Permian Emeishan Large Igneous Province (LIP) was a relatively small LIP that erupted in a marine setting in its early stage. This unique setting enables us to conduct comprehensive conodont biostratigraphic and facies analysis studies on Maokou Limestones that were underlying and/or intercalated with the initial lava flows. The studies sections span the localities from the LIP central area via LIP periphery to several hundred kilometers beyond the LIP margin. The results suggested the initial onset of the Emeishan volcanism was probably around middle Capitanian *Jinogondolella altudaensis* conodont zone, which was seen at Xiong Jia Chang and Pingdi sections of Guizhou Province. The large-scale eruption only occurred later around *J. xuanhanensis* zone, as recorded in six sections in Sichuan and Yunnan provinces. The onset of Emeishan volcanism coincided with a major (~-6‰) negative shift of carbonate carbon isotope around *J. altudaensis* zone, the extinction of keriotheca-walled fusulinaceans (*e.g.*, Neoschwagerinidae), and a turnover amongst calcareous algae.

Together with former studies, we conclude that the initial and main stages of Emeishan volcanism were within the Capitanian Stage (~263 Ma) rather than around the Guadalupingian–Lopingian boundary (~259 Ma). The onset of eruptions is seen to coincide with a crisis amongst shallow-water platform carbonate taxa both in South China and globally.

Oceanic Anoxic Event 1a: dinoflagellate cysts as indicators of mid-Cretaceous palaeoenvironmental change

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Oceanic Anoxic Event 1a (OAE1a; 120 Ma) represents a major turning point in mid-Cretaceous palaeoceanography. This transient event is expressed in southern France as the 'Niveau Goguel' constituting a major perturbation in the global carbon cycle, which altered the chemical and thermal state of the Tethys Ocean.

The palaeoenvironmental changes during OAE1a for the Tethyan realm are being investigated, utilising the well-dated Lower Aptian section of Cassis-La Bédoule in the South Provencal Basin (SE France). In this transgressive interval, a positive excursion is recorded in both the carbonate and organic carbon-isotope records across the Goguel level, preceded by a negative excursion.

To our knowledge, a high-resolution organic-walled dinoflagellate cyst (dinocyst) palaeoenvironmental study of the sequence has not been done before. By sampling the succession for dinocysts and documenting changes in autotrophic and heterotrophic taxa, it is possible to obtain a better understanding of the changing nutrient levels accompanying the development of OAE1a. Variations in abundance, species richness, and occurrences of key taxa will provide new constraints on the causes and consequences of OAE1a in northern Tethys, in conjunction with providing an improved high-resolution mid-Cretaceous biostratigraphic record. Preliminary dinocyst data from the succession spanning OAE1a will be presented and discussed.

REE compositions in fossil vertebrate dental tissues – key to biomineral preservation

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Rare earth element (REE) abundances have been measured in a number of Palaeozoic and Mezozoic vertebrate hard tissues (teeth and dermoskeleton) using Laser Ablation Inductive Coupled Plasma Mass Spectrometry (LA-ICP-MS). Fossil vertebrates analysed comprise scales and tesserae of Silurian and Devonian thelodonts, chondrichthyans, galeaspids, mongolepids, spines of acanthodians, as well as teeth of Cretaceous lungfish and marine reptiles.

Pre-evaluation of fossil preservation level has been made by semi-quantitative spot geochemistry analyses on fine polished teeth and scale thin sections, using Energy Dispersive

X-ray Spectroscopy (EDS). Silicification of bioapatite, together with elevated heavy element concentrations, corresponded to fossil tissue structure and colour alteration. Stable oxygen isotope measurements ($\delta^{18}O$) of bulk biomineral have been conducted in parallel, generally yielding lower heavy oxygen ratios in stronger altered teeth and scales. Clear distinction in REE concentrations was observed between dentine and enamel of Cretaceous plesiosaurs, indicating enamel as more geochemically resistant to diagenetic overprint.

Can commensalism occur in the fossil record?

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Most symbiotic interactions occurring between recent organisms are also recognized in the fossil record. One of the most often described is commensalism. Was it really so common in past communities? There are two ways of understanding commensalism: narrow and broad. Commensalism in the narrow sense can be understood as an interaction strictly neutral for one organism and positive for the other. Neutral interaction is the absence of interaction and as such it cannot be proven (the proof of absence cannot be made) and consequently it can be regarded as a concept unfit for empirical science. In the broad sense, neutrality is acknowledged as unlikely and, instead, replaced with a slightly weak (positive or negative) interaction. This approach also seems imperfect, as weak interactions should be regarded rather as mutualism or parasitism, respectively. The borders between interactions (commensalism/parasitism and commensalism/mutualism) are difficult to define; hence commensalism should be considered as a theoretical interval within the continuum of interactions. It is clear that, if detection of commensalism in recent associations is so difficult, identifying it in the fossil record may be impossible. The terms 'paroecia' and 'endoecia' seem to be more useful to use in cases when a particular ecological relationship is difficult to prove.

Did tabulate corals have symbiotic algae?

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Tabulate corals formed colonies up to 1m in diameter. Many tabulates display growth periodicity often interpreted to have been caused by seasonal changes in the environment. On the basis of analogies with modern scleractinians, namely similar colony structures and growth pattern (massive colonies and growth periodicity), it can be inferred that tabulates possessed symbiotic algae (zooxanthellae) probably as early as the Devonian.

Recent zooxanthellate scleractinians show characteristic stable isotope ratios: -6.0 to -2.0‰ $\delta^{18}O$ and -2.0 to +2.0‰ $\delta^{13}C$. Azooxanthellate corals also have characteristic, different ratios: within the values of -6.0 to -2.0‰ $\delta^{18}O$ the $\delta^{13}C$ values are below -4.0; and $\delta^{18}O$ values can reach +3.0‰, which never occurs in zooxanthellate corals. Carbon and oxygen isotope ratios of investigated tabulate corals, namely *Favosites* sp. from the Eifelian of the Eifel Mountains (Germany) and Permian syringoporids from Hornsund, Spitsbergen, display values of, respectively, -5.0‰ $\delta^{18}O$ / +2.0‰ $\delta^{13}C$ and -7.5 to -8.7‰ $\delta^{18}O$ / -0.7 to +2.4‰ $\delta^{13}C$. These values are similar to those of recent scleractinians and together with corallum shape and growth periodicity may suggest that zooxanthellate symbiosis was present already in the Devonian.

Annual Meeting 2011

Notification is given of the 55th Annual General Meeting and Annual Address.

This will be held at Plymouth University on 18th December 2011, following the scientific sessions. Please note that additional items may be added to the agenda following the December Council meeting.

AGENDA

1. Apologies for absence
2. Minutes of the 54th AGM, University of Ghent
3. Trustees Annual Report for 2010 (published in this Newsletter)
4. Accounts and Balance Sheet for 2010 (published in this Newsletter)
5. Election of Council and vote of thanks to retiring members
6. Palaeontological Association Awards
7. Annual address

H. A. Armstrong
Secretary

DRAFT AGM MINUTES 2010

Minutes of the Annual General Meeting held on Saturday, 18th December 2010 at the University of Ghent.

1 Apologies for absence: *Prof. J. C. W. Cope*

2 Minutes: *Agreed a correct record*

3 Trustees Annual Report for 2009. Proposed by Dr L. R. M. Cocks and seconded by Prof. G. D. Sevastopoulo, the report was agreed by unanimous vote of the meeting.

4 Accounts and Balance Sheet for 2009. Proposed by Prof. J. Francis and seconded by Prof. M. P. Smith, the accounts were agreed by unanimous vote of the meeting.

5 Election of Council and vote of thanks to retiring members

Prof. R. J. Aldridge extended a vote of thanks to the following members of Council who were retiring this year: Prof. J. C. W. Cope, Dr T. Servais, Dr M. A. Purnell, Dr M. Sutton, Dr P. Orr, Prof. Donovan, Mr W. Fone, Prof. D. A. T. Harper, Dr A. Rasmussen, Dr E. Rayfield and Dr G. Harrington. Dr L. Anderson was retiring as a scientific editor. The following members of Council were elected to serve on Council:

President:	Prof. J. Francis
Vice Presidents:	Dr P. Orr and Prof. J. W. Cope
Treasurer:	Mr P. Winrow
Secretary:	Dr H. A. Armstrong
Chair of Publications Board:	Prof. M. P. Smith
Editor Trustee:	Dr P. C. J. Donoghue
Book Review Editor:	Dr C. Jeffrey-Abt
Publicity:	Dr E. Rayfield
Newsletter Reporter:	Dr L. Herringshaw
Newsletter Editor:	Dr R. J. Twitchett
Web Officer:	Dr M. Sutton (for a second term)
Ordinary Members:	Dr C. Klug
	Dr W. Renema
	Dr T. R. A. Vandenbroucke

Mr D. Ward was co-opted to assist with outreach and Dr M. A. Purnell was co-opted to complete outstanding projects. Dr Twitchett will organise the Annual Meeting in 2011 at the University of Plymouth.

6 **Association Awards:** The following awards were made:

- Lapworth Medal to Dr L. R. M. Cocks
- President's Medal to Dr N. Butterfield (University of Cambridge)
- Hodson Award to Dr T. R. Vandenbroucke (University of Ghent)
- Mary Anning award to Mr Daniel Vizcaino.

Honorary Life membership was awarded to Prof. Edwards, Prof. Bassett and Dr Skelton. Sylvester-Bradley Awards were made to Cotton, Halliday, Koot, O'Brien and Young. It was noted that a number of proposals this year were either incomplete or had not followed the guidelines and these could not be considered. The President's Award was made to Abigail Clifton (University of Leeds) and the Council Poster Prize was presented to Tom Harvey (University of Cambridge).

The Annual Address entitled "Ancient origin of the deep sea fauna: new evidence from the fossil record" was given by Prof. A. Gale (University of Portsmouth).

Trustees Annual Report 2010

Nature of the Association. The Palaeontological Association is a Charity registered in England and Wales, Charity Number 276369. Its Governing Instrument is the Constitution adopted on 27th February 1957, amended on subsequent occasions as recorded in the Council Minutes. The aim of the Association is to promote research in Palaeontology and its allied sciences by (a) holding public meetings for the reading of original papers and the delivery of lectures, (b) demonstration and publication, and (c) by such other means as the Council may determine. Trustees (Council Members) are elected by vote of the Membership at the Annual General Meeting. The contact address of the Association is c/o The Executive Officer, Dr T. J. Palmer, Institute of Geography and Earth Sciences, University of Aberystwyth, Aberystwyth, SY23 3DB, Wales, UK.

Trustees. The following members were elected to serve as trustees at the AGM on 21st December 2009: *President*: Prof. R. J. Aldridge; *Vice Presidents*: Dr T. Servais and Dr P. Orr; *Treasurer*: Prof. J. C. W.

Cope; *Secretary*: Dr H. A. Armstrong; *Chair of Publications Board*: Prof. M. P. Smith; *Editor Trustee*: Dr P. Orr and Dr P. C. J. Donoghue; *Book Review Editor*: Dr C. Jeffrey-Abt; *Publicity*: Dr M. A. Purnell; *Newsletter Reporter*: Dr L. Herringshaw; *Newsletter Editor*: Dr R. J. Twitchett; *Web Officer*: Dr M. Sutton; *Ordinary Members*: Mr W. Fone, Prof. S. K. Donovan, Dr C. Underwood, Dr E. Rayfield, Dr C. Buttler and Dr D. Schmidt. Dr Harrington and Dr Vandenbroucke remained on Council as Annual Meeting organisers. *The Executive Officer*: Dr T. J. Palmer and *Editor-in-Chief*: Dr S. Stouge continued to serve Council but are not Trustees.

Membership. Membership on 31st December 2010 totalled 1,197 (1,184 at end 2009), and did not appear to have been significantly affected by the subscription increases that were introduced at the beginning of the year. Of these 745 were Ordinary Members, 162 Retired and Honorary Members and 290 Student Members. There were 78 Institutional Members and 89 institutional subscribers to *Special Papers in Palaeontology*. Wiley Blackwell also separately manage further Institutional subscribers and distribute publications to these Institutional Members on behalf of the Association.

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

Reserves. The Association holds reserves of £673,871, in General Funds, which enable the Association to generate additional revenue through investments, and thus to keep subscriptions to individuals at a low level, whilst still permitting a full programme of meetings to be held, publications produced and the award of research grants and grants-in-aid. They also act as a buffer to enable the normal programme to be followed in years in which expenditure exceeds income, and new initiatives to be pursued. The Association holds £86,551 in Designated Funds which contribute interest towards the funding of the Sylvester-Bradley, Hodson Fund and Jones Fenleigh awards, and which will contribute interest towards the funding of the new Callomon and Whittington awards. Funds carried forward to 2011 totalled £760,422.

Finance. Total charitable expenditure in 2010, through grants to support research, scientific meetings and workshops, was £288,764. Governance costs were £13,107. Total resources expended were £325,745. 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*. During the year the Association received bequests totalling £30,000.

Risk. The Association is in a sound financial position. Succession planning for executive officers remains a concern and will be considered as part of the Annual Review of Officers in 2011.

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

Grants. Palaeontological Association Research Grants were awarded to Dr B. Lomax (University of Nottingham), "SporoMALDI-resolving terrestrial palaeoecosystem responses to perturbations in the global carbon cycle using isolated single sporomorphs"; Dr J. Wheeley (University of Birmingham), "Nitrogen and organic carbon isotopes of Ordovician conodonts"; Dr J. Antcliffe (University of Bristol) "Integrating the White Sea Ediacara into a global framework"; Dr J. Zalasiewicz (University of Leicester) "Exploring new stratotypes for Silurian (Llandovery) stages in Wales."

Grants–in-aid. The Association provided funds to support the following meetings: Siluria Revisited

(IUGS); 8th International Symposium, Cephalopods present and past; 9th International Congress of Vertebrate Morphology (ICVM); 2nd International Sclerochronology Conference July 2010; PalaeoDbase course in Glasgow 2011. The Association provided a grant of £44,000 to the Third International Palaeontological Congress, held in London. This caused a substantial increase in the amount of money paid out in Grants, compared with 2009.

Sylvester Bradley Fund. A review of these awards was made in 2010. Application guidelines were changed and the amount per award increased. Fifteen proposals were received. Seven were recommended for funding. These included proposals from Brewer, Butler, Hopley, Lecuona, Nunn, Peralta-Medina and Sallan.

Online activities. The online activities of the Association continue to expand. During the year new server provision was made and a new system for advertising PhD studentships was developed. Funding was provided to develop palaeontological outreach through the website. The Association continues to host mirror sites for the PaleoDbase, *Palaeontologia Electronica*, the EDNA fossil insect database, the Palaeontographical Society website and a database of fossils from Kent produced by the Kent RIGS Group.

Public meetings. Three public meetings were held in 2010, and the Association extends its thanks to the organisers and host institutions of these meetings:

54th Annual General Meeting. This was held on 17–20 December at University of Ghent. Dr Vandenbroucke with much local support organised the meeting which included a symposium on "Biological proxies in climate modelling" and comprised a programme of internationally recognised speakers. There were 221 attendees. The Annual Address entitled "Ancient origin of the deep sea fauna: new evidence from the fossil record" was given by Prof. A. S. Gale (University of Portsmouth). The President's Award for best oral presentation from a member under 35 was made to Abigail Clifton (University of Leeds). The Council Poster Prize was presented to Tom Harvey (University of Cambridge). Due to the severe weather the post-conference field trip was to the Royal Belgium Institute of Natural Science, Brussels.

British Science Festival, Palaeontological Association Symposium. This is an annual forum for presentations to the public and general scientists. The Symposium "Firsts for life: Different views on the origins of animals and plants" was organised by Dr Purnell (University of Leicester) and funds were provided in support of four internationally renowned speakers.

Progressive Palaeontology. The annual open meeting for presentations by research students was organised by Aude Caromel, Roger Close, Alex Dunhill, Jenny Greenwood, Duncan Murdock and Rachel Warnock, and was held at the University of Bristol.

In addition to hosting public meetings the Association manages the Stuart Baldwin Lecture Series. This enables amateur societies to fund visiting speakers. Two awards were made in 2010.

Publications. Publication of *Palaeontology* and *Special Papers in Palaeontology* is managed by Wiley Blackwell. Volume 53 of *Palaeontology*, comprising six issues, was published. *Special Papers in Palaeontology 83*, "Silurian conodonts from the Yangtze Platform, south China," edited by Wang Cheng-Yuan and Richard J. Aldridge; and *Special Papers in Palaeontology 84*, "Evolution and Development of the Brachiopod Shell," edited by F. Alvarez and G.B. Curry, were also published during the year. Two field guides, on "Fossils from the Lower Lias of the Dorset Coast," edited by Alan R. Lord and Paul G. Davis, and "Fossils of the Gault Clay," edited by J. R. Young, A. S. Gale, R. I. Knight, and A. B. Smith, were published. The Association is grateful to the National Museum

of Wales and the Lapworth Museum (University of Birmingham) for providing storage facilities for publication back-stock and archives. Council is indebted to Meg and Nick Stroud for assistance with the publication and distribution of *Palaeontology Newsletter*.

Publicity. The Association continues to promote palaeontology and its allied sciences through press releases to the national media, radio and television.

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 Dr L. R. M. Cocks (Natural History Museum). The President's Medal for a palaeontologist in recognition of outstanding contributions in his/her earlier career, coupled with an expectation that they will continue to contribute significantly to the subject in their further work, was awarded to Dr N. Butterfield (University of Cambridge). The Hodson Award, for a palaeontologist under the age of 35 who has made an outstanding achievement in contributing to the science through a portfolio of original published research, was awarded to Dr T. J. Vandenbroucke (University of Ghent). The Mary Anning Award, for an outstanding contribution by an amateur palaeontologist, was made to Mr Daniel Vizcaino. Council also awards an undergraduate prize to each university department in which palaeontology is taught beyond Level 1. Honorary Life membership was awarded to Prof. Edwards, Prof. Bassett and Dr Skelton. The "Golden Trilobite Award" was made to <**www.bryozoa.net**>, a high-quality, information-rich amateur website which provides a wealth of carefully collated information.

Governance. The Association continues to improve its administration with further improvements to the *Newsletter* and website. Trustees were members of the Joint Committee for Palaeontology; Prof. Aldridge (Chair) and Dr Servais represented the Association. Dr Armstrong acted as the Association representative on the International Palaeontological Association. During the year the Association responded to requests for information from the HEFCE consultation on the Research Excellence Framework, NERC and the BGS.

Forthcoming plans. Council will continue to make substantial donations, from both General and Designated funds, to permit individuals to promote the charitable aims of the Association. Resources will be made available from General Funds to support the Association Research Grant, Grants-in-Aid, provided to carry out research into palaeontological subjects, to disseminate findings in print and at conferences and support the provision of palaeontological workshops. The Association will continue to recognise the contribution individuals have made to palaeontology and associated sciences through its awards. A similar programme of public meetings and publications will be carried out in 2011. Funds will be made available to further develop the website aimed at encouraging outreach. It is intended that one new *Field Guide to Fossils* will be published within the year. The 55th Annual meeting will be held at the University of Plymouth. Progressive Palaeontology will be held at the University of Leicester. The Association will sponsor a symposium at the British Science Festival, "Paradise Lost? Strange environments and major events from the geological past," and provide travel grants for the Congress of the European Geosciences Union. The Association will host the Lyell Meeting in 2011 on the topic of "Island faunas, migration and evolution." During 2011 the Association will amalgamate the storage of back-stock and its archive to a new office in Aberystwyth.

Howard A. Armstrong
Secretary

THE PALAEONTOLOGICAL ASSOCIATION Registered Charity No. 276369
STATEMENT OF FINANCIAL ACTIVITIES FOR THE YEAR ENDED 31st DECEMBER 2010

			General Funds		Designated Funds	TOTAL 2010	TOTAL 2009
Incoming Resources							
Generated Funds							
Voluntary income	Subscriptions		66,913			66,913	68,202
	Legacies		30,000			30,000	0
	Donations		0		1,589	1,589	4,886
				96,913	1,589	98,502	73,088
Charitable activities							
Sales	Palaeontology		198,361				
	Special Papers		12,598				
	Offprints		1,581				
	Newsletters		0				
	Field Guides		12,671				
	Distribution		1,663				
				226,874		226,874	226,761
Investment income				12,069	94	12,163	15,230
TOTAL INCOMING RESOURCES				335,856	1,683	337,539	315,079
Resources expended							
Costs of generating funds							
for voluntary income	Administration		21,029				18,670
Investment management	Stockbroker fees		2,845				1,771
				23,874	0	23,874	20,441
Charitable activities							
Publications	Palaeontology		73,217				
	Special Papers		9,972				
	Offprints		1,230				
	Field Guides		20,831				
	Newsletters		13,795				
	Distribution		1,234				
	Marketing		2,974				
	Editorial costs		55,150				
	Total Publications		178,403			178,403	154,134
Scientific Meetings & Costs			70,931			70,931	18,939
Grants and Awards			7,525		7,260	14,785	14,877
Research Grants			5,619			5,619	6,637
Administration of charitable activities			26,286			26,286	23,337
				288,764		296,024	217,924
Governance costs	Examiner's fee		400				
	Trustee expenses		7,450				
	Administration		5,257				
				13,107	0	13,107	13,013
TOTAL RESOURCES EXPENDED				325,745	7,260	333,005	251,378
NET INCOMING RESOURCES				10,111	-5,577	4,534	63,701
INVESTMENT GAINS/LOSSES							
Realised gain			3,122				
Unrealised gain			43,127				
				46,249		46,249	44,838
NET MOVEMENT IN FUNDS				56,360	-5,577	50,783	108,539
TRANSFERS BETWEEN FUNDS				-50,000	50,000	0	0
SURPLUS/DEFICIT FOR THE YEAR				6,360	44,423	50,783	108,539
FUNDS BROUGHT FORWARD				667,511	42,128	709,639	601,100
FUNDS CARRIED FORWARD				673,871	86,551	760,422	709,639

THE PALAEONTOLOGICAL ASSOCIATION Registered Charity No. 276369

BALANCE SHEET as at 31st DECEMBER 2010

2009			Note			2010
£						£
		INVESTMENTS				
	454,924	At market value				534,720
		CURRENT ASSETS				
171,134		Cash at Banks		138,151		
147,424		Sundry Debtors	7	126,690		
318,558		Total Current Assets			264,841	
		CURRENT LIABILITIES				
24,244		Subscriptions in Advance		20,795		
39,599		Sundry Creditors	8	18,344		
63,843		Total Current Liabilities			39,139	
	254,715	NET CURRENT ASSETS				225,702
	709,639	TOTAL ASSETS				760,422
		Represented by:				
	667,511	GENERAL FUNDS				673,871
		DESIGNATED FUNDS	9			
4,656		Sylvester Bradley Fund			20,325	
23,064		Jones-Fenleigh Fund			22,805	
14,408		Hodson Fund			13,421	
0		Callomon Fund			10,000	
0		Whittington Fund			20,000	
	42,128					86,551
	709,639					760,422

Notes to the Financial Statements for the year ended 31st December 2010

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 March 2005 and cover all the charity's operations, all of which are continuing.

The effect of events relating to the year ended 2010 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 2010 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 Coumcil 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 meseum collections.

1.3 Incoming Resources

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

During the year the Association received bequests from two former members totalling £30,000.

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. In view of the low rates of interest on cash balances, Council allocated an additional sum of £50,000 to the investment portfolio.

2. Analysis of Financial Resources Expended

	Staff costs	Other costs	Total 2010	Total 2009
Generating Funds	15,652	8,222	23,874	20,441
Charitable activities	19,565	271,759	291,324	217,924
Governance	3,913	9,194	13,107	13,013
	39,130	289,175	328,305	251,378

3. Staff Costs

	Salary	National Insurance	Pension Contributions	Total 2010	Total 2009
Publications: 1 employee (2009 – 1)	29,425	0	4,687	34,112	32,795
Administration: 1 employee (2009 – 1)	31,305	3,303	4,522	39,130	36,775
	60,730	3,303	9,209	73,242	69,570

4. Trustees Remuneration and Expenses

Members of Council neither received nor waived any emoluments during the year (2009 – nil).

The total travelling expenses reimbursed to 12 Members of Council was £7,450 (2009 – £7,746).

5. Costs of Independent Examiner

	2010	2009
Examination of the accounts	400	400
Accountancy and payroll services	1,400	1,350
	1,800	1,750

6. Transfers between Funds

Council has transferred £30,000 from General Funds representing the sums received under the bequests to Callomon Fund £10,000 and Whittington Fund £20,000 (see note 1.2). In view of the cumulative deficit in the Sylvester-Bradley Fund, Council has transferred £20,000 from General Reserves into this fund in order that these grants may continue to be supported.

7. Debtors

	2010	2009
Accrued income – receivable within one year	126,690	147,424

8. Creditors – falling due within one year

	2010	2009
Social Services costs	3,182	3,172
Accrued expenditure	10,462	36,427
	13,644	39,599

9. Designated Funds

See next page.

THE PALAEONTOLOGICAL ASSOCIATION Registered Charity No 276369

STATEMENT OF FINANCIAL ACTIVITIES FOR THE YEAR ENDED 31st DECEMBER 2010

DESIGNATED FUNDS

Note 9 to the Accounts:

	Sylvester-Bradley	Jones-Fenleigh	Hodson	Callomon	Whittington	TOTAL 2010	TOTAL 2009
Donations	400	1,189	0	0	0	1,589	3,886
Interest Received	10	51	32	0	0	94	285
TOTAL INCOMING RESOURCES:	410	1,241	32	0	0	1,683	4,171
Grants made	4,742	1,500	1,019	0	0	7,261	8,154
NET SURPLUS / (DEFICIT):	-4,331	-259	-987	0	0	-5,577	-3,983
Transfers in	20,000	0	0	10,000	20,000	50,000	0
SURPLUS / (DEFICIT) FOR THE YEAR:	15,669	-259	-987	10,000	20,000	44,423	-3,983
FUNDS BROUGHT FORWARD:	4,656	23,064	14,408	0	0	42,128	46,111
FUNDS CARRIED FORWARD:	20,325	22,805	13,421	10,000	20,000	86,551	42,128

	Sylvester-Bradley	Jones-Fenleigh	Hodson	Callomon	Whittington	TOTAL 2010	TOTAL 2009

Independent Examiner's Report on the Accounts of The Palaeontological Association for the year ended 31st December 2010

Respective responsibilities of trustees and examiner

The charity's trustees consider that an audit is not required for this year (under section 43(2) of the Charities Act 1993 (the Act), as amended by s.28 of the Charities Act 2006) and that an independent examination is needed.

It is my responsibility to:

examine the accounts (under section 43 of the Act as amended)

follow the procedures laid down in the General Directions given by the Charity Commissioners (under section 43(7) of the Act as amended), and

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 I do not express an audit opinion on the accounts.

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 trustees have not met the requirements to ensure that:

- proper accounting records are kept (in accordance with section 41 of the Act) and
- accounts are prepared which agree with the accounting records and comply with the accounting requirements of the Act

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

Dated: 1st May 2011

G R Powell F.C.A.
Nether House, Great Bowden,
Market Harborough
Leicestershire LE16 7HF