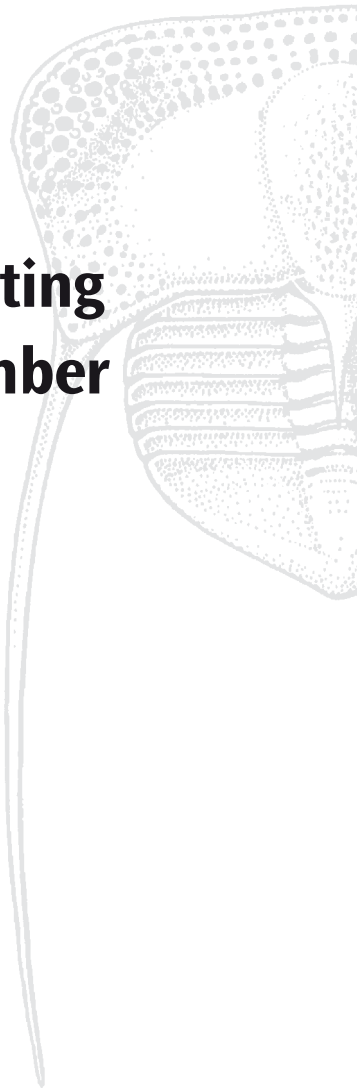
The Palaeontological Association

53rd Annual Meeting

13th–16th December 2009

University of Birmingham

ABSTRACTS



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13th–16th December 2009

School of Geography, Earth and Environmental Sciences, University of Birmingham

The programme and abstracts for the 53rd Annual Meeting of the Palaeontological Association are outlined after the following summary of the meeting.

Third circular and late registration

The third circular will be sent to delegates in mid-November. The deadline for late registration is Friday 20th November. Registration is via the Palaeontological Association website (<**http://www.palass.org/**>).

Venue

The meeting will take place in the Haworth large lecture room, Chemistry Building at the University of Birmingham on the main Edgbaston campus. Information on the University can be found at <**http://www.birmingham.ac.uk**>, and the lecture room is Y3 (Yellow 3) on the online map at <**http://www.about.bham.ac.uk/maps/edgbastonmap.shtml**>.

Accommodation

Please note that accommodation is not included in the online registration form and must be booked separately. We recommend that delegates stay in the city centre. The University is approximately three miles from the centre but connected to the city by a very frequent direct train service. Accommodation is also available in Edgbaston (Hagley Road area), though this is less convenient for travel to the University unless you have private transport. Rooms at a variety of prices can be reserved through the website set up specifically for the Annual Meeting at <**http://www.visitbirmingham.com/paam**>. For a fuller view of accommodation options, we have also placed suggestions under the accommodation and downloads tab on the Annual Meeting website that cover a broad range of prices from backpacker-type hostels to high-end hotels.

Travel

Birmingham is easily accessible from throughout the UK and very well served by trains into New Street (main station connecting to the airport and London Euston), Snow Hill and Moor Street (both connecting down to London Paddington via the Chiltern Line). Birmingham International Airport (code BHX) serves many different European and international destinations including direct flights from Newark (Continental Airlines) and Philadelphia (US Airways). Several flights a day shuttle to Frankfurt, Amsterdam and Paris. Birmingham is 1.30 hours from London Euston by train. If flying to Birmingham, we suggest routing through mainland Europe and into Birmingham rather than hitting London Heathrow direct; travel into Heathrow will involve either a three-hour National Express coach ride or transit via central London. If you intend travelling to the University by car, there are two main car parks: South Car Park and Pritchatts Road car park. Parking on campus is £1 per day and operates as pay and display. Anyone with a blue badge can park in the disabled car parking bays outside the University Centre (Building R23), Main Campus.

Registration at the conference

Registration will take place in the Chemistry Building outside the Haworth lecture room. The desk will be open from 10.00 to 17.00 on 13–15 December.

Symposium

The opening symposium, entitled "Macroecology in deep-time", will take place in the Haworth lecture theatre beginning at 2pm on 13th December. This will be followed by a reception at the Birmingham Museum and Art Galleries, Victoria Square, Birmingham city centre (very close to the Victoria Street exit from New Street rail station). This will commence at 7pm.

Oral and poster contributions

Oral presentations will take place in the Haworth lecture theatre; posters and coffee breaks will be taken in the Avon room which is across the road from the venue (Building R23). Posters will be available for viewing throughout the meeting. Details regarding the presentation of talks and posters will be sent to all contributors.

Annual address

The Annual Address will be given at 17.15 on Monday 14th December by Prof. Larry Witmer, on "Digital dinosaurs: Unlocking the riddles of the past using advanced 3D imaging".

Annual Dinner

The Annual Dinner will take place at 7pm in the Birmingham Botanical Gardens, 12A Westbourne Road, Edgbaston. Transport will be arranged to take participants to the venue and to drop participants back in the city centre.

Field excursion

The meeting will conclude on Wednesday 16th December with a **field excursion** to the south Cotswolds area to view (and collect) freshly quarried sections in the Oxford Clay. The trip will depart at 09.00 from outside the Lapworth Museum at the University of Birmingham on the Ring Road south (Red 4 on the online maps). Further information will be circulated to those opting for the trip in mid-November.

Acknowledgements

We would like to express our appreciation to the following for providing financial assistance towards this meeting: Wiley-Blackwell, and the Paleontological Institute University of Kansas.

Schedule of events and timetable for presentations

Sunday 13th December

Symposium

The meeting will take place in the Haworth lecture theatre at the University of Birmingham (Y3 on <**http://www.about.bham.ac.uk/maps/edgbastonmap.shtml**>) where registration will also take place, 10.00–17.00. Coffee breaks and posters will be in the Avon Room (R23).

The speakers and their topics at the half-day symposium "**Macroecology in deep-time**" on the afternoon of the 13th December will be:

13:50 **Introductory remarks**

14:00 **Palaeobiological macroecology at the species level**
Andy Purvis*, Paul N. Pearson, Tracy Aze and Thomas H. G. Ezard

14:30 **Geographic, environmental, and intrinsic biotic controls on Phanerozoic marine Diversification**
John Alroy

15:00 **Additive diversity partitioning in palaeobiology: revisiting Sepkoski's question**
Steven M. Holland

15:30 Coffee

16:00 **Origins of marine patterns of biodiversity: correlates and applications**
James W. Valentine* and David Jablonski

16:30 **Competitive Accommodation and the Response of Ecological Community Structure to Environmental Perturbation**
Thomas D. Olszewski* and Leigh M. Fall

17:00 **Cope's Rule, Climate Change, and Body Size Evolution in Deep-sea Ostracodes**
Gene Hunt*, Satrio Wicaksono and Julia Brown

19:00 Reception at the Birmingham Museum and Art Gallery, Victoria Square, Birmingham.

* Presenter.

Monday 14th December

Oral presentations

The meeting will take place in the Haworth lecture theatre at The University of Birmingham (Y3 on <**http://www.about.bham.ac.uk/maps/edgbastonmap.shtml**>) where registration will also take place, 10.00–17.00. Coffee breaks and posters will be in the Avon Room (R23).

* indicates the presenter.

Session 1

9:00 **What lived on the land before the land plants?**
Charles H. Wellman* and Paul K. Strother

9:15 **Biomarkers and biomats. Interpreting Proterozoic molecular fossils**
Maria M. Pawlowska

9:30 **Why do Ecosystems Collapse? Evidence from Complexity Theory and Foraminiferid Architecture**
Jonathan B. Antcliffe* and Martin D. Brasier

9:45 **Earliest evidence for metazoan-style locomotion in the fossil record: trace fossils from the ~565Ma Mistaken Point Formation, Newfoundland**
Alexander G. Liu*, Duncan McIlroy and Martin D. Brasier

10:00 **Modelling the Dynamics of Ediacaran Communities**
Emily G. Mitchell*, Nicholas J. Butterfield and Anje-Margriet Neutel

10:15 **The Impact of the Earliest Land Plants on the Evolution of Cambrian to Devonian Alluvial Environments**
Neil S. Davies* and Martin R. Gibling

10:30 Coffee and Posters

Session 2

11:00 **Key Contributions of Inter-Group Variation to Macroevolutionary Inference**
Thomas H. G. Ezard*, Tracy Aze, Paul N. Pearson and Andy Purvis

11:15 **Co-evolution in deep time: using Geographical Information Systems (GIS) to test Cretaceous dinosaur-plant associations**
Paul M. Barrett*, Richard J. Butler, Paul Kenrick and Malcolm Penn

11:30 **Return to the light: Evolution of photosymbiosis after the end Cretaceous mass extinction**
Heather Birch*, Helen Coxall, Paul Pearson and Daniella Schmidt

11:45 **The Devonian nekton revolution**
Christian Klug*, Björn Kröger, Wolfgang Kiessling, Gary L. Mullins, Thomas Servais, Jiří Frýda, Dieter Korn, and Sue Turner

12:00 **The initial rise of pelagic cephalopods and the emergence of a complex pelagic food chain during the earliest Ordovician**
Björn Kröger* and Thomas Servais

12:15 **A Late Cretaceous rocky shore ecosystem, Ivö, Sweden**
Anne Mehlin Sørensen* and Finn Surlyk

12:30 Lunch

Session 3

13:30 **Biomolecular evidence of methanogenesis in ancient herbivores**
Fiona Gill*, Rich Pancost, Richard Dewhurst and Ian Bull

13:45 **Experimental insights into carbon isotope fractionation under Phanerozoic conditions using the model plant *Arabidopsis thaliana***
Barry H. Lomax*, Christopher P. T. Peters and Janice A. Lake

14:00 **Preservation of Silurian and Devonian early vertebrate microfossils: stable isotope and elemental geochemistry**
Živilė Žigaitė*, Alberto Pérez-Huerta and Michalel M. Joachimski

14:15 **Conodonts as palaeothermometers for ancient oceans?**
James R. Wheeley*, Paul Smith and Ian Boomer

14:30 **Tooth wear and damage in conodonts: a new tool for testing hypotheses of ecology and function**
David Jones* and Mark A. Purnell

14:45 **A functional investigation into the dietary ecology of two of the earliest stem mammals, *Morganucodon watsoni* and *Kuehneotherium praecursoris***
Emily J. Rayfield*, Pamela G. Gill, Mark A. Purnell, Kate A. Robson Brown and Neil J. Gostling

15:00 Coffee and Posters

Session 4

15:30 **Putting Humpty together again: reconstructing the *Bilignea* plant**
Leyla J. Seyfullah*, Richard Bateman and Jason Hilton

15:45 **Virtual Carboniferous 'Cockroaches'**
Russell J. Garwood* and Mark D. Sutton

16:00 **Anatomically preserved seeds from the Oxford Clay: has the living fossil *Ginkgo* changed in 150 million years?**
Andrew R. Rees*, Jason Hilton, Paul Kenrick, Mark D. Sutton

16:15 **A Silurian soft-bodied lophophorate**
Mark D. Sutton*, Derek E. G. Briggs, David J. Siveter and Derek J. Siveter

16:45 Annual General Meeting (see pages 79–88)

17:15 Annual Address:
Digital dinosaurs: Unlocking the riddles of the past using advanced 3D imaging
Lawrence M. Witmer

19:00 Annual dinner in the Birmingham Botanical Gardens

Tuesday 15th December

Session 5

9:00 **Experimental decay of lampreys and hagfish provides taphonomic constraints on jawless vertebrate evolution**
Robert S. Sansom*, Sarah E. Gabbott and Mark A. Purnell

9:15 **No bones about it: Skeletal histology suggests *Palaeospondylus gunni* (Devonian) is an osteichthyan vertebrate**
Zerina Johanson*, Anton Kearsley, Jan den Blaauwen, Michael Newman and Moya Meredith Smith

9:30 **The interrelationships of hagfishes, lampreys and gnathostomes, and the nature of the ancestral vertebrate**
Alysha M. Heimberg, Philip C. J. Donoghue, and Kevin J. Peterson*

9:45 **About the ears: *Acanthodes* re-examined and gnathostome origin re-analyzed**
Samuel P. Davis and Michael I. Coates*

10:00 **Integrating molecular and palaeontological approaches to telling evolutionary time**
James E. Tarver*, Alistair J. McGowan, Ziheng Yang and Philip C. J. Donoghue

.10:15 **Plant palaeogenomics: inferring ancestral genome sizes through comparison of cell sizes in living and fossil seed plants**
Richard Bateman*, Jason Hilton, Charley Knight, Ilia Leitch, Barry Lomax and Paula Rudall

10:30 Coffee and Posters

Session 6

11:00 **Calcitic composition of *Protospongia* spicules and the evolution of Cambrian sponges**
Alex Page*, Nicholas J. Butterfield and Thomas H. P. Harvey

11:15 **Bristling beginnings: Molecular palaeobiological perspectives on annelid evolution**
Jakob Vinther

11:30 **Ontogeny and phylogeny of Early Cambrian stem Rhynchonelliform brachiopods**
Lars E. Holmer*, Christian B. Skovsted, Sandra Pettersson Stolk, Glenn A. Brock[2] and Leonid Popov

11:45 **Soft part relicts in *Metaconularia manni* substantiate the phylogenetic association of Conulariida with scyphozoan-like cnidarians**
Nigel C. Hughes*, Douglas John, Heyo Van Iten and Matthew Colbert

12:00 **Absence of echinoderms in the Chengjiang Lagerstätte, China: a case study of benthic ecosystem differentiation during early Cambrian times**
Sébastien Clausen*, Xian-Guang Hou, Jan Bergström, Christina Franzén and Artem Kouchinsky

12:15 **Morphology of Lower Cambrian lobopodian eyes and their evolutionary significance**
Xiaoya Ma

12:30 Lunch

Session 7

13:30 **Getting beneath the skin of fossil holothurians**
Andrew B. Smith* and Mike Reich

13:45 **A history of trilobite body size evolution: environmental controls and the Lilliput effect**
Mark A. Bell*, Simon J. Braddy and Richard A. Fortey

14:00 **Silurian trilobite diversity**
Andrew J. Storey* and Alan T. Thomas

14:15 **Was coccolith evolution in the Quaternary exceptionally rapid?**
Jeremy R. Young*, Craig Koch and Lee Toms

14:30 **The fossil pollen record as a tool for studying spatial heterogeneity in extinct plant assemblages**
Phil Jardine* and Guy Harrington

14:45 **Latitudinal selectivity of foraminifer extinctions during the late Guadalupian crisis**
David P. G. Bond* and Paul B. Wignall

15:00 **Recovery after Triassic–Jurassic mass extinction (Tr-J): An evaluation of the richness, composition, and ecological traits in the marine fauna**
Luis-Felipe Opazo* and Richard J. Twitchett

15:15 **Closing Romer's Gap: new tetrapods and arthropods from the basal Carboniferous of the Scottish Borders**
Tim Smithson* and Stan Wood

15:30 Coffee and Posters

Session 8

16:00 **A mollusc for all seasons: high fidelity climate records of the Weddell Sea during a warm interval of the Early Pliocene**
Mark Williams*, Anna E. Nelson, John L. Smellie, Melanie J. Leng, Daniel R. Jarram, Andrew L.A. Johnson, Alan M. Haywood, Victoria L. Peck, Jan Zalasiewicz, Carys Bennett and Bernd R. Schöne

16:15 **Fossil floras of the British Tertiary Volcanic Province: Deciphering floral diversity and climate**
Jon Poulter*, Jane Francis, Marge Wilson and Yves Candela

16:30 **Experimental taphonomy of *Artemia*: analysing the role of microbial activity**
Aodhán D. Butler*, Philip C. J. Donoghue and John A. Cunningham

16:45 **Return to the Sirius Pass: An unusual taphonomic window on the Cambrian Explosion**
David A. T. Harper*, Arne T. Nielsen, M. Paul Smith and Jakob Vinther

17:00 **Instant fossilization! Just add hot water**
Crispin T. S. Little

17:15 **Is there a rock-bias to diversity patterns in the deep sea?**
Graeme T. Lloyd*, Andrew B. Smith and Jeremy R. Young

Abstract of Annual Address

Digital dinosaurs: Unlocking the riddles of the past using advanced 3D imaging

Lawrence M. Witmer
Professor of Anatomy and Chang Professor of Paleontology,
Department of Biomedical Sciences, Ohio University College of Osteopathic Medicine, Athens, Ohio, 45701 USA
<witmerL@ohio.edu>

The fossil remains of ancient organisms exist in the physical realm. In the past couple of decades, however, palaeontology has made the jump into the digital or virtual realm. Using techniques such as CT scanning, laser scanning, and other imaging modalities, the morphological structure of fossils can now be mapped into 3D coordinate space for analysis in a computer environment.

This 3D revolution, still in its infancy, is transforming the discipline of palaeontology. Early on, the goal was simply to peer through the encasing rock matrix. Today, that goal has been expanded to include the digital extraction and 3D visualization of not just the hard parts, but also of reconstructed soft-tissue structures of extinct animals.

Research in our lab has been directed toward the evolution of anatomical systems in the heads of archosaurs, the clade that includes birds and crocodilians today and such marquee extinct taxa as nonavian dinosaurs and pterosaurs. Although fossil specimens, of course, remain a central focus, biological interpretation of extinct organisms requires direct reference to their extant relatives for information on such unpreserved attributes as soft-tissue anatomy, physiology, and behaviour. Evaluated in a phylogenetic context, these data allow biological hypotheses about extinct taxa to be adequately tested.

Recently, our team has been using CT scanning, 3D modeling, and, in the extant realm, anatomical dissection to track the evolution of the brain, inner ear, blood vessels, muscles, air spaces, and other structures in the heads of dinosaurs and their kin to test hypotheses on sensory biology and behaviour. Although the brain's neurons have long since degraded, the contours of the brain reflect different levels of cognitive and sensory abilities and emphases (*e.g.*, the relative importance of vision or smell) in different dinosaur groups.

Likewise, the structure of the delicate inner ear provides key information on not only the relative importance of hearing, but also the sense of balance; perhaps surprisingly, the inner ear also sheds light on the visual system and the 'alert' posture of the head, which may relate to the evolution of feeding behaviours in different clades of dinosaurs.

Reconstruction of the air spaces provides new information on physiological functions and behaviours, potentially relating to metabolic physiology and communication, respectively. Again, this kind of research is still in its early stages, but clearly the future is bright for the generation of testable and informative 3D models of the anatomical and functional organization of extinct organisms.

Abstracts of symposium presentations

Geographic, environmental, and intrinsic biotic controls on Phanerozoic marine diversification

John Alroy

The Paleobiology Database, University of California, Santa Barbara, USA

The Paleobiology Database now includes enough occurrences of taxa within distinct fossil collections to produce useful time series of geographic and environmental variables in addition to a robust global Phanerozoic marine diversity curve. The curve is produced by a new 'shareholder quorum' sampling standardisation method that removes biases but avoids overcompensating for them by imposing entirely uniform data quotas. It involves drawing fossil collections until the taxa that have been sampled at least once (the 'shareholders') have a summed total of frequencies (*i.e.*, coverage) that meets a target (the 'quorum'). Each taxon's occurrence count is decreased by one prior to computing frequencies, which causes estimated total coverage and therefore required sampling intensity to vary amongst time intervals. Analyses focus on a global diversity curve and a 'tropical' curve for collections below 30° N or S palaeolatitude. Multiple regression is used to explain changes in diversity as a function of standing diversity; the number, spacing, and palaeolatitudinal position of sampled geographic cells; the mean onshore-offshore position of cells; and proportions of cells from carbonate, onshore, or reefal environments. The key factors are standing diversity, which modulates diversification to produce logistic growth, and the proportion of reefal environments, which superimposes exponential but changing trends on the logistic pattern. The end-Ordovician, Permo–Triassic and Cretaceous–Palaeogene mass extinctions have relatively short-term effects, but reef collapse explains large global diversity decreases in the mid-Devonian and across the Triassic–Jurassic boundary. Conversely, the expansion of reef ecosystems may explain newly recognised major radiations in the mid-Permian and mid-Jurassic.

Additive diversity partitioning in palaeobiology: revisiting Sepkoski's question

Steven M. Holland

Department of Geology, University of Georgia, USA

Using Whittaker's concepts of alpha, beta and gamma diversity, Sepkoski (1988) asked how global diversity was assembled at various scales from the community, to onshore-offshore gradients, to provinces. In the years since then, ecologists have recast diversity in terms of additive partitions where total diversity can be decomposed into sample-level alpha diversity plus the sum of a series of beta diversity terms that reflect progressively larger spatial scales. Given that marine alpha diversity represents a tiny fraction of global diversity, Phanerozoic global diversity patterns must be dominated by changes in beta diversity at one or more scales. A currently ballooning ecological literature demonstrates exceptional heterogeneity in the size of beta diversity at a variety of scales among ecosystems, regions and taxa, suggesting that large changes in beta diversity on evolutionary time scales are likely. But the question is, which scales are the most

important? Several recent palaeontological studies help to constrain beta diversity within sedimentary basins, and the emergence of sample-based databases puts an answer to Sepkoski's question within reach.

Cope's Rule, Climate Change, and Body Size Evolution in Deep-sea Ostracodes

Gene Hunt [1], Satrio Wicaksono [2] and Julia Brown [3]

[1]*Department of Paleobiology, National Museum of Natural History, Smithsonian Institution USA*

[2]*Wesleyan University, USA*

[3]*Department of Ecology and Evolutionary Biology, Yale University, USA*

One main goal of macroecological research is to understand the factors that determine body sizes of organisms. Here we investigate body sizes of deep-sea ostracodes at one site in the Indian Ocean (DSDP 253, 1,962m water depth) over the past 40 million years. We tracked size (measured as projected valve area) in all well-represented species-level lineages and compared this body size record to proxies for deep-sea temperature over this interval. We used statistical models of trait evolution to test the support for non-directional (random walk), directional (Cope's Rule) and temperature-tracking modes of evolutionary change. We found that most lineages show irregular, but net increases in body size, and that these increases occur more often during intervals of net cooling of the deep ocean. These findings demonstrate that secular trends of increasing size can result from directional changes in environmental conditions, and therefore need not reflect intrinsic, context-independent advantages that are frequently invoked to explain Cope's Rule.

Competitive Accommodation and the Response of Ecological Community Structure to Environmental Perturbation

Thomas D. Olszewski and Leigh M. Fall

Department of Geology and Geophysics, Texas A&M University, College Station, TX, USA

The composition and diversity of ecological communities under particular environmental conditions reflects a dynamic balance between processes that lead to the maintenance and addition of species (*e.g.*, immigration, environmental partitioning, speciation) and processes that lead to the exclusion of species. Competition is generally regarded as one of the processes thought to drive down richness because species that are too similar in their resource requirements and modes of life cannot coexist indefinitely. However, recent theory suggests that ecological communities with a high diversity of very similar species can develop a dynamic of competitive accommodation. Although such a state is transient, it can allow a large number of species to coexist for millions of generations – a duration comparable to the stratigraphic duration of fossil species. Communities showing accommodation dynamics display quite stable population sizes and are resistant to invasion, but they are very sensitive to externally imposed perturbations. When perturbed, communities become open to new species before rapidly returning to an accommodated state in which species abundances can be entirely reordered relative to the pre-perturbation state. Disruption of accommodated regional-scale communities may provide an explanation for patterns of long-term ecological stability punctuated by sudden reorganization observed in the fossil record.

High-diversity Middle Permian brachiopod communities from the Guadalupe Mountains of west Texas provide an example of punctuated ecological change and a potential opportunity to test for the influence of accommodation dynamics. Multivariate analyses of collections from the Bell Canyon Member suggest a compositional break between its lower members (Pinery and Rader) and upper members (Lamar and Reef Trail). Communities from all units share a core of common taxa, but the Lamar includes genera that are otherwise limited to units below or above it as well as several new taxa. In addition, the Lamar's rank occurrence distribution is significantly different than that of the other intervals, suggesting a distinct ecological dynamic. We propose that the Lamar records communities that had not yet reached a stable accommodated state immediately following a basin-scale sea level perturbation. This can explain the presence of invaders and new taxa in the Lamar despite its higher diversity. The return to a pre-Lamar community structure with different taxonomic composition after the Lamar suggests re-establishment of accommodated dynamics.

Palaeobiological macroecology at the species level

Andy Purvis [1], Paul N. Pearson [2], Tracy Aze [2] and Thomas H. G. Ezard [1]

[1]Division of Biology, Imperial College London, UK

[2]School of Earth and Ocean Sciences, Cardiff University, UK

Macroecology takes a broad-scale and generally top-down approach to the ecology of complex systems. It has increasingly considered historical explanations for present-day patterns, thus converging with the longstanding palaeobiological research agenda into macroevolution. However, truly integrated research is less common than this confluence of interests would suggest. One simple but central reason is that researchers in the different communities think of species differently, even if they espouse similar species concepts. We explore how these differences feed through into a range of analyses, and show how they can be reconciled with a sufficiently complete fossil record. The Cenozoic macroperforate planktonic foraminifera have probably the best record of any group, permitting unusually detailed analyses of anagenesis and cladogenesis. We present a lineage phylogeny for the whole clade which forms the basis for an analysis of how macroecology feeds into macroevolutionary dynamics. Such species-level, phylogenetic approaches have the potential to discriminate between scenarios that are otherwise hard to separate.

Origins of Marine Patterns of Biodiversity: Some Correlates and Applications

James W. Valentine [1] and David Jablonski [2]

[1]Museum of Paleontology, University of California, Berkeley

[2]Department of Geophysical Science, University of Chicago

Marine shelf diversity patterns correlate with macroecological features of basic importance that may play causal roles in macroevolution. We have investigated the global diversity pattern of Bivalvia, which is dominated by the latitudinal diversity gradient (LDG), maintained by high tropical origination rates. Generic-level lineages are exported to poleward, chiefly through speciation, so that species richness within provinces and globally is positively correlated with generic geographic ranges. A gradient in diversity accommodation progressively lowers both immigration and speciation in higher latitudes.

The LDG correlates with seasonality of trophic resources but not with area; tropical provinces are diverse, not because they are large, but because they are tropical. A similar explanation evidently applies to Jurassic and Carboniferous LDGs. Larval developmental modes correlate with the LDG and thus with resource seasonality, with tropical dominance of planktotrophs grading to nonplanktotroph dominance to poleward. The independent aquisition of planktotrophy in several early Palaeozoic clades indicates a change in macroecological relationships during the bilaterian radiations, and suggests a tie to the evolution of developmental gene networks, a relationship that should be explored during the early evolution of metazoan clades, with their distinctive patterns of early embryogenesis.

Abstracts of oral presentations

Why do Ecosystems Collapse? Evidence from Complexity Theory and Foraminiferid Architecture

Jonathan B. Antcliffe and Martin D. Brasier

Department of Earth Sciences, University of Oxford, Parks Road, Oxford, UK

Searching for causal factors in major events of Earth history is one of the primary goals in the natural sciences. Mass extinctions, for example, are currently explained by a variety of mechanisms including famously bolide impacts. But why do the largest triggers not regularly correlate with mass extinctions? Here we show that mass extinctions are determined by existing ecological conditions within the biosphere. Therefore the ecological responses in palaeontological consequences vastly outweigh the nature and size of various "triggers." An ecosystem model based on the neural network algorithms of complexity theory is used to demonstrate how connections of energy and matter flow between organisms to determine ecosystem stability. This shows how the biosphere has repeatedly evolved towards instability and extinction before reconstructing and stabilising. These cycles can be exemplified using a parsimony index (PI) demonstrating how the degree of ecosystem integration and stability can be proxied using foraminiferid test architecture. This independently provides evidence for major collapse of ecosystems on at least ten occasions during the last 540 million years. In this view, mass extinction is seen as the breakdown of ecosystem connections and not just the result of triggers external to the biosphere.

Co-evolution in deep time: using Geographical Information Systems (GIS) to test Cretaceous dinosaur-plant associations

Paul M. Barrett [1], Richard J. Butler [2], Paul Kenrick [1] and Malcolm Penn [3]

[1]*Department of Palaeontology, Natural History Museum, London, UK*

[2]*Bayerische Staatssammlung für Paläontologie und Geology, Munich, Germany*

[3]*Department of Botany, Natural History Museum, London, UK*

Field and laboratory-based experiments demonstrate that co-evolutionary interactions play a major role in the promotion and maintenance of modern biodiversity. The prevalence of such interactions in extant biomes has led to the suggestion that similar processes may have had major impacts on macroevolutionary events occurring over extended geological timescales (*e.g.* 'escalation', as posited to occur between predators and prey). Several authors have proposed that reciprocal interactions between Cretaceous dinosaurs and plants were important in shaping the evolutionary histories of both groups: for example, the origin and radiation of angiosperms has been linked to the rise of various ornithischian dinosaurs, whereas the decline of cycads has been associated with a decrease in sauropod diversity. Here, we use palaeobiodiversity estimations and a quadrat-based sampling approach (conducted within a GIS) to compare the spatiotemporal distributions of Cretaceous dinosaur and plant clades to determine if correlated changes occurred in the distributions and species-richness of each group. Statistical analysis of these data identifies few significant correlations between specific plant and dinosaur groups in multiple time slices, suggesting that co-evolutionary interactions were unlikely. GIS-based spatial analysis represents a useful set of tools for testing deep-time macroevolutionary and macroecological scenarios, enabling rapid handling of large datasets.

Plant palaeogenomics: inferring ancestral genome sizes through comparison of cell sizes in living and fossil seed plants

Richard Bateman [1,2], Jason Hilton [1], Charley Knight [3], Ilia Leitch [2], Barry Lomax [4], and Paula Rudall [2]

[1]*School of Geography, Earth & Environmental Sciences, University of Birmingham, Birmingham, UK*

[2]*Jodrell Laboratory, Royal Botanic Gardens Kew, Richmond, Surrey, UK*

[3]*Biological Sciences Department, California Polytechnic State University, San Luis Obispo, CA, USA*

[4]*Department of Animal and Plant Sciences, University of Sheffield, Sheffield, UK*

Over the last 15 years much information has accumulated on the density and size of stomata (breathing pores) in leaves of well-preserved fossil plants, primarily to use them as proxies for changes in atmospheric composition through the last 420 my. Complementary studies have recorded these properties in living plants under variable growth conditions, providing an interpretative framework for the fossil data. Recent work has demonstrated strong positive correlations (r^2 = *ca* 0.52–0.55) between size of both stomatal guard cells and less differentiated epidermal cells versus genome size in extant seed plants (angiosperms plus gymnosperms). This insight offers the possibility (various complicating factors permitting) of estimating genome size in fossil plants by extrapolation from their epidermal cell dimensions. Estimated genome sizes constitute a novel dataset for addressing the ongoing conundrum of high-level relationships among seed plants. Duplication events that double genome size have been implicated in the origin and diversification of the angiosperms, yet basally divergent extant angiosperms have small genome sizes compared with extant gymnosperms. Determining genome size in extinct gymnospermous groups could narrow the currently wide range of potential angiosperm ancestors, also revealing correlations with morphological diversification, molecular divergence, mass extinctions, climatic shifts and/or ecological preferences of major clades.

A history of trilobite body size evolution: environmental controls and the Lilliput effect

Mark A. Bell [1,2], Simon J. Braddy [1] and Richard A. Fortey [2]

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

[2]*Department of Palaeontology, Natural History Museum, London, UK*

As one of the most diverse fossil groups, trilobites provide excellent candidates for macroevolutionary investigations. Despite an average length of 100 mm, individuals or entire populations are known to have well exceeded this length. The distribution of body-size evolution within the group was studied through the construction of a database of measurements from 13,000 individuals, designed to cover the taxonomic, temporal and geographic range of the class.

Trilobite body-size increases rapidly in the Cambrian and Ordovician followed by a decreasing trend through to the end-Permian, interrupted by a peak in the Middle Devonian. Databases of diversity and environmental proxies are used to correlate body size against environmental and ecological fluctuations. Rank correlations show strong positive relationships with diversity and temperature, and negative relationships with weathering rates and productivity. The support of these trends is discussed though the use of several resampling techniques.

Finally, the effect on body-size from the Ordovician extinctions is shown. The Lilliput effect, down-sizing of faunas across extinction events, is recognised across the Hirnantian/Rhuddinian but not the Rawtheyan/Hirnantian extinctions; possible causes are discussed. By comparing victim and survivor species of the Rawtheyan/Hirnantian extinction there is some evidence for size-selectivity against smaller forms.

Return to the light: Evolution of photosymbiosis after the end-Cretaceous mass extinction

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The end-Cretaceous mass extinction seriously affected the marine ecosystem. Surface to deep-ocean carbon isotope gradients and carbonate accumulation records suggest that the extinction coincided with a crash in organic matter flux to the sea floor and was followed by a long (3Myr) delay in recovery. This critical interval in Earth's history is crucial for understanding how the marine ecosystem reacts to major perturbations. Much work on palaeoceanography and palaeoecology is dependent on stable isotopes of planktonic foraminifera, but the foraminifera themselves were profoundly affected by the extinction as they re-diversified. Understanding the effects of changing ecology and depth habitats on the isotopic composition of their tests is crucial for disentangling the effects of changing ecology.

Here we present new multispecies foraminiferal stable isotope data and planktic shell size distributions from a new, well-dated and continuous Atlantic deep sea core. The data document the evolution and diversification of photosymbiosis in Palaeocene planktonic species three million years after the end-Cretaceous extinction when the pelagic carbon system finally recovered. The data show that the geochemical signature of photosymbiosis evolved in an initially thermocline-dwelling species, *Preamurica pseudoinconstans,* that started stepped migration to shallower photic levels during later life stages.

Latitudinal selectivity of foraminifer extinctions during the late Guadalupian crisis

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A database of Middle–Upper Permian foraminiferal genera has been compiled from the literature for 75 Guadalupian and 62 Lopingian localities. Cluster analysis reveals that five Guadalupian faunal provinces were reduced to four in the Lopingian, following the disappearance of the Eastern Panthalassa Province. Extinction magnitudes across the Guadalupian/Lopingian boundary reveal strong regional variation to losses at low palaeolatitudes. Central and Western Tethys experienced markedly lower provincial and global extinction magnitudes than Eastern and Northern Tethys. Panthalassa experienced high extinctions amongst endemics, but a global extinction magnitude similar to Central and Western Tethys. This regional bias is seen in the fusulinacean and non-fusulinacean foraminifera, although fusulinaceans suffered much higher extinction magnitudes. This regional selectivity persisted during Lopingian radiations. Thus, of 35 new genera recorded from the Lopingian, 27 are recorded in Central and Western Tethys, compared to five and

12 genera respectively in Panthalassa and in Eastern and Northern Tethys. The Emeishan igneous province erupted within Eastern and Northern Tethys and may have influenced the high extinction–low radiation regime of this region. Regression (and shallow-marine habitat loss) may have been a significant factor, because a major late Guadalupian regression is best recorded in areas that suffered the greatest extinctions.

Experimental taphonomy of *Artemia*: analysing the role of microbial activity

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Taphonomy, the study of decay and fossilisation, has been transformed into an experimental science over the past two decades. This work has focused most especially on the mineralisation of soft-tissues, providing novel insights in the interpretation of fossil remains. However, the process of fossilisation – the mineral replication of tissue – tells us nothing about the transformation of the organic substrate on which mineralisation occurs. It is this step which is most crucial to correctly interpreting the anatomy of exceptionally preserved fossil organisms and thus fully realising their evolutionary significance.

Determination of the processes behind this initial stage of organic transformation through experimental simulations of decay was our primary aim, in particular investigating the role of microbial activity. Replication of plant and animal tissues by microbes is well documented in the fossil record but has only recently become the subject of experimental investigation.

Controlled experiments tested inhibition of decay processes, providing further insight into the fossilisation process. Decay trajectories were distinctly altered under experimental controls in addition to production of distinct decay-induced microbial pseudomorph fabrics. Elemental analyses indicate the co-localisation of biofilm and mineral precipitation within decaying organisms. Microbial processes not only mediate, but dominate this early stage of decay. Understanding the formation and subsequent mineralisation of these decay fabrics informs interpretations of soft-tissue preservation in light of taphonomic bias.

Absence of echinoderms in the Chengjiang Lagerstätte, China: a case study of benthic ecosystem differentiation during early Cambrian times

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The Neoproterozoic–Cambrian transition does not only represent a period of taxonomic biodiversification (the so-called 'Cambrian explosion') but also an interval of ecosystem differentiation, during which biotic and abiotic factors were involved in a complex and still poorly understood feedback process. As other benthic sessile or vagile organisms, one of the abiotic factors generally considered to have controlled the evolution of echinoderms is

substrate availability. However, the capacity of their skeleton to disarticulate rapidly, which tended to enlarge during Cambro–Ordovician times, has also been suggested to favour the development of hard-grounds at the end of this time span (positive feedback between extrinsic and intrinsic factors). Therefore, the echinoderms represent a good proxy of ecosystem differentiation during early Cambrian times. Chengjiang fossils first described as echinoderms – *Cambrofengia yunnanensis* Hou *et al*., 1999, *Cotyledion tylodes* Luo and Hu, 1999 and two vetulocystids (*Dianchicystis jianshanensis* and *Vetulocystis catenata* Shu *et al*., 2004) – are here critically reviewed. Particular attention is given to *Cotyledion*, which, based on newly sampled specimens, is tentatively assigned to the cnidarians. This review emphasizes how different phylogenetic conceptions can influence the interpretation of primitive metazoans and, as a direct consequence, their ecological radiation. We suggest that the so-called Chengjiang Biota, one of the most diverse earliest Cambrian communities, was most probably devoid of echinoderms. This is not interpreted as a taphonomic artefact but as a clue of palaeoecological radiation of echinoderm and early benthic ecosystems differentiation during Neoproterozoic–Cambrian times. The repartition of echinoderms throughout the Yangtze platform argues for a proximal radiation of echinoderms during the early Cambrian in carbonate substrates, subsequently followed by a later colonization of siliciclastic, proximal and distal environments. A similar colonization trend is generally observed at a global scale, even if observed timing can vary locally, most probably depending on local palaeogeographical controls.

talks

The Impact of the Earliest Land Plants on the Evolution of Cambrian to Devonian Alluvial Environments

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A comprehensive review of 144 Cambrian to Devonian alluvial successions documented in published literature was combined with original field data from 34 alluvial successions across Europe and North America. The study was designed to identify changes in alluvial environments during the period that vegetation was evolving and first colonizing them. An increase in mudrock proportion and sandstone maturity is apparent, along with a decrease in overall sand grain size through the Early Palaeozoic. These trends suggest that primitive vegetation cover promoted the production and preservation of muds from the mid Ordovician onwards and increased the residence time of sand-grade sediment in alluvial systems. The compilation also enabled the first stratigraphic occurrence of certain vegetation-dependent sedimentary features, such as pedogenic calcite, charcoal, coal and lateral accretion sets, to be pinpointed and related to the evolution of specific palaeobotanical adaptations. The analysis suggests that the evolution of vascular plants had a profound effect on alluvial processes, deposits, and environments, and must be considered amongst the most significant environmental and geomorphological changes in Earth history, with profound consequences for all aspects of the Earth system.

About the ears: *Acanthodes* re-examined and gnathostome origin re-analyzed

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Discoveries of Devonian and Silurian osteichthyans and chondrichthyans have refocused attention on the base of the gnathostome crown, and the memberships of their respective

crown groups. *Acanthodes bronni* from the Lower Permian of Germany has been re-examined because conditions in this exceptionally well-preserved taxon influence early gnathostome tree topologies. New silicone rubber peels of *Acanthodes* expose existing reconstructions as incomplete and inaccurate. The skeletal anatomy is unexpectedly shark-like. The braincase roof has a central ridge and endolymphatic fossa; otic capsule and semicircular canal arrangement resemble *Cladodoides*; the upper jaw articulates with the postorbital process; the hyomandibula with the otic capsule rear; cranial nerve exits display further shark-like characteristics. These discoveries beg the question of whether *Acanthodes* is a stem-chondrichthyan. The answer: probably not. The take-home message is that these data deliver a new hypothesis of anatomical conditions close to the gnathostome crown-node, polarizing characters for osteichthyans as well as chondrichthyans and providing new data for exploring paraphyly in placoderms and acanthodians. These data also highlight the degree to which the general pattern of crown-gnathostome crania, *i.e.* post-placoderm and osteostracan conditions, results from transformed relations of soft and hard tissue structures about the otic capsules.

Key Contributions of Inter-Group Variation to Macroevolutionary Inference

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Understanding how biodiversity has arisen is a fundamental challenge for evolutionary biology. Addressing it requires understanding of how speciation, extinction and character change interrelate. Approaches based purely on extant diversity attempt to reconstruct the past using only modern groups and therefore neglect extinctions in deep time. If the fossil record is sufficiently complete, palaeontological approaches can provide insight into the fall and rise of clades, elucidating processes that phylogenetic reconstructions can only imply. Using our recently-compiled phylogeny of all Cenozoic macroperforate planktonic foraminifera, we will show (1) how overall diversity fluctuates due to interactions among abiotic and biotic processes and (2) that the importance of morphogroups exhibiting key innovations within the whole phylogeny waxes and wanes. In other words, parts of the tree are 'hot' whilst others are 'not'. Furthermore, 'hotness' – the influence of particular morphogroups on overall structure – is not static: it fluctuates with changing ecological conditions, abrupt examples of which include the Eocene–Oligocene transition and the radiation of distinctive morphogroups, such as tubulospinose hantkeninids. Here, we explore how considering such inter-group variation may give a clearer picture of diversification and adaptive radiation than can be had by analysing the clade as a homogeneous whole.

Virtual Carboniferous 'Cockroaches'

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Three-dimensionally preserved, siderite-hosted fossils provide many insights into Carboniferous life. Despite their relative abundance, the study of such fossils has been limited by difficulties in recovering data from within nodules; high-resolution x-ray microtomography (XMT) and 'virtual fossil' reconstruction techniques provide a solution

which can be applied to many Carboniferous plant and animal groups. One such group is the 'roachoid' insects, which represent stem-dictyopterans (the Dictyoptera includes cockroaches, termites and mantises). While abundant, this fossil group is paraphyletic and its phylogeny is poorly understood; the relationship of many fossils to crown-Dictyoptera remains unresolved. Several siderite-hosted archimylacrid 'roachoids' from the Upper Carboniferous Coseley Lagerstätte have been reconstructed to reveal new anatomical detail. Low-angle virtual lighting was used to image the taxonomically important wing veination, while limbs, antennae, mandibles and body were resolved in their entirety for the first time in a Palaeozoic dictyopteran, providing palaeobiological insights. Our preliminary study demonstrates that XMT-based reconstructions are a powerful tool for the study of these 'difficult' fossils. They have the potential to provide new characters to supplement wing veination in the study of 'roachoid' taxonomy and phylogeny, and hence help to untangle the complex origins of the Dictyoptera.

Biomolecular evidence of methanogenesis in ancient herbivores

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A biomarker is a molecule that can be attributed to a biological source on the basis of a known structural product–precursor relationship. Pilot studies have shown that a variety of lipid biomarkers may be preserved in coprolites where they provide unique information on the diet, digestive processes and notably, the digestive tract microbial community of the producer.

Studies have been conducted on modern herbivorous animals in order to investigate more closely the relationship between faecal lipid biomarkers and specific diets and digestive processes. Faecal lipid biomarkers were analysed from two groups of cattle which had been fed either a predominantly silage-based or predominantly concentrates-based diet. The former group of animals produced substantially more methane than the latter and also exhibited significantly higher concentrations of the archaeal biomarker archaeol, which is attributed to methanogenic archaea living in the rumen.

Archaeol recovered from coprolites may therefore infer that the depositor of the coprolite was a methane producer and, subject to taphonomic considerations, the concentrations of archaeol observed may reflect the amount of methane produced by extinct animals. We report the first occurrence of archaeol derived from ancient dung, obtained from 2,500-year-old "ovi-caprid" dung from the Yang-Hai tomb, Xinjiang Province, China.

Return to the Sirius Pass: An unusual taphonomic window on the Cambrian Explosion

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The pioneering expeditions of the 1980s and the early 1990s to the remote area of Sirius Passet, North Greenland, established its fauna as one of the key and earliest of the Phanerozoic lagerstätten. A great deal is now known about the geological setting of this unique locality, but the composition and taxonomy of its fauna together with its environmental setting, and not least its role in understanding the Cambrian explosion, are less well known than those of the other Cambrian lagerstätten. Bed-by-bed investigation of 8.5 m of exposed Buen Formation has yielded new fossil material, and a preliminary rarefaction analysis suggests more taxa remain to be discovered. A number of characteristics are unusual for Cambrian lagerstätten, including 1) the high abundance of taxa, 2) the mode of preservation on smooth bedding surfaces with some mouldic preservation, abundant silicified gut contents and muscle tissue, commonly associated with microbial mats, 3) the autochthoneity of much of the fauna and the presence of large, soft-bodied arthropods, and 4) the very restricted distribution of the fauna. Together the fauna and its taphonomy indicate deep-water, dysoxic conditions and the abundance of soft-bodied animals suggests few predators and scavengers. Burgess Shale type preservation occurs within beds where abundant carbonized films of sponges and arthropods occur.

The interrelationships of hagfishes, lampreys and gnathostomes, and the nature of the ancestral vertebrate

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Hagfishes and lampreys are the only living representatives of the jawless vertebrates (the agnathans), an assemblage of fishes that dominated the first 140 millions years of vertebrate evolutionary history. Although the fossil record provides a surprisingly clear picture of the origin of the jawed fishes (the gnathostomes) from the jawless ones, an understanding of the origin of vertebrates themselves has been precluded by controversy concerning the relationships of the two agnathan lineages with respect to the gnathostomes – morphological cladistic analyses have found lampreys to be more closely related to gnathostomes than to hagfish, whereas molecular phylogenetic studies consistently recover a monophyletic Cyclostomata (hagfish + lamprey). Here we show through deep sequencing of small RNA libraries, coupled with genomic surveys, that hagfishes and lampreys share five unique microRNA families not found in gnathostomes, and gnathostomes share five unique families not found in cyclostomes. Further, the two cyclostome lineages share 15 specific nucleotide substitutions in the mature sequence of ancient microRNAs, substitutions not found in gnathostomes, and no shared substitutions are found in lampreys and gnathostomes to the exclusion of the hagfish. These data provide conclusive evidential support for the monophyly of cyclostomes, and suggest that the last common ancestor of all living vertebrates was a more complex organism than conventionally accepted by comparative morphologists and developmental biologists.

Ontogeny and phylogeny of Early Cambrian stem Rhynchonelliform brachiopods

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The ontogeny of fossil brachiopods is of great importance in deciphering phylogenetic relationships, but poorly known. Early Cambrian Chileida are presently placed within crown group Rhynchonelliformea. Chileids are the earliest known brachiopods with a calcareous and strophic shell, but unfortunately mostly silicified. Findings of phosphatised material from South Australia show that their early ontogeny is similar to that of the Early Cambrian "paterinate" *Salanygolina* from Mongolia. The anterior margin of the ventral larval shell has an unrestricted notch that develops into an umbonal foramen, which is enlarged by resorption and covered by a triangular plate – the colleplax. The colleplax in *Salanygolina* is considered to be homologous with that of chileates. The foramen and colleplax clearly represent a hold fast that was retained in the adult. However, the colleplax holdfast cannot be considered homologous with the pedicle of other Cambrian brachiopods. The early ontogeny of the tommotiid *Paterimitra* is basically like that of *Salanygolina*; it has a bivalved larval shell with a colleplax structure, here considered to be homologous with that of *Salanygolina* and the chileids. We propose that *Salanygolina* and the chileids, as well as the tommotiid *Paterimitra*, belong to the stem of the crown group Rhynchonelliformea.

Soft part relicts in *Metaconularia manni* substantiate the phylogenetic association of Conulariida with scyphozoan-like cnidarians

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Although conulariids have been considered molluscs or vertebrates, and even awarded their own phylum, recent work allies them to the polyp stage of scyphozoan-like cnidarians. Putative cnidarian synapomorphies of the apatitic conulariid periderm are few, and the association remains unsubstantiated. A Silurian specimen from Iowa contains relict softparts. This *Metaconularia manni* is preserved in an unusual apical-downward 'Maltese cross' configuration. Softparts consist of a rosette of silicious structures arranged radially about an amorphous central column. The mildly deformed rosette includes five thin tubes, aligned with a facial midline in two cases, with each bordered by paired, outward widening, teardrop-shaped pouches with a basal keel. We suggest that the tubes are homologs of the septal muscles of living stauromedusans and coronates, and that the keeled structures are homologous with the bases of the lanceolate ovaries of some stauromedusan and scyphozoan females. There appear to be five tubes and five pairs of keeled structures in this *M. manni*, rather than the normal four-fold symmetry of this species. However, individuals of other conulariid species are known to show three-, five- or six-fold symmetry. These relict soft parts confirm the cnidarian affinities of conulariids, and resolve a more than 130-year-old debate.

The fossil pollen record as a tool for studying spatial heterogeneity in extinct plant assemblages

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Understanding the spatial dynamics of compositional change is fundamental to our knowledge of the mechanisms that maintain patterns of biodiversity. But how much spatial information can be obtained from the fossil record, and what are the most appropriate analytical techniques to study these data? Using the pollen record as a plant proxy, we assess compositional heterogeneity between Late Palaeocene tropical plant communities on the western and eastern U.S. Gulf Coast. 57 samples were taken from the Calvert Bluff Fm. in east-central Texas, and from the Tuscahoma Fm. in western Alabama and eastern Mississippi. The two study areas are taphonomically similar, both being marginal marine, muddy strand lines deposits with occasional emergent swamps. We evaluate compositional heterogeneity between the study areas using both similarity metric-based approaches (ordination and NPMANOVA), and additive partitioning of species richness compared against a randomised null model. Both approaches demonstrate a statistically significant compositional difference between the western and eastern Gulf Coast. Our findings demonstrate that meaningful spatial information can be derived even from fossil deposits with a low spatial resolution, such as the marginal marine deposits discussed here. We also show the value and feasibility of using up-to-date ecological analytical methods in palaeoecological studies.

No bones about it: Skeletal histology suggests *Palaeospondylus gunni* (Devonian) is an osteichthyan vertebrate

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Palaeospondylus gunni (Devonian, Scotland) is an enigmatic vertebrate, assigned to various jawless and jawed groups since its original description. Despite hundreds of collected specimens, histology of the skeleton has never been assessed. Here we describe a novel skeletal tissue structure for *Palaeospondylus*, involving a complete absence of bone. Tissue present in every part of the skeleton is interpreted as cartilage, characterized by enlarged cell spaces bordered by matrix. The matrix is mineralized, with a differential localization of deposition within the cartilage that indicates a biogenic origin, with subsequent diagenetic modification of composition. The enlarged spaces, representing hypertrophied cells, differ from nested cartilage cells of lampreys or the Devonian jawless vertebrate *Euphanerops*. Instead, tissue characteristics are similar to cartilage prior to endochondral bone development, but one in stasis, before blood vessels with osteoblasts invade the cartilage to deposit bone. This coincides with a total lack of bone in the *Palaeospondylus* skeleton. We suggest this may represent a loss of the regulatory differentiation pathway

of the osteoblasts. Endoskeletal bone is characteristic of osteichthyan vertebrates. We propose that *Palaeospondylus* belongs to the Osteichthyes, based on the hypertrophied cell spaces, surrounded by regionalized mineralized matrix, most comparable to preliminary developmental stages of endochondral bone.

talks

Tooth wear and damage in conodonts: a new tool for testing hypotheses of ecology and function

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Analysis of dental wear and damage is becoming an increasingly important tool in unravelling the trophic ecology of a wide range of vertebrates. Conodonts have the best fossil record of any vertebrate group and their skeletal elements are known to exhibit surface wear and damage. Yet no systematic survey or analysis of the frequency and extent of damage and wear in conodonts has hitherto been conducted, and perceptions of its prevalence vary widely among conodont specialists. Here, we report the first systematic investigation of conodont wear and damage. Using focus variation optical microscopy, we acquired high resolution images of lateral and oral surfaces of P1 elements from a range of taxa. Damage and wear were found in all elements sampled. Statistical analysis revealed that morphologically similar elements have the most similar patterns of wear/damage. We also found consistent differences in the pattern of wear/damage in the blade region of the elements, potentially reflecting the differing environments occupied by the taxa. The success of this technique has wide-ranging implications for unlocking the fossil record of conodonts: it offers a means of validating functional hypotheses and furnishing direct evidence of the diet-mediated processes that may have driven observed patterns of evolutionary change.

The Devonian nekton revolution

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Impressive discoveries of Neoproterozoic and Early Palaeozoic fossil lagerstätten drew attention to evolutionary and ecological processes within these timespans. It almost seemed that nothing essential happened after the Ordovician. Contrariwise, some major ecological fluctuations have been recorded from Devonian times, several having less prominent Silurian precursors. Classic examples are the radiation of land plants, jawed fish and land

animals. Marine invertebrates show significant ecological and morphological changes: major cephalopod groups such as bactritoids as well as ammonoids evolved and reef growth increased until the Late Devonian crises. Both the rise and fall of dacryoconarids occurred, graptolites became extinct, and various mollusc clades modified early ontogenetic strategies during the Devonian, documenting a planktonic turnover. In addition, there is a macroecological change in marine faunas from a demersal and planktonic habit towards a nektonic habit. Various interpretations may explain this Devonian Nekton Revolution: (1) demersal and nektonic modes of life were initially driven by competition in the diversity-saturated benthic habitats or (2) the availability of rich planktonic food resources. Escalatory feedbacks probably promoted the rapid evolution of nekton in the Devonian. Both these radiations and Late Devonian mass-extinctions were linked to the increasing nutrient input to sea waters during eutrophication episodes.

The initial rise of pelagic cephalopods and the emergence of a complex pelagic food chain during the earliest Ordovician

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Cephalopods are swimming animals, and as such often considered as organisms of the free water column. Cephalopods of today inhabit nearly the complete spectrum of marine environments of the world. Such a global distribution in a wide variety of environments did not exist from the beginning of cephalopod evolution. Cephalopods appeared and diversified rapidly in the latest Cambrian but were confined to palaeoenvironments in low latitude carbonate platforms up to the earliest Ordovician. We reconstructed the cephalopod departure from originally exclusively neritic habitats into the pelagic zone by the compilation of occurrence data in offshore palaeoenvironments from the Paleobiology Database, and from our own data, by evidence of the functional morphology, and the taphonomy of selected cephalopod faunas. The occurrence data are consistent with morphological evidence, indicating the initial cephalopod occupation of the pelagic zone as sluggish, vertical migrants early in the Early Ordovician, and a subsequent diversification which peaked during the Darriwilian. Because, this emergence of large pelagic predators was nearly synchronous with the initial diversification of several independent invertebrate clades in the open sea, the latest Cambrian to Middle Ordovician interval is interpreted as a major step in the establishment of a complex, and sustainable global pelagic food chain.

Instant fossilization! Just add hot water

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Apart from a few well-known, special occurrences (*e.g.* Burgess Shale, Beecher's Trilobite Bed) fossilization is generally thought to be a slow process that leads to the preservation of hard parts only. An exception to this is at deep-sea hydrothermal vent sites where, because of rapid mineralization, fossilization can be very rapid and traces of organic structures, such as worm tubes and bivalve periostracum, are often preserved in silica and/or sulphides (particularly pyrite).

In this presentation I will show data from seafloor fossilization experiments at hydrothermal vent sites at 9°50'N, East Pacific Rise conducted from May 2005 to December 2008. The fossilization experimental devices consisted of identical titanium mesh cages, inside each of which were wired a variety of biological substrates: dried vestimentiferan tubes (two species), *Calyptogena* shells (X1), *Bathymodiolus* shells (X2: one with periostracum, one without), *Littorina* (periwinkle) shells (X2: one with periostracum, one without) and tiger prawn (X1) carapaces. Two sets of cages were deployed at two vent sites for 373 days and 319 days in three micro-environments: high temperature (~370 °C) black smoker fluid, diffuse flow and a control away from active venting.

Preliminary results show 1) shrimp carapaces do not last a year in the vent environment, 2) vestimentiferan tubes are extremely robust, 3) molluscan periostracum protects against shell dissolution to some extent, 4) rapid mineralization leads to the preservation of a range of mollusc groups, although only as sulphide replacements, and 5) *Alvinella* tubes growing on the cages are rapidly replaced by silica and/or sulphides, and this replacement is at a microstructural level of detail. These results are entirely consistent with the fossil record of vent organisms and shed new light on how and why animals get mineralized at vents and then potentially get preserved into the geological record.

Earliest evidence for metazoan-style locomotion in the fossil record: trace fossils from the ~565Ma Mistaken Point Formation, Newfoundland

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Metazoan features within the Ediacaran biota are extensively debated. The earliest, Avalonian ecosystems, dated at 579–560 Ma, are widely considered to have been populated by sessile organisms of uncertain affinity, in part because there has been no evidence for locomotion. Younger signs of locomotion in the Ediacaran are scarce, and limited to simple horizontal burrows dated to 555 Ma or later.

We here report formally the discovery of an assemblage of large, horizontal surface traces from the Mistaken Point Formation of Newfoundland, Canada. These traces are slightly younger than 565Ma. Comparisons with recent giant foraminiferan trails show marked differences – not least the presence of clear internal spreite. Structural features of the trails are instead more consistent with production by a cnidarian-grade organism moving in an analogous way to a modern sea anemone, perhaps by hydrostatic inflation of a circular basal disc.

This find has broad implications for our understanding of Ediacaran ecosystems, and indeed for the history of life, suggesting that organisms capable of controlled, muscular locomotion may have existed within the Avalonian communities.

Is there a rock-bias to diversity patterns in the deep sea?

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The fossil record provides the only empirical evidence of the diversification of life, but analyses of the land-based record indicate a worrying correlation between sampled

fossil diversity and the rock record. To discover whether the same applies in the deep sea we apply similar tests to a novel database of fossil calcareous nannoplankton (coccolithophores). Sampled-in-bin diversity curves were constructed at species- and genus-levels from ODP/DSDP site records of the Atlantic and Mediterranean. The genus-level curve shows a rapid increase at c. 150 Ma followed by a plateau, whereas the species-level curve shows a near-linear increase over the same period. This is accompanied by an almost four-fold increase in the ratio of species per genus being recorded. As a measure of the quality of the deep-sea rock record we have counted the number of ODP/DSDP sites sampling fossiliferous sediments dated within successive three-million-year time bins since the start of the Jurassic. Although this curve follows a more exponential trajectory the rock record is a good predictor of sampled species-level diversity, suggesting the recorded rise in species may be more apparent than real.

Experimental insights into carbon isotope fractionation under Phanerozoic conditions using the model plant *Arabidopsis thaliana*

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The use of terrestrial higher-plant-derived carbon for isotope analysis as a tool to probe changes in the long-term carbon cycle has grown rapidly over the last two decades. Research has focused on interpreting negative carbon isotope excursions, for example those associated with mass extinction events, and more recently on using plant carbon isotope values as a tracer for variation in the isotopic composition of atmospheric CO_2. The isotopic composition of higher plant material is essentially governed by the isotopic composition of atmospheric CO_2 and fractionation processes associated with the opening and closure of the stomatal pore complex in response to environment stimuli, for example atmospheric CO_2 and water availability.

Here we report on a series of CO_2 experiments using the model plant *Arabidopsis thaliana* grown with CO_2 held at geologically relevant concentrations. Nested within each CO_2 treatment, plants were either droughted or provided with constantly wet compost. Carbon isotope results will be discussed with reference to leaf evolution, their use as a proxy for the isotopic composition of atmospheric CO_2 and the terrestrial amplification of negative carbon isotope excursions.

Morphology of Lower Cambrian lobopodian eyes and their evolutionary significance

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Evidence of fossil visual systems is crucial for understanding the origin and evolution of eyes. This study investigated the rare visual organs of Cambrian lobopodians from the Chengjiang Lagerstätte, Yunnan, China. The eyes of *Hallucigenia fortis* and *Luolishania longicruris* are composed of three visual units, each of which has a pigment cup and a 'lens'. These eyes are not similar to the simple eyes (ocelli) of tardigrades and onychophorans as previously

thought, but resemble arthropod lateral visual organs. Following phylogenetic analysis, four evolutionary stages towards arthropod eyes are recognised, and the eyes of Cambrian lobopodians seem to represent the ancestral visual systems of arthropods. Calculation of their focal distance suggests that the eyes of *L. longicruris* and *H. fortis* were capable of forming an image. Together with other sensory organs found in *L. longicruris*, such as a pair of antenniform appendages on the head and dense setae on anterior appendages, it is proposed that this animal may already have a well-developed central nervous system.

Modelling the Dynamics of Ediacaran Communities

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The Ediacara biota represents the first documented complex, macroscopic organisms on Earth. However they have few similarities with modern organisms, making the ecology and feeding strategies very difficult to assess. In order to investigate possible feeding strategies for these organisms, we present an ecological network model for a middle Ediacaran (575–560 Ma) Avalonian-type biota.

Nutrients, bacteria, plankton and algae are input into the model, and for each species a range of possible life history traits are considered. Different feeding strategies have different metabolisms and life history traits. Life history traits form the coefficients for Lotka–Volterra type differential equations which describe the population dynamics. The Jacobian community matrix of species interactions is calculated, from which ecosystem stability is described. Feedback loops and their weights are used to reveal the most important species and factors for ecosystem stability. The amount of dissolved inorganic compounds and prey needed for osmotrophic and suspension feeding rangemorphs are found. Feeding strategies can be ruled out if their corresponding ecosystems do not have a functioning dynamics or require unfeasible amounts of nutrients. By addressing these problematic organisms as members of dynamic, self-stabilizing communities, it should be possible to gain significant insights into their underlying biology.

Recovery after Triassic–Jurassic mass extinction (Tr-J): An evaluation of the richness, composition, and ecological traits in the marine fauna

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This work evaluates the variations in recovery after the Tr–J mass extinction in terms of species richness, composition, and ecological features in different lithologies of two Tr–J boundary sections, Lyme Regis and St. Audrie's Bay (UK). A total of 80 samples each of 1.5 kg were taken from limestones and mudrocks. For each sample, the number of individuals per species was counted and each species was classified according to tiering, motility and feeding mechanisms. Rarefaction curves were estimated for each lithology, sample and locality. NMDS and ANOSIM were used to identify and evaluate the sample groups. St. Audrie's Bay recorded greater species richness than Lyme Regis. However, both localities show a significant increase in richness after the Tr–J Event. Species richness in limestones was greater than in mudstones; species composition, however, showed a remarkable difference between locations and lithologies. In both areas an initial rapid rate of change in composition occurred when recovery began. In addition, a significant

increase in the number of modes of life is observed. These results are consistent with previous studies of recovery after mass extinction (increase in structure and functionality of the community). The variability in composition could be related to environmental and taphonomical issues.

Calcitic composition of *Protospongia* spicules and the evolution of Cambrian sponges

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Though sponges occupy a key position at the base of metazoan phylogeny, there is little consensus regarding the pattern of their earliest evolution. This in part reflects the paucity of convincing fossil sponges in the pre-Cambrian record, as well as the pervasive classification of Cambrian sponges as crown-group hexactinellids, demosponges or calcareans. However, these classifications are based on putative homologies of spicule morphology that do not account for mineralogy. Here we reassess these homologies based on the taphonomy of *Protospongia* and the Burgess Shale sponges. We find that although the spicules of *Protospongia* are geometrically identical to those of crown-group hexactinellids, they were biomineralised in high-Mg calcite rather than opaline silica. Similarly, *Eiffelia* and an unnamed sponge from the Forteau Fm. possess hexactine-derived spicules with a recalcitrant organic layer not known in extant silicisponges. These extinct character combinations can be used to reconstruct the evolution of Cambrian sponges. Comparison with a consensus topology derived from molecular phylogenies of extant sponges shows that *Protospongia* was a stem-group calcarean whilst *Eiffelia* and the Forteau sponge are best considered to be stem-group silicisponges and stem-group hexactinellids respectively. Contrary to recent suggestions that crown-group demosponges originated in the Cryogenian, this novel scenario of spicule evolution shows that sponge body plans were far from fixed in the Cambrian.

Biomarkers and biomats. Interpreting Proterozoic molecular fossils

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Ancient lipid biomarkers are an increasingly important source of information about Proterozoic biodiversity. Large-scale conclusions have been drawn from these molecular fossils, although little attention has been paid to potential taphonomic and preservation problems. Additionally, as a result of not incorporating palaeobiological data into geochemical analyses, important biotic circumstances have not been considered when interpreting biomarker data. Perhaps the most important of these is the vast presence of biomats in the photic zone. Because transport of molecules through microbial mats happens through diffusion, these biomats formed organic seals on the sediment, which were practically impermeable to lipids. Additionally lipids that settled on the mat were degraded by the oxygen produced by photosynthesising organisms within the biomat. This excluded the possibility of these lipids becoming incorporated into the sediment after being overgrown by the vertically expanding mat. This 'mat-seal effect' precluded any significant preservation of nektonic and/or planktonic biomarkers. As a result biomarkers detected in Proterozoic photic zone sediments will mostly be derived from benthic organisms.

talks

Fossil floras of the British Tertiary Volcanic Province: Deciphering floral diversity and climate

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Fossil floras are preserved within Tertiary volcanic deposits of the Isles of Skye and Mull, Scotland. The fossils represent vegetation that grew in a volcanic landscape during quiescent intervals between eruptive episodes. Lava sequences containing the Mull floras have been dated as ~60.5 Ma and ~59 Ma for Skye, indicating a mid Palaeocene age. The fossil leaves are preserved in fine-grained sediments that represent rivers, lakes and ponds that developed on the lava surface. New collections of fossil plants have been assembled from Skye and are compared to previously described floras from Mull. This investigation has provided the first quantitative palaeoclimate analysis of the Hebridean floras and has revealed that these plants were growing in a cool-wet climate. Leaf margin analysis indicates a mean annual temperature of 7.3 ± 3.2°C and 3.6 ± 2.4°C for Mull and Skye respectively. This decline in temperature is consistent with a cooling event that occurred during the mid Palaeocene, but other factors such as uplift may also be partly responsible. The temperature estimates from the Hebrides floras are compared to other botanically-based Palaeocene temperature estimates from the mid latitudes of the Northern Hemisphere, in order to test the robustness of the climate signal.

A functional investigation into the dietary ecology of two of the earliest stem mammals, *Morganucodon watsoni* and *Kuehneotherium praecursoris*

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Morganucodon and *Kuehneotherium* are important stem mammals of Late Triassic / Early Jurassic age. Their co-existence and differences in jaw morphology are commonly interpreted as evidence of subtle dietary adaptation and niche differentiation in early mammal evolution. We test this hypothesis through comparative study of lower jaw functional morphology, employing finite element analysis (FEA) coupled with tooth microwear analysis. Mandibles were scanned using synchrotron radiation XμCT (SRXTM) or μCT to generate a 3D virtual jaw and FEA model for each taxon. *Morganucodon* has a larger mechanical advantage (MA) than *Kuehneotherium* (0.29 to 0.17) and could generate higher bite forces with lower mandibular stress and strain. The jaw of *Morganucodon* was stiffer, whilst the *Kuehneotherium* jaw experienced torsion. In order to generate two newtons of bite force (required to pierce beetle cuticle), *Kuehneotherium* experiences over twice as much load at the jaw joint than *Morganucodon*. Tooth microwear analysis provides independent support for dietary differences: quantitative analysis of surface microtextural roughness revealed statistically significant differences between the two taxa. Our analysis supports the hypothesis that *Morganucodon* fed on 'hard-object' prey, whereas *Kuehneotherium* was specialized for rapid, snapping jaw closure and consuming more malleable foodstuffs, thereby indicating early ecological diversity within basal mammals.

Anatomically preserved seeds from the Oxford Clay: has the living fossil *Ginkgo* changed in 150 million years?

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Ginkgo biloba, commonly called the Maidenhair tree, is the only extant species of the division Ginkgophyta and is often referred to as a living fossil. Although members of the Ginkgophyta are common in Mesozoic and Cenozoic fossil plant assemblages, they are typically preserved as compression/impressions of vegetative organs and more rarely fertile organs that provide important insights into morphology of ancient members of the group, with anatomical preservation restricted to woody stems. Here we document the first anatomically preserved *Ginkgo* seeds from the fossil record, and employ 3-D reconstruction techniques to unravel their structure and organization. Of the two available specimens, one has been prepared as serial wafers and has been studied by a combination of traditional descriptive techniques and 3-D reconstruction constructed from a small number of tomographic slices, while the second specimen has been investigated by non-destructive methods alone through high resolution CT-scanning. Comparative studies of extant seeds using the same techniques allows extraction of the maximum information from the specimens, and allows results gained from different preparation techniques to be compared against each other. Results show remarkable similarities of fossil and living seed structure, suggesting morphological and anatomical stasis within ginkgoalean seeds since the Jurassic.

Experimental decay of lampreys and hagfish provides taphonomic constraints on jawless vertebrate evolution

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Early vertebrates and extant clades of jawless fishes lack biomineralized hard tissues. Consequently our knowledge of their evolution is limited to the narrow windows provided by exceptional preservation of soft-tissues. Often rare, collapsed and partially-decomposed, soft-bodied fossils are difficult to interpret unequivocally, principally because the sequence of loss and transformation of key anatomical characters during decay is poorly understood. In order to provide rigorous taphonomic constraints upon the interpretation of putative soft-bodied vertebrate fossils, we undertook laboratory experiments to investigate the decay of vertebrate characters using extant proxies.

Comparison of results from the hagfish (*Myxine*) and both larval and adult lampreys (*Lampetra*) highlights differences in their rates of morphological decay. Furthermore, identifying the similarities and differences in their *sequences* of character loss through decay (*e.g.* notochord, keratinous and cartilaginous tissues) enables us to better interpret the anatomy of putative jawless vertebrate fossils and distinguish evolutionary absence from taphonomic loss. This in turn allows more robust phylogenetic analysis of these extinct taxa, and clearer distinction of stem placements that carry evolutionary meaning from those that reflect non-preservation.

Putting Humpty together again: reconstructing the *Bilignea* plant

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The Mississippian tuffaceous sediments of Oxroad Bay, East Lothian, Scotland have yielded one of the most comprehensively known and best preserved Mississippian floras globally. From among the 43 anatomically preserved organ-species reported to date, a whole-plant concept for the early seed plant *Bilignea* Kidston has been developed. This is the first reconstruction based on one of approximately 20 recognised Mississippian 'pycnoxylic pteridosperm' stems that share a dense wood anatomy. Previously reconstructed pteridosperms have a contrasting wood anatomy and inferred growth habit. The plant comprises stems of *Bilignea* cf. *solida* Kidston, vegetative petioles of a unique *Lyginorachis* type, fertile petioles of a new type of *Lyginorachis* previously assigned to *Tristichia*, and fertile organs comprising *Telangium*-type pollen organs bearing triradiate pollen and cupules of the *Pullaritheca*-type bearing ovules of the *Hydrasperma*-type. The present reconstruction is based on organic connection of petioles attached to the stem, ovules attached to the cupule and prepollen found within the pollen organs. This evidence is augmented by comparison of morphospecies via anatomical similarity and association/disassociation against a conceptual model template of the *Bilignea* plant. Inclusion of the reconstructed whole-plant concept in phylogenetic analyses to clarify seed plant evolutionary history has not supported theories of a diphyletic origin.

Getting beneath the skin of fossil holothurians

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Fossil holothurians have the poorest fossil record of any echinoderm class and consequently their early evolution remains the most poorly documented. By far the most spectacular and best-preserved fossil holothurians come from the Early Devonian Hunsrückschiefer Lagerstätte of southwestern Germany. Using X-ray tomography we have been able to document the arrangement of the water vascular system and its relationship to skeletal elements in the most common Hunsrückschiefer taxon, *Palaeocucumaria*. In this taxon no close connection exists between the calcareous ring and the radial water vessel and its tube-feet, and a large calcified madreporite and stone canal abutted against the calcareous ring. This demonstrates that *Palaeocucumaria* is a late stem-group member of the class Holothuroidea, and allows us to make several important deductions about the earliest evolution of holothurians.

Closing Romer's Gap: new tetrapods and arthropods from the basal Carboniferous of the Scottish Borders

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Romer's Gap is a period of some 20my at the base of the Carboniferous characterised by a world-wide break in the fossil record of early tetrapods and terrestrial arthropods.

Hitherto, tetrapod material has only been described from two localities: Horton Bluff, Canada and Dumbarton, Scotland. Earlier this year, we announced the discovery of new tetrapods and arthropods at two localities in the Tweed Basin, Coldstream and Burnmouth. Here we report a further discovery in the bed of Whiteadder Water near Chirnside. These new localities lie within the Cementstone Group in the Courceyan stage of the Tournaisian. Three distinct horizons, each with its own fauna, have been identified at Chirnside in a one metre section of silty mudstone and shale exposed in the bank and bed of the river. Three tetrapod taxa have been identified so far. They include a large form, similar in size to *Pederpes* from Dumbarton, but readily distinguished from it; a small form with a skull c. 20 mm long; and a third of intermediate size. Four myriapods have been identified: each differs from the only other myriapod described from Cementstones of the Tweed Basin, *Anthracodesmus* from Lennel Braes, near Coldstream. The discovery of a diverse fauna of tetrapods and terrestrial arthropods at the base of the Carboniferous indicates that their radiation had not been constrained by low levels of atmospheric oxygen at that time.

A Late Cretaceous rocky shore ecosystem, Ivö, Sweden

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Southern Sweden was transgressed during the early Campanian when global sea-level was approximately 100 m higher than today, and an archipelago was formed with low islands and peninsulas. A late early Campanian rocky shore ecosystem developed on the island of Ivö, comprising a highly diverse fauna. Nearly all faunal groups known from the Late Cretaceous of NW Europe are represented, including most invertebrate groups as well as vertebrates such as mosasaurs, sharks and aquatic birds. Among the invertebrates are the northernmost rudists and hermatypic corals. The rich fauna offers a unique opportunity to reconstruct an almost complete ancient rocky shore ecosystem. The benthic invertebrate fauna comprises ten guilds, and five habitats are recognized, representing different hydrodynamic conditions, illumination levels and predation pressures. A simplified food web is reconstructed and includes all invertebrate and vertebrate species. It contains six trophic levels, three of which are directly associated with the rocky shore and three which are mixed with the pelagic ecosystem. The ecological structures show that the Late Cretaceous rocky shore environment was a dynamic, productive and complex ecosystem inhabited by a highly diverse and well adapted fauna much richer than any known rocky shore ecosystem, ancient or modern.

Silurian trilobite diversity

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Silurian trilobites were globally distributed, displaying a substantial degree of variation in morphology and inferred mode of life. The stratigraphical ranges of Silurian trilobite taxa and formations have been compiled from the literature and plotted against time to determine the total diversity and estimated mean standing diversity. Following the end-Ordovician mass extinctions, trilobite species diversity increased markedly through the Llandovery and into the Homerian because of elevated origination rates. Raw data indicates that origination rates peaked in the Sheinwoodian, falling below extinction rates

in the Upper Silurian. When standardized against the number of formations, however, diversity peaked in the Ludlow and declined in the Prídolí. Plotted against standard graptolite biozones, trilobite species diversity increased in pulses from the Rhuddanian to the Homerian *lundgreWni* Biozone. There was then a sharp drop in diversity which correlates with the Mulde Event. The Ireviken, Linde and Sandvika events are associated with less pronounced reductions in trilobite diversity. The more significant drops in Silurian trilobite diversity are correlated with sea-level falls whereas sea-level rises are associated with the more prominent increases in diversity. In comparison with the Devonian, trilobite diversity in the Silurian is depressed, and this may be explained by low endemicity levels.

A Silurian soft-bodied lophophorate

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The holotype of the brachiopod *Bethia serraticulma* from the Herefordshire Lagerstätte (Wenlock, England) bears several epibionts. The most curious of these is apparently unmineralised, bilaterally symmetrical, and ~2mm long. It comprises a subconical body attached basally to the host and partially enclosed by a broad 'hood'. Towards the tip the body bears paired coiled tentacles, interpreted as a lophophore. Where the hood attaches laterally a series of transverse ridges and furrows occur. The affinities of this form likely lie with Brachiopoda; the hood is interpreted as the homologue of a dorsal valve/mantle-lobe, and the attachment as the homologue of the ventral valve, which in some encrusting brachiopods (*e.g.* craniids, eoconulids) is attached directly to the substrate. The ridges/furrows might represent dorsal mantle canals; the regularity of their arrangement however argues for constructional serial-repetition. Brachiopods are not serially-structured, but palaeontological and molecular evidence implies that they derive from forms that to some degree were. The new form thus most likely belongs to the brachiopod stem-group (other positions remain possible); the absence of mineralisation is however probably derived. It also demonstrates that unmineralised sessile lophophorates are or were ecologically viable; they may have been a significant element of the Palaeozoic lophophorate radiation.

Integrating molecular and palaeontological approaches to telling evolutionary time

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Molecular clocks have usurped the traditional role of the fossil record in providing a timescale for evolutionary history. However, the choice of fossil calibration points and their associated prior probabilities have the greatest effect on any molecular clock study

and, thus, it is critically important that fossil data are correctly represented. No protocols have yet been established for implementing prior probability distributions that reflect the degree to which fossil minima approximate the time of divergence. Instead, clock analyses have adopted expeditious solutions such as normal, log-normal and uniform probability distributions that assume some general relation between fossil minima and divergence dates, but are not informed by any palaeontological or geological data. We have explored the implementation of a variety of palaeontological and geological data as prior probabilities on fossil calibrations within a Bayesian molecular clock analysis of metazoan diversification. These include using subjective data such as phylogenetic bracketing and, more objectively, temporal variation in rock outcrop data. These priors tightly constrain posterior probabilities, yielding divergence estimates that show variable concordance with raw palaeontological estimates.

Bristling beginnings: Molecular palaeobiological perspectives on annelid evolution

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Annelids have always been the angler's best friend. However, their internal phylogeny has been problematic from a morphological as well as a molecular perspective. Molecular phylogenies persistently include other phyla, such as sipunculans within the annelids. This is problematic given that crown group Annelida do not appear until the Cambrian/Ordovician transition, whereas sipunculans are present in the Early Cambrian Chengjiang Lagerstätte. Cambrian annelids are diverse in the Burgess Shale and the Sirius Passet, but belong to the stem group. This would suggest that the fossil record of annelids is biased.

Recent molecular analysis using microRNAs solves these issues. Sipunculans are in fact outside the annelids. Clitellates (earthworms and leeches) are derived polychaetes.

This demonstrates that the fossil record of these soft bodied animals is giving a correct picture of annelid evolution. It can also be inferred that the annelid ancestor was an epibenthic vagile polychaete with parapodia and chaetae, whereas the infaunal burrowing and sessile lifemode is derived.

What lived on the land before the land plants?

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Prior to the origin of land plants in the early Palaeozoic the land surface is considered to have harboured some form of microbial biota, but direct fossil evidence for such a biota is limited. A detailed palynological investigation of the Torridonian deposits of Scotland has yielded over 100 assemblages of diverse and well-preserved palynomorphs from 15 sections representing the Stoer (?1150+/-50 Ma) and the Sleat and Torridon (?1050–520, probably *ca.* 950 Ma) groups. The palynomorphs represent populations of diverse eukaryotic and prokaryotic cells (sheaths, filaments, tubular structures and sphaeromorph acritarchs – including encysted forms and clusters). Many forms are quite large, including organic-walled cysts over 300µm in diameter. Others show complex wall structure. Tantalizing structural elements indicate the presence of larger, multicellular organisms. The palynomorphs largely represent allochthonous elements which were transported, mixed and

deposited in very shallow muddy environments. However, these heterogeneous samples of free-living benthic and planktonic freshwater communities also contain autochthonous wefts of filaments and likely cyanobacteria derived from subaerial siliciclastic mats periodically inundated with water. These mats have also been collected *in situ*. The Torridonian deposits are revealing the nature of the complex communities of organisms adapted to subaerial and freshwater aquatic habitats that existed by 1 Ga.

talks

Conodonts as palaeothermometers for ancient oceans?

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Conodonts are potentially invaluable oceanic water mass palaeothermometers by virtue of their diagenetically inert apatitic composition, their ecological distribution as both pelagic and nektobenthic organisms, their abundance, and their well-established biostratigraphy in Cambrian–Triassic rocks. To date, bulk chemical and ion probe analyses of $\delta^{18}O$ have proceeded directly to palaeotemperature interpretation without appreciation of inter- and intra-element variability. Ion microprobe analysis of selected Ordovician and Silurian taxa establishes that: 1) $\delta^{18}O$ within elements can vary by up to 3.3‰ in crown tissue, but is typically much lower (0.95‰, n = 41, mean SD 0.33‰, mean spot analyses per element 9, mixture of crown tissue and white matter); 2) $\delta^{18}O$ systematically varies along some base–cusp transects in coniforms and across processes of platforms; 3) $\delta^{18}O$ varies between same taxon representatives (mean of differences between means of representatives 1.17‰, n = 8); 4) $\delta^{18}O$ values of CAI 1 conodonts are most reproducible; 5) $\delta^{18}O$ between same sample pelagic and nektobenthic taxa varies by up to 3‰; 6) processing techniques affect $\delta^{18}O$ values; 7) $\delta^{18}O$ of conodonts is offset by ~2‰ to coeval micrite and calcitic brachiopods and comparable with bulk chemical values. The magnitude of variation in $\delta^{18}O$ observed in our analyses is equivalent to ~0.4–14°C. Previously, bulk chemical and ionprobe analyses may have masked such variability.

A mollusc for all seasons: high fidelity climate records of the Weddell Sea during a warm interval of the Early Pliocene

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Shell growth analysis coupled with a signal of seasonality from a pilot isotopic study of Early Pliocene *Austrochlamys anderssoni* bivalves from marine deposits of the Cockburn

Island Formation, northern Antarctic Peninsula suggest an annual sea surface temperature range of about 3.5°C. Assuming no vital effects, and that our estimates of $\delta^{18}O_{sw}$ approximate reality, we estimate annual minimum and maximum temperatures of between about –1 and +2.5°C respectively at 4.7 Ma. *Austrochlamys anderssoni* grew through the year, even during the coldest parts of Winter recorded in our shells, with a high frequency fluctuation in growth increment size that probably reflects periodic agitation of the water column enhancing food supply from organic detritus. This suggests that *Austrochlamys* favoured waters that were ice-free. Our data support interpretation of the Cockburn Island Formation as an interglacial marine deposit and the hypothesis that *Austrochlamys* retreated from the Antarctic as sea ice extent expanded, this transition occurring during climate cooling in the Late Pliocene. Our data diverge from climate models that show extensive sea ice in the Weddell Sea during the Early Pliocene. The signals from the bivalves are especially resonant given the pace of high latitude sea ice reduction as 21st century climate warms.

Was coccolith evolution in the Quaternary exceptionally rapid?

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Quaternary nannofossil research has been dominated by palaeoceanographic studies seeking to reconstruct environmental parameters and oceanographic conditions. This work has tended to emphasise the degree of conformity of modern and fossil coccolith assemblages. However, in fact there are – especially in the Late Quaternary – very rapid turnovers of nannofossils. This is most obviously the case with the reticulofenestrids where a succession of different species dominates the assemblages. For example the ubiquitous species *Emiliania huxleyi* which frequently dominates modern coccolith assemblages only appears at *ca.* 250 ka. Moreover within the Late Quaternary the assemblage changes appear to occur within glacial intervals, with the result that successive interglacial intervals have distinctive assemblages – and can be readily distinguished. This pattern will be described using new core studies from the Porcupine Bank (SW of Ireland) and literature data. It will be compared with geological data from other periods and molecular genetic data, to address the question of whether this pattern is a unique characteristic of Late Quaternary coccolith evolution and whether it is solely characteristic of the reticulofenestrids.

talks

Preservation of Silurian and Devonian early vertebrate microfossils: stable isotope and elemental geochemistry

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Microremains of early vertebrates from the Silurian and Early Devonian of Arctic Norwegian, Siberia, central Asia, and Baltic states have been analysed for stable oxygen isotope and elemental geochemistry. Vertebrate taxa examined include acanthodians, chondrichthyans, galeaspids, heterostracans, mongolepids, and thelodonts. Spot chemistry analyses by Energy Dispersive X-ray Spectroscopy were conducted on fine-polished thin sections of vertebrate scales measuring elemental composition of separate tissues, in relation to their histology and recrystallisation level. Bioapatite silicification and enrichment in heavy elements corresponds to microfossil structure and colour alteration, indicating weaker preservation and re-crystallization respectively. Stable isotope measurements give distinguishably lower heavy oxygen ratios in vertebrate microremains from the Lower Silurian of central Asia, and much higher in those of the Upper Silurian of the Baltic basin. As a first conclusion, this significant loss of initial enrichment in heavy ^{18}O isotopes (concerning the general oxygen isotope composition of Palaeozoic vertebrate bioapatites) may be directly correlated with the poor preservation. Additionally, the $\delta^{18}O$ ratios appear to be strongly species-dependent, which may refer either to specific palaeobiological isotope assimilation in biominerals, or to specific susceptibility to lose primary isotopic signal.

Abstracts of poster presentations

Evolution of shallow marine benthic foraminiferal communities through the Late Palaeocene to Early Eocene in the East Tethys

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The Palaeogene succession of the Greater Indus Basin (GIB) in Pakistan formed on the north-west continental shelf margin of the Indian Plate in the eastern part of the Tethys Ocean. In the Upper Indus Basin of the GIB the termination of carbonate platform sedimentation at the Palaeocene–Eocene (P–E) boundary probably reflects early collision of India with Asia. However, further to the south, in the Lower Indus Basin carbonate platform deposition was continuous through the Late Palaeocene to Early Eocene interval. During Late Palaeocene times, foraminiferal assemblages in the Lower Indus Basin closely resemble those of the West Tethys region. However, this faunal continuity across Tethys appears to be decoupled through the latest Palaeocene–earliest Eocene interval. Two hypotheses are possible for this decoupling: 1) the apparent absence of *Nummulites* from the earliest Eocene of Pakistan and rarity of *Alveolina* – elsewhere used as the prime marker for the base of the Eocene – may imply a geographical barrier between East and West Tethys faunas, perhaps caused by India-Asia collision; or 2) the appearance of *Nummulites* marks the P–E boundary in Pakistan, and *Alveolina* (and species of *Discocyclina* and *Assilina*) therefore appear earlier in East Tethys during the latest Palaeocene.

Ichnology and palaeoenvironmental reconstruction of the lower Cambrian siliciclastic rocks, Um Bogma, Sinai, Egypt

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Ichnofacies of the Lower Cambrian siliciclastic rocks of Um Bogma region is correlated and compared to evaluate changes in palaeoceanographic conditions controlled by palaeogeography in the distal zone of the southern Tethys. Four stratigraphic sections are measured and traced laterally at Um Bogma, G. Sarabit El Khadim, G. Lehian and Wadi Baba. The investigated Lower Cambrian sections are subdivided into two distinctive stratigraphic sequences. The lower is represented by basal conglomeratic successions separated by red ferruginous oxipalaeosols of generally humid to tropical environment and an ichnofossils dominating, slope forming upper fining- and thinning upward successions of sandstone-shale intercalations. A diverse trace fossil association is described from siliciclastic rocks on a finer scale to map local environmental patterns, or biotic responses to episodic events (storms, flood). It includes eight ichnogenera with nine identified ichnospecies assigned to the *Cruziana* and *Skolithos* ichnofacies, including *Arenicolites* sp., *Bergaueria sucta*, *Bergaueria prantli*, *Cruziana aegyptiaca*, *Cruziana salomonis*, *Dimorphichnus* cf. *obliquus*, *Dimorphichnus* cf. *quadrifidus*, *Diplichnites* sp., *Gordia marina*, *Planolites vulgaris* and *Skolithos* isp. This faunal association allows an age determination for these siliciclastic sediments as Early Cambrian. The trace fossils were likely produced by trilobites, suspension-feeding annelids and deposit-feeding"worms", probably polychaetes. Sections bearing abundant *Skolithos* represent the *Skolithos*

ichnofacies, which is typical of high energy environments with loose, sandy, well-sorted to slightly muddy substrates in intertidal to shallow subtidal zones. The other trace fossils represent the *Cruziana* ichnofacies, which is typical of subtidal, poorly sorted and soft substrates, from moderate energy to low energy environments between the fair weather and storm wave base. The Lower Cambrian siliciclastic sediment was deposited at an early stage in a fluvial condition, followed by subsidence in a later stage affected by normal faults along which shallow marine clastic sedimentation took place in the final stage of the shelf's development.

Darwin's Upraised Shells

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The Sedgwick Museum of Earth Sciences holds the largest single concentration of geological samples collected by Charles Darwin during the famed second voyage of HMS *Beagle* (1831–1836). From 1842, the collection at Down House was used in conjunction with Darwin's notebooks as an *aide-mémoire* whilst publishing his geological works. After his death in 1882, and that of his wife Emma in late 1896, the geology collection was donated to the forerunner of the Sedgwick Museum in January 1897 by his son, George Howard Darwin.

The eminent petrologist Alfred Harker subsequently selected and labelled the rocks and minerals as 'The *Beagle* Collection'. The fossils in the donation were curated separately, and include over 100 Pleistocene shells which can be directly linked to Darwin's '*Geological Observations on South America*' (1845). These "*upraised shells*" were important as they helped Darwin to:

- determine that active uplift of South America had occurred and was still taking place at a time when sea level was accepted as a global constant;
- determine the effect of 'winnowing' on the composition of shell assemblages through destructive erosion – an early foray into taphonomy.

They also provided their own challenges in terms of field labelling, storage and identification.

Fatally bitten ammonites from the Lower Lias of Charmouth, Dorset

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Little is known about ammonites as prey, and the literature mostly deals with rare examples of conchs with multiple, lateral tooth marks. In the Lower Liassic Charmouth Mudstones, up to 20% of small ammonites (*Promicroceras*, *Xipheroceras*, *Cymbites*, *Asteroceras margaritoides*) show ventral damage at the rear of the body chamber. Single pieces of shell, which extend almost symmetrically on either side and usually reach the umbilical suture on one side, are missing. Midpoint of the damage lies at 80% body chamber length (measured in degrees) with a coefficient of variation of just 6%. Damage at this position would allow

a predator to sever attachment muscles and remove the body. Lack of shell chips preserved adjacent to damaged ammonites precludes scavenging or post-burial crushing. Ammonites were caught in the water column, manipulated into a horizontal position and then bitten at a precise point. The most likely predator was an active swimmer, with the capability to hold and manipulate a smooth, possibly slippery, ammonite shell. We favour teuthoids with suckers over belemnites with hooks; the slightly asymmetrical damage is consistent with bites made by parrot-like, teuthoid jaws. Lobster-like crustaceans are less likely culprits; lack of tooth marks precludes vertebrate predators.

An explanation of biodiversity patterns within organic groups on the planet: Evolution Revolution (ER Theory)

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Movement, size, radiation and behaviour are the cornerstones of genetic change through time. Combinations of these factors determine diversity rates of different organic groups on the planet. This should help answer the question as to why some organic forms evolve and others do not change significantly through time. An attempt will be made to go beyond the fitness model explanation (some animals are adapted to their environments and therefore do not change) and introduce additional variables involved in speciation changes. To date the explanation for speciation has centred on the fourth component 'behaviour' in the ecological theory of adaptive radiation. This theory depicts adaptive radiation as the combined outcome of three things that foster phenotypic diversification: adaptation to local environments (organisms establishing themselves in new niches); second, competition for resources (organisms competing for food resources), and last, the increase of genetic diversity when two diverging groups have genetic exchange (organisms from separate groups mating with each other). All of these processes involve the behaviour of the organism and do not fully explain diversification patterns for all organic groups. Using size and movement components, a mathematical model that predicts potential biodiversity for a species will be presented.

Before the Birds and the Bees – The Origin of Sex in the Fossil Record

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The origin of meiotic sex as a reproduction mechanism is a hugely important marker in evolution. It is intimately linked with the evolution of Eukaryotes, but has significant implications of its own. Most notably, it is the major process that creates the genetic variety upon which natural selection in the Eukaryotic world is built.

Until now, the question of the origin of sex in deep time has been approached from a biological, rather than a palaeontological, direction. The biological theory for how meiotic sex arose is both elegant and comprehensive, but how can we support this theory with information from the fossil record? Much of the characteristic meiotic information is on a sub-cellular level, and is rapidly lost from degrading cells. If we are to recognise sexual reproduction at its very beginnings, in the Proterozoic, then more preservable, large scale

characteristics must be identified. Both direct evidence, including fossilised meiotic tetrads and embryos, and indirect evidence, such as the changes in genetic mixing and evolutionary rate, can be used to build a picture of how and when the many extant sexual mechanisms arose.

If we can use a wide-scale, contextual approach to understand this specific revelation in early biotic evolution, it may shed some light on the complex and murky picture of the Proterozoic fossil record as a whole.

The origin of an opisthotonic posture in fossil vertebrates

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In an 'opisthotonic posture', the neck recurves posteriorly on the dorsal side of the animal and thus lies above the remainder of the vertebral column. The phenomenon can originate peri-mortem; it has been proposed recently that fossil vertebrates that display this attitude acquired it at the time of death. Intuitively, however, postures acquired peri-mortem are likely to be retained only until rigor mortis is resolved, and obliterated by subsequent biostratinomic processes. A very specific set of taphonomic circumstances (rapid entombment) would be required to preserve vertebrates in such attitudes. This hypothesis is tested using three case studies in which vertebrates frequently exhibit opisthotonic postures: the Early Cretaceous lacustrine Jehol Biota, China, the Middle Triassic Besano Formation, Switzerland and the Jurassic Solnhofen Limestone of Germany. Neither rapid burial after deposition nor entombment within depositing event beds is supported. An extended residence time at the sediment surface, during which carcasses could have been re-orientated, is implied by partial *in situ* disarticulation of skeletons. *Archaeopteryx* from the Solnhofen fauna, in which the neck recurves posteriorly, but has separated from the associated bones which remain in life position, provides unequivocal evidence that the posture can be acquired post-mortem, as a result of hypersaline dehydration.

Palaeobiogeographical and palaeoecological brachiopod trends during the Permian–Triassic (P–Tr) and Triassic–Jurassic (Tr–J) mass extinction events

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During the last 500 Million years brachiopods show several changes in diversity and distribution. Since the earliest Mesozoic their diversity decreased rapidly, and other marine invertebrates overtook their place as an important member of shallow marine benthos. This study documents changes in abundance, distribution, diversity, and composition of brachiopod faunas during two major events of brachiopod decline, the Permian–Triassic and the Triassic–Jurassic extinction events.

The occurrence of each genus through these extinction intervals is described. A matrix of absence and presence with environmental settings and latitudinal records of each

geographic area was constructed based on data provided by the Treatise on Invertebrate Palaeontology, Palaeobiology database, and other references. K-cluster analysis was used to group localities, NMDS to evaluate faunal relationships with latitudinal and climatic differences, and variations in the distribution of orders for each stage.

Our results show remarkable differences between these extinction events: the P–Tr event shows a larger magnitude extinction and a dramatic reduction of faunas and spatial distribution, whereas the T–J event is characterized by a large number of genera with wide overlapping geographical distributions above the extinction interval, resulting in an increase in spatial distribution.

Bird traces on tidal flats

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Traces produced by invertebrates in recent tidal flat sediments are well studied in the international Wadden Sea. Also vertebrates, in particular birds, produce here a number of traces. These are foot prints, peck marks and traces related to food-digging activities. Not always are these food-digging traces interpreted correctly. Not every field geologist is also a field biologist. Shelduck (*Tadorna tadorna*) make shallow meandering feeding traces in search of food in soft mud. They also make small (diameter 4 cm) and large feeding holes up to 60 cm in diameter and 20 cm depth. These large holes were sometimes interpreted as 'scour pits', and the sand deposited by the birds with their feet on one side of the hole was seen as an indicator of the current direction. Mallards (*Anas platyrhynchos*) produce comparable feeding pits. Trampling traces produced by food-searching black-headed gulls (*Larus ridibundus*) were sometimes wrongly interpreted as 'resting traces'. Many of such surface traces will be short-lived with a low fossilization potential. However, they indicate the importance of sediment reworking in tidal flat sediments.

Diductor workout: Modelling, brachiopods and trigonometry

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The use of simple trigonometric equations and easily measurable internal morphological features allows us to quantify the efficiency of the articulatory system of brachiopods, based on the relationship between the position of diductor muscle scars and the inclination of the cardinal process. Modelling within the Strophomenata and Rhynchonellata indicates that, physiologically, possible gape angles are not as large as previously thought when analysing the mechanism solely. Closer study of the relationship between diductor muscles and cardinal process shows that in Cambro–Ordovician brachiopods, this system reached moment efficiency after the valve opened at a gape angle of 15–25°. During the Ordovician–Silurian, the system reached its optimum efficiency with low gape angles of less than 5°. After the Devonian, brachiopods adopted morphologies that optimised the moment at the opening of the shell. While external brachiopod morphologies are relatively stable through time for a given group, these transitions indicate internal morphological adaptations and modifications to the system diductors / cardinal process with a migration forward of the position of the diductor scars.

Does Ontogeny Recapitulate Phylogeny in Recent Planktic Foraminifera?

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The apparent parallelism between increasing complexity on the phylogenetic scale and the developmental scale was expressed by Haeckel as the biogenetic law: that ontogeny is a rapid recapitulation of phylogeny. Foraminifera are an ideal group in which to investigate this claim, as they grow by the sequential addition of chambers onto previous developmental stages, thus preserving an individual's entire developmental history. Broadly categorised, the earliest adult Recent planktic foraminifers have a simple globigerine morphology, therefore considered to be primitive and ancestral to other forms; the more complex globorotaline morphology, appearing later in the geological record, is regarded as derived. We used Synchrotron-radiation X-ray computed tomography to obtain high-resolution scans of four modern planktic foraminifer species: *Globigerina bulloides*, *Globigerinoides sacculifer*, *Globorotalia menardii* and *Globorotalia tumida*. The scans were used to generate 3D digital reconstructions. The scan images (approximately 700 per scan) were manually segmented to separate the different chambers of the foraminifer. This digital reconstruction method provides a three-dimensional means of analysing the internalised developmental stages of the foraminifers. The resulting ontogenetic sequences revealed a globorotaline early ontogeny in species which go on to have a globigerine adult morphology, refuting the validity of the biogenetic law in modern planktic foraminifers.

Biodiversity and plasticity in life forms in the Cambrian 'Orsten' benthic meiofaunas in Sweden

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Etching the so-called 'Orsten' limestone nodules from Middle (*Agnostus pisiformis* zone) to Upper Cambrian (Furongian series) alum shale succession in southern Sweden yielded a three-dimensionally preserved assemblage of secondarily phosphatized microfossils. Due to the size limitation, there are different larval stages and small adult forms present in the material. Such animals, likely, belong to 'meiofauna' biota and lived, temporarily or not, on or in a soft-bottom environment. The Swedish 'Orsten' material contains several thousand specimens with preserved softparts of mostly arthropod affinities (*i.e.*, "stem arthropods", lobopods and pentastomids; chelicerates; "stem crustaceans"; phosphatocopines with more than 50,000 specimens and about 15 species; eucrustaceans). Associated with them, a rich conodont fauna, several Small Shelly Fossils and a few non-phosphatized fragments (*e.g.*, brachiopods and sponge spicules) had been identified. We have started a project to investigate the yet unstudied material containing mainly arthropod fragments (*e.g.*, isolated limbs, stalked eyes) of unclear affinities and a few specimens of non-arthropod affinities (*e.g.*, "worms", bacteria, SSF). We aim to 1) describe taxonomically the 'odds and ends' of the bulk of the material and 2) document more precisely the benthic 'Orsten' communities in terms of species-richness and abundance both in time and space within the Middle–Upper Cambrian of Sweden. This will result in a better understanding of the plasticity of life forms and the palaeoenvironment of the Cambrian 'Orsten' meiofauna in Sweden.

Cambrian substrate evolution or revolution? New insights from the Cambrian pelmatozoan holdfasts of Gondwana

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The Neoproterozoic–Cambrian transition is well known by the radiation of complex metazoans, the so-called 'Cambrian explosion'. A recent analysis of key evolutionary events in some margins of Gondwana suggests the radiation was first driven by intrinsic (biological) factors and, along with the ensuing increase of ecosystem complexity, was subsequently enhanced by extrinsic (ecological, geochemical, palaeogeographical) factors. One of the ecological changes that took place during this metazoan radiation is the increase of burrowing patterns, which directly influenced a shift from firm (with low-water content and abundant microbial biofilms and mats) to soupier soft substrates. The response of benthic ecosystems to this modification has been called the "Cambrian substrate revolution", which can be illustrated by the evolution of epibenthic, sessile, suspension-feeding echinoderms. Stemmed echinoderms (or pelmatozoans) are currently believed to have drastically changed their settling strategy at the Cambrian Series 3-Furongian (or middle-upper Cambrian) boundary interval to microbial-free, hard substrate attachment (available on hardgrounds and partly cemented skeletal substrates) associated with development of "true" columnar stems. However, recently discovered attachment structures across the transition of Cambrian Series 2 and 3 (the traditional lower-middle Cambrian transition) in West and East Gondwana (the Brèche à Micmacca Member of the Anti-Atlas, Morocco; the upper Láncara Member in the Cantabrian Mountains, Spain; and the Beetle Creek Formation of Queensland, Australia) suggest this was an older and more progressive adaptation. In particular, new findings of discoidal binding-holdfasts represent the oldest direct evidence of pelmatozoans attaching directly to non-organic hard substrates. Such skeletal structures, associated with meric stems and previously known worldwide since the Furongian, were most probably abundant since the beginning of Cambrian Series 3. As a result, pelmatozoan echinoderms developed different settling strategies to colonize microbial-free, firm to hard substrates that were already available in Gondwana across the traditional lower-middle Cambrian transition.

What leaf anatomy tells us about the ecology of Palaeozoic medullosalean pteridosperms

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The Medullosales were one of the dominant groups of seed plants in the Pennsylvanian (late Carboniferous) tropical wetlands and have an extensive fossil record, especially of their foliage. Details of the anatomy of the foliage have been determined from petrifactions (mainly coal balls) and cuticles, and provide us with a number of insights into the ecology of these plants. The cuticles in particular show that medullosalean species had more diverse anatomies than any other gymnosperm taxon of comparable rank, especially in the structure of the stomata. The stomata, which are usually on the underside of the

leaves, often have features to protect the guard cells and pore. This has been interpreted previously as an adaptation to drier conditions, but is more likely to have been to protect the stomata from excess water blocking the pore. The leaves are often covered by hair bases, but the hairs seem to have been mostly shed in the fully-developed leaves. The few species that consistently retained hairs in the fully-developed leaves seem to be those that show evidence of insect damage. There is some potential for using medullosalean stomatal densities to determine trends in Palaeozoic atmospheric CO_2, but this can only be done within individual species.

Fossil plants from Svalbard and their climatic significance

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During the Palaeogene forests grew beyond the polar circle, up to 80ºN. These forests thrived at a time when the climate was significantly warmer than today and atmospheric CO_2 is estimated to have been four times the present day value (Pagani *et al.*, 2005). Fossil leaves are found in the Palaeocene coal-bearing Firkanten Formation and the Eocene/Oligocene Aspelintoppen Formation. The flora is dominated by angiosperms, including species from the families Betulaceae, Ulmaceae, Fagaceae and Cercidiphyllaceae. Some are represented by modern genera such as *Corylus, Aesculus, Ulmus, Cercidiphyllum* and *Fagus*. The Arcto-Tertiary deciduous conifer metasequoia is common, along with juniper and ferns. Fossil leaves are associated with sediments that indicate a tidal flat environment, and are preserved in mudstones that represent flood plane deposits, and sandstones that represent channel/tidal sand bodies.

Equisetum species are abundant and appear to be the primary colonizers of sand bodies. A particular feature of the fossil leaves found is that many of them are complete, indicating little transportation with quiet water conditions. They occur as leaf mats suggestive of an autumnal leaf fall. In addition to this many leaves have petioles (stems) attached, which is further evidence for autumnal leaf fall. The leaves are notably large, some exceeding 30 cm in length. This may be indicative of a climate with high rainfall and/or an adaptation to the low angle of light at high latitudes.

Understanding the mode of life and biological affinities of *Cloudina*

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The terminal Ediacaran genus *Cloudina* includes some of the earliest biomineralized fossils. It consists of a tube formed by stacked funnel-shaped elements and is usually interpreted as the external skeleton of an early metazoan. The species *Cloudina carinata*, described from central Spain, is characterized by external longitudinal crests, a thickened apertural rim, a basal circular opening and a relatively shallow funnel imbrication. Apart from these morphological traits, the fossil population shows abundant evidence of tube disarticulation and asexual reproduction. The abundance of disarticulated elements indicates an episodic growth in which each funnel was built as an independent unit, not fused with the previous one. However, many specimens show the spaces between nested shell layers filled with siliceous cement suggesting that, sometime after their secretion, funnels could became 'soldered'. The presence of a matrix-filled central canal suggests that the precipitation of

inter-layer cements occurred during the lifetime of the organism, while the central canal was still occupied by the soft parts.

Taken together, available data on the biology of *Cloudina* strongly suggest that it was a gregarious, sedentary and modular organism, a mode of life likely plesiomorphic for the eumetazoa.

Molar microwear of insectivorous bats: implications for the trophic ecology of two early mammals

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Morganucodon and *Kuehneotherium* are important basal mammals found in the Early Jurassic fissure-fill sites of Glamorganshire. Microwear analysis of the dentition of these two taxa suggests that each utilized a distinct food source. This study aimed to determine the nature of this food source through validation of microwear textural analysis based on comparative data from extant analogues: insectivorous bats. Bat species were selected to represent a range of dietary preferences, including fly specialists, moth specialists and mixed foragers. High-resolution 3D data were acquired via focus variation microscopy (Alicona IFM) from functional surfaces on the molars, and facet surface roughness was quantified through microtextural analysis. Multivariate statistical analysis of these data revealed a strong relationship between textural parameters and diet. Applied to the fossil taxa, the analysis supports the hypothesis that *Kuehneotherium* was a specialist on insects lacking hard cuticle. MicroCT analysis provides additional support: *Morganucodon* molars have thicker enamel, suggesting the teeth could withstand greater loading forces. Validation of the microwear signals apparent on these fossil taxa confirms the power of quantitative microtextural analysis as a tool for testing hypotheses of diet in extinct vertebrates and provides direct evidence of trophic niche partitioning early in mammalian evolution.

The first description of an anomalocaridid appendage from the Sirius Passet Lagerstätte of North Greenland

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The Sirius Passet biota of North Greenland is one of the oldest Cambrian lagerstätten, and although it is dominated by non-mineralized arthropods and lobopods, anomalocaridids have never been identified. Here, we describe for the first time a single specimen of an appendage with possible anomalocaridid affinities as suggested by its large size and an overall gross morphology similar to that of *Anomalocaris*. The Sirius Passet taxon consists of an elongated appendage with paired spines, set in a V, along one margin. It differs from *Anomalocaris* in that segment boundaries are absent, and ventral spines are relatively long and lacking in auxiliary spines. These differences may be taphonomic, but the entire surface of the appendage is covered in a fine fabric, making it unlikely that this appendage was originally segmented or sclerotized. As such, the Sirius Passet appendage may have had a similar composition to the frontal appendages of the lobopods *Kerygmachela* and *Pambdelurion* from the same locality, and could also have occupied an intermediate

location in the lower stem group of the euarthropods between these more basal lobopods and the anomalocaridids.

Investigating the diet of extant and fossil fishes through dental microtexture analysis

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Recent work has shown that modern populations of fishes can differ significantly in their diet yet remain anatomically similar, raising concerns about the assumptions and reliability of functional morphology as a method for investigating diet in fossil fishes. Semi-automated quantification of tooth microwear can offer a solution, but in many cases, teeth are damaged to the point where individual microwear features (pits and scratches) cannot be recognized.

Here we use a new technique based on microtextural analysis of high-resolution three-dimensional data acquired with a focus variation microscope (Alicona IFM).

Data were collected from: molariform teeth of two populations of *Archosargus probatocephalus* (Teleostei, Sparidae) which differ in the degree to which they are durophagous; from Atlantic wolffish (*Anarhichas lupus*, Teleostei, Anarhichadidae) a specialised shell-crusher; and from pharyngeal teeth of populations of *Astatoreochromis alluaudi* (Teleostei, Cichlidae) with known diets. We then compared the results of microtextural analysis with data collected from teeth from the extinct pycnodontid fishes *Gyrodus* and *Eomesodon*, both assumed on the basis of tooth morphology to be specialised shell-crushers. This reveals that *Gyrodus* is unlikely to have been a specialised shell-crusher, and confirms that microtextural analysis provides a powerful test of hypotheses of diet in fossil organisms.

Soft-tissue preservation in Devonian rhynchonelliform brachiopods

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The presence of soft tissue preservation in brachiopod fossils is incredibly uncommon in proportion to their diversity and abundance in the fossil record. To date, the majority of reported incidences of soft tissue have been from linguiliformean brachiopods, with less than a handful of reports of soft tissue from rhynchonelliformean brachiopods. The use of computer-aided micro-tomography has not previously been exploited in the study of brachiopods. Here, its use is reported on *Mucrospirifer* spp. from the Silica Shale (Middle Devonian) of the United States. Presence of pyrite replacement of the original soft tissue is revealed, showing detailed internal casts of the musculature and internal morphology. In addition, this technique has shown the presence of enigmatic structures within the calcitic valves which bear a striking resemblance to the borings of certain parasitic organisms, with possible preservation of the parasites *in situ*.

The "Supertree Tool Kit" and a supertree of fossil birds

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Creating supertrees containing thousands of taxa requires hundreds of source input trees. Managing and processing these data in a systematic and error-free manner is challenging and will become even more so as supertrees contain increasing numbers of taxa. Protocols for processing input source phylogenies have been proposed to ensure data quality, therefore any tool for processing source phylogenies should enable these protocols to be followed.

The aim of the Supertree Tool Kit (STK) is to aid in the collection, storage and processing of input source trees for use in supertree analysis, and is therefore invaluable when creating supertrees containing thousands of taxa. We have added metadata via XML files to each tree containing information such as the bibliographic information for the tree and how the data were derived, including the character data used. These data are essential components of proposed protocols. Here we demonstrate the efficiency and ease of use of the STK by creating a supertree of fossil birds from a subset of data derived from a large avian dataset of over 6,000 taxa. This subset took less than an hour to create, rather than the more usual weeks or months of effort.

Disarticulated echinoderm remains from the Lower–Middle Cambrian transition of Morocco suggest early origin of mitrates (stylophorans)

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Disarticulated skeletal elements of echinoderms have been recovered from the lower–middle (Series 2–3) Cambrian transitional beds of Morocco (the "Micmacca Breccia" of the Lemdad Valley, High Atlas). The echinoderm fauna comprises the oldest known pelmatozoans with holomeric columnals, and the oldest cornute stylophorans. New exceptionally preserved bilaterally symmetrical ossicles have been studied through synchrotron radiation-based X-ray mictrotomography (SRXTM) carried out at the TOMCAT beamline of the Swiss Light Source (SLS, Paul Scherrer-Institut, Villigen, Switzerland). These ossicles can be interpreted as parts of a complex distal aulacophore (stylophoran appendage). Their external morphology (median furrow flanked by two lateral depressions on their upper side and aboral blade-like knobs) shows diagnostic characters of mitrate appendages. If this assignation is confirmed, the stratigraphic interval of mitrates will be significantly extended, as the previously oldest known occurrences were in the lower Ordovician. Moreover, this extended interval will be more congruent with the interpretation of stylophorans as basal rather than derived echinoderms. The material also gives new information about the biology of these early echinoderms. Stylophoran plates are constructed of a three-dimensional mesh, similar to the stereom of living echinoderms, which provides a reliable guide to the nature of the associated soft tissues. Through comparisons with modern echinoderm anatomy, the stereom microstructure of these new mitrate elements, revealed by SRXTM, gave unprecedented insight into mitrate functional morphology and palaeobiology.

The tale of two *Kuphus* tubes (Neogene Mollusca) from the late Cenozoic of Jamaica

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Tubes of the crypt-dwelling teredinid bivalve *Kuphus* sp. from the Miocene 'Newport Formation,' White Limestone Group, are among fossils reworked into the Late Pleistocene 'red beds' on Farquhar's Beach, parish of Clarendon, south central Jamaica. Two tubes are the focus of this paper. One tube, collected from a fallen boulder, is bored on one side by *Entobia* isp. and a *Gastrochaenolites* isp., and on the other by a large, partial *Gastrochaenolites*? isp. and rare *Entobia* isp. The second tube, collected *in situ* from the base of the Late Pleistocene sequence, is bored on all external surfaces apart from the ends by *Entobia* isp. These reworked Miocene fossils were bored in the Late Pleistocene, as indicated by the lack of a lithified (Miocene) infill that is typical of the *Kuphus* tube; indeed, bored *Kuphus* has not been reported from the White Limestone Group (Blissett and Pickerill, 2004, *Cainozoic Research*, **3** (for 2003), 167–187). These specimens and cobbles bored by bivalves provide evidence of a marine base to an otherwise non-marine, 'red bed' Pleistocene succession. They also present an unusual association of the crypt of a teredinid, a group that includes obligate borers, with other boring organisms.

posters

Nektaspid arthropods from the Lower Cambrian Emu Bay Shale Lagerstätte, South Australia, and their bearing on lamellipedian phylogeny

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The lower Cambrian (Series 2, Stage 4) Emu Bay Shale on Kangaroo Island, South Australia, contains the most informative Cambrian Burgess Shale-type biota in Australia. Excavations through 2007–2009 at a quarry situated inland from the original cliff and wavecut-platform exposures have uncovered several new unmineralised arthropods, among them two new lamellipedians. A cladistic analysis of Lamellipedia based on 37 characters for 28 terminals resolves the new Australian clade as a monophyletic group that is sister to Naraoiidae + Liwiidae, and it is classified within the Nektaspida as a new family. Shared derived characters of the Emu Bay Shale nektaspids involve a bipartite, elongate hypostome and an elongation of the pygidium relative to the cephalic shield and very short thorax (the latter consisting of three or four segments). Among the other nektaspids, a monophyletic Liwiidae is composed of *Liwia* and the Ordovician *Taricooia* + *Soomaspis* but excludes the Sirius Passet *Buenaspis*, and even the membership of *Buenaspis* in Nektaspida is contradicted among the shortest cladograms. New morphological interpretations favour affinities of the Chengjiang arthropod *Kwanyinaspis* with Conciliterga (=helmetiids) rather than with Aglaspidida, and the controversial Sinsk taxon *Phytophilaspis* with Petalopleura.

The effects of pedal geometry and morphology on track depth: taking a step towards using fossil tracks as palaeopenetrometers through finite element analysis and physical experimentation

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A vertebrate track is the resultant deformation caused by the interaction of an animal and a substrate. The final morphology (before burial) is determined by three factors; substrate properties, pedal morphology, and forces applied. Through computer simulation employing finite element analysis, it is shown that the relative length of the foot perimeter affects track depth even when pressure and substrate properties are kept constant. In cohesive substrates, an increased perimeter allows more sediment to move laterally and upwards, rather than be forced down beneath the load, resulting in a shallower track. Non-cohesive substrates (*e.g.* sand) behave differently, shearing more readily at the edge of the foot, and causing those indenters with a relatively larger perimeter to indent more deeply. The implications of this are that two tracks made by similar sized animals may be different depths due purely to the shape of the feet. This means that employing fossil vertebrate tracks as palaeopenetrometers (gauges of palaeo-substrate consistency) must take into account the pedal morphology and geometry. Secondly, conclusions of neoichological experiments conducted using one type of substrate, may not be directly relatable to fossil tracks imprinted in other substrates, particularly when considering the full three-dimensional track volume.

Distribution of planktonic foraminifera across the Cenomanian Turonian Boundary Event [CTBE] in the Rehkogelgraben section (Upper Austria)

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The sediments of the Ultrahelvetic Zone of the Eastern Alps (Upper Austria) were deposited on the distal European continental margin of the Tethys. The Rehkogelgraben section (~40 Km east of Salzburg) comprises a 5 m thick succession of Upper Cenomanian marl–limestone cycles overlain by a black shale interval composed of three black shale layers and carbonate–free claystones, followed by Lower Turonian white to light grey marly limestones with thin marl layers. The stratigraphic position of the black shale intervals is shown to be coeval with the global "Cenomanian Turonian Boundary Event" (CTBE) by the extinction of *Rotalipora* spp. and the first appearance of *Helvetoglobotruncana helvetica*. As this work was based on an analysis of ~40 thin sections, it has not been possible to identify all of the detailed faunal changes normally recorded at this level. The data do, however, complement the foraminiferal analysis of the processable marl samples within the succession (Wagreich *et al*., 2008). Many of the thin sections from immediately above the CTBE are crowded with calcispheres, and this is a feature of many other successions in Europe and the Middle East.

The Developmental Evolution of Neural Crest and the Emergence of Vertebrate Complexity

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The origin of the vertebrate body plan has long been a topic of considerable interest to palaeontologists. The neural crest is a multipotent, migratory cell population responsible for many of the features associated with this body plan and is able to generate a diverse range of cell types in vertebrates, including three distinct types of pigment cell. These pigment cells are thought to share a common developmental precursor and can serve as a model system for exploring the evolution of neural crest potentiality, and the emergence of vertebrate complexity. Whilst it has previously been suggested that the repertoire of pigment cells has expanded gradually throughout vertebrate evolution, at least two of these cell types are present in agnathans, meaning that the pigment cell repertoire was at least partially expanded in the earliest crown group vertebrates.

Pigment cells have been posited as the earliest neural crest derivative and may be present in the invertebrate chordates, implying that the neural crest is not strictly a vertebrate-specific innovation. However, it remains to be seen whether these cells are homologous to vertebrate crest-derived pigment cells, the vertebrate RPE, or are independently evolved cell populations. By exploring the roles of the key genes involved in the development of vertebrate pigment cells in those found in invertebrates, their relationships can be understood more clearly.

posters

Brachiopod ecostratigraphy of the lower Middle Ordovician Lysaker Member (Huk Formation) at Skara, western Oslo Region

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The Lysaker Member of the Huk Formation (Dapingian) is unusually thick in the western part of the Oslo Region (southern Norway), measuring *c.* 10 m at Skara near Krekling. The unit, however, is only 4.5 m thick in the Oslo-Asker district farther east. Fossils have been sampled from the unit, bed-by-bed at Skara and are dominated by brachiopods, but trilobites are also fairly common. It appears that the thick unit only represents the *Asaphus lepidurus* Zone, *i.e.* the uppermost part of the Volkhov Regional Stage, whereas the *Asaphus expansus* Zone (Kunda Regional Stage) apparently is absent. The investigated locality is located close to where the classic brachiopod material investigated by Öpik in the late 1930s was derived. The study revises those taxa and documents their distribution in detail, facilitating a detailed ecostratigraphical correlation of this expanded section. The new data also indicate that in this part of the Baltic province, during the *A. lepidurus* Zone, brachiopod faunas were already diverse apparently prior to the main Darriwilian radiation, signalling the establishment of orthide-strophomenide dominance during the Great Ordovician Biodiversification.

Late Ordovician, deep-water *Foliomena* brachiopod fauna from Cellon, Carnic Alps

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A hitherto unreported low-diversity brachiopod fauna from upper Katian (middle Ashgill) strata in the Cellon section, Carnic Alps includes species of the following small and thin-shelled genera: *Christiania*, *Dedzetina*, *Leptestiina*, *Kozlowskites* and *Skenidioides*. Together these taxa belong to the widespread, deep-water *Foliomena* fauna that occupied circum-cratonic habitats during the Late Ordovician. Multivariate analyses of distributional data for the *Foliomena* and related faunas from 30 localities, globally, through the early Sandbian to late Katian interval, place the Cellon fauna within deeper-water, marginal biofacies; not surprisingly the fauna is placed adjacent to the late Katian faunas from the Králův Dvůr Formation, Czech Republic and the Domusnovas Formation, in Sardinia but it also has links to assemblages on the Baltic and Laurentian margins together with South China. The new assemblage confirms the persistence of deep-water facies in this part of the Carnic Alps during the late Katian, and develops further the evolutionary and geographical patterns of the *Foliomena* fauna around the margins of Gondwana.

Phosphatic preservation in the lower Cambrian Comley Lagerstätte of England: implications for Orsten-type taphonomy and the evolutionary history of small shelly fossils

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Early diagenetic phosphatization of embryos and small, non-mineralizing metazoans provides a unique window onto evolution across the Proterozoic–Phanerozoic transition. However, a poor understanding of the underlying taphonomic mechanisms limits the palaeobiological inferences that can be drawn. We describe the modes of phosphate occurrence within the lower Cambrian Comley limestones of England, including the horizon that yields exceptionally preserved soft parts of small phosphatocopine arthropods. Our re-excavation of a classic locality combined with petrographic and energy-dispersive x-ray analysis has allowed a new, high-resolution reconstruction of the Comley succession, while extensive new collections of microfossils have revealed a preservational spectrum with implications for the depositional and post-burial environment. We find that the shallow depositional setting of the Comley sequence is comparable to that of the embryo-bearing facies of the Doushantuo Formation (Neoproterozoic, China), although the style of phosphatization is closer to that of the arthropod-dominated, quiet-water Orsten deposits from the middle to late Cambrian of Sweden. Our results demonstrate that exceptional phosphatic preservation need not be associated with extensive secondary phosphatization of sediments or skeletal fossils, and we suggest that the degree of winnowing is a key factor in determining the composition of phosphatized assemblages. In addition, the diverse Comley microfossil assemblage emphasizes the preservational non-dependence of many

small shelly taxa on secondary phosphatization, counteracting a megabias in the early animal fossil record.

New Terebratulid species from the Cretaceous of Farafra Oasis, Egypt

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Maastrichtian chalky limestone rocks of the Khuman Formation, Farafra Oasis, have yielded several small capillate terebratulids. Specimens were recorded for the first time from Cretaceous rocks in Egypt, and among these the first occurrences of *Terebratulina cf. terebratulina* Louisianae Stenzel are described in other work by the same authors. The specimens have affinities to the genus *Terebratulina* d'Orbigny, which is characterized by small shell, capillate ornamentation, circular outline of dorsal valve, gently convex to inflated dorsal valve. Anterior commissure incipiently to broadly uniplicate and deltidial plates disjunct. The differences included having small foramen, calcalifer type of crura, massive teeth inserted into wide socket floor, and bilobed cardinal process in present materials. Surprisingly, among these materials one specimen, so called *Terebratulina* sp., has a larger shell size and strongly deflected anterior with two costellae extending along the dorsal valve from the anterior to umbonal region.

Using biomineralized tissues to evaluate trophic structure of a Cretaceous ecosystem from Argentina

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Stable isotopes of nitrogen and organic carbon have been widely used in the evaluation and understanding of food webs in modern and archaeological ecosystems since the late 1970s. More recently, palaeontological studies of Tertiary lagerstätte have revealed that these stable isotopes can also provide trophodynamic information regarding ancient ecosystems when preserved soft tissues and organic components are analysed. Biomineralized tissues from vertebrate fossils have now been found to preserve an organic component retaining measurable amounts of nitrogen and organic carbon within their crystal lattices. The Mata Amarilla Formation in southern Patagonia contains numerous fragments of bones, scales and teeth from vertebrates of the Upper Cretaceous, thus presenting an exceptional opportunity to gain valuable insights into a much older, little known fossil community by using stable isotopes. N and C isotope data were obtained for a variety of fish and reptiles from similar stratigraphic levels to allow trophic reconstruction. Inferences regarding food web structure from the stable isotope data were consistent with the ecology of the taxa as inferred from other criteria. The retrieval of this bulk isotope data from hard biomineralized tissues opens up new possibilities for further palaeoecological assessments via this method for many more ancient fossil communities.

Givetian Stromatopotoids and tabulate corals: A palaeobiogeographical approach

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The Palaeozoic stromatoporoids and tabulate corals are generally considered as fossils associated with a reefal environment, tabulates as pioneers and stromatoporoids as builders. The Devonian of the Ardennes is a time of high α-diversity. Hubert *et al.* (2007) have inventoried 138 species of stromatoporoids (distributed into 28 genera) and 113 species of tabulates (distributed into 31 genera). During the Givetian, the stromatoporoids (81 species) and tabulates (47 species) reached their maximal diversity (Zapalski *et al*. 2007). The diversification of these organisms is strictly correlated with carbonate production (Hubert *et al*. 2007). The first aim of the work, based on a statistical approach (*i.e.* Jaccard, Shannon index, *etc.*), is to compare the diversity of the Ardennes faunas with different other areas (*e.g.* Bergischen Landes, Holy Cross Mountains, Afghanistan, *etc.*). For example, 253 species of stromatoporoids have been listed, which are distributed into 39 genera (most of these species are known in Ardennes and only nine species and six genera are known in Bohemia). The second topic, using others' statistical coefficients, is to establish a comparison of the affinities in these two groups inside the areas cited before. Affinities are high between Ardennes–Boulonnais and Bergischen Landes, and low between Ardennes–Bohemia and Poland.

Two New Crinoid Obrution Lagerstätten from the Middle Jurassic (Bathonian) of the Cotswold Hills, England and their Palaeoecological Significance

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A review of Middle Jurassic crinoid collections at the Oxford University Museum and the Natural History Museum London has revealed the existence of two new obrution Lagerstätten, doubling the number published. A new species of *Chariocrinus* from Sharps Hill Formation of Horsehay Quarry, Banbury, Oxfordshire and specimens of *Pentacrinites dargniesi* from the Forest Marble Formation of Malmesbury, Wiltshire are here reported. This is the first time articulated specimens of these genera have been described from the Middle Jurassic of Northern Europe.

The taxonomic and taphonomic significance of these spectacularly preserved crinoids are compared with other Middle Jurassic assemblages from Switzerland (Hauptrogenstein Formation), eastern France, southwest Poland and the classic British localities (Bradford-on-Avon and Northleach). Both the Central European and British assemblages are monospecific, consisting of dense aggregations of many articulated individuals buried by mud or sand, although the new British assemblages occupied soft substrates. The new obrution Lagerstätten described here suggests that the variety of ecological niches occupied by Middle Jurassic crinoids and their catastrophic burial within barrier shoal systems occurred far more commonly than previously thought, as this mode of preservation was only previously known from Switzerland. This explanation is also favoured for other British Middle Jurassic crinoid assemblages.

Temperature change and the Late Permian mass extinction event

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The end-Permian mass extinction was the greatest mass extinction in the Phanerozoic. The cause of this event is still unknown but is thought to coincide with a dramatic negative shift in both the $\delta^{13}C$ and the $\delta^{18}O$ isotope record, with previous studies identifying isotope excursions in shallow water, carbonate-dominated environments, (*e.g.* Val Brutta, Southern Alps) as well as terrestrial settings. This study proposes to produce a new well constrained palaeotemperature curve through the extinction event. Previous studies have indicated diagenesis and dolomitisation as the cause of the isotopic variation, casting doubt on the validity that $\delta^{13}C$ and the $\delta^{18}O$ shifts relate to atmospheric and climatic changes. In this study biogenic calcite from articulate brachiopod shells collected in Northern Italy were used as well as inarticulate shells. Cathodoluminescence and trace elemental geochemistry were used to evaluate the state of shell preservation. Brachiopod shells typically preserve the changes in the geochemical signature of the seawater they lived in, and therefore can be used to reconstruct changes in ancient seawater temperatures. A change in water temperature through the extinction event is expected, with some studies showing a rise of 5-6 degrees. Our new data are used to assess the magnitude of temperature change.

The true nature of the eurypterid 'horn organs'

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Restudy of the so-called 'horn organs' found in those eurypterids (Chelicerata: Eurypterida) which were traditionally presumed to be females – with the horn organs acting as putative spermathecae – yielded an alternative interpretation for these structures as male hemispermatophores. These are pairs of structures produced within the male body to carry the sperm during mating, and are combined to a single spermatophore as they are set down onto the ground. Since hemispermatophores are also present in many Recent arachnids, the common ancestry of (Eurypterida + Arachnida) could be supported by this character; to the exclusion of Xiphosura. Scorpions, amblypygids and uropygids (all Arachnida) were studied using micro-ct in order to assess morphological variation among such mating organs today, as well as their location within the body. Based on these studies a revised scheme of gender recognition for eurypterids is proposed and a new model of their possible mating behaviour is reconstructed.

Integrated biostratigraphy chart of the Jurassic in the Sverdrup Basin, Arctic Canada

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In connection with Arctic studies such as sandstone provenance investigations, CASP has been working on the Mesozoic of the Sverdrup Basin since 2006. Integrated biostratigraphic data are here presented for the Jurassic period in a single chart. Most

published biostratigraphic schemes of the area are based on single organism groups, and an integrated biostratigraphic chart is presented based on the published literature and ongoing fieldwork. Macrofauna, of particular importance for field orientation, includes ammonites and bivalves. Palynology and micropalaeontology are represented mainly by dinoflagellate cysts and foraminifera respectively. Several palynological schemes have been proposed and they are all shown together. 22 ammonite horizons have been identified in the Sverdrup Basin during the Jurassic, while up to 18 palynological divisions have been made. There are eight micropalaeontological zones, some of which can be subdivided making up a total of 13 divisions, and there are also 13 bivalve zones or divisions. The tabulation of the information shows readily the types of biostratigraphic data that can be expected from any prescribed interval. The use of these data in ongoing field and laboratory studies is testing the quality of the proposed integrated chart.

Examining Palaeozoic wetland plant communities: a methodology for large-scale comparison

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Ancient wetland plant communities (coal-forming forests) persisted from the mid-Carboniferous period in North America and Europe through to the end of the Permian in South China. Recent palaeobotanical findings have proposed significant taxonomic and systematic similarities between these two temporal and geographic end members, postulating a united Amerosinian phytogeographic realm which linked the North China block to Euramerica before the end of the Carboniferous, and a Euramerican origin for the wetland communities in China. A UK-based high-resolution study of Pennsylvanian wetland plant community similarity over a confined area was undertaken, as a basis for extrapolation to global scale comparison. Results are perhaps surprising: strong geographically-controlled patterns emerge, with stratigraphic position overprinting these to a much lesser degree. This confirms that wetland plant communities were highly dynamic and heterogeneous locally, but further suggests that even small geographic separation can cause a significant degree of endemism in communities. Caution therefore is advised when combining proximal assemblages for convenience. A robust methodology has been established for extending this study, whereby these results can be tested at a global level to investigate whether localised community differences are absorbed or elevated, and how this impacts the proposed linkage between Euramerica and China.

First record of a belemnite preserved with beaks, arms and ink sac from the Nusplingen Lithographic Limestone (Kimmeridgian, SW Germany)

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An unusually preserved belemnite from Nusplingen comprises remains of beaks, arm-hooks, ink sac and the phragmocone. *Hibolithes semisulcatus* is the only larger belemnite known from the Nusplingen Lithographic Limestone which has the same phragmocone

shape and size, hence the taxonomic assignment. The rostrum was probably lost during a lethal predation attempt. For the first time, a belemnite fossil reveals details of the beak morphology. This specimen represents the only known rostrum-bearing belemnite of post-Toarcian age which has been preserved with non-mineralised body parts. Some morphological characters of the lower beak of *Hibolithes* more closely resemble Recent decapods than Recent octopods. The upper beak differs in the long, narrow and curved rostrum from those coleoid beaks known from Nusplingen. The dark part of the lower beak also shows a unique outline with a short and pointed rostrum. This beak form might reflect a special diet of the belemnites. Taking into account the shape of their buoyancy apparatus, the arm hooks and the sharp beaks, belemnites may be interpreted as having been fast-swimming medium-sized predators. With the new discovery, Nusplingen now represents the only locality which has yielded complete beak apparatuses from all major Jurassic cephalopod groups.

Red Devonian trilobites with green eyes from Morocco and the silicification of the trilobite exoskeleton

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Latest Emsian (Early Devonian) sediments at the famous mud-mound- and trilobite-locality Hamar Laghdad (Tafilalt, Morocco) yielded some red-coloured remains of phacopid trilobites. Closer examination revealed that the eyes of these phacopids are often greenish in colour. EDX-analyses showed that the lenses retained their original calcitic composition, possibly greenish due to Fe- and Mn-impurities, while most of the exoskeleton was silicified. The silicified parts contain elevated concentrations of iron which causes the red colour. This phenomenon is explained by the porosity of the exoskeleton in contrast to the homogeneous and massive construction of the lenses and their Mg-content. These incompletely silicified trilobites enabled a reconstruction of the silicification process in trilobites. Their diagenetic alteration probably occurred as a result of events associated with the Cretaceous transgression.

A new phylogeny for Stylonurina and gigantism and competitive replacement among the Eurypterida

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Stylonurine eurypterids comprise a monophyletic suborder of aquatic chelicerates known from marine, brackish and freshwater environments through the late Ordovician to end Permian. Compared to the nektonic predatory Eurypterina the relationships of the Stylonurina are poorly known, with current phylogenetic analyses unable to resolve the topology of the various familial clades. Restudy of the genus *Drepanopterus* has shown it to be polyphyletic, with *Drepanopterus* sensu stricto being a primitive sweep-feeding hibbertopteroid, and several Silurian species appearing to be basal members of the Eurypterina. Including this new data in a phylogenetic analysis of the suborder results in a well-resolved tree showing that hibbertopterids, formerly considered to be a separate order to Eurypterida, clade within Stylonurina, and that a sweep-feeding lifestyle evolved twice

independently within the suborder. It is also apparent that Stylonurina remained relatively unaffected by the drastic decline in Eurypterina diversity during the Early Devonian; macroevolutionary analysis of maximum size and diversity across the whole of Eurypterida suggests that competition with early jawed vertebrates and other predators may have been the cause of the gigantism and pattern of extinction seen in Eurypterina, while Stylonurina adopted a non-competitive strategy that allowed them to survive into the Permian.

A restudy of the Scorpion *Archaeoctonus glaber* (Peach, 1882): Ontogeny meets phylogeny

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A restudy of the scorpion fauna of Glencartholm (Lower Carboniferous, Viséan), in Scotland, has revealed that many previously described species are invalid: most taxa represent ontogentic stages of a single taxon, *Archaeoctonus glaber* (Peach, 1882). A new phylogeny of Palaeozoic scorpions indicates that the same sequences of changes that occur throughout *A. glaber*'s ontogeny also occur throughout Palaeozoic scorpion evolution, *i.e.* ontogeny recapitulates phylogeny. In particular, abdominal plate morphology, an important taxobase in many previous classifications, varies considerably with ontogeny, and is therefore useful for determining the age of fossil scorpions. Regression analysis indicates that many aspects of the anatomy of *A. glaber* grew isometrically. Isometric scaling indicates that the largest specimen represents the ninth moult and may have grown to a length of over 510 mm.

The Eocene foraminiferal index species *Subbotina patagonica* (Todd and Kniker, 1952) and *Subbotina linaperta* (Finlay, 1939)

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The taxonomic relationship of the foraminiferal index species *Subbotina patagonica* (Todd and Kniker, 1952) from the Early Eocene of NW Europe and the North Atlantic has been extensively discussed in the literature. It bears many morphological similarities with *Subbotina linaperta* (Finlay, 1939) and has been widely confused with this species or put in several undifferentiated groups with it. *S. linaperta* and *S. patagonica* have been widely used in Eocene biostratigraphy on a global scale, but their morphological similarities have resulted in confusion and inconsistent biostratigraphical schemes. It has been suggested that *S. linaperta* is a descendant of *S. patagonica* and the present study supports this view. *Subbotina* tests from the Rønsnæs Clay Formation of Denmark were compared morphologically with topotypes of *S. linaperta* from New Zealand and *S. patagonica* from Chile, with the aim of demonstrating their taxonomic relationship on the species level. Morphometric analyses were performed using univariate, bivariate and multivariate statistical analyses on selected landmarks and qualitative characters. They show that *S. patagonica* is very similar to *S. linaperta*, but they can be distinguished by their different shapes of the aperture. The analyses also reveal the most common *Subbotina* species within the Røsnæs Clay Formation to be *S. patagonica*. *S. linaperta* was not observed from this locality, and it probably did not immigrate to NW Europe prior to the Middle Eocene.

Taphonomy of exceptionally preserved arthropods from Burgess Shale-type deposits

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Many non-trilobite arthropods occur in Cambrian Burgess Shale-type deposits, where they are usually preserved in fine-grained siliciclastics. The gut traces of well-preserved naraoiids from the Chengjiang (Cambrian Series 2, Qiongzhusian Stage), Kaili (Cambrian Series 3, Maozhuangian Stage) and Burgess Shale (Cambrian Series 3, Marjuman Stage) biotas were analyzed and compared. SEM-EDX analyses revealed the presence of C, P and Fe in all three. Iron-rich clusters associated with organic remains are interpreted to be a result of mineralization during anaerobic microbial decay. Differences in the composition of the gut traces in the three biotas appear to be a product of later diagenesis. The Sinsk biota (Cambrian Series 2, Botomian Stage) from the Siberian Platform, in contrast, is preserved in carbonate. Analysis of samples of the enigmatic arthropod *Phytophilaspis pergamena* from this deposit show that the cuticle is composed mainly of calcium phosphate, which appears to be original. The co-occurring trilobite *Jakutus primigenius* cuticle contains only calcium carbonate. While phosphatic cuticle occurs rarely among large Cambrian arthropods (*e.g.* aglaspidids) arthropod cuticle of this composition clearly evolved a number of times.

Reconstructing vegetation cover in deep time: macrofossil leaves, pollen and spores, or both?

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Reconstructions of ancient vegetation are often based on either plant macrofossils or pollen and spores (sporomorphs) alone. In such instances, interpretations may be limited by a lack of understanding of how accurately the fossil record of a particular plant, or group of plants, reflects the original standing vegetation. To explore this issue, the relative proportional representation of three botanical groups has been compared in the macrofossil and sporomorph fossil records across a Triassic–Jurassic (*c.*200Ma) boundary section in East Greenland. These groups are: 1) ferns, comprising all representatives of the class Filicopsida; 2) conifers and seed-ferns, comprising all representatives of the class Coniferopsida and the order Corystospermales; 3) monosulcate producers, comprising all representatives of the classes Cycadopsida, Ginkgopsida, Bennettitopsida and the order Peltaspermales. Ferns appear relatively over-represented in the sporomorph record, whereas monosulcate producers appear relatively under-represented in the sporomorph record. Conifers and seed-ferns appear relatively over-represented in the sporomorph record, although mass occurrences of *Stachyotaxus* and *Podozamites* leaves result in considerable relative over-representation of conifers and seed-ferns in the macrofossil record at certain horizons. The results of this study indicate that vegetation reconstructions based on a single fossil group may be misleading, and should be interpreted with caution.

High resolution $\delta^{13}C$ stratigraphy of the Homerian (Wenlock) of the English Midlands

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Closely spaced micrite samples from the Coalbrookdale, Much Wenlock Limestone (MWLF) and basal Elton formations were collected from limestone mines, a borehole core and surface outcrops in the Dudley area, West Midlands, and their stable carbon and oxygen isotope compositions determined. These units span the upper *lundgreni* to *ludensis* biozones, known times of significant global change in the carbon cycle. A positive carbon isotope excursion occurs in the Lower Quarried Limestone Member of the MWLF, with $\delta^{13}C$ rising to +5.54‰ VPDB, declining to +0.83‰ low in the Nodular Beds Member, and then rising again to +3.99‰. The positive excursions correlate with times of relative sea-level lows and the intervening dip with a relative sea-level high. The double-peaked curve resembles that documented previously, but our $\delta^{13}C$ values are consistently some 2‰ higher, according more closely with values obtained elsewhere. A feature not recorded before is that the lower positive excursion is punctuated by a short-lived negative excursion, associated with a minor flooding surface and spanning only 3 m of core, in which $\delta^{13}C$ values fall to -0.14‰ VPDB. $\delta^{18}O$ values fall sharply in this interval also, though in other parts of the section $\delta^{13}C$ and $\delta^{18}O$ values are not strongly correlated.

Trilobites from the Antiklinalbugt Formation (Early Ordovician) of North-East Greenland: revisiting old collections within the context of new litho and biostratigraphic studies

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The Antiklinalbugt Formation (Skullrockian/Gasconadian) comprises a succession of peritidal to subtidal carbonate sediments, deposited in a variety of shallow shelf settings during a transgressive–regressive megacycle. The fossils described here are from the two main areas where the formation crops out in North-East Greenland: Ella Ø and Albert Heim Bjerge. The formation has yielded brachiopods, gastropods, crinoids and graptolites, in addition to a diverse trilobite fauna. The trilobites include two new species of the dimeropygid *Tulepyge*, along with the hystricurids *Millardicurus* and *Hystricurus*. The occurrence of several species of the biostratigraphically-important nileid *Symphysurina* at various levels throughout the formation indicates that much of it lies within the *Symphysurina* Zone. Brachiopods are generally rare but apart from acrotretides and lingulides, species of *Eoorthis*, *Finkelnburgia* and *Polytoechia* occur, recording the widespread, low-diversity assemblage that characterized the Laurentian margins at this time. Conodonts show that the lower part of the Antiklinalbugt Formation belongs to the *Cordylodus intermedius* Zone and the upper part is constrained to the *Rossodus manitouensis* Zone. The agnostid *Micragnostus chiushuensis* is a rare element of the fauna,

as are *Lunacrania*, ?*Bellefontia*, *Clelandia* and ?*Mannschreekia*. The fauna has affinities with other macrofaunas from shallow shelf carbonates laid down along the margins of Laurentia during the Early Ordovician, including Utah and Oklahoma in the USA, western Newfoundland and Alberta in Canada, and northwest Greenland.

Do the ammonoids of the Upper Muschelkalk represent a 'species flock'?

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Epicontinental seas have been proposed as regions where 'species flocks' of ammonoids might evolve. Radiations of *Ceratites* in the Germanic Basin during the Upper Muschelkalk (Anisian–Ladinian) were investigated as a potential 'species flock'. Phylogenetic data and information on the number of occurrences, localities and variations in the amount of outcrop throughout the three subdivisions of the Upper Muschelkalk were combined to test this hypothesis.

The 'species flock' hypothesis receives little support from the phylogenetic results, which also cast doubt on Tethyan immigrants into the Muschelkalk Basin being the 'rootstock' for radiations, as many of the immigrants are relatively derived. However, it is still possible that partitioning of basin environments might be a significant factor in the speciation of *Ceratites*. Strong, positive correlations were observed between species-richness, number of occurrences and number of localities, and partial correlation revealed that the number of occurrences is the dominant factor. Measures of faunal similarity among localities remain more or less uniform throughout the three subintervals, indicating no strong evidence for partitioning of localities among lineages, despite increasing species-richness. Mechanisms other than immigration of single taxa and subsequent endemic radiation into different habitats must be explored to explain the species-richness of the Muschelkalk ammonoids.

Organic preservation of fossil musculature with ultracellular detail

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The very labile (decay-prone), non-biomineralised, tissues of organisms are rarely fossilised. Occurrences thereof are invaluable supplements to a body fossil record dominated by biomineralised tissues, which alone are extremely unrepresentative of diversity in modern and ancient ecosystems. Fossil examples of extremely labile tissues (*e.g.* muscle) that exhibit a high degree of morphological fidelity are almost invariably replicated in minerals such as calcium phosphate. There is no consensus as to whether such tissues can be preserved with similar morphological fidelity as organic remains, except when enclosed inside amber. Here we report fossilised musculature from a *ca.* 18 million-year-old

salamander from lacustrine sediments of Ribesalbes, Spain; the muscle is preserved organically, in three dimensions, and with the highest fidelity of morphological preservation yet documented from the fossil record. Preserved ultrastructural details include myofilaments, endomysium, layering within the sarcolemma, and endomysial circulatory vessels infilled with blood. Slight differences between the fossil tissues and their counterparts in extant amphibians reflect limited degradation during fossilisation. Our results provide unequivocal evidence that high-fidelity organic preservation of extremely labile tissues is not only feasible, but likely to be common. This is supported by the identification of similarly preserved tissues in the Eocene Grube Messel biota.

A diverse dinosaur track fauna from the Lower Cretaceous, Cedar Mountain Formation, San Juan County, Utah, USA

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A newly discovered tracksite in the Poison Strip Sandstone Member of the Cedar Mountain Formation represents a snapshot of a diverse Lower Cretaceous dinosaur fauna from southeastern Utah. The tracks were found at a construction site where the sandstone had been bulldozed and broken up. The majority of tracks were found as deep, well-preserved natural casts on the underside of the sandstone slabs. Sauropod tracks were found with pes lengths of 50–100 cm, and interestingly, three distinct shapes of manus tracks. Theropod tracks ranged in size from 3–60 cm, and ornithopods from 20–40 cm in length. In addition, a number of tracks are tentatively attributed to thyreophoreans. Dinosaur skeletal material from the Cedar Mountain Fm. is comprised of sauropods, small and large theropods, ankylosaurs, iguanodontids, and ceratopsians, clustered in two dinosaurian assemblages: a lower one, including fossils from the Poison Strip Sandstone, which shows affinities with the Morrison Formation and the early Cretaceous of Europe, and an upper assemblage that has greater affinities with the dinosaur faunas from the Cretaceous of Asia. This new trackfauna demonstrates the existence of a more diverse dinosaurian assemblage in the Poison Strip Member than what was previously documented by the skeletal record.

Geomuseum Faxe – a window to the Danian Sea

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Faxe Limestone Quarry is located about 70 km south of Copenhagen, Denmark, and contains a highly fossiliferous fossil coral reef from the Danian times, 63 mya. The fossil reef is the only known extensive coral reef from the Danian of Europe, where similar aged deposits consist of bryozoan limestone. Due to the lack of algae, the presences of abundant deep water taxa, and the fact that the nearest coastline was located approximately 150 Km to the east in Southern Sweden, it is interpreted as a deep-water reef at an estimated water depth of 200–400m. The diversity of animals is enormous, and gastropods alone are represented by more than 100 species. A newly built museum, right on the edge of the quarry, is set out to honour this fantastic locality and to serve as an eye opener to

encourage people to visit the quarry, as well as serve as a base for international scientific research. The museum is divided into a small historic exhibition that tells the cultural history of more than 900 years of quarrying in Faxe, and a large main exhibition that tells the story about the life in the Danian Sea. In addition to the exhibition, the museum houses an extensive research collection.

Upper Ordovician ostracods from carbonate lithofacies in southwest Scotland

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The Craighead Limestone Formation of southwest Scotland formed a carbonate platform on the eastern tropical margin of the Laurentia palaeocontinent during the Late Ordovician. It has yielded the most diverse and well-preserved ostracod fauna from the Scottish Ordovician succession, with some 25 species divisible into two distinct marine biotopes of shallow lagoon and deeper platform margin settings respectively. The ostracods show strong biogeographical links at species-level with Sandbian and early Katian faunas of North America, including *Krausella arcuata, Steusloffina cuneata, Monoceretella teres* and species of *Levisulculus* and *Platybolbina*. Many of the genera that characterise the Craighead Limestone Formation have origins in the Baltica palaeocontinent, suggesting enhanced migration of ostracod species from mid (*ca*. 30°S) to low latitudes in the late Sandbian and early Katian interval. These ostracods include typical Baltic-origin genera such as *Distobolbina*, *Kiesowia* and *Platybolbina*. Notable is the wide biogeographical occurrence of *Steusloffina cuneata*, extending from warm tropical Laurentia to cooler high-latitude Gondwana, a wide latitudinal range for a shelf-dwelling marine ostracod.

Small is beautiful: new investigations into Lower Devonian plant mesofossils and their *in situ* spores

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Much of our understanding of the anatomy of the earliest land plants comes from well-preserved charcoalified mesofossils. Whilst representing only a facet of early land vegetation, initial studies indicate that these minute axes with terminal sporangia continue to make a significant contribution to the understanding of biodiversity and the development of terrestrial ecosystems during the Lower Devonian. As well as exceptional anatomical preservation, many sporangia contain *in situ* spores, many of which represent new taxa (both cryptospore and trilete), whilst some have been recognised in the dispersed spore record, but have not previously been recorded *in situ*. A new investigation aims to obtain detailed morphological, anatomical and ultrastructural data on both the mesofossils (particularly the axes) and their *in situ* spores, predominately using SEM and TEM techniques. With this data it is hoped that the affinity of these mesofossils may be elucidated, and their taxonomic relationship with the early tracheophytes and bryophytes

can be explored. Recent evidence of highly-branched mesofossil sporophyte axes suggests that at least some of these minute plants may represent stem-group embryophytes with bryophytic characters.

Preservation of graptolites in the Lower and Upper Fezouata Formations (Tremadocian-Floian; Ordovician) near Zagora, southeastern Morocco

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Deposits encompassing the top of the Lower and the entire Upper Fezouata Formations near Zagora are becoming increasingly well known as a Konservat-Lagerstätte. As yet little work has been done on the taphonomy of the fauna. Understanding how classical fossils such as graptolites are preserved may provide insights into the preservation of less recalcitrant groups. At some localities multi-branched planktic graptolites are preserved with stipes at different levels within the rock, without the rhabdosome being broken. In order to preserve the three-dimensional form of the rhabdosome, burial must have occurred rapidly and in a thick layer but with only gentle transport, or the sediment must have been at least locally soupy. A variety of minerals are involved in graptolite preservation. In some graptolites, the stolon is three-dimensionally pyritised, which must have happened soon after burial, while the thecae are preserved as flattened outlines. Some specimens are entirely flattened, with the original organic periderm surviving only where protected by a mineral coating. The taphonomy of the graptolites shows that a variety of preservational styles operated in the Lower and Upper Fezouata Formations. Although there was some early mineralisation, other processes operated later in diagenesis, potentially confusing the taphonomic signal.

Testing tommotiids: The inside story of the brachiopod-stem

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The earliest skeletal animal remains in the fossil record are represented by the so-called 'small shelly faunas (or fossils)' (SSFs) of the early Cambrian. One group of SSFs, the tommotiids, are characterised by multi-unit phosphatic skeletons composed of small basal-internal accreted sclerites with variable morphologies. The discovery of articulated tommotiid scleritomes (Skovsted *et al.* 2008, 2009) and redescriptions of key tommotiid taxa have led to a compelling hypothesis of the acquisition of crown-brachiopod characters through a paraphyletic tommotiid stem. Using synchrotron radiation X-ray computed tomography (SRXTM), the microstructure, modes of growth and skeletal assembly of these enigmatic fossils have been decoded through the interrogation of complete submicron-resolution 3D models. The sclerite architecture of a spectrum of tommotiid genera, including *Eccentrotheca*, *Sunnaginia*, *Lapworthella*, *Camenella*, *Tannuolina* and *Micrina* are compared, along with the stem-brachiopod *Mickwitzia*, to investigate the acquisition of crown-brachiopod characters, such as shell-penetrating setae and the reduction of complexity towards a bi-membrate scleritome. These data are used to test a number

of questions pertinent to tommotiid phylogeny, including, the affinity of tannuolinids with stem-brachiopods; the validity of the 'camenellan' clade; and the role of irregular, disorganised, sclerites such as *Eccentrotheca* and *Sunnaginia*.

Biogeographic correlation of Scottish Lower Devonian vertebrates

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The northern Palaeozoic continent of Laurussia contained four of the recognised Lower Devonian fish 'realms' stretching from North America to the Baltic. Similarities of acanthodian taxa across these regions have been alluded to in the past but no direct work to correlate faunas outside continental Europe has been completed, due in part to lack of diagnostic morphological and histological characters for dermal hard tissues. Acanthodians are useful as they can be identified to species level, even from fragmentary remains. New evidence is now emerging from many years of work by the present authors, which encompasses a systematic taxonomic reassessment of all the Scottish Lower and Middle Devonian acanthodian fishes. This investigation utilises fresh material that was not previously available, and includes morphological and histological analysis of scales and fin spines. Comparison with acanthodian taxa from Canada, and the recent identification of a new cornuate from a rediscovered locality in the Scottish Midland Valley, are shedding light on potential migration patterns, and evolutionary origins of species, both in close proximity and widely distributed. Looking forward, other taxonomic correlations across Laurussia will be investigated, and new acanthodian species within the Scottish realm will be described.

Trace fossil assemblage associated with the end-Ordovician 'extinction' event, Llangranog, Dyfed

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The end-Ordovician crisis associated with the Gondwanan Glaciation is thought to have resulted in some 85% of marine species disappearing from the fossil record. Recently published work has shown that through much of the extinction event a substantial shallow water fauna remained, at least intermittently, active.

Contemporaneous deeper water ("*Nereites* facies") turbidites offer spectacular coastal exposure in and around Llangranog, Dyfed. Despite the absence of any significant body fossils these rocks also display a significant, again at least intermittently developed, ichnofaunal assemblage. That assemblage is described by way of a south to north transect through the study area.

Fossil Perspectives on the Evolution of Insect Diversity

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Comprising over half of described species, insects are a major component of terrestrial ecosystems. Part of understanding this diversity is a comprehensive appreciation of their fossil record, which spans ~400 million years. An updated dataset for the age-ranges of insect families in the fossil record is necessary to 1) provide minimum dates for major nodes on phylogenies; 2) analyse extinction and origination rates with respect to physical factors (*e.g.* mean temperature, atmospheric O_2 and CO_2 levels, global sea level, formation and breakup of supercontinents *etc.*) and biotic events (*e.g.* evolution of angiosperms); 3) analyse rates of cladogenesis between groups, with the possibility of identifying key innovations which have allowed increased diversity; and 4) use palaeolatitude data of first occurrences to re-test phylogenesis models based on the effects of latitudinal zonality.

A New Stalked Filter Feeder from the Burgess Shale

Lorna J. O'Brien and Jean-Bernard Caron
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A stalked, gregarious, filter-feeding animal is described from the S7 Burgess Shale site, Mount Stephen. It has a large calyx connected to a long, narrow stem terminating in a flattened disc or a small bulb. Over 700 specimens range from 50 to 250 mm in length and 16 to 59 mm in calyx width. The stem is composed of two layers: an inner rigid core surrounded by a soft deformable outer sheath. Internally, the calyx contains a sac-like stomach, followed by an intestinal tract that extends to the top of the calyx, terminating in a central opening representing the anus. The stomach is arranged over a rigid conical structure and surrounded by six radially symmetrical comb-like elements, each consisting of a central spine, from which two rows of tooth-like projections extend inwards, interpreted as the filter feeding apparatus. The calyx is enclosed by a flexible outer sheath which folds in around the comb-like elements. The biological affinities of the animal remain unclear. While a stalk and a calyx is present in several unrelated extant forms (*e.g.*, Cnidaria, Entoprocta, Ectoprocta) and other Burgess Shale animals (*i.e. Dinomischus*), the internal morphology is incomparable, and these animals are probably not directly related.

The Phylogeny of Aglaspidid Arthropods

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Aglaspidids are a group of poorly understood Lower Palaeozoic arthropods whose classification and affinities remain largely unresolved. This study comprises an extensive re-evaluation of aglaspidid taxonomy and phylogenetic affinities. Re-study of alleged aglaspidid-like arthropods from the Upper Ordovician Letná Formation (Czech Republic) allowed their reinterpretation as representatives of the Trilobita and Xiphosura. Material from the Upper Cambrian of Tasmania was described and recognized as a new genus of aglaspidid arthropod. A cladistic analysis indicates that Aglaspidida forms a clade, sister-taxa to *Emeraldella* + (*Sidneyia* + cheloniellids). Both clades form part of the mandibulate stem-lineage, along with Trilobitomorpha and Crustaceomorpha, adding support to recent phylogenetic hypotheses that rely on both palaeontological and developmental evidence.

The diagnosis of Aglaspidida is emended to include *Kwanyinaspis, Beckwithia, Kodymirus* and *Quasimodaspis*. The aglaspidid affinities of *Strabops, Paleomerus* and *Parapaleomerus* were not supported; strabopids form a distinct clade, but their exact phylogenetic position remains uncertain. Previous hypotheses for the placement of aglaspidids, xenopodians, cheloniellids and trilobitomorphs as part of the chelicerate stem-lineage can be explained through the widespread distribution of homoplastic characters amongst these taxa (*e.g.* a differentiated exopod lobe). A new systematic classification for aglaspidid arthropods is proposed based on the results of the analysis.

A new skeletal reconstruction reveals the phylogenetic affinities of the stratigraphically important conodont *Lochriea homopunctatus* (Ziegler)

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The conodont originally described as *Gnathodus commutatus homopunctatus* Zeigler 1962 is an important marker for the base of the Visèan (one of the three stages of the Mississippian Subsystem), and is used to correlate around the world. Despite its stratigraphic significance, the taxonomy and phylogeny of this conodont is confused. Originally erected as a subspecies of what is now *Locheria commutata*, it has since been referred to *Gnathodus*, *Paragnathodus*, *Protognathodus* and *Pseudognathodus*, with no sign of taxonomic consensus. These problems have arisen because of over-reliance on the morphology of only one part of the skeleton (the P_1 element) in determining evolutionary relationships and generic assignment. Here we present the first multielement skeletal reconstruction of this species, revealing that its affinities lie with *Lochriea*. Recognition of the apparatus of *Lochriea homopunctatus* has important implications for understanding the currently cryptic origins of the *Lochriea* lineage, species of which are used to correlate and define important stratigraphic boundaries in the Carboniferous.

Morphological evidences of the presence of dinoflagellates in Cambrian oceans

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RNA sequence analyses and the presence of biological markers of dinoflagellates (triaromatic dinosteroids) in the Neoproterozoic suggest an early origin for this group. Although there are several references reporting their presence in the Palaeozoic, all of them have recently been questioned and at present the first accepted dinoflagellates are Triassic. Abundant and well-preserved acritarchs of the Oville Formation (Middle Cambrian) in Northern Spain and the MacLean Brook Formation (Middle–Upper Cambrian) in Nova Scotia (Canada) indicate an important diversification of acritarch species with clear similarities with dinoflagellates. These species belong to the genera *Cristallinium*, *Vulcanisphaera* and *Stelliferidium*, all of which show evidence of paratabulation. The strongest evidence comes from the species *Stelliferidium magnum* and *S. albanii*, with forms representing the two distinct preservable stages of the life cycle of dinoflagellates: the encystment (cyst formation) and excystment stages, the later one with a detached polygonal archeopyle. The processes and archeopyle in both species show a close morphological similarity with those of dinoflagellate cysts, particularly with those of the Cretaceous species *Oligosphaeridium complex*. All these features support a close morphological

affinity between the above-mentioned acritarch genera and the dinoflagellates, and constitute clear evidence of their presence in Cambrian oceans.

Upper Cambrian acritarchs from the Comley area of Shropshire, England

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Palynological studies were undertaken on samples from three Upper Cambrian exposures in the Comley area of Shropshire, England, UK. Three diverse and abundant assemblages of acritarchs were revealed, containing 22 recognised species including one new species belonging to the genus *Sylvanidium*. All three assemblages contained stratigraphically significant species including *Leiofusa stoumonensis*, *Veryhachium dumontii* and *Dasydiacrodium caudatum* and one sample *Trunculumarium revinium*. They correlate with microfloral assemblages described from Random Island, eastern Newfoundland and are placed in the *Parabolina spinulosa* Trilobite Zone. This study demonstrates the potential of acritarchs to refine the stratigraphy of a classic English Cambrian locality.

Palaeontological investigation of the Bristol coal field: evidence for a critical period of global change

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At the Late Carboniferous (Westphalian–Stephanian) boundary a dramatic turnover event is evident in the floral record of the tropical Euramerica peat mires. Lycopsid diversity and abundance are severely reduced, and the more tolerant tree ferns became dominant. This is believed to coincide with the mires contracting to nearly half their pre-Stephanian size. The causes of this floral event are uncertain, but probably relate to substrates drying out due to tectonic uplift, that possibly also coincided with a period of global climate change. This study focuses on the much overlooked Upper Coal Measures of the Bristol coal field. A detailed palaeontological investigation has been undertaken on the youngest strata in the basin: this includes palynology (miospores and megaspores) and palaeobotany (including newly discovered leaf beds). This has enabled: 1) the strata to be securely age constrained, for the first time; 2) a detailed understanding of the nature and dynamics of the floral changes to be established.

Land cover in a warmer world: A global Late Miocene vegetation reconstruction

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Predicting the response of Earth's climate to greenhouse gas emissions using computer simulations is a major way of providing policy makers with the information they need to make society-wide decisions about the future climate and its impacts on civilisation. To test the predictive ability of these models requires the use of substantial databases of

palaeoclimatic data from periods in Earth history significantly different from the modern. The Miocene is considered a recent warm period in Earth history and provides a potential test-bed for global climate models.

To reconstruct climate a palaeobotanical database consistent with the BIOME4 mechanistic model of vegetation has been constructed for the Tortonian Stage (Late Miocene). This database combined with model output has been used to create a global vegetation reconstruction for the Tortonian. This reconstruction can now be used as future input for other modelling studies and the vegetation distribution corresponds to a warmer world. Provisional analysis of the reconstruction indicates that the tree line has migrated towards the poles with taiga forests above 79° North. Desert areas are greatly reduced and there is an expansion of tropical forests in the Indian sub-continent. Europe during the Tortonian has a predominantly warm-temperate evergreen broadleaf forest cover.

The Cambrian–Ordovician faunal transition in southern Kopet-Dagh, north-eastern Iran

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posters

The Cambrian–Ordovician boundary beds in the Kalat section of the southern Kopet-Dagh Range comprise a monotonous, predominantly siliciclastic succession deposited in an outer shelf environment. Autochthonous benthic faunas are dominated through the sequence by low diversity trilobite associations, including *Shumardia* and *Asaphellus inflatus*. A few taxa of rhynchonelliform and linguliform brachiopods are also present as minor components. A low diversity conodont fauna comprises only six taxa. In spite of the absence of the index conodont species *Iapetognathus fluctivagus*, the occurrence of *Cordylodus caseyi* in association with the graptolite *Rhabdinopora* aff. *socialis* forms a satisfactory criterion for relatively precise definition of the stratigraphical position of the lower Ordovician System boundary in the section. The Tremadocian trilobite faunas of northern Iran show close similarity to contemporaneous trilobite faunas of South China, where the *Dactylocephalus dactyloides–Asaphellus inflatus* Biozone is recognised as the lowermost trilobite-based biostratigraphical unit in the Ordovician. However, in the Simeh-Kuh section of the eastern Alborz Mountains, the first appearance of the Ordovician trilobites characteristic of the *Asaphellus inflatus–Dactylocephalus* Association correlates closely with a sharp facies change from a shallow-shelf, predominantly carbonate sequence characteristic of the Middle to Upper Cambrian Mila Formation to the fine siliciclastic sediments of the lower part of the Lashkarak Formation, which accumulated within an outer shelf environment.

Not such an armless echinoderm after all

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Dehmicystis globulus is an enigmatic solute echinoderm from the Lower Devonian Hunsrück Slate, Germany. To date, only one or two specimens have been described; these are highly incomplete and do not preserve important characters of the group, for example ambulacra. We present three new individuals on the same slab of slate, two of which possess a single anterior ambulacrum. The distal extremity of the posterior appendage is strongly bent in one specimen, suggesting that, like other solutes, *Dehmicystis* attached itself to hard substrates using a muscular stalk. Our new material offers important insights into the anatomy and mode of life of *Dehmicystis* and solutes in general.

Use of morphometrics in taxonomy – example of Devonian *Palmatolepis* conodonts

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Palmatolepis conodont elements are good stratigraphical markers during the Devonian. It is therefore essential to have a good knowledge of the systematic of this genus. We propose here to use morphometric tools to test hypotheses relative to conodont taxonomy. We focus on one Famennian sample from northern Thailand that presents the interest of containing many conodonts of the genus *Palmatolepis*. We propose to test the validity of some of the taxonomic assignations of the genus *Palmatolepis*, *via* an outline analysis, *i.e.* by an elliptic Fourier transform and a principal component analysis. The species *Pa. adamantea*, *Pa. delicatula*, *Pa. mystica*, *Pa. regularis* and *Pa. tenuipunctata* have been studied more particularly. These species are clearly distinguished with the geometric morphometric. Moreover, the existence of several morphotypes has been established for some species (*Pa. regularis*, *Pa. delicatula*), and the existence of *Pa. angusta* as a distinct species from *Pa. regularis* has been confirmed. But the strong intra- and inter-specific relationships between the species considered do not allow going further in the systematic interpretations. Nevertheless, this method is a useful complementary tool to discriminate conodont morphotypes and species and to solve the interrogations regarding some species.

Taphonomy of amphibians from the Carboniferous exceptional fauna of Nyrany, Czech Republic

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The Carboniferous vertebrate fauna from Nyrany in the Czech Republic includes both semi-aquatic and terrestrial components. Isolated skeletal elements are common, indicating

extensive disarticulation of taxa during, or before, transport to the site of deposition. Critically, however, the same lithologies also yield numerous partially disarticulated skeletons. Their disarticulation occurred after deposition, primarily via explosive rupture of the body following the build up of decay gases internally. There is, however, also a phylogenetic control on the physical taphonomy of the vertebrate taxa from this fauna. Elongate taxa (the 'snake-like' Aistopoda, and *Scincosaurus crassus*) illustrate unusual preservation of their tails. In otherwise highly articulated specimens, vertebrae in the tail occur separated, consistent with extension, and/or show displacement generated by compression parallel to the tail axis. These features are accompanied by curvature of the tail, although the trunk vertebrae remain in a straight, or only slightly curved, line. The phenomenon is attributed to the tail having curved upwards into the water column during the initial stages of decay while the anterior of the specimen remained on the sediment–water interface. This flexure of the tail generated the compressional displacements. Separation between successive or short lengths of vertebrae occurred upon collapse of the tail following further decay.

Reinvestigation of the actinopterygian fish *Birgeria stensioei* from the Middle Triassic of Monte San Giorgio (southern Switzerland) and Besano (northern Italy)

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The two previous descriptions of *Birgeria stensioei* (Birgeriidae, Actinopterygii) from the Middle Triassic of Monte San Giorgio (Canton Ticino, Switzerland) were based on a few fragmentary remains or only a single specimen. Here we present the first study that is based on multiple specimens of this basal ray-finned fish. The 67 investigated specimens reveal new information at species and genus level. *B. stensioei* most obviously differs from the other species of the genus *Birgeria* in the arrangement of the pterygiophores of the dorsal fin. While usually two series of pterygiophores are present throughout the dorsal fin base, only one series exists in the anterior part of the dorsal fin base of *B. stensioei*. Furthermore the caudal peduncle and the caudal fin lobes are elongate. The specialized dorsal fin base and caudal fin indicate that propulsion of *B. stensioei* might have been more advanced compared to that of the other species of *Birgeria*. *B. stensioei* is also distinguished from most other species of *Birgeria* by the degree of ossification of the brain case and the palatoquadrate. A dermohyal is developed in *B. stensioei* and this bone is probably also present in the other species of *Birgeria*.

The evolutionary origin of teeth: do placoderms have teeth?

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It has long been held that teeth evolved in concert with jaws and that, in combination, these key innovations underpinned an adaptive radiation of jawed vertebrates. This evolutionary scenario has been confronted recently with the observation that the earliest members of the principal lineages of jawed vertebrates lack teeth. Focal to the controversy is the condition in the earliest jawed vertebrates, the placoderms.

Using synchroton X-ray tomographic microscopy we characterised the ontogenetic development of jaw structure in the basal antiarch placoderm *Bothriolepis* and the derived arthrodire *Compagopiscis*. *Bothriolepis* has organized and patterned denticles, lacking regular dentine, with large cavities under the denticle; while it has tooth-like structures performing a tooth function, these structures share only some similarities to the teeth of crown-gnathostomes. The tooth-like structures of *Compagopiscis* are composed of orthodentine, a pulp cavity, patterned and organized development, and also functioned as teeth; they fulfil all typological definitions of a gnathostome tooth.

If *Bothriolepis* is representative of antiarchs, if antiarchs are basal placoderms, and if placoderms are paraphyletic stem-gnathostomes, then these data indicate that teeth evolved gradually. Jawed vertebrates primitively had tooth-like structures formed from condensations of bone on the jaw margin and teeth proper evolved through co-option of denticles to the jaw margin. The gnathostome tooth-condition was established in arthrodires long before the radiation of crown-gnathostomes, supporting the view that teeth evolved just once.

Functional analysis of Lower Cambrian eye systems – and its relevance for interpretation of palaeoecology

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The Lower Cambrian Chengjiang Lagerstätte is one of the most famous of all Lagerstätten, with excellently preserved fossils. More than 1,400 species have been described during more than 35 years of successful collection. The body plans typical of that time may continue an evolutionary scenario with its origins hidden in the Precambrian, and many related forms are still represented in the Middle Cambrian of the Burgess Shale. Although the Chengjiang fossils are flattened, their exquisite preservation allows the detailed analysis of such features as cuticular structures and especially even of the morphology of eyes. Many of the different kinds of eye systems known in Recent animals are already present in the Chengjiang fauna. The arthropods that bore these eyes were all adapted to particular life habitats, while the design of visual systems is conditioned by the availability of light and the need for acute vision. All visual systems have to obey the same physical rules in the same way, and an analysis of the structure of fossilised eyes – in comparision to those of marine arthropods living today – may reveal how, and under which conditions, the now fossilised visual organs may have worked. The result of the investigations presented here is that some of the Lower Cambrian arthropods of Chengjiang Fauna show 'experimental' designs, which are hardly bettered at the present time; others may be confidently assigned to a life habitat at a water depth of ~120m, which is consistent with the geological interpretation of the Kunming area during the early Cambrian.

The analysis of the stalked eyes of *Leanchoilia*, which was thought for a long time to be blind, has shown that the acuity of the eye is far too low to support any idea that this animal was an active free-swimming predator, finding its prey with its eyes. Such optical tracking of prey, however, should have been possible for *Anomalocaris,* known as the greatest predator of the Cambrian. The species investigated here swam with its bulbous eyes laterally stretched out to scan the world below. The quality of the eye is high, but not like that of eagles or other predators. These eyes could have been used in predation, but as

well to look for algal meadows or other attractive places for feeding. As with these species, a functional analysis and a discussion of the relevance of these functions to ecology are introduced also for several other Chengjiang arthropods in this presentation.

Description, taphonomy and phylogenetic implications of a new Jurassic turtle from Spain

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Turtles originated in the Triassic and began diversifying in the Late Jurassic. However, Jurassic turtle fossils are comparatively rare, making phylogenetic analysis of the relationships between groups at this important time in turtle evolution difficult. Any turtle remains from this period are therefore significant. This research focuses on preparing and describing a new Upper Oxfordian turtle from the Betic Cordillera in southern Spain. Taxonomic assessment places it basally within the Eucryptodira, as a member of the genus *Plesiochelys*. This lends further support to the hypothesis that basal cryptodiran lineages established rapidly following the evolution of Testudines in the Late Jurassic. The specimen is an important addition to our knowledge of basal Eucryptodires, representing a new species from the first group to fully adapt to the marine environment: the Plesiochelyidae. These turtles form the sister group to all other Eucryptodires, and therefore convergently adapted to the marine realm prior to the Chelonioidea, or true marine turtles, which appeared in the Cretaceous. The taphonomy of this specimen is also of interest since it is the only known vertebrate from this heavily sampled locality. Thin section and scanning electron microscopy data reveal new information on bone histology and possible bacterial engagement in preservation.

Nectocaris, a cephalopod-like predator from the Burgess Shale

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91 new specimens from the Burgess Shale permit a re-interpretation of *Nectocaris pteryx* (= *Vetustovermis* Glaessner), a creature originally described with arthropod-like and chordate-like characters, on the basis of one obliquely preserved specimen. The predatory animal had a cephalic 'nozzle' connected to a large body cavity. Upon entering this cavity through two anterior openings, water passed through a pair of internal gills into a central canal, and was subsequently exhaled through the flexible nozzle. This exhalent flow would have produced a jet of water that could be used in propulsion. This system of organs is strongly reminiscent of the modern cephalopods, and *Nectocaris* shares further characters with this group: it possesses the earliest known camera-type eyes, and a pair of long, flexible tentacles (probably used to manipulate prey). The currently accepted theory of cephalopod evolution suggests a benthic chambered monoplacophoran-like ancestor, which became buoyant and then nektonic. *Nectocaris*, which extends the record of cephalopod-like organisms from the Late to Early Cambrian, does not resemble the ancestral cephalopod that such a model would predict.

Late Tremadoc (Early Ordovician) conodonts from the Bjørkåsholmen Formation, Vestfossen, Oslo Region, Norway

Peter Spøer and Jan Audun Rasmussen

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The Tremadoc Bjørkåsholmen Formation from Vestfossen, situated within the Sandsvær-Eiker district, Oslo Region, Norway, yielded a thermally altered but well-preserved conodont fauna. At this locality the Bjørkåsholmen Formation is approximately 1.2 m thick and consists of limestone beds and nodules with interbedded, thin shale deposits. Glauconite is common within the upper part of the formation. The diverse conodont fauna is dominated by *Paroistodus numarcuatus*, *Paltodus deltifer*, *Drepanoistodus* cf. *forceps*. *Drepanodus arcuatus* and *Decoriconus peselephantis*, among others, occur in smaller numbers together with fragile, wide-based platform elements related to forms previously documented from Bed 8, Cow Head Group, western Newfoundland. The fauna characterizes the Late Tremadoc *Paltodus deltifer* Zone.

Joining the brachiopod stem? – A new bivalved organism from the lower Cambrian of Nevada

Michael Streng

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The stem-group brachiopod *Mickwitzia* is a conspicuous and common member of the lower Cambrian fauna of the Montezuman Range in Nevada, USA. It is most abundant in the upper *Nevadella* zone, but is also found in older strata of the lower *Nevadella* and *Fallotaspis* zones. The genus *Mickwitzia* is distinguished by a unique shell structure that is characterized by an abundance of canals penetrating its phosphatic shell perpendicularly. Recent re-study of the specimens of *Mickwitzia* from Nevada revealed several specimens of a potential new organism, apparently confined to the lower *Nevadella* zone. It is similar to *Mickwitzia*, not only in its size and circular outline, but also in its external shell ornamentation, which is typified by a dense reticulate pattern of radial and concentric ridges. Unlike *Mickwitzia*, it has a poorly mineralized (organic?) shell and completely lacks shell-penetrating canals. One of the specimens is preserved in a presumed bivalved state revealing a centrally situated apex in both of the valves. The two valves are indistinguishable. Size, shape and ornamentation of the new organism seem to favour an interpretation as a stem-group brachiopod close to *Mickwizia*. However, the absence of other brachiopod-like features (*e.g.*, setae, interarea) in combination with a potentially non-mineralized shell might also suggest a comparison with the dorsal and ventral disc of the problematic eldoniids.

Using microfossils to provenance the materials for Roman Mosaics: examples from Leicester and Silchester

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The use of late Cretaceous chalks in Roman mosaics is widespread across England. The white and off-white tesserae are used particularly to pick out patterned designs, but they are also used as backgrounds to pictorial representations. Determining the provenance of the chalk as a building stone helps to resolve questions about the origin, manufacture and transportation of chalk tesserae and thus shed light on the mosaic industry and its organisation at different times of Roman Britain. One tool for provenancing the source of this building stone is the microfossil signature contained within the tesserae. Analyses recently carried out on foraminifera recovered from tesserae from the Roman town of Calleva Atrebatum, modern Silchester, suggest that the source-rock originated in the Dorchester–Swanage area, and that the late Campanian Chalk was transported some 100 km from the south-west. The microfossil signature is now being used to characterise tesserae from Ratae Corieltavorum, Roman Leicester, which contain foraminifera characteristic of chalk strata of eastern England.

New insights into the nature of Neoproterozoic–Early Palaeozoic organic-walled palynomorphs by application of laser Raman micro-spectroscopy

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Proterozoic and Palaeozoic organic walled microfossils (palynomorphs) comprise a wide range of organisms (*e.g.*, oceanic photosynthetic microplankton, microzooplankton, and microscopic spores from earliest land plants), which can be used to characterize important evolutionary events in Earth's biosphere. Classical morphological comparative analytical methods are limited to those cases in which direct comparisons with extant organisms are available, but in many instances the biological affinities of pre-Devonian palynomorphs remain unknown. Recently, new techniques based on microchemical analysis of individual organic-walled microfossils demonstrated their potential for elucidating the cellular anatomy, composition and mode of preservation of microfossils, thus offering new insights into their palaeobiology. In this study Laser Raman micro-spectroscopy was applied to a range of exceptionally well-preserved palynomorphs of late Neoproterozoic to early Devonian age, in order to better characterize their chemical composition. Raman spectra were successfully obtained from the studied palynomorphs; all showed characteristic bands attributable to C=C stretching for polycyclic aromatic compounds and contributions from CH2/CH3 bending. Interestingly, younger (Devonian) *Tasmanites* evidenced presence of a C=O moiety in their spectra. Not only these results elucidate palynomorphs' wall composition, but in principle the presence/position/intensity of the spectral bands can be exploited in future analysis for identification purposes.

Notification is given of the 2009 Annual General Meeting

This will be held at the University of Birmingham on 14th December 2009, at the end of the first day of scientific sessions in the 53rd Annual Meeting. Please note that other items may be added to the agenda following the October Council meeting.

Agenda

Apologies for absence

Minutes of the 52nd AGM, University of Glasgow

Annual Report for 2008 (published in Newsletter 71)

Accounts and Balance Sheet for 2008 (published in Newsletter 71)

Election of Council and vote of thanks to retiring members

Palaeontological Association Awards

Annual address

H. A. Armstrong
Secretary

DRAFT AGM MINUTES 2008

Minutes of the Annual General Meeting held on Saturday, 20th December 2008 at the University of Glasgow.

Apologies for absence: None reported

1. **Trustees Annual Report for 2008.** Agreed, proposed by Prof. I. Rolfe and seconded by Prof. J. Callomon.
2. **Accounts and Balance Sheet for 2008.** Proposed by Prof. Sevastopoulo and seconded by Prof. Hallam, the accounts were agreed by unanimous vote of the meeting.
3. **Increase in Subscriptions.** In view of the projected more difficult financial circumstances Prof. Cope recommended subscriptions from 2010 should be at the following levels: Student Membership £10; Ordinary Membership £36; Retired Membership £18. The recommendations were proposed by Prof. Sevastopoulo and seconded by Prof. Smith. The Annual Report was agreed by unanimous vote of the meeting.
4. **Election of Council and vote of thanks to retiring members.**
   Prof. M. Bassett extended a vote of thanks to the retiring members of Council.

   The following members of the Association were elected to serve on Council: *President:* Prof. R. J. Aldridge; *Vice Presidents:* Prof. N. Macleod, Dr Thomas Servais; *Treasurer:* Prof. J. C. W. Cope; *Secretary:* Dr H. A. Armstrong; *Chair of Publications Board:* Prof. M. P. Smith; *Editor Trustees:* Dr P. J. Orr, Dr P. C. J. Donoghue; *Book Review Editor:* Dr C. Jeffrey-Abt; *Publicity:* Dr M. A. Purnell; *Newsletter Reporter:* Dr A. McGowan; *Newsletter Editor:* Dr R. J. Twitchett; *Web Officer:* Dr M. Sutton; *Ordinary Members:* Mr W. Fone, Prof. S. Donovan, Dr J. A. Rasmussen, Dr C. Underhill, Dr E. Rayfield, Dr C. Buttler, Dr D. Schmidt

   Drs Harrington and Vandenbrouche were co-opted as Annual Meeting organisers for 2009 and 2010 respectively. It was agreed Prof. Harper would be co-opted as the IPA representative, and would when necessary attend Council meetings to report on IPC3 2010 planning progress.
   Prof. R. J. Aldridge extended a vote of thanks to Prof. M. Bassett, the retiring President.

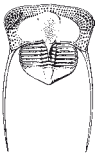
5. Association Awards

The following awards were made:

- Lapworth Medal to Prof. C. H. Holland (Trinity College Dublin)
- President's Medal to Dr P. Upchurch (Natural History Museum)
- Hodson Award to Dr B. Wade (Texas A&M)
- Mary Anning award to Mr D. J. Ward
- Honorary Life membership was awarded to Sir Peter Crane.

The Annual Address entitled "The emergence of tetrapods: how far have we come in the last twenty years and where can we go in the next?" was given by Prof. J. Clack (University of Cambridge).

H. A. Armstrong
Secretary



The Palaeontological Association Trustees Annual Report 2008 (Draft)

Nature of the Association. The Palaeontological Association is a Charity registered in England, 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 Wales, Aberystwyth SY23 3DB, Wales, UK.

Trustees. The following members were elected to serve as trustees at the AGM on 17th December 2007: President: Prof. M. G. Bassett; Vice-Presidents: Prof. N. Macleod, Dr C. H. Wellman; Treasurer: Prof. J. C. W. Cope; Secretary: Dr H. A. Armstrong; Chairman of the Publications Board: Prof. D. A. T. Harper; Newsletter Editor: Dr R. J. Twitchett; Book Review Editor: Dr P. J. Orr; Newsletter Reporter: Dr A. McGowan; Internet Officer: Dr M. D. Sutton; Publicity Officer: Dr M. A. Purnell; Editor Trustees: Dr P. C. J. Donoghue, Prof. M. P. Smith (Secretary of the Publications Board); Other Members: Dr G. Budd, Prof. S. K. Donovan, Mr W. Fone, Dr C. Jeffery, Dr J. A. Rasmussen, Dr E. Rayfield, Dr T. Servais. Prof. M. Cusack organized the Annual meeting in Glasgow, 2008 and was co-opted to serve on Council for two years. The Executive Officer: Dr T. J. Palmer and Editor-in-Chief: Prof. D. J. Batten will continue to serve Council but are not trustees. Prof. R. J. Aldridge attended Council meetings as the President Elect.

Membership. Individual membership totalled 1,224 on 31st December 2008, an overall decrease of 45 over the 2007 figure. There were 742 Ordinary Members, a decrease of 11; 169 Retired and Honorary Members, an increase of 1; 313 Student Members, a decrease of 35. There were 108 Institutional Members in 2008, and 94 institutional subscribers to *Special Papers in Palaeontology*.

Professional Services. The Association's Bankers are NatWest Bank, 42 High Street, Sheffield. 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 Citi Quilter, St Helen's, The Undershaft, London EC3A 8BB.

Reserves. The Association holds reserves of £554,989 in General Funds. These reserves 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 £46,111 in Designated Funds which contribute interest towards the funding of grants-in-aid, the Sylvester-Bradley, Hodson Fund and Mary Anning awards. Funds carried forward to 2009 totalled £601,100. Following the recommendation of Citi Quilter it was agreed that the Association investment portfolio should contain up to 5% in hedge funds.

Finance. Total charitable expenditure for 2008 was £213,394. Total resources expended were £246,480. The Association continues its membership of the International Palaeontological Association and remains a Tier 1 sponsor of *Palaeontologica Electronica*. In view of the increasingly difficult international financial situation it was agreed at the AGM that the new subscriptions commencing 2010 should be: Ordinary Membership £36; Student Membership £10; Retired Membership £18.

Risk. The recent falls in capital values have not adversely affected the ability of the Association to continue with its current and future charitable activities. The transition to the new Editor in Chief had been relatively smooth and was made possible by a period of overlap with Prof. Batten. It is recognised that this might not always be the case in the future and succession planning for executive officers should be reviewed.

Charitable Activities.

The Association continues to increase its range and investment in charitable activities, whilst continuing to keep individual membership subscriptions low.

Grants. Ten applications had been received for the Palaeontological Association Research Grant and funds were awarded to Dr Porter (University of California, Santa Barbara) and to Dr Upchurch (University College London). 'Grants-in-aid' included financial support for postgraduate attendance at the IPC/IOBC meeting in Bonn; a symposium at the GSA annual meeting in Houston; travel for Prof. Peterson who has been invited to attend the EED meeting in Ghent and for a symposium on fossilized ontogenies at the same meeting. An award was made from the Jones Fenleigh Fund and from Association General Funds to support an Association symposium at the SVP meeting. In addition it was agreed £6,000 should be made available to support up to 20 members from outside North America to attend NAPC 2009. We have continued to provide funds to support student and speaker attendance at our own and international meetings.

Online activities. The online activities of the Association continue to expand. Electronic versions of *Special Papers in Palaeontology* were produced and abstracts from *Palaeontology* were scanned to allow online searching of back issues. New links have been made to national guidelines on fossil collecting and geo-diversity. The Association now hosts mirror sites for the PalaeoDatabase,

Palaeontologica Electronica and the EDNA fossil insect database. The Association continues to support the "Ask a Biologist" website.

Public meetings. Three public meetings were held in 2008, and the Association extends its thanks to the organisers and host institutions of these meetings.

52nd Annual Meeting was held on 18–21 December at University of Glasgow, Scotland. Prof Cusack, Dr Owen and Dr Clark organised the meeting with much local support. This meeting included a symposium on "Biominerals – the hard part of palaeontology" and comprised a programme of internationally recognised speakers. There were 250 attendees. The Annual Address entitled "The emergence of tetrapods: how far have we come in the last twenty years and where can we go in the next?" was given by Prof. J. Clack (University of Cambridge) and was attended by 250 people. The President's Award was made to Robert Sansom (University of Leicester). The Council Poster Prize was presented to Heather Birch (Cardiff University). The pre-conference field trip was to sites in the local Carboniferous.

British Science Festival, Palaeontological Association Symposium: the annual forum for presentations to the public and general scientists was "Climate Change in the past: the latest evidence from fossil plants and animals," organised by Dr Charlotte Jeffery-Abt and Prof. Jim Marshall (University of Liverpool).

Progressive Palaeontology was held at the University of Manchester on 29–31 May. The annual open meeting for presentations by research students was organised by Karl Bateson.

IPC3 2010. During the year the Association agreed to host this prestigious international meeting. The proposal included a consortium of Imperial College, the Natural History Museum, the TMS and Palaeontographical Society.

Publications. During the year Prof. Batten tendered his resignation and was replaced by Dr Stouge. Prof. Batten is duly thanked for all his hard work whilst in the post, in particular moving our journals to online publication. Publication of *Palaeontology* and *Special Papers in Palaeontology* is managed by Wiley Blackwell, who also make sales and manage distribution on behalf of the Association. Volume 51 of *Palaeontology*, comprising six issues, was published. *Special Papers in Palaeontology* 79, "Nautiloids before and during the origin of ammonoids in a Siluro–Devonian section in Tafilalt, Anti-Atlas, Morocco" by B. Kroeger, and *Special Papers in Palaeontology 80*, "Early Jurassic pterosaur *Dorygnathus banthensis* (Theodori, 1830) and The early Jurassic pterosaur *Campylognathoides* Strand, 1928" by K. Padian, were published during the year.

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

Publicity. The Association continues to promote palaeontology and its allied sciences through its website and press releases to the national press, 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 Prof. C. H. Holland (Trinity College Dublin). The President's Medal (new) 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 P. Upchurch (Natural History Museum). 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 B. Wade (Texas A & M). The Mary Anning award, for an

outstanding contribution by an amateur palaeontologist, was made to Mr D. J. Ward. Council also awards an undergraduate prize to each university department in which palaeontology is taught beyond Level 1. Honorary Life membership was awarded to Sir Peter Crane.

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. Bassett (Chair) and Dr Donoghue represented the Association. Dr Armstrong acted as the Association representative on the International Palaeontological Association. Sir Peter Crane gave, on behalf of the Association, a lecture on the Life of Hooker at Kew Gardens as part of the "Local Heroes" series, as part of the Geological Society of London bicentennial celebrations.

Increasingly the Association is a respondent in national consultation exercises. During the year the Association responded to requests for information from the HEFCE consultation on the Research Excellence Framework, the proposed closure of the MSc. Micropalaeontology course at University College, London and the future of the *Treatise on Invertebrate Paleontology*.

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. In 2009, a similar programme of public meetings and publications will be carried out. The 53rd Annual Meeting and Progressive Palaeontology will be held at the University of Birmingham. The Association will again sponsor a symposium at the British Science Festival.

Resources will be made available from General Funds to support the Association Research Grant, Grants-in-Aid, provided to carry out research into palaeontological subjects, to disseminate findings in print and at conferences, and to support the provision of palaeontological workshops. The Association will continue to recognise the contribution individuals have made to palaeontology and associated sciences through its awards.

Funds will be made available to develop the website further, aimed at encouraging outreach and improving the Governance of the Association. It is intended that one new *Field Guide to Fossils* will be published within the year.

It is recognised that the Association is now one of the premier international learned societies. During the forthcoming year mechanisms will be developed by which the Association can have a greater presence at international geological meetings. Hosting IPC3 2010 will be a significant undertaking for the Association and Trustees during 2009 and 2010.

Howard A. Armstrong
Secretary

Nominations For Council

At the AGM in December 2009, the following vacancies will occur on Council:

- President Elect
- Vice president
- Treasurer
- Newsletter Reporter

THE PALAEONTOLOGICAL ASSOCIATION Registered Charity No. 276369
STATEMENT OF FINANCIAL ACTIVITIES FOR THE YEAR ENDED 31st DECEMBER 2008

			General Funds	Designated Funds	TOTAL 2008	TOTAL 2007
Incoming Resources						
Incoming resources from generated funds						
Voluntary income	Subscriptions	66,376			66,376	61,688
	Donations	6,410		1,418	7,828	1,377
			72,786	1,418	74,204	63,065
Incoming resources from charitable activities						
Sales	*Palaeontology*	156,901				
	Special Papers	6,210				
	Offprints	1,123				
	Newsletters	300				
	Field Guides	2,813				
	Distribution	643				
			167,990	0	167,990	165,506
Investment income			19,231	2,068	21,299	20,958
TOTAL INCOMING RESOURCES			260,007	3,486	263,493	249,529
Resources expended						
Costs of generating funds						
… for voluntary income	Admin.	19,237				18,852
Investment management	Stockbroker	1,891				2,220
			21,128	0	21,128	21,072
Charitable activities						
Publications	Palaeontology	63,967				
	Special Papers	4,021				
	Offprints	1,164				
	Newsletters	15,033				
	Field Guides	0				
	Distribution	120				
	Marketing	2,530				
	Management	47,081				
	Total	133,916			133,916	154,632
Scientific Meetings & Costs		21,042			21,042	14,752
Grants and Awards		9,451		9,939	19,390	19,614
Research Grants		15,000			15,000	0
Admin. of charitable activities		24,046			24,046	23,550
			203,455	9,939	213,394	212,548
Governance costs	Examiner's fee	400				
	Trustee expenses	6,749				
	Administration	4,809				
			11,958	0	11,958	10,523
TOTAL RESOURCES EXPENDED			236,541	9,939	246,480	244,143
NET INCOMING RESOURCES			23,466	-6,453	17,013	5,386
INVESTMENT GAINS/LOSSES						
Realised loss		-1,488				
Unrealised loss		-75,075				
			-76,563		-76,563	4,337
NET MOVEMENT IN FUNDS			-53,097	-6,453	-59,550	9,723
FUNDS BROUGHT FORWARD			608,086	52,564	660,650	650,927
FUNDS CARRIED FORWARD			554,989	46,111	601,100	660,650

THE PALAEONTOLOGICAL ASSOCIATION Registered Charity No. 276369

BALANCE SHEET as at 31st DECEMBER 2008

2007 £				2008 £
	INVESTMENTS			
477,438	At market value			383,587
	CURRENT ASSETS			
162,995	Cash at Banks	216,682		
62,842	Sundry Debtors	77,959		
225,837	Total Current Assets		294,641	
	CURRENT LIABILITIES			
23,036	Subscriptions in Advance	26,732		
19,589	Sundry Creditors	50,396		
42,625	Total Current Liabilities		77,128	
183,212	NET CURRENT ASSETS			217,513
660,650	TOTAL ASSETS			601,100
	Represented by:			
608,086	GENERAL FUNDS			554,989
	DESIGNATED FUNDS			
14,421	Sylvester Bradley Fund		8,526	
21,649	Jones-Fenleigh Fund		22,175	
16,494	Hodson Fund		15,410	
52,564				46,111
660,650				601,100

Agreed and signed 11th March 2009
R.J. Aldridge, President
J.C.W. Cope, Hon. Treasurer
H.A. Armstrong, Hon. Secretary

Notes to the Financial Statements for the year ended 31st December 2008

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 financial statements have been prepared in accordance with the revised Statement of Recommended Practice applicable from 2005 and include the results of all the charity's operations, all of which are continuing. The incoming resources and resources expended have been analysed under the headings laid down in the new SORP and the comparative figures from 2005 have also been analysed on the new basis.

The effect of events relating to the year ended 31st December 2007 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 2007 and the results for the year ended on that date.

1.2 Fund Accounting

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

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

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

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

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

1.3 Incoming Resources

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

1.4 Resources Expended

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

Charitable expenditure is that which is incurred in furtherance of the charity's objectives. Administrative costs have been allocated to the various cost headings based upon 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.

2. Analysis of Financial Resources Expended

	Staff costs	Other costs	Total 2008	Total 2007
Generating Funds	13,860	7,268	21,128	21,072
Charitable activities	28,107	185,287	213,394	212,548
Governance	3,465	8,493	11,958	10,523
	45,432	201,048	246,480	244,143

3. Staff Costs

	Salary	National Insurance	Pension Contributions	Total 2008	Total 2007
Publications - 1 employee (2007 - 1)	8,888	913	982	10,783	32,048
Administration - 1 employee (2007 - 1)	27,660	2,852	4,137	34,649	32,064
	36,548	3,765	5,119	45,432	64,112

4. Trustees Remuneration and Expenses

Members of Council neither received nor waived any emoluments during the year (2007 – nil)
The total travelling expenses reimbursed to 20 Members of Council was £6,749 (2007 – £5,600)

5. Costs of Independent Examiner

	2008	2007
Examination of the accounts	400	350
Accountancy and payroll services	1,150	1,100
	1,550	1,450

6. Debtors

	2008	2007
Accrued income - receivable within one year	77,959	62,842

7. Creditors - falling due within one year

	2008	2007
Social Services costs	3,679	1,790
Accrued expenditure	46,717	17,799
	50,396	19,589

THE PALAEONTOLOGICAL ASSOCIATION Registered Charity No 276369
DESIGNATED FUNDS
STATEMENT OF FINANCIAL ACTIVITIES FOR THE YEAR ENDED 31st DECEMBER 2008

	Sylvester Bradley	Jones-Fenleigh	Hodson	TOTAL 2008	TOTAL 2007
Donations	744	674	0	1,418	1,377
Interest Received	567	852	649	2,068	2,341
TOTAL INCOMING RESOURCES	1,311	1,526	649	3,486	3,718
Grants made	7,206	1,000	1,733	9,939	11,381
NET SURPLUS / (DEFICIT)	-5,895	526	-1,084	-6,453	-7,663
FUNDS BROUGHT FORWARD	14,421	21,649	16,494	52,564	60,227
FUNDS CARRIED FORWARD	8,526	22,175	15,410	46,111	52,564

Independent Examiner's Report
on the Accounts of The Palaeontological Association
for the year ended 31st December 2008

Respective resonsibilities 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
- to state whether particular matters have come to my attention

Basis of independent examiner's statement

My examination was carried out in accordance with the General Directions given by the Charity Commissioners. An examination includes a review of the accounting records kept by the charity and a comparison of the accounts presented with those records. It also includes consideration of any unusual items or disclosures in the accounts and seeking explanations from the trustees concerning such matters. The procedures undertaken do not provide all the evidence that would be required in an audit and consequently 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: 13 May 2009

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