

**The  
Palaeontological  
Association**

**54th Annual Meeting  
17th–20th December  
2010**

***Ghent University***

**PROGRAMME  
and  
ABSTRACTS**





# The Palaeontological Association

## 54th Annual Meeting

### 17th–20th December 2010

Department of Geology and Soil  
Sciences, Ghent University (Belgium)

In collaboration with the Department  
Géosystèmes of the University of Lille 1  
(France), the University of Namur (Belgium) and  
the Royal Belgian Institute of Natural Sciences

The programme and abstracts for the 54th Annual Meeting of the Palaeontological Association are outlined after the following summary of the meeting.

#### *Venue*

The conference will take place at two of Ghent University's conference venues in the historical city centre of Ghent. The 'Aula' is the University's official ceremonial hall, and will be the venue for the palaeoclimate thematic symposium and reception on Friday (address: Volderstraat 9, 9000 Ghent). The second venue, 'Het Pand', is the University's official conference centre, and will be the site for the scientific sessions on Saturday and Sunday (address: Onderbergen 1, 9000 Ghent; see circulars for maps).

#### *Accommodation*

Delegates must make their own arrangements for accommodation. Rooms were reserved for the conference in a variety of hotels at a range of prices and within easy reach of the venues up until 30th October. Some likely will still be available in these establishments, although this can no longer be guaranteed. Rooms there and elsewhere can be booked using the links on the Annual Meeting pages on the Association's website (<<http://www.palass.org/>>). We also suggest using <<http://www.visitgent.be/>> to explore all further possibilities. **In the run-up to Christmas the city will be busy during the weekends so we suggest you arrange accommodation early.**

## Travel

For all travel information, we refer you to the Annual Meeting pages on the Palaeontological Association website (<<http://www.palass.org/>>).

From neighbouring countries, it is probably most convenient to take a high-speed train to Brussels. Ghent is on the crossroads of the international lines London–Brussels–Köln and Paris–Lille–Antwerpen–Amsterdam. Eurostar connects London St. Pancras to Brussels South Station in just under two hours; from Brussels South, take the train to Ghent St.-Pieters railway station (about 30 minutes). When you are flying to Belgium, we recommend flying into Brussels Airport (Zaventem). Many (European) airlines fly directly into Belgium's main airport and SN Brussels Airlines probably has one of the most frequent flight schedules. From the airport, we suggest taking the train to Ghent St.-Pieters railway station (allow one hour for the journey). For international transport, we recommend booking early, as planes and trains usually get busy close to Christmas.

## Registration at the conference

Registration on Friday 17th December will take place in the Aula (Volderstraat 9). The registration desk will be open from 13:00 to 18:30. Registration on Saturday 18th and Sunday 19th December will be in 'het Pand' (Onderbergen 1), where the registration desk will be open from 08:30 (Saturday) or 09:00 (Sunday) until 17:00.

## Symposium

A special symposium entitled “Biological proxies in climate modelling, or *why palaeontologists and climate modellers should be thick as thieves*”, will take place in the main lecture theatre of the Aula, beginning at 13:45 on Friday 17th December. This will be followed by a drinks reception in the same building, commencing at 18:00.

This symposium will document major steps in the evolution of Phanerozoic climate, its links to biotic change, and the ways in which these climates can be tracked by fossil proxies and simulated by advanced numerical computer models. It will showcase the importance of using (mainly fossil but potentially also other) proxy data to build and ground-truth these climate models. Sophisticated numerical climate models are nowadays at the forefront of climate change studies, but it remains essential to evaluate the robustness of the output produced by such models through comparison to palaeoclimate proxies, such as synthesised (micro)fossil data (which are especially important for deep-time applications). With this symposium, we seek to promote further integration of geological and numerical approaches to facilitate the development of comprehensive reconstructions of Earth's past and future climate. We have approached climate modellers, palaeoclimatologists and palaeontologists to give synthesis papers on complementary endeavours or integrated projects. The main themes that will be considered are: (1) Data-model comparisons, (2) Modelling Phanerozoic climates with General Circulation Models; (3) Climate events, extinction and recovery; (4) Large-scale Icehouse to Greenhouse transitions and their control mechanisms; (5) Deep-time warm periods and how they can aid our understanding of Cenozoic and recent climate change, and of the impact of future warming; (6) new proxies for deep-time climate.

## Oral and poster contributions

All oral and poster presentations will take place in 'het Pand'. At the conference, each poster will be assigned a poster board. Posters will be available for viewing throughout the conference and there will be a dedicated poster session from 9:00 to 10:30 on Sunday 19th December.

## Annual Address

The annual address will be given at 17:15 on Saturday 18th December at 'het Pand' by Professor Andrew Gale on “Ancient origin of the deep sea fauna: new evidence from the fossil record”.

## Drinks Reception & Annual Dinner

There will be a drinks reception followed by the Annual Dinner in St. Peter's Abbey (St. Peter's Square, Ghent) on Saturday 18th December. The drinks reception will commence at 19:00 and the dinner at 20:00. Afterwards, delegates will have the opportunity to try our finest Belgian beers in the Abbey's crypt bar.

## Field excursion

The field excursion will leave Ghent centre early in the morning of Monday 20th December. Participants should assemble at the main entrance of 'Het Pand' at 07:40 from where we will guide you to the bus stop (a 1 km walk), or directly at the bus stop “Bijlokekaa” at 08:00 (K&R2 – see circular for directions). During the morning and early afternoon we will visit two quarries in the Mons Basin of South Belgium. Field guides will be Johan Yans (University of Namur) and Jacques Verniers (Ghent University). We will then drive to Brussels and visit the Royal Belgian Institute of Natural Sciences, where the famous *Iguanodon* specimens of Bernissart are on display. We will also see some of the spectacular vertebrate finds of the Messel site. The visit will end around 17:30–18:00. Participants can then choose to be dropped off at the railway station in Brussels (Brussels South Station, and from there take high speed trains – Eurostar, Thalys – home, or a local train to the airport), or can choose to stay on the bus that will return to Ghent.

## Acknowledgements

We would like to express our appreciation to the following who provided generous financial support: Wiley-Blackwell, Taylor & Francis, Cambridge University Press, Carl Zeiss NV – Belgium, the Research Foundation Flanders (FWO-Flanders), and the Faculty of Sciences of Ghent University.

**Thijs Vandenbroucke, Stephen Louwye and Jacques Verniers**

# Schedule of events and timetable for presentations

## Friday 17th December 2010

### *Thematic Symposium: “Biological proxies in climate modelling”*

The meeting will take place in the main lecture hall of the ‘Aula’, which is the University’s main ceremonial hall. The address is ‘Volderstraat 9, Gent’; access through the double doors at the right hand side of the main entrance. Registration will also take place at the ‘Aula’, 13:00-18:30. The welcome reception will be at the same address, in the ‘peristilium’ of the same building, just outside the lecture theatre.

Chair: Mark Williams

- 13:45 **Introductory Remarks**
- 14:00 **Biological proxies, sea level, and stable isotope geochemistry: towards an understanding of Silurian climate**  
Axel Munnecke
- 14:30 **The Early Palaeozoic climatic trend**  
Yves Godd ris, Elise Nardin, Yannick Donnadieu, Guillaume Le Hir, Ron C. Blakey, Emmanuelle Puc eat and Marcus Aretz
- 15:00 **Comparison of 4 state-of-the-art climate models with Eocene palaeodata – can any model get it ‘right’?**  
Daniel J. Lunt, Malte Heinemann, Allegra N. LeGrande, Arne Winguth and Tom Dunkley Jones
- 15:30 **Vegetation of a warmer world: Global biome reconstruction and data-model comparison for the late Neogene**  
Ulrich Salzmann, Matthew Pound, Alan M. Haywood, Daniel J. Lunt, James B. Riding and Harry Dowsett
- 16:00 Coffee Break
- 16:30 **The Mid-Piacenzian Warm period: Integrating Biological Proxies and Climate Models**  
Alan M. Haywood, Harry J. Dowsett, Daniel J. Lunt, Ulrich Salzmann, Daniel J. Hill and Aisling M. Dolan
- 17:00 **Dinoflagellate cysts and foraminiferal geochemistry: a new combined proxy for environmental change in the Pliocene and Early Pleistocene of the North Atlantic Ocean**  
Martin J. Head, Stijn De Schepper, Jeroen Groeneveld, Eva I. Fischer and Jan Hennissen
- 17:30 **Biological proxies for reconstructing Holocene climate and ecosystem dynamics**  
Dirk Verschuren
- 18:00 Welcome reception at the ‘Aula’ (ends c. 19:30)

## Saturday 18th December

### *Oral Presentations*

\* Candidates for the President’s Award are marked with an asterisk

The meeting will take place in ‘Het Pand’ at Ghent University (Onderbergen 1, see circular for directions), where registration will also take place, 08:30-17:00. Posters will be on display in the same venue.

8:45 **Introductory Remarks**

### Session 1

- 9:00 **Chelicerate tagmosis: inferred mechanisms of development in extinct taxa.**  
\*Joanna M. Wolfe and David A. Legg
- 9:15 **Look, no arms race: predator-prey interactions between durophagous fishes and camerate crinoids following the Hangenberg mass extinction.**  
\*Lauren Cole Sallan, Thomas W. Kammer, William I. Ausich and Lewis A. Cook
- 9:30 **Holocene morphospace expansion of *Bellamyia* gastropods from Lake Malawi as potential evidence for punctuated morphological change.**  
\*Bert Van Bocxlaer
- 9:45 **Computational simulation of macroevolution.**  
Russell J. Garwood and Mark D. Sutton
- 10:00 **Experimental taphonomy of *Xenopus laevis* tadpoles.**  
Ragna Redelstorff and Patrick J. Orr
- 10:15 **Morphological decay experiments and the fossil record of non-biomineralized vertebrates.**  
Robert S. Sansom, Sarah E. Gabbott and Mark A. Purnell
- 10:30 Coffee and Posters

### Session 2

- 11:00 **New insights into the Triassic ammonoid radiation from time-sliced cladistic analyses.**  
Alistair J. McGowan
- 11:15 **The Hunsr ck Slate, the origin of ammonoids, and evolutionary changes in development.**  
\*Kenneth De Baets, Christian Klug and Dieter Korn
- 11:30 **Devonian pearls and ammonoid-endoparasite co-evolution.**  
Christian Klug, Kenneth De Baets and Dieter Korn
- 11:45 **Belemnite sclerochronology: a new technique for understanding ontogeny and ecology.**  
\*Elizabeth V. Nunn, Gregory D. Price and Bernd R. Sch ne

12:00 **Cameral deposits in a sublethally damaged Pennsylvanian *Pseudorthoceras* sp. from the Buckhorn Asphalt Lagerstätte in southern Oklahoma, USA.**

Barbara Seuß, Royal H. Mapes, Christian Klug and Alexander Nützel

12:15 Lunch

### Session 3

13:30 **Ecological impacts of global warming: Measuring marine microfossil community change during past episodes of climate change.**

Amelinda Webb

13:45 **Was the Carboniferous ostracod freshwater colonization event driven by climate change?**

\*Carys E. Bennett

14:00 **Ice in a greenhouse world? Late Cretaceous climates of Antarctica.**

Jane Francis, Vanessa Bowman, Alan Haywood, Stephen Hunter, James Riding, Rob Raiswell, Peter Frost, Duncan Pirrie and James Marshall

14:15 **Response of marine biota to rapid global warming during the Paleocene-Eocene thermal maximum.**

Robert P. Speijer

14:30 **Neritic foraminiferal responses to a runaway greenhouse during the PETM.**

Peter Stassen, Ellen Thomas, Etienne Steurbaut and Robert P. Speijer

14:45 **Pliocene climate of the southern North Sea Basin: a sclerochronological approach.**

Annemarie Valentine, Andrew Johnson, Melanie Leng and Peter Balson

15:00 Coffee and Posters

### Session 4

15:30 **The life cycle of putative embryos from the Ediacaran Doushantuo biota.**

John A. Cunningham, Philip C. J. Donoghue, Stefan Bengtson, Chongyu Yin, Federica Marone and Marco Stampanoni

15:45 **The Role of Microbial Mats in Ash-Based Conception-style Ediacaran Preservation.**

Marc Laflamme, James D. Schiffbauer, Jay J. Ague, Guy M. Narbonne and Derek E. G. Briggs

16:00 **Trophic interactions: Possible clues to investigate fossil assemblage complexity and implications for Early Cambrian ecosystems.**

David Casenove and Tatsuo Oji

16:15 **Macro- vs. micro-Burgess Shales: complementary records of early Palaeozoic life.**

Nicholas J. Butterfield and Thomas H. P. Harvey

16:45 Annual General Meeting

17:15 Annual Address:

**Ancient origin of the deep sea fauna: new evidence from the fossil record**

Professor Andrew Gale

19:00 Reception and Annual Dinner at the St.-Peter's Abbey

## Sunday 19th December

### Oral Presentations

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

The meeting will take place in 'Het Pand' at Ghent University (Onderbergen 1, see circular for directions), where registration will also take place, 09:00–17:00. Posters will be on display in the same venue.

### Session 5: poster session

Coffee and light breakfast will be available from 9:30.

See abstracts section for an overview of the posters programme.

9:00 Delegates are requested to stand by their poster(s).

### Session 6 (Parallel with session 7)

10:30 **New data confirm the dominance of wetland ecology throughout the Phanerozoic record of hot spring floras.**

Alan Channing and Dianne Edwards

10:45 **Paleobiology of a Nonmarine Precambrian Shale: Well-Preserved Eukaryotes from the 1.1 Ga Nonesuch Formation.**

Paul Strother and Charles Wellman

11:00 **Resetting the clock on the origin of land plants.**

Wilson A. Taylor, Paul K. Strother, Marco Vecoli and John H. Beck

11:15 **The oldest flora of the South China block, and other plant remains from the Ngoc Vung series, northern Vietnam.**

Paul Gonez, Nguyễn Huu Hung, Ta Hoa Phuong, Gaël Clément and Philippe Janvier

11:30 **Palynological evidence for Pennsylvanian (Late Carboniferous) vegetation change in a neglected British coalfield: the Coalpit Heath Basin, Bristol.**

\*Janine L. Pendleton, Charles H. Wellman and Christopher J. Cleal

11:45 **Palaeogene flora of Svalbard and its climatic significance.**

\*Abigail Clifton, Jane E. Francis, Alan Haywood, M. Jensen and P. Markwick

12:00 **A Late Miocene global vegetation reconstruction.**

Matthew J. Pound, Alan M. Haywood, Ulrich Salzmann and James B. Riding

### Session 7 (Parallel with session 6)

10:30 **Functional morphology and ontogeny of *Yohioia tenuis* – evolution of mantis shrimp-like predators in the Cambrian.**

Joachim T. Haug, Dieter Waloszek, Andreas Maas and Carolin Haug

- 10:45 **The Phylogeny of Marrellomorph Arthropods.**  
\*David A. Legg, Mark D. Sutton and Gregory D. Edgecombe
- 11:00 **More than meets the eye: What cuticle ornamentation tells us about trilobite segmentation.**  
\*Javier Ortega Hernandez and Nicholas J. Butterfield
- 11:15 **The morphological variability of the trilobite digestive system: insights from the frontal auxiliary impressions.**  
Rudy Lerosey-Aubril and Thomas Hegna
- 11:30 **Segmentation polarity during regeneration in trilobites.**  
Kenneth J. McNamara and M. Tuura
- 11:45 **The Sophisticated Visual Strategy of a Cambrian Predator – or what can be seen from an eye.**  
Brigitte Schoenemann, Christoffer Castellani, Euan N. K. Clarkson, Joachim T. Haug, Andreas Maas, Carolin Haug and Dieter Waloszek
- 12:00 **Crustaceans from a bitumen clast in Carboniferous glacial diamictite.**  
Paul A.Selden, Rony Huys, Michael H. Stephenson, Alan P. Heward and Paul N. Taylor
- 12:15 Lunch

**Session 8**

- 13:30 **Visualizing Paleocene-Eocene evolution of beta-diversity among ungulate mammals in North America.**  
Simon A. F. Darroch, Amelinda Webb and Nicolas Longrich
- 13:45 **Insights in the Early Eocene mammal faunas from Indo-Pakistan based on the Perissodactyla from the Ghazij Fm. of Pakistan.**  
Pieter Missiaen, Gregg F. Gunnell and Philip D. Gingerich
- 14:00 **A new specimen of the enigmatic perissodactyl-like archaic ungulate mammal *Olbitherium* from the early Eocene of Wutu Coal Mine, Shandong Province, China.**  
Thierry Smith, Pieter Missiaen and Cheng-Sen Li
- 14:15 **Can morphometric analysis of osteological variation in the skulls of extant crocodylians give biologically congruent definitions of inter and intraspecific variation?**  
\*Chloe L. Marquart
- 14:30 **Fossil fishes and a modern paradox – reconciling form and function.**  
\*Laurent Darras, Mark A. Purnell and Ralph G. Turingan
- 14:45 **Integrated new results from the *Iguanodon*-bearing Wealden facies of the Mons basin (Belgium).**  
Johan Yans and Working Group FRFC-FNRS .4.568.04.F
- 15:00 Coffee and Posters

**Session 9**

- 15:30 **Whiterock on the roof of the World: New data from the Ordovician tropics in Tibet.**  
David A.T. Harper, Lars Stemmerik, Zhan Renbin, Liu Jianbo, Steve K. Donovan and Svend Stouge
- 15:45 **Palaeobiology of the Tentaculitoids from the Lower Devonian Hunsrück Slate (Germany).**  
Heike Drapatz and Jes Rust
- 16:00 **The marine Triassic-Jurassic record of northern Chile: facies, fossils and palaeoenvironments.**  
Richard J. Twitchett, Guillermo Chong, Alfonso Rubilar, F. Amaro Mourges and L. Felipe Opazo
- 16:15 **The microfossil memory of ancient artefacts.**  
Mark Williams, Ian Wilkinson, Jawad Afzal, Alison Tasker, Neil Christie, Matt Edgeworth, Jeremy Taylor and Ruth Young
- 16:30 **The arachnid fossil record: progress and prospects.**  
Jason A. Dunlop and David Penney
- 16:45 **Different records give different curves: comparing deep sea and land-based palaeobiodiversity.**  
Graeme Lloyd, Andrew B. Smith and Jeremy R. Young
- 17:00 **Testing the pseudoplanktonic hypothesis: Model for the longevity of Early Jurassic crinoid floating wood colonies.**  
Aaron W. Hunter, David Casenove, Simon A.F. Darroch, Timothy A.M. Ewin and Tatsuo Oji
- 17:15 Announcement of prize winners and close of meeting

## Abstract of Annual Address

### Ancient origin of the deep sea fauna: new evidence from the fossil record

**Andrew S. Gale**

*School of Earth & Environmental Sciences,  
University of Portsmouth,  
Portsmouth PO1 3QL  
UK*

The origin and possible antiquity of the spectacularly diverse modern deep-sea fauna have been controversially debated since the beginning of deep-sea research in the nineteenth century. Recent hypotheses have thus far mostly been based on biogeographical distribution patterns and molecular clock estimates, and have predominantly suggested a latest Mesozoic or Cenozoic date of origin. Mesozoic Oceanic Anoxic Events and the mid-Cenozoic cooling of deep water masses have been considered to have eradicated pre-existing deep-sea communities which were successively replaced by re-colonisation. However, in the near absence of direct fossil evidence, considerations on the origin of the modern deep-sea fauna have been highly speculative.

Well-preserved body fossils of a Lower Cretaceous (114 Ma) echinoderm assemblage from bathyal (1km+) sediments in the NE-Atlantic, consisting of diagnostic disarticulated skeletal parts, have been discovered recently. The composition of the assemblage at family and genus level is similar to modern deep-sea echinoderm communities. It is therefore likely that at least part of the modern deep-sea fauna is considerably older than previously assumed, which is supported by independent evidence from diverse crustacean and other arthropod groups. It can be demonstrated that many Mesozoic benthic families lived in both deep and shallow habitats, but were progressively excluded from the continental shelves during the Cenozoic.

## Abstracts of symposium presentations: Biological proxies in climate modelling

### The Early Palaeozoic climatic trend

**Yves Godd ris <sup>1</sup>, Elise Nardin <sup>2</sup>, Yannick Donnadieu <sup>3</sup>, Guillaume Le Hir <sup>4</sup>, Ron C. Blakey <sup>5</sup>, Emmanuelle Puc at <sup>6</sup>, Marcus Aretz <sup>1</sup>**

<sup>1</sup>*LMTG, CNRS-Observatoire Midi-Pyr n es, Toulouse, France*

<sup>2</sup>*Institut of Geology and Mineralogy, University of Cologne, Germany*

<sup>3</sup>*LSCE, CEA-CNRS, Gif-sur-Yvette, France*

<sup>4</sup>*IPGP, Paris, France*

<sup>5</sup>*Northern Arizona University, Flagstaff, USA*

<sup>6</sup>*Biog osciences, Universit  de Dijon, France*

The early Palaeozoic climate has been described as warm and equable. However, recent data based on conodont oxygen isotopic composition reveal a large, long cooling trend through the Ordovician, followed by an abrupt cooling during the Late Ordovician glaciation. This long-term climate change is associated with a major radiation in Earth history. Nonetheless, the driving mechanisms for this cooling trend remain unknown. Simulations with a climate model coupled to a biogeochemical model (GEOCLIM) show that atmospheric CO<sub>2</sub> decreases from more than 20 PAL (~5600 ppmv) in the Furongian down to around 10 PAL (~2800 ppmv) in the Llandovery before rising again in the Early Devonian. We suggest that changes in geography and exposure of fresh volcanic rocks on continents are required to explain the large CO<sub>2</sub> drawdown leading to the onset of cooler to glacial conditions from the Middle Ordovician to the Llandovery. The weathering of fresh volcanic rocks is itself responsible for 33% of the Late Ordovician atmospheric CO<sub>2</sub> decrease; the rest being related to continent motion through the intertropical convergence zone (ITCZ). Mean annual continental temperature falls by 3°C from the Furongian to the Middle Ordovician, reaching 13.5°C, during the glacial interval.

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### The Mid-Piacenzian Warm period: Integrating Biological Proxies and Climate Models

**Alan M. Haywood <sup>1</sup>, Harry J. Dowsett <sup>2</sup>, Daniel J. Lunt <sup>3</sup>, Ulrich Salzmann <sup>4</sup>, Daniel J. Hill <sup>5</sup> and Aisling M. Dolan <sup>1</sup>**

<sup>1</sup>*School of Earth and Environment, University of Leeds, UK*

<sup>2</sup>*US Geological Survey, Reston, Virginia, USA*

<sup>3</sup>*School of Geographical Sciences, University of Bristol, UK*

<sup>4</sup>*School of Built and Natural Environment, Northumbria University, Newcastle, UK*

<sup>5</sup>*British Geological Survey, Keyworth, Nottingham, UK*

The mid-Piacenzian Warm Period (mPWP) was the last time in Earth history when global mean temperatures were significantly higher than present day caused, at least in part, by higher than pre-industrial levels of carbon dioxide in the atmosphere. The period provides an unparalleled opportunity to examine the long term response of the Earth System to elevated greenhouse gas concentrations. Through a combination of biological proxies, geological data synthesis, with numerical climate and environmental modelling I place the mPWP in context of climatic and environmental evolution over the last five million years. I



examine the behaviour of critical elements of the Earth System to elevated greenhouse gas concentrations. This includes examination of the mPWP Greenland and East Antarctic Ice Sheets, global vegetation distribution, the El-Niño Southern Oscillation and concluding with an assessment of Earth System Sensitivity. I discuss how the mPWP is now being used as a springboard for a new international project (Pliocene Modelling Intercomparison Project or PlioMIP) which seeks to understand how different climate predictions for the Pliocene from different climate models can be.

### Dinoflagellate cysts and foraminiferal geochemistry: a new combined proxy for environmental change in the Pliocene and Early Pleistocene of the North Atlantic Ocean

**Martin J. Head 1, Stijn De Schepper 2, Jeroen Groeneveld 3, Eva I. Fischer 1 and Jan Hennissen 4**

<sup>1</sup>*Department of Earth Sciences, Brock University, St. Catharines, ON, Canada*

<sup>2</sup>*Geosciences Department, University of Bremen, Bremen, Germany*

<sup>3</sup>*Alfred Wegener Institute, Bremerhaven, Germany*

<sup>4</sup>*Department of Geology, University of Toronto, Toronto, ON, Canada*

The Pliocene and Pleistocene reflect a long-term cooling trend that began in the Middle Miocene with the progressive expansion of Northern Hemisphere ice sheets. The North Atlantic Current (NAC) played a major role in the development of these ice sheets, delaying or promoting their expansion, due to its poleward transport of heat and moisture. To understand this process better, we have developed a combined dinoflagellate cyst and foraminiferal geochemical proxy to assess NAC strength and direction for several time slices during the Pliocene and Early Pleistocene. Marine Isotope Stage (MIS) M2 at 3.3 Ma is a severe cooling event immediately preceding the mid-Pliocene warm period. This event shows gradual cooling at the onset of MIS M2 based on foraminiferal geochemistry, although an abrupt dinoflagellate cyst assemblage overturn reflects a rapid decline in NAC influence, implying strong instability. The most profound changes in our North Atlantic dinoflagellate cyst record occur at around 2.7-2.6 Ma corresponding to intensification of Northern Hemisphere glaciation near the newly defined base of the Pleistocene. Notable climatic fluctuations also occur at around 1.8 Ma in the western North Atlantic DSDP Site 603, with the dinoflagellate cyst record reflecting the interplay of oceanic and coastal signals.

### Comparison of 4 state-of-the-art climate models with Eocene palaeodata – can any model get it ‘right’?

**Daniel J. Lunt 1, Malte Heinemann 2, Allegra N. LeGrande 3, Arne Winguth 4 and Tom Dunkley Jones 5**

<sup>1</sup>*University of Bristol, UK*

<sup>2</sup>*Max Planck Institute for Meteorology, Germany*

<sup>3</sup>*NASA/GISS, USA*

<sup>4</sup>*University of Texas at Arlington, USA*

<sup>5</sup>*Imperial College, London, UK*

Simulating the Early Eocene represents a challenge to climate models for a number of reasons. Firstly, our knowledge of the boundary conditions required to run the models, especially atmospheric trace gases such as carbon dioxide, is very poor. Secondly, the climate



is so different to modern that extremely long model simulations are required to obtain an equilibrium. Thirdly, there is a dearth of quantitative palaeo proxies, such as SST, with which to evaluate models. Despite these problems, one often-cited conception is that models fail to reproduce reconstructed high latitudes warmth when driven by elevated greenhouse gas concentrations. In this paper, we aim to quantify this apparent weakness for a suite of recent IPCC-class climate models: HadCM3L, ECHAM5, GISS-ModelE-R, and CCSM3. We do this in a consistent framework for each model, presenting a new data synthesis of Eocene SSTs.

### Biological proxies, sea level, and stable isotope geochemistry: towards an understanding of Silurian climate

**Axel Munnecke**

*GZN Erlangen, Erlangen, Germany*

In the past two decades our picture of the apparently ‘calm’ Silurian has changed dramatically. Investigations of stable carbon and oxygen isotopes suggest a highly volatile ocean-atmosphere system. The presence of four major positive stable carbon isotope excursions in the Silurian (early Wenlock, late Wenlock, late Ludlow, Silurian-Devonian boundary) suggest that fundamental changes in the global carbon cycle were much more frequent in the comparatively short Silurian Period than in any other system of the Phanerozoic. The amplitudes of the Silurian stable isotope excursions are extremely high compared to Mesozoic and Cenozoic excursions, and there is no general agreement on the palaeoenvironmental changes responsible for these excursions. The carbon isotope excursions are also characterised by elevated oxygen isotope values, and are closely correlated with extinction events and with lithological changes. At the very beginning, or even prior to, the increase of C- and O-isotope values, many groups of organisms were affected. Especially conodonts, graptolites and trilobites, but also acritarchs, chitinozoans, ostracods, brachiopods, and corals show extinctions, sometimes of a stepwise nature; organisms living in hemipelagic environments were more strongly affected than organisms occupying shallow-water settings. Comparison of published sea-level curves with the geochemical curves indicates that, although the geochemical shifts are probably accompanied by changes in sea level, relationships are far from simple (the sea-level curves are based on contrasting techniques and show some conflicting patterns). Nevertheless, the fact that the pronounced carbon isotope excursions are preceded by biological events (extinctions) indicates that some as yet totally unknown processes occurred prior to the onset of such excursions. Therefore, we advocate a strong focus on these intervals in order to further elucidate the causes for the isotope excursions and the extinctions.

### Vegetation of a warmer world: Global biome reconstruction and data-model comparison for the late Neogene

**Ulrich Salzmann 1, Matthew Pound 2, Alan M. Haywood 2, Daniel J. Lunt 3, James B. Riding 4 and Harry Dowsett 5**

<sup>1</sup>*School of the Built & Natural Environment, Northumbria University, Newcastle upon Tyne NE1 8ST, UK*

<sup>2</sup>*School of Earth and Environment, University of Leeds, Leeds LS2 9JT, UK*

<sup>3</sup>*School of Geographical Sciences, University of Bristol, Bristol BS8 1SS, UK*

<sup>4</sup>*British Geological Survey, Kingsley Dunham Centre, Keyworth, Nottingham NG12 5GG, UK*

<sup>5</sup>*Eastern Geology and Paleoclimate Science Center, U.S. Geological Survey, Reston VA 22033, USA*

The late Neogene is the most recent period of greater global warmth, which can be used as





an accessible example of a world that is similar to what models estimate could represent the Earth of the late 21st century. We present a review of our ongoing late Pliocene and late Miocene data analysis and climate modelling efforts. We focus on a new data-model hybrid vegetation reconstruction approach for which we used internally consistent palaeobotanical datasets and predictions from state-of-the-art climate and coupled vegetation models, the output of which is used to provide biome estimates for data sparse regions. The overall climate pattern shown by our new Miocene and Pliocene vegetation reconstruction is of a warmer and wetter world. The distribution of biomes in both reconstructions is characterised by a northward shift of the taiga-tundra boundary and general spread of tropical savannas and woodland at the expense of deserts. In order to further understand the differences in model response to imposed palaeoclimate boundary conditions, our new biome reconstructions provide a valuable tool to validate and compare different model simulations

### Biological proxies for reconstructing Holocene climate and ecosystem dynamics

**Dirk Verschuren**

*Limnology Unit, Department of Biology, Ghent University*

Biological proxies preserved in lake-sediment records are either derived from aquatic organisms, in which case they help reconstruct the aquatic ecosystem being affected by climate change, or from terrestrial organisms, in which case they help reconstruct climate-driven dynamics of the surrounding terrestrial ecosystem and landscape. Excluding biological carriers of geochemical signatures (e.g., the stable-isotope composition of ostracod calcite), biological techniques of palaeoenvironmental reconstruction mostly exploit the shifting of species' distribution ranges in response to climate change, creating stratigraphic changes in the abundance of indicator species or the composition of species assemblages. Sometimes the link between species distribution and climate is quite direct (e.g., aquatic organisms responding to water temperature, as influenced by air temperature), more often the link is complex (e.g., aquatic organisms responding to the habitat change caused by the substrate and water-chemistry changes associated with lake-level fluctuation, itself due to climatic moisture-balance variation). Definitive statements about past climates become more difficult as the proxy-climate link becomes more complex. The advantages of Holocene studies are mainly that 1) fossils are derived from currently living species, allowing calibration of species as palaeoenvironmental proxies using their modern-day distributions in relation to climate-sensitive environmental gradients (the method of space for time substitution), and 2) the possibility of proxy validation against historical data. Biological proxies are evidently instrumental in reconstructing long-term ecosystem dynamics, and their effects on biogeochemical cycles. In multiple-proxy reconstructions of past climate they often constrain and support the validity of sedimentological or geochemical proxies.



## Abstracts of oral presentations

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

### Was the Carboniferous ostracod freshwater colonization event driven by climate change?

\***Carys E. Bennett**

*Department of Geology, University of Leicester, Leicester, UK*

Ostracods are extant small aquatic crustaceans with a history stretching back to the earliest Ordovician. Today they live in a range of water bodies including oceans, lakes and even aquifers. For the first 130 million years their fossil record shows an entirely marine habit, prior to their colonisation of terrestrial aquatic ecosystems during the Early Carboniferous. The Carboniferous was characterised by southern hemisphere glacial episodes that generated high-frequency (<0.5Ma), high-magnitude (<100m) eustatic sea-level changes. The timing of the start of a major glacial episode is coincident with a second order marine invertebrate extinction, at the Mississippian/Pennsylvanian boundary. The ostracod radiation that followed this event involved the first long-lived colonisation of terrestrial aquatic environments. Were changes in global sea level caused by high latitude glaciation implicated in the ostracod terrestrialization event?

### Macro- vs. micro-Burgess Shales: complementary records of early Palaeozoic life

**Nicholas J. Butterfield and Thomas H. P. Harvey**

*Department of Earth Sciences, University of Cambridge, Cambridge CB2 3EQ, UK*

The Burgess Shale, Chengjiang and Sirius Passet *Lagerstätten* provide unparalleled views of macroscopic diversity in the Early-Middle Cambrian, but the rarity of such biotas frustrates statistical analysis. Focussed searching continues to yield new occurrences of Burgess Shale-type macrofossils, but these tend to be represented by taphonomically recalcitrant end-members dominated by claws and carapaces – a “plesiomorphic” residuum that fails to reflect true diversity or evolutionary dynamics. A similar pattern is also becoming apparent among Burgess Shale-type microfossils, where a recalcitrant background signal of, e.g., *Wiwaxia* sclerites, priapulid-like scalids and molluscan radulae is only occasionally accompanied by taphonomically more labile and evolutionarily more illuminating material. In terms of absolute occurrence, however, micro-Burgess Shales are proving to be substantially more common than their macroscopic counterparts, offering unique insights into the early Palaeozoic distribution of, e.g., algae, sponges, arthropods and various problematic forms. The broader distribution of micro-Burgess Shales derives, at least in part, from the relative ease with which small organisms can be transported to circumstances conducive to organic preservation.



### Trophic interactions: Possible clues to investigate fossil assemblage complexity and implications for Early Cambrian ecosystems

David Casenove<sup>1</sup> and Tatsuo Oji<sup>2</sup>

<sup>1</sup>Department of Earth Science and Astronomy, The University of Tokyo  
3-8-1 Komaba, Meguro, Tokyo 153-8902, Japan

<sup>2</sup>Nagoya University Museum, Nagoya University, Furocho, Chikusa-ku, Nagoya 464-8601, Japan

Congruent patterns of evolution have been described for both biodiversity and predation. This observation thus supported the idea of a possible link between predatory and macroevolutionary processes but the debate pertaining to the validity of this hypothesis still goes on due to the scarcity of exploitable information in the fossil record.

Combining recent size-based models of ecosystem structure to the detailed fossil record of two Burgess Shale-type biota (Maotianshan Shale biota 520Ma and Burgess Shale biota 510 Ma), we propose a reconstruction of Early and Middle Cambrian planktonic trophic structures. Our model differs from previous works, as it does not consider actual fossil evidence of predation to infer the predatory process but considers solely the size spectrum of various consumers. Therefore, our method assumes that the size structure of ecosystems reflects their trophic organization.

Our results comparing planktonic ecosystems support previous conclusions that predatory interactions during the Cambrian present a complexity comparable to Recent marine ecosystems (Barents Sea plankton data) with trophic levels reaching a maximum between 4.5-5. However, the lower average trophic level and increased trophic specificity of predators in the Recent setting suggest that modern plankton presents a stabilization process reducing the competitive exclusion in the water column.

### New data confirm the dominance of wetland ecology throughout the Phanerozoic record of hot spring floras

Alan Channing and Dianne Edwards

School of Earth and Ocean Sciences, Cardiff University, Wales, UK

Observations of permineralised plants from hot spring deposits spanning from the Neogene to Lower Palaeozoic confirm an overwhelming bias towards the preservation of specialised wetland species. Neogene to Mesozoic examples with close living relatives indicate that typical hot spring higher plants have anatomical and ecophysiological adaptations to the wide variety of stresses common in this environment. They are demonstrably wetland plants with well developed aerating systems in stems, roots and rhizomes. They also have anatomical characters that illustrate high water use efficiency required to mitigate the physiological drought experienced in oligohaline and alkaline hot spring waters. Commonly species biomineralise silica in life, this process (based on analogy with extant plants) confers ecophysiological tolerance of not only high salinity and alkalinity but other stresses presented by life in hot spring waters including high temperatures and chemical stressors (e.g., heavy-metals and metalloids). Typically plants favour vegetative reproduction over sexual and cover substrates by producing short (perhaps stunted) aerial stems from shallow rhizome-root systems. Physical and chemical conditions of the plant growth and preservation environments and the reproductive mode account for two other typical features of hot spring floras, low species diversity and the near-absence of dryland mesophyte plants.



### Palaeogene flora of Svalbard and its climatic significance

\*Abigail Clifton<sup>1</sup>, J. E. Francis<sup>1</sup>, A. Haywood<sup>1</sup>, M. Jensen<sup>2</sup> and P. Markwick<sup>3</sup>

<sup>1</sup>University of Leeds, Leeds LS2 9JT, UK

<sup>2</sup>University Centre in Svalbard, P.O. Box 156, N-9171 Longyearbyen

<sup>3</sup>Getech, Kitson House, Elmete Hall, Elmete Lane, Leeds LS8 2LJ, UK

The fluvio-deltaic deposits of the Eocene Aspelintoppen Formation on Svalbard contain a rich fossil flora. A new collection of this flora is dominated by angiosperms, which include the Betulaceae (birch), Ulmaceae (elm), Fagaceae (beech) and Cercidiphyllaceae (katsura), along with Corylus (hazel) and Aesculus (chestnut). The deciduous conifer *Metasequoia* (dawn redwood) is common, along with cypress and ferns. The associated sediments indicate a fluvial delta-plain environment with significant tidal influence. The leaves are preserved within floodplain mudstones and siltstones and at the base of crevasse splay/tidal channel sandstones. *Equisetum* (horsetail) is abundant in sandstone units and is commonly associated with immature paleosols, indicating that it was the primary colonizer of abandoned channels. Most fossil leaves are complete, indicating little transportation and deposition in quiet water conditions. Many of the leaves are preserved in leaf mats, suggestive of autumnal leaf falls. The leaves are notably large, some exceeding 25 cm in length, which may be indicative of a climate with high rainfall or an adaptation to the low angle light at high latitudes.

### The life cycle of putative embryos from the Ediacaran Doushantuo biota

John A. Cunningham<sup>1</sup>, Philip C. J. Donoghue<sup>1</sup>, Stefan Bengtson<sup>2</sup>, Chongyu Yin<sup>3</sup>, Federica Marone<sup>4</sup> and Marco Stampanoni<sup>4,5</sup>

<sup>1</sup>Department of Earth Sciences, University of Bristol, Bristol BS8 1RJ, UK

<sup>2</sup>Department of Palaeozoology, Swedish Museum of Natural History, Stockholm, Sweden

<sup>3</sup>Institute of Geology, Chinese Academy of Geological Sciences, Beijing, China

<sup>4</sup>Swiss Light Source, Paul Scherrer Institute, CH-5232 Villigen, Switzerland

<sup>5</sup>Institute for Biomedical Engineering, University and ETH Zurich, 8092 Zurich, Switzerland

Fossils from the Ediacaran Doushantuo biota interpreted as animal embryos have been central to debates over the early evolution and development of metazoans. The fossils appear to represent only the earliest stages of cleavage, however. Taphonomy experiments have shown that preservation of early embryos is more feasible than that of later developmental stages, leading to the suggestion that taphonomic bias might be responsible for the absence of fossils of post-embryonic stages. Nonetheless, the absence of plausible late-developmental stages presents problems for the animal interpretation. Indeed, a number of “unicellular” organisms produce cell lineages through binary division that result in cell aggregates resembling early embryonic stages of animals. The absence of later developmental stages may thus be a correct reflection of the organisms’ life cycle. We report new material from the Doushantuo biota in which individual fossils are comprised of tens of thousands of cells, representing hitherto unknown later ontogenetic stages. These preserve features that are critical in resolving the phylogenetic position of the organisms.

talks

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**Fossil fishes and a modern paradox - reconciling form and function****\*Laurent Darras<sup>1</sup>, Mark A. Purnell<sup>1</sup> and Ralph G. Turingan<sup>2</sup>**<sup>1</sup>*Department of Geology, University of Leicester, Leicester, UK*<sup>2</sup>*Department of Biological sciences, Florida Institute of Technology, Melbourne, FL, USA*

Palaeontological analyses of function are commonly underpinned by the assumption that an organism's ecology and anatomy are closely correlated. However, analysis of extant animals reveals that morphologically specialised species often behave as generalists, especially with regard to feeding. Specialist trophic modes are adopted only during times of critical resource scarcity. This is known as Liem's paradox. Sheepshead seabream (*Archosargus probatocephalus*) provide an example of this decoupled form and function: teeth and jaws are morphologically specialised for shell crushing, but populations vary greatly in the proportion of hard prey consumed, conditioned by local availability, yet display no clear morphological differences. We have investigated dietary preferences of sheepshead through quantitative microtextural analysis of high-resolution three-dimensional data from their molariform teeth (which lack wear facets and distinct microwear features). ISO standard roughness parameters reveal differences in microwear linked to the degree of durophagy. Applying the same methods to fossil pycnodont fishes indicates that their teeth were not used exclusively for shell-crushing, falsifying hypotheses that they were specialist shell-crushers. This supports the view that pycnodonts were ecologically diversified and adaptable, and confirms that Liem's paradox must be considered in palaeontological analyses of function.

**Visualizing Paleocene-Eocene evolution of beta-diversity among ungulate mammals in North America****Simon A. F. Darroch, Amelinda Webb and Nicholas Longrich***Department of Geology and Geophysics, Yale University, New Haven CT, USA*

The Paleocene and Eocene in North America marks a critical interval in the diversification of land mammals, incorporating the recovery of terrestrial ecosystems after the K/T extinction and subsequent adaptive radiation, and the greatest global warming of the Cenozoic during the PETM. However, changing patterns and processes in Paleocene-late Eocene mammal faunal distributions remain poorly described on a continental scale. Here we present a computer-intensive and highly visual approach to examining these patterns - fossil localities are plotted onto geological plate reconstructions using ArcGIS software, and converted to point sources of family and genus richness, and genus/family ratios. Statistical software is used to calculate changing family and genus richness in ungulate mammals over the first seven stages (Danian-Priabonian) of the Cenozoic, and analyze the development of beta-diversity across continental North America using Jaccard Similarity indices between paired localities. The results suggest 1.) decreases in both familial and generic richness over the Paleocene-Eocene boundary; 2.) decreases in genus-family ratios over the first three stages of the Paleogene; and 3.) decrease in beta-diversity between the Danian and Thanetian, followed by subsequent increase towards the end of the Paleogene contributing to a continent-wide decrease in beta-diversity from the earliest Paleocene to latest Eocene.

**The Hunsrück Slate, the origin of ammonoids, and evolutionary changes in development****\*Kenneth De Baets<sup>1</sup>, Christian Klug<sup>1</sup> and Dieter Korn<sup>2</sup>**<sup>1</sup>*Paläontologisches Institut und Museum, Universität Zürich, Zürich, Switzerland*<sup>2</sup>*Museum für Naturkunde, Leibniz Institute at the Humboldt University Berlin, Berlin, Germany*

The middle Palaeozoic is marked by an increasing coiling in several mollusc groups (ammonoids, dacroconarids, gastropods, nautiloids). This happens during a time of turnover in the marine ecosystems ('Devonian Nekton revolution'). In the lineage from Orthocerida via Bactritoidea to plesiomorphic and derived Ammonoidea, an increase in coiling in embryonic and post-embryonic whorls occurred. The early Emsian Hunsrück Slate yielded material of many cephalopods showing most of the morphological transformational steps. Most of them are sometimes completely preserved. This enabled us to investigate this transition in a stratigraphic framework and to examine the embryonic conchs of several taxa for the first time. We investigated Early through Middle Devonian changes in shape and size of protoconchs, embryonic shafts, and first whorls of over 30 species (including Hunsrück materials). Interestingly, several lineages such as the Mimoceratidae, the Anarcestidae, and the Agoniatitidae convergently developed a trend towards increased coiling (e.g., decrease in umbilical window size). The Ammonoidea of the Hunsrück Slate can only be understood in the light of this driven evolutionary trend towards tight coiling. The driving factors might have been a mix of adaptation towards improved swimming capabilities, towards an r-strategy reproduction, and increasing predation pressure by jawed fish.

**Palaeobiology of the Tentaculitoids from the Lower Devonian Hunsrück Slate (Germany)****Heike Drapatz<sup>1</sup> and Jes Rust<sup>2</sup>**<sup>1</sup>*Steinmann-Institut, Division of Palaeontology, University of Bonn, Bonn, Germany*<sup>2</sup>*Steinmann-Institut, University of Bonn, Bonn, Germany*

The systematic affinity of tentaculitoids is uncertain and even today their palaeobiology is controversially discussed. The presented study provides astonishing new insights into the palaeobiology of tentaculitoids. Presumed findings of tentaculitoid opercula (Blind & Stürmer 1977) were re-evaluated with micro CT scans. They revealed that these objects are either veliger shells of mussels or juvenile brachiopods. In addition, the authors postulated the existence of preserved soft parts, but these structures derive from crushed parts of the shell. Furthermore, epizoan growth on tentaculitoid shells is documented and discussed for the first time. Findings of accumulated tentaculitoids turned out to be agglutinated worm tubes. They were built of small tentaculitoids and thus may represent the oldest existing worm tubes built of other organisms. The investigation of tentaculitoids associated with larger fossils allowed postulation of a life-position and conclusions about their feeding behaviour and habitat selection. A pelagic way of life is rejected for adult dacroconarids in favour of a suspension to carrion feeding way of nutrition. The mode of life of tentaculitoids could have resembled that of gastropods and therefore they may indeed be classified as an extinct molluscan taxon.

talks

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## The arachnid fossil record: progress and prospects

Jason A. Dunlop<sup>1</sup> and David Penney<sup>2</sup>

<sup>1</sup>Museum für Naturkunde, Leibniz Institute for Research on Evolution and Biodiversity at the Humboldt University Berlin, D-10115 Berlin, Germany

<sup>2</sup>Faculty of Life Sciences, University of Manchester, Manchester, UK

Uniquely among terrestrial invertebrates, the entire raw species data for fossil arachnids and their relatives (Chelicerata) is now freely available online as a searchable pdf. The list of taxa, and associated literature, is currently hosted via Norman Platnick's *World Spider Catalog* under: <http://research.amnh.org/iz/spiders/catalog/INTRO1.html> [tag "Fossils"] and is updated every six months. The chelicerate fossil record currently includes 2,107 valid species; the most diverse groups being spiders (1,106 species), mites (305, including subfossils), eurypterids (244), scorpions (115) and xiphosurans (98). The lists include basic stratigraphic and locality data and reveal clear taphonomic biases towards highly productive sites like the Carboniferous Coal Measures and Eocene Baltic Amber. While the dataset remains of considerable value as a starting point for standard systematic revisions, the intention is for it to be available for future projects such the *Treatise on Invertebrate Paleontology*, as well as more sophisticated and applied aspects such as its inclusion into the *Paleobiology Database* or its integration, as calibration points, with molecular data in order to better understand the timing and radiation of major events in arachnid evolutionary history.

## Ice in a greenhouse world? Late Cretaceous climates of Antarctica

Jane Francis<sup>1</sup>, Vanessa Bowman<sup>1</sup>, Alan Haywood<sup>1</sup>, Stephen Hunter<sup>1</sup>, James Riding<sup>2</sup>, Rob Raiswell<sup>1</sup>, Peter Frost<sup>3</sup>, Duncan Pirrie<sup>3</sup> and James Marshall<sup>4</sup>

<sup>1</sup>University of Leeds, UK

<sup>2</sup>British Geological Survey, Keyworth, UK

<sup>3</sup>University of Exeter, UK

<sup>4</sup>University of Liverpool, UK

Although the Cretaceous is considered to have been a greenhouse world without permanent ice caps, it has been suggested that ice was present in high latitudes and influenced global sea levels, especially during the latest Cretaceous (Maastrichtian). The Maastrichtian sequence on Seymour Island, Antarctica is over 1200 metres thick and provides the highest resolution record in the world of the end of the Cretaceous. It is also the highest latitude sequence and the site most likely to preserve signals of Cretaceous ice. We investigated this sequence for signals of cold climates. Oxygen isotopes indicate marine ocean temperatures of ~10°C and terrestrial palynofloras represent cool temperate, but not freezing, climates. Glauconite-rich horizons represent periods of low sedimentation rates, probably associated with high sea levels, but marine plankton floras show evidence of sea level low stands – were these in response to glaciation? Sand grains have surface textures characteristic of glacial weathering. In addition, climate model simulations for the Maastrichtian indicate that an ice sheet the size of the Greenland ice cap could have been present on Antarctica with atmospheric CO<sub>2</sub> levels 2 x pre-industrial levels. Ice could have been present – but was it?



## Computational simulation of macroevolution

Russell J. Garwood and Mark D. Sutton

Department of Earth Science & Engineering, Imperial College, London SW7 2AZ, UK

The computer modelling of evolution allows experimental investigation of the processes and patterns of evolution, in a system removed from the biochemistry of life. It provides short generation times and high accuracy, impossible in biochemical experimentation. Current work provides an excellent opportunity for experimentation in a system analogous to the microbial populations of a chemostat, but studies are limited to population sizes of 10,000 individuals, and 15,000 generations. Even the most comprehensive studies are limited in their applicability to palaeontological patterns and processes.

We present an alternative, EvoSim, which allows the computer investigation of evolution on palaeontological population sizes (>1,000,000 individuals) over millions of generations. The program allows spatial and temporal variation, and the co-existence of isolated, evolving populations/species. The digital organisms possess both 'coding' and 'non-coding' genome and the ability to breed, allowing genome recombination. All variables can be user-defined, allowing a wide range of experiments to be conducted. The system can demonstrate speciation and niche tracking within the organisms. This represents the first steps towards computer modelling long-term evolutionary processes and patterns such as punctuated equilibrium and plus ça change, and will also allow knock-out studies and investigation of environmental impact on evolution.

## The oldest flora of the South China block, and other plant remains from the Ngoc Vung series, northern Vietnam

Paul Gonez<sup>1</sup>, Nguyễn Hữu Hùng<sup>2</sup>, Tạ Hoa Phương<sup>3</sup>, Gaël Clément<sup>4</sup> and Philippe Janvier<sup>4</sup>

<sup>1</sup>Palaeobotany, Palaeopalynology, Micropalaeontology, Department of Geology (B18),

University of Liège, allée du 6 aout, Sart Tilman, 4000 Liège 1, Belgium

<sup>2</sup>Vietnam National Museum of Nature, 18 Hoang Quoc Viet Str., Hanoi, Vietnam

<sup>3</sup>Vietnam National University, Department of Geology, 334 Nguyễn Trãi street, Thanh Xuan, Hanoi, Vietnam

<sup>4</sup>Muséum National d'Histoire Naturelle, UMR-CNRS 7207 CR2P, Bâtiment de Paléontologie, CP 38, 47 rue Cuvier 75231 Paris cedex 05, France

Several outcrops of the Late Silurian and Early to Middle Devonian of the Ngoc Vung Series, Northern Vietnam, yield plant remains. The Upper Silurian localities delivered the earliest known flora of the South China block. Although the fossils are fragmentary, they demonstrate diversity and complement our knowledge about the global composition of the flora. The flora is dominated by zosterophylls. Plants with dichotomous habit and terminal bivalvate sporangia are also represented. Plants with possible euphyllophyte affinities and bryophytes are occasionally present. This floral composition is similar to that of the rich, slightly younger South China block assemblages from the Posongchong and Xujiachong Formations of China, considered as Pragian (Early Devonian) in age. The South China block flora is therefore likely to have been dominated by zosterophylls at least from the Late Silurian to the Pragian (i.e., a 20 million years long-period). It also strengthens the hypothesis that more derived plants were present in eastern Gondwana, earlier than elsewhere, in the first steps of the Tracheophyte evolution. The Lower-Middle Devonian localities of the Ngoc Vung Series yielded a *Psilophyton*-like plant and a possible wood fragment. This would be one of the oldest occurrences of a woody remain.

talks

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## Whiterock on the roof of the World: New data from the Ordovician tropics in Tibet

David A. T. Harper<sup>1</sup>, Lars Stemmerik<sup>2</sup>, Zhan Renbin<sup>3</sup>, Liu Jianbo<sup>4</sup>, Steve K. Donovan<sup>5</sup> and Svend Stouge<sup>1</sup>

<sup>1</sup>Natural History Museum of Denmark (Geological Museum), University of Copenhagen, Copenhagen, Denmark

<sup>2</sup>Department of Geology and Geography, University of Copenhagen, Copenhagen, Denmark

<sup>3</sup>Institute of Geology and Palaeontology, Chinese Academy of Sciences, Nanjing, China

<sup>4</sup>Institute of Palaeontology and Palaeoenvironment, School of Earth and Space Sciences, Peking University, China

<sup>5</sup>National Centre for Biodiversity – Naturalis, Leiden, The Netherlands

The summit of Everest is capped by Middle Ordovician (Whiterock) carbonates, exposed above the Qomolangma detachment. Initial correlations with the Permian System by some of the first groups to attempt the summit in the 1930s, were revised by Chinese expeditions to the region in the 1960s, who correlated the rocks with the Ordovician and described some of the fauna. Fortunately this unit crops out at lower altitudes, for example near Jiancun, adjacent to the Lhasa - Kathmandu highway, north of Nyalam. These exposures, at some 5 km altitude, have yielded new shallow-water faunas dominated by brachiopods and crinoids. New conodont data precisely correlate the top of the section investigated with the *Pygodus serra* conodont Zone (upper Darrwilian); the conodonts have a Colour Alteration Index of 6, indicating a finite temperature of 350°C to 550°C. The shelly faunas formed shallow-water communities dominated by suspension feeders including orthide and strophomenide brachiopods and a robust pentameride crinoid, '*Pentagonopentagonalis*'. Multivariate statistical analyses of the distributional patterns of the Brachiopoda, place the fauna within the Toquima-Table Head realm, a circum equatorial province contrasting with the higher latitude Celtic and Gondwanan faunas during the Mid-Ordovician.

## Functional morphology and ontogeny of *Yohoia tenuis* – evolution of mantis shrimp-like predators in the Cambrian

Joachim T. Haug, Dieter Waloszek, Andreas Maas and Carolin Haug

Biosystematic Documentation, University of Ulm, Ulm, Germany

*Yohoia tenuis* Walcott, 1912 (Chelicerata *sensu lato*) has a pair of prominent, so-called 'great appendages' as most anterior appendages. Our observations indicate that the morphology of these appendages differs significantly from previous descriptions and that it changes throughout ontogeny. These ontogenetic changes question the validity of using differences in the 'great-appendage' morphology for distinguishing species, as has been done, e.g., for short 'great-appendage' arthropods from the Chengjiang biota, such as *Fortiforceps foliosa* Hou & Bergström, 1997 and *Tanglangia longicaudata* Luo & Hu in Luo *et al.* (1999). The 'great appendages' of *Y. tenuis* possess a jackknifing mechanism, which is formed by the distal one of two peduncle elements and the most proximal one of four spine-bearing 'claw' elements, but not by two peduncle elements as previously thought. This morphology appears to have facilitated hunting like a modern spearer-type mantis shrimp. This assumption is supported by data from several specimens preserved in different positions of such an assumed movement. The arrangement of the joint resembles that of chelicerae of modern chelicerates, such as Xiphosura, Opiliones or Palpigradi and, hence, supports the idea that the 'great appendage' evolved into the chelicera of Chelicerata *sensu stricto*.



## Testing the pseudoplanktonic hypothesis: Model for the longevity of Early Jurassic crinoid floating wood colonies

Aaron W. Hunter<sup>1,2</sup>, David Casenove<sup>3</sup>, Simon A. F. Darroch<sup>4</sup>, Timothy A. M. Ewin<sup>5</sup> and Tatsuo Oji<sup>6</sup>

<sup>1</sup>Department of Geoscience and Petroleum Engineering, Petronas University of Technology, Tronoh, Perak, Malaysia

<sup>2</sup>Faculty of Geoscience and Geography, Georg-August University Göttingen, Germany

<sup>3</sup>Department of Earth Science and Astronomy, University of Tokyo, Komaba, Tokyo, Japan

<sup>4</sup>Department of Geology and Geophysics, Yale University, New Haven, CT, USA

<sup>5</sup>Department of Palaeontology, Natural History Museum, London, UK

<sup>6</sup>Nagoya University Museum, Nagoya, Japan

It is widely documented that fossil invertebrates are found attached to floating substrates; in the case of the Posidonia shales this was to avoid anoxic bottom conditions. The crinoids *Seirocrinus subangularis* and *Pentacrinites fossilis* are central to this argument, with considerable debate surrounding either a benthic mode of life (Rasmussen 1977) or pseudoplanktonic adaptation (Seilacher *et al.* 1968; Simms 1986). Opponents of the pseudoplanktonic hypothesis argue that floating log substrates were unable to support populations for the >15 years needed to reach maturity. We investigate the feasibility of the establishment of a crinoid community on a drifting log, by reconstructing the increasing density of the developing population based on growth rates and physical properties found in recent populations. We model moisture absorption rates for various types of soft/hard woods, as possible modern analogies for those that could have existed in the Early Jurassic. Preliminary results suggest that the longevity of a population would be dependent upon the properties of the wood substrate itself, with the most likely wood types being remarkably stable. We suggest that in order for a colony to sink the log would have to become supersaturated or the crinoid community reached a critical threshold of over population.

## Devonian pearls and ammonoid-endoparasite co-evolution

Christian Klug<sup>1</sup>, Kenneth De Baets<sup>1</sup> and Dieter Korn<sup>2</sup>

<sup>1</sup>Paläontologisches Institut und Museum, Universität Zürich, Zürich, Switzerland

<sup>2</sup>Museum für Naturkunde, Leibniz Institute at the Humboldt University Berlin, Berlin, Germany

Raised shell projections on the inner shell walls that form pits on the internal moulds of Devonian ammonoids have been long known. New specimens from Morocco revealed novel details; most of the pearls consist of a capsule of ammonoid shell covering tiny tubes attached to the shell wall from the inside. In accordance with comparable structures in Recent molluscs, we use the term "pearls" for these structures. Because of the presence of these tubes inside the pearls, their arrangement, organization, and similarity to modern mollusc occurrences, the tubes are interpreted as traces of parasitoses. The pearls and pits were grouped into five types based on differences in morphology, size, and arrangement. We used these traits for a simple cladistic analysis. The resulting cladogram was compared to the phylogeny of early ammonoids. Based on this comparison, it appears likely that the parasites underwent a co-evolution with the ammonoid hosts, which lasted >10 Ma. Because of the lack of fossilised soft tissue, only speculations can be made about the systematic affiliation of the parasites, their life-cycle, and infection strategy. The tubes are, however, tentatively interpreted as artifacts of trematode infestations, which would extend their fossil record into the Early Devonian.

talks

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## The role of microbial mats in ash-based conception-style Ediacaran preservation

**Marc Lafflamme<sup>1</sup>, James D. Schiffbauer<sup>2</sup>, Jay J. Ague<sup>1</sup>, Guy M. Narbonne<sup>3</sup> and Derek E. G. Briggs<sup>1,4</sup>**

<sup>1</sup>*Department of Geology and Geophysics, Yale University, PO Box 208109, New Haven, CT 06520-8109, USA*

<sup>2</sup>*Department of Geosciences, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061, USA*

<sup>3</sup>*Department of Geological Sciences and Geological Engineering, Queen's University, Kingston, ON K7L 3N6, Canada*

<sup>4</sup>*Peabody Museum of Natural History, Yale University, P.O. Box 208118, New Haven, CT 06520-8118, USA*

The soft-bodied Ediacara biota from the Mistaken Point Ecological Reserve in Newfoundland includes the oldest complex macroscopic eukaryotes. The microbial mats that dominated this deep water palaeoenvironment created a firm substrate upon which macroscopic organisms could anchor. The mats also played a role in the preservation of the soft-bodied Ediacaran fossils, many thousands of which occur on bedding planes along the coast. Bedding plane exposure is facilitated by the recessive nature of the volcanic ash beds which occur throughout this deep-water turbidite sequence. Several of the ash beds yield zircons which provide precise U-Pb age constraints (578-565 Ma). This is the first attempt to characterize the properties of the ashes in detail and determine their influence, and that of microbial systems, on early lithification and fossilization. We employed environmental scanning electron microscopy, energy dispersive X-ray spectroscopy, and electron probe microanalysis to analyse the volcanic ash and underlying turbidites within the Drook, Briscal, and Mistaken Point Formations. Distinct chemical signatures at the ash-sediment interface suggest that microbial processes promoted the precipitation of authigenic minerals. A complex interplay of the ash and sulphate-reducing bacterial mat communities on the seafloor accounts for the exceptional preservation of the Mistaken Point biota.

## The phylogeny of marrellomorph arthropods

**\*David A. Legg<sup>1</sup>, Mark D. Sutton<sup>1</sup> and Gregory D. Edgecombe<sup>2</sup>**

<sup>1</sup>*Department of Earth Science and Engineering, Imperial College London, London, UK*

<sup>2</sup>*Department of Palaeontology, The Natural History Museum, London, UK*

The marrellomorphs are a small group of Cambrian-Devonian arthropods noted for their aberrant morphology, which has precluded resolution of their phylogenetic position. Marrellomorpha includes two clades, the marrellids (including *Marrella*, *Furca* and *Mimetaster*) and the acerostracans (*Vachonisia* and *Xylokorys*), allied by the shared possession of numerous (>25) trunk somites with appendages that reduce in size posteriorly. The marrellids are characterised by the possession of extensive head spines and the acerostracans are characterised by the possession of a dorsal “shield” that covers their entire body and appendages. Recent work on marrellomorph anatomy, including descriptions of unpublished material from the Hunsrück Slate, has augmented understanding of the morphology of the group, and enabled us to identify potential homologies with other arthropod taxa. A cladistic analysis including all currently recognised marrellomorphs and a variety of extinct and extant arthropods supports monophyly of Marrellomorpha, composed of marrellids, acerostracans, and “skaniids”, the latter a paraphyletic group of Cambrian arthropods that, like the acerostracans, possess a

dorsal “shield”. This analysis resolves the marrellomorphs as part of a stem-mandibulate; the implications for the evolution of mandibulate arthropods are discussed.

## The morphological variability of the trilobite digestive system: insights from the frontal auxiliary impressions

**Rudy Lerosey-Aubril<sup>1</sup> and Thomas Hegna<sup>2</sup>**

<sup>1</sup>*Senckenberg Research Institute, Frankfurt am Main, Germany*

<sup>2</sup>*Department of Geology & Geophysics, Yale University, USA*

The digestive system of trilobites is rarely preserved and its organization remains poorly known. The exoskeleton sometimes preserves evidence of soft-tissue insertion sites that can be used to infer internal anatomy. Among them are the frontal auxiliary impressions (FAIs), probable soft-tissue insertion sites located on the frontomedian glabellar lobe of some trilobites. FAIs are herein described for the first time in the order Proetida. A taphonomic scenario is proposed to explain their variability. Common in the Phacopina, FAIs are also found in several other orders. Comparisons with modern analogues suggest that they were insertion sites for muscles associated with a differentiated crop.

A review of purported remains of the trilobite digestive system indicates that it usually consisted of a tube-like tract flanked by a variable number of paired diverticulae. Its anterior portion is not individualized, except in some rare taxa. This differentiation of a crop might have constituted a secondary evolution in trilobites, occurring independently in different clades. Accompanied by a strengthening of associated extrinsic muscles, this modification might explain the more conspicuous muscle insertion sites on the glabella. Study of FAIs might therefore provide a new approach to the study of the variability of feeding habits in trilobites.

## Different records give different curves: comparing deep sea and land-based palaeobiodiversity

**Graeme Lloyd, Andrew B. Smith and Jeremy R. Young**

*Department of Palaeontology, Natural History Museum, Cromwell Road, London SW7 5BD, UK*

Most palaeobiodiversity curves are based on fossil collections from land-based localities, but for certain microfossil groups a rich deep-sea record is also available. Here we use a novel database to compare deep sea and land-based palaeobiodiversity curves of the same group for the first time. We use Coccolithophores as our study group and construct curves based on c. 35k deep-sea and c. 20k land-based species occurrences. The results clearly show major differences, with the deep-sea showing a rising curve and the land a more humped profile. Further examination shows both records, and hence both curves, are dominated by sampling. However, attempts to remove sampling signal with modelling leave residuals that still differ, with the land-based record consistently less biased. Taken together, these results offer the strongest evidence yet that raw palaeobiodiversity curves should not be taken at face value.

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### Can morphometric analysis of osteological variation in the skulls of extant crocodylians give biologically congruent definitions of inter and intraspecific variation?

\*Chloe L. Marquart

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

When classifying fossils, many of the factors that may be sources of variation in bones such as age, sex, geographical isolation and taphonomy may be unknown. In reality it is very difficult to tell where inter and intraspecific variations begin and end. To help disentangle this problem palaeontologists often utilise morphometric methods to both visualise and quantify these differences. However, better knowledge of the scale and location of morphological variation does not necessarily tell us its cause.

Skulls of extant *Caiman* crocodylians and geometric morphometrics have been used to investigate some of these issues. Using Relative Warps and Canonical Variates Analysis, specimens of known sex and subspecies are used to give a better understanding of the patterns and causes of variation within and between species. Being able to account for species, age, sex, location and taphonomy allows us to show what variation is independent of these factors and better identify where and how they manifest themselves osteologically. It also allows an investigation into the utility of morphospace separation as a taxonomic indicator, showing the most morphologically disparate specimens may not be the furthest removed evolutionarily or taxonomically.

### New insights into the Triassic ammonoid radiation from time-sliced cladistic analyses

Alistair J. McGowan

School of Geographical and Earth Sciences, University of Glasgow, UK

The monophyletic clade Ceratitida originated during the Late Permian, survived the Permian/Triassic mass extinction and gave rise to nearly all of spectacular taxonomic and morphological diversity of the Mesozoic Ammonoidea. However, many of the relationships among higher taxa are poorly resolved, despite the best efforts of many distinguished researchers. Indeed, the monophyly of many higher taxa within Ceratitida is uncertain. Previous authors have proposed openly paraphyletic and polyphyletic superfamilies. New cladistic analyses of Early Triassic ammonoid genus-level taxa, based on the time-slicing approach of Ausich (1998) are now complete. They clarify the nature of the evolutionary relationships, and associated patterns of character evolution, among Early Triassic higher taxa. These cladograms also provide significant new insights into the quality of the Early Triassic ammonoid record. The major findings are: 1) few previously proposed higher taxa are monophyletic; 2) analysis of evolutionary trees based on the cladograms and collection curves indicates that the Griesbachian ammonoid record is significantly poorer than the Dienerian and Smithian records. These new findings support previous proposals, based on taxon-counting and disparity analyses, that apparently rapid radiations of ammonoids during the Dienerian–Smithian are dominated by genuine biological events, rather than preservational failure or other sampling biases.



### Segmentation polarity during regeneration in trilobites

Kenneth J. McNamara<sup>1</sup> and M. Tuura<sup>2</sup>

<sup>1</sup>Department of Earth Sciences, University of Cambridge, Cambridge CB2 3EQ, UK

<sup>2</sup>Department of Geology, University of Otago, Dunedin 9054, New Zealand

A recently collected complete moulted exoskeleton of the asteropygine phacopid trilobite *Greenops widderensis* Lieberman and Kloc, 1997 from the Middle Devonian (Givetian) Widder Formation in southwestern Ontario, Canada that has suffered predatory trauma provides insights into the sequence of regeneration of segments in trilobites. Predatory trauma affected four areas of the exoskeleton of this trilobite. The pygidium shows loss of the spinose margin on one side and damage to a single spine on the other; one genal spine has been broken and partially regrown; and the posterior of the glabella has been removed. Analysis of the degree of regeneration of the pygidial pleurae indicates that there was an anteroposterior polarity to the sequence of regeneration. Other examples showing the same pattern of regeneration, affecting either the thorax or pygidium, are documented in species of *Redlichia*, *Prionopeltis*, *Elrathia*. All these examples suggest that this regeneration polarity pattern may have been widespread in trilobites. It is likely that, as in modern arthropods and annelids, this sequential regeneration was under the control of segmentation polarity genes.

### Insights in the Early Eocene mammal faunas from Indo-Pakistan based on the Perissodactyla from the Ghazij Fm. of Pakistan

Pieter Missiaen<sup>1,2</sup>, Gregg F. Gunnell<sup>3</sup> and Philip D. Gingerich<sup>3</sup>

<sup>1</sup>Research Unit Palaeontology, Ghent University, Ghent, Belgium

<sup>2</sup>Royal Belgian Institute of Natural Sciences, Ghent, Belgium

<sup>3</sup>University of Michigan, Museum of Paleontology, Ann Arbor, MI, USA

Despite ample study, the origin of modern mammals is still unknown. Many hypotheses focus on Asia, with sometimes a prominent role for the poorly known Indian subcontinent. The only Early Eocene mammal faunas known from Indo-Pakistan are those from the Vastan mine (India) and from the Ghazij Formation (Pakistan). Both are under active study, and here we present the first results on the Ghazij perissodactyls.

The most abundant small forms are two closely similar species of Isectolophidae, known from 121 dental specimens from a single locality. The most abundant larger forms are a group of puzzling bunodont perissodactyls, presenting similarities to the supposed anthracobunid *Nakusia* from the middle Ghazij Formation, to *Indobune* from Vastan and to the middle Eocene *Hallensia* from Europe. Brontotheriidae are represented by three new species that are morphologically similar to primitive forms known from the North American Bridgerian. New species of both Lophialetidae and Eomoropidae are rare faunal elements. The Ghazij perissodactyls thus represent a broad phylogenetic diversity and are markedly distinct from those at Vastan. They are moreover of a so far unique biogeographical and biochronological importance, suggesting faunal exchange between Indo-Pakistan and most or all Laurasian continents.

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### Belemnite sclerochronology: a new technique for understanding ontogeny and ecology

\*Elizabeth V. Nunn<sup>1</sup>, Gregory D. Price<sup>2</sup> and Bernd R. Schöne<sup>1</sup>

<sup>1</sup>Department of Applied and Analytical Palaeontology, University of Mainz, Mainz, Germany

<sup>2</sup>School of Geography, Earth and Environmental Sciences, University of Plymouth, Plymouth, UK

The belemnite mode of life is poorly understood. How long did belemnites live for? Where did they live (shallow/deep waters; benthic/pelagic)? Did they migrate extensively (vertically/laterally) during their lives? Such factors could significantly influence the fractionation of certain isotopes and trace elements into biogenic calcite, and as long as they remain unknown, it will be difficult to accurately reconstruct past environments and climates from belemnite-derived geochemical data. *Acroteuthis lateralis* is one of the largest and most robust belemnite species known. It therefore provides a unique opportunity to investigate growth increment and geochemical variability at a very high resolution. Here we present data from a Russian *A. lateralis* specimen. The data suggest that this specimen was probably spawned in relatively warm waters and then experienced fluctuating temperatures, most likely on a seasonal basis, throughout the rest of its life. This would indicate a life span of c. 2.5 years, with growth slowing after the first year. Speculative palaeotemperature calculations strongly suggest that *A. lateralis* was, for the most part, nekto-benthic although the belemnite may have intermittently migrated to warmer surface waters during the summer months, presumably for spawning.

### More than meets the eye: What cuticle ornamentation tells us about trilobite segmentation

\*Javier Ortega Hernandez and Nicholas J. Butterfield

Department of Earth Sciences, University of Cambridge CB2 3EQ, Cambridge, UK

Trilobites are the oldest and best-known group of arthropods in the fossil record, mainly due to their biomineralized exoskeletons. The sheer abundance of trilobite remains has allowed the study of their ontogenetic development and growth, but the intrinsic mechanisms responsible for their peculiar pattern of body segmentation persist elusive. Study of trilobite cuticle ornamentation from the Lower Cambrian Mural Formation (British Columbia, Canada) revealed the occurrence of a polygonal cell network on the surface of various olenellid genera, which is interpreted as homologous to the exocuticular imprints produced by the margins of underlying epidermal cells (interprismatic septa) in Recent biomineralizing crustaceans. Consistent patterns of transverse cellular elongation along the anterior margins of the trunk pleurae indicate the presence of a distinct antero-posterior differentiation on each of the segments, attributable to the expression of the highly conserved segment polarity gene engrailed. Recognition of polarized epidermal cell morphologies implies a parasegmental origin for the trilobite trunk. These observations provide support to traditional segmentation models that explain the organization of the trilobite trunk based on the ontogenetic development of the pygidium and teratologies affecting the pleural furrows, and suggest that somitogenesis mechanisms present in recent organisms were already incorporated early during arthropod evolution.



### Palynological evidence for Pennsylvanian (Late Carboniferous) vegetation change in a neglected British coalfield: the Coalpit Heath Basin, Bristol

\*Janine L. Pendleton<sup>1</sup>, Charles H. Wellman<sup>1</sup> and Christopher J. Cleal<sup>2</sup>

<sup>1</sup>Department of Animal and Plant Sciences, University of Sheffield, Sheffield, UK

<sup>2</sup>Department of Biodiversity & Systematic Biology, National Museum Wales, Cardiff, UK

The Late Carboniferous (Middle-Late Pennsylvanian boundary) was a time of dramatic change in the floral record of the tropical Euramerican peat mires. The lycopsids, which dominated these water saturated coastal environments, began to rapidly decline in abundance and diversity. A more dry-tolerant flora dominated by tree ferns began to take over and the mires contracted to nearly half their pre-turnover 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.

The Bristol Upper Coal Measures provides a glimpse of the flora of these peat mires in the several million years prior to this pan-equatorial floral turnover. A detailed study of the palynology of borehole material reveals the demise of the lycopsid-dominated forests may have started as early as the Bolsavian in the Bristol region. Pronounced cyclicity in floral dominance is superimposed onto this trend towards more dry-tolerant flora. This cyclicity was likely driven by fluctuations in moisture levels in the peat mires. This suggests that a progressive switch to fern-dominance, driven by drying conditions, may have begun ~3 million years prior to the Westphalian-Stephanian boundary.

### A Late Miocene global vegetation reconstruction

Matthew J. Pound<sup>1,2</sup>, Alan M. Haywood<sup>1</sup>, Ulrich Salzmann<sup>3</sup> and James B. Riding<sup>2</sup>

<sup>1</sup>School of Earth and Environment, University of Leeds, Leeds, UK

<sup>2</sup>British Geological Survey, Kingsley Dunham Centre, Keyworth, Nottingham, UK

<sup>3</sup>School of Applied Sciences, Northumbria University, Newcastle upon Tyne, UK

Numerical climate models are a widely used tool to assess the future impacts of climate change. To test the predictive ability of climate models the use of substantial databases of palaeoclimatic/environmental information from periods in Earth history significantly different from the modern is required. The Miocene provides such a time period.

Focussing on the Tortonian Stage (Late Miocene; 11.61-7.25Ma), a database of 223 palaeobotanical sites has been created. This database records the vegetation using the 27 biome classification of the BIOME4 vegetation model to reconstruct the global vegetation. This makes it consistent with climatically-forced model output from the HadAM3 global circulation model (GCM) coupled to BIOME4. This allows easy data-model comparisons and an advanced data-model hybrid global vegetation reconstruction to be created.

This Tortonian reconstruction shows changes in the distribution of vegetation compared to the present day potential natural vegetation indicative of a warmer and wetter climate. Mean annual global temperature from the GCM shows the Tortonian was 4.5°C warmer than the pre-industrial era. This warming is seen at all latitudes and requires a global forcing agent such as CO<sub>2</sub>. However current estimates of CO<sub>2</sub> for the Tortonian do not appear consistent with the warming seen in the palaeoecological data.



**Experimental taphonomy of *Xenopus laevis* tadpoles****Ragna Redelstorff and Patrick J. Orr***School of Geological Sciences, University College Dublin, Dublin 4, Ireland*

The term ‘soft tissues’ disguises variation in fossilization potential of the different tissues and organ systems of chordates, even within a single taxon. Decay experiments provide information to help constrain the interpretation of specific anatomical features within fossils. We experimentally decayed tadpoles of *Xenopus laevis* to establish the general sequence of degradation, in particular the fate of the notochord, nerve cord and intestinal system. Distinguishing between these is potentially problematic in fossil material. Gills, nervous and muscle tissues decayed rapidly. Next, the integument decomposed, and its outline was pseudomorphed by fungal hyphae and bacterial mats. Subsequently, the intestinal system disintegrated. The inner notochord sheath was the linear structure that persisted longest. The eyeballs decomposed over an extended interval, the lens being little modified at termination of the experiment. A thick bacterial biofilm developed rapidly around the decaying tadpole. This was either “blanket-like”, with its margins fixed to the jar bottom and the tadpole trapped below it, or tightly encased the specimen and secured it firmly to the jar bottom. No variable could be identified that correlated with the pattern of biofilm. Such biofilms inhibit disarticulation of the carcass, and its floating after the build-up of internal decay gases.

**Look, no arms race: predator-prey interactions between durophagous fishes and camerate crinoids following the Hangenberg mass extinction****\*Lauren Cole Sallan<sup>1</sup>, Thomas W. Kammer<sup>2</sup>, William I. Ausich<sup>3</sup> and Lewis A. Cook<sup>2</sup>**<sup>1</sup>*Department of Organismal Biology and Anatomy, University of Chicago, Chicago, IL, USA*<sup>2</sup>*Department of Geology and Geography, West Virginia University, Morgantown, WV, USA*<sup>3</sup>*School of Earth Sciences, The Ohio State University, Columbus, OH, USA*

Predator-prey interactions are a basis of modern ecosystems and major marine revolutions. Yet, few studies have quantitatively linked predator and prey in the fossil record, and fewer have focused on the initiation and conclusion of arms races. The later Palaeozoic crinoid and jawed vertebrate records present a set of natural experiments in which predators are removed from and added to an otherwise stable prey biota. The end-Devonian Hangenberg extinction (359 million years ago, mya) eliminated most predators of crinoids, including placoderm fishes and ammonoids. This ended an arms race that had driven camerate crinoids to develop greater spinosity and thicker armour. Released from predatory pressures, camerates flourished, establishing an “Age of Crinoids” in the early Mississippian. Chondrichthyan and actinopterygian fishes recovered in the midst of this abundant food source, resulting in radiations of novel predators. These overpowered the camerates upon reaching critical mass at the Tournaisian-Visean boundary (345 mya). The expected predator-prey arms race never developed, and camerates went into an abrupt decline. Camerates had apparently failed to modify their retained, but now obsolete, defences in an effective manner. This is an illustration of “legacy adaptations”: once beneficial traits that prevent an optimal response to novel pressures.

**Morphological decay experiments and the fossil record of non-biom mineralized vertebrates****Robert S. Sansom, Sarah E. Gabbott and Mark A. Purnell***Department of Geology, University of Leicester, Leicester, UK*

Only through analysis of fossils can we determine the sequence and rate of events during the origin and early evolution of vertebrates. These are landmark episodes in the history of life, but interpreting the record is fraught with difficulty: the relevant organisms lacked biomineralized hard tissues and we are reliant on taxa from exceptionally preserved biotas, with their associated taphonomic difficulties. Experimental investigation of the morphological decay of extant proxies reveals new information about the rate and sequence of character decay and highlights sources of potential taphonomic bias. Combining these decay data with detailed analysis of the mode of preservation of exceptionally preserved, non-biom mineralised vertebrates provides a new approach which allows us to test controversial anatomical interpretations, and to constrain the degree to which fossils have been affected by decay-related character loss. This reveals a complex pattern with regard to preservation of phylogenetically significant characters in the fossils: some are confirmed as present, some are recorded for the first time, and some are identified as being absent due to decay rather than for phylogenetic reasons. Our results have significant implications for interpreting the anatomy and phylogenetic placement of important fossil taxa, and for understanding patterns of vertebrate character acquisition.

**The Sophisticated Visual Strategy of a Cambrian Predator – or what can be seen from an eye****Brigitte Schoenemann<sup>1</sup>, Christoffer Castellani<sup>2</sup>, Euan N. K. Clarkson<sup>3</sup>, Joachim T. Haug<sup>2</sup>, Andreas Maas<sup>2</sup>, Carolin Haug<sup>2</sup> and Dieter Waloszek<sup>2</sup>**<sup>1</sup>*Steinmann-Institut für Geologie, Mineralogie und Paläontologie der Universität Bonn, Bonn, Germany*<sup>2</sup>*Biosystematic Documentation, University of Ulm, Ulm, Germany*<sup>3</sup>*Grant Institute, School of Geosciences, University of Edinburgh, Edinburgh EH9 3JW, Scotland, UK*

The exceptionally good preservation of phosphatised Swedish “Orsten” material allows deep insights into structures of visual systems. In tiny stalked compound eyes the underlying substructure can be made out; it is that of a typical apposition eye. The analysis reveals four areas of different orientation and acuity, but with a balanced sensitivity. The most remarkable is a visual area orientated inwardly. Here the optical axes of both eyes form a wide field of stereoscopic vision, while its acuity can be changed by moving the stalks.

Most fascinatingly, here we have a new, and effective principle of vision. The acuity of this compound eye itself is very low, because of the low number of pixels in the visual mosaic. If, however, an object is moving in this three dimensional field of view, it would be detected by a different pair of facets each time, as in a coordinate system. Size, velocity or distance of the moving object can be estimated. Thus, despite their small size and limited equipment the sophisticated strategy of these tiny eyes may have enabled an active predatory life-style. Not to have used them in this way, would have been a waste of energy.

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**Crustaceans from a bitumen clast in Carboniferous glacial diamictite****Paul A. Selden<sup>1,2</sup>, Rony Huys<sup>3</sup>, Michael H. Stephenson<sup>4</sup>, Alan P. Heward<sup>5</sup> and Paul N. Taylor<sup>6</sup>**<sup>1</sup>*Paleontological Institute and Department of Geology, University of Kansas, 1475 Jayhawk Boulevard, Lawrence, Kansas 66045, USA*<sup>2</sup>*Department of Palaeontology, Natural History Museum, London SW7 5BD, UK*<sup>3</sup>*Department of Zoology, Natural History Museum, London SW7 5BD, UK*<sup>4</sup>*British Geological Survey, Keyworth, Nottingham NG12 5GG, UK*<sup>5</sup>*Petrogas E&P, PO Box 353, PC112, Ruwi, Muscat, Oman*<sup>6</sup>*Exploration, Petroleum Development Oman, Muscat 113, Oman*

Copepod crustaceans are extremely abundant but, because of their small size and fragility, they fossilize poorly. Their fossil record consists of one Cretaceous (c. 115 Ma) parasite and a few Miocene (c. 14 Ma) fossils. In this talk, we describe abundant crustacean fragments, including copepods, from a single bitumen clast in a glacial diamictite of late Carboniferous age (c. 303 Ma) from eastern Oman. Geochemistry identifies the source of the bitumen as an oilfield some 100–300 km to the southwest, which is consistent with an ice flow direction from glacial striae. The bitumen likely originated as an oil seep into a subglacial lake. This find extends the fossil record of copepods by some 188 Ma, and of free-living forms by 289 Ma. The copepods include evidence of the extant family Canthocamptidae, thought to have colonized fresh water on Pangaea during Carboniferous times.

**Cameral deposits in a sublethally damaged Pennsylvanian *Pseudorthoceras* sp. from the Buckhorn Asphalt Lagerstätte in southern Oklahoma, USA****Barbara Seuß<sup>1</sup>, Royal H. Mapes<sup>2</sup>, Christian Klug<sup>3</sup> and Alexander Nützel<sup>4</sup>**<sup>1</sup>*GeoZentrum Nordbayern – Paläoumwelt, Friedrich-Alexander Universität Erlangen-Nürnberg, Erlangen, Germany*<sup>2</sup>*Department of Geological Sciences, Ohio University, Athens, USA*<sup>3</sup>*Paläontologisches Institut und Museum der Universität Zürich, Zürich, Switzerland*<sup>4</sup>*Bayerische Staatssammlung für Paläontologie und Geologie, München, Germany*

The recovery of two well preserved chambers of the phragmocone of *Pseudorthoceras* sp. from the Buckhorn Asphalt Lagerstätte provides new insight into the controversy over how cameral deposits are developed in orthoconic nautiloids. The specimen has two oval openings on the conch, a result of penetrating the outer test and present cameral deposits. The animal survived the attack and was able to still precipitate cameral deposits, astonishing because in the oral chamber the bite-marks opened the chamber to the seawater. Three hypotheses of cameral deposit precipitation can be tested: (1) direct precipitation from the cameral fluid; (2) precipitation from the cameral fluid with a reoccurring organic template/membrane; (3) secretion by a cameral tissue. (1) and (2) cannot be supported because the precipitation chemistry of the cameral fluid is altered and cannot be controlled by the animal. (3) remains possible: the penetration marks would be sealed by cameral tissue regeneration and cameral deposits would be precipitated directly by such tissues. Thus, the cameral fluid chemistry would appear to not be important for cameral deposit precipitation. Anyhow, this hypothesis remains problematic: there are no known openings that would allow tissue connections from the siphuncle through the connecting ring to the cameral chamber.

**A new specimen of the enigmatic perissodactyl-like archaic ungulate mammal *Olbitherium* from the early Eocene of Wutu Coal Mine, Shandong Province, China****Thierry Smith<sup>1</sup>, Pieter Missiaen<sup>2</sup> and Cheng-Sen Li<sup>3</sup>**<sup>1</sup>*Department of Palaeontology, Royal Belgian Institute of Natural Sciences, Brussels, Belgium*<sup>2</sup>*Research Unit Palaeontology, Ghent University, Ghent, Belgium*<sup>3</sup>*Institute of Botany, Chinese Academy of Sciences, Beijing, China*

The famous early Eocene locality of Wutu has been revisited in the scope of a bilateral cooperation program between Belgium and China. At this occasion a skull associated with postcranial elements of a perissodactyl-like archaic ungulate has been discovered. The specimen comes from the middle coal-bearing Member of the Wutu Formation around the seventh coal layer about 250 metres deep. Based on the morphology of the teeth the specimen belongs to the enigmatic mammal *Olbitherium* that has been described from the same locality by Tong and Wang (2004). The new specimen is characterized by a moderate lophodonty, double rooted P1 and P2 and by the presence of an extra cusp near the metaconule on the P4. The upper molars are not much transverse giving a relatively square aspect to the teeth. A cladistic analysis based on dental, cranial and postcranial characters is performed in order to situate *Olbitherium* in the phylogeny of the primitive ungulates. This genus belongs to the order Perissodactyla and is close to basal isctolophids such as *Cardiolophus* and *Homogalax*. However, *Olbitherium* presents several autapomorphies suggesting that it is a member of new group of perissodactyls.

**Response of marine biota to rapid global warming during the Paleocene-Eocene thermal maximum****Robert P. Speijer***Department of Earth and Environmental Sciences, K.U. Leuven, Leuven, Belgium*

The early Palaeogene greenhouse world is characterized by a series of global warming events, or hyperthermals. The most pronounced and best documented hyperthermal, the Palaeocene-Eocene thermal maximum (PETM) is associated with the extinction of ~40% of deep-sea benthic foraminifera, short-term radiations in planktic foraminifera and calcareous nannofossils and poleward migrations of tropical dinoflagellates. These are all well established features of the PETM. By contrast the response of most marine invertebrates to palaeoclimatic change during the PETM is poorly documented and understood. An exception are the reef building corals that virtually disappeared from low latitudes, giving way to the dominance of larger foraminifera as the main carbonate producers of early Eocene platforms (Scheibner & Speijer, Earth-Sci. Rev. 2008). Yet, the impact of this extreme warming event on the distribution and evolution of common macro-invertebrates such as molluscs, echinoderms or brachiopods is largely unknown. A comprehensive understanding of biotic responses to rapid global warming in deep time will strongly benefit from turning research focus to continental margin records and outcrops yielding rich invertebrate faunas.

**Neritic foraminiferal responses to a runaway greenhouse during the PETM****Peter Stassen<sup>1</sup>, Ellen Thomas<sup>2</sup>, Etienne Steurbaut<sup>1,3</sup> and Robert P. Speijer<sup>1</sup>**<sup>1</sup>*Department of Earth and Environmental Sciences, Katholieke Universiteit Leuven, Belgium*<sup>2</sup>*Department of Geology and Geophysics, Yale University, New Haven, CT, USA*<sup>3</sup>*Royal Belgian Institute of Natural Sciences, Brussels, Belgium*

The Palaeocene-Eocene thermal maximum is characterized by a worldwide 5-8°C warming. In order to establish the biogeographic response of benthic foraminiferal communities to these climate changes, we compare three shallow marine settings. In Egypt, PETM saprolitic beds were formed as the result of increased upwelling. Widespread anoxia led to the collapse of the Palaeocene outer-middle neritic communities and triggered basin-wide downslope migrations of pioneering shallow water taxa. In Tunisia, the PETM interval is not marked by distinct dysoxia, yet, a sharp faunal turnover is observed with the replacement of the prevailing coastal assemblage by a more diverse fauna composed of deeper-dwelling infaunal species. The onset of the PETM in the New Jersey Coastal Plain (USA) is placed at the transition from glauconite sands to clays. Diverse middle-outer neritic Palaeocene benthic foraminiferal assemblages were replaced by opportunistic outer neritic assemblages as the result of stressed eutrophic low-oxygen environments due to increased runoff. In all studied settings, rather stable latest Palaeocene foraminiferal assemblages are abruptly replaced by opportunistic faunas at the onset of the PETM, reflecting more stressed low-oxygen environments, higher sedimentation rates and rising sea level. This also implies that the continental margins became major carbon sinks during the PETM.

**Palaeobiology of a non-marine Precambrian shale: Well-preserved eukaryotes from the 1.1 Ga Nonesuch Formation****Paul Strother<sup>1</sup> and Charles Wellman<sup>2</sup>**<sup>1</sup>*Department of Geology & Geophysics, Boston College, Weston MA, USA*<sup>2</sup>*Department of Animal & Plant Sciences, The University of Sheffield, Sheffield, UK*

Macerations of samples from the Nonesuch Formation from two drill cores in Upper Peninsula Michigan USA yield abundant well-preserved palynomorphs. The Nonesuch grey shales are conformably sandwiched between alluvial conglomerates (Copper Harbor Fm) and fluvial red sandstones (Freda Fm). The depositional environment of the Nonesuch Fm is lacustrine, befitting its regional setting in the failed Mid-Continent Rift System. As with the coeval Torridon Group in northwest Scotland, eukaryotes dominate the assemblages. Acanthomorphic acritarchs are absent. Excellent preservation of cell walls reveals quite distinct variation in wall construction - from homogenous to granular to plate-like to submicron fibrillar. Morphological complexity ranges from simple cysts with well-defined excystment features to multicellular, branched filaments. Few fossils resemble extant freshwater algae, except for a possible euglenid. There is some taxonomic overlap with the Torridonian assemblages, including *Valeria lophostriata* and small ellipsoidal cells resembling the *Halotheca-Euhalotheca* Group of halotolerant cyanobacteria. Nearly 50 provisional taxa have been identified, enabling a nascent picture of life in terrestrial settings at the beginning of the Neoproterozoic. Our findings provide direct evidence for early eukaryotic colonization of terrestrial habitats, both in and around lakes, although evidence of distinct morphological adaptations to the planktonic habit is intriguingly lacking.

**Resetting the clock on the origin of land plants****Wilson A. Taylor<sup>1</sup>, Paul K. Strother<sup>2</sup>, Marco Vecoli<sup>3</sup> and John H. Beck<sup>2</sup>**<sup>1</sup>*Department of Biology, University of Wisconsin-Eau Claire, Eau Claire, WI, USA*<sup>2</sup>*Geology & Geophysics, Weston Observatory of Boston College, Weston, MA, USA*<sup>3</sup>*Geosystems CNRS, Université Lille, Villeneuve d'Ascq, France*

The origin of land plants (embryophytes) is nominally dated as Darriwilian based on isometric (tetrahedral) spore tetrads, which are considered plesiomorphic for all embryophytes. Laminated sporoderm occurs in crown group liverworts (and not in the charophyte sister group) – its presence in the fossil record should set a minimum date for the origin of land plants. Laminated spore walls have been used previously to assign liverwort affinity to Ordovician and younger cryptospores, including some found in spore masses. Transmission electron microscopy (TEM) studies show that laminated sporoderms are widespread in dispersed monads and dyads as old as Cambrian (Drumian). TEM analyses show that some Cambrian cryptospores (*Agamachates*) are actually packets of dyads formed by cell divisions within resistant spore mother cell walls (endosporic development). In the Kanosh Shale (Dapingian), similar endosporic packets coalesce to form small sporogenic thalli, directly supporting Bower's 1908 interpolational hypothesis for the origin of the land plant sporophyte. The tetrahedral tetrad (Darriwilian) benchmark is probably recording a shift from successive to simultaneous meiosis within an evolving land plant lineage, rather than demarcating the charophyte-embryophyte lineage split. These observations, and others, indicate a substantial re-evaluation of the timing of land plant origins back to the Cambrian.

**The marine Triassic-Jurassic record of northern Chile: facies, fossils and palaeoenvironments****Richard J. Twitchett<sup>1</sup>, Guillermo Chong<sup>2</sup>, Alfonso Rubilar<sup>3</sup>, F. Amaro Mourges<sup>3</sup> and L. Felipe Opazo<sup>1</sup>**<sup>1</sup>*School of Geography, Earth and Environmental Sciences, University of Plymouth, Plymouth PL4 8AA, UK*<sup>2</sup>*Departamento de Ciencias Geológicas, Universidad Católica del Norte, Angamos 0610, Antofagasta, Chile*<sup>3</sup>*Sernageomin, Calle Til Til 1993, Ñuñoa, Santiago, 10465, Chile*

The Triassic-Jurassic interval witnessed one of the major extinction events of the Phanerozoic. Most data concerning this event comes from localities in North America and Europe and comparatively less is known about the Triassic-Jurassic transition in other regions. Previously published work on sections in northern Chile has demonstrated that they preserve a relatively complete, continuous and fossiliferous marine Triassic-Jurassic record. Abundant ammonites provide an excellent biostratigraphic framework, with some conodont data from the Upper Triassic, and the tectonic setting is well understood. We conducted fieldwork in an area in the Domeyko Cordillera, southeast of Antofagasta, in order to undertake detailed palaeoecological and palaeoenvironmental analyses through the Late Triassic mass extinction and Early Jurassic recovery interval. Upper Triassic (Rhaetian) shallow water reef carbonates were sampled at several localities, recording a diverse and abundant assemblage of corals, molluscs, echinoderms and brachiopods. Palaeoecological analyses demonstrate considerable temporal and spatial variation in the fossil communities, with significant differences between localities. No Hettangian reefs were encountered.



Triassic-Jurassic successions deposited in deeper water contain abundant ammonites (including *Choristoceras* and *Psiloceras*), but a much lower diversity benthic macrofossil assemblage. Horizons of phosphatic concretions and laminated strata indicate upwelling conditions and associated oxygen restriction on the seafloor.

### Pliocene climate of the southern North Sea Basin: a sclerochronological approach

**Annemarie Valentine<sup>1</sup>, Andrew Johnson<sup>1</sup>, Melanie Leng<sup>2</sup> and Peter Balson<sup>3</sup>**

<sup>1</sup>*Geographical, Earth and Environmental Sciences, University of Derby, Derby DE22 1GB, UK*

<sup>2</sup>*NERC Isotope Geosciences Laboratory, British Geological Survey, Keyworth, Nottingham NG12 5GG, UK*

<sup>3</sup>*British Geological Survey, Keyworth, Nottingham NG12 5GG, UK*

With ever more recognition of modern climate change, investigations into climate from time-intervals of Earth's past with global temperatures elevated by 2-4.5 °C (as anticipated by Global Circulation Models - GCMs – for the end of the 21st century) have become increasingly significant. A time-interval suitable for such analysis is one within the Pliocene (*c.* 5.3-2.6 Ma), the mid-Piacenzian (*c.* 3.0-3.3 Ma), with a generally warmer world, increased atmospheric CO<sub>2</sub> and comparable palaeogeography to present. Oxygen isotope thermometry and microgrowth increment datasets obtained from the bivalve *Aequipecten opercularis* from mid-Piacenzian deposits in Belgium and the Netherlands have indicated that winter and summer temperatures are similar to present-day southern North Sea Basin (SNSB) seasonal extremes and thus indicate the existence of a cool-temperate climatic regime. These datasets contradict previous views that the Pliocene/mid-Piacenzian climate of the SNSB was predominantly warm-temperate to subtropical. The cool recorded temperatures could relate to either (i) global temperature downturns linked to Milankovich Cycles; (ii) a regional effect relating to a loss or reduction of Gulf Stream/North Atlantic Drift (GS/NAD) heat supply or (iii) a change within the local palaeogeography with a less open basin restricting GS/NAD access.

### Holocene morphospace expansion of *Bellamya* gastropods from Lake Malawi as potential evidence for punctuated morphological change

**\*Bert Van Boclaer**

*Research Unit Palaeontology, Department of Geology and Soil Science, Ghent University, Ghent, Belgium*

Evolutionary punctuations are hard to study because they occur faster than is observable in the fossil record, but generally too slow for study on biological timescales. We studied a potential evolutionary punctuation in four endemic *Bellamya* gastropod species derived from a common ancestor that is preserved in early to middle Holocene, radiocarbon-dated lacustrine deposits in the Malawi Basin. Morphometric comparison of extant and fossil morphs with semi-landmark analysis and traditional measurements documents a 3.1-5.4 times morphospace expansion since the middle Holocene. We combine modelling of evolutionary divergence and calculation of evolutionary rates of phenotypic change to show that morphological divergence could have completed within 25 to 500 years for each species depending on trait heritabilities and the strength of selection. The divergence results from rates of morphological change within or above the genetic drift range but slower or equal to those commonly observed in selection experiments. We also illustrate that

geographic isolation in separate drainage basins allowed cladogenesis and morphological conservatism in riverine taxa, which may result in the recognition of pseudo-stationary lineages, while speciation in lacustrine environments led to increased disparity by morphological adaptation following greater ecological opportunity.

### Ecological impacts of global warming: Measuring marine microfossil community change during past episodes of climate change

**Amelinda Webb**

*Department of Geology and Geophysics, Yale University, New Haven, CT, USA*

The impact of global warming on biodiversity is the subject of varied and sometimes contradictory predictions. Past global warming events provide an opportunity to investigate the ecological impact of climate change. This study examines ostracod, calcareous nannoplankton, benthic and planktic foraminiferal assemblages from the Palaeocene-Eocene thermal maximum, mid-Palaeocene biotic event, and late Maastrichtian thermal maximum. Ecological impact is assessed through: 1) changes in diversity, measured using meta-analyses, and 2) changes in community structure, measured by quantifying rank-abundance curve shape which allows inference of relative stress levels.

When all taxonomic groups from all events are combined, diversity increases during thermal maxima. A diversity increase was observed separately within fossil assemblages from the Palaeocene-Eocene and the late Maastrichtian, although no change was observed for the mid-Palaeocene. Diversity increased in planktonic groups during the three thermal maxima, while the benthic groups lost diversity. Changes in community structure (relative stress) differed across the groups, with relative stress increasing or decreasing irrespective of changes in species richness. The results of this study show the biotic impact of global warming is varied between groups and highlight the importance of understanding an ecosystem before making conservation decisions or predictions about changing biodiversity in response to climate change.

### The microfossil memory of ancient artefacts

**Mark Williams<sup>1</sup>, Ian Wilkinson<sup>2</sup>, Jawad Afzal<sup>1</sup>, Alison Tasker<sup>1</sup>, Neil Christie<sup>3</sup>, Matt Edgeworth<sup>3</sup>, Jeremy Taylor<sup>3</sup> and Ruth Young<sup>3</sup>**

<sup>1</sup>*Department of Geology, University of Leicester, Leicester, UK*

<sup>2</sup>*British Geological Survey, Keyworth, Nottingham, UK*

<sup>3</sup>*School of Archaeology and Ancient History, University of Leicester, Leicester, UK*

Reconstructing ancient trade routes and cultural connections is a mainstay of archaeology. High value items, such as amber in Europe or jade in pre-Columbian America, defined major and early long-distance trade routes. More enigmatic are the sources of items used in the daily lives, and deaths, of ancient peoples, such as the commoner burial goods of graves, the clay pots of kitchens, the bricks and stones of walls, or the earthworks surrounding homesteads, towns or forts. Using examples from settings as diverse as Iron Age forts and medieval ramparts we show how microfossil evidence of provenance provides unique insights into the geological, engineering, manufacturing and trading knowledge of ancient peoples and of the extent of their cultural contacts.

talks

talks

**Chelicerate tagmosis: inferred mechanisms of development in extinct taxa****\*Joanna M. Wolfe<sup>1</sup> and David A. Legg<sup>2</sup>**<sup>1</sup>*Department of Geology and Geophysics, Yale University, New Haven, CT, USA*<sup>2</sup>*Department of Earth Sciences and Engineering, Imperial College London, London, UK*

Arthropod tagmosis is the differentiation of segments along the anterior/posterior axis, producing appendages specialized for sensation, feeding, and locomotion. Characters relating to segment and limb number and morphology are important in constructing phylogenies that include fossil taxa. Chelicerates are a diverse group, including the extant spiders, mites, harvestmen, scorpions, xiphosurans, and the extinct trigonotarbids, eurypterids, chasmataspids, and synziphosurans. The extant pyggononids (sea spiders) may also belong to this group. The chelicerate body is divided into two major tagmata: prosoma and opisthosoma. There is variation, however, within this bauplan (e.g., number of segments in a limb, fusion of dorsal tergites). Developmentally, patterns of tagmosis are associated with changes in the expression of Hox genes. The distribution of extant taxa for which Hox expression patterns are known is sparse. Therefore, we studied morphological traits for which the developmental basis is understood in extant chelicerates. We constructed a new phylogeny for chelicerates from over 400 morphological characters. Representative extant taxa with sequence or developmental gene expression data were included, as well as fossils with unique patterns of tagmosis or other morphological traits. Using this morphological topology, ancestral character states were inferred. Results under different models of character evolution (parsimony, likelihood, Bayesian) are compared.

**Integrated new results from the *Iguanodon*-bearing Wealden facies of the Mons basin (Belgium)****Johan Yans<sup>1</sup> and Working Group FRFC-FNRS 2.4.568.04.F**<sup>1</sup>*Department of Geology, FUNDP, Namur, Belgium*

Wealden facies from new boreholes drilled within the natural pit (“Cran aux Iguanodons”) of Bernissart and from new/revisited successions in several sites were used for a multidisciplinary research. The Wealden facies of Bernissart are laminated dark pyritic clays with mm-thick brown and white silty levels. Several topics were investigated such as palynology and determination of woody and plant-mesofossil fragments, to the precise age and palaeoenvironments of the iguanodons. The formational processes of the “Cran” were documented by multidisciplinary approach, i.e., sedimentology of the lacustrine Wealden facies (including clay mineralogy, granulometry and magnetic susceptibility), characterization of the organic matter with Rock-eval, palynofacies, soluble alkane content, carbon isotope and structural analysis. The palaeontological content was also studied (palaeohistology, characterization of amber, preparations for diatoms and ostracods). Moreover, Wealden facies from IRSNB collection (historical searches of 1878-1881) and other sites in the Mons basin (Hautrage, Thieu, Baudour) were investigated, notably for their content of numerous fishes and coprolites. In Hautrage and Baudour, we note the discovery of teeth of freshwater sharks and a fragment of a sauropod. In Thieu the occurrence of dinoflagellate cysts suggests the marine influence for the Wealden facies in the Eastern part of the Mons basin.

**Abstracts of poster presentations**

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

**Modelling variation in the fidelity of skeletal preservation of fossil vertebrates****Sue Beardmore<sup>1</sup>, Patrick Orr<sup>1</sup> and Heinz Furrer<sup>2</sup>**<sup>1</sup>*UCD School of Geological Sciences, University College Dublin, Belfield Campus, Dublin 4, Ireland*<sup>2</sup>*Paläontologisches Institut und Museum der Universität Zürich, Karl Schmid-Strasse 4, CH-8006, Zürich, Switzerland*

Most vertebrate fossil skeletons are at least partially disarticulated and incomplete, the result of decay and biostratinomic processes in the death to final burial interval. We assessed the skeletal taphonomy of the pachypleurosaurid reptiles *Serpianosaurus* (Besano Formation) and *Neusticosaurus* (Meride limestone) from the Middle Triassic of Monte San Giorgio, Switzerland, using a semi-quantitative approach: completeness and articulation are assessed for nine specific ‘skeletal units’ (skull, neck, ribs, thorax, four limbs, tail). From this, values for the completeness and articulation of each skeleton can be calculated. Thus, not only is the state of preservation of the specimen as a whole known, but whether, and to what extent, specific parts of the skeleton are contributing to the loss of skeletal fidelity can be identified. In *Serpianosaurus* a decrease in skeletal articulation and completeness are positively correlated. Articulation in *Neusticosaurus* is extremely variable (40-100%), but values for completeness consistently high (>75%). Analysis of the individual skeletal units reveals subtle differences between the two taxa that indicate *Serpianosaurus* were exposed on the sea-floor for longer before burial, and, as decay progressed, were more prone to reworking by bottom currents.

**A new insight in the phylogeny of the Devonian Asteropyginae (Trilobita)****Arnaud Bignon and Catherine Crônier***Laboratoire Géosystèmes (FRE 3298 du CNRS), Université des Sciences et Technologies de Lille 1, Villeneuve d'Ascq, France*

The subfamily of Asteropyginae constitutes one of the most famous groups of Devonian trilobites. Indeed this subfamily is composed of genera with an unusual morphology among the order Phacopida such as the long spines of *Heliopyge* and of *Psychopyge*, the eye shaped like a tower of *Erbenochile* or the long precephalic trident of *Walliserops*. This subfamily comprised more than 250 species from the Lochkovian to the Frasnian. Its biodiversity was affected by important fluctuations in agreement with the Devonian crises and radiations. Moreover, the Asteropyginae is worldwide represented from America to Afghanistan via Europe and North Africa. Asteropyginae may be crucial for studying various research topics such evolution, ontogeny, palaeoenvironment and palaeobiogeography.

A reliable phylogeny is required for such studies. Lieberman and Kloc (1997) realised a phylogenetic analysis on this subfamily. But, since their work new discoveries provide the opportunity to examine the extent of biodiversity. The purpose of the present work is to update the Asteropyginae phylogeny via a cladistic analysis. This study leads also the modification of genus diagnoses implying the recombination of several species.

**Testing morphometric multivariate data analyses: Missing data and taxonomic clustering****\*Caleb M. Brown***Department of Ecology and Evolutionary Biology, University of Toronto, ON, Canada*

Missing data is an unavoidable problem in palaeontology and the performance of missing data deletion/estimation techniques in morphometric datasets are poorly understood. Here these techniques are tested on an extant sample to measure the introduced error. Additionally, multivariate morphometric data analyses are tested for their suitability for deciphering patterns of taxonomic clustering. A large sample of extant crocodylian skulls was measured and analyzed with Principal Components Analysis (PCA), Canonical Variate Analysis (CVA) and hierarchical cluster analysis. Twenty-three different proportions of missing data were randomly introduced into the dataset, re-estimated, analyzed, and compared to the original result (1000 replicates). Bayesian PCA and Gower's coefficient introduce significantly less error than pair-wise deletion or mean/median substitution. The rate of error of re-estimation shows no distinct loss of accuracy at any proportion of missing data. Specimens with small sample sizes and those most morphologically disparate have the highest estimation error. PCA was able to cluster most taxonomic groups in non-overlapping morphospace, but consistent distinct taxonomic clusters were not obtained without *a priori* knowledge of the groups. CVA reliably assigned specimens to taxonomic groups when the group membership was established *a priori*, but the most useful variables did not necessarily correspond to those of PCA.

**The Pliensbachian brachiopod fauna of Case Canepine (Monti Martani, Umbria) in the context of Liassic carbonate platforms of Tethys****Giuseppe Buono<sup>1</sup> and Federico Famiani<sup>2</sup>**<sup>1</sup>*School of Geography, Earth and Environmental Sciences (SoGEES), University of Plymouth, UK*<sup>2</sup>*Laboratorio Ecologico di Geo-Paleontologia – Assisi, Italy*

We report the results of a preliminary study on a brachiopod assemblage sampled in two "localities" about 1 km apart on Monte Rotondo, near the town of Case Canepine (Castel del Monte, Acquasparta, Terni, Monti Martani, Umbria, Central Italy). It is possible that our outcrops are partially coincident with those described by Principi (1910) [localized between Case Canepine and Colle Lungo]. Brachiopods are preserved mainly as re-crystallized shells and sometimes show internal geopetal structures. They are contained in a mainly pink to brownish or whitish 15 and 50 cm thick re-crystallized micritic limestone with other bioclasts, especially crinoids. These layers are referable to the Corniola Fm. The fauna seems an impoverished version of that described by Principi (1910), even if possibly this is linked to less sampling. It is dominated by small smoothed rhynchonellids (Basioliolidae morphotype), with almost no strongly ribbed rhynchonellids (the exception is given by one specimen of *Tetrarhynchia zitteli*, and one tentatively attributed to *Lokutella liasina*). Spiriferida are also represented by *Liospiriferina obovata*, and at least one specimen of *Liospiriferina rostrata*.

Principi P. 1910. Brachiopodi del Lias medio di Castel del Monte (presso Acquasparta). *Riv. Ital. Paleont.* 16(3), 63-88.

**Dimerelloidea (Brachiopoda) and their relationships with chemosynthetic environments****Giuseppe Buono***School of Geography, Earth and Environmental Sciences (SoGEES), University of Plymouth, UK*

Brachiopods are one of the mayor components of ancient chemosynthesis-based environments. In particular the brachiopod superfamily Dimerelloidea shows numerous fossil genera associated with cold seeps and hydrothermal vents (chemosynthesis-based) environments. All of these genera are characterized by long ensiform crura showing a larger ratio of length of crura to length of shell than other rhynchonellid genera.

Considering that crura support the lophophore, the characteristic feeding and respiratory organ of brachiopods, it is suggested that ensiform crura can represent an adaptation to oxygen depleted environments typical of cold seeps and hydrothermal vents. These crura could be associated to a larger lophophore and/or to the necessity of position closer to the shell margin of the lophophore. Both features argue for an improvement of the feeding and respiratory capacities.

**A new brachiopod fauna from Early Triassic of Oman****Giuseppe Buono<sup>1</sup> Richard Twitchett<sup>1</sup>, Lindsay Hadfield<sup>2</sup> and Colin Mitchell<sup>3</sup>**<sup>1</sup>*School of Geography, Earth and Environmental Sciences (SoGEES), University of Plymouth, UK*<sup>2</sup>*Abbey Road, Barking IG11 7GH, UK*<sup>3</sup>*13 Argyle Street, Darwen, Lancashire BB3 1EX, UK*

The first description of brachiopods (rhynchonellids and spiriferids) from the Lower Triassic (Lower Induan, *isarcica-carinata* zones) Al Jil Formation in the Wadi Wasit area of Oman is presented here. These small brachiopods belong to a diverse, partially silicified fauna including micro-gastropods, echinoderms, bivalves, and ostracods. The brachiopods have been assigned to *Orbicoelia extima* (Grant) and *?Lissorhynchia* n. sp., and each species has been analyzed taxonomically and biometrically. Moreover this association has been examined from a palaeobiogeographical and palaeoecological point of view. Both species show a micromorphic look, following the general trend of many Permian/Triassic boundary marine invertebrates, possibly because of productivity decrease. *Orbicoelia* survived the end-Permian mass extinction due to a number of survival mechanisms/strategies, such as opportunism, generalism, eurytopy, widespread and rapid biogeographical distribution, and chance/luck. This was an unspecialised and morphologically simple dysaerobic genus, able to withstand both low and well oxygenated environments. The presence of *?Lissorhynchia* in the lower Induan (upper Griesbachian) could represent the oldest record of these genus previously known from the upper Induan (Dienerian). Moreover this new species seems to have intermediate characteristics between *Prelissorhynchia* and *Lissorhynchia*.

**The Furongian Biotas of the Alum Shale Sea: discovery of unexpected benthic faunas.****Christopher Castellani, Andreas Maas and Dieter Waloszek***Biosystematic Documentation, University of Ulm, Ulm, Germany*

The late Cambrian Alum Shale Formation of Sweden consists of dark, organic-rich, and finely laminated shales with intercalated limestone concretions and beds. These nodules



were possibly formed in a poorly oxidized, sulphur-rich epi-continental sea. Trilobites, agnostids and small brachiopods dominated the faunal succession of the shales, while the nodules (orsten, stinkstones) yielded a diversified arthropod assemblage. It ranges from lobopods and pentastomids to chelicerates and crustaceans, dominantly phosphatocopines, and, most likely, represented a small-sized 'meiofauna' community. Besides this and the abundant conodonts, the discovery of many more faunal elements demonstrates that a rich benthic macro- and meiofaunal community inhabited the Alum Shale Sea during the Furongian. First results are presented, revealing the presence of cyanobacteria, hexactinellid and demosponge spicules, putative pelmatozoan columnals, fragments of brachiopod, conulariid and mollusk shells, sclerites resembling those of the vertebrate *Anatolepis*, tommtiids, and more remains of unclear affinities. The presence of benthic organisms in the Alum Shale Sea indicates that during their lifetime water was not anoxic, and that the bottom was firm enough to allow also colonization by sessile organisms. This situation in the Alum Shale Sea during the Furongian may have been restricted spatially and temporarily.

### Early Pliocene Weddell Sea seasonality determined from bryozoans

**Nicola Clark<sup>1</sup>, Mark Williams<sup>1,2</sup>, Beth Okamura<sup>3</sup>, John Smellie<sup>1</sup>, Anna Nelson-Laloe<sup>4</sup>, Tanya Knowles<sup>5</sup>, Paul Taylor<sup>6</sup>, Melanie Leng<sup>7</sup>, Jan Zalasiewicz<sup>1</sup> and Alan Hayward<sup>8</sup>**

<sup>1</sup>Department of Geology, University of Leicester, Leicester LE1 7RH, UK

<sup>2</sup>British Geological Survey, Keyworth, Nottingham NG12 5GG, UK

<sup>3</sup>Department of Zoology, Natural History Museum, London SW7 5BD, UK

<sup>4</sup>British Antarctic Survey, High Cross, Cambridge CB3 2EQ, UK

<sup>5</sup>Department of Palaeontology, Natural History Museum, London SW7 5BD, UK

<sup>6</sup>Earth Science and Engineering, Prince Consort Road, Imperial College, London SW7 2BP, UK

<sup>7</sup>NERC Isotope Geosciences Laboratory, British Geological Survey, Keyworth, Nottingham NG12 5GG, UK

<sup>8</sup>School of Earth and Environment, University of Leeds, Leeds LS2 9JT, UK

Rapid warming at high latitudes during the 21st century represents a significant threat to polar-regions. Here we use morphological data from fossil bryozoans to assess seasonality at high latitude during the warm Early Pliocene. The Pliocene was the last interval of Earth History when the climate was, overall, warmer than present and it therefore represents a plausible scenario for near future climate change. Early Pliocene cheilostome bryozoans are preserved in glacial deposits of James Ross Island, Northern Antarctic Peninsula. Several different marine bryozoan genera were incorporated into diamictites during Pliocene ice advance(s). Bryozoan zooid-size Mean Annual Range of Temperature (zs-MART) analysis provides estimates of seasonality which suggest annual marine temperatures for the James Ross Island region varied by at least 4°C and possibly by as much as 10°C during Early Pliocene warm intervals. This represents greater seasonality for the northern Weddell Sea than seen at the present day (MART ca 2°C) and also signals summer sea temperatures warmer than present. Coupled with growth increment and geochemical data from bivalves, bryozoans provide a powerful proxy for reconstructing high latitude climate during the warm Early Pliocene.



### A new functional morphology in coiled crinoids from the Middle Devonian (Eifelian) of New York State

**Simon A. F. Darroch<sup>1</sup> and Aaron W. Hunter<sup>2</sup>**

<sup>1</sup>Department of Geology and Geophysics, Yale University, New Haven CT, USA

<sup>2</sup>Department of Palaeontology, Natural History Museum, Cromwell Road, London SW7 5BD, UK

This study reports the recovery and reconstruction of recumbent *Mariacrinus* sp. crinoids from the earliest Middle Devonian (Eifelian) Onondaga Formation, New York State. The crinoid stems are arranged in planispiral coils, and possess a unique constructional morphology that produced a rigid, coiled stem that could be sunk into soft substrates as an anchor, and which would have supported a crown lifted at a shallow angle across the sediment-water interface. While other crinoids with coiled stem morphologies have been interpreted as 'snowshoe' strategists, whereby the weight of the stem would have been evenly distributed on the sediment surface, the *Mariacrinus* sp. individuals differ from previously described coiled 'snowshoe' forms in terms of stem size, stem symmetry and articulation between stem ossicles, leading to interpretation instead as an 'iceberg' strategist. Although the crown parts have so far not been discovered at the site preventing definite taxonomic assignment, analysis of the stem sections in the context of functional morphology allows interpretation of a previously undescribed life strategy for stabilization on soft substrates, and the first potential 'iceberg' strategist described for the Crinoidea.

### Supermatrix or supertree? A comparison of supertree and supermatrix methods using the landfowl (Aves: Galliformes)

**Katie E. Davis<sup>1,2</sup>, \*Aodhán Butler<sup>3</sup> and Roderic D. M. Page<sup>1</sup>**

<sup>1</sup>DEEB, FBLS, Graham Kerr Building, University of Glasgow, Glasgow G12 8QQ, UK

<sup>2</sup>Department of Zoology, The Natural History Museum, Cromwell Road, London SW7 5BD, UK

<sup>3</sup>Department of Palaeontology, The Natural History Museum, Cromwell Road, London SW7 5BD, UK

There are two distinct methods available to construct large-scale trees: supermatrix and supertree. Each has advantages and disadvantages, but supertrees in particular have come under heavy criticism from some authors. Supertrees are secondary constructions, built from individual phylogenetic trees, whereas a supermatrix is constructed from primary data collated into a single, large matrix. We look at the supertree vs. supermatrix "controversy" in order to assess which, if either, is a more suitable method for building large phylogenetic trees. We did this by building both a supertree and a supermatrix based on the same set of molecular data downloaded from GenBank. Each tree was then compared to the input source trees of the supertree to assess how well each tree represented the input data. Both methods performed equally as well in fitting the source data. The supermatrix was quicker to construct, but took substantially longer to calculate. The supertree took a long time to construct, mainly due to the stringent data control protocols in place, but was very quick to calculate. Dependent upon the data at hand and the other factors involved, the choice of which method to use appears, from this study, to be of little consequence.



### Intraspecific variability of Early Devonian heteromorph ammonoids (Anetoceratinae) and Buckman's law

\*Kenneth De Baets, Christian Klug and Claude Monnet

Paläontologisches Institut und Museum, Universität Zürich, Zürich, Switzerland

The earliest ammonoids are loosely coiled ('heteromorph'). A high number of species was introduced for these forms (e.g., 25 species of *Erbenoceras*). The actual diversity is obscured by a great intraspecific variability, which may be related to their loose coiling. Due to the scarcity of well-preserved material and difficulties in stratigraphy, the intraspecific variability was never quantified in early Emsian ammonoids and other heteromorphs, although results of such a study will have implications for taxonomy, diversity, palaeobiogeography, and understanding their shell morphogenesis. Pronounced covariance of some morphological and geometrical ammonoid shell traits might depend on coiling. Studies of Mesozoic coiled ammonoids revealed a marked negative correlation of ornamentation strength with the whorl height/width ratio and the involution (Buckman's first law of covariation). Intraspecific variability of early ammonoids was examined throughout ontogeny using nearly 100 specimens with at least one whorl from a restricted stratigraphic interval (Erbenoceras Beds) in the Moroccan Anti-Atlas. Several species of *Erbenoceras* could be synonymised, augmenting their geographic distribution and reducing diversity. Correlations between rib strength, whorl section, and coiling were detected. More coarsely ribbed forms are more tightly coiled while many coiled Mesozoic ammonoids with coarse ornament are more evolute.

### Unravelling the (palaeo)autecology of Pliocene dinoflagellate cysts

Stijn De Schepper<sup>1</sup>, Eva Fischer<sup>2</sup>, Jeroen Groeneveld<sup>3</sup> and Martin J. Head<sup>2</sup>

<sup>1</sup>Geosciences Department, University of Bremen, Bremen, Germany

<sup>2</sup>Department of Earth Sciences, Brock University, St. Catharines, ON, Canada

<sup>3</sup>Alfred Wegener Institute, Bremerhaven, Germany

In an attempt to unravel the (palaeo)autecological preferences of extant and extinct dinoflagellate cysts, Late Pliocene and Early Pleistocene dinoflagellate cyst assemblage data have been compared with geochemical data from the same sample. The database contains >125 dinoflagellate cyst samples from four North Atlantic IODP/DSDP sites that are calibrated to Mg/Ca ratios of *Globigerina bulloides* as a measure of sea surface temperatures (SST). Comparing the fossil dataset with present-day dinoflagellate cyst distributions demonstrates good agreement between the SST ranges of extant taxa today and in the past. This shows that our new approach and methods are also a valuable tool for inferring the SST of extinct taxa. For example, *Ataxiodinium confusum*, *Impagidinium solidum* and *Invertocysta lacrymosa* had a preference for warmer conditions, whereas *Habibacysta tectata* inhabited cooler environments. However, it is notable that the extant cold-indicating *Impagidinium pallidum* shows important differences between its present and past temperature range and spatial distribution.



### The role of the North Atlantic in the mid-Pliocene glaciation of Marine Isotope Stage M2

Stijn De Schepper<sup>1</sup>, Jeroen Groeneveld<sup>2</sup>, B. David A. Naafs<sup>2,3</sup> and Martin J. Head<sup>4</sup>

<sup>1</sup>Geosciences Department, University of Bremen, Bremen, Germany

<sup>2</sup>Alfred Wegener Institute, Bremerhaven, Germany

<sup>3</sup>Leibniz Center for Earth Surface and Climate Studies, Institute for Geosciences, Potsdam University, Potsdam, Germany

<sup>4</sup>Department of Earth Sciences, Brock University, St. Catharines, ON, Canada

We have combined Mg/Ca and <sup>18</sup>O from *Globigerina bulloides*, alkenone records, and dinoflagellate cyst assemblage data from three IODP/DSDP sites to reconstruct the eastern North Atlantic palaeoceanography between ca. 3.4 and 3.2 Ma. During most of this episode, sea surface temperature (SST) reconstructions demonstrate a reduced north-south gradient, implying increased heat transport to the north by a vigorous North Atlantic Current. However, a remarkable overturn in the dinoflagellate cyst assemblages and sea-surface cooling at the northern sites suggest a major oceanic reorganisation about 2.3–3.5 ka before the maximum glaciation of MIS. This likely led to the thermal isolation of Greenland and prepared the conditions necessary for ice-sheet expansion during the full glacial conditions of MIS M2. During MIS M2, all sites record the coolest conditions, the north-south SST gradient increases and dinoflagellate cyst assemblages at the northern sites have an important cooler water component. This combined evidence suggests a reduction of northward heat transport due to a weakened North Atlantic Current during MIS M2. Shortly afterwards, a shift in dinoflagellate cyst assemblages and reduced north-south temperature gradient imply a return to an active North Atlantic Current, bringing warmer waters again to the higher latitudes.

### Upper Hirnantian acritarch abnormal growth forms from Anticosti Island, Canada

Aurélien Delabroye<sup>1,2</sup>, Axel Munneke<sup>3</sup>, Thomas Servais<sup>2</sup>, Thijs Vandenbroucke<sup>2</sup> and Marco Vecoli<sup>2</sup>

<sup>1</sup>LMTG - UMR 5563 UR 154 CNRS, Université Paul-Sabatier, Toulouse, France

<sup>2</sup>Laboratoire Géosystèmes – FRE 3298 CNRS, Université de Lille 1, Villeneuve d'Ascq, France

<sup>3</sup>GeoZentrum Nordbayern, Fachgruppe Krustendynamik, Universität Erlangen-Nürnberg, Erlangen, Germany

Abnormal growth forms of acritarchs have been recorded in high abundances in the upper Hirnantian strata from western Anticosti Island, Canada (Ellis Bay Formation, upper most member 6, *S. taugourdeau* chitinozoan Biozone). Two species are particularly affected – *Disparifusa psakadoria* Loeblich and Tappan, 1978 which presents abnormally hypertrophied central vesicle, and a new species of *Peteinosphaeridium* of which teratological forms present appendices which could be fused along their length making them to appear as long and high crests on the vesicle surface. A literature review highlights that this Late Ordovician event of increasing abundance of abnormal acritarchs is not unique in the lower Palaeozoic. Several similar events have already been recorded in the Silurian. They all share the fact that only particular species are affected by malformations. Geochemical analyses are currently performed to better comprehend potential origins of such recurrent biological events that may be related to chemical changes of the ocean waters.



**Did Mammoth end up a Lilliput?****Natasja den Ouden<sup>1,2</sup>, Lars W. van den Hoek Ostende<sup>1</sup> and Jelle W. F. Reumer<sup>2,3</sup>**<sup>1</sup>Netherlands Centre of Biodiversity/Naturalis, Leiden, the Netherlands<sup>2</sup>Natural History Museum Rotterdam, Rotterdam, the Netherlands<sup>3</sup>Department of Geosciences, Utrecht University, Utrecht, the Netherlands

It has been suggested that the woolly mammoth *Mammuthus primigenius* dwindled in size towards its extinction (Vartanyan *et al.* 1993, 2008). Missing in the discussion is an overview of the variation of the woolly mammoth through time. Particularly in a species which displays a respectable amount of variation and sexual dimorphism, such a baseline needs to be established before we can draw any conclusions. The North Sea is one of the largest resources for mammoth material in the world and provides an extraordinary opportunity to study the size and morphology of the mammoths from through time from one area. The results of both morphological and radiocarbon analyses provide a baseline variation study, allowing a comparison to those of other localities. Preliminary results show that the variation in the woolly mammoth is larger than is generally presumed. New material uncovered since the study of Maglio (1973) has considerably broadened the range of morphological features found within the species. Also, we tentatively suggest that the Lilliput effect might not be as pronounced as suggested.

**Upper Viséan (Mississippian) rugose corals of the microbial-sponge-bryozoan-coral bioherm from Kongul Yayla (Taurides, S. Turkey).****Julien Denayer***Service de Paléontologie animale et humaine, Département de Géologie, Université de Liège, Belgium*

Unexpectedly, an Upper Viséan bioherm discovered in the central Taurides (South Turkey) has yielded a rich and diversified rugose coral association with a European affinity. Among them, numerous *Siphonodendron pauciradiale*, *Lithostrotion araneum*, *L. vorticale*, *L. maccoyanum*, *Palaeosmilia purchisoni*, *Axophyllum* aff. *pseudokirsopianum*, *Espiella* sp. are dominant with small solitary undissepimented rugose corals. The rugose corals are associated with lithisid and chaetetid sponges as well as fistuliporid and fenestellid bryozoans, and michelinid and favositid tabulate corals. These skeletal elements are involved with microbialite structures in a bioherm overlaid by bioclastic shale and limestone. *S. pauciradiale* and *L. maccoyanum* are the guide taxa for the RC7 coral biozone and give the Asbian age (Warnantian, Upper Viséan) for the reef and overlying beds. The Kongul Yayla reef shares many features with age-equivalent buildups from British Isles, south France, south Spain and north Africa, particularly with Cracoan-type reefs known (among other localities) from England and Morocco.

**A cladistic test of echinoderm homologies, phylogenetic trees and character polarities****\*Léa Devaere<sup>1</sup> and Sébastien Clausen<sup>1,2</sup>**<sup>1</sup>FRE CNRS 3298 'Géosystèmes' – Université Lille 1, France<sup>2</sup>UMR CNRS 7207 'Centre de recherche sur la paléobiodiversité et les paléoenvironnements' – Muséum National d'Histoire Naturelle, Paris, France

Despite echinoderms being one of the most important and extensively studied invertebrate constituents of Palaeozoic ecosystems, their phylogenetic relationships are still highly debated. Their very incomplete Cambrian fossil record and their high disparity makes the reconstruction of their initial radiation difficult to understand. As a result, numerous models of homologies and related phylogenies have been proposed. Two major models (the Extraxial-Axial Theory and the 'Carpoids as basal' model) are evaluated herein through cladistic analysis. For the first time, 90 morphological traits in 38 basal echinoderm taxa have been successively coded according to each model and each matrix processed using PAUP 4.0. Different taxa (echinoderms or hemichordates) have been selected for rooting in order to assess the effect of outgroup selection on the resulting phylogenies, and the self-consistency of each model appraised by comparing the topology of the obtained trees with *a priori* phylogenetic hypotheses. This study allows comparison of how the two phylogenetic models perform in terms of (i) character interpretation, (ii) tree-topologies, and (iii) statistical support.

**Benthic foraminiferal response during early Eocene hyperthermals at DSDP Site 401 (Bay of Biscay, NE Atlantic)****Simon D'haenens<sup>1</sup>, André Bornemann<sup>2</sup>, Ursula Röhl<sup>3</sup>, Peter Stassen<sup>1</sup> and Robert P. Speijer<sup>1</sup>**<sup>1</sup>Department of Earth and Environmental Sciences, K. U. Leuven, Leuven, Belgium<sup>2</sup>Institut für Geophysik und Geologie, Universität Leipzig, Leipzig, Germany<sup>3</sup>Center for Marine Environmental Sciences (MARUM), Universität Bremen, Bremen, Germany

The early Palaeogene "hothouse" (60-50 Ma) was a climatically dynamic period with transient intervals of extreme global warming, also known as hyperthermals. The most prominent and best-documented hyperthermal is the Palaeocene-Eocene Thermal Maximum (PETM; ~55.5 Ma), which left a major mark on the biogeosphere evolution. In early Eocene deposits worldwide, additional smaller hyperthermals have been detected using stable isotope records. The biotic aspects, however, remain largely unexplored. Studying these early Eocene hyperthermals helps to assess whether or not they display similar biotic patterns as the PETM, as has been suggested by several authors.

Lower Eocene deep-sea sediments from DSDP Site 401 show a well-developed cyclicity in Biozone NP11; several marly levels stand out in the greyish-brown calcareous chalks. The <sup>13</sup>C and <sup>18</sup>O records on bulk material and benthic foraminifera clearly show the iconic isotopic excursion of the PETM and at least four additional negative excursions in Biozone NP11. Some, but not all, of these isotopic excursions correlate with strong short-term benthic foraminiferal assemblage changes and small long-term shifts in species composition. These benthic foraminiferal changes seem to confirm the idea that the biotic patterns of early Eocene hyperthermals display many similarities with the PETM.



### Sampling and completeness of the fossil record of the Lower Jurassic (Hettangian to Toarcian) of the Dorset Coast, Southwest England

\***Alexander M. Dunhill and Michael J. Benton**

Department of Earth Sciences, University of Bristol, Bristol, UK

Many studies have compared measures of the rock and fossil record, and the common pattern of covariance between sampling proxies and palaeodiversity have suggested that the fossil record is biased by the amount of rock available for sampling. However, recent studies using remote sensing and GIS to compare regularly used sampling proxies with rock exposure area have suggested that global or regional measures of rock volume or area are most likely poor representations for the amount of sedimentary rock available for sampling. It may be more appropriate to compare regional rock availability with local fossil collection data to obtain an accurate picture of rock record bias. Measures of rock outcrop and exposure area for each geological formation, together with counts of fossil-bearing localities have been compiled for the Lower Jurassic of the Dorset Coast. These sampling proxies are compared with local palaeodiversity data to assess whether the covariance between the rock and fossil records detected on global and continental scales reflects a bias, a 'common cause', or redundancy between the two signals. Local, constrained studies allow direct confrontation of actual collecting patterns with areas of exposed rock, numbers of formations, and abundance and diversity of fossils.

### Dispersed spores reunited with their parents: new mesofossil taxa from the Early Devonian

**Dianne Edwards<sup>1</sup>, John. B. Richardson<sup>2</sup>, Kevin Davies<sup>1</sup>, Jennifer Morris<sup>1</sup> and Lindsay Axe<sup>1</sup>**

<sup>1</sup>School of Earth and Ocean Sciences, Cardiff University, UK

<sup>2</sup>Natural History Museum, London, UK

Although dyads dominate Ordovician to Lower Devonian palynological assemblages, little is known about the form and affinities of their producers. Here we report on two groups of sporangia containing ornamented dyads and hilate monads. The first comprises sporangia with single layered walls which split into four valves. A single specimen has bifurcating axis and stomata. At least four types of spinose permanent dyads are recorded, belonging to the dispersed taxon *Cymbobolates horridus* complex. Hilate monads are found within discoidal masses similar to *Cooksonia pertoni*, but enveloped within non-cellular layers, with tufts on the proximal walls representing the remains of the subtending axes. The spores include the dispersed taxa *Cymbobolates variabilis*, *C. allenii* var. *allenii* and *C. allenii* var. *magnus*. A third group of sporangia are similar in gross morphology to the hilate masses, but contain triletes (*Streelispota newportensis*, *Aneurospora* spp., *Ambitisporites*). TEM studies show that both have bi-layered spore walls comparable to those of *Cooksonia pertoni*. The permanent dyads have multilayered walls with the ornamented outer layer extending over both units of the dyad. They are thus reminiscent of older dispersed permanent dyads. However stomata and a branching axis precludes inclusion in the Marchantiophyta, affinities postulated for other dispersed representatives.



### The first description of Kimmeridgian stalked crinoids (*Balanocrinus* sp.) from the Upper Kimmeridge Clay of Dorset, England

**Timothy Ewin**

Department of Palaeontology, The Natural History Museum, London, UK

Crinoid assemblages from the Kimmeridge Clay of Dorset (and elsewhere in England) are dominated by the planktonic comatulid *Saccocoma*. The inhospitable nature of the sea floor during much of the deposition of the Kimmeridge Clay in Britain precluded the widespread colonisation by benthic organisms resulting in the domination of planktonic and nektonic organisms as fossils. However, articulated stalked crinoids recently found in the Pectinatites pectinatus zone of the Upper Kimmeridge Clay Formation at Swyre Head near Kimmeridge bay, Southern England have allowed the first formal description of stalked crinoids from the Kimmeridgian of Britain. The remains predominantly consist of articulated portions of small gracile, pentagonal stems with long cirri, collected together in localised masses along with many disarticulated ossicles and a single articulated thecae and arm fragments. This crinoid, previously identified as *Balanocrinus subteres*, is compared with other Middle and Upper Jurassic stalked crinoids from Poland, Austria and France.

### A shallow marine fauna from the Late Bathonian of northern Sinai

**Howard R. Feldman<sup>1</sup>, Mena Schemm-Gregory<sup>2</sup>, Barbara Radulovic<sup>3</sup> and Mark A. Wilson<sup>4</sup>**

<sup>1</sup>Division of Paleontology (Invertebrates), American Museum of Natural History, New York, USA

<sup>2</sup>Centre of Geosciences and Department of Earth Sciences, University of Coimbra, Coimbra, Portugal

<sup>3</sup>Department of Palaeontology, University of Belgrade, Belgrade, Serbia and Montenegro

<sup>4</sup>Department of Geology, The College of Wooster, Wooster, USA

This fauna, from Gebel Maghara, northern Sinai, is correlative with the upper part of the Sherif Formation in the Negev, southern Israel. In somewhat older strata the ammonite *Micromphalites pustuliferus* indicates a Middle Bathonian age. Coeval strata within Gebel El Maghara show two bivalve and gastropod assemblages: One dominated by *Nuculana decorata* with abundant *Paleonucula tenuistriata*, *P. variabilis*, *Astarte pisiformis*, *Discohelix elegantula*, *Procerithium bouchardi*, *Exelissa solitudinis*, *Dicroloma armata*, and *D. tumida*. The second dominated by *Eligmus asiaticus*-*Africogryphaea costellata* and is common in marly and limy strata with *Bucardiomya lirata*. In addition to brachiopods fine benthic foraminifers (lagenids and trocholinids), bivalves, gastropods and microgastropods are found. A foraminifer species, occurring in the overlying lower part of the Gebel Arroussiah Formation, was first identified as *Meyendorffina bathonica*. This well-known marker of the Late Bathonian in western Europe is now considered to be new species of *Kilianina* that is indicative of an Early Callovian age and characterizes the southern Tethys Province. A Late Bathonian age is supported by two rhynchonellid species, *Globirhynchia sphaerica* and *Daghanirhynchia angulocostata*, also known from Bathonian of Saudi Arabia as well as the genus *Ectyphoria*.



### First report on the Early Ordovician (Tremadocian) micromorphic lingulate brachiopods from Deh-Molla, Eastern Alborz, Iran

Mansour Ghobadi Pour<sup>1</sup>, Leonid E. Popov<sup>2</sup> and Mohammad Reza Kebriaee-Zadeh<sup>3</sup>

<sup>1</sup>Department of Geology, Faculty of Sciences, Golestan University, Gorgan 49138-15739, Iran

<sup>2</sup>Department of Geology, National Museum of Wales, Cathays Park, Cardiff CF10 3NP, UK

<sup>3</sup>Department of Geology, Payame Noor University, Tehran, Iran

The Cambrian-Ordovician transition coincides with significant decline in linguliform brachiopod biodiversity. Early Tremadocian micromorphic linguliform brachiopod associations are usually oligotaxic, often including species of the acrotretides *Eurytreta* and *Ottenbyella*, lingulides of the family Elkaniidae and occasionally siphonotretides. The newly discovered lingulate brachiopod association from the *Paltodus deltifera* Biozone of Deh-Molla shows clear signs of the beginning of recovery. It is still of relatively low taxonomic diversity, yet it incorporates the ephippelasmatisids, earliest *Elliptoglossa*, *Eoconulus* and *Acrotreta*; all of these taxa diversified and became widespread later in the Ordovician. The Iranian Tremadocian fauna contains *Acrotreta dissimilis*, *Akmolina minor* and *Diencobolus* in common with the contemporaneous linguliform microbrachiopod association from Tremadocian chalconites of Holy Cross Mountains, Poland. However, it does not contain siphonotretides. New data on the early ontogeny of the enigmatic lingulide *Diencobolus* show a distinct pattern, including the presence of a metamorphic protogulum ornamented with flat-based pits, and a single pair of larval setal bundles, which links this taxon with *Paterula* and suggests close a phylogenetic relationship of both taxa to the Discinoidea.

### Lipid biomarker analysis of herbivore coprolites

Fiona L. Gill<sup>1</sup>, Rich D. Pancost<sup>2</sup> and Ian D. Bull<sup>2</sup>

<sup>1</sup>Earth Surface Science Institute, School of Earth and Environment, University of Leeds LS2 9JT, UK

<sup>2</sup>Bristol Biogeochemistry Research Centre, University of Bristol, Cantock's Close, Bristol BS8 1TS, UK

Biomarkers are molecules that can be attributed to a specific biological source on the basis of their chemical structure. Recent research has shown that lipid biomarker analysis of coprolites has the potential to reveal unique details of the diet, digestive processes and digestive tract microbiota of extinct animals. However, the degree of information that can be recovered from coprolites may be influenced by a variety of factors including age, preservation and thermal maturity of the material.

We present results from a lipid biomarker survey of over twenty coprolites from the Cretaceous, Miocene and Pleistocene. The coprolites have been attributed to herbivorous taxa (including sauropod dinosaurs, perissodactyls and ruminants), on the basis of gross morphology, stratigraphic association with known herbivores and/or identification of preserved dietary plant fragments. Our data indicate that the abundance of lipid biomarkers in coprolites is correlated mainly with the total organic carbon content of the material, rather than age or thermal maturity; although lipids recovered from thermally mature samples tend to consist of less diagnostic, defunctionalised compounds. Lipid biomarker analysis is therefore particularly appropriate for coprolites with high organic carbon content and low thermal maturity, such as those from Pleistocene cave deposits in North America.



### The last polar dinosaurs: high diversity of latest Cretaceous dinosaurs in northeastern Russia

Pascal Godefroit<sup>1</sup>, Lina Golovneva<sup>2</sup>, Serguei Shchepetov<sup>2</sup>, Pavel Alekseev<sup>2</sup> and Géraldine Garcia<sup>3</sup>

<sup>1</sup>Department of Palaeontology, Royal Belgian Institute of Natural Sciences, 1000 Bruxelles, Belgium

<sup>2</sup>Botanical Institute of the Russian Academy of Sciences, St. Petersburg 197 376, Russia

<sup>3</sup>Université de Poitiers – Faculty of Sciences, CNRS UMR 6046 – IPHEP, Institut International de Paléoprimatologie et Paléontologie Humaine, Evolution et Paléoenvironnements, 86 022 Poitiers Cedex, France

Recent discoveries of vertebrate fossil assemblages at high latitudes show that dinosaurs could live close to the Mesozoic poles from the Early Jurassic until the Late Cretaceous. Here, we describe a Late Maastrichtian (68 to 65 million years ago) dinosaur fauna from north-eastern Russia, which demonstrates that polar dinosaurs were still highly diversified just before the Cretaceous-Tertiary mass extinction event. Dinosaur eggshell fragments, belonging to hadrosaurids and non-avian theropods, indicate that several latest Cretaceous dinosaur taxa could reproduce in polar region and were probably year-round residents of high latitudes. Palaeobotanical data suggest that these polar dinosaurs lived in a temperate climate (mean annual temperature about 10°C), but the climate was apparently too cold for ectothermic tetrapods. The high diversity of Late Maastrichtian dinosaurs in high latitudes, where ectotherms are absent, indicates that dinosaur extinction was not a result of temperature decline, caused or not by the Chicxulub impact.

### The Villech section (Spanish Central Pyrenees): Middle Devonian and Lower Frasnian conodont biostratigraphy and the start of a regional high resolution composite standard

Sofie Gouwy<sup>1</sup>, Jau-Chyn Liao<sup>2,3</sup> and José Ignacio Valenzuela-Ríos<sup>3</sup>

<sup>1</sup>Department of Geological Sciences, University of Missouri-Columbia, 101 Geological Sciences Building, Columbia, MO 65211, USA

<sup>2</sup>Departamento de Paleontología, Facultad de Ciencias Geológicas, Universidad Complutense; c/ Antonio Novias, 2 Ciudad Universitaria; E-28040 Madrid, Spain

<sup>3</sup>Departamento de Geología, Universitat de València, C/ Dr. Moliner 50; E- 46100 Burjassot, Spain

The study of the Villech section (Compte “subfacies” area, SE Spanish Pyrenees), contributes to the knowledge of the Middle Devonian of NE Spain. The studied section exposes part of the Comabella Formation (Eifelian - lowermost Frasnian) and its study provides the first elaborated conodont biostratigraphy for the Eifelian in this area.

Nine Middle Devonian conodont zones are found. The Formation base is placed in the *costatus* Zone (lower Eifelian) The Eifelian *kockelianus* and *eiflius* zones are recognized in the lower half of the section, the *australis* Zone is not recognized. The uppermost Eifelian and lowermost Givetian (*ensensis* and *hemiansatus* zones respectively) have not been found. The Givetian Lower and Middle *varcus*, *semialternans*, *hermanni*, *disparilis* and *norrisi* zones are recognized. The base of the Frasnian is marked by the first appearance of *Ad. binodosa* and *Ad. pristina*. A black thin limestone layer in the section can be the local



signature of the Taghanic event, identified for the first time in the SE Spanish Pyrenees. Graphic correlation of the studied part of the Villech section with the Givetian Compté section provides a high resolution conodont biostratigraphy, based on 65 taxa for the Eifelian to lowermost Frasnian of the Compté “subfacies” area. All standard conodont zones except the *australis* and *hemiansatus* zones were identified.

### Microfossil evidence for diverse macroscopic crustaceans in the middle Cambrian Earlie Formation of Saskatchewan

\***Thomas H. P. Harvey<sup>1</sup>, Maria Velez<sup>2</sup> and Nicholas J. Butterfield<sup>1</sup>**

<sup>1</sup>Department of Earth Sciences, University of Cambridge, Downing Street, Cambridge CB2 3EQ, UK

<sup>2</sup>Department of Geology, University of Regina, Saskatchewan, S4S 0A2, Canada

New carbonaceous microfossils from the Earlie Formation (middle Cambrian, Saskatchewan, Canada) include exceptionally preserved appendages of macroscopic crustaceans. This discovery expands the temporal, geographic and palaeoenvironmental range of comparable preservation, which was previously known only from a single horizon in the Mount Cap Formation (early Cambrian, Northwest Territories, Canada). In one Earlie assemblage, Mount Cap-type filter plates and scraping armatures occur in articulated arrays, revealing these structures to be elements of lobate appendages characteristic of the phyllopodous limbs of branchiopod crustaceans. The Earlie Formation has also yielded mandibular molar surfaces, which differ from those of the Mount Cap in ways that reinforce comparisons with branchiopods. Meanwhile, a separate Earlie assemblage includes a distinct type of feeding appendage that shares detailed similarities with the mandibles of living copepod crustaceans. Whatever their precise taxonomic identities, the Mount Cap and Earlie fossils provide the only clear evidence for phylogenetic and ecological divergences among macroscopic crustaceans during the Cambrian. They therefore constitute a crucial bridge between Cambrian Orsten-type assemblages and the rather later crustacean Lagerstätten of Herefordshire and the Rhynie Chert. By contrast, the inadequacy of the conventional fossil record of early mandibulates is brought into sharp relief.

### Palaeo-Evo-Devo: Ontogenetic data of fossil Crustacea from Mesozoic limestones

**Carolin Haug, Joachim T. Haug, Andreas Maas and Dieter Waloszek**

*Biosystematic Documentation, University of Ulm, Ulm, Germany*

‘Palaeo-Evo-Devo’ describes the scientific field of reconstructing ontogenies of fossil species, including the embedding of these data into an evolutionary framework. Palaeo-Evo-Devo appears to be well-established for certain taxa, e.g., Mollusca. In Arthropoda, it is mainly limited to studies of dorsal hard parts of ostracods and trilobites. Ontogenetic sequences including ‘soft parts’ were reconstructed for crustaceans from Cambrian ‘Orsten’-type sites and from the Devonian Rhynie chert. Yet, these deposits have not yielded malacostracan Crustacea, while Mesozoic limestones from the Upper Jurassic of southern Germany (Solnhofen, Nusplingen) contained many fossils of immature and adult malacostracans. However, only little Palaeo-Evo-Devo research has been taken out on these fossils yet. One reason may have been the smallness of certain specimens. We, therefore, have modified established methods and used, e.g., composite fluorescence microscopy to study these small specimens and details of larger specimens. These newly adopted methods facilitated the



discovery of several larval and juvenile crustaceans, among them representatives of mantis shrimps and Decapoda. Based on these specimens, we could also identify heterochronic events (evolutionary changes in ontogeny), e.g., in the early evolutionary lineage of slipper lobsters. In summary, the Mesozoic limestones give us first access also to malacostracan Palaeo-Evo-Devo.

### A remarkable wolf skull from the fissure fillings of Gargano, Southern Italy

\***Nicola S. Heckeberg and Gertrud Rössner**

*Lehrstuhl für Paläontologie und Geobiologie am Department für Geo- und*

*Umweltwissenschaften der Ludwig-Maximilians-Universität München Bayerische*

*Staatsammlung für Paläontologie und Geologie, Richard-Wagner-Str. 10, 80333 München, Germany*

The Miocene fissure fillings of the Gargano peninsula (Southern Italy) are famous for their diverse island fauna. However, apart from one otter species and some birds of prey, carnivores are lacking in this fauna. In a collection of the Gargano site, acquired by the Bavarian State Collection, a skull appeared which did not fit to any of the animals known so far from this location. After comparisons with fossil and extant material, it turned out that this skull is most similar to the extant *Canis lupus*, although the Gargano specimen is slightly smaller. The long bones of big mammals in the accompanying material of the skull suggest a younger age, probably after the island has been connected to the continent and a faunal exchange. The preservation of the skull is poor, as only parts of the posterior skull roof and of the left and right maxilla with few teeth and tooth fragments are preserved. To get a reconstruction of the whole skull, the pieces were virtually put together and completed based on an extant grey wolf skull.

### Intraspecific variations in the beak morphology and beak size of the African seed-cracker *Pyrenestes ostrinus*

\***Nicola S. Heckeberg<sup>1</sup>, Phil Anderson<sup>2</sup> and Emily Rayfield<sup>2</sup>**

<sup>1</sup>Department for Geo- and Environmental Sciences of the Ludwig-Maximilians-University Munich, Germany

<sup>2</sup>University of Bristol, Wills Memorial Building, Queens Road, Bristol BS8 1RJ, UK

Intraspecific beak variation in *Pyrenestes ostrinus* is a textbook example for disruptive selection and initiation of speciation. As the observed polymorphism is unique amongst birds and more remarkable than that observed in Darwin’s finches, the African seed-cracker has been part of many studies for 40 years in terms of heritability of the bill traits and observation of its feeding behaviour. The three different morphs of *Pyrenestes ostrinus* feed on three types of sedge seeds (*Scleria*), which differ significantly in hardness. During times of food scarcity the large morphs specialise on the harder sedge seeds to reduce intraspecific competition. The mechanisms which drive and maintain the polymorphism are still not thoroughly understood and no biomechanical studies on the different beak morphs have been undertaken so far. The aim of the research presented here was to find out, whether the variation in beak shape between morphs affects the efficiency of cracking the different seeds. Physical fracture experiments using a guillotine testing device and specially designed tools, which simulate the different beak shapes and sizes, showed that there is no apparent biomechanical advantage for the large morphs to crack the large seeds in terms of shape.

**Phylogeography of Ice Age Beringian Beetles: an Ancient DNA Approach****\*Peter D. Heintzman<sup>1</sup>, Ian Barnes<sup>1</sup> and Scott A. Elias<sup>2</sup>**<sup>1</sup>*School of Biological Sciences, Royal Holloway University of London, Egham, UK*<sup>2</sup>*Department of Geography, Royal Holloway University of London, Egham, UK*

The Beringian region consists of northeast Asia, northwest North America and the now inundated land bridge between the two. During ice ages, much of this region remained ice free and, together with its variety of habitats and large size, provided a refuge for populations of animals that were escaping the advancing ice sheets. At the end of an ice age, these populations could recolonise the newly ice free continents. Beetles, a group important for ice age climatic reconstruction, took refuge in Beringia and subsequently recolonised Asia and North America, although the exact mode of this recolonisation is not fully understood. A phylogeographic approach, using both ancient and modern DNA of beetles from the Eastern Beringian region, as well as the rest of North America, is proposed here in order to address this important question. Initial work is focusing on the ground beetle *Amara alpina*, which has shown that the modern population mostly consists of two distinct haplogroups, only one of which contains ancient individuals from Beringia. The implications of this are discussed.

**Reconstructing western North Atlantic oceanic conditions during the mid-Pliocene MIS M2 (3.30 Ma): integrating palynology and foraminiferal geochemistry****Jan Hennissen<sup>1</sup>, Martin J. Head<sup>2</sup>, Jeroen Groeneveld<sup>3</sup> and Stijn De Schepper<sup>4</sup>**<sup>1</sup>*Department of Geology, University of Toronto, Toronto, ON, Canada*<sup>2</sup>*Department of Earth Sciences, Brock University, St. Catharines, ON, Canada*<sup>3</sup>*Alfred Wegener Institute, Bremerhaven, Germany*<sup>4</sup>*Geosciences Department, University of Bremen, Bremen, Germany*

Marine Isotope Stage (MIS) M2 represents a global cooling event around 3.30 Ma that interrupts the stable and warm climate of the mid-Pliocene. Diminished heat transport to high northern latitudes established conditions comparable to some Quaternary glacial stages. For our study, we reconstruct Pliocene oceanic conditions utilizing a same-sample methodology to combine data from two proxies: (1) a palynological record including dinoflagellate cyst assemblages, the composition of which reflects changes in sea surface temperatures, salinity, sea-ice cover, and nutrients; and (2) planktonic foraminiferal oxygen isotope analyses and Mg/Ca ratios to assess sea surface palaeotemperatures and salinity independently. Benthic foraminiferal isotopes provide age control. Presently, DSDP Hole 603C, situated in the western North Atlantic, is in the direct path of the Gulf Stream, although cold currents from the north flow nearby. Its position is ideal for assessing the strength and stability of the Gulf Stream in the past. Here, we show changes in the composition of dinoflagellate cyst assemblages on a temporal resolution of 2.5 kyr, under sea surface palaeotemperatures that range from 14.6 to 22.2°C. We combine our results with similar studies conducted in the northeastern North Atlantic in an effort to reconstruct basin-wide oceanic conditions during MIS M2.

***Morganucodon oehleri*: a CT analysis of the holotype, looking at dentition and cranial morphology****\*Brandon T. Jardine<sup>1</sup>, James A. Hopson<sup>2</sup> and Neil J. Gostling<sup>1</sup>**<sup>1</sup>*Department of Biological Sciences, SUNY Oswego 7060 Route 104, Oswego, NY 13126, USA*<sup>2</sup>*Department of Organismal Biology & Anatomy, University of Chicago, 1027 E. 57th St., Chicago, IL 60637, USA*

The monographic study on “The skull of *Morganucodon*” by K. A. Kermack *et al.* (1981) provided a thorough morphological description of the holotype of the Late Triassic-Early Jurassic mammaliaform *Morganucodon oehleri*, (FMNH-CUP2023). What could Kermack’s group have done with a CT scanner? Computed tomography allows non-destructive study of the internal structure of fossilized specimens. Applied to the holotype specimen of *Morganucodon oehleri*, this technique has revealed detailed data concerning the organism’s dentition. Additionally, preservation of the specimen is good enough to allow study of the internal cranial anatomy allowing us to produce estimates of brain size.

Here we present the initial work on dentition and skull morphology using CT analysis. Our preliminary findings are compared with the descriptions of Kermack *et al.*

K.A. Kermack, F. Mussett and H. Rigney. 1981. The Skull of *Morganucodon*. *Zoological Journal of the Linnaean Society* 71, 1-158.

**Pattern of early eukaryote evolution in Precambrian oceans****Emmanuelle J. Javaux***Department of Geology, University of Liege, Liege, Belgium*

A hypothesis is proposed to offer a new reading of the diversification pattern of early eukaryotes, divided into three steps involving different taxonomic levels. During Period I (?Archean-1.8 to 1.2 Ga), moderately diverse stem (and possibly but not necessarily crown-group) eukaryotes appeared. During Period II (1.2-0.63 Ga), a major diversification occurred at the supergroup level. The diversity of protists and macroalgae increases gradually. Major biological innovations such as multicellularity, sex, biomineralisation, heterotrophy and eukaryotic photosynthesis appeared, and possibly the first appearance of animals, leading to ecological tiering and complex food webs and interactions. Later diversification within pre-existing supergroups in the Ediacaran (Period III) led to increased morphological disparity and macroscopic size, possibly resulting from an exponential complexification of ecological interactions, and favoured by environmental conditions (improving already earlier). The diversification of eukaryotic supergroups occurred early during Period II, and coincided with major environmental changes, with Rodinia amalgamation and breakup, progressively spreading oxygenated shallow-water niches above declining euxinic conditions, and transient anoxia followed by two glaciations at the end of the Period. Although the direct role of these geological events on eukaryotic evolution is not clear yet, they contrast sharply with the quiet times of Period I.



## Parallel evolution controlled by adaptation and covariation in ammonoid cephalopods

**Christian Klug, Kenneth De Baets and Claude Monnet**

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

Major goals in evolutionary biology are understanding the processes that shape the path of evolution and explaining evolutionary patterns documented in fossil and living organisms. Parallel evolution is such a process, rarely studied over time intervals > 1 myr. Repeated and similar large-scale morphological evolutionary trends of distinct lineages suggest that adaptation by means of natural selection is its major cause. However, some aspects of parallel evolution can result from other processes which are often ignored or difficult to identify, such as developmental constraints. In this study, we present two ammonoid lineages (Auguritidae, Pinacitidae), which evolved in parallel several more or less independent shell characters. The morphological evolution of the two Early and Middle Devonian ammonoid lineages follows a common parallel evolutionary path of some important shell characters during ca. 10 myrs through their phylogenetic sequence. Evolutionary transformations of some shell traits appear mainly driven by adaptation to improve hydrodynamic properties. Most other characters evolving in parallel (e.g., sutural complexity) appear to be triggered by covariation, which plays a central role in the morphogenesis of mollusc shells. This example provides evidence that parallel evolution can be driven simultaneously by different factors such as covariation (fabricational constraints) and adaptation (natural selection).

## Shark teeth from the Middle Permian-Triassic Arabian continental shelf area of Oman

**\*Martha B. Koot<sup>1</sup>, Gilles Cuny<sup>2</sup>, Michael J. Orchard<sup>3</sup>, Charles M. Henderson<sup>4</sup> and Richard J. Twitchett<sup>1</sup>**

<sup>1</sup>*School of Geography, Earth and Environmental Sciences, University of Plymouth, Plymouth, UK*

<sup>2</sup>*Natural History Museum of Denmark, Copenhagen, Denmark*

<sup>3</sup>*Geological Survey of Canada, Vancouver, BC, Canada*

<sup>4</sup>*Department of Geoscience, University of Calgary, Calgary, AB, Canada*

Elasmobranchs are newly reported from Middle Permian-Triassic deposits representing a variety of depositional environments exposed in the northern regions of Oman. Conodont residues obtained by processing limestone samples in buffered acetic acid have yielded numerous well-preserved elasmobranch remains. The well-exposed, low-palaeolatitude (boundary) sections represent both autochthonous shallow marine deposits outcropping in the interior Huqf area along the eastern coast (Khuff Fm, Wordian), and the allochthonous Oman Exotics, which consist of autochthonous olistoliths that have been redeposited in younger strata throughout the Oman Mountains: Wadi Alwa in the Ba'id region (Alwa Fm, Olenekian) and Jabel Safra (exotics within Guwayza Fm, Olenekian). Preliminary data show that the Permian fauna consists of at least four taxa (e.g., Eugeneodontiformes, Symmoriiformes) and the Triassic of three or more (e.g., *Synechodus*, *Hybodus*), and whilst the faunas are largely dissimilar, Hybodontidae seem to occur in both. Besides focusing on the description and identification of the material, this study also addresses ecological and taxonomic aspects of the Permian-Triassic shark community. Ongoing work is currently aimed at obtaining a detailed reconstruction of the elasmobranch fauna in the region.



## A foraminifera-based sea-level reconstruction across the Cretaceous-Palaeogene boundary at Brazos River, Texas

**Tanja J. Kouwenhoven<sup>1</sup>, Robert P. Speijer<sup>1</sup> and Peter Schulte<sup>2</sup>**

<sup>1</sup>*Department of Earth and Environmental Sciences, K.U. Leuven, Leuven, Belgium*

<sup>2</sup>*Institut für Geologie und Mineralogie, Universität Erlangen-Nürnberg, Erlangen, Germany*

The Chicxulub impact is thought to have triggered numerous extinctions at the Cretaceous-Palaeogene boundary (KPB). Yet, it has also been suggested that sea-level change preceding the impact contributed to the extinction. Benthic foraminiferal distributions can be used to unravel sea-level history across the KPB. We studied two cores drilled at Brazos River, constituting an expanded succession of 15 m of the upper Maastrichtian and lower Danian. The quantitative benthic foraminiferal record shows a succession of three distinct assemblages. The Maastrichtian Corsicana assemblage was stable right up to the base of the spherule-rich siliciclastic unit, considered as the KPB. In the overlying deposits, many typical Corsicana taxa disappeared and an impoverished disaster assemblage settled. Subsequently, a stable Midway (Danian) assemblage became established. Our results indicate a stable palaeodepth prior to the KPB and accordingly sea-level change is not a likely cause for extinction prior to the Cretaceous-Palaeogene boundary. The subsequent faunal patterns, however, do indicate biofacial shifts in response to sea-level changes during the earliest Danian.

## The Cephalic Median Organ of trilobites and its possible relationships with the Sensory Dorsal Organ of modern crustaceans

**Rudy Lerosey-Aubril<sup>1</sup> and Kenneth J. McNamara<sup>2</sup>**

<sup>1</sup>*Senckenberg Research Institute, Frankfurt-am-Main, Germany*

<sup>2</sup>*Department of Earth Sciences, University of Cambridge, Cambridge, UK*

Trilobite cuticle exhibits numerous enigmatic structures, the functions of which remain unknown. This is true for the Cephalic Median Organ (CMO), a small complex of structures on the cephalon of some trilobites, usually on their occipital ring. Composed of four pits arranged like the corners of a square, it is common in odontopleurids and corynexochids. Our investigations on the CMO reveal that in fact it occurs in all but one order of trilobites. Its existence can be documented from the Middle Cambrian to the Late Carboniferous. It appears extremely conservative in organization, morphology, and position despite a great variability of CMO-bearing trilobites, suggesting an early origin for this organ and that it was essential for trilobites. The CMO strikingly resembles the Sensory Dorsal Organ (SDO) of malacostracans. This raises the question of the kind of relationships existing between them. The SDO is known to be widely distributed but its function is still debated. However, the variability and distribution of these two organs already provide critical arguments concerning their possible function(s) and relationships. These suggest that a common origin is credible, which has profound effects on reconstructions of phylogenetic relationships between major arthropod clades.

**Ordovician rhynchonelliform brachiopods and palaeobiogeography****M. Liljeroth and David A. T. Harper***Natural History Museum (Geological Museum), Copenhagen, Denmark*

In the earliest Ordovician the majority of the world's continents were located on the southern hemisphere, in relative close mutual proximity. During the Ordovician many of these palaeoplates, excluding the core Gondwanan continental assembly, dispersed and fragmented as they moved north towards the Equator. By the Hirnantian-late Silurian a new assembly of continents formed around the Equator as Laurentia, Baltica, Avalonia and a variety of Iapetus terranes collided. New analyses of diversity together with computer based palaeogeographic reconstructions indicate that palaeoplate movements had a profound effect on articulated brachiopod diversity which in general expanded and contracted as the continents dispersed and assembled. This new, high resolution palaeobiogeographic study of the rhynchonelliform brachiopods covers more than 1400 localities and nearly 600 genera distributed across the globe and comprising the whole Ordovician, divided into eight timeslices. Here we present data and analyses for four timeslices: Tremadocian-Floian, Darriwilian, early Katian and Hirnantian. New palaeogeographic and faunal province models were constructed from Cluster and Principal Coordinates Analyses respectively using the Cosine Similarity Index. The analyses were performed in PAST and the palaeogeographic reconstructions were based on the current GIS coordinates for all the localities and taxa plotted on the Ordovician globe by BugPlates.

**Ostracods and Taghanic Event in southern Ardennes****Sébastien Maillet and Bruno Milhau***Géosystèmes, FRE 3298 du CNRS, Faculté Libre des Sciences et Technologies, Lille, France*

The Taghanic Event, originally defined in the Tully Formation (New York State, USA), is currently known in several areas in the world. It consists in a succession of extinctions, concerning several fossils groups, framed by two major transgressive episodes around the middle/upper Givetian boundary (Middle Devonian). This event seems to be precisely located in the southern border of the Dinant synclinorium (Fromelennes area, Ardennes, France), in the first member (Flohimont Member) of the Fromelennes Formation. During the Givetian, the Fromelennes area could be considered as belonging to a carbonated platform with reefal barriers, where numerous organisms lived, including the ostracods.

Following a major transgressive episode located at the boundary between the Mont d'Haurs Formation and the Fromelennes Formation, a significant decrease in the ostracods biodiversity has been observed in the middle of the Flohimont Member. The Taghanic Event seriously affects the species of ostracods living in a continental margin environment. Moreover, this crisis seems to be responsible of the transition between a Givetian and a Frasnian ostracods fauna at least in the Ardennes and Boulonnais.

**First report of an echinoderm Lagerstätte in the Ordovician of the Ougarta Range, western Algeria****Yamouna Makhlouf<sup>1</sup>, Bertrand Lefebvre<sup>2</sup>, Serge Régnauld<sup>3</sup> and Aaron W. Hunter<sup>4</sup>**<sup>1</sup>*Université des Sciences et de la Technologie Houari Boumediene, Faculté des Sciences de la Terre, de Géographie et de l'Aménagement du Territoire, Alger, Algeria*<sup>2</sup>*UMR CNRS 5125 Paléoenvironnement & Paléobiosphère, Université Lyon 1, Villeurbanne, France*<sup>3</sup>*Muséum d'Histoire Naturelle, Nantes, France*<sup>4</sup>*Universiti Teknologi Petronas, Bandar Seri Iskandar, Tronoh, Perak, Malaysia*

For historical reasons, Ordovician echinoderm faunas are extremely well-known in southern Morocco (Anti-Atlas). In the second half of the 20th century, the Anti-Atlas was extensively sampled by Jacques Destombes, yielding abundant echinoderm remains thoroughly studied by Jean Chauvel throughout several major monographic contributions. In the early 21st century, rich and diverse, exquisitely preserved new faunas were collected in several echinoderm lagerstätten discovered in both Zagora (Lower Ordovician) and Erfoud areas (Upper Ordovician). Consequently, Moroccan echinoderm faunas constitute one of the best documented and most diverse assemblages reported for the Ordovician time interval in high latitude Gondwanan and peri-Gondwanan regions. In contrast, Ordovician echinoderm faunas have been extremely little investigated in Algeria. Here, we report for the first time the occurrence of an exquisitely preserved echinoderm fauna in Ordovician deposits of the Ougarta Range, western Algeria. The assemblage is apparently dominated by the eocrinoid *Ascocystites*, associated with ophiuroids. *Ascocystites* is known from the Middle Ordovician of France (Normandy) and Portugal, and the Upper Ordovician of Czech Republic (Bohemia) and Morocco (western Tafilalt). The association of *Ascocystites* with ophiuroids suggests strong palaeobiogeographic links between Algeria and other Gondwanan and peri-Gondwanan regions in Ordovician times.

**Preliminary results of a study on foraminifera palaeoecology in the Galicia-Minho muddy deposit****Maria Virginia Martins<sup>1</sup> and M. Cristina Carapito<sup>2</sup>**<sup>1</sup>*University of Aveiro, Portugal*<sup>2</sup>*Ghent University, Belgium*

During the RRS Charles Darwin Cruise 110 (part of the OMEX II-II Project) a kasten core was collected from the NW Iberian Atlantic continental shelf, of which 77cm in a Galicia-Minho muddy deposit. Approximately 110 species of benthic foraminifera were recorded from the sedimentary fraction >63µm of 31 samples from this core. R-mode cluster analysis on relative abundance data of the main benthic foraminifera species and genera (≥10% at least in one sample) through the core, allowed us to study the distribution patterns of these assemblages. We draw conclusions on the influence of palaeoceanographic conditions and food availability during the establishment of these communities.

**Ammonoids and mash-ups: A map-based portal to the Carboniferous ammonoid collections of Ethel M. Currie****Alistair J. McGowan and Katie M. Strang***School of Geographical and Earth Sciences, University of Glasgow, UK*

'Mash-ups' are web services that bring together data from a number of sites and display them in a graphic format. They offer a superb means for engaging with non-specialist users who lack the technical vocabulary to use museum catalogues or specialist palaeontological databases. The user-friendliness and familiarity of Google Earth™ and Google Maps™ for both developers and users makes these ideal webtools for such projects. We have built a demonstration site that shows the Scottish Carboniferous ammonoid-bearing localities that formed the basis of the important monograph of Currie (1954). Basic information is given on the age, formation and names of the ammonoids known from the site come up as 'call-outs.' Hyperlinks lead users directly to relevant entries in the PaleoDB and AMMON databases, which give additional geological and taxonomic information. We advocate the use of map-based 'mash-ups' for raising peoples' awareness of the history of geological and palaeontological research in their local area, as they offer non-specialist users an alternative to traditional keyword-driven searches, while democratizing access to palaeontological data. Basic sites require little effort to construct and use, and could significantly aid to museums, voluntary geoconservation and geological societies seeking methods to improve their outreach work.

**Understanding fossil colour: the taphonomy of structural colours in fossil beetles****Maria McNamara<sup>1,2</sup>**<sup>1</sup>*Department of Geology & Geophysics, Yale University, 210 Whitney Avenue, New Haven, CT 06511, USA*<sup>2</sup>*UCD School of Geological Sciences, University College Dublin, Belfield, Dublin 4, Ireland*

Structural colours are the most intense, reflective and pure colours in nature and are generated when light is scattered coherently by complex nanometer-scale tissue structures. Iridescent and metallic structural colours are widespread among modern insects, but are preserved rarely in insect fossils. This suggests that fossilization of structural colours requires a specific, unknown, set of taphonomic circumstances. We studied ~800 specimens of beetle taxa known to exhibit structural colour from six Cenozoic fossil lagerstätten. Differences in the fidelity of structural colour preservation among these biotas are independent of the age of the biota and its stratigraphic and sedimentological context. Instead, the variation between biotas is attributed to differences in the late diagenetic history of the host sediments. SEM and TEM analyses reveal that well-preserved metallic colours are invariably generated by an epicuticular multilayer reflector. In modern beetles, multilayer reflectors occur commonly in other cuticular layers. An epicuticular location may therefore enhance the preservation potential of fossil multilayer reflectors and of structural colour in fossil insects. Further, preservation of an epicuticular multilayer reflector correlates positively with preservation of other cuticular ultrastructures. The latter is therefore the basis of a predictive model for the presence of multilayer reflectors in fossil beetles.

**A coprolite in the MDCT-scanner – internal architecture and bone contents revealed****Jesper Milàn<sup>1,2</sup> and Bo W. Rasmussen<sup>2</sup>**<sup>1</sup>*Geomuseum Faxe, Østsjælland Museum, Østervej 2, 4640 Faxe, Denmark*<sup>2</sup>*Department of Geography and Geology, University of Copenhagen, Øster Voldgade 10, 1350 Copenhagen K, Denmark*

A well-preserved coprolite from the Lower Palaeocene (Danien) limestone of Faxe Quarry, Denmark was investigated in a MDCT (Multi-Detector Computed Tomography) scanner. The coprolite measures 34 mm in length and is 16 mm in diameter, and in one end of the coprolite a fish vertebra, 3.8 mm long and approximately 2.7 mm in diameter, is partly exposed. The scanning data showed the coprolite to be composed of several concentric layers of approximately 2 mm thicknesses each. This may reflect the original mode the faecal mass was excreted in the intestines of the producer. Further, the scanning showed the embedded vertebra to be complete and three-dimensionally preserved, and it was possible to identify the vertebra from the MDCT images alone. In addition to the vertebra, the scan further showed numerous other, smaller, elongated bone fragments in the coprolite. These could not be readily identified. The high quality of the MDCT images demonstrates that MDCT scanning is a useful non-destructive technique to examine internal architecture and bone contents of well-preserved, non-recrystallized coprolites.

**A possible Medusa from the Uppermost Maastrichtian of Stevns Klint, Denmark****Jesper Milàn<sup>1</sup> and Lothar H. Vallon<sup>2</sup>**<sup>1</sup>*Geomuseum Faxe, Østsjælland Museum, Østervej 2, 4640 Faxe, Denmark*<sup>2</sup>*Østsjælland Museum, Højerup Bygade 38, 4660 Store Heddinge, Denmark*

A peculiar fossil was found in the uppermost Maastrichtian at Stevns Klint, 20 cm below the Cretaceous-Tertiary boundary, exposed at Korsnæb Odde, Rødvig. The more or less circular fossil has a diameter of about 13 cm and is preserved as a slightly bowl-shaped depression. Eight lobe-like extensions surround a central circular part which contains four bean-shaped elevations. Apart from the garland-like wrinkles of the lobes, the surface of the fossil is smooth, without any evidence of shell-material or other skeletal structures. A second incomplete specimen found at Sigerslev, Stevns Klint shows the same morphology and dimensions. The (double-) tetramerous radial symmetry of the fossils suggests a Cnidarian affiliation and the lack of a velum probably puts it into the class Scyphozoa. The fossil medusa-genus *Acraspedites* Haeckel, 1869 from Pfalzpaint (Solnhofen Lithographic Limestones, Upper Jurassic) displays a very similar anatomy to the specimens from Stevns Klint. A similar specimen was depicted by von Ammon in 1886 and described as "*Medusites latilobatus*". However, this specimen had a different symmetry and was later reinterpreted as possible sponge. Based on the morphology and lack of any visible organ or skeletal structures, we cautiously interpret the fossil as a medusa.





### Testing the ecological stability of mollusc communities in tropical reefs through the Quaternary: a new approach based on corporations

**Julien Millet and Wolfgang Kiessling**

*Museum für Naturkunde, Leibniz Institute for Research on Evolution and Biodiversity at the Humboldt University, Berlin, Germany*

The ecological response of reef communities to severe climate change – such as the Pleistocene glaciations or modern global warming – has received much attention from ecologists and palaeontologists. Most studies focus on reef corals but little is known about other reef organisms, such as molluscs. We studied Pleistocene and Holocene mollusc communities to assess their ecological stability through time. These communities are extremely diverse in the modern tropics and well represented in the Pleistocene fossil record. The great diversity and variable ecology of molluscs call for a modification of methods that are usually applied to assessing stability in coral communities. We compared modern communities from the Red Sea (Egypt) with fossil assemblages by degrading modern assemblages considering a preservation probability for each species and by applying sub-sampling methods. Community stability was assessed by changes in community structure revealed by “corporations”, which are similar to ecological guilds but differing in the definition of the resources exploited. Corporations are hierarchically organized allowing their utilisation over large temporal and spatial scales. Preliminary results suggest that the ecological structure of mollusc communities is more stable through time than suggested by taxonomic analyses.

### Early ostracods from the Ordovician (Tremadocian) of Iran

**Mohibullah Mohibullah<sup>1,2</sup>, Mark Williams<sup>1</sup>, Mansoureh Ghobadi Pour<sup>3</sup>, Leonid E. Popov<sup>4</sup> and Tatiana Yu Tolmacheva<sup>5</sup>**

<sup>1</sup>*Department of Geology, University of Leicester, Leicester, LE1 7RH, UK*

<sup>2</sup>*Department of Geology, University of Balochistan, Quetta, Pakistan*

<sup>3</sup>*Department of Geology, Faculty of Sciences, Golestan University, Gorgan, Iran*

<sup>4</sup>*Department of Geology, National Museum of Wales, Cardiff CF10 3NP, Wales, UK*

<sup>5</sup>*A.P. Karpinskii, Russian Geological Research Institute, Sredny pr. 74, 199106 St. Petersburg, Russia*

Earliest Ordovician (Tremadocian) ostracod biodiversity was low, with just three (possibly four genera) and perhaps a dozen species. New Tremadocian ostracod material from the Alborz Mountains of Iran confirms the early and widespread occurrence of the Ordovician genus ‘*Nanopsis*’ – from South America to the Baltic, and the apparently simultaneous first appearance of ostracods in the fossil record at about the level of the ‘*P. deltifer*’ conodont biozone (ca. 485.5 Ma) from China to Argentina. The presence of Early Ordovician ostracods in Alborz, their occurrence elsewhere in Gondwana, Baltica and China coupled to their marked absence from the Tremadocian of Laurentia and Siberia, hints at an earliest occurrence of ostracods centred on Gondwana/Baltica.



### The chitinozoans of the ravine 700 m east section of Neuville-sous-Huy, Condroz Inlier, Belgium (Upper Llandovery to middle Wenlock)

**Jan Mortier and Jacques Verniers**

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

The ravine 700 m east of the Parc de la Neuville is situated in Neuville-sous-Huy, central Condroz Inlier, Belgium. The 200 m thick sequence ranges from the Telychian up to the middle Wenlock. A restudy in detail of this section has led to a lithostratigraphical division into 6 units. Red fine siltstones occur in units 1, 2 and 4. We could distinguish 11 volcanic or volcanoclastic interbedded layers. Almost each of them has his own characteristics that distinguish themselves from the other volcanic or volcanoclastic layers. Chitinozoans were sampled from 54 samples. Although some beds contain only poorly preserved chitinozoans, other beds contain a diverse and moderately to sometimes well preserved chitinozoan assemblages. The biostratigraphical results of the chitinozoans and calibration with the graptolite biozonation will be presented.

### Cyrtospiriferid brachiopods from the mid-Late Devonian of southern Belgium (Namur-Dinant Basin)

**Bernard Mottequin**

*Department of Geology, University of Liège, Liège, Belgium*

Brachiopods of the family Cyrtospiriferidae (Spiriferida) proliferated in the argillaceous environments of the Namur-Dinant Basin (southeastern margin of Laurussia) during the Late Frasnian and the Early Famennian (*rhenana* to *triangularis* conodont zones). Study of abundant material collected on both sides of the Frasnian/Famennian boundary led to the recognition of a quite diverse cyrtospiriferid fauna represented by 16 species belonging or temporarily assigned to the genera *Cyrtospirifer*, *Tenticospirifer*, *Sinospirifer*, *Tiocyrpsis*, ‘*Cyrtiopsis*’ and ‘*Pseudocyrtiopsis*’. Moreover, three cyrtospiriferid interval zones are proposed for the Late Frasnian of southern Belgium. In this area, the last Frasnian cyrtospiriferid occurrence is recorded with certainty in the Upper *rhenana* Zone. Soon after the Frasnian/Famennian boundary, cyrtospiriferids re-appeared (Lower?/Middle *triangularis* zones) and re-diversified rapidly; they became again one of the dominant members of the brachiopod fauna. The Early Famennian is also characterized by the development of the *Cyrtiopsinae* which progressively supplanted the *Cyrtospiriferinae*. However, our knowledge of Late Devonian cyrtospiriferid brachiopods from southern Belgium is still incomplete despite numerous studies and needs revision in order to document their story from the Late Givetian to the very Late Famennian (‘Strunian’) and to provide phylogenetic relationships.

### Allometric trends in blastozoans: examples from the genus *Hyperblastus* (Blastoidea, Fissiculata) from the Middle Devonian of the Rhenish Massif (Germany)

**Elise Nardin<sup>1</sup>, Jan Bohatý<sup>1</sup> and Uwe Hein<sup>2</sup>**

<sup>1</sup>*Institut für Geologie und Mineralogie der Universität zu Köln (Cologne), Germany*

<sup>2</sup>*Klingestr. 204A, D-42651 Solingen, Germany*

Ontogenetic trends among blastozoans are poorly known, mostly because of the lack of appropriate and abundant material. Rare studies have focused on the most primitive



blastozoans (middle Cambrian eocrinoids) or the most derived ones (Mississippian blastoids). Recent field campaigns revealed well-preserved and abundant faunas of hyperblastids from the Middle Devonian strata of the Rhenish Massif (Germany). They possess a tripartite endoskeleton, composed of a stem articulated to a globular to pyriform theca with a five-fold symmetry and a food-gathering system of erect brachioles beard by ambulacra lying on the theca. More than 100 specimens of *Hyperoblastus eifelensis* were collected in the Junkerberg Formation (middle Eifelian). In addition, about 140 specimens of *H. gilbertsoni* and 30 specimens of *H. acutangulus* were collected in the Loogh Formation (Lower Givetian). All these faunas show various ontogenetic stages. We propose to evaluate and to compare the ontogenetic trajectories and the growth changes of each *Hyperoblastus* species. Measurements describe the size, shape and curvature of the theca and of the ambulacra, and the stem insertion. Preliminary results on *H. eifelensis* suggest that the growth of the theca is mainly driven by the growth of the radials and the straightening up of the ambulacra.

### The fauna of the Upper Ordovician Huet & Madot formations (Brabant Massif, Belgium)

**Anthony Neyt, Frank Gelaude and Jacques Verniers**

*Research Unit Palaeontology, Department Geology and Soil Sciences, Ghent University, Ghent, Belgium*

A re-collection of the Huet and Madot formations around the village of Fauquez in the Sennette Valley (Brabant Massif, Belgium) showed the presence of mainly brachiopods, bryozoans, cystoids, trilobites and ichnofossils; we also found cephalopods and corals, but only in the Huet Formation. The preservation is moderate and the diversity relatively poor compared to other known localities of a similar age (e.g., Fosses Formation), but the localities are still one of the “richest” macrofossil bearing levels of the entire Lower Palaeozoic of the Brabant Massif. Based on chitinozoans and cystoids, the Huet Formation is dated to the Katian (just below the Caradoc-Ashgill limit). The Madot Formation is dated as Katian (Ashgill). The fossil assemblages from both formations indicate a rather shallow setting, but were transported to a deeper environment by tempestites (Huet Formation) or by mudflows (Madot Formation).

### Differential dissolution susceptibility of Palaeocene-Eocene planktic foraminifera from North Pacific ODP sites

**Thi Minh Phuong Nguyen<sup>1</sup>, M.R. Petrizzo<sup>2</sup>, Peter Stassen<sup>1</sup> and Robert P. Speijer<sup>1</sup>**

*<sup>1</sup>Department of Earth and Environmental Sciences, Katholieke Universiteit Leuven, Leuven, Belgium*

*<sup>2</sup>Dipartimento di Scienze della Terra, Università degli Studi di Milano, Italy*

We experimentally investigated the differences in dissolution susceptibility and shell characteristics for planktic foraminifera from Palaeocene-Eocene sequences (ODP Sites 865, 1209B, 1210B and 1212A) in order to evaluate the role of dissolution in the generation of foraminiferal assemblages deposited prior, during and after the Palaeocene-Eocene thermal maximum. We find that the large muricate *Acarinina* and *Morozovella* are most resistant, followed by the cancellate *Subbotina* and the small praemuricate *Igorina*. A dissolution ranking scheme for these taxa, at species level is proposed. Among the shell parameters,



wall thickness and size play the most important role on the dissolution robustness of planktic taxa. We propose a dissolution resistance formula, based on the combination of these two shell parameters. Application of this formula shows a good agreement between the calculated and the measured dissolution resistance, indicating that the formula is applicable to the experimental dissolution process and that results can be meaningful for interpretations of foraminiferal dissolution in natural environments and specifically in studies on early Palaeogene climate.

### Seasonality of Early Cretaceous temperatures recorded in subtropical to Arctic belemnites

**\*Elizabeth V. Nunn<sup>1</sup>, Gregory D. Price<sup>2</sup> and Bernd R. Schöne<sup>1</sup>**

*<sup>1</sup>Department of Applied and Analytical Palaeontology, University of Mainz, Mainz, Germany*

*<sup>2</sup>School of Geography, Earth and Environmental Sciences, University of Plymouth, Plymouth, UK*

Research into the seasonality of Cretaceous temperatures is fundamental for addressing key palaeoclimatic uncertainties such as the nature of the equator-to-pole temperature gradient and the presence or absence of polar ice sheets at this time. This study presents new high-resolution <sup>18</sup>O data obtained from transects across well-preserved belemnite rostra. The belemnites were collected from Valanginian–Hauterivian successions in Morocco and Russia. Specimens from both putative icehouse (Late Valanginian) and greenhouse conditions were analysed in order to provide a unique examination of the subtropical to Arctic seasonal response to climate change. The Moroccan data show consistently warm temperatures (18–24°C) in both the warm and cool phases, as well as very little seasonal variation in either phase. The Russian data showed that during the warm interval, belemnite <sup>18</sup>O ratios fluctuated by as much as 3‰ over the course of one year, which is potentially equivalent to fluctuations of over 10°C. Conversely, the belemnites from the Late Valanginian cool interval showed a <sup>18</sup>O variability of typically less than 1‰. A possible explanation is that during the cool phase, high latitude temperatures remained consistently low throughout the year, whilst in the warm phase, summer temperatures increased significantly.

### Preliminary investigation into the geology and palaeoecology of the “S7” Burgess Shale locality

**\*Lorna J. O’Brien<sup>1,2</sup>**

*<sup>1</sup>Department of Ecology and Evolutionary Biology, University of Toronto, Canada*

*<sup>2</sup>Department of Natural History - Palaeobiology, Royal Ontario Museum, Toronto, Canada*

As the best-known site of Cambrian exceptional preservation, the Burgess Shale (Canada) provides key biological and ecological information on the first appearance of most modern phyla in the aftermath of the Cambrian Explosion. Previous palaeoecological investigations have concentrated on the Walcott Quarry, the most famous of the Burgess Shale localities, although about a dozen other sites are known in the Canadian Rockies. The preliminary results of an investigation into the most numerically abundant (~10,000 specimens) of these sites, “S7” on Mount Stephen, are presented here. Fieldwork in Summer 2010 confirmed that “S7” is one of the oldest Burgess Shale localities and is situated 42.5 m above the base of the Stephen Formation within the Campsite Cliff Shale Member. Preliminary quantitative



analysis indicates a dominance of epifaunal suspension feeders, and suggests that this site has a conspicuously different taxonomic and ecological composition than previously studied localities on Fossil Ridge. The “tulip animal”, a large epifaunal suspension feeder, is the most abundant taxon in the “S7” collections and unknown from other Burgess Shale localities. The gregarious life habit of the “tulip animal”, its dominance of the “S7” community, and the abundance of other epifaunal taxa, indicate a complex tiered community that appears to be unique to this locality in the Burgess Shale.

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### An empirical study of potential biases to stratigraphic congruence metrics

**Anne O'Connor and Matthew A. Wills**

*Department of Biology and Biochemistry, University of Bath, Claverton Down, Bath, Somerset BA27AY, UK*

Unsurprisingly, many studies report congruence between the order in which taxa branch within cladograms and their stratigraphic sequence in the fossil record. The strength and significance of this congruence varies greatly, both across higher taxa and through geological time. For example, arthropods tend to have poorer congruence than vertebrates, while congruence in the Mesozoic is typically superior to that at other times. Do these differences reflect the quality of the fossil record and the accuracy of cladograms, or are they a function of other parameters?

Published measures of stratigraphic congruence are logically and empirically biased by tree size, tree balance, taxonomic level and the temporal extent of clades. Many of these parameters are not uniformly distributed through time or among higher taxa. Using statistical modelling methods, we ask whether the influence of these biases is sufficient to explain the patterns reported in the literature. We focus on the Gap Excess Ratio (GER) and the Stratigraphic Consistency Index (SCI) as they address different concepts of congruence (ghost ranges and nodes respectively). We find that some higher taxa continue to show a congruence signature that probably owes much to their preservation potential. However, temporal trends in congruence are much less robust.

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### Global patterns of Cretaceous forest distribution and productivity inferred from fossil wood

**Emiliano Peralta-Medina and Howard Falcon-Lang**

*Department of Earth Sciences, Royal Holloway University of London, Egham, Surrey TW20 0EX, UK*

Global patterns of Cretaceous forest distribution and productivity are analyzed based on a comprehensive fossil wood database. To ascertain patterns, fossil wood records (n=1514) were classified by botanical affinity and plotted on palaeomaps. Results confirm previous conjecture that araucarian conifers were globally dominant in Early Cretaceous times, but reduced in numbers and geographic range during the Late Cretaceous, coincident with the rapid expansion of angiosperms. Podocarpoid conifers were restricted to Gondwanan fragments, where they were co-dominant with araucarians. Cupressoid conifers were most common in arid mid-latitudes. Pinoid conifers were mostly restricted to the Northern Hemisphere, suggesting that their modern distribution was established in Cretaceous times. To ascertain productivity patterns, mean tree-ring width data (n=248) were obtained by thin section analysis and plotted by palaeolatitude. Comparison with modern data shows



that Cretaceous forest productivity was greatly elevated, especially in high-latitudes and to a lesser degree in mid- to low-latitudes. Elevated productivity may reflect the extreme Greenhouse warmth that characterized the Cretaceous Period and offers an analogue for the effects of future global warming. Results reveal, for the first time, global patterns of conifer distribution and productivity in the Cretaceous Greenhouse climate mode.

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### A late Darriwilian – Sandbian radiolarian assemblage from Kazakhstan: insights to Ordovician radiolarian biodiversity

**Lauren Pouille<sup>1</sup>, Taniel Danelian<sup>1</sup> and Leonid Popov<sup>2</sup>**

*<sup>1</sup>University of Lille 1, Géosystèmes (FRE 3298 CNRS) Earth Sciences Department, 59655 Villeneuve d'Ascq cedex, France*

*<sup>2</sup>Department of Geology, National Museum of Wales, Cathays Park, Cardiff CF10 3NP, UK*

Ordovician oceans witnessed profound changes in their ecosystem structure during the “Great Ordovician Biodiversification Event”. In order to understand those changes, a comparison of trends in biodiversity between the main plankton groups is needed. However, data regarding Radiolaria are still fragmentary. We here report on a detailed study of a diverse and well-preserved radiolarian fauna from Kazakhstan, which was sampled from the Shundy Formation in the Aksuran Mountain (North Balkhash region), composed of bedded limestones that accumulated on a carbonate platform slope. Identified trilobites and graptolites suggest a Late Darriwilian-Sandbian age (interval 4c-5b *sensu* Webby *et al.* 2004). The taxonomic study conducted so far suggests the presence of at least 5 families, 16 genera and 35 radiolarian species. The significant diversity of this assemblage contributes to improved knowledge of radiolarian diversity for the Late Darriwilian-Sandbian subintervals 4c-5b, previously considered to be between 5 and 15 species. On the basis of SEM observations on over 600 specimens it was found that three quarters of the fauna belong to representatives of the family Inaniguttidae. We focused on the study of the internal structure of the skeleton which allows us to identify new morphotypes and to conduct a taxonomic revision of the Inaniguttidae.

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### Making tiny footsteps – The examination of a well-preserved trackway from the Lower Paleocene (Danian) coral limestone of Faxø Quarry, Denmark

**Bo W. Rasmussen<sup>1</sup>, Jan Audun Rasmussen<sup>2</sup> and Jesper Milàn<sup>1,3</sup>**

*<sup>1</sup>Institut for Geografi og Geologi, Østervoldgade 10, 1350 Copenhagen K, Denmark*

*<sup>2</sup>Natural History Museum of Denmark, Øster Voldgade 5-7, 1350 Copenhagen K, Denmark*

*<sup>3</sup>Geomuseum Faxø, Østsjælland Museum, Østervej 2, 4640 Faxø, Denmark*

Two small, well-preserved trackway segments are preserved on the surface on a slab of Middle Danian Coral limestone from Faxø Quarry, Denmark. The two trackways are preserved in a negative epirelief and are characterized as repichnia, a locomotion trace. Each trackway segment is approximately 100 mm in length and 5 mm wide. The trackways are preserved on a small surface of hardened, undisturbed bottom sediments, which is interpreted as a small protected microenvironment within the coral reef, like a cave floor or natural cavity. To determine which kind of animal made the tracks, an experimental setting, comprising an aquarium with reconstructed sea-floor conditions was constructed. Within this arrangement, a number of extant marine invertebrates, crabs, polychaete worms, isopods and amphipods were encouraged to walk over the substrate, so their tracks could



be compared to the fossil ones. In conclusion, the fossil traces were most likely created by a small isopod. Although isopod body fossils are well known from Danian deposits in Denmark, this is the first documentation of their traces.

### An atypical Late Ordovician Red River brachiopod fauna from eastern North Greenland: Eastward, offshore migration of the *Hiscobeccus*-fauna

Christian M. Ø. Rasmussen<sup>1,2</sup> and David A. T. Harper<sup>3</sup>

<sup>1</sup>Center for Macroecology, Evolution and Climate, Natural History Museum of Denmark, University of Copenhagen, Copenhagen, Denmark

<sup>2</sup>Nordic Center for Earth Evolution (NordCEE), Natural History Museum of Denmark, University of Copenhagen, Copenhagen, Denmark

<sup>3</sup>Geological Museum, Natural History Museum of Denmark, University of Copenhagen, Copenhagen, Denmark

Late Ordovician rhynchonelliformean brachiopods typical of the North American Red River Fauna occur sporadically in the Børglum River Formation in the Centrum Sø area, eastern North Greenland. This expands, significantly, the geographical range of this characteristic brachiopod fauna to the easternmost extremity of the Laurentian craton. Moreover key taxa, notably *Hiscobeccus gigas*, confirm assignment of the assemblage to the North American *Hiscobeccus* brachiopod fauna. For the first time this more-typically inland, shallow-water fauna has been found associated with deeper-water genera like *Bimuria*, inferring its migration into deeper-water facies. The current study thus demonstrates the spatial range expansion of the *Hiscobeccus* fauna that now possibly occupied the edge of its preferred habitat. The *Hiscobeccus* fauna was highly provincial during the Late Katian (Richmondian) around parts of Laurentia. The new data from North Greenland indicate extension of this distinctive province all the way to the northeastern margin of the Laurentian Craton. The occurrence of the *Hiscobeccus* fauna indicates well-oxygenated, tropical conditions for the Centrum Sø area in the Late Ordovician. The occurrence of deeper-water components indicate that the Børglum River Formation in this area, however, was deposited in deeper water environments than seen elsewhere in North Greenland.

### Conodont stratigraphy and palaeoenvironments in the Bjørnaskalle Formation, Hardangervidda, southern Norway: mid Ordovician island environments on the edge of Baltica

Jan Audun Rasmussen, Arne Thorshøj Nielsen and David A. T. Harper

Natural History Museum of Denmark, University of Copenhagen, Copenhagen, Denmark

New finds of conodonts are reported from strongly folded limestones of the Bjørnaskalle Formation some 30 km east of the town Odda, southern Norway. The conodont fauna is poorly preserved but correlates with the *Lenodus variabilis* Zone, suggesting an early Darriwilian age. It is characterized by e.g. *Drepanoistodus stougei*, *Baltoniodus norrlandicus*, *Protopanderodus rectus*, *Lenodus* cf. *variabilis* and *Semiacontiodus cornuformis*. The brachiopod fauna is poorly known but the presence of *Antigonambonites* of Öpik's *plana* species group suggests a late Dapingian-early Darriwilian age. Poorly preserved cephalopods belonging to the Ormoceratidae (possibly *Adamsoceras*) and the order Endocerida also indicate a Darriwilian age. The biogeographic affinities of the

brachiopod fauna are similarly poorly constrained but the brachiopods have links with both the Baltic and Celtic provinces at this time, while the conodont fauna shows a clear Baltic affinity. Multivariate analyses of the conodont fauna indicate that it represents a relatively shallow or nearshore palaeoenvironment probably slightly deeper than that of the contemporary Huk Formation of the Oslo-Asker area farther to the east, but significantly more shallow or nearshore than the faunas described from the allochthonous Stein Formation situated in the Scandinavian Caledonides northeast of the study area.

### New records of lingulid brachiopods from Northern South America and their biogeographical implications

Alexis Rojas-Briceño<sup>1</sup>, Mena Schemm-Gregory<sup>1,2</sup>, Austin Hendy<sup>1</sup>, Javier Luque<sup>1</sup> and Carlos Jaramillo<sup>1</sup>

<sup>1</sup>Center for Tropical Paleocology and Archaeology, Smithsonian Research Institute, Ancón, Republic of Panama

<sup>2</sup>Centre of Geosciences and Department of Earth Sciences, University of Coimbra, Coimbra, Portugal

Fossil brachiopods are quite common in Colombia and Panama, however, their description under modern palaeontological aspects is still lacking. In this work we present the lingulid brachiopod fauna found within the Panamá Geology Project of the Smithsonian Tropical Research Institute. The lingulid brachiopod *Lingularia* is reported from the Maastrichtian Plaeners Formation from Colombia and suggest a connection between Colombian Upper Cretaceous basin and northern south Atlantic margin basins from Brazil. *Glottidia* is reported from the Miocene Gatun Formation of Panama and its occurrence is discussed in the context of the formation of the Central America isthmus.

### A new specimen of the hybodont shark *Palaeobates polaris* with three-dimensionally preserved Meckel's cartilage from the Smithian (Early Triassic) of Spitsbergen

Carlo Romano and Winand Brinkmann

Palaeontological Institute and Museum, University of Zürich, Karl Schmid-Strasse 4, CH-8006 Zürich, Switzerland

A new specimen of the Early Triassic hybodontoid shark *Palaeobates polaris* from the Arctic island of Spitsbergen (Norway) is presented. The new find is more complete than the type material of this species and includes a three-dimensionally preserved Meckel's cartilage with associated dentition as well as elements of the hyoid arch and a portion of the anterior dorsal fin. *Palaeobates* was primarily defined on tooth structure (orthodont teeth with pulp cavity) – a character which has been shown to be problematic for assessing hybodontiform phylogeny. Based on the new fossil of *P. polaris*, two additional traits are proposed to be apomorphic for *Palaeobates* in general: (1) the lower margin of the dental groove of Meckel's cartilage runs nearer to the ventral than to the dorsal border of the mandible; and (2) the number of tooth files and arrangement of the teeth are distinct from those of other hybodontoids. However, more material is needed to test the diagnostic value of these two new characters.



### Hidden Brachiopod Treasures of the Paul Choffat collection in the Geological Museum of Lisbon (Portugal)

**Mena Schemm-Gregory<sup>1</sup>, Maria H. Henriques<sup>1</sup> and Artur Sá<sup>1,2</sup>**

<sup>1</sup>Centre of Geosciences and Department of Earth Sciences, University of Coimbra, Coimbra, Portugal

<sup>2</sup>Department of Geology, University of Trás-os-Montes e Alto Douro, Vila Real, Portugal

Jurassic brachiopods are quite abundant in Portugal and are important tools for Jurassic stratigraphic and palaeobiogeographic interpretations. One of the first significant and extensive brachiopod collection of this area was made by Paul Choffat (1849-1919) and published in the late 19th century. However, not much work has been done with brachiopods in Portugal since that time. In our current project we describe the brachiopod fauna from the classical section Cape Mondego of the Lusitanian Basin (Central Portugal) where the Bajocian GSSP and the Bathonian ASP (both Middle Jurassic) are defined. Special attention is paid to the Paul Choffat type collection. All types are redescribed and photographed for publication of a new brachiopod catalogue of the Geological Museum of Lisbon. The revision of these brachiopods using modern palaeontological aspects, including digital 3D reconstruction of the internal morphology, helps to define these important stratigraphic intervals. In a second step, the comparison with coeval Tethyan brachiopod faunas gives new insights on palaeobiogeographical interpretations and clarifies faunal migration ways.

### The Lower Cretaceous brachiopod fauna from Central Colombia and their relationship to low latitude Tethyan brachiopods

**Mena Schemm-Gregory<sup>1,2</sup> and Alexis Rojas-Briceño<sup>2</sup>**

<sup>1</sup>Centre of Geosciences and Department of Earth Sciences, University of Coimbra, Coimbra, Portugal

<sup>2</sup>Center for Tropical Paleocology and Archaeology, Smithsonian Research Institute, Ancón, Republic of Panama

In the eastern Andes of Colombia, there are extensive Lower Cretaceous outcrops consisting of a more than 1000 m thick sequence of shallow marine carbonate and siliciclastic rocks. The brachiopod layers within the upper part of the Upper Rosablanca Formation (Valanginian to Hauterivian) were sampled and their faunal content is introduced in this work. The brachiopods occur together with ammonites, echinoids, bivalves, and gastropods in a black micritic and almost pure limestone sequence that is interpreted as a broad carbonate platform. We could identify species of *Gemmarcula*, *Musculina*, *Sellithyris*, and *Hadrosia*. Whereas the first three genera are cosmopolitan, *Hadrosia* has only been reported from France so far. This supports the theory of a direct faunal migration way through the low latitude Tethys Sea due to the opening of the South Atlantic Ocean. We assume that the unusual high abundance of brachiopods in the Lower Cretaceous strata from Colombia can be related to the beginning of the globally proposed late Valanginian cool climatic period during which the low-latitude regions were as warm as today.



### The revision of Middle and Upper Devonian Ambocoeliids from Northeastern North America by modern 3D reconstructions

**Mena Schemm-Gregory<sup>1</sup> and James Zambito<sup>2</sup>**

<sup>1</sup>Centre of Geosciences and Department of Earth Sciences, University of Coimbra, Coimbra, Portugal

<sup>2</sup>Department of Geology, University of Cincinnati, Cincinnati, USA

Ambocoeliid brachiopod are a common occurrence throughout Middle and Upper Devonian strata across northeastern North America. Almost no taxonomic work on Ambocoeliid brachiopods has been undertaken since the time of James Hall in the late 1800's, and most of the names he gave for the New York Ambocoeliids have been applied to similar brachiopods elsewhere in northeastern North America without any corresponding taxonomic analysis. In this study we present taxonomic revision of two taxa of the genus *Ambocoelia* based on material collected from the Upper Devonian Appalachian Basin of western New York and the Middle Devonian Silica Shale of northwestern Ohio. Material has been sampled from type localities and 3D reconstructions were created after digitized peels of serial sections and gave for the first time detailed views on internal shell morphology. As a result we can confirm the taxonomic elevation of *A. umbonata* var. *gregaria* back to *A. gregaria*, as a species discrete from *A. umbonata*. Both forms occur in the Appalachian Basin. The study of Ambocoeliids from the Silica Shale of Ohio, which were assigned by previous workers to *A. umbonata*, has resulted in the identification of a new species of *Ambocoelia*.

### Changes in surface waters: a malacological analysis of a Late Glacial and early Holocene palaeolake in the Moervaartdepression (Belgium)

**Lynn Serbruyns<sup>1</sup>, Dirk Van Damme<sup>1</sup>, Marc Antrop<sup>4</sup>, Machteld Bats<sup>2</sup>, Jean Bourgeois<sup>2</sup>, Mona Court-Picon<sup>1</sup>, Philippe Crombé<sup>2</sup>, Philippe De Maeyer<sup>4</sup>, Jeroen De Reu<sup>2</sup>, Philippe De Smedt<sup>3</sup>, Peter Finke<sup>1</sup>, Marc Van Meirvenne<sup>3</sup>, Ilke Werbrouck<sup>4</sup>, Ann Zwertvaegher<sup>1</sup> and Jacques Verniers<sup>1</sup>**

<sup>1</sup>Department of Geology and Soil Science, Ghent University, Ghent, Belgium

<sup>2</sup>Department of Archaeology, Ghent University, Ghent, Belgium

<sup>3</sup>Department of Soil management, Ghent University, Ghent, Belgium

<sup>4</sup>Department of Geography, Ghent University, Ghent, Belgium

The *Moervaartdepression* is a key locality for the study of Latest Weichselian palaeoecology and archaeology. This lowland area, situated in NW Belgium, used to harbour a large and shallow palaeolake. The malacological survey presented here, which is part of the interdisciplinary project 'Prehistoric settlement and land-use systems in Sandy Flanders (NW Belgium): a diachronic and geoarchaeological approach' (GOA project, UGent), represents the first extensive analysis of mollusc assemblages in this area and aimed at studying the local environment. Mollusc remains were recovered from a trench through the deepest part of the former lake and were especially abundant in the lake marl. The molluscan fauna (32 species) is mainly dominated by freshwater taxa. Terrestrial molluscs (seven species) have also been recovered, but are rare. Changes in mollusc assemblages enable identification of five mollusc assemblage zones spanning approximately the Oldest Dryas to the Preboreal. Overall, shallow water with abundant vegetation and quiet conditions are indicated. Finally, the absolute lack of freshwater mussels (Mollusca: Unionoida) and fish remains -indicating a closed lake system- possibly shed new light on the formation history of the Moervaartdepression.



### Anatomical 3D X-ray Micro Tomography reconstructions: maximising palaeobotanical data capture through preliminary non-destructive techniques

\*Alan R. T. Spencer<sup>1</sup>, Jason Hilton<sup>2</sup> and Mark D. Sutton<sup>1</sup>

<sup>1</sup>Royal School of Mines, Earth Science & Engineering, Imperial College London SW7 2AZ, UK

<sup>2</sup>School of Geography, Earth and Environmental Sciences, University of Birmingham, Edgbaston B15 2TT, UK

Over the last decade Micro-CT and X-ray Micro Tomography (XMT) have become increasingly available as an investigative tool within physical sciences. Development of scanning technology has been matched by a rise in computational power and advances in software, reducing the financial and time constraints previously associated with these processes. As a consequence, three-dimensional reconstruction via XMT can now expand from being reserved for one-off samples with known preservation to being a preliminary method of investigation. Palaeobotanical material is often three-dimensionally preserved, and therefore can be well suited to tomographic reconstruction. These reconstructions can serve as an important guide for more traditional (destructive) investigative techniques, such as serial sectioning, enabling the maximum amount of data to be acquired. We report here results from an investigation on the anatomy and morphology of a potential novel *Stephanospermum* seed from Mazon Creek (USA); using preliminary 3D XMT reconstructions combined with targeted traditional destructive techniques.

### Systematics and palaeobiology of Psychodidae (Diptera) from the Miocene Mexican amber

A. I. Frauke Stebner and Jes Rust

Steinmann Institute for Geology, Mineralogy and Palaeontology, Section Palaeontology, University of Bonn, Nussallee 8, 53115 Bonn, Germany

Besides the Baltic and Dominican amber, the Miocene amber is one of the most important Tertiary amber deposits. The amber derives from Simojovel de Allende, Chiapas, a state located in the southeast of Mexico. Although Mexico is considered to be a megadiversity region its highly diverse recent insect fauna is still poorly investigated. Furthermore only few studies deal with Diptera from Mexican amber although the most frequent inclusions therein belong to the Nematocera. Thereby, the investigation of fossil species offers many possibilities for biogeographical analysis as well as for ecological studies. The present study is based on 40 individuals of Psychodidae from Mexican amber. It comprises the systematic analysis of the fossil specimens, the comparison with living relatives, and their biogeographical distribution. The majority of the investigated fossil Psychodidae could be assigned to recent genera within the subfamilies Psychodinae, Trichomyiinae and Phlebotominae. Because living Psychodidae are restricted to certain ecological conditions the fossil representatives from amber allow conclusions on the former ecosystem of the amber forest.



### Multi-proxy analysis of a sediment core from an isolation basin in the Antarctic Peninsula

Ines Tavernier<sup>1</sup>, Elie Verleyen<sup>1</sup>, Rafael Fernández-Carazo<sup>2</sup>, Dominic A. Hodgson<sup>3</sup>, Steve Roberts<sup>3</sup>, Louise Newman<sup>4,5</sup>, Koen Sabbe<sup>1</sup>, Katleen Van der Gucht<sup>1</sup>, Mieke Sterken<sup>1</sup>, Annick Wilmotte<sup>2</sup>, Sofie D'Hondt<sup>1</sup>, Renaat Dasseville<sup>1</sup> and Wim Vyverman<sup>1</sup>

<sup>1</sup>Protistology and Aquatic Ecology – Ghent University, Belgium

<sup>2</sup>Centre for Protein Engineering, University of Liège, Belgium

<sup>3</sup>British Antarctic Survey, UK

<sup>4</sup>PAGES International Project Office, Switzerland

<sup>5</sup>Lake sediment and Paleolimnology, University of Bern, Switzerland

As knowledge of past climate variability and its influence on ecosystems is crucial for understanding and modelling current and future climate changes, there is a need for well-dated high-resolution long-term palaeoclimate and palaeoenvironmental records, particularly from the Southern Hemisphere. The aim of this study was to assess past changes in community structure from a lake near the tip of the Antarctic Peninsula, where current climate warming is most pronounced. We applied a multi-proxy reconstruction on a radiocarbon dated sediment core. We analysed the CHN-content (carbon, hydrogen and nitrogen), fossil pigments, loss-on-ignition, ancient DNA, faunal microfossils and diatoms. The most prominent changes in all proxies analysed, coincide with the isolation of the lake from the sea, where marine fossilized organisms were replaced by lacustrine taxa. The major changes during the lacustrine phase occurred in the upper 5 centimetres, which probably correspond to the recent decades. These changes exceed the threshold of natural variability for at least the past 5400 years, and are probably the result of natural processes affecting lake evolution. The latter include the colonization of the lake by new keystone species, and perhaps, superimposed on this, accelerated change in lake ecosystem structure resulting from a recent temperature increase.

### Temporal and spatial variation in the palaeocommunity structure of Late Triassic coral reefs from northern Chile

Richard J. Twitchett<sup>1</sup>, Felipe L. Opazo<sup>1</sup>, Alfonso Rubilar<sup>2</sup>, Guillermo Chong<sup>3</sup> and F. Amaro Mourges<sup>2</sup>

<sup>1</sup>School of Geography, Earth and Environmental Sciences, University of Plymouth, Plymouth PL4 8AA, UK

<sup>2</sup>Sernageomin, Calle Til Til 1993, Ñuñoa, Santiago, 10465, Chile

<sup>3</sup>Departamento de Ciencias Geológicas, Universidad Católica del Norte, Angamos 0610, Antofagasta, Chile

We have undertaken a study of the Late Triassic reefs of the Domeyko Cordillera, northern Chile. Sections at Portezuelo de la Sal and Punta del Viento were described and sampled. These two sections are correlated with the Rhaetian *Epigondolella mosheri* conodont biozone. In order to assess how species composition, abundance and richness varied spatially and temporally, palaeoecological data were collected from 7 horizons in each section using 6 randomly spaced 25x25 cm quadrats per horizon. Rarefaction curves were produced for each horizon and locality, and correlations between richness and dominance were made. NMDS, ANOSIM and SIM PER routines were used to evaluate the differences in composition within and between horizons, and rank-abundance models



were fitted to each community. Species composition and richness varied significantly between locations. A geometric rank-abundance model best fitted the Punta del Viento data, whereas a log-normal model was the best explanation of species abundance at Portezuelo de la Sal. The palaeocommunities in each reef locality seem to have their own temporal and spatial dynamics. In agreement with other studies, those communities act more like 'metacommunities' where each subset species 'patch' is affected independently by disturbance, habitat distribution and/or environmental gradients, generating discrete communities through time.

### Polar front shift and atmospheric CO<sub>2</sub> during the glacial maximum of the Early Palaeozoic Icehouse

**Thijs R. A. Vandenbroucke<sup>1</sup>, Howard A. Armstrong<sup>2</sup>, Mark Williams<sup>3,4</sup>, Florentin Paris<sup>5</sup>, Jan A. Zalasiewicz<sup>2</sup>, Koen Sabbe<sup>6</sup>, Jaak Nölvak<sup>7</sup>, Thomas J. Challands<sup>2</sup>, Jacques Verniers<sup>8</sup> and Thomas Servais<sup>1</sup>**

<sup>1</sup>Géosystèmes, FRE 3298 du CNRS, Université Lille 1, France

<sup>2</sup>Palaeoclimate Group, Department of Earth Sciences, Durham University, Durham, UK

<sup>3</sup>Department of Geology, University of Leicester, Leicester, UK

<sup>4</sup>British Geological Survey, Keyworth, UK

<sup>5</sup>Géosciences, UMR 6118 du CNRS, Université de Rennes I, Rennes, France

<sup>6</sup>Protistology and Aquatic Ecology, Department of Biology, Ghent University, Ghent, Belgium

<sup>7</sup>Institute of Geology, Tallinn University of Technology, Tallinn, Estonia

<sup>8</sup>Research Unit Palaeontology, Department of Geology, Ghent University, Ghent, Belgium

Our data address the paradox of Late Ordovician glaciation under supposedly high  $p\text{CO}_2$  (8 to 22x PAL: Pre-industrial Atmospheric Level). The palaeobiogeographical distribution of chitinozoan ("mixed layer") marine zooplankton biotopes for the Hirnantian glacial maximum (440 Ma) are reconstructed and compared to those from the Sandbian (460 Ma): they demonstrate a steeper latitudinal temperature gradient, and an equator-wards shift of the Polar Front through time from 55-70°S to c. 40°S. These changes are comparable to those during Pleistocene interglacial-glacial cycles. In comparison with the Pleistocene, we hypothesize a significant decline in mean global temperature from the Sandbian to Hirnantian, proportional with a fall in  $p\text{CO}_2$  from a modeled Sandbian level of ~8x PAL to ~5x PAL during the Hirnantian. Our data suggest that a compression of mid-latitudinal biotopes and ecospace in response to the developing glaciation was a likely cause of the end-Ordovician mass extinction.

### Palaeotemperature and seasonality during the Early Eocene Climatic Optimum (EECO): evidence from stable O and C isotope profiles of fish otoliths from Belgium

**Daan Vanhove<sup>1,2</sup>, Peter Stassen<sup>1</sup>, Robert Speijer<sup>1</sup> and Etienne Steurbaut<sup>1,2</sup>**

<sup>1</sup>Department of Earth and Environmental Sciences, Katholieke Universiteit Leuven, Leuven, Belgium

<sup>2</sup>Department of Paleontology, Royal Belgian Institute of Natural Sciences, Brussels, Belgium

The early Palaeogene greenhouse world comprises variable palaeoclimate conditions providing an indispensable deep-time perspective for the possible effects of human-



induced climate change. We investigate the long-term trend of rising global temperatures culminating during EECO, based on data from the mid-latitude marginal marine Belgian Basin. These data are derived from fish otolith  $\delta^{18}\text{O}$  compositions of four non-migratory benthic species belonging to the families Congridae and Ophidiidae. Both bulk and incremental microsamples were analyzed by IRMS. A cross-plot of bulk otolith  $\delta^{18}\text{O}$  vs.  $\delta^{13}\text{C}$  results shows significant offsets between the taxa of both families. Ophidiid data probably represent true bottom water temperatures of the Belgian Basin. The mean annual temperature (MAT) of the EECO is calculated at 27.5 °C, which is in line with other proxy results. However, variations in MAT up to 6 °C suggest a more pronounced expression of climate variability in mid-latitude marginal basins than in tropical areas. Incremental analyses revealed a ~9.5 °C mean annual range of temperatures, similar to modern seasonality in the same region. These results suggest that early Eocene mid-latitude marginal marine environments such as the Belgian Basin are well suited to infer palaeoclimate variability at seasonal and long-term time scales.

### New age model for the Tjörnes section, northern Iceland

**Koen Verhoeven<sup>1</sup>, Stephen Louwye<sup>1</sup>, Jon Eiriksson<sup>2</sup> and Stijn De Schepper<sup>3</sup>**

<sup>1</sup>Research Unit Palaeontology, Ghent University, Ghent, Belgium

<sup>2</sup>Earth Science Institute, University of Iceland, Askja, Reykjavik, Iceland

<sup>3</sup>Geosciences Department, University of Bremen, Bremen, Germany

The Tjörnes peninsula in northern Iceland contains the most complete marine sequence of Plio-Pleistocene age in Iceland. Marine sandstones alternate with terrestrial deposits (lignites) and lavas. The Tjörnes beds contain an unique climate archive which is of major importance for the correlation of climatic signals from the eastern and western Atlantic. The deposits from the Tjörnes section are divided into the Pliocene Tjörnes beds (subdivided into the Tapes, Mactra, and Serripes mollusc zones), and the Plio-Pleistocene Breidavík Group. Both sedimentary units are separated by the Höskuldsvík lavas.

A biostratigraphical study with dinoflagellate cysts – in combination with a renewed correlation of the palaeomagnetic polarity data to the international timescale – allowed the construction of a new age model. The entire Tjörnes beds are of Early Pliocene age, and the upper boundary is dated at circa 4.00 Ma. A massive invasion of cold water Pacific molluscs on the Mactra/Serripes boundary is dated at circa 4.5 Ma. Two major hiatuses are found, one between the Tjörnes beds and the Höskuldsvík lavas (0.5 Ma) and one between the Furuvík and Hörgi Formation (0.7 Ma).

### *Selenopemphix islandensis*: a new dinoflagellate species

**Koen Verhoeven and Stephen Louwye**

Research Unit Palaeontology, Ghent University, Ghent, Belgium

A palynological study with organic-walled dinoflagellate cysts has been carried out in the Plio-Pleistocene sections of the Tjörnes peninsula in northern Iceland. Marine palynomorphs from 68 samples from the Tjörnes beds and 20 samples from the younger Breidavík Group were studied. The stratigraphic range of the new dinoflagellate species *Selenopemphix islandensis* is restricted to the Serripes mollusc zone (upper part of the Tjörnes beds). In contrast to other recorded species from the genus *Selenopemphix* within the Tjörnes beds, this new species is only recorded in the uppermost Serripes Zone. Mollusc



studies indicate a sudden invasion of cold water Pacific molluscs in the base of this zone, and the appearance of *Selenopemphix islandensis* is probably related to this invasion. The cyst has a reniform outline in apical view. The cyst is strongly polar compressed and has a very thin wall. The processes show a dimorphism between the dorsal part of the cingulum (simple processes) and the ventral arches (fan shaped processes).

### The spatial distribution and (palaeo)ecology of a new late Quaternary dinoflagellate cyst from the Pacific Ocean

**Thomas J. Verleye<sup>1</sup>, Vera Pospelova<sup>2</sup>, Kenneth N. Mertens<sup>1</sup> and Stephen Louwye<sup>1</sup>**

<sup>1</sup>Research Unit Palaeontology, Ghent University, Krijgslaan 281/S8, B-9000 Ghent, Belgium

<sup>2</sup>School of Earth and Ocean Sciences, University of Victoria, New Science Building (OEASB) A405, P.O. Box 3065 STN CSC, Victoria, B.C., Canada V8W 3V6

Detailed palynological studies in the northeast (NE) Pacific, Strait of Georgia (BC, Canada), southeast (SE) Pacific and northwest Pacific (Dongdo Bay, South Korea) resulted in the recognition of a new dinoflagellate cyst species of the genus *Selenopemphix*. The distribution of the new cyst is restricted to cool temperate to sub-polar climate zones, where it is found in highest relative abundances in high productivity non- to reduced upwelling regions with an annual mean sea-surface temperature (aSST) below 16 °C and an annual mean sea-surface salinity (aSSS) between 20 and 35 psu. Those observations are supported by the late Quaternary fossil records from Santa Barbara Basin (ODP 893; 34°N) and offshore Chile (ODP 1233; 41°S), where this species thrived during the last glacial. This period is characterised by high nutrient availability and the absence of species favouring upwelling conditions. The indirect dependence of the abundance of the new species on nutrient availability during non- or reduced upwelling periods is expressed by the synchronous fluctuations with diatom abundances, since the distribution and growth rates of the latter are directly related with the availability of macronutrients in the surface waters.

### Constraints on the applicability of dinoflagellate cyst based quantitative palaeohydrographical reconstructions (Transfer Function Method/Modern Analogue Technique)

**Thomas J. Verleye and Stephen Louwye**

Research Unit Palaeontology, Ghent University, Krijgslaan 281/S8, B-9000 Ghent, Belgium

The Modern Analogue Technique (MAT) for dinoflagellate cysts is a transfer function method used in palaeoceanography for the quantification of past sea-surface conditions. The main presupposition of the MAT is that similar dinoflagellate cyst assemblages derive from similar environments, and that the environmental variables of interest are ecologically important. The validation exercise of the SH350 database (350 Southern Hemisphere surface samples from 10 different studies) results in a striking correlation between the observed and estimated SSS and SST values, which gives the impression that the MAT is capable to perform SSS and SST reconstructions with high accuracy. However, the background data shows a geographical clustering of the analogues in the immediate vicinity of the sites from which their SSS and SST are attempted to be estimated. 75% of the analogues were selected in the same cluster, while 63% were found within a range of 2.5° longitude/latitude. In the open ocean, the environmental variables remain rather unchanged

within a 2.5° range. So any variable which varies less within clusters than between clusters will appear possible to reconstruct, irrespective of its ecological relevance. Furthermore, the MAT does not consider interaction between the ecological parameters, which considerably influences the assemblages.

### Chitinozoans from the Upper Wenlock-Ludlow of the Holy Cross Mountains, Poland

**Jacques Verniers<sup>1</sup> and Monika Masiak<sup>2</sup>**

<sup>1</sup>Ghent University, Research Unit Palaeontology, Department Geology and Soil Sciences, Ghent, Belgium

<sup>2</sup>Institute of Geological Sciences, Polish Academy of Sciences, Warszawa, Poland

The Pragowiec Ravine in Holy Cross Mountains, Poland, is considered a standard section for the Silurian of southern Baltica, especially for the interval Homerian to lower Ludfordian in its deeper shelf facies with black graptolithic mudstones. The well preserved graptolites have attracted since long many researchers as well as collectors. Tomczyk (1962) and Tomczyk *et al.* (1981) established a stratigraphical division. Graptolites have been recollected and restudied by Porebska (in Masiak 2007). Masiak (2007) studied the acritarchs of the section showing an assemblage, variously diversified and abundant. The chitinozoans from 20 samples from that section are presented here, with the index species or other characteristic species for certain biozones as *Cingulochitina cingulata*, *C. serrata* and *C. convexa*. For the studied interval the three biozonations graptolites, acritarchs and chitinozoans are calibrated versus one another and correlated with the global chitinozoan biozonation of the Silurian (Verniers *et al.* 1995), with regional biozonations in a shallower facies of Baltica (Laufeld 1974; Nestor 1994), or in Avalonia: type area of the Wenlock and Ludlow in Wales and the Welsh Borderland (Sutherland 2004; Verniers 1999), Silurian sections in the Brabant Massif and Condroz Inlier, Belgium (Verniers 1983), and with other sections on other palaeocontinents.

### When molluscs go wormy - molecular and fossil evidence that aplacophorans are derived chiton-like molluscs

**Jakob Vinther<sup>1</sup>, Erik A. Sperling<sup>2</sup>, Kevin J. Peterson<sup>3</sup> and Derek E. G. Briggs<sup>1</sup>**

<sup>1</sup>Department of Geology and Geophysics, Yale University, New Haven, CT, USA

<sup>2</sup>Department of Earth and Planetary Sciences, Harvard University, Cambridge, MA, USA

<sup>3</sup>Department of Biological Sciences, Dartmouth College, Hanover, NH, USA

Molluscs diversified in the Early Cambrian into a number of disparate classes including bivalves, gastropods and cephalopods. The less diverse classes, such as chitons (polyplacophorans) and aplacophorans, are usually considered 'primitive' and have played a central role in hypotheses about the evolutionary origin of the phylum. Neither chitons nor aplacophorans are known from the Early or Middle Cambrian. Fossil evidence indicates that aplacophorans evolved from chiton-like forms, which are known from the Silurian and Upper Ordovician.

Our molecular analyses of chitons and aplacophorans show that they are sistergroups in a clade previously referred to as the Aculifera. Molecular clock analyses suggest that aculiferans diverged in the Ordovician congruent with the hypothesis that the aculiferan





ancestor was a chiton-like form with a foot and rows of dorsal shell plates. Thus, rather than being primitive, the morphology of aplacophorans — worm-like with a reduced foot and lack of many typical molluscan organs — evolved secondarily from a more typical molluscan ancestor, likely through progenesis. Hypotheses about molluscan ancestry should focus on chitons and other molluscs rather than on aplacophorans.

### Integrated lower Ordovician chitinozoan and graptolite biostratigraphy of Yiyang, South China

Wenhui Wang<sup>1,2</sup>, Jacques Verniers<sup>2</sup> and Hongzhen Feng<sup>1</sup>

<sup>1</sup>School of Earth Sciences and Engineering, Nanjing University, Nanjing, P. R. China

<sup>2</sup>Department of Geology and Soil Science, Ghent University, Ghent, Belgium

Three assemblages of chitinozoans are recorded from the Lower Ordovician argillaceous succession of Nanba Section, Yiyang area, South China. The chitinozoans, recovered from four graptolite zones (in ascending order: the *Adelograptus tenellus* zone, *Aorograptus victoricae* zone, *Araneograptus murrayis* zone and *Hunnegraptus copiosus* zone), are characterized by a low abundance and a high diversity. Five genera and 22 species were identified at 47 different stratigraphical levels. The Early Ordovician chitinozoan index species *Lagenochitina destombesi* and *Euconochitina symmetrica*, important for global correlation, have their FAD in *Adelograptus tenellus* biozone and *Araneograptus murrayis* biozone, respectively. The new Chinese material allows us to calibrate the lowest chitinozoan assemblage versus the lowest Upper Tremadocian graptolite biozone in South China. As the chitinozoans coexist with the graptolites, this provides an additional tool for precise correlation at both regional and global scale, especially in areas where only one of the two faunas is present. Our new material is also significant with respect to the palaeobiogeography of early chitinozoans and the early start of the chitinozoan diversification. This research was funded by the National Natural Science Foundation of China (No. 40972009).

### How should palaeontological data be used in calibrating the molecular clock?

\*Rachel C. M. Warnock<sup>1</sup>, Walter G. Joyce<sup>2</sup>, James F. Parham<sup>3</sup>, Tyler R. Lyson<sup>4</sup> and Philip C. J. Donoghue<sup>1</sup>

<sup>1</sup>Department of Earth Sciences, University of Bristol, Bristol, UK

<sup>2</sup>Institut für Geowissenschaften, University of Tübingen, Tübingen, Germany

<sup>3</sup>Alabama Museum of Natural History, University of Alabama, Tuscaloosa, Alabama, USA

<sup>4</sup>Peabody Museum of Natural History, Yale University, New Haven, Connecticut, USA

Molecular clocks have usurped the traditional role of the fossil record in providing a timescale for evolutionary history. However, it is of critical importance that fossil data are correctly represented in any molecular clock study. Bayesian methods have become increasingly popular but no protocols have yet been established for implementing prior probability distributions that reflect the degree to which fossil minima approximate the true 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. We examine the consequences of this base strategy on the estimation of divergence times among the major lineages of Testudines and explore the impact of different prior probability distributions implemented in 3



Bayesian programs. Results demonstrate that calibration priors can have a profound impact on the posterior age estimates within this group. We also show that although the inclusion of informative fossil maxima can ameliorate the impact and increase concordance with raw palaeontological estimates, posterior estimates always remain sensitive to the prior distribution of ages. This highlights the urgent need for innovative ways of incorporating detailed palaeontological knowledge into molecular dating of divergence times.

### Late Miocene (Tortonian) dinoflagellate cysts and sea surface parameters

\*Stephanie E. L. Wood<sup>1</sup>, Matthew J. Pound<sup>1,2</sup>, James B. Riding<sup>2</sup> and Alan M. Haywood<sup>1</sup>

<sup>1</sup>School of Earth and Environment, University of Leeds, Leeds, UK

<sup>2</sup>British Geological Survey, Kingsley Dunham Centre, Keyworth, Nottingham, UK

Dinoflagellates are one of the major groups of phytoplankton, present in all marine environments. Many present day and Quaternary studies of dinoflagellate cyst distributions indicates that they are controlled by sea surface temperature, salinity, sea ice cover and nutrient availability. A growing number of studies have shown that fossil dinoflagellate cysts can be useful for determining sea surface parameters (SSP).

Understanding SSP is essential for palaeoclimate studies. Many palaeoclimate studies used global circulation models (GCM) to simulate past climates and to test the predictive abilities of the models. GCMs are an important tool to advise policy makers on the impacts of anthropogenic greenhouse gas emissions and their potential effects on society.

We have constructed an ArcGIS – MS Access database for the Tortonian Stage (11.6-7.25 Ma) using published studies on dinoflagellate cysts. This technique allows the distribution of individual taxa to be studied and assessed for SSPs. The proportions of protoperidinoïd and gonyaulacoid dinoflagellate cysts at each site allow a measure of palaeoproductivity to be assessed. This database, combined with ongoing modelling and terrestrial proxy work, is advancing our understanding of Tortonian climate and the utility of GCMs.

### Controls of growth patterns in tabulate corals

Mikolaj K. Zapalski

Institute of Paleobiology, Polish Academy of Sciences, Twarda 51/55, 00-818 Warszawa, Poland

Seasonal and annual variations are well recognized in corals. The growth patterns of tabulates were usually analyzed on vertical sections: one transect was made in a colony. Such data were therefore averaged for the colony. Comparison of growth patterns in multiple individuals within a colony reveals that growth of neighbouring corallites is not always correlated. Spectral analysis shows that three types of growth pattern can be distinguished: 1. well correlated throughout the colony (most Favositina, some Heliolitida), 2. discordant between individuals (Alveolitina), and 3. growth between coenenchyme and individuals not correlated (Heliolitida). The 'type 1' colonies show one significant peak at the 0.01 significance level, while others show numerous peaks, much below the 0.05 significance level. The control over the growth pattern is a mixture of genetic and environmental factors. Control factors in corals with discordant growth remain unrecognized, as individuals in the colony share the same genetic information and microenvironment. Correlated growth of Favositina is an effect of strong environmental control over the growth, and they may be useful in palaeoenvironmental reconstructions.



Heliolitids, with discordance between corallites and coenenchyme growth show different gene expressions in these two anatomical units, but they potentially may also be useful in such reconstructions.

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### The Palaeoceanographic significance of Permian Radiolaria from the Yangtze Platform (South China)

**Lei Zhang<sup>1,2</sup>, Zhang Qiang<sup>1</sup>, Yan Ai<sup>1</sup>, Weihong He<sup>1</sup>, Qinglai Feng<sup>1</sup>, Martial Caridroit<sup>2</sup> and Taniel Danelian<sup>2</sup>**

<sup>1</sup>China University of Geosciences (Wuhan), Department of Earth Sciences, Wuhan, P.R. China

<sup>2</sup>University Lille 1, Géosystèmes (FRE 3298 CNRS), Department of Earth Sciences, Bât SN5, 59655 Villeneuve d'Ascq cedex, France

The Yangtze platform is one of the three major cratons occurring in China, characterized mainly by shallow water carbonate sedimentation. Situated during the Late Palaeozoic in a tropical position, it entered since the Permian into collision with the Cathaysian and North China blocks. During the Permian, siliceous sediments are particularly abundant around and within the Yangtze platform, with a good Radiolarian record for the Middle Permian *Pseudoalbaillella globosa* biozone. Albaillellarian Radiolaria, considered in the literature to represent deep water niches, from six localities of the Northern part of the Yangtze platform and from one basin situated in its southern part (Qinfang trough), were compared between them and with a coeval assemblage from equatorial oceanic chert sequences, preserved today in Japan. Results of a similarity analysis show that the assemblages from the northern Yangtze basins cluster together, while the Japanese assemblage plots in between the northern and southern assemblages. This may reflect the presence of two different oceanic water masses around the Yangtze platform. We believe this is the result of a bottleneck formed at this time between the Qinling Sea and the Palaeo-pacific ocean, which had as a result the restricted circulation of oceanic currents.

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### New vertebrate assemblages from the the Andrée Land Group, Spitsbergen, and their biostratigraphic significance

**Živil Žigait<sup>1,2</sup>, Henning Blom<sup>1</sup>, Daniel Goujet<sup>3</sup> and Valentina Karatajt-Talimaa<sup>2</sup>**

<sup>1</sup>Department of Organismal Biology, Uppsala University, Sweden

<sup>2</sup>Department of Geology and Mineralogy, Vilnius University, Lithuania

<sup>3</sup>CNRS UMR 7207 CR2P, National Museum of Natural History, France

The Lower and Middle Devonian successions of Spitsbergen provide excellent examples of vertebrate biostratigraphy applied to sedimentary basin analysis. A number of previous works on the Red Bay Group (Lochkovian, Lower Devonian) made a notable study of the earliest Devonian vertebrate record, and their use in biostratigraphy. Our current study concerns the Lower to Middle Devonian of the Andrée Land Group, which comprises the Wood Bay Formation, spanning from Pragian to Emsian in age, and the Grey Hoek Formation, representing the Eifelian. It consists of thick layers of terrigenous sediments, the stratigraphy is largely based on the lithofacies. Two new thelodont assemblages are considered to represent different depositional phases of the late Lower - early Middle Devonian of the Andrée Land Group. The first, older assemblage comprises turiinid, talivaliid, and furcacauid thelodonts, and identifies the lower Wood Bay Formation. The second, younger assemblage is prevailed by the talivaliid thelodont *Amaltheolepis winsnesi*,



and is characteristic for the upper Wood Bay Fm., as well as the lower Grey Hoek Fm. The recognition of these two new thelodont assemblages allows us to precise the relative age of the Lower – Middle Devonian strata.