

The Palaeontological Association

51<sup>st</sup> Annual Meeting

16<sup>th</sup>–19<sup>th</sup> December 2007

*Uppsala University, Sweden*

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PROGRAMME WITH  
ABSTRACTS

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edited by

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Uppsala, 2007

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## The Palaeontological Association

# 51<sup>st</sup> Annual Meeting

## 16<sup>th</sup>–19<sup>th</sup> December 2007

Department of Earth Sciences, Uppsala University

The programme and abstracts for the 51<sup>st</sup> Annual Meeting of the Palaeontological Association are outlined after the following summary of the meeting.

### *Third Circular and late registration*

The third circular will be sent out to delegates in mid-November. The deadline for late registration is Wednesday 14<sup>th</sup> November.

### *Venue*

The meeting will take place in the *Uppsala Konsert & Kongress* conference centre. Details available from <<http://www.palass.org>>.

### *Accommodation*

All delegates should make their own accommodation arrangements, with suggestions given in <<http://www.palass.org>>.

### *Travel*

Travel details and maps for the conference are available at <<http://www.palass.org>>; further details will be included in the Third Circular.

### *Registration*

Registration will commence at midday on Sunday 16<sup>th</sup> December in the conference centre, and will continue through the meeting.

### *Seminar*

A seminar on “*The origin of major groups*” will take place in the *Stora Salen* of the conference centre, beginning at 13:00 on Sunday 16<sup>th</sup> December. This will be followed by a reception in the Museum of Evolution.

### *Oral and poster contributions*

All oral and poster contributions will take place in the *Uppsala Konsert & Kongress* conference centre. There will be two plenary sessions and the other talks will be in parallel, in the *Stora Salen* and *Lilla Salen*.

### *Annual address*

The annual address will be given at approx. 16:50 (following the AGM) on Monday 17<sup>th</sup> in *Stora Salen* by Adrian Lister on “*Evolution in the Ice Age*”. It will be followed by the Member’s Reception and Poster Session sponsored by Wiley-Blackwell Publishing.

### *Annual dinner*

The annual dinner will take place in *Norrlands Nation* from 19:00-01:00.

*Field excursion*

There will be a “field excursion” to visit various Linnaean sites in Uppsala and the Swedish Museum of Natural History in Stockholm on Wednesday 19<sup>th</sup> (09:00 to c. 17:00).

*Acknowledgements*

We would like to thank warmly Wiley-Blackwell Publishing; the Dept of Earth Sciences and the Museum of Evolution, Uppsala University; and the Swedish Museum of Natural History, Stockholm, for their support.

**Graham Budd**

on behalf of the organising committee:

Graham Budd (chair)

Allison Daley

Michael Streng

Sebastian Willman

Contact: [Uppsala2007@palass.org](mailto:Uppsala2007@palass.org)

## Schedule of events and timetable for presentations

The presenter's name is given; candidates for the President's Award are marked with an asterisk.

Sunday 16 <sup>th</sup> December	<i>Seminar on origins of major groups (Stora Salen) Chair: Graham E. Budd</i>
13:00	<b>Introductory remarks</b> ( <i>Budd</i> )
13:10	<b>Clues to the evolution of the three domains of life</b> ( <i>Poole</i> )
13:40	<b>Arthropod origins: palaeontological and phylogenomic perspectives</b> ( <i>Edgecombe</i> )
14:10	<b>Echinoderms: Attachment, torsion and the origins of a radical new body plan</b> ( <i>Smith</i> )
14:40	<i>Coffee and Tea</i>
15:10	<b>The origin of tetrapods</b> ( <i>Ahlberg</i> )
15:40	<b>Origin of angiosperms</b> ( <i>Friis</i> )
16:10	<b>Neandertal genomics</b> ( <i>Pääbo</i> )
<b>Museum of Evolution</b> 18:00-20:00	<i>Icebreaker</i>

Monday 17 <sup>th</sup> December	<i>Stora Salen</i>	<i>Lilla Salen</i>
8:50	<b>Welcome</b>	
9:00	<b>A possibly juvenile nemathelminth from the Cambrian 'Orsten' of Australia</b> ( <i>Maas</i> )	
9:15	<b>Problems on the origin and interrelationships of early gnathostomes (jawed vertebrates)</b> ( <i>Brazeau</i> )	
9:30	<b>The relative contribution of regional rock records to global Phanerozoic marine diversity curves</b> ( <i>McGowan</i> )	
9:45	<b>A new multifoliate rangeomorph frond from the Ediacaran of Newfoundland and northwestern Canada</b> ( <i>Laflamme*</i> )	
10:00	<b>Seawater chemistry and the early evolution of carbonate skeletons</b> ( <i>Porter</i> )	
10:15	<b>Graptolites in four dimensions</b> ( <i>Snelling</i> )	
10:30-11:00	<i>Coffee and Tea; Posters</i>	
11:00	<b>Late Ediacaran Avalon-type biota of Siberia</b> ( <i>Grazhdankin</i> )	<b>Biomarker analysis: a tool for investigating the diet and digestive biochemistry of ancient animals</b> ( <i>Gill*</i> )
11:15	<b>Preservation of Ediacaran fossils in limestones from the Khatyspyt Formation (Siberia)</b> ( <i>Balthasar</i> )	<b>Mutation, adaptation or selective predation – assessing possible causes for unusual tetragonal symmetry of crinoids from two sunken wood associations in the Jurassic of Poland</b> ( <i>Hunter*</i> )
11:30	<b>A new cloudinid from the terminal Ediacaran of Spain</b> ( <i>Cortijo</i> )	<b>Dietary change in a plant eating mammal across the Eocene/Oligocene transition</b> ( <i>Joomun*</i> )
11:45	<b>The Lower Cambrian paterinate brachiopod <i>Askepasma</i> from South Australia</b> ( <i>Pettersson*</i> )	<b>Fossil echinoderm endosymbionts: Host/symbiont interactions, new taxa, and application of neutron-, micro- and synchrotron-computer-tomography</b> ( <i>Neumann</i> )
12:00	<b>A new priapulid-like worm from the Lower Cambrian Chengjiang biota of Yunnan, China</b> ( <i>Ma*</i> )	<b>Differential time averaging in brachiopod accumulations from sub-tropical and temperate latitudes</b> ( <i>Krause</i> )

12:15	<b>Animal, vegetable or mineral? Strange structures from the Cambrian of Scotland and Sweden</b> ( <i>Herringshaw</i> )	<b>Ammonite and foraminiferal evidence for opening of the South Atlantic Ocean in the early/mid Aptian (Early Cretaceous)</b> ( <i>P. Bengtson</i> )
12:30	<b>The Lower Cambrian of Scandinavia: Sequence stratigraphy, sea-level changes and palaeogeography</b> ( <i>Nielsen</i> )	<b>Exceptionally well-preserved lacustrine ostracod crustaceans from the Middle Miocene of Antarctica: implications for high latitude palaeoenvironment at 77° South</b> ( <i>Williams</i> )
12:45	<b>Expanding the taxonomic affinities of Ediacaran and Phanerozoic acritarchs</b> ( <i>Cohen</i> )	<b>Phylogeny and palaeobiography of the Asian delthyridoid spiriferid clade</b> ( <i>Schemm-Gregory</i> )
13:00-14:00	<i>Lunch; Council meeting</i>	
14:00	<b><i>Eccentrotheca</i> from the Lower Cambrian of South Australia – the first known tomotioid scleritome and its biological implications</b> ( <i>Skovsted</i> )	<b>Morphology and provenance of mysterious lycopsid with exceptional preservation</b> ( <i>Stevens*</i> )
14:15	<b>Yet another ‘great appendage’ arthropod</b> ( <i>Stein</i> )	<b>Arctic vegetation community change in the early Palaeogene</b> ( <i>Harrington</i> )
14:30	<b>The ecology and phylogeny of Cambrian pancrustaceans</b> ( <i>Harvey*</i> )	<b>Punctuations in the Australian Mesozoic floristic succession</b> ( <i>McLoughlin</i> )
14:45	<b>Ocean chemistry at Cambrian deposits with exceptional preservation and the influence of sulfate on soft-tissue decay</b> ( <i>Hammarlund</i> )	<b>Plant evolution and chemical weathering</b> ( <i>Baars</i> )
15:00	<b>Affinities of Cambrian scleritomorph animals</b> ( <i>Caron</i> )	<b>Reconstructing early terrestrial vegetation: the role of mesofossils</b> ( <i>Morris*</i> )
15:15	<b><i>Hurdia</i>, a new anomalocaridid from the Burgess Shale and the origin of biramous limbs in arthropods</b> ( <i>Daley*</i> )	<b>On morphological diversity and taxon boundaries in Platanaceae from the Late Cretaceous of Quedlinburg (Germany)</b> ( <i>Tschan</i> )
15:30-16:00	<i>Coffee and Tea</i>	
16:00-c.17:00	<i>AGM</i> <b>Evolution in the Ice Age</b> ( <i>Lister</i> )	
17:00-18:00	<i>Poster Session &amp; Wiley-Blackwell Members' Reception</i>	
<b>Norrlands Nation</b> 19:00-01:00	<i>Annual Dinner</i>	

Tuesday 18 <sup>th</sup> December	<i>Stora Salen</i>	<i>Lilla Salen</i>
9:00	<b>Adventures in protein world reveal the Tree of Life and the evolution of complexity</b> ( <i>Lloyd*</i> )	<b>Gastéropodes à la carte: Durophagy on Ordovician gastropods from Manitoulin Island, Canada</b> ( <i>Ebbestad</i> )
9:15	<b>Diversification shifts and the data: influence of sampling on the complete Hominoidea and Old World monkey tree</b> ( <i>Tarver*</i> )	<b>Were hederelloids horseshoe worms? Expanding the diversity of the minor phylum Phoronida</b> ( <i>Taylor</i> )
9:30	<b>Are switches to non-planktotrophic larval development concentrated in particular intervals of geological history?</b> ( <i>Cunningham*</i> )	<b><i>Trophocrinus</i> – a broody microcrinoid?</b> ( <i>Sevastopulo</i> )
9:45	<b>Juvenile plasticity and evolutionary trends in Devonian ammonoids</b> ( <i>De Baets*</i> )	<b>Unique siphonal structure in an orthoconic nautiloid from the Boggy Formation, Pennsylvanian, USA</b> ( <i>Dunca</i> )
10:00	<b>The trilobite family Asaphidae: Cope's Rule and the evolution of the hypostome</b> ( <i>Bell</i> )	<b>Bristling with spines – machaeridian palaeobiology</b> ( <i>Högström</i> )

10:15	<b>Measurement and scale dependency in geometric approaches to morphological disparity analyses</b> ( <i>Krieger</i> )	<b>Review of the Russian Permian procolophonoids, and their implications on procolophonoid evolution and biogeography</b> ( <i>Säilä*</i> )
10:30-11:00	<i>Coffee and Tea; Posters</i>	
11:00	<b>The size of the earliest molluscs: did small helcionellids grow to become large adults?</b> ( <i>Marti Mus</i> )	<b>The neurocranium and taxonomic affinities of the gigantic varanid lizard 'Megalania' prisca from the Pleistocene of Australia</b> ( <i>Barrett</i> )
11:15	<b>Taphonomy of Cambrian gogiid echinoderms from Guizhou, China</b> ( <i>Lin*</i> )	<b>Age discrimination: Analysis of ontogeny and heterochrony in conodonts</b> ( <i>D. Jones</i> )
11:30	<b>The expanding brachiopod stem-group – First record of <i>Mickwitzia</i> from the Early Cambrian of South Australia</b> ( <i>Holmer</i> )	<b>The diversification of skulls and feeding apparatus in the Rhynchocephalia (Diapsida: Lepidosauria)</b> ( <i>M. Jones</i> )
11:45	<b>A reassessment of fossil preservation in the Burgess Shale</b> ( <i>Page*</i> )	<b>Arandaspid microvertebrates from the Amdeh Formation (Ordovician) of Oman</b> ( <i>Miller</i> )
12:00	<b>Enigmatic, spore-like, organic-walled microfossils from middle-late Cambrian sediments in Algeria: terrestrial or aquatic origin?</b> ( <i>Vecoli</i> )	<b>The sabre-toothed dinosaurs once more: caniniform tooth function in <i>Heterodontosaurus</i></b> ( <i>Porro*</i> )
12:15	<b>First chemostratigraphical data in the lower-middle Cambrian transitional interval of the Iberian Chains (Spain)</b> ( <i>Dies Álvarez</i> )	<b>Tracing the evolution of bite force in finches and carnivores</b> ( <i>Sakamoto*</i> )
12:30	<b>Lophotrochozoan roots and stems</b> ( <i>Butterfield</i> )	<b>Obtaining crystallographic information from conodonts by electron backscatter diffraction (EBSD)</b> ( <i>Pérez-Huerta</i> )
12:45-14:00	<i>Lunch</i>	
14:00	<b>Cephalopod assemblages from the Upper Ordovician Børglum River Formation, Peary Land, North Greenland</b> ( <i>J. A. Rasmussen</i> )	<b>The higher-level phylogeny of Archosauria (Tetrapoda: Diapsida)</b> ( <i>Brusatte*</i> )
14:15	<b>First report on the occurrence of Early Ordovician (Tremadocian) rhynchonelliformean brachiopods in the Eastern Alborz, Iran</b> ( <i>Popov</i> )	<b>Why bigger is not better in the long run: investigating mammal lineage survivorship using Neogene mammals of Eurasia</b> ( <i>Liow</i> )
14:30	<b>New insights into ctenocystoid (deuterostomes) morphology and palaeobiology using 3-D reconstruction techniques</b> ( <i>Rahman*</i> )	<b>Ecological changes in marine macrobenthic assemblages across the Cretaceous/Palaeogene boundary in Patagonia: evidence for a productivity crisis and uncoordinated recovery</b> ( <i>Aberhan</i> )
14:45	<b>Machaeridians – polychaetes masquerading as molluscs</b> ( <i>Vinther*</i> )	<b>Towards a high-resolution palaeotemperature curve through the Permian/Triassic extinction horizon</b> ( <i>Kearsey</i> )
15:00	<b>Chitinozoan biotopes and biozones in the Ashgill of the Welsh Basin, UK</b> ( <i>Challands*</i> )	<b>Aftermath of the late Frasnian mass extinction (Upper Devonian) on brachiopods in the Namur-Dinant Basin (Belgium)</b> ( <i>Mottequin</i> )
15:15	<b>Virgiana BILLINGS, 1857: on top of the world after 150 years</b> ( <i>C. M. Ø. Rasmussen</i> )	<b>Testing multivariate models of extinction risk in Eocene bivalves</b> ( <i>Harnik</i> )
15:30-16:00	<i>Coffee and Tea</i>	
16:00	<b>Dinosaur tectonics – structural geology as a tool to interpret theropod walking dynamics</b> ( <i>Graversen</i> )	

16:15	<b>Computerizing and evaluating modified Brooks' Parsimony Analysis in palaeobiogeography, with case studies from trilobites and dinosaurs</b> ( <i>Upchurch</i> )	
16:30	<b>Cystoid preservation in the Kukruse Oil Shales (Upper Ordovician, Caradoc) of northern Estonia shows rapid early sea floor calcite cementation and post-mortem encrustation of internal molds</b> ( <i>Wilson</i> )	
16:45	<b>Spatial heterogeneity through the end Ordovician extinction events: How complete is the Hirnantian brachiopod record?</b> ( <i>Harper</i> )	
17:00	<b>Environmental setting of Late Cretaceous New Zealand Plesiosaur remains – a palynological investigation</b> ( <i>Vajda</i> )	
17:15	<b>Burgess Shale-type deposits share a common taphonomic mode</b> ( <i>Gaines</i> )	
17:30	<b>Presentation of awards; close</b>	

## Sunday 16<sup>th</sup> December

Meeting registration will take place between 12:00 and 17:00 at the conference centre.

*Stora Salen, Uppsala Konsert & Kongress*

13:00-16:40 *Seminar on the origin of major groups*

13:00 **Introductory remarks**

*Graham E. Budd*

13:10-13:40 **Clues to the evolution of the three domains of life**

*Anthony Poole*

13:40-14:10 **Arthropod origins: palaeontological and phylogenomic perspectives**

*Greg D. Edgecombe*

14:10-14:40 **Echinoderms: Attachment, torsion and the origins of a radical new body plan**

*Andrew B. Smith*

14:40-15:10 *Coffee and Tea*

15:10-15:40 **The origin of tetrapods**

*Per Erik Ahlberg*

15:40-16:10 **Origin of angiosperms**

*Else Marie Friis, Kaj Raunsgaard Pedersen and Peter R. Crane*

16:10-16:40 **Neandertal genomics**

*Svante Pääbo et al.*

18:00-20:00 *Icebreaker, Museum of Evolution*

## Monday 17<sup>th</sup> December

*Plenary I (Stora Salen, Uppsala Konsert & Kongress) Chair: Derek E. G. Briggs*

08:50 **Welcome**

09:00 **A possibly juvenile nemathelminth from the Cambrian 'Orsten' of Australia**

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

09:15 **Problems on the origin and interrelationships of early gnathostomes (jawed vertebrates)**

*Martin D. Brazeau*



- 09:30 **The relative contribution of regional rock records to global Phanerozoic marine diversity curves**  
*Alistair J. McGowan and Andrew B. Smith*
- 09:45 **A new multifoliate rangeomorph frond from the Ediacaran of Newfoundland and northwestern Canada**  
*Marc Laflamme and Guy M. Narbonne*
- 10:00 **Seawater chemistry and the early evolution of carbonate skeletons**  
*Susannah M. Porter*
- 10:15 **Graptolites in four dimensions**  
*Andrea Snelling, Jan Zalasiewicz and John Wright*
- 10:30 *Coffee and Tea; posters*
- Geon 5 I (Stora Salen) Chair: Chair: Nicholas J. Butterfield*
- 11:00 **Late Ediacaran Avalon-type biota of Siberia**  
*Dima Grazhdankin, Uwe Balthasar, Konstantin Nagovitsin and Boris Kochnev*
- 11:15 **Preservation of Ediacaran fossils in limestones from the Khatyspyt Formation (Siberia)**  
*Uwe Balthasar and Dima Grazhdankin*
- 11:30 **A new cloudinid from the terminal Ediacaran of Spain**  
*Iván Cortijo, Sören Jensen, Teodoro Palacios and Mónica Martí Mus*
- 11:45 **The Lower Cambrian paterinate brachiopod *Askepsma* from South Australia**  
*Sandra Pettersson Stolk, Lars E. Holmer and Glenn A. Brock*
- 12:00 **A new priapulid-like worm from the Early Cambrian Chengjiang Lagerstätte, China**  
*Xiaoya Ma, Xianguang Hou, Derek J. Siveter, David J. Siveter, Richard J. Aldridge and Sarah E. Gabbott*
- 12:15 **Animal, vegetable or mineral? Strange structures from the Cambrian of Scotland and Sweden**  
*Liam G. Herringshaw*
- 12:30 **The Lower Cambrian of Scandinavia: Sequence stratigraphy, sea-level changes and palaeogeography**  
*Arne Thorshøj Nielsen*
- 12:45 **Expanding the taxonomic affinities of Ediacaran and Phanerozoic acritarchs**  
*Phoebe Cohen, Robin Kodner and Andrew H. Knoll*
- Ecology, taphonomy and biogeography (Lilla Salen) Chair: Paul D. Taylor*
- 11:00 **Biomarker analysis: a tool for investigating the diet and digestive biochemistry of ancient animals**  
*Fiona Gill, Ian Bull, Richard Pancost, Remmert Schouten and Tim Ewin*
- 11:15 **Mutation, adaptation or selective predation - assessing possible causes for unusual tetragonal symmetry of crinoids from two sunken wood associations in the Jurassic of Poland**  
*Aaron W. Hunter, Andrzej Kaim Simon Darroch and Tatsuo Oji*
- 11:30 **Dietary change in a plant eating mammal across the Eocene/Oligocene transition**  
*Sarah C. Joomun, Jerry J. Hooker and Margaret E. Collinson*
- 11:45 **Fossil echinoderm endosymbionts: Host/symbiont interactions, new taxa, and application of neutron-, micro-, and synchrotron-computer-tomography**  
*Christian Neumann, Olev Vinn, Nikolay Kardjilov, André Hilger, Ingo Manke and Simon Zabler*
- 12:00 **Differential time averaging in brachiopod accumulations from sub-tropical and temperate latitudes**  
*Richard A. Krause, Jr., Adam Tomašových, Michał Kowalewski, Darrell S. Kaufman, Christopher S. Romanek and Marcello G. Simões*
- 12:15 **Ammonite and foraminiferal evidence for opening of the South Atlantic Ocean in the early/mid Aptian (Early Cretaceous)**  
*Peter Bengtson, Eduardo A. M. Koutsoukos, Mikheil V. Kakabadze and Maria Helena Zucon*
- 12:30 **Exceptionally well-preserved lacustrine ostracod crustaceans from the Middle Miocene of Antarctica: implications for high latitude palaeoenvironment at 77° South**  
*Mark Williams, David J. Siveter, Allan Ashworth, Philip R. Wilby and David J. Horne*
- 12:45 **Phylogeny and palaeobiography of the Asian delthyridoid spiriferid clade**  
*Mena Schemm-Gregory*
- 13:00-14:00 *Lunch; Council meeting*
- Geon 5 II (Stora Salen) Chair: Greg D. Edgecombe*
- 14:00 ***Eccentrotheca* from the Lower Cambrian of South Australia – the first known tomotiid scleritome and its biological implications**  
*Christian B. Skovsted, Glenn A. Brock, John R. Paterson, Lars E. Holmer and Graham E. Budd*
- 14:15 **Yet another ‘great appendage’ arthropod**  
*Martin Stein*

- 14:30 **The ecology and phylogeny of Cambrian pancrustaceans**  
*Thomas H. P. Harvey and Nicholas J. Butterfield*
- 14:45 **The ocean chemistry at Cambrian deposits with exceptional preservation and the influence of sulfate on soft-tissue decay**  
*Emma Hammarlund, Donald E. Canfield and Stefan Bengtson*
- 15:00 **Affinities of Cambrian scleritomorph animals**  
*Jean-Bernard Caron and Simon Conway Morris*
- 15:15 ***Hurdia*, a new anomalocaridid from the Burgess Shale and the origin of biramous limbs in arthropods**  
*Allison C. Daley, Graham E. Budd and Jean-Bernard Caron*

*Palaeobotany (Lilla Salen) Chair: Dianne Edwards*

- 14:00 **Morphology and provenance of mysterious lycopsid with exceptional preservation**  
*Lil Stevens and Jason Hilton*
- 14:15 **Arctic vegetation community change in the early Palaeogene**  
*Guy J. Harrington, Ben le Page and Leo Hickey*
- 14:30 **Punctuations in the Australian Mesozoic floristic succession**  
*Stephen McLoughlin*
- 14:45 **Plant evolution and chemical weathering**  
*Christian Baars, Hefin Jones and Dianne Edwards*
- 15:00 **Reconstructing early terrestrial vegetation: the role of mesofossils.**  
*Jennifer Morris*
- 15:15 **On morphological diversity and taxon boundaries in Platanaceae from the Late Cretaceous of Quedlinburg (Germany)**  
*Georg F. Tschan and Thomas Denk*

15:30-16:00 *Coffee and Tea*

16:00-c. 17:00 AGM followed by the Annual Address:

**Evolution in the Ice Age**

*Adrian Lister*

17:00-18:00 Poster Session & Wiley-Blackwell Members' Reception (*Uppsala Konsert & Kongress*)

19:00-01:00 Annual Dinner (*Norrlands Nation*)

## Tuesday 18<sup>th</sup> December

*Evolutionary Patterns (Stora Salen) Chair: Mark A. Purnell*

- 09:00 **Adventures in protein world reveal the Tree of Life and the evolution of complexity**  
*Graeme T. Lloyd, Philip C. J. Donoghue and Julian Gough*
- 09:15 **Diversification shifts and the data: influence of sampling on the complete Hominoidea and Old World monkey tree**  
*James E. Tarver*
- 09:30 **Are switches to non-planktotrophic larval development concentrated in particular intervals of geological history?**  
*John A. Cunningham and Charlotte H. Jeffery-Abt*
- 09:45 **Juvenile plasticity and evolutionary trends in Devonian ammonoids**  
*Kenneth De Baets and Christian Klug*
- 10:00 **The trilobite family Asaphidae: Cope's Rule and the evolution of the hypostome**  
*Mark A. Bell, Simon J. Braddy and Richard A. Fortey*
- 10:15 **Measurement and scale dependency in geometric approaches to morphological disparity analyses**  
*Jonathan Krieger and Norm MacLeod*

*Palaeozoic Faunas I (Lilla Salen) Chair: Lars E. Holmer*

- 09:00 **Gastéropodes à la carte: Durophagy on Ordovician gastropods from Manitoulin Island, Canada**  
*Jan Ove R. Ebbestad and Christopher A. Stott*
- 09:15 **Were hederelloids horseshoe worms? Expanding the diversity of the minor phylum Phoronida**  
*Paul D. Taylor and Mark A. Wilson*
- 09:30 ***Trophocrinus* – a broody microcrinoid?**  
*George Sevastopulo*
- 09:45 **Unique siphonal structure in an orthoconic nautiloid from the Boggy Formation, Pennsylvanian, USA**  
*Harry Mutvei and Elena Dunca*

10:00 **Bristling with spines – machaeridian palaeobiology**  
*Anette E. S. Högström*

*Vertebrate palaeobiology (Lilla Salen) Chair: Michael J. Benton*

10:15 **Review of the Russian Permian procolophonoids, and their implications on procolophonoid evolution and biogeography.**  
*Laura K. Säilä*

10:30 *Coffee and Tea; posters*

*Geon 5 III (Stora Salen) Chair: Małgorzata Moczyłowska*

11:00 **The size of the earliest molluscs: did small helcionellids grow to become large adults?**  
*Mónica Martí Mus, Teodoro Palacios and Sören Jensen*

11:15 **Taphonomy of Cambrian gogüid echinoderms from Guizhou, China**  
*Jih-Pai Lin*

11:30 **The expanding brachiopod stem-group – First record of *Mickwitzia* from the Early Cambrian of South Australia**  
*Lars E. Holmer, Christian B. Skovsted and Glenn A. Brock*

11:45 **A reassessment of fossil preservation in the Burgess Shale**  
*Alex Page, Sarah E. Gabbott and Philip R. Wilby*

12:00 **Enigmatic, spore-like, organic-walled microfossils from middle-late Cambrian sediments in Algeria: terrestrial or aquatic origin?**  
*Marco Vecoli, Florentin Paris and Blaise Videt*

12:15 **First chemostratigraphical data in the lower-middle Cambrian transitional interval of the Iberian Chains (Spain)**  
*Maria Eugenia Dies Álvarez, Rodolfo Gozalo, Eladio Liñán and Juan B. Chirivella*

12:30 **Lophotrochozoan roots and stems**  
*Nicholas J. Butterfield*

*Vertebrate Palaeobiology (cont.) (Lilla Salen) Chair: Michael J. Benton*

11:00 **The neurocranium and taxonomic affinities of the gigantic varanid lizard '*Megalania*' *prisca* from the Pleistocene of Australia**  
*Jason J. Head, Paul M. Barrett and Emily J. Rayfield*

11:15 **Age discrimination: Analysis of ontogeny and heterochrony in conodonts**  
*David Jones, Mark A. Purnell and Helen Hewitt*

11:30 **The diversification of skulls and feeding apparatus in the Rhynchocephalia (Diapsida: Lepidosauria)**  
*Marc E. H. Jones and Susan E. Evans*

11:45 **Arandaspid microvertebrates from the Amdeh Formation (Ordovician) of Oman**  
*C. Giles Miller, Ivan J. Sansom, Neil S. Davies and Alan Heward*

12:00 **The sabre-toothed dinosaurs once more: caniniform tooth function in *Heterodontosaurus***  
*Laura B. Porro*

12:15 **Tracing the evolution of bite force in finches and carnivores**  
*Manabu Sakamoto*

12:30 **Obtaining crystallographic information from conodonts by electron backscatter diffraction (EBSD)**  
*Alberto Pérez-Huerta, Maggie Cusack and Carlos Méndez Fernández*

12:45-14:00 *Lunch*

*Palaeozoic Faunas II (Stora Salen) Chair: David A. T. Harper*

14:00 **Cephalopod assemblages from the Upper Ordovician Børglum River Formation, Peary Land, North Greenland**  
*Jan Auden Rasmussen*

14:15 **First report on the occurrence of Early Ordovician (Tremadocian) rhynchonelliformean brachiopods in the Eastern Alborz, Iran**  
*Leonid E. Popov and Mansoureh Ghobadi Pour*

14:30 **New insights into ctenocystoid (deuterostomes) morphology and palaeobiology using 3-D reconstruction techniques**  
*Imran A. Rahman, Sébastien Clausen and Mark D. Sutton*

14:45 **Machaeridians - polychaetes masquerading as molluscs**  
*Jakob Vinther, Peter Van Roy and Derek E. G. Briggs*

15:00 **Chitinozoan biotopes and biozones in the Ashgill of the Welsh Basin, UK**  
*Tom J. Challands and Howard A. Armstrong*

- 15:15 **Virgiana BILLINGS, 1857: on top of the world after 150 years**  
*Christian M. Ø. Rasmussen and David A. T. Harper*

*Vertebrate palaeobiology (cont.) (Lilla Salen) Chair: Michael J. Benton*

- 14:00 **The higher-level phylogeny of Archosauria (Tetrapoda: Diapsida)**  
*Stephen L. Brusatte and Michael J. Benton*

- 14:15 **Why bigger is not better in the long run: investigating mammal lineage survivorship using Neogene mammals of Eurasia**  
*Lee Hsiang Liow, Mikael Fortelius, Ella Bingham, Kari Lintulaakso, Heikki Mannila, Larry Flynn and Nils C. Stenseth*

*Crisis and Recovery (Lilla Salen) Chair: John S. Peel*

- 14:30 **Ecological changes in marine macrobenthic assemblages across the Cretaceous/Palaeogene boundary in Patagonia: evidence for a productivity crisis and uncoordinated recovery**  
*Martin Aberhan, S. Weidemeyer, W. Kiessling, R. A. Scasso and F. A. Medina*

- 14:45 **Towards a high-resolution palaeotemperature curve through the Permian/Triassic extinction horizon**  
*Tim Kearsey, Richard J. Twitchett, Gregory D. Price and Stephen T. Grimes*

- 15:00 **Aftermath of the late Frasnian mass extinction (Upper Devonian) on brachiopods in the Namur-Dinant Basin (Belgium)**  
*Bernard Mottequin*

- 15:15 **Testing multivariate models of extinction risk in Eocene bivalves**  
*Paul G. Harnik*

15:30-16:00 *Coffee and Tea*

*Plenary II (Stora Salen) Chair: Michael G. Bassett*

- 16:00 **Dinosaur tectonics – structural geology as a tool to interpret theropod walking dynamics**  
*Ole Graversen, Jesper Milàn and David B. Loope*

- 16:15 **Computerizing and evaluating modified Brooks' Parsimony Analysis in palaeobiogeography, with case studies from trilobites and dinosaurs**  
*Paul Upchurch and Alistair J. McGowan*

- 16:30 **Cystoid preservation in the Kukruse Oil Shales (Upper Ordovician, Caradoc) of northern Estonia shows rapid early sea floor calcite cementation and post-mortem encrustation of internal molds**  
*Mark A. Wilson and Andrew J. Milligan*

- 16:45 **Spatial heterogeneity through the end Ordovician extinction events: How complete is the Hirnantian brachiopod record?**  
*David A. T. Harper and Jiayu Rong*

- 17:00 **Environmental setting of Late Cretaceous New Zealand Plesiosaur remains – a palynological investigation**  
*Vivi Vajda*

- 17:15 **Burgess Shale-type deposits share a common taphonomic mode**  
*Robert R. Gaines, Derek E. G. Briggs and Yuanlong Zhao*

- 17:30 *Presentation of awards and close*

## Wednesday 19<sup>th</sup> December

09:00-c. 17:00 *Linnaean and Stockholm excursion*

## Abstract of Annual Address

### Evolution in the Ice Age

**Adrian Lister**

*Natural History Museum, London*

The study of Quaternary mammals has great potential for illustrating patterns and processes of evolution. The timescales, stratigraphic resolution and dating ( $10^2$ - $10^6$  yr) are suitable for testing among different models of species-level evolution; the well-known climatic and vegetational changes of the glacial/interglacial cycle provide a dramatic backdrop against which to view the responses of the mammals; and the persistence of many of the species (or close living relatives) to the present day provides a fixed point of ecology and adaptation against which to view their fossil precursors. In addition, the recent expansion of research in ancient biomolecules (especially DNA sequence data) is providing a new source of information to complement traditional morphological studies.

In theory there are many reasons why episodes of dramatic environmental change might promote an evolutionary response; but several theorists have proposed that the rapid changes of the Quaternary might, on the contrary, have suppressed it. A brief overview of faunal records is presented, suggesting that in some regions at least, speciation and adaptive change have clearly been driven by Quaternary environmental change. The evolutionary role of range expansions, and contractions into refugia, is a particular topic of current debate.

Individual case histories of Quaternary mammals provide some of the best-documented examples of speciation captured in the fossil record. The origin of dwarfed forms of large mammals on islands is a valuable source of data; red deer on Jersey are shown to have dwarfed in only a few thousand years of the last Interglacial, and current studies are focussing on elephants in the Mediterranean and hippos on Madagascar.

On the mainland, the evolution of the mammoth lineage has been traced through four million years of Plio-Pleistocene time, from its precursors in Africa to the origin of the woolly mammoth in Eurasia and the Columbian mammoth in North America. An original concept of gradual evolution in Europe has given way, with better dating and broader geographic sampling, to a model of successive allopatric speciation events, the transitions taking place first in China and then in NE Siberia, followed after variable intervals by spread of the new forms into Europe and North America.

In tandem with morphological studies, DNA sequence data is providing further insights into population structure and movements, in mammoth and other species, in the Late Pleistocene. This includes evidence of significant turnover at a sub-specific level, on relatively short timescales, with implications for the fine structure of species extinctions.

## Abstracts of seminar presentations

### Clues to the evolution of the three domains of life

**Anthony Poole**

*Stockholm University, Sweden*

The question of how the three domains of life (archaea, bacteria and eukaryotes) evolved from a common ancestor is a question that regularly courts controversy. This far back in evolutionary history, most of the tools conventionally used to study the origins of groups (fossil data, phylogenetic trees, morphological characters) provide only limited resolving power. It is therefore perhaps not surprising that the field is awash with speculation. In this talk I will try and describe how one can productively address this question by looking at molecular and cellular traits. While it is difficult to reconstruct a comprehensive picture of the nature of the Last Universal Common Ancestor (LUCA), the theory of evolution nevertheless enables us to build plausible selective explanations to account for the vast differences between the three domains. Moreover, Darwinian thinking provides an indispensable framework for generating testable hypotheses and eliminating implausible models.

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### Arthropod origins: palaeontological and phylogenomic perspectives

**Gregory D. Edgecombe**

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

Phylogenomic analyses such as those based on Expressed Sequence Tags (ESTs) support an alliance between arthropods and other moulting animals (Ecdysozoa hypothesis) that has repeatedly been retrieved from analyses of small numbers of genes. Affinities of arthropods to nematoid and scalidophoran worms remove segmentation from the character suite immediately stemward of the panarthropod ancestor. Analysis of up to 100 genes for an expanded taxonomic sample of ESTs in the “Assembling the Protostome Tree of Life” project allies onychophorans and arthropods to the exclusion of tardigrades, and variably supports panarthropod monophyly, and thus a single origin of paired, segmental ventrolateral appendages. Although most molecular approaches split the extant arthropods into crustacean-hexapod (Tetraconata or Pancrustacea) and myriapod-chelicerate (Paradoxopoda or Myriochelata) groups, the classical Mandibulata hypothesis (myriapods with crustaceans and hexapods) is supported by anatomical evidence, and a Myriapoda-Tetraconata sister group relationship is favoured by parsimony analysis of combined morphological and sequence data. The stalemate over the shape of the arthropod tree is essentially a rooting problem – most competing hypotheses are compatible with the same unrooted network – and invites the addition of fossil terminals to identify the position of the root. The recognition of fuxianhuidi in a relatively crownward position on the arthropod stem group has broad support and sheds light on how characters of head segmentation, tagmosis, and appendage morphology were acquired. Resolving megacheirans (“great appendage arthropods”) as stem-group chelicerates and trilobites as stem-group mandibulates dates internal nodes for the arthropod crown group to the Early Cambrian and alleviates the formerly problematic issue of pycnogonid-chelicerate affinities. Dinocarida (= *Opabinia* + anomalocaridids) are reasonably interpreted as stem-group arthropods but theories that derive biramous limbs from dinocarid lateral lobes or

putative trunk appendages of these animals are flawed or require more convincing defence. Whether the Cambrian AOPK group (anomalocaridids-*Opabinia-Pambdelurion-Kerygmachela*) is mono-, para-, or polyphyletic is the essential question for resolving the lobopod-arthropod transition in a palaeontological context.

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## **Echinoderms: Attachment, torsion and the origins of a radical new body plan**

**Andrew B. Smith**

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

Molecular data show us that echinoderms nest within the deuterostomes and that they retain the same battery of body-patterning genes as their bilaterian sister groups, yet have evolved a radically new body plan - pentaradiality. Developmental biology further shows that the echinoderm pentamerous body plan is built upon an original primary asymmetry, which in turn seems to be derived from an even more fundamental bilateral symmetry. Echinoderms are also unusual amongst the major phyla in having a rich and diverse fossil record of stem-group representatives. Stem-group fossils provide hard data on the anatomy of pre-radiate echinoderms and bring a unique insight into some of the steps that must have been involved in the remarkable transformation from bilateral symmetry to pentamerous. One important step appears to be larval attachment, since the two deuterostome groups with larval attachment, tunicates and echinoderms, are also the most highly derived in terms of body plan. Stem group fossils also help to constrain what the latest common ancestor of echinoderms and hemichordates looked like. Molecular data confirm the monophyly of hemichordates but cannot resolve internal relationships satisfactorily. Although either a stalked and tentaculate pterobranch or a worm-like enteropneust could represent the basal hemichordate body plan, once stem group echinoderms are taken into account the former becomes more likely.

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## **The origin of tetrapods**

**Per Erik Ahlberg**

*Subdepartment of Evolutionary Organismal Biology, Uppsala University, Sweden*

The “origin of tetrapods”, that is the emergence of tetrapod morphology and terrestrial competence, occurred within the tetrapod stem group during the Devonian period, with the main morphological and ecological shift taking place during the Givetian and Frasnian (392-375 mya). It involved drastic changes in lifestyle and substantial morphological innovation, but the latter occurred within a conserved overall architecture and produced only a few novel structures such as the choana (internal nostril), middle ear, digits, and sacrum. Recently discovered fossil evidence indicates that the choana and digits evolved by fairly modest repatterning of existing structures, and for the digits this interpretation is also supported by gene expression data. The origin of the middle ear may have involved more radical patterning changes within the hyoid arch and otic capsule. Curiously, the choana seems to have originated as a device for active olfaction rather than breathing, whereas the middle ear was primitively used for breathing and only later acquired a hearing function. Terrestrial locomotion evolved through an intermediate “tripodal” stage, exemplified by *Tiktaalik* and *Panderichthys*, where the body was supported on pectoral fins and tail but the pelvic fins were small and a sacrum apparently lacking. The morphologically transitional members of the stem group are all large predators, a metre or more in length.

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## Origin of angiosperms

**Else Marie Friis<sup>1</sup>, Kaj Raunsgaard Pedersen<sup>2</sup> and Peter R. Crane<sup>3</sup>**

<sup>1</sup>*Department of Palaeobotany, Swedish Museum of Natural History, Stockholm, Sweden*

<sup>2</sup>*Department of Earth Sciences, Aarhus University, Denmark*

<sup>3</sup>*Department of Geophysical Sciences, University of Chicago, USA*

The fossil record strongly suggests that the first major diversification of angiosperms took place during the Cretaceous period and that differentiation into the major lineages of extant angiosperms also occurred through this interval. During the past few years our understanding of early angiosperms has been greatly improved by numerous discoveries of fossil flowers and other angiosperm reproductive structures. Molecular phylogenetic analyses have also clarified our understanding of interrelationships among angiosperms resulting in many new, sometimes surprising constellations among angiosperm taxa. Some changes in the angiosperm tree were not unexpected and the adjustments have helped resolve character conflicts. There are still areas in the angiosperm tree that needs clarification but results from the molecular studies are largely consistent with results from the fossil record. In contrast, the origin of angiosperms and the position of the group in relation to other seed plants remains controversial. Phylogenetic analyses that have incorporated both extant and extinct seed plants have generally supported earlier hypotheses that extant Gnetales and extinct Bennettitales are the closest relatives to angiosperms. In these analyses, angiosperms, Gnetales and Bennettitales, sometimes together with the extinct *Pentoxylon*-plant, form a monophyletic group, the anthophytes, that is usually nested among two or more of the Mesozoic seed ferns, Glossopteridales, Caytoniales, Corystospermales, and Peltaspermales. Recent molecular phylogenetic analyses reject the anthophyte hypothesis and present alternative interpretations of relationships among extant seed plants. In some of these analyses angiosperms are the sister group to a clade comprising all other extant seed plants (cycads, *Ginkgo*, conifers, Gnetales). Several analyses are also support the radical conclusion that Gnetales should be included within conifers. Conifers would therefore be paraphyletic as they are traditionally defined. Other analyses indicate monophyly for conifers. Taken together current molecular data do not appear to be sufficient for unambiguous identification of relationships among extant seed plants. Extant seed plant are only a small part of a much greater extinct diversity in the seed plant clade, and new information from fossil seed plants is therefore likely to be crucial for clarifying patterns in seed plant relationships and the origin of angiosperms. New fossil material that suggests a revival of some aspects of the anthophyte theory will be presented together with new information on early angiosperms.



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## Neandertal Genomics

**Svante Pääbo<sup>1</sup>, Tomislav Maričić<sup>1</sup>, Richard E. Green<sup>1</sup>, Johannes Krause<sup>1</sup>, Adrian Briggs<sup>1</sup>, Janet Kelso<sup>1</sup>, Kay Prüfer<sup>1</sup>, Udo Stenzel<sup>1</sup>, Johann Visagie<sup>1</sup>, Michael T. Ronan<sup>2</sup>, Jan F. Simons<sup>2</sup>, Lei Du<sup>2</sup>, James R. Knight<sup>2</sup>, Michael Egholm<sup>2</sup>, Jonathan Rothberg<sup>2</sup>, Dejana Brajković<sup>3</sup>, Ivan Gušić<sup>3</sup>, Pavao Rudan<sup>4</sup> and Željko Kučan<sup>5</sup>**

<sup>1</sup>*Max-Planck Institute for Evolutionary Anthropology, Leipzig, Germany*

<sup>2</sup>*454 Life Sciences, Branford, CT, USA*

<sup>3</sup>*Institute of Quaternary Paleontology and Geology, Croatian Academy of Sciences and Arts, Zagreb, Croatia*

<sup>4</sup>*Institute for Anthropological Research, Croatian Academy of Sciences and Arts, Zagreb, Croatia*

<sup>5</sup>*Croatian Academy of Sciences and Arts, Zagreb, Croatia*

Neandertals, who diverged from modern humans about half a million years ago and became extinct around 30,000 years ago, are the closest relatives of current humans. A Neandertal genome sequence would allow nucleotide sequence differences between the human and the chimpanzee genomes to be assigned to fully modern humans during and after their descent from the Neandertal-modern human ancestor. The Neandertal genome, which falls partially within the coalescence of human genes, would also allow novel approaches to detect positive selection in modern humans.

We are applying novel large-scale DNA sequencing methods to DNA extracts of Neandertal bones with the ultimate goal of achieving 1-fold coverage of the entire genome. Strategies to estimate the authenticity and reliability of the DNA sequences will be reviewed as well as preliminary analyses of the Y chromosome and a gene involved in speech and language.

## Abstracts of oral presentations

### **Ecological changes in marine macrobenthic assemblages across the Cretaceous/Palaeogene boundary in Patagonia: evidence for a productivity crisis and uncoordinated recovery**

**Martin Aberhan<sup>1</sup>, Sven Weidemeyer<sup>1</sup>, Wolfgang Kiessling<sup>1</sup>, Roberto A. Scasso<sup>2</sup> and Francisco A. Medina<sup>2</sup>**

<sup>1</sup>*Museum für Naturkunde, Humboldt-Universität Berlin, Germany*

<sup>2</sup>*Departamento de Ciencias Geológicas, FCEN, Universidad de Buenos Aires, Argentina*

The mass extinction at the Cretaceous/Paleogene (K/Pg) boundary is generally explained by a severe, global crisis in primary productivity, following a catastrophic bolide impact. To test this hypothesis, we studied the taxonomic and ecological composition of the marine macrobenthos across the K/Pg boundary from so far poorly-known Southern Hemisphere mid-palaeolatitudes in the Neuquén Basin of Argentina. Consistent with the productivity scenario, the early Paleogene (Danian) mollusc-dominated benthic shelf ecosystems are characterized by (1) a stratigraphically limited low in macrofossil abundances in the earliest Danian, reminiscent of the "dead zone" found in two Northern Hemisphere localities; (2) an increase in starvation-resistant, nonplanktotrophic deposit-feeders (nuculoid bivalves) and chemosymbionts (lucinid bivalves); (3) a reduction in the average body size of individuals as compared to those from Late Maastrichtian assemblages; and (4) individuals with low metabolic rates and inactive lifestyles being more common than in the late Maastrichtian. Return to pre-extinction conditions of the various synecological attributes occurred over unequal time spans, indicating that recovery was uncoordinated with respect to ecological traits. Thus, pre-extinction abundance levels were reached at a short distance above the K/Pg boundary, whereas late Maastrichtian mobility levels were re-established somewhat later. Trophic composition once again resembles that of Maastrichtian samples only near the end of the studied interval, and mean body size within assemblages did not reach values typical of late Maastrichtian times in the study interval.

Comparison of ecological patterns with those from other K/Pg boundary sites suggests that reduced food supply was a controlling factor in both Northern and Southern Hemispheres. It also affected macrobenthic marine faunas at various distances from the Chicxulub impact site. Finally, low nutrient availability was presumably more effective in siliciclastic environments as compared to carbonate settings. This later finding may be explained by the presence of a more starvation-resistant, low nutrient-adapted benthic fauna in oligotrophic carbonate shelf settings, as represented for example by the very small-sized bivalves and brachiopods of the Danish chalk.

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### **Plant evolution and chemical weathering**

**Christian Baars, Hefin Jones and Dianne Edwards**

*Department of Earth Sciences, Cardiff University, UK*

A decrease in atmospheric carbon dioxide (CO<sub>2</sub>) concentration during the mid Palaeozoic is postulated to have been partially the consequence of the evolution of rooted land plants. Root development increased the amount of carbonic acid generated by root respiration within soils.

This led to increased chemical weathering of silicates and subsequent formation of carbonates, resulting in lower atmospheric CO<sub>2</sub> concentrations. To test this assumption, analogue (morphologically equivalent) plant species, ranging from those possessing no roots to those with complex rhizomatous rooting systems, were grown in trays within microcosms at ambient (360ppm/0.37 mbar) and highly elevated (3500ppm/3.55 mbar) atmospheric CO<sub>2</sub> concentrations in a purpose-built controlled environment facility. Substrate CO<sub>2</sub> concentrations increased significantly under elevated atmospheric CO<sub>2</sub> and *Equisetum hyemale* (L.); this could be the effect of deeply-rooted plants growing on the substrate, elevated atmospheric CO<sub>2</sub> concentrations, or both. Plants with simple or no rooting systems, or the addition of dead organic matter as a substrate for microorganisms did not enhance substrate CO<sub>2</sub> concentrations. Organic acids were not detected in the bulk substrate.

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## **Preservation of Ediacaran fossils in limestones from the Khatyspyt Formation (Siberia)**

**Uwe Balthasar<sup>1</sup> and Dima Grazhdankin<sup>2</sup>**

<sup>1</sup>*Department of Earth Sciences, Palaeobiology, Uppsala University, Sweden*

<sup>2</sup>*Institute of Petroleum Geology and Geophysics, Novosibirsk, Russia*

Understanding the anatomy of Ediacaran organisms revolves to a significant degree around understanding their taphonomy, made somewhat difficult by their widespread death-mask preservation in siliciclastic rocks that obscures any histological information. The only known examples of classical Ediacaran taxa being preserved in limestone come from the Siberian Khatyspyt Formation and include *Palaeopascichnus*, *Charnia*, *Inaria*, ‘*Mawsonites*’ and *Ediacaria*. Two types of fossil preservation can be distinguished, (1) preservation as a concretion, and (2) preservation as a compression. Preservation as compressions is only found in *Palaeopascichnus* and the filament-like extensions of ‘*Mawsonites*’ whereas the central body of ‘*Mawsonites*’ is preserved as a concretion. All other taxa are preserved as concretions with the individual quilts of *Charnia* composed of single concretions that form a series of elliptical discs in cross section. Concretions exhibit no apparent internal morphological features and are composed of early diagenetically cemented peloidal silt. The concretions were probably induced by the decomposition of the organisms. The confinement of the cementation to the inside of the organisms suggests that the body wall formed a barrier to diagenetic fluids. The lack of concretionary growth associated with *Palaeopascichnus* or the filaments of ‘*Mawsonites*’ suggests different properties for these structures.

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## **The trilobite family Asaphidae: Cope’s Rule and the evolution of the hypostome**

**Mark A. Bell<sup>1,2</sup>, Simon J. Braddy<sup>2</sup> and Richard A. Fortey<sup>1</sup>**

<sup>1</sup>*Department of Palaeontology, Natural History Museum, London, UK*

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

Cope’s Rule (the “active” trend of organisms towards larger size) is tested here for the first time within the Trilobita, specifically, the family Asaphidae (one of the largest in the class). Ranging from the Upper Cambrian to Ordovician this family has had several larger trilobites assigned to it (e.g. *Isotelus rex*). A phylogeny was constructed using sixty in-group taxa intended to cover the morphological spectrum of the family. Holaspid lengths were recorded from European collections and literature sources; incomplete sclerites were scaled to “total length” from equations achieved from complete specimens. Using squared-change parsimony,

mean and maximum values were calculated for all ancestral nodes and used for several independent comparisons. The results of these comparisons suggest that size change occurs through random or 'passive' diffusion within an increasing morphospace rather than a so-called 'active' mechanism. Finally, when mean size was traced through several lineages within the six main clades, there is a strong correlation between the development of the hypostomal posterior border from a subrounded condition to a distinct fork (presumably allowing for the capacity to deal with bulkier prey) and an increase in body length.

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### **Ammonite and foraminiferal evidence for opening of the South Atlantic Ocean in the early/mid Aptian (Early Cretaceous)**

**Peter Bengtson<sup>1</sup>, Eduardo A. M. Koutsoukos<sup>2</sup>, Mikheil V. Kakabadze<sup>3</sup> and Maria Helena Zucon<sup>4</sup>**

<sup>1</sup>*Geologisch-Paläontologisches Institut, Universität Heidelberg, Germany*

<sup>2</sup>*Petrobras - CENPES, Rio de Janeiro, Brazil*

<sup>3</sup>*A. Djanelidze Geological Institute of Georgia, Tbilisi, Republic of Georgia*

<sup>4</sup>*Departamento de Biologia/CCB, Universidade Federal de Sergipe, São Cristóvão, Brazil*

The exact timing of the final opening of the South Atlantic Ocean in the Early Cretaceous has long been in dispute. The oldest marine faunas along the margins of the central South Atlantic are dated as Aptian; however, the crucial question is whether these faunas entered the area from the south ("Austral" South Atlantic) or the north (equatorial South Atlantic), in the latter case indicating an "opening" of the ocean. Study of the early/mid Aptian ammonite and foraminiferal faunas of northeastern Brazil has revealed overwhelming affinities with coeval Tethyan faunas, which can only be explained through the existence of at least surface-water connection with the equatorial South Atlantic at that time. Although there is evidence of Aptian marine influx in the northeast Brazilian intracontinental basins, it appears more likely that the first, surface-water breakthrough occurred in the Gulf of Guinea shear zone rather than through an epicontinental seaway across northeastern Brazil. The early/mid Aptian opening of the South Atlantic was probably in the form of intermittent surface-water connections, with full deep-water circulation being established considerably later (probably late Albian).

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### **Problems on the origin and interrelationships of early gnathostomes (jawed vertebrates)**

**Martin D. Brazeau**

*Subdepartment of Evolutionary Organismal Biology, Evolutionary Biology Centre, Uppsala University, Sweden*

The origin and early evolution of gnathostomes remains one of the most problematic areas of Palaeozoic vertebrate palaeontology. The rarity of endoskeletal mineralization in early gnathostomes, the overall morphological disparity of known taxa, and the lack of multi-generic phylogenetic tests have hampered progress on this question. The monophyly of key groups such as the Acanthodii and the Placodermi remain untested by phylogenetic analysis. The present study aims to address these issues through outgroup-based comparisons of early gnathostome taxa. Based on new fossil data as well as previously described material a broad-scale phylogenetic analysis is conducted using genera from the Chondrichthyes, Osteichthyes,

Acanthodii, and Placodermi to address the question of their large scale interrelationships, as well as group monophyly. Characters of the head endoskeleton (braincase, jaws, hyoid and gill arches) provide significant new data bearing on this problem. The results provide some novel branching arrangements and illuminate some of the problems with determining character polarity at the base of the gnathostome tree.

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## **The higher-level phylogeny of Archosauria (Tetrapoda: Diapsida)**

**Stephen L. Brusatte and Michael J. Benton**

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

Crown group Archosauria, which includes birds, dinosaurs, crocodylomorphs, and several extinct Mesozoic groups, is a primary division of the vertebrate tree of life. However, the higher-level phylogenetic relationships within Archosauria are poorly-resolved and controversial, despite years of study. The phylogeny of crocodile-line archosaurs (Crurotarsi) is particularly contentious, and has been plagued by problematic taxon and character sampling. Recent discoveries and renewed focus on archosaur anatomy enable the compilation of a new dataset, which assimilates and standardizes character data pertinent to higher-level archosaur phylogeny, and which is scored across the largest group of taxa yet analyzed. This analysis produces a well-resolved phylogeny, which recovers mostly traditional relationships within Avemetatarsalia, places Phytosauria as the basal-most crurotarsan clade, finds a close relationship between Aetosauria and Crocodylomorpha, and divides “rauisuchian” taxa into two disparate clades. Support values are low, suggesting rampant homoplasy within Archosauria, but the phylogeny is highly congruent with stratigraphy. Comparison with alternative analyses identifies numerous scoring differences, but indicates that character sampling is the main source of incongruence. The phylogeny implies major missing lineages in the Early Triassic, suggests that Triassic archosaur clades were cosmopolitan, and may support a Carnian-Norian extinction event.

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## **Lophotrochozoan roots and stems**

**Nicholas J. Butterfield**

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

The Lophotrochozoa is one of the three great clades of bilaterians that evolved during the course of the Cambrian explosion. In addition to the appearance of what appear to be crown-group brachiopods, molluscs and annelids, the early fossil record documents a diverse range of problematic forms that fall outside the range of extant phyla. Slug-like forms such as *Kimberella*, *Halkieria*, *Wiwaxia*, *Odontogriphus* and *Orthrozanclus* have been proposed as stem-group molluscs on the basis of inferred molluscan synapomorphies (e.g., radula, ctenidia, foot, mantle cavity) and inferred plesiomorphies (e.g., sclerites, cataphract scleritome, shells, shell composition, body shape). Recent cladistic analyses, however, have failed to consider the potential for convergent evolution, particularly in light of major discrepancies in mode of development, histology/biomineralization and overall bodyplan. *Wiwaxia* and *Odontogriphus*, for example, have an anterior feeding apparatus that has been interpreted as a distichous radula, despite this structure having no morphological comparisons among extant molluscs, and differing fundamentally in its mode of growth. Juvenile *Wiwaxia* jaws recovered from the Middle Cambrian Hess River Formation, NW Canada, reveal the early establishment of a two-rowed apparatus, while adult Burgess Shale specimens show the two tooth-bars to follow distinct developmental trajectories, quite unlike patterns of modern

radulogenesis. Significantly, the dorsal scleritome of microvilli-secreted chaetae that characterizes *Wiwaxia* is unknown in any mollusc, but stands as an unambiguous synapomorphy of the polychaetous annelids. *Odontogriphus* differs from *Wiwaxia* in lacking a dorsal scleritome and, in the absence of any other diagnostic features, cannot be resolved further than the Lophotrochozoa; indeed, it might be usefully viewed as the “hypothetical ancestral lophotrochozoan”. Character-rich *Halkieria* and *Orthrozanclus* are also identifiable as lophotrochozoans – probably a clade (or grade) of stem-group molluscs. The degree to which any of these fossils can be used in the reconstruction of early lophotrochozoan evolution depends critically on the accurate identification of phylogenetically significant characters.

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## Affinities of Cambrian scleritomorph animals

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The advent of skeletal structures marks a major turning point in animal evolution. Starting about 542 million years ago, the fossil record contains diverse decay-resistant skeletal elements of many groups of invertebrates. Resolving the affinities of these elements, however, has been a remarkably frustrating exercise. Thanks to exceptional fossil deposits with preservation of complete articulated specimens, the morphologies of *Wiwaxia* from the Burgess Shale and *Halkieria* from Sirius Passet in Greenland have now been revealed. Both were slug-like and their dorsal surfaces were covered by a scleritome, but *Halkieria* further possessed two shells. A previously unknown sclerite-bearing animal from the Burgess Shale named *Orthrozanclus reburrus* has recently been described. This animal bears a prominent convex shell at the front and the scleritome consists of at least three zones of sclerites. *Orthrozanclus* convincingly unites halkieriids and wiwaxiids within a new and larger group the Halwaxiida. Halwaxiids may represent a stem-group mollusc or molluscs had already diverged before the evolution of the halwaxiids. This second hypothesis would imply biomineralization was achieved independently in the earliest molluscs and halwaxiids.

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## Chitinozoan biotopes and biozones in the Ashgill of the Welsh Basin, UK

**Tom J. Challands and Howard A. Armstrong**

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There is strong evidence that graptolite assemblages were depth stratified and existed in discrete biotopes whose composition responded to major periods of climate change, largely during episodes of glacioeustatic sea-level change. Unlike graptolites, chitinozoans are microfossils of unknown biological affinity and little is known about their palaeoecology. If they are truly planktonic, do they demonstrate the same depth stratification and biotope distribution as graptolites do during episodes of abrupt climate change?

Pre-Hirnantian (Katian) strata in the Welsh Basin show a pattern of repeated anoxic/oxic events. Lithostratigraphical, trace fossil and geochemical proxy data show these were due to climatically induced fluctuations in coastal upwelling, increased organic productivity and an expansion in the oxygen minimum zone (OMZ). Two assemblages of Chitinozoa are defined: 1) the *Belonechitina-Hercochitina* assemblage characteristic of oxic waters and, 2) the *Bursachitina* assemblage indicative of the OMZ. During the development of anoxia the *Bursachitina* assemblage expanded into the basin and the *Belonechitina-Hercochitina*

assemblage expanded shelf-wards. A reverse pattern of change occurred during the Hirnantian glacial lowstand.

It is concluded that water column oxygen was the primary ecological control on chitinozoans. Chitinozoa show similar depth stratification to the graptolites, indicating a planktonic mode of life for the chitinozoan animal. Further to this, chitinozoan biozone boundaries are coincident with major ecological overhaul events suggesting that biozones are largely controlled, for Chitinozoa and graptolites at least, by external events where opportunistic taxa most suitable to new environmental conditions are able to flourish. This study indicates the potential utility of Chitinozoa in palaeoceanographic and palaeoclimate reconstructions in the Palaeozoic.

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## **Expanding the Taxonomic Affinities of Ediacaran and Phanerozoic Acritarchs**

**Phoebe Cohen<sup>1</sup>, Robin Kodner<sup>2</sup> and Andrew H. Knoll<sup>2</sup>**

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Acritarchs have historically been considered as phytoplankton because of their small size, paleoenvironmental distribution, and morphological similarity to extant algae. Morphological and ultrastructural comparisons to modern prasinophyte phycomata provide strong evidence for the green algal affinities of some taxa. However, distinctive prasinophyte ultrastructure has yet to be convincingly demonstrated in Proterozoic microfossils. Dinoflagellates are commonly favored as the producers of process-bearing acritarchs in Palaeozoic successions based on external morphology, but coeval bitumens contain only small concentrations of dinoflagellate-sourced biomarker molecules, leaving the generality of this interpretation in doubt. Animals have seldom been considered as acritarch progenitors, but a phylogenetically wide diversity of metazoans produce recalcitrant dormant egg cases and egg hulls that accumulate in modern sediments. In particular, Ediacaran and Palaeozoic acritarch assemblages include a diversity of acritarchs that are morphologically most similar to animal, and not algal, forms. Comparison of wall ultrastructure between modern invertebrate egg structures and a diversity of Ediacaran acritarchs strengthens the hypothesis that process-bearing acritarchs in Ediacaran rocks record evidence of metazoans. Thus, some Ediacaran and early Paleozoic acritarchs may record direct, and not just indirect (i.e. ecological), evidence of the radiation of animals in the world's oceans, while younger Phanerozoic acritarchs may provide additional information on animal evolution and paleoenvironmental conditions.

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## **A new cloudinid from the terminal Ediacaran of Spain**

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*Cloudina* is one of the earliest biomineralized metazoans and is generally considered an index fossil for the terminal Ediacaran. It is a tubular fossil composed of stacked funnel-shaped elements forming a relatively long cone-in-cone structure. *Cloudina* has a wide geographical distribution but within present-day Europe it is only known from Spain. The study of secondarily silicified material from the eastern part of the Badajoz province, central Spain, has revealed the presence of a new species of *Cloudina*. It differs from previous material by the presence of prominent external longitudinal crests which yield a polygonal cross-section. The crests are developed only in the flaring portion of the individual funnels, and seem to

occur at comparable positions in successive funnels. This material also contains specimens with asexual division, previously only reported from South China.

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### **Are switches to non-planktotrophic larval development concentrated in particular intervals of geological history?**

**John A. Cunningham and Charlotte H. Jeffery-Abt**

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In spite of the widespread interest in the interplay between evolutionary and developmental processes, we still know relatively little about the evolutionary history of larval development. Many clades seem to exhibit multiple shifts from planktotrophic (feeding) to non-planktotrophic (non-feeding) larval development. An important, but much overlooked, question is whether these switches are scattered randomly through geological history or are concentrated in particular intervals of time. We address this question using the Cretaceous spatangoid sea urchins, which are unusual in that larval strategy can be inferred unambiguously from abundantly fossilized adult tests. We find that multiple clades of non-planktotrophic taxa make their first appearance in the fossil record in the Campanian and Maastrichtian but, importantly, none do so in any of the other Cretaceous stages. This strongly suggests that shifts to non-planktotrophic development are clustered in certain episodes of geological history. This, in turn, suggests that extrinsic factors operating at these times are responsible for driving shifts in developmental strategy.

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### ***Hurdia*, a new anomalocaridid from the Burgess Shale and the origin of biramous limbs in arthropods**

**Allison C. Daley<sup>1</sup>, Graham E. Budd<sup>1</sup> and Jean-Bernard Caron<sup>2</sup>**

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Anomalocaridids are among the largest Cambrian organisms and characterized by possession of a pair of frontal appendages and a circular jaw structure. However, affinities of this group to the stem lineage Arthropoda have remained problematic. A previously undescribed anomalocaridid from the Burgess Shale has been studied based on 730 isolated and articulated parts. Most specimens were collected by Royal Ontario Museum field parties on Fossil Ridge, B.C. in the Burgess Shale Formation. Like *Anomalocaris* and *Laggania*, this animal unites “genera” previously described in isolation. Not only does it possess a “*Peytoia*” jaw structure and a pair of “appendage F”, it also has a three-part carapace structure at its anterior end consisting of two “*Proboscicaris*” carapaces and one “*Hurdia*” carapace, from which the whole animal takes its name. Formerly enigmatic morphological characters of anomalocaridids, such as the relationship between gills and lateral flats, are elucidated by the exquisite preservation of gill-like structures from the *Hurdia* animal. Not only do these observations provide insight into the origin of biramous limbs, they also help clarify the morphology and relationships of the still enigmatic *Opabinia*. Inclusion of *Hurdia* in phylogenetic analyses places the anomalocaridids in the stem group of the Euarthropoda.



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## Juvenile plasticity and evolutionary trends in Devonian ammonoids

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The loosely coiled early Devonian ammonoids of the subfamily Anetoceratinae are considered the closest to their bactritoid ancestors. Based on their coiling and ribbing, a fairly high number of taxa has been erected worldwide. The intraspecific variability of these ammonoids was examined for the first time using mainly specimens from the Moroccan Anti-Atlas. Major evolutionary trends are an increasingly allometric growth, wider and higher whorls and narrower umbilici towards more derived Devonian ammonoids.

Bivariate plots were used to illustrate the intraspecific variability of the gyroconic forms from Morocco. These show a considerable intraspecific variability in the loosely coiled forms, especially in the pre-adult whorls, which we interpret as an example of extremely high juvenile plasticity. Several taxa fall in this range of variability, which has important taxonomic implications. To assess the evolutionary and ontogenetic trends in Devonian ammonoids, umbilical width versus whorl height index plots were constructed using data from representative taxa from our Moroccan material and literature. From these bivariate plots it became evident that more derived forms show a morphological reversal in ontogeny and that the phylogenetic change is similar to ontogenetic change in quantity, but perpendicular in direction.

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## First chemostratigraphical data in the lower-middle Cambrian transitional interval of the Iberian Chains (Spain)

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Carbon isotope excursions are being tested as an interesting tool for international correlations during the Cambrian. The most significant biotic turnovers and environmental changes took place in the lower-middle Cambrian transitional interval.

Analysis of both  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  in the carbonate nodules of the Valdemiedes Formation (lower-middle Cambrian, Iberian Chains, northeastern Spain) have allowed us to obtain two curves where we can compare the variation of these two isotopes and their relationships with the fossil record. The curves seem to have a similar development in those levels with less fossil record and independent development in those levels with a big palaeontological content (mainly trilobites and brachiopods). There is a general negative excursion on the  $\delta^{13}\text{C}$  curve in the lower-middle Cambrian boundary, coinciding with the beginning of the Valdemiedes Event. This change could be correlated with the AECE excursion, marking the extinction of the archaeocyaths.

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**Gastéropodes à la carte: Durophagy on Ordovician gastropods from Manitoulin Island, Canada****Jan Ove R. Ebbestad<sup>1,2</sup> and Christopher A. Stott<sup>3</sup>**<sup>1</sup>*Department of Earth Sciences, Palaeobiology, Uppsala University, Sweden*<sup>2</sup>*Museum of Evolution, Uppsala University, Sweden*<sup>3</sup>*Department of Earth Sciences, University of Western Ontario, London, Canada*

Shell repairs resulting from presumed failed predation were found in gastropods from the Late Ordovician (Cincinnatian; Richmondian) mid to upper Kagawong Submember, Georgian Bay Formation, on Manitoulin Island, Ontario, Canada. The bryozoan-mollusc biota and lithology of this unit suggest nearshore, shallow (<10 m), low energy (lagoonal) conditions which by analogy with relatively recent faunas and carbonates of similar character may point to a mesotrophic to eutrophic nutrient regime. Division of the number of individual shells with at least one scar by the total number of shells in each sample, yielded a shell repair frequency of 4.8% for 207 (total) specimens of *Lophospira trilineata* and 35.7% in 28 specimens (total) of *Trochonemella* sp. Repairs in *Trochonemella* occur primarily in the largest size class, suggesting that a size refuge was achieved by this species. The low repair frequencies observed in *L. trilineata* suggest that this species experienced a higher predation success rate or a lower level of predation pressure. This is the only case study to date which documents Ordovician shell repair frequencies in consistent, homogenous sample sets collected from the same stratigraphic unit, evaluated against standardized analytical approaches. The results suggest that the paradigm of a standardized low level of shell repair in Ordovician and Silurian gastropods is oversimplistic, and that a range of frequency rates can be expected.

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**Burgess Shale-type deposits share a common taphonomic mode****Robert R. Gaines<sup>1</sup>, Derek E. G. Briggs<sup>2</sup> and Yuanlong Zhao<sup>3</sup>**<sup>1</sup>*Geology Department, Pomona College, Claremont, CA, USA*<sup>2</sup>*Department of Geology and Geophysics, Yale University, New Haven, CT, USA*<sup>3</sup>*Key Laboratory for Paleobiology, Guizhou University, Guiyang, China*

Although Burgess Shale-type (BST) biotas are fundamental to understanding the initial Phanerozoic radiation, the nature of their extraordinary preservation has been controversial. We have conducted a comprehensive taphonomic study of soft-bodied fossils from nine BST deposits from Laurentia and South China using SEM-EDX. Results indicate that conservation of organic remains is the primary mechanism responsible for preservation of BST fossils in Cambrian and Proterozoic strata, although early authigenic mineralization may occur in association. The data suggest that BST preservation worldwide represents a single process that presumably shares a common cause. The preservation of BST fossils requires a mechanism that can account for the suppression of organic decay.

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**Biomarker analysis: a tool for investigating the diet and digestive biochemistry of ancient animals****Fiona Gill<sup>1</sup>, Ian Bull<sup>1</sup>, Richard Pancost<sup>1</sup>, Remmert Schouten<sup>2</sup> and Tim Ewin<sup>3</sup>**<sup>1</sup>*OGU, Bristol Biogeochemistry Research Centre, University of Bristol, UK*<sup>2</sup>*School of Earth Sciences, University of Bristol, UK*<sup>3</sup>*Bristol City Museum, UK*

Biomarkers are biogenic molecules linked to particular taxa or biochemical processes, on the basis of their chemical structure. Biomarkers have been used extensively to investigate microbial communities in modern and ancient environments. We present evidence that the biomarker approach can be extended to the fossil record on the scale of individual macro-organisms, to elucidate diet and digestive biochemistry, including relationships with symbiotic gut micro-organisms.

We used established organic geochemical techniques to extract biomarkers from faecal samples from a variety of modern animals, to test the hypothesis that there is a correlation between diet, digestive processes and biomarkers present in faeces. The organic geochemical content of faecal material comprised biomarkers derived from dietary materials, as expected, but also biomarkers from gut microbes, including the archaeal biomarker “archaeol”, which is attributed to methanogenic archaea, and various bacterial fatty acids. Based on these results, we applied the biomarker approach to a variety of coprolites, including one from the Pleistocene ground sloth *Nothrotherium shastaensis*. The sloth coprolite biomarker assemblage was dominated by a plant-derived sapogenin, providing evidence for the diet of the animal. We also analysed the preserved gullet contents of a well-preserved scelidosaur specimen, to determine diet and taphonomy.

The preservation of diagnostic microbial and plant biomarkers in ancient coprolites and related materials indicates that this approach, together with traditional palaeontological methods, can provide critical complementary evidence for the diet of ancient animals and their digestive processes.

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**Dinosaur tectonics – structural geology as a tool to interpret theropod walking dynamics****Ole Graversen<sup>1</sup>, Jesper Milàn<sup>1</sup> and David B. Loope<sup>2</sup>**<sup>1</sup>*Department of Geography and Geology, University of Copenhagen, Denmark*<sup>2</sup>*Department of Geosciences, University of Nebraska, Lincoln, NE, USA*

A dinosaur trackway in the Middle Jurassic eolian Entrada Sandstone of southern Utah, USA, exposes three undertracks that we have modeled as isolated tectonic regimes showing the development of fold-thrust ramp systems induced by the dinosaur's feet. The faulted and folded sequence is comparable to crustal scale tectonics associated with plate tectonics and foreland fold-thrust belts. A structural analysis of the dinosaur tracks shows the timing and direction of the forces exercised on the substrate by the animal's foot during the stride. Based on the structural analysis, we establish a scenario for foot movements and weight distribution in the feet. During the end of the weight-bearing phase of the stride, the weight of the animal was transferred to the front of the digits, creating a rotated disc below the foot that was bounded by an extensional fault at the front and a thrust ramp toward the back. As the body accelerated, the foot was forced backward. The rotated disc was forced backward along a detachment fault that was bounded by lateral ramps. The interramp segment matches the

width of the dinosaur's foot which created an imbricate fan thrust system that extended to the far end of the undertrack. The total length of the tectonic disturbance created by the dinosaur is up to three times that of the original footprint. Early, near-surface cementation gave the substrate the rheological properties necessary for development of the observed structures.

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### **Late Ediacaran Avalon-type biota of Siberia**

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The earliest known communities of macroscopic organisms are represented by the extinct Avalon, Ediacaran and Nama biotas. The Avalon biota is typified by rangeomorphs (fusiform, frondose and plumose organisms characterized by the diagnostic fractal quilting) and frondose organisms distributed in low-energy shelf habitats. It has generally been regarded as the oldest (575-560 Ma) assemblage of Ediacara-type fossils and endemic to the Avalon Terrane. However, a diverse, abundant, and exceptionally well-preserved assemblage of Avalon-type macrofossils occurs in the much younger (<544 Ma) late Neoproterozoic Khatyspyt Formation cropped out along the Khorbusuonka River on the Olenëk Uplift, which is located at the northeastern margin of the Siberian Craton. The assemblage includes an assortment of holdfast structures (*Mawsonites*, *Inaria*, *Protodipleurosoma*, *Aspidella*), a frondose erect organism *Khatyspytia*, a rangeomorph *Charnia*, serially and radially chambered structures (*Eoporpita* and *Palaeopascichus*), problematic *Hiemalora*, as well as microbial colonies (*Cyclomedusa*, *Ediacaria*, *Paliella*, *Nimbia*). The Avalon-type biota of Siberia inhabited low-energy carbonate ramp environment in a foreland basin setting and is closely associated with a peculiar assemblage of carbonaceous compression fossils. The Khatyspyt fossil assemblage significantly extends both the stratigraphic and biogeographic ranges of the Avalon biota. If the Khatyspyt fossil assemblage is considered together with older low-energy shelf assemblages, a pattern emerges from the stratigraphic distribution of the Avalon-type fossils, with a gradual shift in dominance from rangeomorphs to frondose organisms. But is this an evolutionary succession?

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### **The ocean chemistry at Cambrian deposits with exceptional preservation and the influence of sulfate on soft-tissue decay**

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Cambrian deposits with exceptional fossil preservation have been investigated to promote understanding of the marine environment and taphonomy in the early Phanerozoic. Water-column anoxia, commonly correlated to these sites, was evaluated via contents of highly reactive iron, and no clear correlation between preservation and anoxia was found. Low pyrite contents reveal that periods of anoxia were iron-rich and non-sulfidic. Furthermore, the isotopic composition of the pyrite demonstrates low fractionations (4-17‰) from Cambrian seawater sulfate. This is indicative of low concentrations of seawater sulfate, arguably around 1 mM, and is one factor, apart from low levels of bioturbation, that these deposits have in common. The influence of sulfate on soft-tissue decay was tested. Decay rate and visual

distortion of shrimp cuticles appears to be slower in an environment without sulfate than in an environment with modern marine concentrations, but the results were inconclusive. X-ray and neutron tomography showed that decay obliterated soft tissue within six weeks under both high and low sulfate conditions, but that destruction of the cuticle appeared to proceed faster when sulfate levels were high.

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## Testing multivariate models of extinction risk in Eocene bivalves

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Ecological characteristics such as abundance are widely believed to influence extinction risk and to have influenced diversity dynamics of clades. While the importance of such characteristics has been established for many extant and extinct taxa, most studies have assumed independence among these characteristics when measuring their effects on extinction rates. Here I use the Eocene marine bivalve fossil record of the U.S. Gulf and Atlantic Coastal Plains to assess the covariance between species characteristics - abundance, body size, and geographic range - and their combined effects on extinction rates. Contrary to the general assumption of independence, preliminary results for species from three superfamilies (Carditoidea, Pectinoidea, and Veneroidea) show a positive covariance between geographic range and both body size and abundance. Given this non-independence, I employ multivariate linear models to examine the direct and indirect effects of these characteristics on extinction rates and find that geographic range explains much of the variation in extinction probability with abundance having weak to negligible effect and body size seemingly entirely decoupled. Using a model selection approach, I then test the generality of extinction rate predictors among these three clades that differ in basic aspects of life history and ecology.

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## Spatial heterogeneity through the end Ordovician extinction events: How complete is the Hirnantian brachiopod record?

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Interrogation of a new database of all currently-known Hirnantian localities yielding brachiopods supports the reality of the end Ordovician extinctions but suggests that despite intensive research the global collector curve has yet to reach a plateau. Regional curves from Avalonia, Baltica and Laurentia indicate further potential but also reflect the heterogeneous and sporadic development of the Hirnantian across these continents. South China, however, displays a plateau at 25 taxa and nearly 100 occurrences. Range-through data, invoking the pull of the Silurian, together with an extrapolation of the global collector curve suggest that when compared with actual occurrences, 30% of the range-through genera are still to be recovered from the stage. The recent reduction in the numbers of Lazarus taxa through the interval together with the new rarefaction curves highlight the heterogeneity of biotic data across the Ordovician-Silurian boundary but confirms South China as the most completely-sampled region to execute studies of the end Ordovician extinctions and subsequent recoveries. The late Ordovician *persculptus* transgression was associated initially with a drop

rather than a rise in biodiversity probably associated with the widespread development of black shales.

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## Arctic vegetation community change in the early Palaeogene

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Pollen and megafloal data from Stenkul Fiord, Ellesmere Island, Canada (c. 77° N) that span the Late Palaeocene-Early Eocene demonstrate significant shifts in community membership over time. Terrestrial strata (coals and palaeosols) are poorly dated in Stenkul Fiord but those sections that are considered Palaeocene (n=15 samples) contain 42 taxa and an abundance of gymnosperm pollen (pinaceous types and taxodiaceae) and ubiquitous angiosperms such as the birch and walnut family. Eocene sections (n=37 samples) are dated by mammals and plants (including *Salvinia*) to within the first 3 My of the Eocene (Ypresian) and yield a significantly richer angiosperm flora with 50 taxa that are not found in older strata. Eocene samples show a "drift" in composition over time driven by first occurrences. There are no last occurrences. Eocene samples contain the same number of taxa as those from Wyoming (c. 40° N) in the same time period. However, the arctic flora is significantly different from any other region and 47% of taxa (n=43) are restricted to these very high latitudes. This suggests that arctic regions during warm periods in Earth history were distinct biogeographically and a source of evolution.

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## The ecology and phylogeny of Cambrian pancrustaceans

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

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Pancrustaceans are a phenomenal success. Crustaceans dominate modern aquatic arthropod faunas, and insects account for the majority of living animal diversity. However, the early evolution of pancrustaceans is poorly resolved: they constitute only minor components of Cambrian arthropod assemblages, with unambiguously identified representatives restricted to the phosphatized Orsten fauna. We present organically preserved crustacean mouthparts from the Early Cambrian Mount Cap Formation (Northwest Territories, Canada) which contribute crucial complementary data. The centimetric body length of the reconstructed Mount Cap taxon sets it apart from the millimetre-scale larvae and miniaturized adults of the Orsten fauna, while its possession of a sophisticated feeding apparatus, adapted for the handling of fine particulate food and developed through substantial appendage differentiation, contrasts with the poorly selective feeding ecologies of macroscopic trilobites and Chengjiang/Burgess Shale arthropods. The Early Cambrian Mount Cap crustacean thus exhibits an innovative combination of large body size and fine-particle feeding, a trophic strategy which would have carried enormous adaptive potential for new feeding styles and extensive niche partitioning. Why, then, are major crustacean radiations not evident in the fossil record until much later in the Palaeozoic and Mesozoic?

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## **The neurocranium and taxonomic affinities of the gigantic varanid lizard ‘*Megalania*’ *prisca* from the Pleistocene of Australia**

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‘*Megalania*’ *prisca* was the largest terrestrial lizard of all time, reaching an estimated body length of 5-7 metres and a mass of 2.2 tonnes. Complete specimens are unknown, but many individual elements have been referred to this taxon, representing parts of the skull, axial column and appendicular skeleton. The taxonomy and systematics of ‘*Megalania*’ have been confused and there is no consensus on its relationship to other varanids. This undermines attempts to understand various problems in varanid evolutionary history, including the repeated(?) evolution of large body size and possible palaeobiogeographical scenarios. Here, we provide the first detailed description of the only known braincase of ‘*Megalania*’ and compare it with those of other species of *Varanus*. Several features of the braincase are shared only with the Komodo dragon (*V. komodoensis*), suggesting that these taxa were more closely related to each other than to other varanids. This conclusion implies that the genus ‘*Megalania*’ should be sunk into synonymy with *Varanus*. Moreover, varanid phylogeny indicates that gigantism characterized a clade of Indo-Australian monitor lizards, which includes ‘*Megalania*’, Komodo dragons and several other taxa.

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## **Animal, vegetable or mineral? Strange structures from the Cambrian of Scotland and Sweden**

**Liam G. Herringshaw**

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The Palaeozoic taxon *Spatangopsis* Torell has been interpreted variously as a body fossil, a trace fossil and an inorganic sedimentary structure. Most recently it was assigned to the putative cnidarian clade Psammocorallia by Seilacher and Goldring (1996). Detailed morphological studies of Lower Cambrian material from the Pipe Rock Member (Eriboll Formation) of Northwest Scotland and the Mickwitzia Sandstone, Västergötland, Sweden, support a body fossil interpretation, but the internal structure of *Spatangopsis* has never been scrutinized previously. Since such information is critical to any detailed interpretation of the affinities of the taxon, serially repeated thin sectioning has been combined with CAT scanning to provide unprecedented new detail. Interpretations of an inorganic or ichnological origin are rejected, and the palaeoecology, taphonomy and taxonomic affinities of *Spatangopsis* reappraised.

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## **Bristling with spines – machaeridian palaeobiology**

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Well preserved extraordinarily spiny machaeridian (*Machaeridia* n. gen.) sclerites from the Upper Ordovician (Katian) Fjäcka Shale of Sweden promote an expansion of the

machaeridian scleritome concept as well as that of machaeridian palaeobiology. The minute sclerites, roughly around 500 µm – 1 mm in length, exhibit an impressive array of thin spines along both non-accreting margins that in cases approximate the length of the actual sclerite. This in combination with the universal presence of spines on both inner and outer sclerites makes it difficult to reconstruct a typical machaeridian scleritome for this taxon. A very loosely semi-articulated scleritome is suggested as a “snow-shoe” adaptation to epibenthic life on a soft muddy bottom typical for the Fjäckå facies during deposition. Swimming by a dorso-ventral undulating movement similar to recent nudibranchs and polyclad flatworms rather than the lateral undulation seen in swimming polychaetes is also suggested as a possibility.

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### **The expanding brachiopod stem-group – First record of *Mickwitzia* from the Early Cambrian of South Australia**

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New findings of *Mickwitzia* in the Flinders Ranges of South Australia represent the first record of this important genus in eastern Gondwana and show that it had a nearly global distribution in the Early Cambrian. The new fossils come from the late Early Cambrian Ajax Limestone (*Pararaia tatei* trilobite biozone – late Atdabanian-Botoman equivalent) of Mount Scott in the Flinders Ranges, South Australia. The new Australian *Mickwitzia* show distinct similarities with the roughly coeval material from Canada, including evidence for a possible pedicle foramen. *Mickwitzia* is regarded to be a derived member of the brachiopod stem group and combine important traits of crown group brachiopods with characters that are otherwise found among the problematic, tommotiids (*sensu lato*), particularly *Micrina*. Most importantly the shells of *Micrina* and *Mickwitzia* are provided with penetrative setal canals that have been recorded in all available material of mickwitziid, including the new Australian material. Recent studies have showed that shell penetrative setae are more widely distributed among brachiopods than previously thought, and even are retained in some rhynchonelliform lineages.

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### **Mutation, adaptation or selective predation - assessing possible causes for unusual tetragonal symmetry of crinoids from two sunken wood associations in the Jurassic of Poland**

**Aaron W. Hunter<sup>1</sup>, Andrzej Kaim<sup>1,2</sup>, Simon Darroch<sup>1</sup> and Tatsuo Oji<sup>1</sup>**

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Despite numerous published accounts, few attempts have been made to investigate the unusual phenomenon of crinoids possessing tetragonal symmetry. Previous work by Donovan *et. al* (1995) demonstrated that (Ordovician) *Xenocrinus* belong within a distinct genus. However, in this study we present examples of tetragonal columnals from the Middle Jurassic (Bathonian) Gnaszyn and 'Anna' sections from south-central Poland, which are not distinct taxa. Using bulk sampling we extracted columnals from two different stratigraphically sunken wood associations where the tetragonal characters are expressed as two different morphotypes of *Chariocrinus* and *Balanocrinus*, associated with a rich mollusc and echinoid fauna.



Furthermore, the number of tetragonal ossicles is expressed as a significant fraction of the total number of columnals, and thus it seems likely that they originated from more than one individual. In this study we try to account for this unusual and uncommon state in fossil and recent crinoids. Three hypotheses are put forward; either a behavioural mutation driven by environmental factors, an adaptation, conserved through successive generations and resulting in an endemic population, or a result of trauma and re-growth. Only one of these hypotheses is testable, thus we attempt to artificially reproduce the effects of selective predation upon living crinoids, in order to try and simulate the development of a tetragonal population.

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### **Age discrimination: Analysis of ontogeny and heterochrony in conodonts**

**David Jones, Mark A. Purnell and Helen Hewitt**

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Heterochrony, evolutionary change in rates and timing of development, is widely invoked as an explanation for patterns in the fossil record, yet, in most cases, these hypotheses are poorly constrained because the ontogenetic age of individuals is unknown, and size is used as a proxy. This is a significant problem, but organisms that preserve a record of their ontogeny in the form of growth increments, like tree rings, allow the relationship between size and age to be analysed and hypotheses of heterochrony to be tested. Conodonts are one such group, and we have conducted quantitative analyses of the relationship between element size and age in conodonts based on counts of growth increments preserved in the basal cavity. Element growth is complicated by the fact that although growth occurred throughout life, it was not continuous: periods of growth and apposition of multiple apatite lamellae alternated with periods of element function. Elements were not shed, so the number of growth increments present should correspond to a conodont's age at death. Our analysis focussed on cavusgnathid conodonts, and the results allow us to investigate suggestions that the well-known cavusgnathids from Granton, which provide almost all our evidence for conodont soft-part anatomy, were paedomorphic.

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### **The diversification of skulls and feeding apparatus in the Rhynchocephalia (Diapsida: Lepidosauria)**

**Marc E. H. Jones and Susan E. Evans**

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The past few decades have seen a dramatic improvement in the fossil record of the Rhynchocephalia revealing an unexpected diversity in skull shape, body size, body proportions, tooth shape, and tooth arrangement. As a result six distinct morphotypes are now recognised: a paraphyletic assemblage of 'basal taxa', more robust clevososaurs, long-bodied pleurososaurs, short-bodied sapsheosaurs, *Sphenodon*-like sphenodontines, and the highly derived eilenodontines. However, a functional interpretation of differences between the groups has been largely omitted. 'Basal taxa' possess long thin jaws, small adductor muscle capacity, relatively weakly sutured skulls and narrow acuminate teeth. This suggests a mainly insectivorous diet (fast weak prey) with only a minor degree of food processing. By contrast the more derived taxa (e.g. *Clevosaurus*) possess short jaws, large adductor muscle capacity, strong interlocking skull bones, and stouter teeth with elaborate flanges. All these attributes suggest evolution of a harder bite and increased food processing that would have allowed access to larger and harder food items (small vertebrates, plant material). Coupled with increased body size, this seems to have permitted the radiation of derived taxa into different

feeding niches. This challenges the view that rhynchocephalians were only minor components of global Mesozoic palaeoecosystem.

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### **Dietary change in a plant eating mammal across the Eocene/Oligocene transition**

**Sarah C. Joomun<sup>1,2</sup>, Jerry J. Hooker<sup>2</sup> and Margaret E. Collinson<sup>1</sup>**

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The Late Eocene to Early Oligocene was a period of considerable climatic change, from greenhouse to icehouse conditions. The “Grande Coupure” was a major mammalian faunal turnover which occurred in the Early Oligocene, coincident with the first major glaciation of the Cenozoic (Oi-1). Most of the endemic European mammal fauna became extinct and there was a large number of incoming taxa from southwest Asia. The perissodactyl *Plagiolophus minor* is the only member of the endemic European family Palaeotheriidae to survive the Grande Coupure and persist over a wide area.

Dental microwear takes the form of microscopic pits and scratches on the tooth enamel. It is produced by the interaction of ingested material with the teeth and can be used to determine diet and to help reconstruct palaeoenvironments. A significant difference has been found between the microwear of *Plagiolophus minor* from the pre-Grande Coupure sites of La Débruge, France and Frohnstetten, Germany and the post-Grande Coupure site of Soumaillies, France. The pre-Grande Coupure specimens have polished enamel surfaces and fewer pits than the post-Grande Coupure specimens. This indicates that there was a change in the diet of *Plagiolophus minor* across this climatic and biotic event.

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### **Towards a high-resolution palaeotemperature curve through the Permian/Triassic extinction horizon**

**Tim Kearsley, Richard J. Twitchett, Gregory D. Price and Stephen T. Grimes**

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The end-Permian mass extinction event coincides with a dramatic negative shift in both the  $\delta^{13}\text{C}$  and the  $\delta^{18}\text{O}$  isotope records, at or near the extinction horizon, from multiple marine and terrestrial sections round the globe. This study has identified the isotope excursions at a shallow water, carbonate-dominated, section at Val Butta in the Italian Dolomites. High resolution bulk rock sampling revealed that there is an average  $\delta^{13}\text{C}_{\text{carb}}$  negative shift of -2.21‰ and a  $\delta^{18}\text{O}_{\text{carb}}$  shift of -3.70‰ through this interval. This is similar to the isotope record at other nearby localities. The boundary beds, however, like those at many other localities in the region, have been recrystallised, which hampers the calculation of absolute palaeotemperatures from the bulk rock isotope data. Fortunately, fossils of articulate brachiopods, including *Comelicania* and *Janiceps*, occur within the boundary beds at Val Brutta. These fossils are well preserved and still retain their internal structure and, importantly, the primary isotopic variation across the shell. Analysis of the  $\delta^{18}\text{O}$  values of these brachiopod shells have been successfully used to produce a seawater palaeotemperature estimate, at the time of the isotope anomaly in the latest Permian, of between 27 and 32°C.

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## Differential time averaging in brachiopod accumulations from sub-tropical and temperate latitudes

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Variation in time resolution between environments is a major uncertainty in the study of fossil assemblages. Shell accumulations from different climatic regimes are subject to variation in resolution due to differing sedimentation rate, sediment composition, ambient water temperature, and current intensity. This study investigates differential time averaging of modern brachiopod accumulations in sub-tropical and high temperate latitudes.

Individual shells of two extant brachiopod species were dated using amino acid racemization dating (D/L aspartic acid). Separate calibrations were developed for each species using AMS radiocarbon dates. Shells were dredged from the uppermost several centimeters of sediment from a mixed carbonate-siliciclastic shelf off the coast of Brazil (*Bouchardia rosea*, n=103, 20° S latitude), and from coarse sand and gravel-filled channels in the Puget Sound off the coast of Washington, USA (*Terebratalia transversa*, n=92, 48° N latitude).

Age frequency distributions from both sites are right-skewed with most shells populating the youngest age bins. However, *T. transversa* (mean age=256 yrs, std=190 yrs) are younger with less age-variation than *B. rosea* (mean age=2007 yrs., std=2342 yrs), indicating greater time averaging duration in the sub-tropical setting. Young shells likely dominate in the Puget Sound because old shells are continually transported by strong tidal currents. Thus, the formation of a winnowed lag surface results, perhaps counter intuitively, in less time averaging in this setting. This finding has important implications for the fossil record because brachiopods were common in such settings for much of their history.

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## Measurement and scale dependency in geometric approaches to morphological disparity analyses

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Over the past decade studies of morphological disparity have become increasingly popular in palaeontology. A variety of approaches have been taken to such studies ranging from the formally morphometric to the semi-quantitative. However, while comparisons between quantitative and semi-qualitative approaches have been made with respect to their ability to produce broadly consistent disparity results, the issues of measurement dependency and scale dependency have yet to be formally assessed in this context. In order to investigate these topics traditional 2D and 3D geometric morphometric approaches were compared and contrasted with a new morphometric approach-eigensurface analysis-that that supports direct comparison of 3D surfaces. Analysis of synoptic morphometric datasets for trilobites and bivalves suggests disparity measures are strongly influenced by the manner (e.g., 2D vs.3D

data), type (e.g., cranidium vs. cephalon) and effective spatial scale of measurements which are taken. Broadly speaking, inter-taxon disparities can be made to appear, grow larger, diminish, and/or disappear depending on how one chooses to measure the forms under consideration. While none of these results are incorrect characterizations of these morphologies, all are incomplete if interpreted in isolation. These results suggest some of the primary generalizations of the morphological disparity research programme may need to be reassessed, but also provides a much richer and more nuanced analytic vocabulary for undertaking those reassessments.

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### **A new multifoliate rangeomorph frond from the Ediacaran of Newfoundland and northwestern Canada**

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Kingston, Ontario, Canada*

Rangeomorphs were an Ediacaran group characterized by complexly fractally branching elements that were combined as modules to construct a wide array of growth forms, from flat-lying recliners to bushes and elevated fronds. Specimens of a new multifoliate Ediacaran rangeomorph frond preserved in four different taphonomic styles are described, including two types of Conception-style preservation beneath thin and thick ash (positive epirelief preservation) from Mistaken Point, Newfoundland; Nama-style of preservation within muddy turbidites from Spaniard's Bay, Newfoundland; and Fermeuse-style positive hyporelief beneath a sandy turbidite in the Sheepbed Formation of northwestern Canada. Each petalodium was characterized by a parallel series of primary rangeomorph branches that emerged along a common branching plane. In contrast with other rangeomorph fronds such as *Rangea*, primary branches were not attached to their neighbours, which commonly resulted in significant branch overlapping in preserved specimens. Only through detailed comparison of specimens from all four preservational regimes was it possible to reconstruct the original morphology of this frond, in addition to isolating specific features which were entirely taphonomic in nature from those which represent true morphological characters.

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### **Taphonomy of Cambrian gogiid echinoderms from Guizhou, China**

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Gogiid echinoderms are the most abundant and widespread stalked echinoderms in the Cambrian, but they are rarely reported in South China. New material, including the lower Cambrian Balang fauna and the middle Cambrian Kaili fauna of Guizhou, allows us to fill an important gap of Cambrian echinoderm palaeobiogeography and to understand better the early echinoderm radiation.

Based on 381 specimens examined, taphonomic considerations include entombment patterns, decay sequences, individual-specific diagenetic histories, unusual burial postures, selective disarticulation patterns, and post-mortem elongation. In particular, five categories of gogiid entombment patterns are proposed to better describe the multi-directional orientations recorded at the time of burial. In addition, preservation of calcareous stereomic microstructure suggests that the dissolution of echinoderm plates in the fine-grained siliciclastic settings, yielding characteristic mouldic preservation, is sub-Recent.

Studying disarticulation patterns gives us a sense of the articulation of the gogiid when it was alive. The results show that regardless of the morphological differences between helicoplacoids and gogiids, these two groups belong to a similar biologic grade with undifferentiated mesodermal connective tissue binding the endoskeleton. In contrast, although the basic body plans of gogiids are in some ways similar to those of crinoids, gogiid disarticulation is distinctively different from crinoid decay.

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### **Why bigger is not better in the long run: investigating mammal lineage survivorship using Neogene mammals of Eurasia**

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It is commonly postulated that body size is an overarching factor intimately linked with many other biological traits such as fecundity, geographic range and metabolic rates. However, does body size matter for lineage longevity or survivorship and why should it matter? We use a densely sampled Neogene Old World mammal dataset (NOW) to investigate these questions. Using multiple approaches to correct for sampling biases, we calculated longevity, survivorship and turnover rates for mammals grouped into two body size classes. Large mammal genera and species have shorter durations than small mammal genera and species as a result of higher rates of both origination and extinction. This result is robust to treatments of the data using approaches with vastly different assumptions. We also discuss preliminary results from testing a related hypothesis, namely, that it is not body size *per se* that influences survivorship, but the ability to hide from adverse conditions. This ability seems more common among smaller mammals.

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### **Adventures in protein world reveal the Tree of Life and the evolution of complexity**

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The structure of the Tree of Life and the relationship between complexity and evolution have been enduring questions since the inception of evolutionary science. Here we use a database of whole genome sequences, interpreted in terms of the protein domains that they encode, to produce presence-absence matrices for 385 species comprising: 238 Bacteria, 27 Archaea, 26 'basal eukaryotes', 9 plants, 53 fungi, 19 chordates, 8 arthropods and 5 other invertebrates. Phylogenetic analysis reconstructs the Tree of Life with a fidelity that competes with all other approaches and, critically, provides insights into the enduring questions of complexity and

convergence in evolution. Disparity analyses easily separate Bacteria, Archaea and Metazoa, but not plants, fungi and basal eukaryotes, which form a separate cluster. Finally, analyses of tempo along the path from LUCA to *Homo* show a general increase in rates with bursts of acceleration at the origin of eukaryotes, mammals and humans. Taken together, these results demonstrate that the information content in proteomics has the power to address unresolved evolutionary questions.

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### **A new priapulid-like worm from the Early Cambrian Chengjiang Lagerstätte, China**

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A new priapulid-like worm is described from the Lower Cambrian Chengjiang biota of Yunnan, China. The animal is divided into an introvert bearing two types of scalids, an unsegmented trunk with annulations, and a distinctively expanded post-trunk region. Exquisite preservation of the introvert, scalids, pharynx, alimentary canal, possible ventral nerve cord and other internal organs, provides unique evidence for interpretation of the anatomical complexity, functional morphology and modes of life of Early Cambrian priapulid-like animals and allows direct comparison with living priapulids. The phylogenetic significance of the new taxon is investigated through comparison with other Cambrian priapulid-like fossils and by a cladistic analysis incorporating extant scalidophoran animals.

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### **A possibly juvenile nemathelminth from the Cambrian 'Orsten' of Australia**

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*Workgroup Biosystematic Documentation, Center of 'Orsten' Research and Exploration*

*C.O.R.E., University of Ulm, Germany*

A 120 µm long fossil in 'Orsten'-type three-dimensional preservation has been discovered in etching residues of Middle Cambrian limestones from Australia. It shows characters that point to cycloneuralian nemathelminth affinities and is interpreted as a possibly immature representative of a new species of this group. Features implying nemathelminth relationships include a terminal mouth surrounded by a ring of pharyngeal teeth and a body subdivided into two parts. The anterior one is finely annulated, while the posterior part bears scale-like sclerotisations arranged in alternating circles. The pharyngeal teeth and the scale-like sclerotisations are strongly reminiscent of similar structures found in some of the cycloneuralians (scalidophorans and nematomorph larvae), while the scale-like structures occur only in scalidophorans (kinorhynchs, loriciferans, priapulids). The new form has, furthermore, a bifid tail end similar to that of gastrotrichs (putative sister group to cycloneuralians) and kinorhynchs, therefore possibly representing a possible ground-pattern feature of Nemathelminthes. The set of features of the new form is discussed in the light of the morphology of extant nemathelminth taxa. We propose that the new species is close to the ground pattern of Cycloneuralia.

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**The size of the earliest molluscs: did small helcionellids grow to become large adults?****Mónica Martí Mus, Teodoro Palacios and Sören Jensen***Área de Paleontología, Universidad de Extremadura, Badajoz, Spain*

For the last 30 years, the study of Cambrian molluscs has focused on microscopic, secondarily mineralised specimens obtained by acid digestion of limestones, a technique that renders free, exquisitely preserved specimens ready for morphological study under the scanning electron microscope. This has contributed to the development of evolutionary models that view early molluscs as millimetric animals. Larger molluscs are not uncommon in Cambrian strata but have received considerably less attention, perhaps because their mode of preservation (usually as moulds or recrystallized specimens in crack-out samples) renders them less gratifying for study. Here we describe a large mollusc from Lower Cambrian siliciclastic rocks of Spain which preserves a millimetric apical shell indistinguishable from those commonly found in acid resistant residues. The fossils are characterized by a thin, centimetre-sized, limpet-like shell showing comarginal ornamentation of rounded-triangular ribs. The new mollusc provides novel data on the ontogeny of Early Cambrian helcionellids, and questions the currently accepted model of molluscan evolution, particularly the idea that early molluscs in general, and early conchiferans in particular, were millimetric animals.

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**Punctuations in the Australian Mesozoic floristic succession****Stephen McLoughlin***Department of Paleobotany, Swedish Museum of Natural History, Stockholm, Sweden*

The Palaeozoic-Mesozoic boundary in Australia is marked by mass-extinction of glossopterids and a shift from coals to redbeds. Peltasperms then corystosperms were dominant through the Triassic (forming widespread coals in the Middle and Late Triassic). Extinction of the dominant corystosperm, *Dicroidium*, and an influx of cheirolepidacean conifer pollen mark the Triassic-Jurassic boundary. Early Jurassic cheirolepid- and caytonialean-rich floras were curtailed during the Toarcian by proliferation of araucariacean and podocarp conifers. Pisolitic ironstone beds characterize this transition. Middle Jurassic to Neocomian floras are remarkably uniform and dominated by araucarian and podocarp conifers, bennettitaleans and pentoxylaleans. Humid seasonal conditions persisted in Australia throughout this interval. Middle Jurassic coals are particularly widespread. Seed-ferns were replaced by angiosperms through the Barremian to Cenomanian. Aptian-Albian sediments show evidence of seasonal freezing. Angiosperms expanded to dominate at least some Australian floras by the Cenomanian but Coniacian-Maastrichtian macrofloras are not yet available for evaluation. A dearth of suitable sections has so far prevented high-resolution palynological analysis of the Cretaceous-Paleogene transition. Although traditionally considered to have become extinct by the K-Pg boundary, new evidence suggests at least one seed-fern lineage survived into the Cenozoic in Tasmania emphasizing the role of high-latitude settings as ecological refugia during environmental crises.

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## **The relative contribution of regional rock records to global Phanerozoic marine diversity curves**

**Alistair J. McGowan and Andrew B. Smith**

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Recent research has revived concerns about the role of variation in marine rock availability in biasing estimates of past marine biodiversity. Several proxies for quantifying changes in the amount rock available to search for fossils have been developed, but most of these proxies do not rely directly on evidence from large-scale geological maps (maps that cover small areas) and accompanying memoirs. Most previous map-based studies focused on single regions, or relied on small-scale synoptic maps. Outcrop and fossil data were compiled from geological maps and memoirs from western Europe, Australia and Chile, and then amalgamated with Peters (2005) COSUNA data to generate a multiregional data set for investigating whether the global Phanerozoic marine diversity record is a truly global record, or is biased towards North America and western Europe. Both short and long-term trends in variation in rock at outcrop display limited correlation among the regions studied, undermining the concept that global eustatic curves provide a reliable means of estimating changes in rock availability. A series of long-term diversification models obtained significantly better fits between observed diversity and diversity predictions based on the European/North American rock records than for the Chilean and Australian rock records, indicating that the global Phanerozoic diversity curve is disproportionately influenced by European and US palaeontological data.

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## **Arandaspid microvertebrates from the Amdeh Formation (Ordovician) of Oman**

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Arandaspid microvertebrate fragments have been recovered from sections within the Amdeh Formation of Oman. Most of the fragments are oak-leaf shaped tubercles that have been detached from the surface of tesserae whilst more complete fragments show the surface with up to 20 tubercles and a cancellous middle layer underlying the scale surface consistent with *Sacabambaspis* previously described from the Ordovician of Bolivia, Argentina and Australia.

The Amdeh Formation is 3.5km thick, and largely consists of quartzites and so precise dating has proved problematic. However, unpublished acritarch and chitinozoan assemblages from the lowest occurrence suggests that this part of the Amdeh Formation is Floian (Arenig) in age. The material is only pre-dated by the poorly known arandaspid *Porophoraspis* (basal Floian) in the Gondwanan pteraspidomorph record. Detailed sedimentary logging of the arandaspid sections indicates that the most likely environment of deposition was a high energy shallow water setting similar to the *Skolithos* ichnofacies as described for the type area for *Sacabambaspis* in Bolivia (Davies *et al.* 2007). The discovery of arandaspids from the Ordovician of Oman demonstrates that arandaspid fish were peri-Gondwanan. This has important implications for models of global vertebrate dispersal.



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**Reconstructing early terrestrial vegetation: the role of mesofossils.****Jennifer Morris***School of Earth, Ocean and Planetary Sciences, Cardiff University, UK*

Charcoalified, three-dimensionally preserved mesofossils a few millimetres long, from the Pridoli and Lochkovian Welsh Borderland, have provided a new source of data on early land plants. However, whether or not these specimens indicate short, turf-sized vegetation or were the tips of much larger, more highly branched plants, remains conjectural. Here for the first time, coalified compressions in green, wavy and parallel-laminated, mica-rich siltstones from the lower Lochkovian at Tredomen Quarry (Brecon Beacons, Wales) provide unequivocal evidence for highly branching, minute plants, which inhabited floodplains of sandy, meandering perennial river systems.

These coalified compressions are no more than 4.5 mm long, with axes up to 500 microns thick, with terminal sporangia up to 0.9 mm in length. In some specimens, 4 dichotomies at branching angles of approximately 40° have been recorded, with evidence of overtopping. Sporangia occur just above the final dichotomy, resulting in sporangial clusters.

These mesofossils occur alongside megafossils, including fertile tips of basal embryophytes e.g. *Cooksonia hemisphaerica*, that attain a minimum height of 16mm, and possess sporangia five times larger than mesofossil sporangia, confirming the presence of at least two components of early land vegetation. However, due to the lack of anatomical preservation, the affinity of these mesofossils remains enigmatic.

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**Aftermath of the late Frasnian mass extinction (Upper Devonian) on brachiopods in the Namur-Dinant Basin (Belgium)****Bernard Mottequin***Department of Geology, Trinity College, Dublin, Ireland*

Due to their diversity and their abundance in Frasnian communities, brachiopods are prime tools for evaluating the extinction events related to the late Frasnian mass extinction whose causes are still hotly disputed. In the Namur-Dinant Basin (southeastern margin of Laurussia), Frasnian brachiopod decline occurred in three steps within the interval spanning the Lower *rhenana* conodont Zone to the *linguiformis* Zone. The major losses occurred at the top of the Upper *rhenana* Zone. These extinction episodes were linked principally to diachronous regional facies changes related to transgressions. Atrypids and pentamerids disappeared at the top of the Lower *rhenana* Zone in the deeper part of the basin, just before the deposition of the dark shales (indicative of hypoxic bottom conditions) of the Matagne Formation, but persisted within the Upper *rhenana* Zone in its shallow parts. The *linguiformis* Zone yielded only productids (Chonetidina), rhynchonellids and lingulids. Post-extinction brachiopod recovery was rapid in the basal Famennian but, despite their great abundance, their diversity was quite low. At present, only one surviving athyridid species (Lazarus taxon) is definitely recognized in the lower Famennian. New cosmopolitan spiriferid, athyridid and rhynchonellid genera appeared at this time concomitantly with new species of pre-existing orthid and orthotetid genera.

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**Unique siphonal structure in an orthoconic nautiloid from the Boggy Formation, Pennsylvanian, USA****Harry Mutvei and Elena Dunca***Department of Palaeozoology, Swedish Museum of Natural History, Stockholm, Sweden*

Numerous orthoconic nautiloids occur in the asphalt-rich bed of the Boggy Formation (Pennsylvanian, Desmoinesian) of south of Sulphur, Oklahoma (Buckhorn Asphalt). The shells of these nautiloids are fractured into small fragments, usually consisting of a few chambers. One of the dominant nautiloid in this formation was described belonging to the genus *Mitorthoceras*. We have studied the siphonal structure and compared it with that of other nautiloids.

The structure of the connecting ring in *Mitorthoceras* differs from that in hitherto described nautiloids, consisting of a single, thick, organic layer, perforated by numerous small pores, and the spherulitic-prismatic transitional layer, which is porous and originates from the nacreous layer of the septal neck forming a transition between the septal neck and the connecting ring proper. The combination of these two features is unique and hitherto unknown in other nautiloids. Only in prosiphonate ammonoids the connecting ring is composed of a thick, single, organic layer, similar to that in *Mitorthoceras*. This layer in ammonoids, as well as in *Mitorthoceras*, was probably tanned and therefore often well preserved. We propose the use of these features in order to clarify the taxonomical position of this nautiloid.

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**Fossil echinoderm endosymbionts: Host/symbiont interactions, new taxa, and application of neutron-, micro-, and synchrotron-computer-tomography****Christian Neumann<sup>1</sup>, Olev Vinn<sup>2</sup>, Nikolay Kardjilov<sup>3</sup>, André Hilger<sup>3</sup>, Ingo Manke<sup>3</sup> and Simon Zabler<sup>3</sup>**<sup>1</sup>*Museum für Naturkunde, Humboldt Universität, Berlin, Germany*<sup>2</sup>*Geologia Instituut, University of Tartu, Estonia*<sup>3</sup>*Hahn-Meitner Institut, Department of Materials, Berlin, Germany*

Direct evidence of biotic interactions (such as symbiosis) among extinct organisms is rarely preserved in the fossil record, and even when clear evidence for some type of an association exists, interpretation is difficult. Echinoderms such as crinoids and echinoids may act as an exceptional model system for studying symbiosis in deep time. The calcareous echinoderm skeleton (stereom) represents a living tissue and thus, reacts directly to disturbances such as parasite/symbiont attacks. These reactions may include callus formation (neoplasia) and embedment of the parasite by the host tissue (bioclaustration).

We studied various symbionts dwelling inside crinoid skeletons and echinoid spines by applying various non-destructive techniques of computer tomography (neutron- micro- and synchrotron-CT) which proved to be a powerful tool. Results allow new insights in infestation strategies of different parasites and skeletal response of echinoderm tissues to symbiont/endoparasite infestation. Moreover, a new symbiont taxon (most probably a lophophorate) has been discovered. On the basis of different examples, we compare these various techniques and will discuss their advantages and drawbacks in practical operation.

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## **The Lower Cambrian of Scandinavia: Sequence stratigraphy, sea-level changes and palaeogeography**

**Arne Thorshøj Nielsen**

*Geological Museum, University of Copenhagen, Denmark*

A sequence stratigraphical framework comprising two supersequences and 13 third order sequences has been developed for the Lower Cambrian of Scandinavia, based on compilation of all sections described from the region. Comparisons have also been made with East Baltic and Polish sections, revealing inconsistencies in interregional correlation. The Lower/Middle Cambrian boundary is e.g. defined at a lower level in the East Baltic area than in Scandinavia. The Baltic craton was overall quite stable during the Early Cambrian, but some local uplift/subsidence did take place, primarily associated with the mild inversion of the Volhyn-Orcha Aulacogen from the mid Early Cambrian onwards. The terminal Early Cambrian so-called Hawke Bay Event was also associated with regional uplift and changes in basin outline. A scaled sea-level curve has been modelled and palaeogeographical maps have been reconstructed for each regional stage. A contoured map of the Subcambrian peneplain has also been sketched, using the modelled sea-level curve as scale. The sea level rose dramatically during the Early to Mid Cambrian, leading to increasing flooding of Scandinavia. The stepwise transgression was associated with progressive clastic starvation and eventually outer shelf depositional rates were only a few times higher than in modern deep sea environments.

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## **A reassessment of fossil preservation in the Burgess Shale**

**Alex Page<sup>1</sup>, Sarah E. Gabbott<sup>2</sup> and Philip R. Wilby<sup>3</sup>**

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Despite the Burgess Shale's palaeobiological importance, there is little consensus regarding its taphonomy. Much debate focuses on whether early diagenetic permineralisation in clay minerals led to the exceptional preservation of its fossils. An alternative scenario sees its fossils preserved as organic compressions which were subsequently coated by phyllosilicates metamorphism. The phyllosilicate films that coat the otherwise carbonaceous fossils of the Burgess Shale display an anatomy-specific distribution: K, Al-rich micas are associated with labile anatomy and Si-rich micas are associated with recalcitrant anatomy. This has been considered to represent differences in their earliest decay. However, these phyllosilicates show a remarkable similarity to those found on graptolites, with the latter forming in metamorphism due to mineral-organic interactions in maturation. In bedding plane assemblages where graptolites are preserved with other organic compression fossils, the phyllosilicate films show a remarkable taxon-specificity: distinct phyllosilicate assemblages are associated with each different type of carbonaceous fossil due to differences in their maturation pathways. As such, I argue that the anatomy-specific phyllosilicate distribution in Burgess Shale fossils reflects differences in the late diagenetic history of labile and recalcitrant anatomy. This suggests that phyllosilicate films formed too late to account for the exceptional preservation of Burgess Shale fossils, which is characterised by the differences in the organic preservation of labile and recalcitrant anatomy.

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**Obtaining crystallographic information from conodonts by electron backscatter diffraction (EBSD)****Alberto Pérez-Huerta<sup>1</sup>, Maggie Cusack<sup>1</sup> and Carlos Méndez Fernández<sup>2</sup>**<sup>1</sup>*Department of Geographical & Earth Sciences, University of Glasgow, UK*<sup>2</sup>*Facultad de Geología, Universidad de Oviedo, Spain*

Characterisation of the crystalline structure of conodonts is essential to understand their susceptibility to diagenesis and thus, their suitability for geochemical studies. Previous studies have used transmission electron microscopy (TEM) to obtain crystallographic information from conodonts, mainly from Ordovician single elements. Electron backscatter diffraction (EBSD) is a useful technique for analysis of crystallography of carbonate fossils. Advantages of EBSD over TEM are the relatively simple sample preparation required for EBSD as well as the lack of electron beam damage. Single Pa elements of *Idiognathodus* from Pennsylvanian (Bashkirian) deposits of the Great Basin (USA), with colour alteration index (CAI) of 1, were selected to test the application of EBSD to conodonts. Preliminary results show that these elements are composed of a polycrystalline matrix of small (<50 nm) crystals with lattice parameters close to those of francolite (calcium carbonate phosphate fluoride hydroxide). In addition, diffraction intensity, which indicates crystallinity and/or crystal size, is not uniformly distributed within each element and these elements do not seem to preserve most of the original crystalline structure. Further research is required to fully understand the crystallographic information that can be extracted from conodonts by EBSD but preliminary results demonstrate the potential of this technique.

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**The Lower Cambrian paterinate brachiopod *Askepasma* from South Australia****Sandra Pettersson Stolk<sup>1</sup>, Lars E. Holmer<sup>1</sup> and Glenn A. Brock<sup>2</sup>**<sup>1</sup>*Department of Earth Sciences, Palaeobiology, Uppsala University, Sweden*<sup>2</sup>*Centre for Ecostratigraphy & Palaeobiology, Macquarie University, Australia*

The morphology and the organophosphatic shell structure of the paterinate (Cryptotretidae) brachiopod *Askepasma* is examined here using previously collected and new material from the Lower Cambrian of South Australia. Based on these characters, some of the fossils previously identified by Holmer and Ushatinskaya (2001) as *Askepasma?* sp.; by Jago *et al.* (2006) as *Askepasma* A and *Askepasma* B; and by Holmer *et al.* (2006) as *Askepasma* B and *Askepasma* sp., require redescription. The latter form most likely represents a new genus. The lamellose shell of *Askepasma* sp. is perforated by phosphatic tubular canals, oriented subparallel to the shell lamination and open to the exterior. These tubules most likely contained organic setae that would have emerged between growth lamellae. This type of setigerous canal system was previously only known from the stem group *Mickwitzia*, as well as the problematic scleritome tannuolinid *Micrina*, interpreted as a more basal stem group brachiopod. The species *Askepasma* sp. occurs as the sole taxon in the early-mid Atdabanian, well below the *Abadiella huoi* Zone, in the basal part of the Wilkawillina Limestone type section in the Bunkers Graben and the Wirrapowie Limestone in the Chace Range, Arrowie Basin, suggesting a potential use in further biostratigraphic studies.

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**First report on the occurrence of Early Ordovician (Tremadocian) rhynchonelliformean brachiopods in the Eastern Alborz, Iran****Leonid E. Popov<sup>1</sup> and Mansoureh Ghobadi Pour<sup>2</sup>**<sup>1</sup>*Department of Geology, National Museum of Wales, Cardiff, UK*<sup>2</sup>*Department of Geology, Faculty of Sciences, Gorgan University of Agricultural Sciences and Natural Resources, Iran*

A low diversity fauna, which includes new brachiopod species of the polytoechioids *Polytoechia* and *Protambonites* and the orthides *Paralenorthis*, *Ranorthis*, *Tarfaya* and *Xianorthis* has been recovered from the lower part of the Lashkarak Formation in the Eastern Alborz, Northern Iran. The upper Tremadocian age of the fauna is confirmed by the occurrence of conodonts characteristic of the lower *Paroistodus proteus* Biozone (*Drepanoistodus* aff. *amoenus* Subzone) in beds of limestone underlying and overlying the brachiopod bearing units. The Iranian fauna preserves the earliest record of the occurrence of *Polytoechia*, which was previously unknown outside Laurentia and the Uralian margin of Baltica, together with *Paralenorthis* and *Ranorthis*, which were widespread along Gondwanan margins and in Baltica since the Arenig, and *Xianorthis*, which was known previously only from the Arenig of South China. *Tarfaya* forms a low diversity association with the endemic nileid trilobite *Vachikaspis*; it proliferated through an interval of considerable sea level fall, probably corresponding with the *Ceratopyge* Eustatic Event. Concentrations of disarticulated valves of *Prototambonites* occur in two storm beds and were probably transported into the basin from the nearshore. In some beds brachiopods are found in association with abundant trilobites, including *Asaphellus* and *Tanghunshania*, ostracods and a few bryozoans. The enigmatic *Tarfaya* is considered in some recent publications as one of the earliest endopunctate brachiopods, but study of the shell structure in Iranian specimens demonstrates convincingly the impunctate nature of the shell. Instead it has rows of penetrative canals along the dorsal valve posterior margin resembling epipunctae similar to those discovered recently in plaesiomyids.

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**The sabre-toothed dinosaurs once more: caniniform tooth function in *Heterodontosaurus*****Laura B. Porro***Department of Earth Sciences, University of Cambridge, UK*

The primitive ornithischian *Heterodontosaurus tucki* exhibited a specialized dentition which included enlarged caniniform teeth. These teeth are similar in morphology to those of carnivorous theropods; however, the maxillary and dentary dentition of *Heterodontosaurus* was clearly adapted for an herbivorous diet. Previous authors have suggested a number of different functions for these caniniform teeth including defense against predators, omnivory, and intraspecific display or combat. This latter hypothesis is often supported by the inferred presence of sexual dimorphism. This study utilizes evidence from dental morphology and finite-element analysis (FEA) of the cranium to objectively test different hypotheses for caniniform tooth function in *Heterodontosaurus*. FEA demonstrates that the skull was mechanically well-adapted to vertical biting on the caniniforms; however, horizontally-directed forces resulted in potentially damaging tensile stress. These results suggest that the enlarged caniniforms could not have been used to subdue struggling prey or during intraspecific combat during which the teeth would have been loaded with large horizontal

forces. Furthermore, juveniles have well-developed caniniforms, wear is absent, and morphology is unlike extant tusked cervids that utilize their caniniforms for fighting and display. This study suggests that the caniniforms of heterodontosaurids may have been utilized, along with the powerful forearm and manus, to capture small prey.

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## Seawater chemistry and the early evolution of carbonate skeletons

**Susannah M. Porter**

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A longstanding question in paleontology is why different taxa evolved to use one mineral rather than another to build their skeletons. I focused on the first appearance of carbonate biomineralization in animal taxa that independently evolved skeletons near the beginning of Phanerozoic time. Of 18 taxa whose primary mineralogy could be constrained with moderate to high confidence, all (N=8) that evolved mineralized skeletons during Ediacaran and Nemakit-Daldynian time were aragonitic, whereas all (N=10) that evolved mineralization during Tommotian through Ordovician time were calcitic. This matches direct and indirect constraints on seawater chemistry that suggest Ediacaran seas favored aragonite precipitation whereas Tommotian through Ordovician seas favored calcite precipitation. Skeletal mineralogies rarely changed once skeletons evolved, despite subsequent changes in seawater chemistry. This is likely because controlled biomineralization is directed by a complex array of organic molecules—some polymorph-specific—and this complexity makes the initial choice of mineral difficult to change. Thus, carbonate skeletal mineralogy appears to have been dictated by seawater chemistry at the time a taxon first evolved its mineralized skeleton.

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## New insights into ctenocystoid (deuterostomes) morphology and palaeobiology using 3-D reconstruction techniques

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Ctenocystoids are a small group of Lower Palaeozoic marine deuterostomes. They belong to the carroids and are perhaps the most enigmatic members of this controversial group; little is known about ctenocystoid morphology, palaeobiology or phylogeny.

Using X-ray microtomography and custom computer software (SPIERS) a specimen of the ctenocystoid *Ctenocystis utahensis* was reconstructed in three-dimensions for the first time. In addition the skeletal microstructure of the species was studied from SEM images of exceptionally preserved 3-D disarticulated plates. These techniques allowed *Ctenocystis* to be described in greater detail than previously possible, providing a number of new morphofunctional insights.

Two openings are identified in *Ctenocystis*: (i) a posterior cone-shaped aperture; and (ii) a void within the anterior ctenoid apparatus. Insertion pits and articulation surfaces show that ctenoid plates were movable, creating gaps through which water currents could bring suspended particles into two narrow feeding grooves. One of the plates in the ctenoid apparatus is morphologically very similar to elements of the holothurian calcareous ring, suggesting that *Ctenocystis* may have possessed oral tentacles analogous to those found in

modern holothurians. Reconstructing the anatomy of ctenocystoids in 3-D is clearly critical to a full understanding of their palaeobiology and systematic position within the deuterostomes.

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## **Cephalopod assemblages from the Upper Ordovician Børglum River Formation, Peary Land, North Greenland**

**Jan Auden Rasmussen**

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

Field investigations initiated in Summer 2006 indicate that both cone-shaped and coiled cephalopods are common in the upper part of the Upper Ordovician Børglum River Formation in Peary Land. Four successive bedding-plane assemblages from c. 30–40 m below the top of the formation were studied in detail. The large, cone-shaped genus *Armenoceras* Foerste, 1924 (order Actinocerida, subclass Actinoceratoidea) is dominant in the lower part of the section. The succeeding assemblages are characterized by a significant increase in coiled taxa of the order Tarphycerida (subclass Nautiloidea) together with more scattered occurrences of straight brevicones of the order Oncocerida (subclass Nautiloidea) and actinoceratoids. A new, loosely coiled taxon belonging to the family Estonioceratidae has been identified from the uppermost assemblage. Study of the overlying Upper Ordovician to Lower Silurian Turesø Formation shows that both the density and diversity of cephalopods decreased significantly through the uppermost Ordovician.

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## ***Virgiana* BILLINGS, 1857: on top of the world after 150 years**

**Christian M. Ø. Rasmussen and David A. T. Harper**

*Natural History Museum of Denmark (Geological Museum), University of Copenhagen, Denmark*

*Virgiana* is a medium to large-sized, costate, pentameroid brachiopod genus restricted to the Lower Silurian (Middle – Upper Rhuddanian). A handful of species is known, all from the North American continent. The genus largely occurs within monospecific coquinas in shallow-water carbonates. Hence, the so-called *Virgiana* community was assigned to the rough water Benthic Assemblage Zone 3, though most species are probably better assigned to the BA 2 zone because they often are strongly abraded and fragmented.

New data indicates that *Virgiana* occurs in nearshore shelf environments in North Greenland as well as in conglomeratic boulders deposited in slope environments. These data also confirm the biogeographical and stratigraphical distribution of the genus on Laurentia. The tropics, thus, may have provided a refuge during the End Ordovician crisis and then subsequently became a source for radiations of recovery faunas into higher latitudes and possibly deeper water during the early Silurian.

Even though this genus generally is biogeographically restricted, *Virgiana* was one of the earliest brachiopod genera to become widespread on Laurentia following the late Ordovician extinction events – perhaps a first indication of the more cosmopolitan shelly faunas that would characterize the emerging North Silurian Realm.

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**Review of the Russian Permian procolophonoids, and their implications on procolophonoid evolution and biogeography.****Laura K. Säilä***Department of Earth Sciences, University of Bristol, UK*

The Procolophonoidea are an important group of parareptiles that emerged in the Permian and achieved a global distribution during the Triassic. Most phylogenetic studies agree that Procolophonoidea can be divided into two major clades: Owenettidae and Procolophonidae. European Russia is the only place outside of southern Africa where a succession of procolophonoids from the Permian and the Triassic are found, and a Permian origin for the clade Procolophonidae was based on the Russian taxon *Microphon exiguus*. This taxon has been reclassified as a seymouriamorph but Bulanov (2002) considered the taxa *Nyctiphruetus*, *Suchonosaurus*, and *Kinelia* from the Upper Permian of Russia as 'procolophons', using subjective classification methods. In recent phylogenies, however, *Nyctiphruetus* is recovered as a non-procolophonoid parareptile, while *Kinelia* and *Suchonosaurus* have never been included in a phylogenetic study. My re-examination of the material assigned to these genera confirms the non-procolophonoid status of *Nyctiphruetus* and in my phylogenetic analysis *Suchonosaurus*, which exhibits a maxillary depression, falls within Procolophonidae. A procolophonoid identity for *Kinelia* is doubtful owing to highly limited material (a single, partial dentary). My results confirm that Procolophidae originated in the Permian of Russia, whereas Owenettidae were restricted to Gondwana.

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**Tracing the evolution of bite force in finches and carnivores****Manabu Sakamoto***Department of Earth Sciences, University of Bristol, UK*

The evolution of bite force is quantitatively traced through phylogeny. Bite force in finches and carnivores were mapped onto their respective phylogeny and ancestral nodal bite forces were reconstructed using the least squares parsimony method. Ancestral body sizes were also reconstructed to test whether changes in bite force were simply reflecting changes in body size. Nodal values were compared to values of neighbouring nodes to determine the polarity of change. Overall, both bite force and body size show no significant change. Significant changes are observed at the family levels, but these changes are highly correlated with changes in body size; change in absolute bite force is merely the result of change in body size. On the other hand, change in bite force corrected for body size (relative bite force) shows significant positive change in certain lineages. Members of these lineages tend to have specific diets such as tough seeds or hypercarnivory indicating that increasing relative bite force is one adaptation in dietary specialisation.

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**Phylogeny and palaeobiography of the Asian delthyridoid spiriferid clade****Mena Schemm-Gregory***Senckenberg Research Institute, Frankfurt am Main, Germany*

Due to their fast evolution and wide-spread distribution, Early and Middle Devonian spiriferids are used for biostratigraphy and palaeobiogeographical reconstructions. Studies based on side-by-side comparisons of spiriferid faunas from different regions have shown that



the development of the Delthyridoida in Europe/North Africa and South China in fact took place in two independent clades during the Early Devonian.

An example for the provinciality of South China in comparison to the Old World Realm is *Orientospirifer*, which is regarded as a member of the subfamily Howellellinae. Substantial differences in the micro-ornamentation even suggest a different family for *Orientospirifer*. The Emsian to Eifelian “*Acrospirifer*-type” brachiopods from Asia and Europe have been analysed with cladistic methods and morphological comparison. As a result, the European/North African *Intermedites* shows similarities to the South Chinese *Otospirifer*. The Siberian “*Undispirifer*” is interpreted as closely related to the sister group *Otospirifer* and *Intermedites*. *Xenospirifer* from Asia shows a less close relationship to the other members of this clade.

According to these analyses, the spiriferid faunas studied show a loss of endemism at the end of the Early Devonian. This may indicate a possible faunal exchange along the Northern Gondwanan shelf between South China and Europe/North Africa.

### ***Trophocrinus* – a broody microcrinoid?**

**George Sevestopulo**

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Recent crinoids are dioecious but sexual dimorphism is not obvious in the skeletons of either fossil or Recent taxa. Even in the few Recent forms in which the females brood their young, the brood chambers are constructed of soft tissues and leave no trace on the pinnules to which they are attached.

*Trophocrinus*, an allagecrinid microcrinoid from the Mississippian of North America, is distinguished from other allagecrinids by the possession of a hood-like structure that was attached to two radials. The hood has been interpreted as having functioned either as a brood chamber or as a current deflector used in food gathering. Microcrinoid faunas containing *Trophocrinus* spp. presently under study contain both hood-bearing individuals and individuals that have thecae of identical shape which lack a hood. The latter are interpreted as males of *Trophocrinus* spp. and the hoods are interpreted as brood chambers.

Although all Recent crinoids produce lecithotrophic larvae, the larvae of primitive crinoids were probably planktotrophs. Brooding in *Trophocrinus* shows that the evolution of lecithotrophic larvae had occurred by the Mississippian. The production of lecithotrophic larvae and brooding have been linked to miniaturisation in several groups of organisms. The larvae of other microcrinoids were probably also lecithotrophic.

### ***Eccentrotheca* from the Lower Cambrian of South Australia – the first known tommotiid scleritome and its biological implications**

**Christian B. Skovsted<sup>1</sup>, Glenn A. Brock<sup>2</sup>, John R. Paterson<sup>3</sup>, Lars E. Holmer<sup>1</sup> and Graham E. Budd<sup>1</sup>**

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The discovery of the first partially articulated scleritome of a tommotiid, *Eccentrotheca* sp. from the Lower Cambrian of the Flinders Ranges in South Australia necessitates a complete revision of the gross morphology and biological function of the problematic tommotiids. The

scleritome of *Eccentrotheca* is an expanding tubular structure with a circular cross-section that was formed by the episodic merging of individual cone-shaped sclerites. The basal region of the tube has an open aperture, the morphology and inclination of which varies considerably. Growth patterns in the apical region indicate that the aperture housed structures that helped anchor the tube to a hard substrate. The *Eccentrotheca* animal is consequently reinterpreted as a sessile, epibiotic filter-feeder. This model contrasts sharply to all previously published models of tommotiid animals, which almost without exception envisages a slug-like animal with a dorsal cover of imbricating sclerites (modelled after the scleritome of the coeval halkieriid animal). Tommotiids have been suggested to fall within the stem group of the Brachiopoda, mainly based on the organophosphatic composition and brachiopod-like shell structure of some tommotiids. The sessile, filter-feeding lifestyle inferred from the scleritome of *Eccentrotheca* appears to strengthen the lophophorate hypothesis of tommotiid relationships, although the tubicous habit of the scleritome is more reminiscent of phoronids than brachiopods.

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## Graptolites in four dimensions

**Andrea Snelling<sup>1,2</sup>, Jan Zalasiewicz<sup>1</sup> and John Wright<sup>1</sup>**

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Graptolites were a major macroplanktonic element of the Early Palaeozoic seas and are frequently found as fossils, most commonly being preserved in laminated mudrocks laid down on anoxic sea floors. However, they are typically only observed on two-dimensional surfaces, the bulk of the information lying within the slab itself and therefore inaccessible to scientific study.

In the Welsh Basin, there are frequent mudrock intervals in which many of the graptolites are wholly or partly pyritized. X-ray analysis of slabs bearing such pyritized graptolites has been used to create 3D stereo images to extract this hidden information. Attainable resolution allows good taxonomic discrimination, and makes possible estimates of the rate of flux of graptolites to the sea floor and of the degree of alignment of the fossils caused by ocean currents. It also allows recognition of predation-induced or tectonic distortion of graptolite skeletons and elucidation of taphonomic pathways in these non-uniformitarian deposits. In tandem with micro-logging of the laminated deposits, this technique promises to provide an effective window into the nature of certain types of graptolite shales and into the fossils buried within them.

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## Yet another ‘great appendage’ arthropod

**Martin Stein**

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Over the last decades, exceptionally preserved arthropods from various Cambrian fossil *Lagerstätten* have been meticulously studied. The mass of accumulated morphological data has made phylogenetic reconstructions feasible and allows biologists to interpret arthropod fossils in the light of results of morphological and molecular studies. We have witnessed a second coming of fossils in attempts to understand arthropod evolution. Yet, with all the progress in this field, some issues remain unresolved, often due to problems in assessment of homology of morphological features. One such problem concerns the homologisation of the

raptorial appendage of the highly problematic anomalocaridids with other fossil and extant arthropods.

Here I report on a new arthropod from the Early Cambrian Sirius Passet fauna of North Greenland. It has biramous limbs with a basipod bearing a paddle shaped exopod and an endopod comprising eight or nine podomeres. The head incorporates at least two, probably three limb-bearing post-antennular segments. This suggests that the species is a late derivative of the euarthropod stem lineage or a member of the Euarthropoda. Yet the antennule shows remarkable similarity with the raptorial appendage of anomalocaridids. While this does not resolve the controversially discussed phylogenetic position of anomalocaridids, it may at least shed some light on the identity of the anomalocaridid raptorial appendage.

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### **Morphology and provenance of mysterious lycopsid with exceptional preservation**

**Lil Stevens and Jason Hilton**

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Lycopsid cone and stem fragments with outstanding 3D preservation are described from a beach worn chert cobble found on the British Jurassic coastline. Associated with the plants are univalve crustaceans (cladocerans) indicating deposition and rapid silicification within a hot spring environment. Vegetative shoots and cones are consistent with those of Carboniferous arborescent lycopsids. Leaves and sporophylls are arranged helically on axes with scalariform tracheids and have stomata organised in rows on the abaxial surfaces. Lagenuclate megaspores arranged in two tetrads are contained in uniseriate megasporangia on the adaxial surface of each sporophyll. Megaspores are up to 1 mm in diameter, have a biseriate wall, pronounced gula and numerous vermiform spines with bulbous apices. Trilete microspores found in a separate cone are elliptic with echinate to granulate surface ornamentation and two equatorial swellings. Comparisons with worldwide lycopsid and chert occurrences indicate that the specimen represents a previously unrecognised Palaeozoic terrestrial *Lagerstätten* with preservation similar to the Rhynie Chert hot spring system. The search is on for the source location and additional specimens, with the audience's help!

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### **Diversification shifts and the data: influence of sampling on the complete Hominoidea and Old World monkey tree**

**James E. Tarver**

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This paper assesses how the discovery of both fossil and extant catarrhine monkeys has shaped our understanding of the large-scale evolutionary changes that have had such a large effect on this important group. A 284 species phylogeny of catarrhines is presented containing all 153 extant taxa and 131 fossil species, eight diversification rate shifts are identified, however, only four of these are shown to be robust and warrant further investigation. These shifts occur within both the Cercopithecinae and Colobinae lineages and correspond to periods of rapid climate change between 15-9mya. Future taxonomic discoveries are likely to correspond to either the splitting of extant species due to the use of molecular data or the discovery of fossil apes. It is observed that the quality of the catarrhine fossil record determined through both stratigraphic congruence and tree imbalance indices has been improving steadily over the past 80 years and that it is now good enough to enable further

investigation of hypothesized macro-evolutionary events. These results are then compared to those obtained from Olenelloidea and Dinosauria phylogenies.

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## **Were hederelloids horseshoe worms? Expanding the diversity of the minor phylum Phoronida**

**Paul D. Taylor<sup>1</sup> and Mark A. Wilson<sup>2</sup>**

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Phoronids, or horseshoe worms, are today a low diversity phylum (10 species) of unmineralized, suspension-feeding lophophorates. Most are solitary and inhabit collagen tubes within soft sediments. However, the primitive *Phoronis ovalis* reproduces asexually to form pseudocolonies that bore into calcareous substrates. With the exception of a Cambrian body fossil from Chengjiang, phoronids are represented in the fossil record only by trace fossils, notably the Devonian-Recent boring *Talpina*. Are phoronids a phylum in decline or have they managed to survive the entire Phanerozoic at low diversity? Here we suggest that the Silurian-Permian hederelloids, a problematical group comprising 109 described species, were pseudocolonial or colonial phoronids that evolved biomineralized skeletons. Especially common encrusting Devonian spiriferid brachiopods, the runner-like hederelloids are usually classified as cyclostome bryozoans, although they have also been referred to the phylactolaemate bryozoans and auloporid corals. None of these assignments is satisfactory in view of their microprismatic skeletal microstructure, zooid size distribution, budding/branching pattern and early development. In contrast, hederelloid zooid sizes fall within the range seen in modern phoronids, the bulb-like origin is similar to a phoronid ampulla, and the budding/branching pattern resembles that of *Phoronis ovalis*. Hederelloids can tentatively be added to tentaculitoids (including cornulitids and microconchids) as candidates for inclusion within at least the stem-group Phoronida. They may have been part of a Palaeozoic diversity acme for horseshoe worms paralleling that seen in the related brachiopods.

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## **On morphological diversity and taxon boundaries in Platanaceae from the Late Cretaceous of Quedlinburg (Germany)**

**Georg F. Tschan and Thomas Denk**

*Department of Palaeobotany, Swedish Museum of Natural History, Stockholm, Sweden*

A Late Cretaceous (Senonian) leaf flora from Quedlinburg, Central Germany, was investigated. Platanoid fossils were comparatively studied and their systematic positions revised. The Northern Hemisphere woody angiosperm family Platanaceae belongs to an early branch in the eudicots and has long been known to have a large number of (extinct) Cretaceous lineages, while it is commonly assumed that the only extant genus *Platanus* appeared not prior to the Tertiary. This assumption is based on reproductive structures associated with leaves both showing distinct features of Platanaceae, but differing substantially from modern *Platanus*. Associated leaf fossils often are so distinct from modern *Platanus* that without information about epidermal features they cannot be linked to the genus. In this study, we evaluated the systematic significance of characters preserved in impression fossils in view of the morphological variability found in extant *Platanus*. A main distinction between many Cretaceous forms of Platanaceae and modern *Platanus* subgenus

*Platanus* is the pinnate leaf organisation in fossils versus the palmate organisation in modern leaves. Leaf margin and size were found to be of no systematic significance. The leaf fossils from Quedlinburg belonging to Platanaceae can be assigned to two extinct genera, *Credneria* and ‘*Macginitiea*’. In addition, a small number of leaves are identical to modern *Platanus*. Infructescences co-occurring with the three leaf morphotypes are most probably linked to the *Credneria*/*Macginitiea* morphotype. Since Platanaceae is an ‘old’ group of flowering plants, we argue that the exclusion of the *Platanus*-like fossils from the extant genus would be artificial. Rather, it seems probable that both extinct and persisting genera within *Platanus* originated in the Cretaceous.

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## **Computerizing and evaluating modified Brooks’ Parsimony Analysis in palaeobiogeography, with case studies from trilobites and dinosaurs**

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Modified Brooks’ Parsimony Analysis (MBPA) is a method for reconstructing biogeographical history using phylogenies. MBPA is designed to detect both vicariance (cladogenesis prompted by the division of areas by geographical barriers) and geodispersal (generation of widespread taxa as a result of barrier destruction). Previously, the use of MBPA has been limited because its algorithm must be applied manually, increasing the risk of error and the time required. We present a computerized version of MBPA and evaluate its performance using artificial data. MBPA often conflates vicariance and geodispersal, and younger biogeographical events within a data set tend to obscure older ones. MBPA vicariance and geodispersal area cladograms can be congruent with each other because of a methodological artefact, undermining previous claims that such congruence indicates cyclical palaeogeographical events (e.g. in Devonian trilobites). We propose a modification to the MBPA algorithm, which improves the method’s performance, and apply both the original and revised algorithms to trilobites and dinosaurs. Although caution is required, there is evidence that valuable biogeographical information can be obtained using these techniques. For example, the traditional view that titanosaurian sauropod dinosaurs evolved as a Gondwanan radiation is contradicted by MBPA results that indicate that titanosaurs dispersed across Pangaea prior to continental fragmentation in the Middle Jurassic.

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## **Environmental setting of Late Cretaceous New Zealand Plesiosaur remains – a palynological investigation**

**Vivi Vajda**

*GeoBiosphere Science Centre, Lund University, Sweden*

Mangahouanga stream, Hawkes Bay, New Zealand is a world-famous site for its high southern latitude vertebrate fossils including plesiosaurs, mosasaurs and more rarely, dinosaurs. The fossils are preserved in the conglomeratic facies of the Maungataniwha Member of the Tahora Formation. Boulders containing the vertebrate fossils were sampled for palynology in order to date the sediments and assess the vegetation and climate of the adjacent mainland.

The well-preserved palynomorph assemblages are dominated by pollen and spores from land plants but also include marine dinoflagellate cysts indicative of a Campanian age. The key pollen taxa *Nothofagidites senectus* and *Forcipites sabulosus* confirm this age.

The terrestrial palynoflora reflects a mixed vegetation dominated by podocarp conifers and angiosperms with a significant tree-fern subcanopy component. The presence of taxa with modern temperate distributions such as *Nothofagus* (southern beech), Proteaceae and Cyatheaceae (tree-ferns), indicates a mild-temperate climate and lack of severe winter freezing during the Late Cretaceous.

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### **Enigmatic, spore-like, organic-walled microfossils from middle-late Cambrian sediments in Algeria: terrestrial or aquatic origin?**

**Marco Vecoli<sup>1</sup>, Florentin Paris<sup>2</sup> and Blaise Videt<sup>2</sup>**

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A previously undated sandstone formation cored by well AMG-1 in western Algeria has yielded profuse and well preserved palynomorph assemblages. The investigated interval consists of alternating coarse to fine-grained sandstones of fluvial origin, and fine-grained sandstones and silts of shallow marine setting. Recovered palynomorphs comprise: a) age-diagnostic marine microphytoplankton (acritarchs) taxa indicating marine sedimentation and middle to late Cambrian depositional ages; b) enigmatic palynomorphs consisting of sub-spherical sporomorphs, appearing much thicker-walled than the associated microphytoplankton, showing complex surface microsculpture (granulation, semipunctation), and commonly arranged in obligate dyad configurations; clusters of 4 organic cells also occur, interpretable as tetrads. The sporomorphs display narrow variability range in cross diameter and consistent type of clustering. Morphological resemblance with *bona fide* previous records of Ordovician cryptospores and sedimentological evidence, are consistent with a non-marine origin for these latter microfossils. Accepting a broad definition of the term "cryptospore" as "a class of organic-walled microfossils of probable terrestrial origin", (Strother and Beck 2000), the present findings would extend of some 40 million years back in time the first occurrence of cryptospores in the Gondwana supercontinent. Biogeochemical analyses are in progress in order to establish the nature of the sporomorphs as marine vs. freshwater algae, or earliest land plant spores.

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### **Machaeridians - polychaetes masquerading as molluscs**

**Jakob Vinther<sup>1</sup>, Peter Van Roy<sup>2</sup> and Derek E. G. Briggs<sup>1</sup>**

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Although a common component of Ordovician-Carboniferous marine shelly assemblages, the Machaeridia have presented one of palaeontology's quintessential enigmas since their shell plates were first described 150 years ago. Machaeridians exhibit a sluglike morphology and a dorsal armour consisting of serially arranged calcitic plates in paired longitudinal rows. Complete skeletons are rare and most species are known only from isolated shell plates. For most of the 20<sup>th</sup> century machaeridians have been grouped with the echinoderms, but more recent authors have favoured either a molluscan or annelid affinity. Here we report the

discovery of a machaeridian with preserved soft tissues from the Upper Tremadoc (Lower Ordovician) of Morocco, solving the 150 year old debate about their systematic position. The exceptional specimen shows the presence of parapodia bearing long chaetae, demonstrating the polychaete annelid affinities of the Machaeridia. Thus an early lineage of polychaetes evolved armour functionally convergent with molluscs, but constrained by an annelid bodyplan. The dorsoventrally compressed morphology and the arrangement of shell plates in epifaunal plumulitid machaeridians recalls polyplacophoran molluscs, while the dorsally hinged shell plates of infaunal lepidocoleids, which enclose a laterally compressed body, may have generated purchase on the sediment like the shell of bivalve molluscs.

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### **Exceptionally well-preserved lacustrine ostracod crustaceans from the Middle Miocene of Antarctica: implications for high latitude palaeoenvironment at 77° South**

**Mark Williams<sup>1</sup>, David J. Siveter<sup>1</sup>, Allan Ashworth<sup>2</sup>, Philip R. Wilby<sup>3</sup> and David J. Horne<sup>4</sup>**

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A newly discovered Middle Miocene *Konservat-Lagerstätte* from the western Olympus Range, Dry Valleys, Antarctica, yields cypridoidean ostracods complete with 3-dimensionally preserved body and appendages, the first record of such fossilization from the continent. The ostracods, which are preserved in goethite, secondary after pyrite, help signal a high latitude (>77°S) lake setting (Palaeolake Boreas) viable for benthic crustacean colonisation prior to 14 Ma. Their presence supports the notion of warmer, tundra-like environmental conditions persisting in the Dry Valleys until the late Middle Miocene.

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### **Cystoid preservation in the Kukruse Oil Shales (Upper Ordovician, Caradoc) of northern Estonia shows rapid early sea floor calcite cementation and post-mortem encrustation of internal molds**

**Mark A. Wilson and Andrew J. Milligan**

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The rhombiferan cystoid *Echinosphaerites aurantium* is common in the Middle and Upper Ordovician of Europe and North America. These cystoids are especially easy to collect from the oil shales of northern Estonia (Kukruse Stage, Caradoc) because they usually weather completely free from the organic-rich kukersite, allowing their outer surfaces to be observed without significant obscuration by the matrix. Almost all the *E. aurantium* specimens in these shales are calcitic internal molds (steinkerns), often with long scalenohedron calcite crystals growing from each thecal plate toward the center of the test. These secondary crystals preserve the undersurfaces of the thecal plates with very fine details, including pore structures. A very few specimens of *E. aurantium* in these shales still possess scattered original thecal plates clinging to the calcitic molds. The cystoids are commonly encrusted by brachiopods, graptolites and bryozoans, but surprisingly they are attached to the outer surfaces of the internal molds, not the original thecal plates. Clearly the encrustation of the

cystoids took place after death, internal cementation, and removal of the thecal plates. This is evidence that calcite cementation occurred very early on the sea floor (a prediction of the Calcite Sea model for the Ordovician), and that the encrusters occupied inanimate crystal spheroids rather than living cystoids as had been previously claimed. We will not be able to deduce the problematic life mode of this cystoid by studying the distribution of post-mortem encrusters on its tests.



## Abstracts of poster presentations

### **Integrated macro-biostratigraphy of the Cenomanian-Turonian transition, Wadi Umm Omeiyed, north Eastern Desert, Egypt: Based on ammonites and echinoids**

**Nasr A. Abdel-Maksoud<sup>1</sup> and Mohamed S. Zakhera<sup>2</sup>**

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The present study aims to analyze biostratigraphically the Cenomanian-Turonian succession exposed at Wadi Umm Omeiyed, north Eastern Desert of Egypt. The study is mainly confined to the Cenomanian-Turonian transition for a refined age determination and a precise definition of the Cenomanian-Turonian boundary, based on integration of the ammonite, and echinoid biozones.

Lithostratigraphically, the Cenomanian-Turonian succession of the study area is composed of fossiliferous siliciclastic and carbonate sediments belonging to the Raha (at the base), Abu Qada and Wata formations of the Galala Group. Based on vertical distribution of the index fauna, the measured section has been divided into six ammonite zones coeval with six echinoid ones. The ammonite zones are: the Late Cenomanian *Neolobites vibrayeanus*, *Vascoceras cauvini*, and the Turonian *Pseudaspidoceras flexuosum*, *Vascoceras proprium*, *Choffaticeras segne* and *Coilopoceras requienianum* zones. The echinoid zones are: the Late Cenomanian *Hemiaster cubicus*, *Coenholectypus larteti*, *Mecaster bantensis* and the Turonian *Hemiaster turonensis*, *Phymosoma libanoticum* and *Petalobrissus ammonis* zones. The proposed zones have been integrated, based on vertical distribution as well as co-existence of the index fauna. The proposed zonal scheme has been correlated with zonal schemes of other well-dated sections.

The Cenomanian-Turonian boundary is marked at the upper boundary of both the ammonite *Vascoceras cauvini* Zone and the echinoid *Mecaster bantensis* Zone, corresponding to basal boundary of both the ammonite *Pseudaspidoceras flexuosum* Zone and the echinoid *Hemiaster (Micaster) turonensis* Zone. It is coincided with irregular surface of a nodular marly bed within the upper part of the Abu Qada Formation.

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### **Paleocene-Eocene foraminifera of the Indus Basin of Pakistan**

**Jawad Afzal, Mark Williams and Richard J. Aldridge**

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The Paleocene-Eocene sedimentary rocks of the Indus Basin of Pakistan were deposited in the eastern Tethys Sea and represent the northwestern continental shelf setting of the Indian Plate. The Paleocene-Eocene interval was a time of major changes, both global (PETM) and regional (collision of Asia and India), and the Early Tertiary stratigraphy of the Indus Basin provides critical evidence to help decouple the effects of these global and regional events. The best exposures of the marine strata of the Indus Basin are in the Kohat area and the Salt Range, where the rocks are remarkably varied in lithology and thickness, but mainly consist of limestone and shale with subordinate sandstone and marl sequences. These rocks preserve a range of foraminifera, including deeper smaller benthic forms, shallow benthic taxa and planktonic species. These foraminifera are being studied to establish a high-resolution

biostratigraphy and to document changes in diversity through the PETM, with specific regard to the pattern of extinction and origination. The foraminiferal data and the improved stratigraphic resolution will aid decoupling of local tectonic effects from global (eustatic) effects and will be applied to an evaluation of local versus global environmental (PETM) influences on this part of the Earth.

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### **A new (stem?) turtle from the Middle Jurassic of Skye, Scotland**

**Jérémy Anquetin**

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

The Middle Jurassic (Bathonian) Kilmaluag Formation at Cladach a' Ghlinne, Isle of Skye, Scotland, has yielded articulated turtle specimens. This material is currently under study and the first results are presented.

A nicely preserved partial skull allows consideration of the phylogenetic position of the Skye turtle. The absence of contact between the pterygoid and basioccipital and especially the absence of flooring of the cavum acustico-jugulare strongly suggest that this turtle is less derived than the stem turtles *Meiolania*, *Mongolochelys*, *Kallokibotion* and all Testudines (crown turtles). However, the position of the foramen posterius canalis carotici interni (FPCCI) might contradict the previous statement. In the skull from Skye, the FPCCI is formed entirely by the pterygoid and opens at the posterior end of this bone. This morphology is similar to the derived morphology of Eucryptodira, though this is probably homoplastic. Recent studies suggest that the evolution of the carotid artery system is more complex than previously thought and this new specimen confirms that.

The turtle material from Skye is abundant and articulated shells are present. The study of this material will help to resolve the phylogenetic relationships of this new turtle and confirm whether it is a stem turtle or not.

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### **A symbiotic relationship of *Echinocorys* faunas from the northern Alborz Mountains**

**Behnaz Balmaki**

*Hamedan, Iran*

A specimen of *Echinocorys scutata* is reported from the late Cretaceous northern area of the Alborz Mountains (northern Iran), with the traces of many bivalves and other parasites. In contrast to most other marine invertebrates, echinoderms favour the attachment of parasites, which leads to a specific response of their skeletal tissues. Among the numerous groups of invertebrates associated with sea urchins, only a few are tightly attached to the external surface of the host, leaving visible damage on the skeleton. The nature of the symbiotic relationship can be considered to be commensalism. *Echinocorys* was the dominant component of the macrobenthic community and is probably a suitable host for symbiotic interactions because of its size and assumed longevity.

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## **Spatial and temporal patterns in trilobite size across the Lower Palaeozoic**

**Mark A. Bell<sup>1,2</sup>, Simon J. Braddy<sup>2</sup> and Richard A. Fortey<sup>1</sup>**

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Trilobites have one of the richest histories of all fossil groups reaching a peak in their diversity in the latest Cambrian – early Ordovician. Certain families are notable for their larger size range, such as the Paradoxidae (Cambrian), Asaphidae (Ordovician) and Lichidae (Ordovician-Silurian) with the largest trilobite (*Isotelus rex*: Asaphida) reaching 700 mm. Measurements of holaspid trilobites were recorded from collections in Europe, Morocco and from literature sources of type specimens. Holaspid body length was analysed from the Cambrian to Devonian, and enabled comparisons between trilobites from lower latitude (i.e. Laurentia) and higher latitude terranes (i.e. Western Gondwana), which has been suggested as a possible control on size in other arthropod groups. The results indicate that 1) mean size is at its highest in the early Palaeozoic followed by a decreasing trend towards the Devonian; 2) there is no significant difference in size between terranes at higher and lower palaeolatitudes; 3) all terranes show a peak in size in the Llanvirn, possibly representing a widespread extrinsic control and; 4) trilobite size was affected by the end Ordovician extinction (the ‘Lilliput effect’), most likely due to the removal of larger-sized families (i.e. Asaphidae).

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## **Linguliform brachiopods from the terminal Cambrian to lower Ordovician Tiñu section, Mexico**

**Barbro Bornsäter Mellbin and Michael Streng**

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The Tiñu Formation of Oaxaca State (Mexico) is the only fossiliferous lower Palaeozoic unit between the Laurentian platform in northwest Mexico and Gondwanan successions in Andean South America. It has recently been shown that the Tiñu section is a condensed passive margin succession with Gondwanan character. The formation is divided into two members, i.e., the uppermost Cambrian Yudachica Member, which rests nonconformably on middle Proterozoic basement, and the Lower Ordovician (Tremadoc) Río Salinas Member. The formation has been studied with respect to its depositional environments and its fossil content of trilobites and conodonts, which both provide excellent biostratigraphical control for the formation.

Linguliform brachiopods of twelve limestone horizons of the Tiñu Formation have been studied. The fauna comprises about five acrotretid taxa, a new siphonotretid species and a few linguloid fragments. Detailed investigations on taxonomy and stratigraphic distribution of the taxa are currently in progress. An assessment of the changes in brachiopod associations across the Cambrian-Ordovician boundary and in relation to the described environmental changes occurring throughout the formation is one of the main points of the investigation.

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**Partial scleritome segments of the widespread palaeoscolecid worm *Hadimopanella* from the Lower Cambrian of South Australia****Glenn A. Brock<sup>1</sup>, Timothy P. Topper<sup>1</sup>, Christian B. Skovsted<sup>2</sup> and John R. Paterson<sup>3</sup>**<sup>1</sup>*Centre for Ecostratigraphy & Palaeobiology, Macquarie University, Australia*<sup>2</sup>*Department of Earth Sciences, Palaeobiology, Uppsala University, Sweden*<sup>3</sup>*Division of Earth Sciences, University of New England, Armidale, Australia*

The geographically widespread Cambrian palaeoscolecid taxon *Hadimopanella* Gedik is currently principally known from single isolated button-shaped phosphatic sclerites. A large number of species have now been described based on relatively minor variations in the spacing and number of nodes on the convex upper surface of the sclerites. For instance, Wrona (1982) described the species *H. apicata*, characterised by a single, centrally located conical node with undulate margin and radial striae, from the upper Lower Cambrian of Spitsbergen. Bendix-Almgreen & Peel (1988) reported specimens of *H. apicata* from Greenland with up to 4 central nodes. This species has been reported from Lower Cambrian rocks in Greenland, Antarctica, and questionably, England. A separate, but morphologically similar taxon, *H. antarctica* Wrona, is characterised by having a central node surrounded at the margin by numerous, smaller, regularly spaced, conical tubercles. This species has previously only been reported from Lower Cambrian glacial erratics on King George Island, Antarctica.

*Hadimopanella* sclerites are now known to belong to palaeoscolecid worms, but although sclerite arrays have been described, new material from the Lower Cambrian Mernmerna Formation of South Australia provides the first well preserved scleritome arrangement for *Hadimopanella*. The scleritome fragments are slightly deformed and wrinkled but appear to represent the main trunk sections of the cuticle; anterior and posterior terminations are lacking. The partial scleritome segments range in length from 900 µm to 1.2 mm. The largest scleritome fragment consists of 39 annuli of uniform width (20-25 µm). Each annulus is ornamented by two rows of irregularly alternating *Hadimopanella* plates. The most abundant plates are circular to subcircular in outline with average diameter of 15 µm. Each plate has a centrally located single, conical node referable to *H. apicata*. The upper surface of plates along the length of each annulus displays considerable variation in the number of central nodes, with some specimens exhibiting 2-3 central nodes. This conforms with the morphological variation in *H. apicata* observed by Bendix-Almgreen & Peel (1988). Importantly, the scleritome also preserves plates situated along the antero-posterior flattened trunk margin that are clearly conspecific with *H. antarctica* Wrona, 1987. The presence of both form taxa on the one scleritome strongly suggest that *H. apicata* and *H. antarctica* are in fact morphological variants of the same species. *H. antarctica* should thus be considered a junior synonym of *H. apicata*.

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## **The use of Geographical Information Systems (GIS) in palaeontology: examples from Late Triassic tetrapod biostratigraphy and Cretaceous dinosaur-plant co-evolution**

**Richard J. Butler<sup>1</sup>, Paul M. Barrett<sup>1</sup>, Emily J. Rayfield<sup>2</sup>, Paul Kenrick<sup>1</sup> and Malcolm G. Penn<sup>3</sup>**

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Geographic Information Systems (GIS) allow integration and visualisation of multiple categories of spatial information. To date, most palaeontological application of GIS has been limited to plotting fossil localities. However, this technique has enormous potential for testing biostratigraphical, palaeobiogeographical and macroevolutionary hypotheses. It has the ability to rapidly (and easily) integrate palaeobiological, palaeoenvironmental and geological data with palaeogeographical maps, permitting visual and statistical comparisons between the temporal and spatial distributions of multiple groups of organisms and environments. Here we outline two case studies that demonstrate the utility of GIS in palaeontology.

The first study tested a Triassic biostratigraphy based on the Land Vertebrate Faunachron concept. This scheme posited various biostratigraphical units constructed on the basis of first appearances of key index taxa. By using GIS we were able to record the spatial and environmental distribution of these taxa in individual timeslices. Comparisons of occurrences between adjacent timeslices allowed us to test the utility of these proposed index taxa in biostratigraphical correlation.

The second example deals with dinosaur-plant co-evolutionary scenarios during the Cretaceous. Comparisons between the plant and dinosaur records through time allows testing of the spatiotemporal patterns that would be expected if these two groups of organisms were interacting.

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## **Crab crushing birds**

**Gerhard C. Cadée**

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Crustaceans are abundant in modern marine environments. During lifetime they moult several times and thus produce several skeletons for the potential fossil record. However, their fossil record is sparse. Taphonomic studies have indicated that their largely chitinous skeleton rapidly decays after death, a process accelerated by bioturbation. Here, I stress the role of predators (exemplified by birds) in destroying crab skeletons. Crabs are excellent food, not only for humans. In the Dutch Wadden Sea, the shorecrab (*Carcinus maenas*) is heavily predated upon by birds such as the Common Eider, Curlews and the Herring Gull.

Common Eiders ingest the crabs entirely and crush them internally, as they also do with mussels and cockles. What remains are small defecated fragments, which may contain partly intact claws. Curlews first shake the crabs to remove the claws and legs. They leave the claws uneaten and ingest the rest of the animal. Herring gulls have two methods to handle crabs. The small crabs (up to 40 mm carapace width) are ingested with all appendages and crushed in their stomach. The larger ones are first freed of their claws and legs by shaking and then the carapace is turned over and the inside cleared of the meat. Coarse particles of the ingested skeletons are regurgitated, the strongest and most heavily calcified parts of the skeleton

usually remain intact. Of the larger crabs, the claws –although they contain a considerable amount of food – are not consumed.

Most shorecrabs in the Wadden Sea will die by predation and their skeletons are fragmented in this process. Only the best calcified parts, the claws, remain recognizable. These are also the best preserved in the fossil record. The fragmented skeletons, like the empty skeletons produced during moulting, also undergo taphonomic decay resulting in an overall poor fossil record.

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## **Middle Ordovician brachiopod associations from the Oslo-Asker District, Norway**

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New, extensively abundant material from the Elnes Formation (middle Ordovician) in Norway is described. The Elnes Formation in the Oslo-Asker District consists, in stratigraphic order, of the Helskjer, Sjøstrand, Engervik and Håkavik members. The Heggen Member corresponds stratigraphically to the Sjøstrand and Engervik members, but is restricted to the southwestern part of the Oslo Region.

The brachiopod fauna collected consists of over 3700 specimens. 24 forms referable to 21 genera are described, including the new genus *Wandaasella modheimrensis*. The fauna is dominated by linguliformean brachiopods, though some sections of the formation are dominated by the plectambonitoids *Alwynella ildjernensis* Spjeldnæs or *Cathrynia aequistriata* (Hadding) or by orthid brachiopods. Statistical analysis of the brachiopod fauna reveals that the general depositional trend of the Elnes Formation is that of a regressive event from the lower part of the Sjøstrand Member to the Håkavik Member. Three main associations are recognised: 1) a deep-water, lingulid dominated association associated with quiet and dysoxic bottom conditions; 2) a sowerbyellid dominated association (e.g. *Cathrynia* and *Alwynella*) found in muddy to marly deposits formed around storm wave base, and; 3) an orthid dominated association representing an environment characterised by a fairly coarse or hard bottom substrate formed well above storm wave base but below fair weather wave base.

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## **Assessing the impact of early aragonite dissolution on the trophic and ecological structure of fossil communities**

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There is growing appreciation of the potential for early, effectively syn-sedimentary, shallow burial diagenetic dissolution of carbonate to skew the skeletal fossil record. Preferential dissolution of aragonite means that the molluscs are potentially most vulnerable among the major macrofossil phyla, even though their fossil record is good. As well as the important implications for marine fossil biodiversity, early dissolution can distort palaeoecological analyses. Quantitative assessment of early lithified skeletal faunas from Ordovician-Jurassic carbonates and siliciclastics identifies those trophic and ecological components commonly 'lost' from fossil benthic faunas through selective dissolution. Two trophic groups are

particularly prone to depletion: the infaunal tier of shallow burrowing bivalves, both suspension and deposit feeders, and the epifaunal niche of vagrant detritus feeders represented by gastropods. Ternary diagrams of feeding habits and substrate niches illustrate the extent of this taphonomic skewing. Environmental gradients make such trophic and ecological shifts especially likely in mid-outer shelf–ramp settings widely represented in the rock record, which seriously limits attempts to reconstruct shelly palaeocommunities.

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## **Filamentous carbonaceous compressions from the terminal Ediacaran-Cambrian of Central Spain**

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Terminal Ediacaran and Cambrian strata in Central Spain consists largely of clay-rich siliciclastic rocks, which have undergone greenschist facies metamorphism. These rocks contain abundant and diverse filamentous carbonaceous compressions. Among them we have identified the genera *Vendotaenia*, *Sabellidites*, *Saarina* and possibly *Tyrasotaenia*. The preservation of the filaments was studied using energy dispersive X-ray spectroscopy (EDS) and backscattered electron (BSE) imaging on a scanning electron microscope. The filaments show a characteristic “Burgess Shale-type” preservation with the presence of carbonaceous films and associated phyllosilicate layers. Also associated with the carbonaceous films we have found abundant small crystals of a rare-earth phosphate, probably monazite. The carbonaceous films are generally cracked and tend to fall off, which explains why they are not recovered in recognizable form after acid digestion of the rock. Even when the carbonaceous films are entirely missing the morphological characters of the filaments are clearly seen (and sometimes even enhanced) under reflected light. BSE images show that the phyllosilicate layers and associated monazite crystals remain after the films are gone, which must account for the faithful replication of the morphological characters.

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## **Trilobites of the Twilight Zone: the phylogeny of the Cyclopygacea**

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The first genus-level phylogeny of the trilobite Superfamily Cyclopygacea Raymond, 1925 is presented. Forty-one cyclopygacean genera and two outgroup taxa were coded for 48 characters using published descriptions. The majority-rule consensus tree from an analysis with CI-reweighted and unordered characters indicates that the Cyclopygidae Raymond 1925 is monophyletic although it includes *Illaenopsis*, a supposed Nileid and the Nileidae Angelin 1854 is also monophyletic but excludes *Illaenopsis*, *Borthaspidella*, *Lakaspis* and *Petrbokia*. The Taihungshaniidae Sun 1931 however is polyphyletic, thus reducing the Cyclopygacea to two families. Examination of character transformations within the cyclopygid lineage towards the pelagic life habit shows that the most fundamental changes defining the group relate to improved streamlining and increased field of vision: an increase in overall length/width ratio, change in glabella outline from a bulb shape, typical of Nileids, to the more hydrodynamically efficient biconvex, cyclopygid form, and migration of the eyes to the lateral margin of the cephalon.

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## **The palaeoecology of the eastern European Palaeogene from deposits of the Boltsh post-impact crater, Ukraine**

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The crater lake formed by the Boltsh meteorite impact structure in central Ukraine represents an ideal depositional basin for the study of Palaeocene and Eocene stratigraphy and the palynomorphs preserved within. It is thus an ideal vector for the study of the regional palaeoecology. The structure is approximately 24 km in diameter and at its deepest in excess of 1 km. Recent  $^{40}\text{Ar}$ - $^{39}\text{Ar}$  dating estimates its age at  $65.17 \pm 0.64$  Ma, placing it within errors of the K/T boundary. After the impact a crater lake formed, which, throughout the Palaeocene and Eocene, accumulated fine grained lacustrine sediment in which a wealth of terrestrial pollen and spores are preserved. The 400 m or so of shale, oil shale, marl, sand and clay preserve a diversity of palynofloras, which are the focus of this study. The primary objective is to reconstruct the regional vegetation from these spores and pollen and to compare the floral changes and palaeoecology of the area over the period represented. Results so far show a dynamic, fluctuating assemblage, revealing the ecological effects the meteorite impact would have had on the floras at the bottom of the section and further up, environmental variability, probably a consequence of the Palaeocene-Eocene Thermal Maximum (PETM), evident in a stark drop in diversity and shift in the floral balance.

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## **A supertree of the hexapod orders**

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The phylogeny of the Hexapoda (insects and their kin) is somewhat contentious at the order level. Both morphologists and molecular biologists have attempted to address various issues with conflicting hypotheses emerging across the hexapod tree. Furthermore, no single phylogeny exists to unite all living and fossil orders. Examining this problem with a selection of supertree methods, we here produce a complete phylogeny of the hexapod orders, identifying especially controversial regions of the tree, which should be the focus of further study. The most widely used supertree method; matrix representation with parsimony (MRP), produces the supertree most compatible with the input trees used to create it, although two other matrix-based approaches (compatibility and flipping) produce supertrees agreeing to only a slightly lesser extent. Supertrees produced by other methods are poor. Deeper relationships are identical using the three matrix-based methods, indicating paraphyletic 'Apterygota' and 'Palaeoptera', and monophyletic Polyneoptera, Paraneoptera and Holometabola. Additionally, the relationships within the 'Apterygota', 'Palaeoptera' and Paraneoptera are consistent. Within the Polyneoptera and Holometabola relationships are more uncertain, although well-acknowledged groups including the Dictyoptera and Neuropterida occur using these three methods. Fossil orders are particularly underrepresented by the primary literature and in rare cases lead to unresolved clades. However, in other cases their inclusion is important in resolving relationships of their living relatives.



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**Neoproterozoic microbiota from the Um Anab Banded Iron Formation (BIF) and the Hammamat "Molasse type" siliciclastic sediments, Eastern Desert, Egypt****Galal H. El-Habaak***Geology Department, Faculty of Science, Assiut University, Egypt*

The Neoproterozoic Um Anab banded iron formation (BIF) is a part of the Pan-African basement complex of Egypt bounded by latitudes 26° 56' and 26° 48' N and longitudes 33° 40' and 33° 25' E. The BIF is overlain by Hammamat "Molasse type" sedimentary rocks. The BIF preserves a record of microorganisms different from and complementary to that preserved in the terminal Proterozoic sandstones and shales (Hammamat Group). Fossiliferous BIF samples were mainly collected, for the first time, from the chert bands and the lean ore samples. The microfossils examined include original organic remains (e.g. permineralized and kerogenous) and organic structures partially replaced by magnetite or siderite as well as stromatolitic structures and coherent mats of cyanobacteria. Fossil coccoids and filaments are commonly seen as individual entities or in a complex association of several taxa. The biostratigraphic significance of the Um Anab BIF microbiota is limited. Many of the taxa are long-ranging. The assemblages are compared with those from the worldwide late Proterozoic (late "Riphean" and early Vendian; c. 800-700 Ma) sequences. The BIF accumulated below the wave base in a predominantly quiet-water shallow restricted basin, probably tidal flats or lagoons along the shores of island arcs. The abundance of cyanobacterial remains in the studied BIF indicates accumulation within the photic zone. The presented microbiota could suggest a genetic relationship between the microorganism and the chemical accumulation of the BIF. Although direct involvement of microorganism in the precipitation of Fe is not yet clear, they are believed to have played an indirect role in changing the Eh and pH of the depositional basin. It is suggested that bedding in the BIF is the result of variation in the local environment of deposition and consequently the flourishing of microorganism productivity. On the other hand, the siliciclastic Hammamat sediments contain elongate tubular microorganisms and structures of algal origin, many of which are very similar to trace fossils. The described microfossils include an algal microflora related to Cyanophyta and Pyrrophyta, in addition to variable amounts of graphite of organic origin. The occurrence of the complex trace fossil *Treptichnus* is documented for the first time from the terminal Proterozoic Hammamat Group. This trace fossil provides strong evidence for advanced latest Proterozoic age. Two distinct Neoproterozoic trace fossil zonation are recognized in the siliciclastic Hammamat sediments.

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**Paleoecology and preservation of two Late Ordovician pyritized trilobite faunas****Úna C. Farrell and Derek E. G. Briggs***Department of Geology and Geophysics, Yale University, New Haven, USA*

Beecher's Trilobite Bed (Ordovician Frankfort Formation, NY) is a classic locality for the preservation of trilobite appendages. In particular, it is the source of our knowledge of the limbs of the olenid *Triarthrus*. Olenid trilobites have been interpreted as having a symbiotic relationship with sulphur bacteria, allowing them to live in environments that are toxic to most invertebrates. Previous studies concentrated on the 4 cm-thick 'Trilobite Bed' and neglected the rest of the sequence, which is essential for understanding the environment in which the trilobites lived. A second locality yielding exceptionally-preserved olenids was discovered recently in the Ordovician Whetstone Gulf Formation near Lowville, NY. The assemblages at Lowville are more diverse and may yield new examples of soft-tissue

preservation. Field-work revealed that pyritization is not confined to the historic 'Trilobite Bed' but is present in multiple horizons at both localities. Geochemical analyses show that soft-tissue pyritization is associated with high 'reactive' iron content and high  $\delta^{34}\text{S}$  values. Preliminary geochemical, sedimentological and paleontological results suggest that conditions in the basin fluctuated, possibly with periods of bottom-water anoxia. The low diversity and high abundance of the trilobites, coupled with the geochemical signature, implies an unusual mode of life.

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## Star gazing

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The unusual and distinctive, stellate crinoid morphogenus *Floricolumnus* (col.) Donovan and Clark is only known from the Llandovery (upper Rhuddanian-lower Aeronian). It occurs at two horizons in the British Isles, the Newlands Farm Formation (Aeronian) of the Girvan district, southwest Scotland, and the Gasworks Mudstone Formation (Rhuddanian) of Haverfordwest, southwest Wales. It is also common as the 'button' in the Button Bed of the Brassfield Formation (Rhuddanian) of Ohio. *Floricolumnus* therefore represents a potential intercontinental stratigraphic marker for the Lower-Middle Llandovery boundary interval. The morphology of *Floricolumnus* is so distinctive due to the broad nodals, pentastellate to serrated circular in outline, with strongly petaloid, inflated epifacets which may have pointed, blunt, bifid or multilobate tips. In contrast, the numerous internodals are much narrower and lack epifacets. A new crinoid morphotaxon with similar features, but much less strongly differentiated nodals, from the underlying Mulloch Hill Sandstone (upper Rhuddanian) of Rough Neuk Quarry, southwest Scotland, may be ancestral. New material collected during fieldwork in 2006 from Newlands Farm adds to our knowledge of the range of morphological variation in the type species *Floricolumnus* (col.) *girvanensis*. For the first time, calcite is preserved in rare specimens.

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## A complete machaeridian from the Lower Ordovician of Shropshire

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We report a moldic specimen of a complete and articulated specimen of *Plumulites* sp. from the *Didymograptus bifidus* zone of the Llanvirn of the Shropshire inlier. The specimen consists of part and counterpart preserved as a mold in black shale, displaying detail of throughout its length, including the anterior end. The specimen has affinity with both *Plumulites follicum* Barrande and *Plumulites llanvirnensis* Withers.

Machaeridia are a problematic group and there has been a long-standing debate about their phylogenetic positioning. Articulated specimens are rare and complete specimens of this genus have been particularly elusive. Most specimens that are partially articulated have an incomplete or absent anterior section and species have been erected in the past on partially articulated or even disarticulated plates. Specimens from the United Kingdom have been described from just a small number of keel plates. This specimen gives workers an opportunity to establish a full set of features to study the phylogeny of this genus.

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## Diversity and distribution of paragastropods, tergomyans and gastropods in the Upper Ordovician Dalby Limestone, Sweden

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During the Upper Ordovician (Kukruse Stage to Idavere substage) exceptional carbonate deposits of the Dalby Limestone developed in the area of Lockne and Tvären (Sweden) as a result of two nearly coeval marine bolide impacts. In this study the diversity and distribution of paragastropods, tergomyans and gastropods in these sections are investigated, and compared with the distribution of these groups in the type area for the Dalby Limestone in the Siljan District, Dalarna. A fauna of 12 species of these mollusc groups comprising about 200 specimens is described presenting a higher diversity than previously documented from the unit. Significant biostratigraphical and biogeographical results from this study are 1) the presence of *Mimospira*, *Laeogyra*, *Sarkanella epelys* indicates a strong faunal connection with Bohemia, Czech Republic; 2) *Sarkanella* is reported from outside Bohemia for the first time; 3) *Bucania erratica* represents one of the earliest records of the genus in Baltoscandia, and a single case of shell repair from failed predation is recorded in this species; 4) Synonyms for *Eccyliopterus princeps* Remelé and *E. regularis* Remelé are proposed, and; 5) The significance of *Laeogyra*, *Eccyliopterus*, and *Deaechospira* for regional correlation within the Upper Ordovician of Baltoscandia is confirmed.

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## A soft-bodied arthropod from the Middle Devonian Huergas Formation (northwestern Spain)

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The fossil described here was collected close to the village of Mirantes de Luna, some 56 km NW of the town of León (northwestern Spain). Geologically, it falls within the Somiedo–Correcilla Unit, in the ‘Fold and Nappe’ Region of the Cantabrian Zone (Iberian Massif). The very fine, dark-grey shales where the fossil was found correspond to the Huergas Formation of Eifelian–Givetian age (Middle Devonian).

There is only a single specimen known of this fossil arthropod. It is 7.8 mm long and shows a flattened, round cephalic shield 4.5 mm in diameter, 6 pairs of uniramous appendages in the thorax, and an abdomen composed of 5 or 6 segments. Based on the available data, this is an arthropod of, as yet, uncertain affinity.

The deposits where this fossil was collected are interpreted as an offshore environment, below wave-base level, with very limited oxygenation. The fossil assemblage includes orthoceratid nautiloids, some tentaculitids, hyoliths, thin-shelled bivalves, ostracods and minute articulate and inarticulate brachiopods. This fossil arthropod constitutes the first evidence of a Devonian *Konservat-Lagerstätte* in Spain.

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## **New assemblage of silicified Middle Cambrian trilobites from Alai Range in Southern Kyrgyzstan**

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A new medium diversity Middle Cambrian faunal assemblage was recovered from an olistolith of bioclastic limestone in the Silurian siliciclastic turbidites exposed on the slopes of the Arpatektyr Mountain, eastern Alai Range. This assemblage includes the early clitambonitidine *Arctohedra pyramidalis*, protorthide *Glyptoria gulchensis*, paterinide *Dictyonina* sp., and trilobites *Raragnostus* cf. *mirus*, *Altikolia* sp. nov., *Corynexochina weberi*, *Dorypyge richthofeniformis*, aff. *Jincella* sp., *Olenoides comptus*, *Skreiaspis* aff. *spinus* and *Suluktella* sp. Three of the listed taxa, *Corynexochina weberi*, *Olenoides comptus* and *Raragnostus* cf. *mirus*, are locally considered as characteristic of the *Pseudoanomocarina* Beds, but *Pseudoanomocarina* itself is not represented. This unit can be dated as the upper Amgan (probably within *Triplagnostus gibbus* to *Ptychagnostus atavus* biozones). According to recent palaeogeographical reconstructions, areas of Turkistan and Alai ranges are considered to be parts of the Alai microplate, which was peri-Gondwanan in origin and accreted to the margin of the Kazakhstani orogen sometime in the Carboniferous. The rhynchonelliform brachiopods from the studied locality show a strong Gondwanan signature: the family Arctohedridae was confined to Gondwana in the Mid Cambrian whereas *Glyptoria* is otherwise known only from the Mid Cambrian of the Rift Valley. The trilobite *Corynexochina* is also reported from the Middle Cambrian of the Boshchekul region in Kazakhstan, and *Skreiaspis* is known otherwise exclusively from the Middle Cambrian of 'West' Gondwana. Due to their preservation in full relief, the study of the silicified trilobite specimens has enabled a better description of some morphological structures, especially related to trilobite enrolment, which remains inadequately known for most Mid Cambrian polymerid trilobites.

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## **Late Cambrian siphonotretide brachiopods from Iran: data on the enigmatic earliest history of the order**

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Linguliformean brachiopods are among the most widespread and characteristic fossils in Cambrian carbonates referred usually to the Mila and Derenjal formations at numerous localities in the Eastern Alborz, Kopet-Dagh and Derenjal mountains of Iran. One of the unusual features of the micromorphic lingulate assemblages is the constant presence of Siphonotretida, a small enigmatic order of brachiopods with a poorly documented Cambrian history. The presence of hollow spines was long considered to be a synapomorphy of siphonotretides, but it has been demonstrated later that all previously known Cambrian siphonotretide genera completely lack spines. Instead their shells are perforated commonly by tubular canals resembling those of the Early Cambrian mickwitziiids, which are currently considered to be stem-group brachiopods. These features are known, in particular, in the

Baltic Cambrian genera *Gorchakivia* and *Helmersenia*. Thus spinose ornament in post-Cambrian siphonotretides is a derived character.

Unlike other Cambrian siphonotretides, however, a surface ornament of hollow spines is definitely present in Iranian siphonotretides as early as the mid Late Cambrian. These shells also preserve canals formed at earlier growth stages. Early siphonotretide ontogeny remains poorly known, but new data obtained from the study of the Iranian specimens demonstrate that the siphonotretide dorsal larval shell has two pairs of lobes that probably represent setal sacs and may be a rudiment of the embryonic shell. The morphology of the ventral larval shell, previously unknown in siphonotretides, confirms earlier observations that the siphonotretide pedicle was related entirely to the ventral mantle and it may not be strictly homologous to the pedicle of other lingulates.

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### **Experimental taphonomy of lophotrochozoan and deuterostome embryos**

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Experimental analyses of decay in a deuterostome and three lophotrochozoans indicate that the controls on decay and preservation of embryos, identified previously based on echinoids, are more generally applicable. Four stages of decay are identified regardless of the environment of death and decay. Embryos decay rapidly in oxic and anoxic conditions, although the gross morphology of embryos is maintained for longer under anoxic conditions. Under reducing conditions, the gross morphology of the embryos is maintained for the longest period of time, compatible with the timescale required for bacterially-mediated mineralization of soft tissues. All four stages of decay were encountered under all environmental conditions, matching the spectrum of preservational qualities encountered in all fossil embryo assemblages. The likelihood of preserving and fossilizing embryos of deuterostomes and lophotrochozoans does not meet with the observation that no such embryos are encountered in the fossil record. Rather, the fossil record of embryos, as sparse as it is, is dominated by putative ecdysozoans, cnidarians and sponges. The dearth of deuterostome and lophotrochozoan embryos may be explained by the fact that ecdysozoans, at least, tend to deposit their eggs in the sediment rather than through broadcast spawning. However, fossil embryos remain very rare and the main controlling factor on their fossilisation may be the unique conspiracy of environmental conditions at a couple of sites.

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### **Detecting subtle morphological changes in Miocene *Pseudononion* (foram.) with multimodel inference**

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The study of microevolution in the fossil record can depend on resolving minor morphological changes. Unfortunately, such changes are often swamped by sampling error and temporal incompleteness, which also reduce the power of conventional statistical tests. This study describes an alternative approach and applies it to a stratophenetic series of the benthic foraminifer *Pseudononion pizarrensis* from the Miocene of ODP Leg 174AX cores Bethany Beach (Delaware) and Ocean View (New Jersey). Probability theory is used to assess the relative merit of different evolutionary models (multiple working hypotheses) by quantifying their relative predictive ability, or weight. These weights are used to resample the multi-model probability distribution and reconstruct the best supported temporal pattern. This

probabilistic “image reconstruction” approach allows the detection of subtle changes in the mean shape of the peripheral outline in *P. pizarrensis*, associated with final whorl expansion. Different principal components of shape variation show different patterns, including directional change, stasis, and possible ecophenotypy.

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#### **4-D reconstruction of *Henningsmoenicaris scutula* and early crustacean evolution**

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We re-examined *Henningsmoenicaris scutula* from the Middle Cambrian of Sweden in ‘Orsten’ type three-dimensional and uncompressed preservation. The original work by Walossek and Müller (1990, *Lethaia* 23, 409-427), based on three specimens, identified *H. scutula* as a derivative of the stem lineage of Crustacea. Our re-study is based on a significantly larger collection, i.e. forty specimens, grouped into no less than ten successive instars and a single fragment of an apparently much older specimen. The body of *H. scutula* is covered by a huge bowl-shaped shield and extends into a small trunk consisting of three tergites and a flat cone-shaped end. We could further track the morphogenesis of various soft part details, especially of the limbs and the lateral eyes. The eyes start as small elevations within an area of soft membrane close to the shield margin, develop into pronounced blisters subsequently and become eventually stalked – a characteristic feature of this species and likewise important since the development of a stalked eye has not been shown before in any euarthropod. Walossek and Müller (1990) identified a small setiferous enditic portion on all post-antennular limbs, proximal to the basipod, called ‘proximal endite’, as a key feature in crustacean evolution. Morphogenesis of the limbs reveals that this proximal endite is not present in early stages of *H. scutula*, but appears not before stage seven and exclusively on the third limb. Subsequently it also occurs on other limbs anterior and posterior to it. This stepwise acquisition of a feature during ontogeny seems to have its correspondence also in the evolution of the Crustacea and demonstrates the significance of knowledge of ontogenies as provided by ‘Orsten’ fossils. Such ontogenetic sequences are also available for other crustacean stem-lineage derivatives in our material and will also be compared to Recent animals in the future. A preliminary analysis of taxa belonging to the crustacean stem lineage, including ontogenetic data is presented.

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#### **New record of Rhynchonellida (Brachiopoda) from the Middle Jurassic rocks at Khashm El Galala of the Gulf of Suez, Egypt**

**Adel A. A. Hegab**

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Brachiopoda from Jurassic rocks of Egypt have an affinity with those from Somalia, Ethiopia and Saudi Arabia. They belong to the Ethiopian province, indicated by the presence of endemic taxa at the species, genus and family levels (*Daghanirhynchia*, *Deltarhynchia*, *Globirhynchia*, *Baeorhynchia*, *Kallirhynchia* and *Gibbirhynchia*). Paleontological studies of Middle Jurassic rhynchonellid fauna from the Gulf of Suez at Khashm El Galala revealed the establishment of a new rhynchonellid genus and species that is characterized by a bat-like outline. Study of the internal structure revealed a long conjunct of deltidial plates, a part of the median septum appearing at its upper part of the dorsal valve, a poorly developed septalium, and small massive teeth with dental plates that are not parallel.

Other fauna elements, which are identified for the first time in this sequence, include *Safarhynchia masajidensis*, *Globirhynchia* sp. and *Burmirhynchia bicostata*. These faunal elements were recovered from the middle shale limestone member that intercalates a lower and an upper clastic member.

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### **Acid treatment effects on fossil fish skeletal $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values**

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Stable isotopes can be a very powerful tool for palaeoecological and palaeoclimatic reconstruction, provided that pre-treatments do not alter isotopic signatures during sample preparation. Prior to any analysis of the  $\delta^{13}\text{C}_{\text{organic}}$  and  $\delta^{15}\text{N}$  isotopic signatures of Early Eocene fossil fish used in this current study, treatment was necessary to remove organic and inorganic material that could potentially alter results. In doing so, it was vital to avoid any chemical damage to the fossils that could result in the alteration of the isotopic signatures therein. A variety of chemical and mechanical extraction techniques have been developed by other authors, principally to recover microscopic fossils from rock samples, and differ according to rock type and fossil composition. These can be severe and potentially lead to specimen damage and chemical alteration, therefore careful monitoring in a controlled environment is necessary to prevent this. In the experiments presented here both buffered and unbuffered weak acids were tested in order to find the optimal technique for removing contaminants prior to isotope analysis. The aim was to identify the most convenient chemical technique for removing contaminants from a large sample set of fossils, while protecting the fluorapatite from any chemical etching, alteration or dissolution.

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### **Silurian trilobites from the reefs of North Greenland: environments and taphonomy**

**Helen Hughes**

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The Upper Llandovery reefs of Peary Land, North Greenland yield abundant and well preserved trilobite faunas belonging to the long-ranging Cheirurid-Illaenid Association. Published palaeontological and sedimentological studies of the reefs are minimal, and the trilobite associations are here interpreted in their environmental and taphonomic context for the first time. Facies analysis has been used to determine palaeoenvironmental settings, and study of the distribution of trilobite sclerites to determine the effects of taphonomic processes. The reefs show evidence of early lithification and stabilization and a moderately high energy environment within the photic zone is inferred. The taphonomic complexity of reef environments is apparent; trilobite accumulations have been strongly influenced by hydrodynamic sorting. This is reflected by size sorting of sclerites, and trilobites and other biota commonly display stacking patterns.

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## **Cleavage patterns in Neoproterozoic and Cambrian fossil embryos**

**Therese Hultgren**

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The Neoproterozoic-Cambrian phosphoritic layers in southern China hold exceptionally preserved embryos of early animals. The specimens, preserved as diagenetically phosphatized replacements and encrustations, represent different developmental stages from early cleavage through hatching. Recent studies, where fossil embryos were analysed with synchrotron-based X-ray tomographic microscopy (srXTM), have yielded details of cellular and sub-cellular information of the internal embryonic structures. In this study, fossil embryos from both the Early Cambrian Kuanchuanpu Member of the Dengying Formation and the Neoproterozoic Doushantuo Formation have been identified for analysis of their complete three-dimensional morphology. The aim of this study is to depict the different cleavage patterns and the cell geometry of the fossil embryos from the two localities. Thus far, the apparent difference, when comparing the fossil embryos found in the early Cambrian with the Neoproterozoic ones, is that the Cambrian embryos have preserved the developmental stages from blastula to hatching, whereas the Neoproterozoic ones generally seem to be restricted to early cleavage embryos that show only pre-blastula features.

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## **The Red Hills Mine flora: a diverse palynological assemblage from the Late Palaeocene of Mississippi**

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The well-preserved Palaeocene sporomorph record of the eastern U.S. Gulf Coast (Mississippi and Alabama) represents an extinct paratropical vegetation type. Studying this record therefore provides a valuable insight into the reassembly of floral communities following the K-T extinction, and can thus shed light on the abilities of highly diverse plant communities to diversify over time. We present data from lignite (swamp) deposits from the Red Hills Mine, Mississippi, that span the boundary between the Late Palaeocene Nanafalia and Tuscahoma formations (c. 57-56.5 Ma). The Red Hills Mine samples contain a diverse (99 morphospecies) angiosperm-dominated assemblage, including 22 morphotypes that have not been recognised in the consulted published literature. The samples are compositionally variable from one another, indicating local patchiness in these swamp communities. These assemblages are significantly more diverse than published accounts from strata of a similar age, and suggest that a reappraisal of Palaeocene sporomorph diversity trends from the Gulf Coast is warranted.

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## **A worm at one end and a tube at the other**

**Sören Jensen, Teodoro Palacios, Marino Contreras Sánchez and Mónica Martí Mus**

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Tubular/filamentous organisms preserved as flattened carbonaceous ribbons, including sabelliditids and vendotaenids, are among the most common macroscopic fossils in the late Ediacaran and earliest Cambrian of central Spain. However, in the Spanish successions these



organisms are also found preserved as ridges and furrows on bedding planes without any carbonaceous material present, which makes them easily mistaken for simple unbranched Ediacaran trace fossils, with which they also share an essentially bedding plane-parallel preservation and comparable sizes. This finding suggests that considerable caution is called for in the identification of simple Ediacaran trace fossils and that evidence for active sediment displacement is important for a positive identification.

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### **Microanatomy of Early Devonian book lungs**

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Remarkable 410 million year old fossils reveal book lung morphology in one of the oldest terrestrial arachnids. Trigonotarbida is an extinct order, known in some detail thanks to extraordinarily well preserved fossils from the Rhynie Chert (Devonian: Pragian) of Aberdeenshire, Scotland, UK. Translucent sections of this silicified material allow investigations of microanatomy, combined here for the first time with 3D-reconstructions. We could resolve new details about this group relating to lung characters which have so far only been observed in Recent arachnids. Cuticular structures on the surface and the distal edges of the book lung lamellae, like trabeculae between the lamellae, are identical to those of tetrapulmonates (spiders, whip spiders and whip scorpions) and scorpions. Hence, the fossils preserve putative autapomorphies of a common (?terrestrial) arachnid ancestor.

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### **Intra-specific variation in the Turonian tissotiid ammonite *Choffaticeras* Hyatt from the Eastern Desert, Egypt: Ontogenetic and biometric study**

**Ahmed S. Kassab**

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Species of the tissotiid ammonite *Choffaticeras* Hayat are widely distributed, characterizing the Lower– Middle Turonian successions in Egypt as well as in other Mediterranean regions. A review of numerous publications dealing with Lower Turonian tissotiid ammonites has revealed that differences in morphological characters were taken by various authors as a basis for discrimination of several species of the tissotiid ammonites, in spite of their coexistence in both space and time. A large collection of the Turonian ammonite *Choffaticeras* Hyatt has been assembled from a carbonate bed in the upper part of the Galala Formation, North Eastern Desert, Egypt. The present study is an attempt to analyze the morphological variability in a single population to elucidate the intraspecific variation and deduce the dimorphism within the species. The collected specimens consist mainly of well-preserved internal moulds. Some specimens retain traces of calcified shells. The specimens are horizontally embedded, but randomly oriented within the bed. Mature conchs were subjected to accurate and complete biometric measurements. The morphometric data were analyzed with cluster analysis, principal component analysis (PCA) and two groups' discriminant function analysis (TG DFA) programs. For ontogenetic and variation purposes, axial and cross sections were prepared, suture lines were traced, and frequency distribution, Dice-Leraas diagrams and growth curves were constructed. The inner whorls were obtained by dissecting some adult specimens.

Results of the ontogenetic and biometric analysis of the examined population show the presence of a single species of the Turonian tissotiid ammonite *Choffaticeras* Hyatt, i.e. *C. segne* Solger with a wide morphological variation and two size groupings. The characters studied are continuously or discretely variable. The ontogeny and biometry relate this variability to ontogenetic differences, sexual dimorphism and ecophenotypy. The two size groupings are interpreted as macro- and micro-conchs. Thus several *Choffaticeras* taxa, previously identified as discrete species, are here regarded as synonyms of *C. segne*. The macroconchs include *C. securiforme* Eck, *C. schweinfurthi* Eck and *C. luciae trisellatum* Freund and Raab. The microconchs comprise *C. quassi* Peron, *C. sinaiticum* Douville, *C. pavillieri* Pervinchiere, and *Pseudotissotia (C.) segnis* Solger var. *discoidalis* Pervinchiere. This kind of study shows the great value of studying populations rather than individuals for reliable ammonite identification.

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## **The early diversification of ray-finned fishes (Actinopterygii): an ecomorphological approach**

**Weronica Klasson**

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The actinopterygians are the now largest and most successful group of living fishes with about 27 000 species in almost every aquatic environment. This diversity is a result of numerous radiations through time, including the origins and early diversification in the Devonian and Carboniferous.

Morphometric analyses have been performed in order to investigate patterns of morphological diversity during these early episodes of actinopterygian evolution. This study shows that the disparity, which has been quantified by various methods, can be correlated to the overall taxonomic diversity. This pattern of morphological and taxonomical diversification starts with a steady increase in the Devonian, followed by what appears to be a major radiation event in the early Carboniferous. However, in the late Carboniferous both the diversity and disparity drastically decrease and the reason for this is still unknown.

This study also shows that there are no relation between body shape and environmental salinity. Instead it seems to be microhabitat and hunting behaviour that have the most effect on body shape.

Six ecomorphological groups have been detected in the studied data set, which can give clues about feeding strategies when compared to ecomorphological groups established for recent fishes. Interestingly, the ecomorphological groupings suggest that the Devonian fishes seem to be “lay-in-wait-predators” and “active rover-predators”. This means that the early ray-finned fishes probably were piscivores, rather than browsers and plankton-eater, which seems to be a later evolutionary innovation.

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**Soft-tissue imprints in fossil and Recent cephalopod septa and phragmocone efficiency****Christian Klug<sup>1</sup>, Kenneth De Baets<sup>1</sup> and Dieter Korn<sup>2</sup>**<sup>1</sup>*Paläontologisches Institut und Museum der Universität Zürich, Switzerland*<sup>2</sup>*Museum für Naturkunde, Humboldt-Universität zu Berlin, Germany*

Several previously undescribed structures, here interpreted as soft-tissue imprints and attachment sites, have been discovered on the inside of the shell wall and on the septum of various fossil and Recent ectocochleate cephalopods. Internal moulds of the body chambers of bactritoids and ammonoids from the Emsian (Early Devonian) as well as Mesozoic and Recent nautilids display various kinds of striations; some of these striations are restricted to the mural band, some start at the suture and terminate at various parts of the annular elevation (especially the mantle myoadhesive band). These structures are here interpreted as the septal furrow as well as imprints of blood vessels and contractile fibres of the septal mantle (subepithelial musculature). Most of these structures have not yet been found in ammonoids younger than Middle Devonian. The nature of these imprints was examined by sectioning the marginal septal mantle of Recent *Nautilus* specimens; longitudinal and transverse sections of contractile fibre bundles (or muscles) and of blood vessels were found therein, arranged exactly like the imprints on nautilid septa. This sheds new light on septum formation and thus phragmocone efficiency.

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**The Oligocene / Miocene transition in Denmark – palynological evidence of a climatic cooling?****Linda Larsson-Lindgren and Vivi Vajda***Department of Geology, Lund University, Sweden*

This study presents palynological results from one drill core and two exposures in Jylland, Denmark, that collectively encompass the latest Oligocene and early Miocene. The results provide new data regarding the vegetation and climate during the earliest Neogene in Denmark.

The ongoing study reveals a well-preserved palynoflora and preliminary results (unpublished data) from samples spanning the Oligocene-Miocene boundary indicate that the interval is characterised by a decrease in thermophile taxa, interpreted as climatic cooling and this corresponds with evidence of increased glaciations and deep-sea cooling at the epoch boundary (23 Ma).

Up-section, the palynological assemblages are dominated by pollen derived from Taxodiaceae-Cupressaceae, indicating swamp forests in Denmark during the Miocene. Interestingly, thermophilous elements such as *Arecaceae* (Palms), *Ilex* (Holly) and *Engelhardtia* return reflecting a warm-temperate climate during the Aquitanian and Burdigalian (early Miocene) in Denmark.

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**Foraminiferal biostratigraphy of the Lower Eocene Røsnæs Clay Formation, Albæk Hoved, Denmark****Maria Liljeroth***Geological Museum, University of Copenhagen, Denmark*

A new high resolution planktic and benthic foraminiferal biostratigraphic zonation for the Lower Eocene Røsnæs Clay Formation at Albæk Hoved, onshore Denmark is presented. Previous published biostratigraphic work on foraminifera from equivalent deposits of the North Sea Basin has mainly focused on the establishment of a regional zonation applicable for the whole of the North Sea basin area, and hence the biostratigraphic resolution was relatively low. At Albæk Hoved, it was possible to erect five new planktic and six new benthic foraminiferal biostratigraphic intervals through the Røsnæs Clay Formation. The new biostratigraphic zonation correlates largely with the previous North Sea zonations, but subdivides the North Sea zones and subzones into shorter intervals. The planktic zonation possibly reflects variations on a more regional scale, while the benthic zonation is probably more local. Further studies of the foraminiferal succession in Denmark and the North Sea are needed to prove if it is possible to recognise the new biostratigraphic intervals on a regional scale.

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**Palaeoecology of the Late Triassic Extinction in southwest United Kingdom****Luke Mander<sup>1</sup>, Richard J. Twitchett<sup>2</sup> and Michael J. Benton<sup>3</sup>**<sup>1</sup>*School of Biology and Environmental Science, University College Dublin, Ireland*<sup>2</sup>*School of Earth, Ocean and Environmental Sciences, University of Plymouth, UK*<sup>3</sup>*Department of Earth Sciences, University of Bristol, UK*

A high-resolution palaeoecological study of the shelly invertebrate macrofauna across the marine Triassic/Jurassic boundary section at St Audrie's Bay (southwest United Kingdom) is presented. Loss of taxonomic richness occurs in the upper Westbury Formation to lower Lillstock Formation (late Rhaetian), but if sample size is taken into account there is little convincing evidence of a catastrophic marine extinction. There is, however, good evidence for significant palaeoecological change in the benthic marine ecosystem at this time. The immediate post-event recovery interval in the upper Lillstock Formation is characterised by assemblages of low abundance, low diversity, high dominance and low evenness. Body-sizes of taxa that survived the event and originated afterwards were low until the later Hettangian. Recovery to higher abundance, higher diversity and higher evenness is recorded in the *Psiloceras planorbis* Zone. Recovery of the benthic ecosystem in the aftermath of the Late Triassic event was disrupted by marine anoxia and shows additional similarities with the (much slower) recovery that followed the Late Permian event. The pattern of body-size changes recorded in the shelly fossil record closely matches that of the trace fossil record. Shell thickness trends do not support a biocalcification crisis during the Late Triassic biotic event.

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## New data on Ordovician and Silurian conodonts from the Severnaya Zemlya Archipelago, Russian Arctic

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The Severnaya Zemlya Archipelago is located in the Arctic Ocean north of the Tajmyr Peninsula, between the Kara and the Laptev seas. Collections made during the SWEDARCTIC international expedition in 1999 have yielded about 2000 conodont specimens in 23 samples from a continuous Early Ordovician to late Silurian succession exposed in the central part of October Revolution Island.

Examination of the Ordovician conodont faunas on Severnaya Zemlya indicates that they are of the Midcontinent Province type. Domination of *Aphelognathus* and occurrence of *Oulodus* in the Ozernaya (Middle Ordovician) and Strojnyaya (Upper Ordovician) formations indicate that these strata formed in shallow marine warm-water environments, with the occasional presence of *Rhipidognathus symmetricus* suggesting extreme shallowing episodes in the basin at the end of Ordovician. This conodont fauna is similar to that described from the Timan-Pechora region of Russia.

The Telychian (Early Silurian) conodont faunas from Severnaya Zemlya are also similar to that found in the Timan-Pechora region, with both being characterized by the presence of several undescribed representatives of *Ozarkodina* and *Ctenognathodus*, and the absence of more typical Telychian elements, such as the *Pterospathodus eopennatus*-*P.*

*amorphognathoides* lineage. Taxa found at both localities also include *Gamachignathus? macroexcavatus*, *Ozarkodina waugoolaensis*, *Oulodus? australis*, and *Pterospathodus*, which have been previously identified in New South Wales (Australia) and the Baltic region. At Severnaya Zemlya, several typical Baltic Telychian taxa have been found for the first time outside the Baltic region, including *Pterospathodus eopennatus*, *Distomodus* cf. *staurogathoides*, *Aulacognathus* cf. *kuehni*, *Apsidognathus* cf. *milleri* and *Nudibelodina sensitiva*. *P. eopennatus* occurs together with *Ozarkodina broenhundi*, which was originally described from North Greenland and so far unknown outside that region, and both regions contain *Aspelundia* aff. *expansa*. These faunal similarities indicate that in the Early Silurian, the Severnaya Zemlya basin was well connected to the modern eastern North Greenland basin, and that these faunas reached also the northern and eastern(?) marginal areas of the Baltica Palaeocontinent.

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## Environmental and geological controls on the diversity and distribution of the Sauropodomorpha

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Although research on sauropodomorphs is a thriving field, few studies have examined the ecological, geographic and geological factors that controlled their biodiversity and biogeography. This work will examine the possible correlation between such factors as their ecological setting and spatial and temporal distribution, and hypotheses concerning macro-evolutionary patterns. One important hypothesis that will be tested is how their state of preservation is affected by the environment in which they lived; this should help tease apart

genuine patterns from taphonomic biases. A large dataset, at the specimen level, is currently being collected from museum visits, field sites, existing datasets and the published literature. Information is stored in over 50 different fields and within thousands of records in this database. The completed database will then be integrated into a Geographic Information System, allowing a variety of statistical analyses to be undertaken in order to test possible correlations between various parameters. These analyses will provide insights into the evolution and palaeoecology of the Sauropodomorpha as well as enable a better understanding of the taphonomic effects that such large terrestrial vertebrates undergo.

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## **Coral diversity at the Oligocene-Miocene boundary in Sabah, Borneo**

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*Palaeontology Department, Natural History Museum, London, UK*

The Indo-West Pacific of today is characterised by the highest global species diversity in reef-corals and associated biota. Despite the importance of the modern biodiversity “hotspot” the geologic origins remain understudied, with little new work on the corals in the last half century. It has previously been suggested that the extant biota formed during a diversification event at approximately the Oligo-Miocene boundary, coinciding with a change in the style of carbonate deposition in the region. This may also have coincided with a reduction in the deep water flow between the Pacific and Indian Oceans and marine incursions in the area.

To test the timing and magnitude of this diversification, changes have been studied in coral diversity across this boundary in patch reef facies located at the Gomantong Formation on Malaysian Borneo. Preliminary dating, using nannofossils, suggests that the sections studied cross this boundary with the majority being from NP25 (Late Oligocene). A new collection of greater than 350 specimens is yielding significant diversity of corals. Associated reef biota also found includes bryozoans, molluscs, worm tubes, and large benthic foraminifera.

Although a range of coral morphologies are present, the most common type of coral found were foliose (platy) forms, which signify that the area was probably in relatively deep water, or had low light levels caused by the high clastic input into the area.

Initial results presented here suggest that coral diversification was already underway by the Late Oligocene, rather than starting around the Oligo-Miocene boundary. This would place the origins of coral reef diversity in the Indo-West Pacific at an earlier point than previously theorised. This study has implications for understanding the causes of marine speciation and development of biodiversity hotspots.

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## **Life cycle of early Cambrian phytoplankton**

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Several radiation and extinction events of phytoplankton, revealed by acritarchs, are recognized on a global scale during the Cambrian. Their early Cambrian radiation was one of the most prominent biotic events, and a part of the Cambrian explosion. The appearance of ornamented acritarchs, both morphologically innovative and diverse, is unique. This conspicuous association of microbiota lasted for ca. 15-20 Myr, coinciding with the emergence of several new clades of bilaterian metazoans. Subsequently evolving morphotypes represent mostly re-combination of features invented during the initial Cambrian radiation, with the exception of advanced excystment structures.

Based on phenetic features alone, around 120 early Cambrian form-species are known. However, because some species produced various, morphologically distinct stages in their life cycle, which may be preserved and thus recognized as separate form-species, the apparent number of species is overestimated. Conversely, convergence among some sphaeromorphic taxa, which belong not only to different biological species but also algal orders as shown by their wall ultrastructure, leads to underestimation of the actual number of species. Acritarch form-species reflect morphological disparity of phytoplankton, displayed by ornamented cysts, internal dormant/reproductive cells and external vegetative envelopes that may pertain to a single species, and ecological variants of discrete species.

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## **Predatory boreholes in Tournaisian (Lower Carboniferous) spiriferid brachiopods**

**Bernard Mottequin and George Sevastopulo**

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A brachiopod fauna picked from bulk samples from the uppermost part of the Tournaisian Tournai Formation (Belgium) contains several taxa, but only the shells of an unidentified species of *Crurithyris* (Spiriferida, Ambocoeliidae) display a high frequency of boring. 8.1% of the 432 specimens with conjoined valves display single, small ( $\leq 1$  mm) boreholes. The holes are smooth-sided, cylindrical or weakly conical, circular to slightly elliptical in plan view, perpendicular to the shell surface and generally complete. Of the 35 bored articulated specimens, 27 were drilled on the ventral valve. Most of the boreholes are located in the posterior half of the shell and no case of edge-drilling has been observed. The strong stereotypy of the location of the drill holes as well as their close resemblance to those in recent bivalves lead us to interpret them as predatory drill holes, probably made by gastropods. *Crurithyris* sp. may have represented an attractive (in terms of energy cost) and easy prey for a small-sized predator that is suggested by the small diameter of the boreholes. The shell of *Crurithyris* is thin ( $< 0.5$  mm thick) and only covered by minute spines, which seem to have been ineffective in deterring the drilling predator.

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## **A juvenile skull of the ornithischian dinosaur *Heterodontosaurus tucki* from the 'Stormberg' (Early Jurassic) of South Africa**

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Heterodontosauridae is an enigmatic clade of primitive ornithischian dinosaurs, the taxonomy, systematics and palaeobiology of which are highly controversial. We describe a new partial skull of a juvenile *Heterodontosaurus tucki* from the 'Stormberg Group' (Early Jurassic, South Africa), with an estimated maximum length of 50 mm indicating a total body length of less than 400 mm. The skull is relatively complete anterior to the left orbit, well-preserved, and referred to *H. tucki* on the basis of numerous dental and cranial autapomorphies. Direct examination of the specimen, combined with information from CT and X-ray imaging, provides new information on the cranial anatomy of *H. tucki* as well as new insights into cranial ontogeny and sexual dimorphism in heterodontosaurids. Ontogenetic changes largely involve skull proportions and fusion; few ontogenetic changes in dental morphology occur, supporting previous suggestions that tooth characters are informative for species-level

taxonomy in heterodontosaurids. The presence of well-developed caniniform teeth in the juvenile specimen does not support the hypothesis that these represent secondary sexual characteristics in heterodontosaurids; furthermore, caniniforms are present in more than 90% of 'Stormberg' heterodontosaurid specimens, and their absence in the holotype specimen of *Abriotosaurus consors* is likely to be of taxonomic rather than sexual significance.

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## **A new arthropod resting trace from the Lower Jurassic Saltford Shale of Warwickshire**

**Lorna J. O'Brien<sup>1</sup>, Simon J. Braddy<sup>1</sup> and Jonathan D. Radley<sup>2</sup>**

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Trace fossils provide direct evidence for the behaviour of extinct organisms and arthropod resting traces especially preserve details of the ventral morphology of their producer, and provide implications for environmental occurrence. A new arthropod resting trace, attributed to a decapod crustacean, is described from the Lower Jurassic Saltford Shale Member of the Blue Lias Formation of Long Itchington Quarry, Warwickshire, England. The new trace fossil consists of isolated, small, bilaterally symmetrical, sub-oval hypichnia comprising three regions. The concave anterior region contains imprints of laterally extended chelate appendages and imprints of antennae and antennules extended anteriorly. The elongate middle region contains appendage imprints that extend laterally, separated by a bifurcated medial imprint. The convex posterior region terminates in a globular V-shaped imprint representing the telson. The producer of this new trace fossil is interpreted as *Eryon wilmcotensis*, from the contemporaneous Wilmcote Limestone Member of Warwickshire. These new trace fossils are found on the base of siltstone storm deposits in what is otherwise an anoxic shale unit, associated with epichnial *Rusophycus*, and interpreted as the escape reactions of these small decapods when trapped below a storm deposit.

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## **Deglacial anoxia in the Early Palaeozoic Icehouse**

**Alex Page<sup>1,2</sup>, Jan Zalasiewicz<sup>2</sup> and Mark Williams<sup>2</sup>**

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Though the Early Palaeozoic has generally been considered a long-lived interval of stable greenhouse climate, recent work has revealed considerable environmental variability during the glacial Early Palaeozoic Icehouse (EPI). The EPI (Caradoc, Ordovician – Llandovery, Silurian) contained seven glacial maxima identified by correlating 1) evidence for ice formation in high-latitude strata with 2) glacioeustatic transgressions and 3) isotopic evidence for cooling. In between these glacial maxima, there were brief intervals of glacial amelioration though no return to stable greenhouse conditions. The deep-water record of this interval is characterised by an alternation between a) the widespread deposition of black shales under conditions of marine anoxia, and b) the deposition of bioturbated hemipelagites in well-oxygenated conditions. Comparison of glacial-interglacial changes in the EPI with the anoxic-oxic stratigraphy reveals that widespread marine anoxia occurred during deglacial transgressions and more oxygenated conditions occurred during periods of ice formation. This might be a consequence of changes in the site of deep-water formation, with a) warmer intervals dominated by the formation of warm saline bottom-waters at low latitudes and



deglacial outwash at high latitudes leading to ocean stratification and the sluggish circulation of oxygen-poor deep-water, and b) brine rejection in ice formation leading to the formation of cool dense waters at high latitudes and vigorous circulation of oxygen-rich deep-water. These observations on the stratigraphic occurrence of both black shales and glacial maxima do not appear to correlate well with those predicted by the P/S models of climate in this interval.

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### **Middle Cambrian-Furgonian acritarchs from the Oville Formation, Cantabrian Mountains, Northern Spain**

**Teodoro Palacios**

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A restudy of the acritarch record in four sections (Barrios de Luna, Porma, Oville and Adrados) of the Oville Formation allowed the construction of a detailed chronostratigraphy of the Middle Cambrian and the establishment of its correlation to trilobite zones. Four middle Cambrian acritarchs zones can be recognized: *Cristallinium cambriense*, *Adara alea* and *Timofeevia lancarae* Zones (defined in the south of Spain) equivalent to the Upper Leonian? - Lower Caesaraugustian, Middle Caesaraugustian and Upper Caesaraugustian respectively. A new zone, the *Symplastosphaeridium cambriense* Biozone, equivalent to the Languedocian is identified in the Cantabrian Mountains. The record of *Timofeevia microretis* and *Stelliferidium* sp. in the middle part of La Barca Mb. in the Barrios de Luna section identifies the base of the Furgonian in the upper part of the Oville Formation. A detailed correlation between the study area, East European Platform and Avalonia is established on the basis of cosmopolitan acritarch species.

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### **First record of *Lingulella waptaensis* with pedicle from the Middle Cambrian Burgess Shale**

**Sandra Pettersson Stolk<sup>1</sup>, Lars E. Holmer<sup>1</sup> and Jean-Bernard Caron<sup>2</sup>**

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The Middle Cambrian linguloid brachiopod *Lingulella waptaensis* Walcott from the Burgess Shale was restudied based on 396 specimens collected by Royal Ontario Museum field parties from the Greater Phyllopod bed (Walcott Quarry Shale Member). The new specimens, including three with exceptional preservation of the pedicle, were collected *in-situ* in discrete obrution beds. The ultrastructure of the organophosphatic shell studied in cross sections shows a non-baculate lamination. The wrinkled pedicle protruded posteriorly between the valves, was composed of a central coelomic space, and was slender and flexible enough to be tightly folded suggesting thin chitinous cuticle and muscular layers. The rather rare preservation of soft tissues indicates that most of the specimens were dead and had decayed before being buried. Nevertheless, specimens with pedicle provide evidence for burial while they were still alive or soon after death. The long, slender and highly flexible pedicle could suggest that *L. waptaensis* did not have an infaunal mode of life.

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**Middle Miocene foraminifera from the Medvednica Mt. (NW Croatia) – a key to understand the palaeoenvironmental conditions in the Central Paratethys****Durdica Pezelj and Jasenka Sremac***Department of Geology, University of Zagreb, Croatia*

Maximal Miocene transgression in the Paratethys realm took place during the Late Badenian *Bulimina-Bolivina* Biozone. Four dominant communities from marls of the Medvednica Mt. reflect the biotic response to the sea-level rise. *Elphidium crispum* – *Asterigerinata planorbis* – *Elphidium macellum* community lived at the inner shelf. High oxygen level and plentiful food supplies resulted with abundant, diverse community with average domination. The *Cassidulina laevigata* – *Globocassidulina oblonga* – *Cibicidoides ungerianus* community of the middle shelf is characterized by maximal biodiversity and abundance, but higher domination and higher percentage of infaunal taxa. Oxygen level slightly decreases and organic detritus becomes the important food source. The *Bolivina dilatata* – *Cassidulina laevigata* – *Bulimina elongata* community with explicit domination of *B. dilatata* lived on the outer shelf. An abrupt decrease of diversity is clearly visible, but the number of specimens is still high. A medium oxygen level is present, with temporary periods of oxygen depletion. The number of infaunal taxa is significantly high. The *Uvigerina venusta* – *Uvigerina semiornata* – *Bolivina dilatata* – *Bulimina elongata* community of the upper bathyal zone is highly diverse, but with lower domination and 50% smaller number of specimens. A medium oxygen level with highly oxygenated episodes can be recognized. The high number of epifaunal taxa indicates the mesotrophic conditions after the maximum transgression.

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**The first records of the Cretaceous chimaeroid fish genus *Lebediodon* Nesson and Averianov, 1996 (Holocephali, Chimaeroidei, “Edaphodontidae”) from Western Europe****Evgenii V. Popov***Department of Palaeontology, Saratov State University, Russia*

The genus *Lebediodon* Nesson and Averianov 1996 was described from, and restricted to, the late Albian of Belgorod Province (2 localities), European Russia. The type species *L. oskolensis* is known from cutting ‘*Rhinochimaera*’-like mandibular and palatine tooth plates where they represent 7% of all chimaeroid plates collected.

During a revision of the fossil chimaeroid collections in Western Europe in the spring of 2007, two previously unrecognized mandibular plates of *Lebediodon oskolensis* were discovered. A partial left mandibular plate was found in the British Geological Survey collection (no. 1482) from the Gault Clay of Folkestone, previously determined as (but not figured) earlier as *Ischyodus incisus* Newton, 1878. Another, more complete, left mandibular plate was found in the private collection of Mr Gilles Lepage (Le Havre, France) from the Octeville locality (“Poudingue ferrugineux”, Middle Albian, dentatus zone) near Le Havre. These new European records extend the geographic range (European Russia, UK, France) and the stratigraphic distribution (middle-late Albian) of *L. oskolensis*, and reduce the range of “*Ischyodus*” *incisus* Newton, 1878 (an undescribed genus) to the Cenomanian (lower Chalk).

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## **You're so sensitive: the effect of material properties, constraints, and applied loads in finite-element modelling**

**Laura B. Porro**

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Finite-element analysis (FEA) is a technique that allows visualization of stress, strain, and deformation within a structure. FEA is increasingly used within palaeontology to explore the relationship between form and function in extinct organisms. However, the accuracy of finite-element results is dependent upon the applied input parameters, particularly material properties, muscle and bite forces, and constraints. How sensitive is model behaviour to variations in these input parameters? These concerns are particularly relevant in the study of extinct taxa for which only estimate input parameters can be obtained.

The influence of variations in input parameters on finite-element results was investigated using a 3D model of the skull of *Heterodontosaurus tucki*. Comparisons to a 'control model' were made by varying: 1) material properties; 2) muscle forces; 3) bite force location and orientation; and 4) model constraints. Variations in bone material properties, muscle force magnitude, and bite location resulted in changes in stress values but did not affect stress/strain patterns or deformation. The rostrum was conservative in its mechanical behaviour while the rear of the skull exhibited greater variability in its mechanical response. Model constraints and bite force orientation were found to have the greatest effect on deformation and overall stress patterns.

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## **A new island fauna from the Lower Jurassic fissure fills of South Wales**

**Matthew Pound**

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Upland areas of Carboniferous limestone in South Wales, formed during the Rhaetic transgression, contain fissure infills containing some of the earliest mammals. The remains are fragmentary, although locally abundant, and considered to be Late Triassic to Early Jurassic in age. The first fissures were discovered by a team from University College London and contained a depauperate fauna consisting of three tetrapods; the pleurodont lepidosaur *Gephyrosaurus* and two mammals *Morganucodon* and *Kuehneotherium*. However, two fissures found at Pant quarry in the 1970s revealed a much wider fauna and contained, in addition, a new species of the sphenodont *Clevosaurus* dominating the assemblage, the tritylodont *Oligokyphus*, the haramiyid *Thomasia*, possible theropods, sphenosuchid crocodylomorphs, and pterosaurs.

A new fissure has recently been found in Pant quarry. This has the same faunal elements as the wider fauna but the relative compositions are very different, with the lepidosaur *Gephyrosaurus* now most abundant. Several inferences can be made from this; including the possibility the three identified faunas are temporally independent of each other and that the new fauna may be intermediate in the succession. This would indicate a loss of diversity on the island, perhaps due to the reduction in size or to wider environmental changes.

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## The seamless amalgamation of computers and dead plants

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A significant number of palaeobotanical specimens have three-dimensional preservation. These reveal high quality data on the morphology and anatomy of extinct species. Specimens permineralised in carbonate typically do not show sufficient density or compositional distinction from the matrix to allow computer aided tomography methodologies to be used. To reconstruct and analyse these specimens in 3-D, new techniques and methodologies have been developed that represent modifications to established palaeobotanical methodologies that effectively increase the specimens suitability for 3-D reconstruction. Combined approaches are advocated, using a combination of wafering, serial grinding and serial peeling. A number of reconstructions have been made of lepidondralean cones and cardiocarpalean seeds using *Serial Palaeontological Image Editing and Rendering System* (SPIERS) as the reconstruction software in order to demonstrate various different preparation strategies. From the results obtained it is concluded that any three dimensional specimen can be reconstructed but, the precise form of the preparation depicts the resolution of the final model and the structural observations that it can include.

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## Where are all the fossil octocorals (Cnidaria: Anthozoa)?

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Octocorals have a rather disjunct record throughout the geological column. The earliest possibly date back to Ediacaran faunas and are widely represented and diversified today as soft and horny corals (Alcyonacea and Gorgonacea), sea pens (Pennatulacea), as well as blue corals and stoloniferans (Helioporacea and Stolonifera) and some other small groups. They are generally characterised by a lightly chitinised exoskeleton (e.g. Gorgonacea) or endoskeletons with microscopic calcareous sclerites or axial rods (e.g. Alcyonacea, Pennatulacea) with poor preservation potential, which is clearly the principal reason for their rarity and occasional absence in the fossil record. Despite this, a number of Palaeozoic octocorallian fossils have been described. In many of these, precise attributions to understand higher-level taxa have not been possible, largely as a result of indifferent preservation of the microstructure. After detection of skeletal carbonate hydroxylapatite in recent gorgonaceous octocorals, previously unknown in modern coelenterates, several Early Cambrian phosphatic 'problematica' (e.g. *Microcoryne*) with unknown relationships to octocorals appear now in another light. Similarly, fossils presumed to be Ediacaran leaf-like pennatulids have been described from Cambrian rocks – the earliest of these is *Priscopennamarina* from the Early Cambrian of eastern Yunnan, China. The Middle Cambrian Burgess Shale taxon *Thaumaptilon* is also presumed to be a pennatulid, while another Burgess Shale fossil – *Echmatocrinus* – originally described as a crinoid, was later interpreted as a probable octocoral. Some Neoproterozoic phosphatised embryos have been attributed to cnidarians, but interpretations of the Ediacarian and Cambrian pennatulid-like fossils and probable octocorals are not always accepted with regard to the further Phanerozoic fossil record. The early fossil record, evolution and phylogeny of Octocorallia and Anthozoa, including recent molecular analyses, is still in a state of confusion and more palaeontologic work must be done to accept or reject any of these hypotheses.

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## Origins and biomechanical evolution of teeth in echinoids and ophiocistioids

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Echinoid teeth are without doubt the most complex and highly evolved skeletal component to have evolved in echinoderms. They are biomechanically constructed to be resilient and tough while maintaining a shelf-sharpening point. Recently, new collections of well-preserved teeth of both echinoids and ophiocistioids have been made from the Late Ordovician and Silurian of Sweden. Based on SEM analysis of these isolated tooth elements, we provide a detailed structural analysis of the earliest echinoderm teeth. Eight distinct constructional designs are recognized encompassing various degrees of sophistication, from a simple vertical battery of tooth spines, to advanced teeth with multiple tooth plate series and a reinforced core of fibres. These provide key data on the early stages of tooth evolution. Despite the obvious homology between the lanterns of ophiocistioids and echinoids, their teeth are very different in microstructural organization and they have evolved different forms of self-sharpening mechanism. Whereas echinoid teeth evolved from a biseries of mouth spines, ophiocistioid goniodonts evolved from a uniseries of mouth spines.

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## Mitrates (Echinodermata: Stylophora) from the Silurian of Gotland, Sweden

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Cornutes and mitrates (Stylophora) were vagile benthic echinoderms, ranging from the Middle Cambrian to the Late Carboniferous, closely related to asterozoan and crinoid echinoderms. They were one of the most diverse groups of Early Palaeozoic echinoderms. Stylophoran echinoderms are non-radiate, calcite-plated forms, consisting of two well-defined regions: a delicate flexible, tripartite appendage, and a massive, asymmetrical, flattened body (theca). Comparable to the situation in other echinoderm groups, the stylophoran skeleton disarticulated more or less rapidly after the death of the organism. Fully articulated specimens are consequently known mostly from fossil *Lagerstätten* deposits, but stylophoran isolated skeletal elements can be locally abundant. Only a few Silurian Stylophora have been described so far, and all of them were reported from shallow, high-energy deposits in low-palaeolatitude regions. Recently, new collections of well-preserved isolated echinoderm material have been made from nearly all Silurian strata of the Isle of Gotland. Several hundred marl and rock samples were investigated using micropalaeontological techniques. More than 50,000 echinoderm ossicles were isolated in the last 10 years. The main focus of preceding research on this material was on echinozoan echinoderms. However, microscopical isolated remains as well as small articulated specimens (proximal appendage and theca) of mitrate stylophorans are occasionally common in some localities. Based on SEM analysis, most of these specimens can be unambiguously assigned to the suborder Peltocystida. This identification relies on their reduced number of marginals, the very large expansion of their two adorals, and their thecal ornamentation. These mitrates from Gotland are the first

peltocystids ever documented in Silurian strata. Consequently, they "fill the gap" between the abundant and diverse peltocystid taxa described from Ordovician strata (Kirkocystidae, Peltocystidae), and the few ones documented in the Late Palaeozoic (Jaekelocarpidae). The new mitrates from Gotland are remarkably intermediate in morphology between Kirkocystidae and Jaekelocarpidae. They show interesting similarities with poorly known peltocystids from the Lower Devonian of Germany (Hunsrück Slate). The palaeoecology of the new peltocystids from Gotland was possibly comparable to that of jaekelocarps (epifaunal stylophorans living in shallow, tropical environments).

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### **The siliceous plankton response of the equatorial Atlantic to the Middle Eocene Climatic Optimum event (ODP Site 1260, Demerara Rise, off Surinam)**

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The Middle Eocene Climatic Optimum (MECO), recently recognised on Site 1260 of ODP, represents a short warming event within the general cooling trend of the Middle Eocene. We studied the siliceous phytoplankton (mainly diatoms, but also silicoflagellates), with the aim of describing changes in assemblages across the MECO and reconstructing palaeoenvironmental changes. We also explored the palaeoecology of the Radiolarian genus *Podocyrtis*.

We establish that the diatom assemblage occurring before the MECO event is dominated by cosmopolitan species of genus *Triceratium*. Following the onset of the MECO, diatom microflora diversifies and becomes dominated by *Hemiaulus grassus*, *Pyxilla gracilis* and *Paralia sulcata*. The assemblage contains a strong tropical endemic component and reflects higher levels of productivity. The post-MECO diatoms are less diverse and dominated by various species of genus *Hemiaulus*. They contain a smaller endemic component and reflect lower productivity levels. All three distinct assemblages have in common the total absence of continental and benthic diatoms.

Quantitative analysis of the various species of the radiolarian genus *Podocyrtis* suggests that they were very little affected by the MECO event (with the exception of species *P. fasciolata* and *P. helenae*) and only partially by changes in productivity throughout the studied interval.

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### **New implications on Lower Devonian rhenorenselaerid palaeobiogeography and phylogeny**

**Mena Schemm-Gregory**

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Taxa of the terebratulid brachiopod genus *Rhenorenselaeria* are important index fossils for the Rhenish Siegenian in the classical German sense. This genus is now regarded as consisting of two different phylogenetic branches in the Rheinisches Schiefergebirge (Germany). The new phylogenetic reconstruction allows brachiopod data to be applied to improve palaeobiogeographical interpretations.

The first evolutionary branch is represented by the type species *Rhenorenselaeria strigiceps* and is restricted to the Middle and Upper Siegenian. The second branch appears in the Upper Siegenian with *Rhenorenselaeria demerathia* and becomes extinct in the Lower Emsian showing close relationships to *Rhenorenselaeria macgerrigleyi* from Gaspé (Canada). *Rh.*

*demerathia* is restricted to the Rheinisches Schiefergebirge whereas *Rh. strigiceps* occurs also in the Ardennes Mountains (Belgium) and the Celtiberian Chains (Spain).

During the revision of *Rhenorenselaeria*, a new species has been identified. It occurs in the Merzâ-Akhsaï Formation of the Dra Valley (Morocco) and the Grauwacke de Montguyon of the American Massif (France). Its similarities to *Rh. strigiceps* show the strong palaeobiogeographical relationship between Central Europe and North Africa/France. Taxa from Gaspé and Central Europe are not as closely related as the taxa from North Africa and Central Europe.

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### **Shell morphologies of juvenile brachiopods from the upper Helderberg Group (New York, Lower Devonian)**

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In an outcrop near Kingston, New York, grainstones yielding a diverse brachiopod fauna have been examined. The shells are highly silicified as indicated by beekite rings. Besides brachiopods, bryozoans and corals were also found.

17 brachiopod taxa can be identified of which eleven can be used as stratigraphic tools. They represent a typical fauna of the upper Helderberg Group. The occurrence of *Rhynchospirina globosa* and *Rhipidomella* sp. allow an assignment to the Kalkberg Formation.

Most of the fauna is represented by juvenile brachiopod specimens; many of them are only 1 to 2 mm long. The material consists mainly of single shells. In one articulated specimen of the terebratulid genus *Nanothyris* parts of the loop are visible.

Spiriferid brachiopods dominate the fauna, the majority consists of ventral valves. Juvenile specimens of *Howellella cycloptera* and "*Acrospirifer*" *murchisoni* are found, some are less than 2 mm wide. The ontogenetic stages of these two genera are well-documented. The development of their internal features show the growth of the dental plates as well as the embedding into secondary shell material in the apical region. The few dorsal valves do not show their ontogeny of either "*H. cycloptera*" or "*A. murchisoni*".

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### **The first report of the rare enigmatic stringocephalid genus *Paracrothyris* (Brachiopoda, Middle Devonian) from North Africa**

**Mena Schemm-Gregory and Ulrich Jansen**

Senckenberg Research Institute, Frankfurt am Main, Germany

For the first time, *Paracrothyris* has been identified from the Western Sahara (Southern Morocco). *Paracrothyris* was originally described from South China and later from Nevada. In all three localities, *Paracrothyris* occurs in beds of Givetian age. The dorsal shell fragments found can be assigned to this genus with certainty due to the combination of preserved characters: the absence of a median septum, the presence of crural plates and the thickness of the shell. Cross-sections of the South Chinese type species *P. distorta* show a median ridge that is more highly elevated than in *Paracrothyris* sp. from Morocco. The specimens from Nevada are very small and regarded as juvenile, the crural plates are very short and the median ridge is fine and thin. The oblique ridges that are very clearly developed in *Paracrothyris* sp. from North Africa are absent, probably because they are not yet developed.

It is concluded that a faunal exchange between Nevada, Morocco, and South China was possible during Late Givetian time. It is assumed that larvae of *Paracrothyris* migrated along the North Gondwanan shelf. Thus, the Early Devonian migration barrier that separated North America from Gondwana and Europe had disappeared before the Givetian.

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### **Faunal turnover between two E.E. subunits: investigating the timing of large-scale faunal turnover in the latest Eifelian of eastern North America**

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The general timing of faunal turnover of ecological-evolutionary sub-units (EESUs) within the Middle Devonian Appalachian Basin is relatively well constrained. However, the precise onset of major turnover events is still under investigation. The first appearance of distinct faunal elements of each of the EESUs is locally controlled by facies. Although, distinct faunal associations may transcend facies, barren or very sparsely fossiliferous facies provide no data. A major faunal turnover in the Middle Devonian of eastern North America occurs between the Stony Hollow-Rogers City Fauna and the Hamilton-Traverse Fauna during the latest Eifelian. The first appearance of the Hamilton Fauna has long been identified as occurring in the Halihan Hill Bed of the Oatka Creek Formation, which lies above the East Berne Member (EBM) shale interval.

Recent attention has focused on investigating the precise timing of this turnover in the stratigraphically expanded interval of the EBM in which special focus was put on a thin (~30 cm) shaly shell bed near the middle of the interval known as the Dave Elliot Bed. The fauna examined shows the earliest appearance of *Tropidoleptus* and *Mucrospirifer* in eastern North America; both genera have hitherto been reported in younger beds.

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### **Jawed polychaetes from the Late Cretaceous of the Isle of Rügen, Baltic Sea**

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Scolecodonts, the jaws of polychaete annelids, are common and diverse acid-resistant microfossils since the Middle Ordovician, but the oldest scolecodonts have been found in the latest Cambrian. Contrary to the Palaeozoic, relatively few jaws and jaw apparatuses of Mesozoic polychaete species have been described so far. Hence, the knowledge of jawed polychaetes from the Triassic, Jurassic and Cretaceous is unsatisfactory and represents a large gap in our understanding of the fossil record of the Polychaeta. Polychaete jaws have been investigated from various outcrops on the peninsula of Jasmund/Rügen, northeastern Germany. Altogether more than 400 detached polychaete jaws and one jaw apparatus were extracted from 75 kg chalk samples collected especially for scolecodonts and pterobranchs. The abundance of scolecodonts in the Rügen chalk ranged averages from five to ten in 1 kg of sample. The material is very well preserved, for instance by three-dimensionality of individual jaws. Ten taxa, belonging to five families were determined. Five of them could be identified down to species level. The Rügen jawed polychaete fauna was dominated by specimens of the Glyceridae (Phyllodocida), while eunicids were extremely underrepresented. Glycerid polychaetes are slender, cylindrical forms that can reach considerable sizes (up to 1



m long). The body is elongated tapering at both ends and consists of numerous segments. Glycerids can easily be recognised by their pointed, usually annulated, prostomium with four appendages and the long, eversible proboscis, which is densely covered with papillae and bears terminal jaws. Jaws were used for grasping in sediment or capturing prey, e.g. crustaceans and other polychaetes, and therefore needed to be resistant to wear.

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## Visualising seeds in 3-D

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A dispersed seed is described from tuffaceous sediments associated with the Emeishan Large Igneous Province from the Xuanwei Formation in Guizhou Province (China; Wuchiapingian to Changhsingian stages, Upper Permian). Observations are made from a series of 180 acetate peels from which a 3-Dimensional reconstruction has been constructed using the *SPIERS* software package. Morphological and anatomical comparisons confirm the seed to represent a new morphospecies although its generic position is uncertain. Inclusion of it into a cladistic analysis of dispersed cardiocarpalean seeds supports the establishment of a new species and also a new morphogenus. The new morphogenus is most closely related to the *Callospermarion* produced by Callistophytalean seed ferns plus *Mitrospermum* produced by *Gothania*-type cordaitan coniferophytes. Anatomical organisation of the ovule suggests a close relationship with the pteridosperm *Callospermarion*. Although a cordaitan affinity cannot be ruled out, complexity of the integument, the extensive nature of integumentary vascularisation, and the large size of the integumentary bundles are more similar with features within the pteridosperms, as is the multiply layered integument. Further supportive evidence of a pteridospermalean affinity comes from the absence of other organs belonging to cordaitan coniferophytes from the Xuanwei Formation.

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## Testate amoebae from a Holocene salt-marsh, Eastern Canada

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Testate amoebae are unicellular protozoa found most commonly in freshwater, organic-rich sedimentary environments such as peat bogs. Their distribution in salt marshes is not well documented, but they are known to show a zonation in relation to surface elevation, reflecting the period of tidal inundation in the upper marsh. If preserved in fossil deposits, they would serve as accurate palaeo-sea level indicators. This study presents results of testate amoebae analysis of a sediment core from Chezzetcook Marsh, Eastern Canada. Testate amoebae were found to be well preserved in the uppermost 30cm and high powered microscopic analysis revealed a low diversity testate amoebae fauna (7 taxa). Foraminifera, unicellular marine protozoa found commonly in salt marshes, were also documented from the same samples under high powered microscopy. Two taxa (*Centropyxis cassis* type and *Arcella* spp.) dominated the assemblages but there were significant changes to a fresher assemblage in the uppermost samples, suggesting a higher marsh elevation in recent years. The ratio of testate amoebae:foraminifera also showed significant changes and may be a further indicator of variations in marsh elevation. The results confirm the main findings from a separate analysis of foraminifera using low powered microscopy on a replicate core from the study area. However, the testate amoebae data may increase the precision of sea-level estimates when a

suitable transfer function based on modern samples is available. The study demonstrates that fossil testate amoebae are preserved in recent saltmarsh sediments and can be used as proxy indicators of changing sea level.

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## **Early land floræ of Gotland and Scotland: Does unanticipated diversity suggest a “Silurian explosion”?**

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Shales from the Ludlovian (late Silurian) Burgsvik Beds, Gotland, and the Old Red Sandstone of Kerrera, Scotland yield a diverse range of organic-walled microfossils. Acid maceration reveals two clearly distinct floræ, despite strong similarities in the time, location and facies, and the preservational grade displayed.

The phytodebris recovered from Gotland is typical of the Ludlow. Nematophyte features show tentative support for a liverwort affinity. Exceptionally preserved *Ornatifilum* tubes display characters that shed new light on their taxonomic position among the fungi. Vascular plant sporophytes may be represented by dyad-bearing stems. The Scottish flora is strikingly different. Digitate "microphylls", which resist placement within any extant crown group, dominate the assemblage; flattened thalli may represent their gametophytic stage. A fungal origin is considered for some tubular fossils; whilst no evidence is found for symbiotic interactions, a confirmed presence of terrestrial fungi supports hypotheses involving early plant-fungus symbioses.

While the “cooked” appearance of the Scottish fossils impedes detailed analysis, the pristine quality of Gotland’s specimens makes the identification of modern contaminants an active concern. The nearby marine (Gotland) or lacustrine (Scotland) shores may partially account for differences between floræ, which may alternatively represent bioprovinciality during the “Silurian explosion” of the land-plant fossil record.

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## **The phylogenetic position of the brachiopods: new evidence from nuclear housekeeping genes and microRNAs**

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Resolving the correct phylogenetic relationships of extant clades allows for a determination of the morphological characters present in the last common ancestor at a specific node. This information is essential to the placement of fossil taxa in their correct position in various stem-lineages. It also reveals the sequence of character acquisition during the early history of the clade and leads to hypotheses regarding evolutionary process. Determining the phylogenetic relationships of the Spiralia or Lophotrochozoa (annelids, brachiopods, molluscs, flatworms and their allies) has been notoriously difficult, both in morphological and molecular phylogenetic studies. Here, we demonstrate using northern analysis that brachiopods and phoronids share specific microRNAs (mir-750 and mir-745) which are found in annelids, molluscs and flatworms but not in deuterostomes and ecdysozoans. Since microRNAs appear to be almost never secondarily lost once they are added to the genome, this result confirms the inference originally based on 18S ribosomal DNA that brachiopods sit

within the Spiralia rather than Deuterostomia. Within the Spiralia, the three-taxon phylogenetic problem of brachiopods, annelids and molluscs remains unresolved. We have sequenced and analyzed a new dataset consisting of seven nuclear housekeeping genes from brachiopods and phoronids that helps place constraints on the position of these taxa within the Spiralia. These results provide a phylogenetic framework for the study of biomineralization in relation to the Cambrian radiation.

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## **Ordovician shelly fossils of the Southern Uplands of Scotland**

**Sarah E. Stewart**

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The Ordovician and Silurian successions of the Southern Uplands of Scotland, south of the Southern Upland Fault, are internationally known for graptolite bearing rocks and their importance in stratigraphy. Less familiar are the Ordovician fossiliferous mudstones and conglomerates of the Caradoc Kirkcolm Formation. Mass flow deposits, exposed mainly at Wallace's Cast and Kilbucho, preserve shelly fossils. These fossils have many similarities to taxa found at Girvan, SW Scotland and Pomeroy, Co. Tyrone, Northern Ireland. Strike-slip faulting is thought to have been an important control on the distribution of these faunas which were close to the active margin of the Iapetus Ocean.

Although the shelly fossils from the Southern Uplands were originally described by Peach and Horne in Geological Survey memoirs, only the trilobites and the scleractiniomorph coral *Kilbuchophyllia* have received much recent interest. Also present are gastropods, bivalves, rare polyplacophorans, cephalopods, the primitive rostroconch *Pinnocaris*, crinoids, algae and bryozoans. Bivalves consist of infaunal and epifaunal types and the gastropod fauna is notable for containing only discoidal and 'low spired' forms which is similar to lower Balclatchie Formation faunas found in Girvan.

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## **Malformation and functional morphology as a clue to pedicle size and pedicle morphology of ceratretid brachiopods (Acrotretida; Linguliformea)**

**Michael Streng**

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Evidence for pedicle sizes and pedicle morphologies of fossil linguliform brachiopods is scarce and mainly restricted to exceptionally preserved specimens of fossil *Lagerstätten*. Recently described specimens of linguloid brachiopods with preserved soft parts have shown that the traditional view of these brachiopods being infaunal and bearing a long pedicle was incorrect, and there existed a wider range of pedicle morphologies and lifestyles. Not all linguloid brachiopods had a burrowing life style, and epibenthic forms with either long thread-like or short and robust pedicles also existed. Despite this variety of pedicles in linguloid brachiopods, virtually nothing is known about pedicle morphology of acrotretid brachiopods, an extremely diverse and common group during the early Palaeozoic. Evidence from a malformed shell of the middle Cambrian *Acanthatrete* suggests that some acrotretids, i.e., the family Ceratretidae, had a short, pad-like pedicle that permanently attached to a hard substrate. The posterior margin of the malformed shell shows two dents symmetrically arranged adjacent to the pseudointerarea. These dents may have formed because the brachiopod larva had settled in a shallow depression on the seafloor, which imposed lateral growth limitations on the brachiopod shell during the juvenile growth state. As these lateral limitations could not be actively compensated for by the organism, a firm attachment with a

short pedicle is assumed. This is in accordance with the funnel shaped external pedicle opening of *Acanthatreta*, which tapers towards the interior of the shells and probably hosted the main part of the pedicle. This type of opening allows the pedicle to expand rapidly in diameter towards the exterior, thereby enlarging the attachment area and facilitating a firm connection to the substrate.

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### **Palynological investigation of a marginal marine depositional environment: the Middle Jurassic Lajas Formation, Neuquén Basin, Argentina**

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The Lajas Formation of the Neuquén Basin is a thick diachronous package of mudstones and sandstones that was deposited during the Middle Jurassic (Bajocian – Callovian) in a tidally dominated estuarine delta. The Neuquén Basin was situated between 30° and 40° South within a winterwet climatic zone.

Palynological analysis of the formation is being undertaken to help differentiate the different mudstone facies within such a complex sedimentary system which can be applied to subsurface investigation elsewhere. Thus far, the palynology has yielded varied assemblages with low diversities of dinoflagellates and acritarchs and high diversities of sporomorphs. The taxa include many cosmopolitan spore and acritarch species such as *Classopollis* spp., *Callialasporites* spp., *Deltoidospora* spp., *Alisporites* spp., *Vitreisporites* spp., *Micrhystridium fragile* and *Micrhystridium stellatum*. Endemic taxa are also present, these include *Rugulatisporites neuquenensis*. Bryophyte spores that are undescribed from the Neuquén Basin have also been observed in high numbers. Assemblages are generally dominated by the taxa *Classopollis* spp., *Inaperturopollenites hians*, *Araucariacites australis*, *Callialasporites* spp. and bisaccate genera *Vitreisporites* and *Alisporites*. Preliminary findings show that assemblages in differing depositional contexts, especially on a proximal – distal axis, each have a unique signature.

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### **The evolution in carapace outline of the Cytheroidea (Ostracoda, Crustacea) - its phylogenetic constraint and adaptive modification**

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Shell outlines viewed from dorsal, lateral, and posterior sides were analysed for 201 extant cytheroidean ostracods using an elliptic Fourier analysis. The result reveals that shell outline viewed from the dorsal side largely depends on the phylogenetic position of the animal. On the other hand, outlines in the lateral and posterior views are both related to ecological aspects as well as phylogenetic constraints. The phytal species living on the tall seagrass are characterised by the following points as compared with benthic ones: their outlines are much rounded in the lateral view and are ventrally protruded in the posterior view. With reference to molecular and palaeontological evidence, the present analysis reveals phylogenetic constraints on shell outlines in the Xestoleberididae–Trachyleberididae monophyletic group throughout their adaption to the benthic or low-growing phytal habit since the Mesozoic. On the other hand, the morphological plasticity of shell outlines might allow the Eucytheridae–Leptocytheridae paraphyletic group to extend their habits to high-growing phytal environments during the Cenozoic.

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## Ground truthing Ordovician climate models using spatial analyses of chitinozoans and graptolites

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Rapid and extreme changes in climate occurred during the middle to late Ordovician, culminating in one of the major glaciations of the Phanerozoic. Its causal mechanisms and duration remain contentious; few climate simulation models have been produced and new General Circulation Models (GCMs) have yet to be tested. Here we examine the potential for using planktonic chitinozoans and graptolites as water mass indicators to ground truth Ordovician climate model predictions of ocean state. At the core of our research strategy is the compilation of a high stratigraphical resolution biogeographical relational database of species occurrences, palaeoenvironmental and ocean-climate proxy data. This will be used to compile surface water (and where possible depth assemblage) palaeobiogeographic maps of chitinozoan and graptolite distributions. These can then be retro-tested against GCM maps of surface currents and used to identify latitudinal temperature/climate belts and gradient. We have identified the key time intervals which characterise the critical climate transitions as the *N. gracilis* graptolite Biozone (extreme greenhouse climate), the Boda Warm Event (“transitional”) and the Hirnantian (icehouse climate). These are stratigraphically well-constrained and represented globally. This poster presents preliminary results from our analysis of the *gracilis* timeslice. This will form a baseline condition for future research.

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## Time for early bilaterians

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The emergence of benthic bilaterian animals with mesoderm and frontal concentration of nervous and sensory systems triggered an unparalleled explosion of animal diversity. While several so-called metazoan-wide molecular phylogenetic dating studies have been published over the last few years to try address the timing of this event and its correlation with palaeoclimatological factors, none of these have included members of the worm groups Acoela and Nemertodermatida. These comparatively simple non-segmented worms have recently been shown to represent the oldest known extant bilaterian lineages, branching off before the split between protostomes and deuterostomes. Using ribosomal molecular data from many acoels, nemertodermatids and other metazoans together with age constraints derived from a wide collection of bilaterian and diploblast fossils, we here present age estimates of the deepest splits within Bilateria and compare results inferred from different dating methods and assumptions.

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## Reconstructing the Late Cretaceous flora of New Zealand

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Studies of well-preserved charcoalfied mesofossils from the Cretaceous of Sweden, Portugal, eastern USA and other Northern Hemisphere sites over the past three decades have revolutionized our understanding of the relationships and diversification of early angiosperms. However, Mesozoic mesofloras from the Southern Hemisphere remain largely undocumented. Our limited knowledge of Cretaceous Gondwanan floras hinders our understanding of global palaeofloristic diversity, terrestrial palaeoecology and phytogeography.

New charcoalfied mesofossils recovered from the Late Cretaceous (Maastrichtian, c. 70 Ma) strata of Kai Point Mine, New Zealand include a wealth of conifer leaves, shoots, scales and seeds together with angiosperm leaves, flowers, fruits and seeds. A selection of these mesofossils illustrated here are potentially crucial for understanding the past climatic and vegetation conditions of the Southern Island of New Zealand.

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## Ordovician ‘Orthoceras Limestone’ lithofacies of Jämtland, Sweden

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The Ordovician ‘Orthoceras Limestone’ of Jämtland, Sweden, represents Baltoscandian autochthonous carbonate platform sedimentation. In the Kunda-Uhaku limestones of Jämtland, three lithofacies are identified. Jämtland Lithofacies One (JL1) is a red-grey-black cephalopod-stromatolite limestone with abundant discontinuities. Stromatolitic surfaces are associated with orthocone nautiloid cephalopod conchs demonstrating weak preferred orientation and *Bumastoides* and *Megistaspis* trilobite moults. *Trypanites*-like borings developed between stromatolite domes, and there are poorly sorted ‘microgastropod’ grainstones. JL1 formed in deep-water during carbonate factory switch-off resulting from upwelling saline and/or dysoxic waters. Jämtland Lithofacies Two (JL2) consists of alternating grey limestones and shales/nodular limestones. *Asaphus raniceps* is the commonest trilobite, recently interpreted as the constructor of extensive *Thalassinoides*. JL2 includes other trilobites, gastropods, bryozoans and brachiopods, and although this benthic fauna indicates oxygenated sea floors, black shale layers with *Chondrites* suggest intermittent oxygen restriction. The carbonate factory appears to have been more productive than during deposition of JL1. Jämtland Lithofacies Three (JL3) is a grey-red nodular limestone with faunas similar to JL2. Intra-nodule bioturbation suggests these formed in early diagenesis. JL1-3 formed on the distal part of an epeiric carbonate ramp at a maximum water depth of several hundred metres. A palaeoceanographic and sedimentological model for the Jämtland lithofacies is presented.

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**Late Ordovician (Hirnantian) scolecodont apparatuses from the Soom Shale Lagerstätte, South Africa****Rowan J. Whittle<sup>1</sup>, Richard J. Aldridge<sup>2</sup> and Sarah E. Gabbott<sup>2</sup>**<sup>1</sup>*Geological Sciences Division, British Antarctic Survey, Cambridge, UK*<sup>2</sup>*Department of Geology, University of Leicester, UK.*

More than 20 examples of partial scolecodont apparatuses have been recovered from the Soom Shale Lagerstätte, South Africa. The scolecodonts were found in association with chitinozoans, algae, conodont apparatuses and the enigmatic needle-like fossil *Siphonacis*. The family Xanioprionidae is identified and a new species is distinguished, but the material is poorly preserved. The family Mochtyellidae is also identified, and a new genus is described. Some poorly preserved specimens may represent a third family. The specimens provide the first described scolecodont fauna from South Africa and the first apparatus based taxonomic study of specimens from Gondwana. It is possible that the polychaete worms had either a benthic or a planktonic mode of life.

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**Assessing the earliest seed plant radiation through three-dimensional reconstruction techniques****Zoe Wickens<sup>1</sup>, Mark D. Sutton<sup>1</sup> and Jason Hilton<sup>2</sup>**<sup>1</sup>*Department of Earth Science and Engineering, Imperial College London, UK*<sup>2</sup>*School of Geography, Earth and Environmental Sciences, University of Birmingham, UK*

Seed plants appear in the fossil record during the Upper Devonian, but in many Devonian and Mississippian floral assemblages they are only unequivocally represented by isolated seeds. The study of seed-fossils is hence of critical importance to studies of the radiation of the clade itself, but previous investigations have been hampered by the three-dimensional nature of the material. New methods of critically examining fossil seeds through computerised three-dimensional reconstruction are being explored, in order to re-evaluate anatomically preserved seeds from the serial-peel collection of Albert Long, which represent the most complete dataset on early seed-plant radiation.

A number of taxa including *Genomosperma latens*, *Genomosperma kidstoni* and *Eosperma oxroadense* are being restudied, using both existing serial-peel datasets and new high-resolution serial-section datasets. Reconstructions have been prepared using a custom computer software suite (*SPIERS*). Study of these 'virtual fossils' will better constrain the morphology of these early seeds, allowing rigorous testing of existing hypotheses of their development and function. Reconstructions will also provide a basis for quantitative analyses, using computerised aerodynamic modelling, which can be expected to provide further insight into the functional morphology of the earliest seed plants.

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**Collections at the Geological Survey of Sweden****Linda M. Wickström***Geological Survey of Sweden, Uppsala, Sweden*

The geological collection at the Geological Survey of Sweden (SGU) dates back to 1858, the founding year of SGU. It contains between 1.5 and 3 million objects, e.g. fossils, minerals,

rock and soil samples, thin sections, polished sections and drill cores. A majority of the collection originates from survey activities, and contains therefore mainly Swedish material. In the late 19<sup>th</sup> century, collections of fossil and minerals were commercially acquired for display at the Museum of the Geological Survey, along with an extensive exchange of material with national and international bodies. The collections are exploited both within the SGU and externally through, for instance, research and exploration.

The 'Type and Figured Collection' contains approximately 9000 fossils and 100 rock samples, published in papers mainly relating to the stratigraphy and palaeontology of the Lower Palaeozoic and Mesozoic of Sweden. Present work is focused on creating an inventory database in order to continue the digitization of the collection. The database follows international standards regarding collection and taxonomic databases, such as Darwin core. The aim is to make the collection accessible for the public through the SGU website.

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## Revealing acritarch affinities by use of transmission electron microscopy

**Sebastian Willman**

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Acritarchs – organic-walled microfossils of unknown, but probably mostly algal affinities – are common components of the rock record, dating back over 2 Ga. Their importance for biostratigraphic correlation, especially in the Ediacaran, is increasingly understood, however it is important to clarify true biological affinities. Transmission electron microscopy (TEM) has been used in biology for many years but, apart from a few studies in the late 1960s, it is only recently that TEM has been used to any great extent in palaeontology. Here I report on the wall ultrastructure of both acanthomorphic and leiosphaeric acritarchs of Ediacaran age from the Officer Basin in Australia. TEM analyses reveal a complex wall ultrastructure that compares to some extent to microalgae and other morphologically diverse acritarchs. Ultrastructures range from single-layered to multilayered, regardless of their light microscope morphology, which in turn indicates that they indeed have different biological affinities. If combined with other techniques such as organic geochemistry (e.g. of lipid biomarkers), TEM has the potential to be a powerful tool for future studies in palynology.

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## The evolution and interrelationships of Metriorhynchidae (Crocodyliformes, Thalattosuchia)

**Mark T. Young**

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

The evolution and interrelationships of the most marine-adapted crocodylians, the metriorhynchids are here investigated using cladistics. Metriorhynchids represent the only group of archosaurs to adapt to, and radiate within the marine realm. Unlike the various other clades of Mesozoic marine reptiles very little has been done to determine their interrelationships, or the monophyly of the genera attributed to the family.

In order to rectify this, a phylogenetic analysis was undertaken using 133 osteological characters and 46 taxa, of which 31 were metriorhynchids. Metriorhynchidae was found to be monophyletic with high nodal support. The genera *Teleidosaurus* and *Metriorhynchus* are paraphyletic, with the European brevirostrine forms of *Metriorhynchus* being attributable to *Suchodus*, and the South American species to *Purranisaurus*. *Geosaurus* is polyphyletic, with the type species nesting with *Dakosaurus*. However, all the other species currently placed within *Geosaurus* are monophyletic, with the type species of *Enaliosuchus*, *Cricosaurus*, and



*Neustosaurus* nesting within this clade. As *Neustosaurus* is the oldest named genus, all species are transferred to that genus (in accordance with ICZN rules), with the exception of *Geosaurus gracilis*, as it lacks the hindlimb synapomorphies of *Neustosaurus*, therefore the name *Rhacheosaurus* is resurrected for this species.

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### **Elucidating the feeding mechanics of *Diplodocus longus* using the Finite-element method**

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Sauropods include some of the most bizarre and biomechanically unfeasible animals ever to have existed. How they fuelled their multi-tonne bodies on an apparently nutrient poor diet of fibrous plant matter challenges our understanding of both extinct and extant biological systems. Amongst the Sauropoda, *Diplodocus* has one of the most bizarre skull and teeth morphologies witnessed (such as an elongate rostrum, teeth restricted to anterior margin of jaws, and fragile peg-like teeth with oblique labial wear facets).

Previous studies focusing on the skull morphology and teeth micro-wear patterns have postulated different feeding behaviour hypotheses for *Diplodocus*, including unilateral branch stripping and horizontal slicing, both. Based upon a CT scan of *Diplodocus longus* CM 11161, these feeding hypotheses were quantitatively tested using finite element analysis (FEA). When these hypotheses were simulated using a FE-model of CM 11161, the deformation experienced by the teeth during the horizontal slicing simulation would have shattered the teeth in real-life. In addition, unilateral branch stripping with anything but low-level loadings to the teeth also deformed the dentition beyond that which could be naturally endured. Quantitative modelling using FEA supports the hypothesis that *Diplodocus* stripped soft leaves from branches via propaliny of the mandible.

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### **Taxonomical value of selected biometrical characters: example of *Alveolites* (Tabulata) from the Frasnian of the Holy Cross Mountains (Poland)**

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Biometrical characters are important species indicators in tabulate corals. Most often used are: corallite diameter (or lumen diameter), wall thickness, pore diameter, pore spacing and tabulae spacing. Their variation was studied on several species of *Alveolites* (*A. compressus*, *A. maillieuxi* and *A. suborbicularis*) coming from the Frasnian of Kowala Railroad Cut in the Holy Cross Mountains, Poland.

The variation coefficient (*vc*) was counted as follows:  $vc = \text{standard deviation} / \text{mean}$ . The study shows that the lowest intracolony variation is that of corallite lumen diameter (*vc*: 0.093–0.196), while the most variable was tabulae spacing (*vc*: 0.207–0.360).

It may be concluded that the corallite lumen diameter is the best species discriminator, while tabulae spacing is rather useless for specific determinations, unless it varies significantly from other species (but in the studied taxa values of spacing were very similar). Pore diameters seem to be rather constant ( $vc$  up to 0.174) and can also be used for determinations.

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## Revision of some orthide genera: implications for Ordovician brachiopod palaeobiogeography

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Although the higher-level taxonomy of the Brachiopoda was substantially revised in the new edition of the ‘*Treatise on Invertebrate Paleontology*’ our understanding of many Ordovician genera, particularly the more cosmopolitan and apparently widespread forms, is still based on concepts that are often more than century old. The main objective of this presentation is to discuss the morphology and taxonomy of three hitherto widespread and well-known genera. Re-definition of their type species has led to a comprehensive revision of all the species presently assigned to each genus. *Porambonites costatus* Pander is formally proposed as the type species of the genus *Platystrophia* to replace *P. biforata*. In a revised diagnosis, *Platystrophia* is restricted to a group of Middle to Upper Ordovician species from Baltica and Avalonia, where the new genera *Neoplatystrophia* and *Siljanostrophia* are also recognized. The new genus *Vinlandostrophia* includes most of the Upper Ordovician *Platystrophia*-like taxa from Laurentia. Rediscovery of specimens of *Porambonites intermedius* in the Billingenian of the East Baltic suggests that the generic name *Porambonites* can only be applied to the Early to Mid Ordovician porambonitid species with a smooth shell, and the genus itself is thus endemic to Baltoscandia. The mosaic records of the distinctive North American genus *Glyptorthis* in the East Baltic basin have also been re-evaluated. Lower Sandbian forms are now assigned to the new endemic genus *Bassettella*, whereas *Glyptorthis* is recorded from the East Baltic only in the Upper Katian.

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