The Palaeontology Newsletter

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Contents

Reminder: The deadline for copy for Issue no. 91 is 8th February 2016.

On the Web: <**http://www.palass.org/**>

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Editorial

I watched the press conference for the publication on the new hominin, *Homo naledi*, with rising incredulity. The pomp and ceremony! The emotion! I wondered why all of these people were so invested just because it was a new fossil species of something related to us in the very recent past. What about all of the other new fossil species that are discovered every day? I can't imagine an international media frenzy, led by deans and vice chancellors amidst a backdrop of flags and flashbulbs, over a new species of ammonite. Most other fossil discoveries and publications of taxonomy are not met with such fanfare. The Annual Meeting is a time for sharing these discoveries, many of which will not bring the scientists involved international fame, but will advance our science and push the boundaries of our knowledge and understanding. But do we need to publicize our work beyond our field? I would argue yes, in order to inform funders and to encourage the view that our science is a vital and relevant part of current research. Palaeontology, on the whole, gets a lot of media coverage but there is still some way to go in informing the public of our field. I remember the careers adviser at university telling me that a neighbour was also interested in palaeontology and had been studying castles from all over Scotland, and more recently someone wanted to give me a stone axe and some arrowheads that they thought I would be interested in. Even fellow scientists can be dismissive and question the importance of a science that doesn't develop new materials or medicine to improve current living standards. I am confident that the continued outreach from Emerald Ant (see page 56) and the fossil festivals (page 76), plus public engagement activities like Adopt-A-Fossil (page 48) and the FossilBlitz (page 54), can help to illuminate just why palaeontology is as relevant as ever in today's society.

Jo Hellawell
Newsletter Editor
<newsletter@palass.org>

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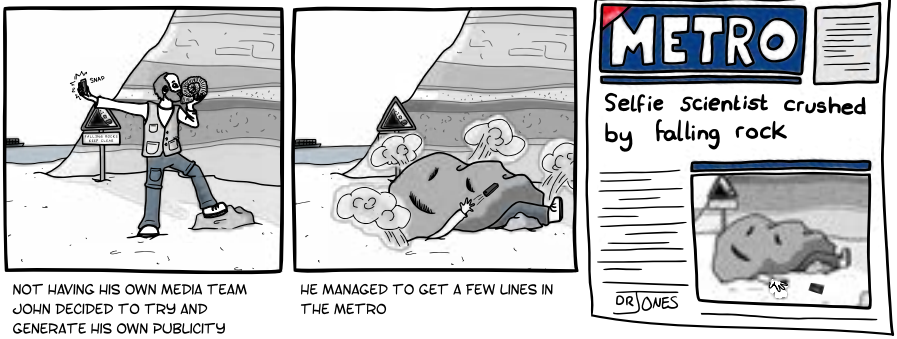

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Association Business

Annual Meeting 2015

Notification is given of the 2015 Annual General Meeting

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

AGENDA

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

Nominations For Council

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

- President Elect
- Vice-President
- Treasurer

Council's nominations are as follows:

- President Elect: Prof. M. Paul Smith
- Vice President: Dr Emily Rayfield
- Treasurer: Mr Paul Winrow (2nd term)

No other nominations were received by the deadline.

Awards and Prizes

The Palaeontological Association recognises excellence in our profession by the award of medals and other prizes. The Association sees its lists of medal and award winners as a record of the very best palaeontologists worldwide, at different career stages, and offering different kinds of contributions to the field. The Association stresses the importance of nominations, and encourages all members to make nominations.

Lapworth Medal

The Lapworth Medal is the most prestigious award made by the Association. It is awarded by Council to a palaeontologist who has made a significant contribution to the science by means of a substantial body of research; it is not normally awarded on the basis of a few good papers. Council will look for some breadth as well as depth in the contributions, as well as evidence that they have made a significant impact, in choosing suitable candidates.

The medal is normally awarded each year. Candidates must be nominated by at least two members of the Association. Nominations should include a single page that summarises the candidate's career, and further supported by a brief statement from the two nominating members. A list of ten principal publications should accompany the nomination. Letters of support by others may also be submitted. Council will reserve the right not to make an award in any one year.

The career summary, statements of support and publication list should be submitted in MS Word or PDF format, ideally as a single document if possible.

Nominations should be sent to <**secretary@palass.org**> by **31st March**.

The Lapworth Medal is announced at the AGM and presented at the Annual Meeting.

President's Medal

The President's Medal is a mid-career award given by Council to a palaeontologist who has had between 15 and 25 years of full-time experience after their PhD, in recognition of outstanding contributions in his/her earlier career, coupled with an expectation that they will continue to contribute significantly to the subject in their further work.

The medal is normally awarded each year. The candidate must be nominated by at least two members of the Association. Nominations should include a single page that summarises the candidate's career, and be further supported by a brief statement from the two nominating members. A list of ten principal publications should accompany the nomination. Letters of support by others may also be submitted. Council will reserve the right not to make an award in any one year. If a candidate has taken time out from their professional career for family and other purposes, this should be highlighted.

The career summary, statements of support and publication lists should be attached in MS Word or PDF format, ideally as a single document if possible.

Nominations should be sent to <**secretary@palass.org**> by **31st March**.

The President's Medal is announced at the AGM and presented at the Annual Meeting.

Hodson Award

The Hodson Award is conferred on a palaeontologist who has had no more than ten years of full-time experience after their PhD, excluding periods of parental or other leave, but not excluding periods spent working in industry, and who has made a notable contribution to the science.

The candidate must be nominated by at least two members of the Association and the application must be supported by an appropriate academic case, namely a single page of details on the candidate's career, and a brief statement from each of the two nominating members. A list of principal publications should accompany the nomination. Letters of support by others may also be submitted. If a candidate has taken time out from their professional career for family and other purposes, this should be highlighted.

The academic case, statements of support and publication list should be attached in MS Word or PDF format.

Nominations should be sent to <**secretary@palass.org**> by **31st March**.

The award will comprise a fund of £1,000 and is presented at the Annual Meeting.

Mary Anning Award

The Mary Anning Award is open to all those who are not professionally employed in palaeontology but who have made an outstanding contribution to the subject. Such contributions may range from the compilation of fossil collections, and their care and conservation, to published studies in recognised journals.

The candidate must be nominated by at least one member of the Association. Nominations should comprise a short statement (up to one page of A4) outlining the candidate's principal achievements, as well as one or more letters of support. Members putting forward candidates should also be prepared, if requested, to write an illustrated profile in support of their nominee for inclusion in the *Newsletter*.

Nominations should be attached in MS Word or PDF format and should include the full contact details of the candidate.

Nominations should be sent to <**secretary@palass.org**> by **31st March**.

The award comprises a cash prize of £1,000 plus a framed scroll, and is presented at the Annual Meeting.

Honorary Life Membership

To be awarded to individuals whom Council deem to have been significant benefactors and/or supporters of the Association. Recipients will receive free membership.

Nominations should be sent to <**secretary@palass.org**> by **31st March**.

Honorary Life memberships are announced at the Annual Meeting.

Annual Meeting President's Prize

Awarded for the best talk at the Annual Meeting. All student members of the Palaeontological Association, and all members of the Association who are early career stage researchers within one year of award of a higher degree (PhD or MSc), excluding periods of parental or other leave, are eligible for consideration for this award, which consists of a cash prize of £200. The prize is announced at the end of the Annual Meeting.

Annual Meeting Council Poster Prize

Awarded for the best poster at the Annual Meeting. All student members of the Palaeontological Association, and all members of the Association who are early career stage researchers, *i.e.* those within one year of the award of a higher degree (PhD or MSc), excluding periods of parental or other leave, are eligible for consideration for this award, which consists of a cash prize of £200. The prize is announced at the end of the Annual Meeting.

Grants

Palaeontological Association grants are offered to encourage research, education and outreach through different means. Undergraduates, early stage researchers, and otherwise unfunded persons are given special encouragement to apply. All of these awards and grants are core to the charitable aims of the Palaeontological Association. A full list of the Association's grants may be found on the Association's website (<**www.palass.org**>). Those with deadlines in the next six months are detailed below.

Grants-in-aid: meetings, workshops and short courses

The Association is happy to receive applications for loans or grants from the organisers of scientific meetings, workshops and short courses that lie conformably with its charitable purpose, which is to promote research in palaeontology and its allied sciences. Application should be made in good time by the scientific organiser(s) of the meeting using the online application form (see website). Such requests will be considered by Council at the March and October Council Meetings each year. If the application is successful, we will require that the support of the Association is acknowledged, preferably with reproduction of the Association's logo, in the meeting/workshop/short course literature and other media. Enquiries may be made to the Secretary (<**secretary@palass.org**>).

Applications should be made through online submission via the appropriate page on the Association's website, for which you will need the following information:

- Title of meeting / workshop / short course
- Date and Place proposed
- Name, position, and affiliation of the organiser(s)
- Brief description (not more than ten lines) of the rationale behind the meeting / workshop / short course
- Anticipated number of attendees
- Amount requested (also whether request is for a loan or a grant)
- Other sources of funding applied for
- Specific use to which requested funds will be put

Note: If funds are requested to support one or more keynote speakers, then full details of their names, affiliations and titles of presentations should be included. The application will be strengthened if the keynote speaker agrees to submit their paper as a review article for possible publication in *Palaeontology*.

The deadlines are **1st March** and **1st September** each year.

Outreach and Engagement Grants

Awards are made to encourage educational outreach, public engagement, and related initiatives in palaeontological themes. Normally, the budget for an individual grant would be less than £5,000. However, under exceptional circumstances, a budget of up to £15,000 for an individual application will be considered. Grants can support either stand-alone complete projects, or they can be 'proof of concept' case studies that have their own outcomes but that form the groundwork for a larger bid elsewhere. The award is open to both amateur and professional palaeontologists. The principal applicant must be a member of the Association. Preference will normally be given to candidates who have not previously received a grant.

Proposals must fit with the charitable aims of the Association and preference is given to applications for a single purpose (rather than top-ups of grants for existing projects). We particularly encourage applications with an innovative aspect, such as engaging with new media, and especially cases that will disseminate good practice. Successful applicants must produce a report for the Palaeontological Association *Newsletter*, and any publicity associated with the activity should mention the support of the Association. Full details of application procedures, terms and conditions are available on the Association's website at <**www.palass.org**>.

For more information please contact the Association's Outreach Officer, Dr Fiona Gill, School of Earth and Environment, University of Leeds, Leeds LS2 9JT; e-mail: <**outreach@palass.org**>.

The deadline is **1st October** each year. The awards will be announced at the AGM, and funds will normally be available from 1st January.

Small Grants Scheme

The Association offers multiple awards each year, in honour of four donors, to fund palaeontological research, travel and fieldwork; these are integrated together under the Small Grants Scheme. These grants are open to any member of the Association, although preference is given to students, early career researchers, and members of the Association who are retired.

- **Sylvester-Bradley Awards**: Multiple awards up to £1,500 each, for palaeontological research.
- **Callomon Award**: An award up to £1,500 for a project which is normally field-based.
- **Whittington Award**: An award up to £1,500 for a project which is normally based on museum collections.
- **Stan Wood Awards**: A maximum of two awards of up to £1,500 for projects in vertebrate palaeontology, and ideally involving fieldwork and fossil collecting.

There will be one application form and Council will decide on the allocation of the awards based upon the nature of the project put forward in the application.

Applications should be made through online submission via the appropriate page on the Association's website, and will comprise:

- An account of project aims and objectives and expected outcomes
- A breakdown and justification of the proposed expenditure
- A curriculum vitae
- Two references: one to review the project, and one personal reference for the applicant
- A summary suitable for the non-specialist, which will be published in the Association's *Newsletter* when the award is made.

Successful applicants will be required to produce a final project report that will be published in the Palaeontological Association *Newsletter*, and are asked to consider the Association's meetings and publications as media for conveying the research results.

Further details and a full list of terms and conditions for the Small Grants Scheme can be found on the appropriate page of the Association's website. Enquiries may be made to the Secretary (<**secretary@palass.org**>).

The deadline is **1st November** each year.

The awards will be announced at the AGM, and funds will normally be available from 1st January.

Undergraduate Research Bursary

The Palaeontological Association Undergraduate Research Bursaries are aimed at giving undergraduate students the opportunity to acquire research skills and experience that will significantly transform their academic career. The bursaries will support projects co-designed by students and their supervisor(s) that give students registered for an undergraduate degree their first experience of undertaking a palaeontological research project. The bursaries provide a stipend for the student of £200 per week for up to eight weeks. The scheme is not intended to fund students to undertake routine work for the supervisor(s) and the Association expects the supervisor(s) to provide significant personal mentoring of successful student applicants.

Applications should be made by the principal supervisor through online submission via the appropriate page on the Association's website, and will include:

- Details of the principal supervisor making the application, and other members of the supervisory team
- Details and academic track record of the named student
- An account of the project aims, methods and expected outcomes
- A project plan including details of supervision
- Ethics statement
- A referee statement in support of the named student

After completion of the work, successful students are required to produce a short report of the findings suitable for publication in the *Newsletter*. This report should be submitted to <**palass@palass.org**> within eight weeks of the stated end date of the project. Successful candidates are requested to prioritise the Association's meetings and publications as media for conveying the research results.

Further details, including eligibility criteria for supervisors and students, and a full list of terms and conditions for the Undergraduate Research Bursary Scheme, can be found on the appropriate page of the Association's website. Enquiries may be made to the Secretary (<**secretary@palass.org**>).

The deadline is **24th February** each year.

Successful applicants will be notified by the middle of May and funds will normally be available from 1st June. A full list of awards will be announced at the AGM.

Research Grants

Several awards of up to £10,000 each are granted each year to assist palaeontological research, normally in support of single research projects or 'proof of concept' proposals with an aim of supporting future applications to national research funding bodies. Field-based projects are also eligible, but the scientific objectives and outcomes of the research must be made clear. Applications for investigator's salary costs will only be considered in exceptional circumstances and if awarded all legal and financial liability will lie with the applicant.

Preference is given to applications for a single purpose (rather than top-ups of other grant applications). The award is open to both amateur and professional palaeontologists, but applicants will normally have a PhD as a minimum qualification and must be members of the Association.

Applications should be made through online submission via the appropriate page on the Association's website, and will comprise the elements shown over the page:

- A two-page curriculum vitae of the principal researcher
- A two-page 'Case for Support' which addresses the following points:
    - Underlying rationale and scientific issues to be addressed
    - Specific objectives of the research
    - Anticipated achievements and outputs
    - Methodology and approach
    - Programme and/or plan of research
    - How the research fits the charitable aims of the Association
    - Proposals for wider dissemination of results including those relating to the wider public understanding of science
    - A list of pending and previous applications (with funding bodies and results) for funds to support this or related research
- A breakdown and justification of the proposed expenditure
- A list of suggested referees who may be approached to review the proposal

Successful applicants will be required to produce a final project report that will be published in the Palaeontological Association's *Newsletter* and are asked to consider the Association's meetings and publications as media for conveying the research results.

Further details and a full list of terms and conditions for the Research Grants Scheme can be found on the appropriate page of the Association's website. Enquiries may be made to the Secretary (<**secretary@palass.org**>).

The deadline is **1st March** each year. Funds will normally be available from 1st June, and the awards will be announced at the AGM.

ASSOCIATION MEETINGS

59th Annual Meeting of the Palaeontological Association
Cardiff University and Amgueddfa Cymru – National Museum Wales, UK
14 – 17 December 2015

The Annual Meeting of the Palaeontological Association will be held at Cardiff University and Amgueddfa Cymru – National Museum Wales, organised by Caroline Buttler (<**Caroline.Buttler@museumwales.ac.uk**>), Lesley Cherns (<**cherns@cardiff.ac.uk**>) and Lucy McCobb (<**Lucy.McCobb@museumwales.ac.uk**>).

Information about the meeting is provided in the coloured supplement at the back of this Newsletter and on the PalAss website at <**http://www.palass.org/modules.php?name=annual_meeting**>.

The final deadline for registration is **Friday 13th November** 2015. The abstracts for the talks and posters will be available on the PalAss website and will be included in the Conference pack at the Meeting. Please address all queries to <**annualmeeting@palass.org**>.

We look forward to seeing you in Cardiff in December!

Abstract of Annual Address

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

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

Professor John Hutchinson
Structure & Motion Laboratory, The Royal Veterinary College, Hatfield, AL9 7TA, UK
<jhutchinson@rvc.ac.uk>

Considering that we cannot observe the behaviour of extinct organisms, and yet their derived or ancestral traits make them attractive scientific subjects, how can we test how certain behaviours evolved? Computational methods are maturing as an approach that complements classical methods such as anatomy, ichnology, morphometrics or analogies with living animals. With the rapid advance of 3D imaging technologies, it is easy to build realistic digital organisms and estimate biological parameters such as body mass. Once a computational model is made, it opens up opportunities for more sophisticated techniques from estimating joint ranges of motion to predictive dynamic simulations that generate novel behaviours.

I discuss examples from our research on the evolutionary biomechanics of locomotion in vertebrates, including simple modelling approaches of how tetrapods first walked, more complex biomechanical modelling of how fast giant dinosaurs like Tyrannosaurus could move, and simulations that test how the form and function of the limb muscles of tetrapods evolved into major locomotor adaptations such as avian bipedalism. A recurrent theme is the importance of the experimental validation of computational models, and the sensitivity analysis of parameters entered into models to test how much unknowns matter for the questions we ask using them in palaeobiology.

The organisers of the Annual Meeting gratefully acknowledge the support of the sponsors:

Frontiers in Earth Science

The Paleontological Institute

Nature Communications

Siri Scientific Press

Taylor & Francis

The Geological Society

Lyell Meeting 2016 – Palaeoinformatics: Synthesising Data from the Past to Illuminate the Future

The Geological Society, Burlington House, London, UK *9 March 2016*

Synthesising palaeontological occurrence data and taxonomy into usable databases and web-systems will be one of the major challenges for palaeontology over the next couple of decades.

On the one hand compiling palaeontological data and integrating it with other databases has immense research potential in fields from palaeoceanography and climate change through to palaeobiology. On the other hand there is an ever increasing expectation that information, on virtually everything, should be available electronically via the web. In both areas palaeontology is nowhere near as advanced as we might hope and there are major challenges for the future – not least since there are particular information technology problems in handling and standardising taxonomic and stratigraphic data.

The purpose of this meeting will be to bring together researchers who are playing lead roles in significant current initiatives and/or who have carried out particularly interesting individual work, with the objective of sharing experience and show-casing good practice for the large numbers of other workers who are interested to develop or improve palaeoinformatics in their own work.

For more information see the meeting website at <**http://www.geolsoc.org.uk/lyell16**>.

Held in the historic Oxford University Museum of Natural History and the contemporary Department of Earth Sciences

Progressive Palaeontology

Oxford 2016

19th - 22nd May 2016

19th May: Registration and Icebreaker reception in the Museum

20th May: Talks and poster session, followed by the conference dinner at Exeter College

21st-22nd May: Museum tour (21st) or field trip (both days)

> Competitive travel grants available for overseas attendees

>Free registration

Join us in Oxford for Prog Pal 2016!

Meet with fellow early stage palaeontologists in our 'Cathedral of Science', the University Museum of Natural History. Join us for drinks and nibbles during the Icebreaker, followed by a day of stimulating talks and posters. Have coffee looking out over the Oxford skyline from the Earth Sciences department. To conclude the day, relax and enjoy the conference dinner and auction.

Hunt for three-dimensionaly preserved vertebrate and invertebrate fossils on our two day field trip to the Isle of Sheppey. Alternatively, take a behind the scenes tour of the musuem collections.

Follow us on social media for further information:

Progressive Palaeontology 2016 @ProgPal2016

Email: progpal2016@palass.org

news

Virtual Palaeontology *Issue 4 online*

Every year, the Palaeontological Association recognises the significant scientific contribution of a single palaeontologist by awarding the Lapworth Medal. In recent years we have asked the recipient to look back over the entire *Palaeontology* archive and select those papers that they feel have made the most impact in their particular field. This year, Professor Richard Fortey has made his choice of arthropod papers which can be accessed in the fourth *Virtual Palaeontology* issue online, at <**http://tinyurl.com/pfpmm3p**>. For more details see page 117 of this *Newsletter*.

Sally Thomas
Publications Officer

#fossilsinthefield

This past Northern Hemisphere summer field season we asked you to share your field photos on social media using the hashtag #fossilsinthefield (*Newsletter* 89), and we had an excellent response. There was a great *Campanile giganteum* from @defneris and a big therapod trackway posted by @MnM_yellow, plus fossil mammals from the team at #Batallones2015 in Spain. Our favourite was from Thomas Clements (@Thomas_Clements) who is researching the exceptional preservation of soft tissues in the Mazon Creek Carboniferous Lagerstätte in the USA. We felt that it captured the essence of fieldwork, with wet feet and the effort required to retrieve fossils in fairly treacherous circumstances. The image shows locals Daniel Holm (left) and his father, Adam Holm, hunting for nodules, using hoes to extract them from riverbed. The Holms are experts at finding fossil-bearing nodules, and can tell if they are fossiliferous often by sight or shape alone. Nodules collected by Thomas are destined for geochemical analysis in order to determine how the nodules formed and if fossil preservation is linked to their chemical composition.

Jo Hellawell
Newsletter Editor

Photo: Thomas Clements

Palaeontology *in the News*

Feel free to correct this statement in the next issue of the *Newsletter*, but there doesn't appear to have been much press coverage of articles from our journals recently. I blame the Association's Publicity Officer, and urge others to castigate him in an appropriate manner. However, there's always plenty going on in the world of palaeontological research, so here are a few highlights from the late summer news.

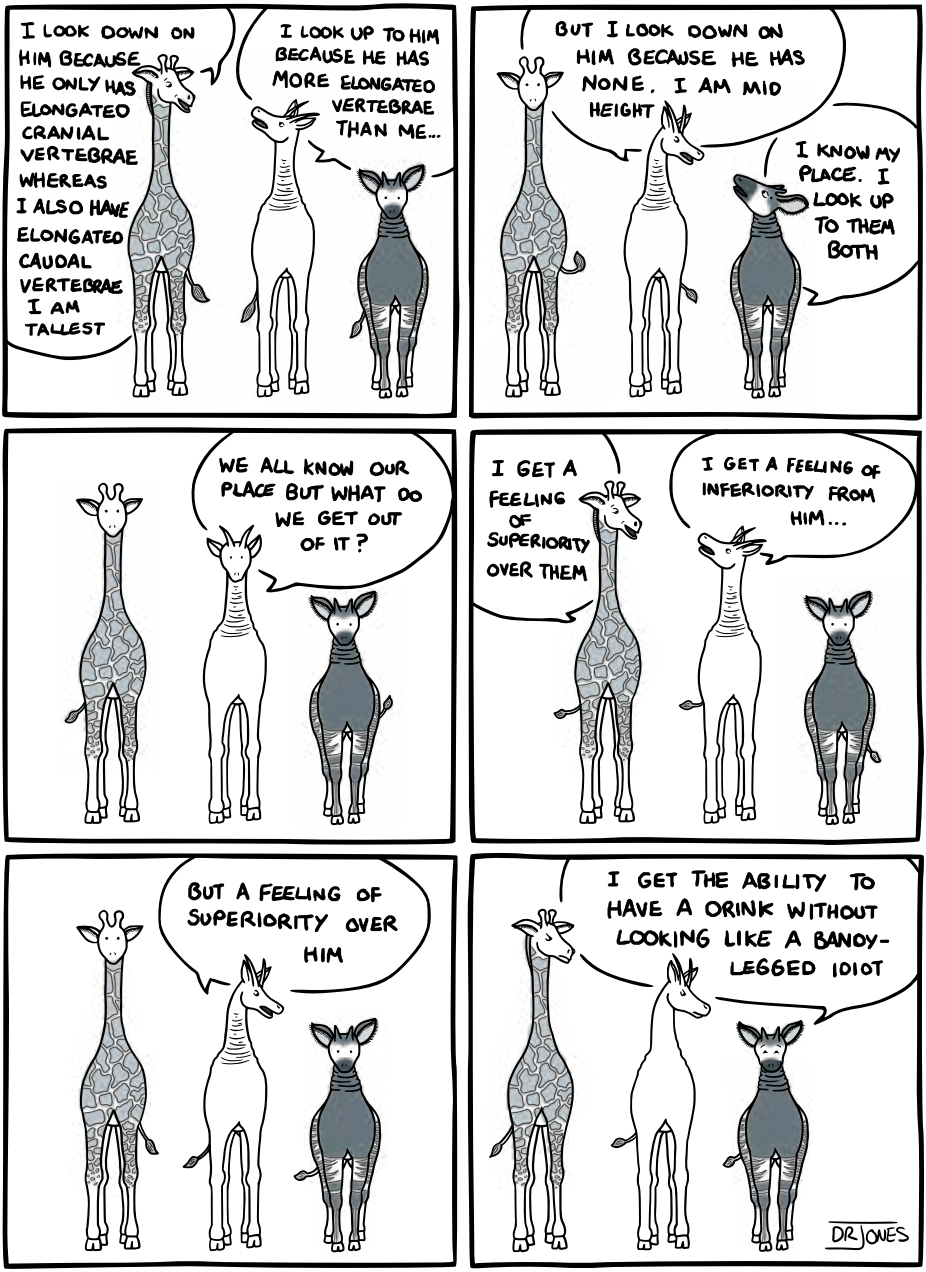
Unravelling how the giraffe got its long neck was one of the most eye-catching recent papers (Danowitz *et al*. 2015: <**http://rsos.royalsocietypublishing.org/content/2/10/150393**>). The study of skeletal material from 11 giraffid taxa, living and fossil, found that the evolution of long-neckedness was anisometric, and that the elongation of cerebral vertebrae occurred before that of the caudal vertebrae. Surprisingly perhaps, the research showed that the elongation preceded the evolution of the Giraffidae, answering the oft-asked question: which came first, the giraffe or the neck?

With a Just-So aspect to the story, plenty of media outlets published articles about it. "Bizarre-looking African mammal's spine stretched in bursts" declared our old favourite the *Daily Mail*, rather painfully. Meanwhile, the *Lighthouse News Daily* (<**http://www.lighthousenewsdaily.com/we-now-know-where-giraffes-get-the-emblematic-neck-from/2163/**>) said "We now know where giraffes get the emblematic neck from", which was adjectivally novel. One reputable dictionary defines *emblematic* as 'something (such as an idea, state, or emotion) that cannot be seen by itself'. For the necks of living giraffes, this definition is just about applicable, but some of the fossil giraffids were decidedly incomplete: vertebrae being found without a great deal else of the body. Perhaps the neck evolved emblematically through the Neogene.

Sticking with ancient grazers – at least in a Latinized version of the Alaskan Inupiat language – we learned that *Ugrunaaluk kuukpikensis* was a duck-billed hadrosaurid from the high Arctic of the northwest US. This Late Cretaceous herbivore was described by Mori *et al*. 2015 (<**https://www.app.pan.pl/article/item/app001522015.html**>) and identified as part of a distinct Arctic dinosaur community. To no one's surprise, the media had a field day.

"Brrr! A dinosaur that loves snow has been discovered", announced the British freebie newspaper *Metro*, portraying the beast in a woolly hat: <**http://metro.co.uk/2015/09/23/brrrr-a-dinosaur-that-loves-snow-has-been-discovered-5403639/**>. With an article written, appropriately enough, by a Mr Coolman, *The Daily Beast* headline-writers showed a true mastery of the English language and plumped for "New dinosaur is a moose-duck, sort of", though to be fair, the rest of the article was pretty thorough (<**http://www.thedailybeast.com/articles/2015/09/24/new-dinosaur-is-a-moose-duck-sort-of.html**>). *Ugrunaaluk* "had crests along its back like Godzilla", added the *Daily Star* (<**http://www.thedailystar.net/environment/new-arctic-discovery-challenges-everything-we-thought-about-dinosaurs-150103**>) meanwhile, but at least that quote could be attributed directly to one of the co-authors.

As for unpublished work, the discovery by a Michigan farmer of a mammoth in one of his soybean fields (<**http://www.theblaze.com/stories/2015/10/02/farmer-discovers-mammoth-skeleton-in-soy-field-then-gives-paleontologists-a-day-to-dig-it-up-so-he-can-stay-on-schedule/**>) presented a marvellous headache for the local palaeontology museum. The work schedules of the farmer



<http://www.ratbotcomics.com/>

– Mr Bristle – meant that they had a single day to dig it up! Thanks to a frenetically literal stint of fieldwork, the museum team succeeded in retrieving the remains, which they estimated as being about 20% complete, and which they interpret as being of an adult male who was around 40 years old when he died. Or was killed, even, as speculative early conclusions suggest the mammoth was butchered by early humans and stored for later consumption.

As for present-day humans, the discovery certainly piqued their interest, with thousands of people coming to the farm to see the dig in progress. "One fellow who makes guitars wanted to buy some of the ivory to make an inlay on a guitar", said Mr Bristle, bemusedly (<**http://www.mlive.com/news/ann-arbor/index.ssf/2015/10/woolly_mammoth_skeleton_headin.html**>), "but we didn't want to go down that road". That was probably wise, but it could have brought new meaning to 'behemoths of rock music'.

A road even less-travelled, meanwhile, led to a new hominin: *Homo naledi*. The tale of its discovery was perhaps the most extraordinary of recent times. A team of intrepid scientists inched their way through the narrowest, most tortuous series of (often-sub-aqueous) South African caves to unearth a distant relative of ours, which, according to the *Guardian* (<**http://www.theguardian.com/science/2015/oct/06/ancient-human-relative-could-walk-on-two-feet-use-tools-and-swing-in-trees**>), "could walk on two feet, use tools, and swing from the trees" (though presumably not all at the same time). Whether *H. naledi* could have played a mammoth ivory guitar was not discussed, but the *Daily Mirror* was intrigued by the possibility that every part of our skeleton had evolved to become different from that of our South African relative, except the feet (<**http://www.mirror.co.uk/news/technology-science/science/every-part-human-body-evolved-6583916**>). One small step for *Homo naledi*, one giant leap for evolutionary anthropology.

If the technique for locating the fossils of *H. naledi* was unusual, the publicity machine was rather novel too. Social media and open-access journals were used to announce the discovery to as many people as possible, and it was a very successful approach, as the research team explained in an article for *The Conversation*: <**https://theconversation.com/homo-naledi-fossil-discovery-a-triumph-for-open-access-and-education-47726**>. If the Association's Publicity Officer is reading this article, maybe he could take note?

Liam Herringshaw
Publicity Officer
<publicity@palass.org>

Featured article

I wanted to finish my first year as a *Newsletter* contributor with a write-up of some fantastic mass extinction research, and there's been lots of good stuff published recently. However, precious little of it is open access, which is a pre-requisite for being selected for this prestigious and highly influential column. Instead, I have chosen a seemingly obscure fossil that highlights how one small find can result in a fascinating story: esteemed entomologist George Poinar Jr., the man whose ideas inspired the *Jurassic Park* franchise, writes about "A new genus of fleas with associated microorganisms in Dominican amber" in the *Journal of Medical Entomology*. The new flea, *Atopopsyllus* (meaning 'strange flea') *cionus*, was discovered many years ago (a sort of entomological 'Alan the Sauropod' moment) in a piece of 20–30 million year-old Dominican amber by Poinar's wife, Roberta, whilst they were looking over their collection at the University of California, Berkeley.

This male flea's most notable features, not known from any extinct or extant relative, are its five-segmented maxillary palps (normally fleas have only four), and a structure similar to cerci (abdominal appendages that in fleas are only found in females). The species name '*cionus*' comes from the Greek 'kion', meaning 'pillar' and refers to this unusual appendage.

Where this story gets really interesting is in what was found in the flea's backside. The flea hosted bacteria, attached to its proboscis in a dried droplet and then compacted in its rectum. Headlines on the www report "Bacteria in ancient flea may be ancestor of the Black Death", highlighting the spin that news outlets like to put on research. Poinar can't be sure that his flea's ancient coccobacillus forms are related to *Yersinia pestis* (the plague bacteria), but their size, shapes (rod and nearly spherical) and characteristics are consistent with modern forms of *Yersinia*. Indeed, of the pathogenic bacteria transmitted by fleas today, only *Yersinia* has such shapes. Additionally, their location in the rectum of the flea is known to occur in modern plague bacteria.

This flea, preserved about 20 million years ago in amber, may carry evidence of an ancestral strain of the bubonic plague. Photo by George Poinar, Jr., Oregon State University, used under the CC BY-SA 2.0 licence.

Poinar's findings are at odds with modern genomic studies that suggest the flea-plague-vertebrate cycle evolved over the last 20,000 years, not the past 20 million (see Gage and Kosoy 2005 for a fascinating review). It seems that past outbreaks of the plague might have been caused by extinct strains of *Yersinia*-like bacteria. These ancient strains presumably evolved as rodent parasites (rodent hair is also known from the Dominican amber) long before humans existed. The spread of insect-borne disease might, rather fancifully, be implicated in the demise of ancient rodents, or even ancient reptiles, since flea-like insects date back to the Cretaceous. The Poinars explored this in their 2008 book, "What bugged the dinosaurs? Insects, disease and death in the Cretaceous", which threw insect-borne diseases into the K–T (K–Pg) scenario alongside the Chicxulub impact and Deccan Traps eruptions. Like two heroes of mine, Tony Hallam and Dolf Seilacher, Poinar is on course to be 'research active' into his eighties (25th April next year). Perhaps proof that the stress-free world of palaeontology is key to longevity? Despite Poinar's assertion that "the ancient [*Yersinia*] strains would certainly be extinct by now", I'd still be wary of that fossilised flea… Remember *Jurassic Park*, anyone?

David Bond
University of Hull

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PDBD for undergraduate research

A project is under way to explore how opportunities for undergraduate education and research experience, particularly in colleges that do not have extensive fossil collections, could be leveraged from the Paleobiology Database (PBDB). "Big data" science initiatives like the PDBD could provide inexpensive and accessible research opportunities, and we hope to test and document the value of such programmes in the undergraduate classroom using guided research activities and a new user interface developed for the PBDB. The project will also investigate how students' attitudes towards scientific research change after engaging in research experiences using a large database such as the PBDB, compared to field- or lab-based research experiences. As part of this project we are interested in learning who is and who isn't currently using the PBDB for education and research and why, and are collecting information using a survey; we would be grateful if you could spare ten minutes to complete it by following this link:

<**http://tinyurl.com/pbdbsurvey**>

Rowan Lockwood
College of William and Mary

iDigBio webinar series

The iDigBio Paleo Digitization Working Group is pleased to announce the continuation of its popular webinar series, with eight upcoming events scheduled. Topics include a tour of the iDigBio data portal, database standards, georeferencing for palaeo collections, and a multipart discussion of digitising US Federal Collections. If you have an idea for a webinar contact <**talia.karim@colorado.edu**> or <**gnelson@bio.fsu.edu**>. All webinars are open to anyone; registration is not required. Instructions for logging in and a link to the virtual meeting room are available on the working group wiki. Additionally, the webinars are recorded and presentation notes and discussions are posted as PDF files on the group's wiki page, so if you miss a webinar you can always watch it later! To receive announcements of webinars and other group activities please subscribe to the working group listserv:

<**https://www.idigbio.org/wiki/index.php/Paleo_Digitization_Working_Group**>

Talia Karim
University of Colorado

The United States of Fossiliferousness

Image: Cason Clagg

This map is a data visualization of the Paleobiology Database and iDigBio.org fossil occurrence data. The map was created in an attempt to find the intersection of fossiliferous surface geology and accessible land, created using Processing 3.0. The size of each dot is related to the number of fossils found in each location. As the dots stack the colour becomes darker, signifying higher fossil occurrence density. A couple of interesting features are immediately apparent. The most obvious is the giant circle in Colorado correlating with the Florissant Fossil Beds. Another interesting feature is the crescent line that cuts across Alabama; known as the "Black Belt" region this is the result of a Cretaceous shoreline. Plans are now under way for an interactive mobile app.

Cason Clagg
Norman, OK @casonclagg

Aquatic plant could be the oldest known flower

Photo: Bernard Gomez

The early and apparently rapid diversification of angiosperms was described by Darwin as "a most perplexing phenomenon", with knowledge of how and where they originated still lacking. My colleagues and I have found evidence that angiosperms lived and reproduced under lake water very early in their history. We investigated more than 1,000 specimens of *Montsechia vidalii* (Zeiller) Teixeira from the Barremian (Lower Cretaceous; 130–125 Ma) lithographic limestones of the Spanish Pyrenees and Iberian ranges. *Montsechia* has opposite decussate long leaves and alternate spiral short leaves, and the two known morphology types both have fruits borne in pairs at shoot ends. Except for a small apical opening in the fruit wall where pollen tubes entered for fertilisation, the fruits remained closed even after dispersal. Cladistic analysis of these and other features shows close affinities with living *Ceratophyllum* L. The ancient age and petalless flower suggest that *Montsechia* is the earliest known, fully-aquatic, freshwater flowering plant.

Bernard Gomez
Université Claude Bernard Lyon 1

Paleourbana

This project started four years ago as "Caracoles en las Aceras" (Snails on the Sidewalk), a website about urban fossils in Spanish cities. Soon I received photographs of urban fossils from other countries, so two years ago I changed the domain to <**http://www.paleourbana.com/**> and translated the website into English, a project that is still ongoing. Paleourbana's map has more than 250 sites of urban fossils in 54 cities around the world. To contribute to the site go to Paleourbana's 'Share' section where you can find more details regarding what information to send. You don't need to identify all the specimens and if you have any questions, I will be happy to help. There are many other urban fossils hidden somewhere, waiting to be found by you … perhaps not far from your home. Get involved!

Ammonites in the benches at the Auditorium of Zaragoza. Photo by Ricardo López.

Rubén Santos Alonso
Vitoria-Gasteiz
@Paleourbana

Large palaeoburrow identified in Rondônia, Brazil

In June, colleagues from the Geological Survey of Brazil (CPRM) discovered a large palaeoburrow excavated by Pleistocene vertebrates near the village of Vista Alegre do Abunã in northern Brazil. The palaeoburrow represents a complex system of horizontal tunnels of more than 100 m in total length; on average the widths and heights are 2 m, consistent with being made by ground sloths, and subvertical excavation marks associated with the claws of sloths are preserved on the walls and the roof. The age of the palaeoburrow is thought to be more than 10 ka, and the extensive tunnels suggest the need to shelter against the rigours of the palaeoclimate in the region, likely dry and cold at that time. The total volume of sediment excavated is thought to be around 400–500m^3, suggesting that multiple generations of ground sloths were responsible for the slow digging of the palaeoburrow over a long period of time.

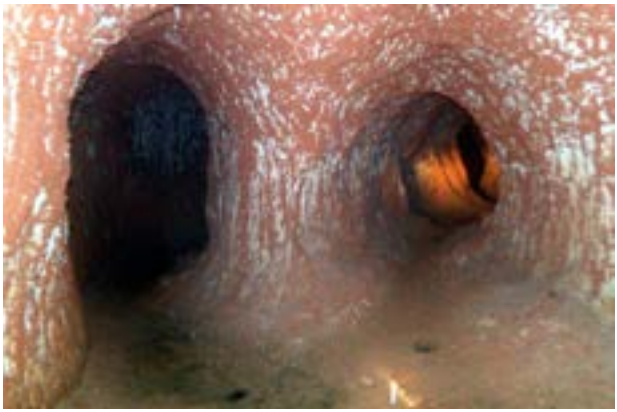

Photo: Amilcar Adamy

Amilcar Adamy
CPRM

From our Correspondents

Legends of Rock

Marie Stopes: a Passion for Palaeobotany

Marie Stopes (1880–1958; Figure 1) was one of the most influential figures of the 20th century. She became infamous in polite society following the publication in 1918 of her best-selling sex manual (*Married Love*) and an influential guide to birth control (*Wise Parenthood*). Later, in 1923, she faced death threats and lawsuits as she bravely took to the streets, offering women birth control advice at mobile clinics around London. This work eventually evolved into the organisation 'Marie Stopes International', arguably her most enduring legacy. Then, as the storms of war gathered, Stopes revealed a darker side, corresponding with Hitler and becoming a leading proponent of Social Darwinism and eugenics. She also wrote many successful novels, plays and works of poetry, some of which were banned for their indecency! However, it was none of these extraordinary facts that first brought Dr Marie Stopes to my attention; rather, it was our mutual interest in fossil plants. As Stopes once confided to an embarrassed Bill Chaloner (PalAss President 1976–78) when he met her at the Geological Society in 1956, her first love and her enduring passion was palaeobotany.

Figure 1. Marie Stopes (1880–1958), studying what appear to be coal ball slides. The photograph was probably taken in 1905 during her time at the Victoria University of Manchester (reproduced with permission of her son, Harry Stopes-Roe).

Carboniferous seed plants

Stopes' introduction to palaeobotany came at "that Godless institution in Gower Street" (UCL) where she read Geology and Botany from 1900 to 1902. Following graduation, the botanist Francis Oliver engaged her as his research assistant for a few months, and Stopes helped him to make the significant discovery that the fern-like plants in the Carboniferous Coal Measures were not ferns at all, but were seed-bearing plants. Together with D. H. Scott at Kew, Oliver named these new plants pteridosperms, or seed-ferns, and in doing so revolutionised our understanding of the early evolution of land plants. This brief taste of research got Stopes hooked and, in 1903, she set off to Munich to undertake her PhD with Karl Goebel. Funded by a Gilchrist Scholarship, she completed her doctorate on the reproduction of extant cycads in only ten months, the first woman to graduate from Munich with such honours. How did she achieve this extraordinary feat? Stopes recorded how she typically laboured for twelve hours per day, and at the weekend sometimes worked thirty hours at a stretch with only a weak beef tea for sustenance. Current PhD students should take note! Back in Britain in late 1904, Stopes was engaged as Demonstrator in Botany at the Victoria University of Manchester, her first academic appointment (Figure 2). There she embarked on a study of plant-bearing nodules known as 'coal balls' from the Lancashire coalmines. Flying in the face of popular opinion, she proved that these nodules represented mineralised peat that formed when seawater periodically flooded Carboniferous coal swamps.

Figure 2. Blue plaque at the University of Manchester commemorating Marie Stopes' lectureship (photo by Duncan Hull).

Cretaceous flowers

In 1907, Stopes changed her research direction completely and obtained Royal Society funding for an eighteen-month excursion to Japan in order to locate the earliest remains of flowering plants. It must have been an amazing experience to explore the uncharted wilds of this remote country, and her published diary of the experience (*A journal from Japan*, 1910) makes for entertaining reading. When she visited the northern island of Hokkaido, the British Government insisted that a large entourage of porters and policemen accompany her to protect her dignity. Seeing as not one of them had more than a few words of English it must have been a logistically-challenging trip. Later on she managed to give her entourage the slip and explored rural Japan alone by bicycle. In the course of her work she found what were then the earliest known flowers (beautifully preserved in Cretaceous nodules), as well as some stunning insect fossils. All of these fossils can still be viewed at the Manchester Museum today. When Stopes returned to Britain in 1909 she became a minor celebrity, giving humorous talks about her travels and translating Japanese plays and poetry for a wider audience.

Canadian biostratigraphy

In 1910, another interesting opportunity came Stopes' way via Reginald Brock, the Director of the Geological Survey of Canada. Brock had a major headache. He was preparing a new set of geology maps for Atlantic Canada, but his staff had radically different ideas about the age of some of the key rock units. Brock needed an independent expert to date the rocks using fossil

plants, and he'd met Stopes on her homeward journey from Japan as she crossed North America. Stopes jumped at the chance and by the end of 1910 she was rummaging through old museum drawers in Ottawa, Saint John and Montreal (Figure 3). However, she got more than she bargained for when, at a conference in St Louis, Missouri, she fell in love, marrying just a matter of weeks later. The lucky man was Reginald Gates, a Canadian geneticist. Whether married or not, Stopes still had a job to do and after a month of fieldwork in Saint John, New Brunswick, in 1911 she was ready to give Brock her opinion on the age of the contentious rocks. Her major monograph (*The Fern Ledges*, 1914) that resulted from this work still stands as one of the enduring classics in systematic palaeobotany and biostratigraphy. It proved once and for all that the rocks were Carboniferous and not Devonian or Silurian as others had earlier argued.

Figure 3. One of the beautiful fossil plants (Asterophyllites) from the Carboniferous 'Fern Ledges' of New Brunswick studied by Marie Stopes in 1911 (reproduced with permission of the New Brunswick Museum).

Marriage breakdown and coal

Back in Britain in late 1911, Stopes and Gates were far from happily married. Stopes claimed that Gates was impotent and that she remained a virgin. Gates had a different opinion, describing Stopes as "super-sexed to a degree that was almost pathological" and ruefully claiming that he could have "satisfied the desires of any *normal* woman"! We know all this from acrimonious court transcripts as Stopes sought to get her marriage annulled. Little could Stopes have realised that the breakdown of her first marriage would signal the beginning of the end of her geological research. However, it was her experiences with Gates that inspired *Married Love* (1918) and eventually took her career off on a radically different trajectory. Nonetheless, there was still one final chapter in Stopes' geological work yet to unfold. During the Great War, she developed a renewed interest in coal. Coal was the fuel that drove the twilight years of the British Empire and in wartime it was especially important to understand more about its combustion properties. Stopes set to work studying hundreds of polished blocks before writing a seminal paper on the four visible ingredients of coal (Stopes 1919) and, in doing so, coined the now familiar terms clarian, vitrain, durain and fusain. Unfortunately, by 1923 when her first birth control clinic opened, Stopes had more or less turned her back on palaeobotany. Naturally, it is tempting to wonder what she might have achieved had she devoted her entire career to our science, although we would live in a very different society today had Stopes not embarked on her better-known humanitarian pursuits.

Howard Falcon-Lang
Royal Holloway, University of London

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On the Four Visible Ingredients in Banded Bituminous Coal: Studies in the Composition of Coal, No. 1.

By Marie C. Stopes, D.Sc., Ph.D., Fellow and Lecturer in Palæobotany University College, London.

(Communicated by Sir George Beilby, F.R.S. Received August 22, 1918.)

[Plates 11 and 12.]

Even after a century of investigation coal remains a complex mass of which the component parts can neither be handled nor separately identified. Many authors have recognised a variety of plant remains in coal, and the specific identification of these organisms and tissues has made good progress; but such work is truly palæontological, and the points of interest in it are the organisms and not the coal mass of which they form a part.

From another point of view coal is a rock, but, unlike most rocks, the nature and orientation of its component parts are scarcely known. One of the most distinguished of living geologists once said to me that he would like to have available sheet microscopic sections of coal rationalised into compatible with those already obtained by petrologists about this rock outlines. The present paper is a contribution in that direction. It is an attempt to present systematically certain observations made incidentally in

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Behind the Scenes at the Museum

Palaeontology in Amgueddfa Cymru – National Museum Wales, UK

The earliest origins of the collections of Amgueddfa Cymru – National Museum Wales can be traced back to the 1840s and 1850s, and small temporary displays put together by learned institutions such as Cardiff Athenaeum and Mechanics' Institute, and Cardiff Literary and Philosophical Society. When Cardiff Naturalists' Society was founded in 1866, one of its main aims was to develop a museum, and the first curator was appointed in 1878. For several years, specimens were exhibited in temporary spaces, including the upper floor of the Free Library, but in October 1880 work began on a new purpose-built building. Cardiff Museum and Free Library opened two years later in Trinity and Working Street. Unfortunately, widening of the street in 1894-5 reduced the already limited space available for display of natural history specimens, and many had to be put back into storage. People soon began petitioning Parliament for a National Museum.

Figure 1. National Museum Cardiff. Image copyright Amgueddfa Cymru – National Museum Wales.

The National Museum of Wales was founded by royal charter in 1907, and the foundation stone for the Museum was laid in Cathays Park by King George V in 1912. However, the outbreak of the First World War meant that it was 1927 before the first phase of the Museum was opened to the public, with a later phase opening in 1932. The architect's original design, for a four-sided building surrounding a central garden, was never realised. The fourth side remains unbuilt, and in the 1980s a 'centre block' was added to increase gallery and office space.

Since its founding, the National Museum of Wales has developed to include seven different sites across the country, including museums focusing on social history, industry, the Romans, slate, wool and coal mining, collectively referred to as Amgueddfa Cymru – National Museum Wales. The original museum building, now known as National Museum Cardiff (Figure 1), currently houses art on its upper floors and natural history on the ground floor, and also holds extensive archaeology collections. The Museum's collections have expanded from an estimated 30,000 specimens in 1914-15 to several million, including over three and a half million natural history specimens. The Palaeontology Section is part of the Natural Sciences Department in Cardiff and has four curatorial staff, who look after over 600,000 specimens. Although the collections reflect the varied geology of Wales very well, they are also international in scope and include specimens from many different countries, with significant holdings from Sweden, China, Turkey and the Middle East. There are over 6,000 specimens in our fossil type collection, and a searchable database of the holotypes can be found on the Museum's website. High-quality images and three-dimensional scans of these specimens were also produced as part of the GB3D Type Fossils Online project.

Perhaps unsurprisingly, the stores teem with Lower Palaeozoic invertebrates, the likes of which would have delighted Sedgwick and Murchison in their race to claim and name fossils for their Cambrian and Silurian. Trilobites, brachiopods and bivalves are particularly abundant, and graptolites and corals are also very well represented. Thanks to the rich coal-mining heritage of Wales, there are extensive collections of Carboniferous Coal Measures plants and freshwater bivalves, with many specimens localised down to the level of individual coal seams. Geologically older palaeobotanical collections chart the very important transition of plants as they established themselves on land during the Silurian and Devonian. Among the Museum's most popular fossils are its large collections of Jurassic ammonites, which are mainly from the south-west of England, but also include representatives from other parts of Europe.

National Museum Cardiff houses one of the world's largest collections of William Smith's geological maps, some of which are on display this year in a special exhibition to mark the bicentenary of his 1815 map of England, Wales and part of Scotland, the first large area geological map ever published. The Museum also holds the archives of Sir Henry Thomas De la Beche, founding director of the British Geological Survey. As well as letters and other written documents, the archive includes his original 1830 watercolour *Duria Antiquior – A more Ancient Dorset*, the first painting to portray extinct animals interacting with each other in their original prehistoric environment. This pioneering palaeoecological reconstruction was based on Jurassic fossils collected by Mary Anning at Lyme Regis, and prints of it were sold by De la Beche to raise funds to help support her.

One of the highlights of the public galleries is 'The Evolution of Wales', which charts the Earth's physical and biological journey from the Big Bang up until the present day. This very specimen-rich gallery is popular with museum visitors and includes meteorites, a Moon rock, Welsh gold

Figure 2. Silurian reef diorama in 'The Evolution of Wales' gallery. Image copyright Amgueddfa Cymru – National Museum Wales.

and of course, dozens of wonderful fossils! Having survived the explosive Big Bang and volatile volcano, visitors can explore a beautifully serene Silurian reef (Figure 2), test their arachnophobia and general feelings towards large creepy-crawlies in the Carboniferous Coal Swamp, and be startled or amused by the (now very ancient indeed) animatronic mammoth and baby in the Pleistocene section.

Inevitably the magnet for many younger visitors is the Mesozoic section, dominated by an imposing *Edmontosaurus* skeleton, several impressive marine reptiles, and a beautiful array of ammonites. A large expanse of fossilised footprints provides the foundations for a dinosaur diorama featuring *Coelophysis* models and skeletons of *Plateosaurus* and *Megalosaurus*. The footprints are from The Bendricks near Barry on the south Glamorgan coast of Wales, one of the best sites in the world for Late Triassic dinosaur footprints. They include small and large three-toed (presumably theropod) footprints and wider, four-toed footprints thought to have been made by herbivorous dinosaurs.

Figure 3. Tip of the jaw and a tooth of the new Welsh dinosaur. Image copyright Amgueddfa Cymru – National Museum Wales.

Last year, an exciting discovery of a new Welsh dinosaur (Figure 3) was made on a local beach by two fossil-hunting brothers; they intend to donate the specimen to the Museum, where it is currently on display. The fossil comprises a significant proportion of a juvenile theropod, about half a metre tall. Not only is this the first skeleton of a meat-eating dinosaur ever found in Wales, it is also one of the earliest Jurassic dinosaurs to have been found anywhere in the world. We are eagerly anticipating publication of the scientific description of the specimen by Dave Martill and colleagues, not least because we will finally be able to answer the public's most popular query: "What's the dinosaur's name?". Meanwhile, we have been running a Twitter campaign asking

for suggested nicknames. Despite inspired suggestions such as 'T. wrexham', 'Dai the Dinosaur' remains a popular choice!

Sci-fi fans will be forgiven for a feeling of déjà vu as they walk around the Museum, which has been used as a filming location for several episodes of Dr Who and Torchwood, as well as featuring in the remake of Upstairs Downstairs and as the fictional 'National Antiquities Museum' in Sherlock. Sadly, staff were kept well out of the way as Benedict Cumberbatch dashed across the dimly-lit Main Hall in pursuit of a mysterious Chinese nemesis.

Lucy McCobb
Amgueddfa Cymru – National Museum Wales

National Museum Cardiff is open to the public Tuesday–Sunday, 10am–5pm (Galleries close at 4.45pm). Closed Mondays. Please see the website for more details:
<**http://www.museumwales.ac.uk/cardiff/**>

 <**https://www.facebook.com/museumcardiff**>

 @CardiffCurator

Kinds of blue

Blue skies. They smiled – if you slowly and lovingly peruse the entry in Wikipedia for that finest of ballads by Irving Berlin – on Ella Fitzgerald, on Frank Sinatra, on Maxine Sullivan, on Whispering Jack Smith[1], and on a host of others. A frown may arise on the brow once the lack of Peggy Lee on that list is noticed, for if the finest singer of popular song ever to walk the Earth[2] did not cover that classic number, then something would really be amiss on this planet. A little swift research soon sets the world spinning properly on its axis once more, for Ms Lee did indeed record the song, with her usual unearthly grace, even if it was in the company of a combo termed The Four of a Kind, who were not having the very best of days (the diversity of micro-environments around the sonofossilization trade[3] never ceases to astonish). Blue skies have long smiled on our home planet, of course. But it is still a little surprising that they may have held such a tight grip on the Cretaceous.

Perhaps, indeed, they might hold the answer to the growing enigma of what seems long to have been the most familiar and *comfortable* of geological periods. The Jurassic, true, may have the name recognition, but it is telling that most of the dinosaurs of the film of the same name were time-transported from the Cretaceous to be pressed into bloodcurdling service (one imagines in Hollywood limousines, whose drivers have undoubtedly seen worse). There is the rock, too. The Chalk is not so much iconic as thoroughly inbuilt into both landscape and memory. I have heard it said that, in medieval times, one of the five tests that were used to tell the sane from the insane was the ability to recognise a lump of chalk. Perhaps apocryphal, but it has the ring

[1] The whispering was the result of respiratory damage resulting from poison gas in the First World War. Reality did, sometimes, intrude into Tin Pan Alley.
[2] The competing claim of Sinatra might be raised, but really there is no contest *at all*.
[3] See *Newsletter* 66.

of plausibility even if not verifiability[4]. It seems inevitable that the Chalk downland was a home to Jane Austen in working life and to Sherlock Holmes in retirement, where that most illustrious and geologically-savvy of sleuths kept bees – as he vouchsafed to Watson in *His Last Bow*. Terry Pratchett wove the Chalk, in a character almost as tangible and as timeless as Death himself, as bedrock to the character of his last witch, the young Tiffany Aching (it was the flint that provided the necessary hardness). And beyond such allegory, the understanding of this impossibly simple rock as representing the continent-drowning deep sea of the balmy Cretaceous is general knowledge, more than it is the secret lore of the palaeontologist.

There is a glitch in that classic tableau, though. It has been developing ever since geologists have been trying to work out how the world – past, present and future – *really* works, mainly by trying to reproduce it within the innards of a computer. The pattern of Cretaceous warmth emerged as a problem, of uncommon stubbornness, persisting as ever more complicated versions of data were input, and the number-crunching power of the hardware was ratcheted up.

The evidence of the rocks is quite clear. Go from equator to pole, and the storybook warmth persists. The equatorial regions, like today, were swelteringly hot – even a touch more than today, but still not so hot, by and large, as to overcome the biological limits of the thriving biological communities[5]. The polar regions were warm too. One wouldn't use the word 'sweltering' perhaps, except on occasional summer days, but it was warm enough to support forests and dinosaurs and all of that kind of thing. A time-travelling human, on emerging from the Tardis, might need a good pullover, but not modern Arctic gear. Overall the temperature gradient between equator and pole was enormously – by some forty degrees or so – smaller than it is today. Quite how was this heat balance maintained, on a spherical planet with a near-circular orbit that gets most of its heat from the parent star?

There have been quite a few explanations put forward – sometimes, it feels, a little hopefully. Could the oceans have redistributed heat more efficiently around the planet then than now? That idea does not square with the thinking-through of the Cretaceous oceans by that modern-day polymath Bill Hay, who plausibly sees them as having been rather sluggish as water masses go, prone to phases of stillness and stagnation (as the rocks certainly suggest), and rather inefficiently circulating via evaporation-driven currents and storm-stirred 'mesoscale eddies'[6]. So – they were quite unlike the more dynamically racing waters of today's oceans, driven by cold dense waters pouring down from the polar regions, and therefore not so plausible as a gargantuan planetary heat transport mechanism.

Other possible mechanisms have been pleasingly various. Very high levels of carbon dioxide – more than fifteen times present values – perhaps? But that doesn't seem to square with the evidence slowly emerging, from admittedly fiddly and difficult proxy evidence, for past carbon dioxide levels, which suggest higher but not *vastly* higher levels than today. Or possibly other greenhouse gases? – well, it's a thought. Those polar forests themselves? They would reflect much less light and heat than ice, for sure, but perhaps an insufficient mechanism in themselves. It has been quite a problem, and much quoted in the business of trying to make effective reconstructions

[4] My brief foray into the web to chase down a source for this intriguing suggestion drew a blank.

[5] But see Aze *et al*. (2014) on when things did get uncomfortable.

[6] Hay (2008) – and if you need evidence of the polymathematicality, then see his scholarly entertainment (2013).

of the climate of the past. So it might be worth considering one of the newer candidates as mechanism to regulate the Cretaceous world – which is where the blue skies come in.

Or rather – for in this narrative style one might be allowed to cheat a little – their converse, via the nature of clouds. This has recently been explored for both the Cretaceous and equally warm – if not warmer – conditions for that now much-studied hyperthermal event that provides a neat boundary between the Paleocene and Eocene epochs[7]. Assume then, that the air in those emphatically pre-industrial days was not as filthy as it is now, so that there were fewer nuclei for liquid cloud droplets to condense on. Thus, there were fewer – but larger – liquid cloud droplets, which grew more quickly and then fell more quickly out of the sky as rain. With shorter-lived clouds, less short-wave radiation from the sun was reflected back into space. Factor this into the computer models, and the polar regions are warmed substantially – and that happens at more realistic carbon dioxide levels – twice present levels rather than fifteen times.

A warmer and sunnier high-latitude Cretaceous, then? Well, that might be the loose and poetic interpretation. Not only that – with the water cycling quickly through the atmosphere via those large liquid cloud droplets, instead of hanging there within dull and interminable low cloud – the climate was one with plenty of rainfall too to support those lush forests. Though one factor might have kept the rain down a touch. Pick through a nicely preserved Cretaceous forest – for instance one that has been preserved in volcanic ash that rained out of the sky, as happened at what is now Wyoming, one dramatic day 73 million years ago[8]. The haul will show fewer flowering plants than today (and those will have fewer veins on the leaves), and a lot of gymnosperms and ferns. Overall, that will mean less transpiration than would be produced by an equivalent amount of modern vegetation, so the sun's heat, instead of being spent on lifting a lot of water as vapour up into the air, will instead go into warming the ground. And with less water being hoisted into the sky, there will therefore be less cloud and – more blue skies.

It sounds heavenly. With the blue skies smiling down, one might then seek to test another part of Irving Berlin's hypothesis (in the third stanza), that once the grey skies were no more, there would be *blue birds, singing a song* (indeed, *all day long* – to show that the great man did not spurn even the most obvious of rhymes). The birds were certainly there in the Cretaceous, with an ever-increasing flock being recognised, from the *Bohaiornithidae* to *Zhyrhaornis* (not forgetting *Zhongjianomis*, *Zhongornis* and *Zhouornis*). The singing, and the stamina, we take on trust – but were these early birds blue?

Astonishingly, one can begin to work this kind of thing out, as palaeontological analysis[9] ventures into realms that are now becoming almost familiar, albeit that not so long ago they would have been regarded as absurd. Both fossil birds and their earthbound saurian cousins have yielded fossil feathers; that is not so surprising, especially when one considers that these don't quite qualify as soft tissue (and that what is now the somewhat disputed 'first bird', *Archaeopteryx*, first made its presence known via a single feather). But some of these feathers from that treasure

[7] Upchurch *et al*. (2015) – and this is where one might find reference to all those other ways of gently heating a Cretaceous world – and Kiehl and Shields (2013) for the Paleocene–Eocene event.

[8] The remains were picked through in marvellous detail by Scott Wing and colleagues (2012). They preserve not just morphology but a vivid immediacy, as some of the preserved leaves seem to have been shed ('traumatically abcissed') in response to the eruption, and some are covered with a sprinkling of biotite crystals.

[9] Zhang *et al*. (2010).

trove of the Jehol Formation of China are well-preserved enough to have yielded those pigment cell-bearing organelles, melanosomes. A good deal of discussion is devoted to establishing that the fossilized structures are melanosomes and not, say, stray bacteria that became fossilized (from their structure, arrangement, position within the feathers and so on). With that nailed down, distinctions are then made between more or less spherical phaeolomelanosomes (carrying reddish-brown to yellow colours in modern birds) and the more rod-like eumelanosomes (giving grey to black colours). Thus, these early birds and their non-avian kin were allotted grey/black and red stripes (the latter being, more precisely, 'chestnut to rufous tones'). So, there's still no sighting – as far as I'm aware – of a blue bird in the Cretaceous: an excuse for further research if ever I heard one.

The connection with human emotions is rather more complicated. Far away and long ago, blue birds (taxonomic affinity unknown, apparently) were symbols of happiness to the Chinese people of three millennia back. More specifically, bluebirds (as opposed to just blue birds) are North American members of the thrush family that belong to the genus *Sialia*, and to the Navajo people they were animal spirits associated with the sunrise (and so a good thing, to be celebrated in song). It's appropriate therefore that there is an American popular song *Bluebird of Happiness* dating from the 1930s (Peggy Lee sensibly seems to have steered well clear of it[10]). But there's serious biogeographic challenge in another song, *There'll be Bluebirds Over The White Cliffs of Dover*, as made famous in wartime by Vera Lynn – for the bluebird isn't native to Europe. It doesn't seem likely that it will make the grade as an invasive any time soon either, given that the European house sparrow is currently vigorously elbowing it out of prime nestbox sites in its home territory, much to the dismay of the local bird-lovers.

The taphonomy is no more straightforward. The Smithsonian Institution helpfully provides information on what makes a feather blue[11]. It's somewhat more subtle than reflecting particular types of melanosome morphology. Cell death inside the blue feathers as they grow leads to desiccation of the structure and a spaghetti-like microstructure of keratin molecules and air. This then acts to make red and yellow wavelengths cancel each other out, while amplifying blue ones – so the visible effect is structural to the feather rather than being the result of pigment blobs. Quite marvellous – but is it fossilizeable? That's a question clearly to be added to the Cretaceous research agenda.

Can one take these kinds of ideas into other times? There's no reason that the Cretaceous should have all the attention, just because it has the biggest dinosaurs. We can go back before dinosaurs, before forests, before trilobites, and even before the mysterious Ediacarans. The mists of time that may be illuminated – or perhaps summoned – here are in the Precambrian. More precisely, between 720 and 635 million years ago, in the Neoproterozoic, where one enigma was finishing, and another one starting.

The first enigma shall remain firmly enigmatic here. It is the 'boring billion', that outrageously large span of time following the early Proterozoic ice ages when (and here is the mystery) not very much happened on Earth. Those early ice ages were at least accompanied by a prime suspect for their initiation – the 'Great Oxidation Event' of a little under two and a half billion years ago, when photosynthetic organisms evolved and began releasing that dangerous stuff, free oxygen,

[10] … and focused instead on the more rewarding *Bye Bye Blackbird*, making (quite unsurprisingly) a classic out of it.

[11] <**http://www.smithsonianmag.com/science-nature/why-are-some-feathers-blue-100492890/?no-ist**>.

into the atmosphere. One of the many effects triggered by this shift in chemistry was oxidation of most atmospheric methane (which before that time could have comfortably accumulated in the air). Remove that powerful greenhouse gas and the Earth can be cooled quite effectively, so reason enough for an ice age. It's a little like reading a detective story that starts by the butler being found standing over the body of the deceased lord of the manor, a guilty look on his face, with pistol in one hand, stiletto knife in the other and a bottle marked 'poison' protruding from his waistcoat pocket[12].

It's the following billion-plus years that are the problem. The Earth came out of the glaciation (somehow) and then placidly went about its business for most of the rest of the Proterozoic. Things did happen, of course. Continents drifted, oceans changed shape, volcanoes small and large erupted, and the odd large meteorite plunged to ground. But the Earth system – as much as one can tell from the carbon isotope traces and evidence (absent) of extremes of warmth and cold – remained as imperturbable as the face of one of the more superior butlers (who, in the event of a deceased duke, would have got their alibi in place not just *pronto* but *pre-mortem*). Extraordinary stability seems to me more of an enigma than extraordinary change, given all the ills a rocky planet is prone to.

It's the termination of the boring billion that has, at least, something that the baffled palaeontologist can insert teeth into. That almost interminable stability terminated, and indeed dropped off a cliff as the 'Snowball Earth' glaciations of the Sturtian and Marinoan began, a little over 700 million years ago. What pushed climate, complete with those carbon isotope ratios, over the edge? Various ideas have been put forward, with weathering of the continents or of a pile of flood basalts prominent among them. But why *then* – given that continents had weathered and basalts had flooded, too, during the boring billion?

One might look to the skies again, as George Feulner and colleagues recently did. A good deal of the cloudiness above oceans today is due to dimethyl sulphide (DMS), which oxidizes to various sulphur compounds that act to seed water droplets. Dimethyl sulphide itself comes from an even more syllabically – and acrononymically – endowed compound, dimethylsulphonopropionate (DMSP), which is produced by eukaryotic marine algae. They churn out, indeed, more of the stuff than volcanoes do. So – potentially a powerful cloud-making and globe-cooling machine – if it did start up just before the Snowball set in. But how could one tell?

Feulner & co have had a go at this conundrum, by invoking all the dark arts of modern palaeontology. In as much as one can recognise a eukaryotic organic-walled microfossil from a prokaryotic one (and the latter stretch way back into the mists of tedium), these seem to have become more abundant and diverse about 800 million years ago. One can look at modern forms, clearly seen both to possess a nucleus and to pump out the DMSP, and use them to construct a molecular clock; this again suggests 800 million years. There are biomarkers to be searched for, that indicate sufficient eukaryotic algae to leave a trace in rocks. Here the figure quoted is 742 million years ago, alarmingly close to the beginning of the Sturtian glaciation. One can go further by finding the most prolific modern DMSP producers (alveolate protists and haptophyte algae, if you're interested), considering enzymatic pathways, and then constructing a time-calibrated phylogenetic tree. The proto-haptophytes, at least, work out by this means to have arrived in pre-Snowball times.

[12] Who knows? – when the investigations are finished, he really may be carted off to the clink.

As circumstantial evidence goes, the case for the timing of the cloud-making algae seems plausible. But could the arrival of a new type of planktonic cell have really tipped a long-stable planet into climatic turmoil? Here the snazzy palaeontology is joined by some equally ultra-contemporary climate modelling. The scenarios run with cloudiness typical of eukaryote-free oceans would need implausibly low levels of carbon dioxide (a miserly 10 ppm) to bring in Snowball conditions. But add the algae and the clouds they bring with them, and 100 ppm carbon dioxide will do the trick.

An open and shut case? Well, hardly. In the world of models, trace markers and phylogenetic inferences, there still seems to be a way to travel before reasonable certainty can be obtained. But it's an intriguing and imaginative piece of detective work. One can imagine even the smoothest of the butler clan putting on a sickly grin and asking to see his lawyer. Taking the inferred appearance of DMSP-producing algae as trigger for Snowball Earth, the authors then pursue that logic by suggesting that the absence of these cloud-creators maintained the eerie palaeoenvironmental calm of the billion previous years. That may be a touch optimistic, but it puts a planetary penchant for blue skies on a time-scale that might have made even the prolific Mr. Berlin think twice before sitting down at the piano.

Blue skies do not always smile upon those below. Things can come out of the blue, too – and these may be of quite different demeanour. The inhabitants of the North and Norwegian Sea coastlines of 8,150 years ago, quietly going about their business, would have had little inkling that they, and their small and fertile world, were about to be smashed flat by a wall of water so thick with sediment that it would have resembled fast-moving wet concrete. It would have been of little comfort to them that the mossy glade, in which they may have been reclining, would come to betray how great their calamity had been – or that its fossilized remains would be pressed into service to maintain the tenuous link between blue and green of this narrative.

The tragedy had begun an hour or so earlier, as a mass of sediment wider than Scotland collapsed down the continental slope of Norway, triggering a tsunami that left washed-in sheets of sediment along the Norwegian and eastern Scottish coasts, and on the facing coast of Greenland too. The Storegga Slide – as, much later, it was termed – has come to be one of the classics of its destructive kind.

The scale of that destruction – of human destruction, at least – was here dependent on timing. The people of the Mesolithic, then, lived to an annual cycle. In the summer and early autumn they would have ventured into the mountains, to hunt reindeer. In the autumn, they returned to the coast, to their settlements on the low ground, to see out the winter. What time of year would the wave have struck?

Knut Rydgren and Stein Bondevik have considered this question. There is evidence on the ground – they quote earlier studies that showed that tsumani deposits were swept on to lake deposits, something that would not have happened if the wave had been in mid-winter, when the lakes were ice-covered. What might help pin the timing down more closely? Entombed tree fruit, perhaps, or the growth rings on fish vertebrae? Unreliable, they considered, because the tsunami could have reworked long-dead material. Preserved moss, though, might tell a truer story. They found fragments of *Hylocomium splendens* among the debris. It's a moss that grows in regular cycles, adding new segments on an annual pattern, that then increase in size through the year.

The specimens in the tsunami sands still preserved some chlorophyll, suggesting that they were alive when they were torn out of the ground and buried. The growing tips of the samples were too big to represent the height of summer, their maturity indicating that it was well into autumn, sometime between October and December, when the wave came in. It's a fateful find. By then, the people would have come down from the hills, to prepare to hunker down until spring came again. With considerable restraint, Rydgren and Bondevik add that for any survivors, that winter – with boats, houses and supplies destroyed – must have been "very difficult"[13].

Exceptional preservation is one thing, and exceptional intuitive deduction is another, and sometimes they come together. So how far can an old song stretch? Higher than the Moon, it turns out, and by far. Recently came the news that the newly-astonishing (if still unjustly demoted) planet Pluto has – above its ice mountains and solid nitrogen plains and mysterious dragon-scale topography – an atmosphere of the purest, brightest blue[14]. The sky, we find ourselves now assured, is not the limit at all.

Jan Zalasiewicz
University of Leicester

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[13] In keeping with the Terry Pratchett valedictory thread, for a description of the aftermath of a tsunami, there are few passages in literature more soberly judged than the opening of his novel *Nation*. Even for the man who invented Death, and who had him at various times eat curry and wear a straw hat, he knew when not to play things for laughs.

[14] <**http://www.bbc.co.uk/news/science-environment-34481347**>.

R for palaeontologists
5. Statistical tests Part 3 – Statistical models continued

Introduction

Previously in this set of articles focusing on using R to perform statistical tests I introduced the topic of statistical models and how to apply a simple linear model to two continuous variables, a linear regression. As I mentioned previously, statistical modelling is a wide subject that could easily fill the next couple of years' worth of articles. Therefore, in this last article on statistical methods I will be covering two other commonly used statistical modelling techniques, multiple linear regression and Analysis of Variance (ANOVA).

Multiple linear regression

In the regression example, we were interested in examining the relationship between our dependent variable against a single independent variable. However, there may be occasions when you have more than one independent variable that you want to include in your model; here you will need multiple linear regression.

To illustrate how to implement a multiple linear regression we will turn to the *extrinsic* dataset that we've used regularly throughout this series. The first step, as always, is to load the file into the R environment creating the new variable **extrinsic**:

```
extrinsic <- read.table(file="extrinsic.txt", header=TRUE)
```

In this case we want to know if there is a relationship between variables representing the amount of rock record sampled (*Rock.area_sum*), the evenness of environmental sampling (*evenness*), and environmental fluctuations (*Temperature* and *CO2*) with a measure of sample-corrected diversity. The latter will be the dependent variable in this study and has been calculated using shareholder quorum subsampling method (SQS) of Alroy (2010).

If you open up the entire *extrinsic* dataset you will see that there are missing entries in some places. A quick and simple fix for this issue is to remove the most recent time-bin, which in this case is the last row in the dataset that has 51 rows, so we can simply ask for rows 1 through to 50 and place this in the new variable **extrinsicLM**:

```
extrinsicLM <- extrinsic[c(1:50),]
```

In this case, the selecting of specific rows works with this dataset; however, it is more likely that gaps in a dataset will not be so evenly spaced. Happily there is a quick way to retain all the rows with complete entries for the columns you are interested in. The function **complete.cases**, used as follows, will return an array detailing which rows are complete (marked as TRUE) and those which are not (marked as FALSE):

```
complete.cases(extrinsic)
```

Remember that the format for selecting a section of a dataframe is with the row followed by the column such as dataframe[row , column]. So, in order to get the rows that are complete, we can place this logical statement into the row part of the dataframe:

extrinsicLM <- extrinsic[complete.cases(extrinsic),]

To clarify this operation: the R command **complete.cases(complete)** converts your data to an array containing values that are either TRUE or FALSE, and returns only the rows that are marked as TRUE. As an aside, if you have a much larger dataset and need to know where your missing data are, and therefore want R to return the rows of a dataset where there are missing data, you can add an exclamation mark '!' in front of the command – **!complete.cases** – or add a logical conditional statement such as:

extrinsic[complete.cases(extrinsic) == FALSE,]

If you run this, you will see that R will return the rows with any missing data; in this case there are three such rows.

Anyway, getting back on track, now that we are selecting the rows we want we can also use the change to restrict the data to just the columns we want to examine. This is not necessary, but can be useful when working with and plotting large datasets. So now we will create a new variable, **extrinsicLM**, containing just the rows and columns that we need for this analysis, using the following:

extrinsicLM <- extrinsic[complete.cases(extrinsic), c("SQS", "evenness", "Temperature", "CO2", "Rock.area_sum")]

As always, plot your data first to get an idea of any issues with the dataset such as outliers, or if there are any trends within the dataset. A handy function for creating multiple scatter plots when you have a lot of variables in your dataset is **pairs**; this will create bivariate plots for all pairs of variables that you are interested in:

pairs(extrinsicLM)

As we have already restricted the file to the variables we want, this makes for an easy-to-read five by five grid of scatter plots (Figure 1). From this you can see that, when comparing our diversity value (first column, *SQS*) with our other variables, the *evenness* variable at first glance appears to show a positive relationship while other combinations show little relationship, as in the case with *SQS* and *Temperature* or a non-linear relationship as in *Temperature* and *CO2*.

Right, moving on to the analysis, the ultimate aim for a multiple regression is to determine which combination of independent variables can be best used to predict our dependent variable, here a measure of sample-corrected diversity. So, the first step is to include all of the variables in the model formulae. Here we can use the same function we used for the linear regression, **lm**, and to make it easier to follow we can just use the column names we wish to include, providing we tell R where the data are using the argument *data*:

model.lm <- lm(SQS ~ evenness + Temperature + CO2 + Rock.area_sum, data = extrinsicLM)

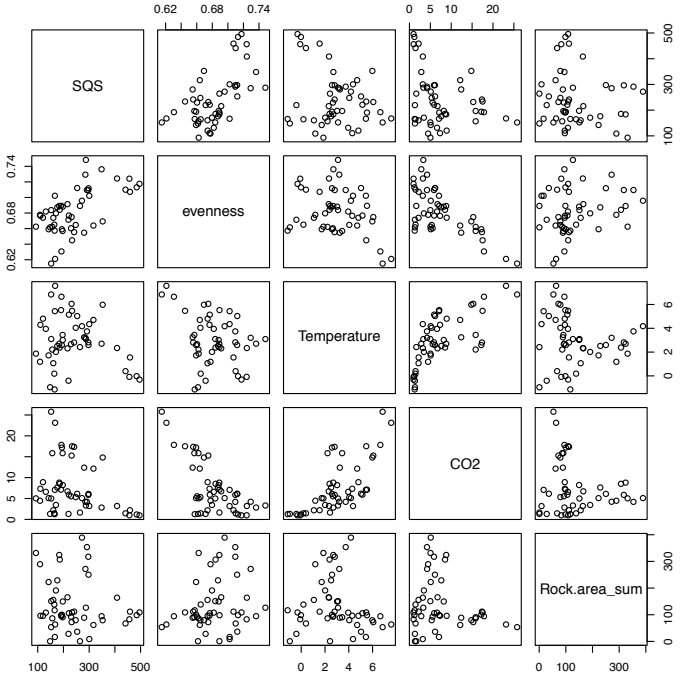

Figure 1. A series of bivariate plots representing all pair-wise combinations of the variables from the extrinsic *variables of interest in the multiple linear regression analysis.*

The function **summary** can be used to get a description of this model:

summary(model.lm)

Call:

lm(formula = SQS ~ evenness + Temperature + CO2 + Rock.area_sum,
data = extrinsicLM, na.action = na.exclude)

Residuals:

Min	1Q	Median	3Q	Max
-121.334	-47.620	-8.036	44.181	182.580

Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-1419.7219	369.0615	-3.847	0.000391 ***
evenness	2424.6739	535.0964	4.531	4.62e-05 ***
Temperature	-4.9951	7.5796	-0.659	0.513396
CO2	5.0093	3.1368	1.597	0.117605
Rock.area_sum	-0.1992	0.1074	-1.854	0.070561 .

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 69.95 on 43 degrees of freedom

Multiple R-squared: 0.3717, Adjusted R-squared: 0.3132

F-statistic: 6.359 on 4 and 43 DF, p-value: 0.0004117

You can see from the last line here that the *p*-value shows that there is an overall significant relationship between our dependent variable and independent variables. However, not all of the variables fit as well if we examine the last column under "Coefficients" which shows that *Temperature* and *CO2* variables are not significant. As we want there to be only significant variables in the model we can systematically remove them one at a time, starting with the least significant variable, *Temperature* in this case ($p = 0.51$). Here we will use the same syntax below but removing the relevant variable:

model.lm2 <- lm(SQS ~ evenness + CO2 + Rock.area_sum, data = extrinsicLM)

If we now call for the same **summary(model.lm2)** we will see that the model has become slightly more significant overall, but the *CO2* variable still remains as non-significant so we can again remove this to leave just the *evenness* and *Rock.area_sum* variables:

model.lm3 <- lm(SQS ~ evenness + Rock.area_sum, data = extrinsicLM)

Finally, looking at the summary for this model (**summary(model.lm3)**) you will see that we now only have a model with significant variables, although *Rock.area_sum* is only significant with a $p < 0.1$ rather than a more acceptable $p < 0.05$. However, if we look at the adjusted R-squared values for these three models it is **model.lm2** that has the highest value, meaning that this model is explaining more of the variation seen in our dependent variable, so perhaps it is the best model overall. We'll come back to this in a moment. In summary, here we have created three models (**model.lm**, **model.lm2**, **model.lm3**) each of which represents a single multiple linear regression. However, through the sequential removal of the least significant terms we have performed a statistical technique called stepwise multiple linear regression. As a point of interest, this method is considered by some to have some significant pitfalls (Whittingham *et al.* 2006).

Akaike information criterion, an alternative method for model selection

An alternative to the approach described above is to use the Akaike information criterion (AIC), which we will come to more in later articles when I discuss comparing models across phylogenies. The AIC is a measure of the 'goodness of fit' of a model and can be used to directly compare a series of models. Importantly, this method shouldn't be used to compare models across different datasets. We can get the AIC value for each of our models by using the function **AIC** as follows:

```
AIC(model.lm)
[1]     550.7193
AIC(model.lm2)
[1]     549.2017
AIC(model.lm3)
[1]     549.9476
```

The AIC value is calculated using the following equation:

$$\mathbf{AIC = 2K - 2ln(L)}$$

Here **L** represents the likelihood of the model and **K** is the number of free parameters (explanatory variables) in the model. In essence the first parameter here (**2K**) penalises a model for being more complex, *i.e.* having more free variables. The best model is the one with the lowest AIC value, so in the case of the three models we've already fitted you can see that **model.lm** has the highest value and therefore the least fit to the data when compared with

the other two models. Of **model.lm2** and **model.lm3** the former has a slightly better fit; if you remember from our stepwise removal of values, this is the model that also has a higher adjusted R-squared value.

Rather than removing each variable in turn, there is a function that will automate this and provide the model that fits best; it is called **step**, and for this you only require the model with all of the variables included.

model.lm.step <- step(model.lm)

This will return a lot of information as it tries out various combinations of variables, but it is the output at the bottom that we are interested in. Here it provides the formula for the best model, which you may notice is the same as we used for **model.lm2**.

Currently we have examined models containing four, three and two independent variables by successively removing the least significant variables in turn. However, if we look at **summary(model.lm3)** that contains two independent variables we can see that the *evenness* variable is far more significant than the *Rock.area_sum* variable. In this case it may be worth checking to see whether a model containing *evenness* as a sole independent variable may be a better fit that the current best fit model, *i.e.* **model.lm2**. So now we can follow the procedure from before and create the variable **model.lm4** containing the new model:

model.lm4 <- lm(SQS ~ evenness, data = extrinsicLM)

Then use **AIC** to get the Akaike information criterion value for this new model:

AIC(model.lm4)
[1] 551.3252

With this value we can now see that, not only is this not a better fit than our current best model that has an AIC value of 549.2017, but this new model is a lower fit than a model that includes all of the variables, **model.lm**.

It should be noted that using AIC to compare models does not operate in the same way as testing a null hypothesis. Therefore, if all the models are a poor fit then you may only select the best of a bad bunch, so care must be taken when using this method.

Analysis of Variance (ANOVA)

The second topic I want to cover this time around is Analysis of Variance, or ANOVA, a family of statistical tests that are used when your dependent variable(s) are categorical (data are classed in groups such as gender) rather than continuous (measurements on a continuous scale such as height or weight) as it would be if you were using a regression analysis. There are several other types of analysis that are related to ANOVA which I will not cover at the moment, with increasingly long acronyms such as Analysis of Covariance (ANCOVA), Multivariate Analysis of Variance (MANOVA) and Multivariate Analysis of Covariance (MANCOVA).

In the case of ANOVA, let's say you've collected a series of measurements across several samples, such as different taxa, and you want to know whether they differ significantly; in this case using an ANOVA would be the appropriate method. The null hypothesis (H_0) for an ANOVA is as follows:

H_0: all samples are taken from populations with equal means

As with all statistical tests there are a series of assumptions that the data must adhere to in order for the results of that analysis to be considered valid and accurate. For ANOVA they are as follows:

[i] The data must be normally distributed.

[ii] All the samples should have the same variance.

[iii] The samples are randomly selected and random of each other.

There are two commonly used ANOVA tests, one-way and two-way ANOVA. The distinction between these is that in the one-way ANOVA there is only one independent variable, in this case the different taxa we are comparing, whereas in the two-way ANOVA there can be multiple independent variables. In this latter case you may wish to know whether there is an interaction between two variables on your dependent variable. Here I will focus solely on the one-way ANOVA. We will ask the question whether there is a significant difference in the size distributions of four taxa using the dataset called *anova.txt* available at:

<**http://cdn.palass.org/r_for_palaeontologists/article_4/anova.txt**>

As always, the first step is to load the file into the R environment, saving the data as the new variable **anova** (see the first article in *Newsletter* **85** if you are unsure of how to go about this):

```
anova <- read.table(file="anova.txt",header=TRUE)
```

This file contains a matrix of two columns representing the size and taxon name, respectively, for 200 individual specimens.

Just a reminder: you can have R return the names of the columns of the variable **anova**:

```
names(anova)
[1]     "size"      "taxon"
```

and if you want a description of the contents of each of the variables you can use:

```
summary(anova)
```

This will provide the five-point summary (*i.e.* minimum, 1st quartile, median, 3rd quartile, maximum) plus the mean value for the *size* variable and the number of occurrences of each taxon name in the *taxon* variable; in this case you can tell that there are fifty rows for each of the four genera represented here.

```
      size          taxon
Min.   :10.41   Taxon A:50
1st Qu.:20.26   Taxon B:50
Median :24.28   Taxon C:50
Mean   :24.65   Taxon D:50
3rd Qu.:28.52
Max.   :39.81
```

The next step should always be to plot your data to check for any anomalies, *i.e.* outliers. Given that here we have a series of categories containing a continuous variable, a boxplot (or box and whisker) is the most appropriate way to display these data. Below is the code to produce the

boxplot in Figure 2 that shows the distribution of sizes of our four taxa. It should be noted that the same result can be achieved if, rather than using the function **boxplot**, you use **plot** instead.

boxplot(anova$size ~ anova$taxon, xlab="Taxon", ylab="Length", notch=TRUE)

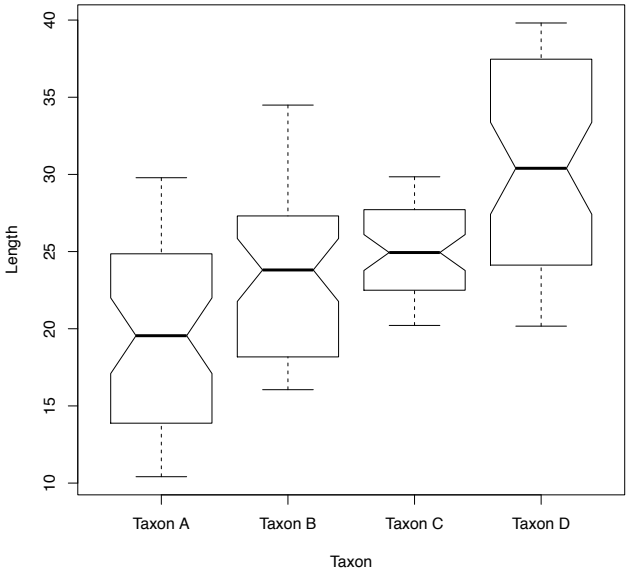

Figure 2. Boxplots showing the size distribution of the four taxa contained within the variable anova.

ANOVA, the *t*-test and Type I errors

Before I go through the implementation of the one-way ANOVA, I want to take a moment to explain in greater detail one aspect of the ANOVA. As I mentioned, the ANOVA test is used to see whether there are significant differences in the mean values across two or more populations. If this sounds familiar, it may be because it is the same hypothesis tested when using a *t*-test (see Part 1 in *Newsletter* **87**). Therefore, performing an ANOVA on only two populations is equivalent to using a *t*-test on the same data. So why don't we just use a *t*-test on three pairs of *anova* datasets, for example, (*e.g.* Taxon A/Taxon B, Taxon B/Taxon C, Taxon A/Taxon C) and that should provide the same result, shouldn't it? The reason that it won't is that, by performing separate *t*-tests, we risk inflating the probabilities of making a Type I error. This, in simple terms, is when you determine that the results are significant when in fact they are not. This is opposed to a Type II error, whereby a genuine effect is rejected when it shouldn't have been.

Coming back to our three-population problem, if we use a significance (or alpha) value of 0.05 (*i.e.* p-values < 0.05 are considered significant), in each case the chance of not making a Type I error is 0.95. Because we have three comparisons in this case we multiply the probabilities together, *i.e.* 0.95*0.95*0.95, which equals 0.857. So, in order to get the probability of making a Type I error we subtract this value from 1, which gives a new alpha value of 0.143 or 14.3%. This is much higher than most scientists would require for an acceptable result. However, when using the ANOVA function in R it controls for this effect and keeps the alpha value at 0.05. It is

important to say here that while you can never completely eliminate the chances of making a Type I error you can have some control over the likelihood of it occurring, therefore controlling that your results are not simply down to chance.

Back to ANOVA

Now, getting back to running our ANOVA analysis on the four taxa. The model formulae are the same as for the linear regression with the dependent variable first, in this case *size*, followed by the independent variables, here *taxon*.

```
aov.mod <- lm(anova$size ~ anova$taxon)
```

You can use the function **aov** to the same effect:

```
aov.mod <- aov(anova$size ~ anova$taxon)
```

We can also run the same model by using just the variable names, providing we tell **aov** the name of the dataset:

```
aov.mod <- lm(size ~ taxon, data=anova)
```

The next step is to use the function **anova** to get the ANOVA table which produces all of the test-statistics:

```
anova(aov.mod)
Analysis of Variance Table
Response: size
```

Df	Sum Sq	Mean Sq	F value	Pr(>F)	
Taxon	3	3151.9	1050.64	37.531	< 2.2e-16 ***
Residuals	196	5486.8	27.99		

```
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The two important numbers here are the test statistic (F value) and the *p*-value. You can see from this result, with a *p*-value < 0.05, that across the *anova* dataset there are significant differences amongst the four taxa. Obviously this does not tell you whether all the pairs of genera are significantly different, so we can apply Tukey's honestly significant difference (HSD) test using the function **TukeyHSD**:

```
TukeyHSD(aov(aov.mod))
Tukey multiple comparisons of means
  95% family-wise confidence level
Fit: aov(formula = aov.mod)
$taxon
```

	diff	lwr	upr	p adj
Taxon B-Taxon A	4.350773	1.608800	7.092745	0.0003348
Taxon C-Taxon A	5.642761	2.900789	8.384733	0.0000016
Taxon D-Taxon A	11.125072	8.383100	13.867045	0.0000000
Taxon C-Taxon B	1.291988	-1.449984	4.033961	0.6143048
Taxon D-Taxon B	6.774300	4.032327	9.516272	0.0000000
Taxon D-Taxon C	5.482311	2.740339	8.224284	0.0000033

This will print a list of all the different pairs of taxa along with corrected *p*-values (p adj) in each case. According to this result, all the different pairs of taxa are significantly different with the exception of Taxon B and Taxon C. If we look again at Figure 2 any lack of overlap in the notches

that are placed at the median signify a significant difference. Taxon B and Taxon C show a lot of overlap in the notches whereas this is not true of all other taxon pairings.

As with the regression analysis in Part 2, *Newsletter* **89**, we should also check that the result doesn't violate the model assumptions (Figure 3). Is this the best model to use for this data?

```
par(mfrow=c(2,2))
plot(aov.mod)
```

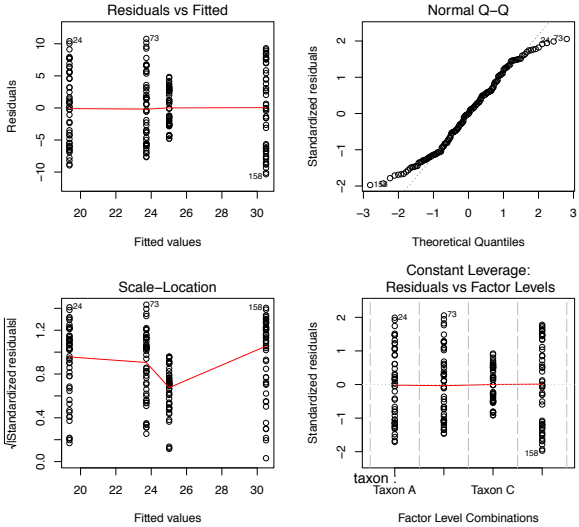

Figure 3. The four model-checking plots from the fitting of a one-way ANOVA model to the anova *dataset.*

Summary

By the end of this second article concerning statistical modelling I hope that you will be at home working in the R environment and be comfortable loading in your own data and conducting basic statistical analyses ranging from one- and two-sample tests to correlations and modelling. For the moment this is where I will leave these kinds of analyses; however, they will no doubt crop up again from time to time. At the very least, my primary intention so far has been to convince anyone who has been wary about learning the art of programming that it is not as complicated or as scary as you may have once thought, and that it doesn't take a lot of work to perform the most basic of tasks.

In the next part of this series I will move into applied methods that are commonly used by palaeontologists, such as data visualization, phylogenetics and multivariate methods. Up until now I have avoided the use of the many packages that are currently available for R users, choosing to restrict my discussion to functions that are available with the basic setup of R. Starting with the next article I will begin to explore some of these packages that make more specific analyses available to us.

Mark A. Bell
University College London
<mark.bell521@gmail.com>

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Rock Fossils

I like heavy metal and fossils. Apparently I am not alone; palaeontology and metal and punk music are all quite esoteric disciplines, but as the touring *Rock Fossils* exhibition will attest, these are worlds that collide more often than you might expect. From a trilobite genus with all of its species named after the members of The Sex Pistols, to prog-metal concept albums about the Proterozoic (The Ocean's *Precambrian*), it seems many palaeontologists love heavy music and that the feeling is mutual.

Naming fossils after rock musicians is not a new phenomenon, with the Permian mollusc *Amaurotoma zappa* named for Frank Zappa in 1972. Frank Zappa has since been a popular choice for new species names, with at least five taxa (one of which is a fossil) named in his honour since. Some palaeontologists are prolific punk fossil describers, with Greg Edgecombe of the Natural History Museum in London claiming the aforementioned Sex Pistols trilobites as well as four species in the genus *Mackenziurus* named after the Ramones. Greg Gaffin blurs the

Photo: Esben Horn.

A model of the polychaete Kalloprion kilmisteri*, named for Lemmy Kilmister.*

lines a bit. He is a founding member of Los Angeles punk band Bad Religion, has lectured on courses in palaeontology at UCLA and also has a dinosaur named after him by Jingmai O'Connor (IVPP). I am also guilty, having recently submitted a paper on a fossil polychaete worm named for Henry Rollins of 80s punk band Black Flag. In fact, it was with polychaetes that the *Rock Fossils* exhibition started. In 2012, Mats Eriksson (Lund University) named a particularly large and mean-looking polychaete jaw apparatus *Kingnites diamondi* after Danish heavy metal legend King Diamond. Jesper Milàn (Geomuseum Faxe) and Esben Horn, a model maker from Denmark specialising in palaeontological and zoological reconstructions, were both pretty amused by the King Diamond worm and, after exchanging a few emails with Eriksson, Horn agreed to make him a model of it. In 2006, Eriksson had also named a polychaete jaw for Lemmy Kilmister, one of Horn's favourite musicians, and Horn made a model of that worm too.

Milàn decided to display the models at Geomuseum Faxe in 2013 and, after searching the literature, found enough fossils named for rock and metal musicians to make an entire exhibition. Milàn was keen to showcase the three parts of the story of the fossils, the organisms themselves, the rock star eponyms and the scientists behind the names. Milàn's favourite quote spawned of this process is from Greg Edgecombe, who argued that naming species in a genus after all members of the same band was not only quite logical, but also "might mildly annoy my older colleagues", highlighting pretty much the only way that systematic palaeontology can harness the rebellious spirit of punk.

Photo: Esben Horn.

Part of the Rock Fossils *exhibition created by Jesper Milàn.*

The exhibition attracted the attention of several of the musicians, with Mark Knopfler offering to buy the model of *Masiakasaurus knopfleri,* a therapod named after him in 2001 by Scott Sampson (Denver Museum of Nature & Science), and loan it to the exhibition for four years. Like many of us, Mark Knopfler didn't have room for a full size therapod skeleton in his house, so Horn made a reconstruction that can be stored outdoors. King Diamond agreed to come to Faxe to unveil the model of *Kingnites* and although he is easily recognised onstage by his make-up, was much less distinctive without it, especially at an exhibition populated with metalheads. As a result Milàn

didn't initially recognise him, even asking Diamond if he was planning on going to his own gig later that week, much to his amusement.

Naturally, the exhibition caught the attention of the international music media and soon Oslo's Natural History Museum wanted to borrow the exhibition. It has been on the road ever since, next visiting Bern where it was greatly expanded thanks to the efforts of Achim Reisdorf (University of Basel), and featured a sea urchin named after Swiss folk metal band Eluveitie. The exhibition most recently visited the Fossilienmuseum in Dotternhausen, coinciding with the Bang Your Head metal festival nearby. The organisers are keen to keep the exhibition on the road and are currently in talks with other museums so that they can continue bringing fossils and metal to the masses. Innovative flight cases help with the transport of the exhibition giving the feel of a full-scale rock tour, which are then transformed into fossil display cases.

Photo: Esben Horn.

King Diamond and the model of his namesake Kingnites diamondi.

The metal–palaeo crossover has even helped to create some new music, with Eriksson teaming up with Tomas Lindberg (vocalist of Swedish melodeath pioneers At the Gates) and American industrial black metal band Invertia to produce "Deep Time Predator", a single based on *Kingnites diamondi*. This single was produced as part of 'Science Slam Sonic Explorers', a transatlantic collaboration between scientists (led by Reisdorf) and Kurt Gluck (aka DJ and bassist Submerged of Ohm Resistance) handling the audio and visual side.

So the *Rock Fossils* exhibition is alive and kicking (and may be coming to a museum near you), and there is an increasing prospect of your favourite metal band writing a tune about your favourite fossil. What a time to be alive!

Luke Parry
University of Bristol

Exhibition website and Facebook page:

<**http://www.10tons.dk/rock-fossils-on-tour**>

<**https://www.facebook.com/rockfossilsontour**>

Adopt-A-Fossil: crowdfunding to support non-vertebrate collections

Overview

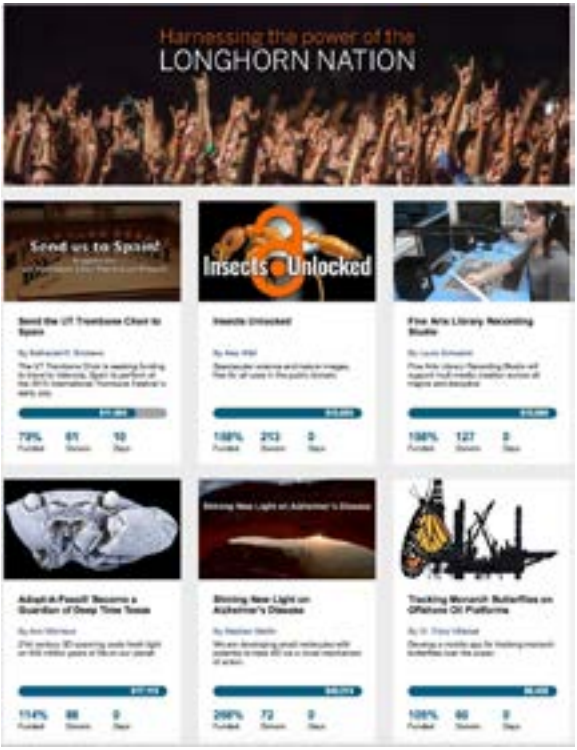
Earlier this year we launched an Adopt-A-Fossil crowdfunding drive at the University of Texas at Austin, as a potential solution to the problem of shrinking traditional funding sources for non-vertebrate palaeontology collections. The Non-vertebrate Paleontology Laboratory is known for its rare and important specimens and was founded in 1999 to provide a unified hub for the development of this vast repository of over four million specimens drawn from a wide array of geological research. It is the fifth largest collection in the United States.

The crowdfunding project was the culmination of several events. First of all, we had a proposal before the NSF and it was part of the competitive CSBR (Collections for Support of Biological Research) group, so we were very uncertain as to its potential fate. This was a proposal to rehouse specimens and improve a large area of our collection repository, home for many of our millions of fossils. Within that proposal was an outreach element to create 3D data files of representative genera and make those available for teaching purposes and to the public in general. The extra funding required for this was small in comparison to the entire proposal, but to us it was an important educational opportunity and a way of illustrating what the collection could provide. The uncertainty with respect to the NSF funding first started us looking at other options.

Second, a talk given by the former editor of *Science*, Marcia McNutt, at the annual Geological Society of America meeting in 2014 provided further inspiration. She was part of a group of speakers who addressed the status and future prospects of funding in all areas of the geological sciences. Her talk made an impression because of her focus on searching for support outside of the traditional sources. Thinking further about non-traditional ways to generate funds obviously included the idea of crowdfunding. Here we faced problems; invertebrate fossils do not have the immediate selling power of vertebrate fossils and a traditional Kickstarter within our University was not a viable option.

We discussed the larger goals of the project with our development group at the University, explaining: 1) the long-term need to develop an endowment to ensure that the collection would remain strong; 2) the need to educate at all levels to show the relevance of collections and their place in our current changing climate; and 3) the need to make easily available scientific evolution as demonstrated within the collections themselves. The third event was serendipitous and followed these discussions. The development group drew our attention to a new opportunity on campus, a crowdfunding enterprise, developed with the help of a commercial company. In essence this was a University of Texas version of a Kickstarter and was aptly called 'HornRaiser'.

The first test group of funding projects was just winding down so we wrote a proposal for a project and it was accepted for the next funding cycle. It was to be called "Adopt-A-Fossil: Become a Guardian of Deep Time Texas", promoting the idea that these were everybody's collections. The project aimed to raise enough money to buy a 3D scanner, and to train students to use it and produce a test suite of scanned fossils. Collaboration with the School of Engineering gave access



to their 'Innovation Station' where the 3D digital files could be uploaded online and printed. The fundraising ran for 45 days (the maximum allowed) and we exceeded the maximum funding request amount allowed ($15,000) by several thousand dollars. Thus, the project was a success.

Requirements

The fundraising platform included a template that each individual project had to follow. The main elements were: project title, owners with biographies, a short video promoting the project, a written description of that project and a series of donation levels, what each of those would achieve, for example, digitize one specimen, or what perk would be provided for that level of donation, for example, a tour of the repository. In addition to the web portal was a whole social media requirement, vital to this type of fundraising and the route to potential donors. Relevant e-mail lists and an active presence on Facebook and Twitter were essential ingredients. The project involved the time and expertise of many people.

Creating the project

The production of a short two-minute video based on the initial proposal turned out to be a challenge. We had been advised not to make it too professional, otherwise donors would not think we needed support. Even using familiar smartphone video equipment, the splicing, audio equalising and general presentation made quite a learning experience for us. We certainly had no problems with it looking too professional! Next, the written description needed to be

engaging and understandable to a general audience, but still convey some sense of the relevance to the expert. The text passed through many eyes, including students at all levels and even a commercial salesman. We were essentially trying to 'sell' the collections and create excitement in our audience.

The perks were fun to develop. The range of eight levels spanned from $10 to $2,000. Each level was a rank in the Linnaean classification system, and all would obtain a digital adoption certificate in addition to a specific perk. Those perks required good, interesting images of the fossils up for adoption. Multiple donors could adopt the same fossil and each certificate contained a small image of their selected fossil.

Selections of fossils were added to the description periodically along with some information

about them. Those images needed to be available in a web-accessible storage site. Updates were required and they were intended to create a place to thank the donors and keep them informed of the project progress, and these updates often provided content for the Twitter and Facebook pages. E-mail lists included current members of the lab, students and staff, research associates and volunteers, palaeontology students and faculty, and alumni of the Jackson School of Geosciences. An e-mail describing the project was sent to all of these groups, with links to the project webpage. We already had a Facebook presence but needed to develop a Twitter handle and set about creating a following and defining those to follow.

Challenges

The first challenge was software-related. The commercial platform did not handle specific perks very well and some donors found that when they changed their minds those changes were not reflected in the donation amount. There was also no clear way to state "I do not wish to have any perk". This meant that we had to re-contact these donors just to make sure. The commercial company is working to improve these aspects. A second challenge related to choosing the fossil for adoption. Illustrating choice within the description alone was totally inadequate. There was no way to include the entire suite and we were gathering the images as the project was in progress. Nor was there any way to know which fossil had been selected by the donor. The solution was to create a new page on our lab website – at <**http://www.jsg.utexas.edu/npl/outreach/adopt-a-fossil**> – and have each donor make their choice and fill out a very simple

online form. This technique worked very well. The final challenge was to get the donors to select their fossil, especially those who had donated early on when the scheme was less than satisfactory. This hampered the fulfilment of perks.

Observations

The time required to develop and run a project such as this is much greater than we were led to believe, unless your project already has a large social network and the perks are very limited. Any materials integral to the project, such as relevant images, need to be available before the project begins. Also, there are many donors who do not use social media and who do not like to be hassled with numerous e-mail updates. These may be donors who can provide substantial help to a project. Several such donors in our project were accommodated outside of the online project page. Finding matching funds from a donor ahead of the project would provide an added incentive to donate and increase the final amount raised. As we are still working on fulfilling the perks on time, our main recommendation for future fundraisers of this type would be to make these perks minimal and easily performed!

Conclusions

The critical shortage of other funding options for many research collections is unlikely to change in the near future. As the available funding remains static or shrinks, competition for those limited funds increases. It is quite feasible to raise funds using this type of platform and as institutions begin to use crowd-sourcing platforms for help to digitize collections, crowdfunding may become even more recognised in the collections environment. There are limitations, at least within our current 'HornRaiser': the amounts that can be raised are quite limited. Beyond that, however, the project serves to generate interest in the collections. It is essentially seed funding for the bigger goal to ensure that such resources are archived and accessible for all users.

Ann M. Molineux
The University of Texas at Austin

Ethics in palaeontology: problems and solutions

Recent events have again brought to the fore an issue that is omnipresent in our field: the ethics of private fossil collection, sale and research. A whole host of questions surrounding this topic, including why considering ethics is essential and what we as palaeontologists can do to prevent conflict, are more important to ask now than ever before in our increasingly international community. In my opinion, ethical considerations are important for two primary reasons: the accessibility of research materials for reproducibility, and the preservation of national cultural and historic identity.

An obvious and vital issue surrounding private collections is accessibility. Fossil materials must be available to everyone in order to have properly reproducible studies. Reproducibility is a core tenet of scientific research. A fossil that cannot be viewed by any interested member of the scientific community has no place in any peer-reviewed journal. Privately-owned fossils cannot be guaranteed to remain available for study; if they are not within a museum collection they can be bought or sold at any time. While I do not come down completely against the entire private fossil sale industry, I do firmly believe that this material should not be published on if the fossil owner is not willing to accession the specimen to a museum on permanent loan (if proper documentation can be provided). When fossils can be sold to the highest bidder, they very rarely end up in any sort of public trust.

Beyond monetary significance, fossils are considered cultural heritage of their origin nation. An item of cultural importance can be difficult to define, especially when talking about an object

Tarbosaurus bataar *on exhibit in Dinosaurium, Prague (photo Radim Holiš / CC-BY-SA-3.0 cz).*

that originated hundreds of millions of years before humans even walked the planet. But, just as geological features and unique landscapes are part of a national identity, the fossils in that environment are part of that identity as well. Exceptional fossils from China and Mongolia are intricately woven into the rich heritage of these nations and, as such, their export is illegal, creating a substantial black market for specimens. This black market prevents local scientists from expanding academic research programmes in their own countries, while also damaging the economy by limiting tourism. Mongol Baatar, the *Tarbosaurus* specimen that was nearly sold illegally but ended up being returned to Mongolia, attracted hundreds of thousands of visitors upon its return to Ulaanbaatar in 2014. These citizens are proud of the incomparable geological history of their nation. When professional palaeontologists publish on private specimens that have been illegally exported, they are promoting and supporting this damaging industry that may disadvantage citizens of these nations in a myriad of ways.

But what can we as scientists and journal reviewers do? This debate frequently kicks off and settles down with no common resolution, as there is no official law or code that prevents a palaeontologist from working on a privately-collected specimen. Academic journals are beginning to take this issue more seriously by establishing clear, firm guidelines for publication on fossil materials. In 2012, *PLoS ONE* set forth a very specific and detailed list of editorial standards for palaeontology-related submissions. They are adamant about not publishing any fossils without explicit written permission, and the specimens must be in a public museum or institution so that they are accessible to all. The journal *Cretaceous Research* states that they will flat-out reject a publication on any fossil of unknown origin without appropriate paperwork, even if it is stored in a museum. On the other hand, the only official publication criterion for a fossil in *Science* is that it is publicly available, and no note is made of permits or written permissions in their guidelines.

Groups like the Geological Society of London have recently added a section to their publishing ethics code citing the need for proof of permission for collected specimens. The Society of Vertebrate Paleontology has clear guidelines relating to what they expect from both professionals and amateurs in the field – from preserving all relevant field collection data to depositing of specimens in a facility that can be accessed by the scientific community in perpetuity. Many journals do not have specific written criteria for publication on fossil material and never request permits, permissions, or double-check the location the specimen was deposited in. It is truly up to us as peer-reviewers to carefully examine the legality, provenance and repository location of the fossils featured in manuscripts that we accept for review. We cannot assume that just because an editor has sent a manuscript out for review that it has been checked thoroughly for any of these issues. Even if a fossil has been legally exported and imported, it may still not be publicly available, hampering any future research. If we are not vigilant, papers on illegal specimens will be published and dilute the reproducibility and respectability of our field.

There is no debating that fossil export and import is against the law in certain nations, but the widely varying application of these laws makes for murky legal situations at museums worldwide. For a passionate palaeontologist it is difficult to pass over a specimen that is valuable to science, because of either a lack of documentation or a questionable legal status. If provenance can somehow be verified, which is a non-trivial and well-documented problem with privately-sold specimens, steps can be taken to create a situation in which the fossil can be accessioned into a

museum and then described in an ethical, inclusive manner.

Photo: Shaena Montanari

On fieldwork in Mongolia.

As I previously mentioned, publishing on illegally collected and exported specimens is systematically excluding researchers from countries with rich fossil deposits. We cannot over-estimate how damaging this will be to the field if it is allowed to continue. I posit that it is imperative that palaeontologists collaborate with other palaeontologists in the country of origin of whichever fossil they are studying. By doing this, international relationships are promoted and the palaeontological community can be strengthened as a whole. Including a younger generation of researchers in countries frequently exploited for their incredible fossils, like China, Mongolia and Brazil, will inspire new scientists and keep the field alive in these countries rather than homogenizing the field and transporting it all elsewhere. As palaeontologists, we need to have respect, understanding and patience when dealing with these issues so that we can preserve and strengthen the ethical foundation of our field moving forward.

Shaena Montanari
University of Edinburgh

FossilBlitz!

For more than 20 years, BioBlitz events worldwide have engaged members of the public in questions relating to the biodiversity of their local environment, especially concerning the impact of current climate change. These time-limited surveys of modern ecosystems involve a collaborative effort between professional scientists and citizen scientists to collect and record relative abundance data of plant or animal species. As part of their 50th anniversary Summer of Science celebrations, the Natural Environment Research Council (NERC) in the UK funded a team of us to extend this concept to deep time as a means of engaging the general public with questions relating to past biodiversity change, and as a way of promoting our recent NERC-funded research in this area (<**www.lifeandplanet.net**>).

Our 'Jurassic FossilBlitz' took place on Saturday 1st August at the western end of Monmouth Beach, part of the Undercliffs National Nature Reserve southwest of Lyme Regis. This site was chosen because of the fantastic and world famous exposures of the accessible, highly fossiliferous Blue Lias Formation that records marine ecosystem responses to early Jurassic environmental change following the Late Triassic mass extinction event, and because it has been a focus of some of our scientific studies over the past few years (*e.g.* Barras and Twitchett 2007; Dunhill *et al*. 2012; Pugh *et al*. 2015). We also benefited enormously from the involvement of local,

enthusiastic individuals from Natural England (Tom Sunderland), the Jurassic Coast World Heritage Site team (Sam Scriven and Richard Edmonds) and the Lyme Regis Powerboat Club (Sean Budge); without their support the event would not have been possible.

In total, some 200+ citizen scientists of all ages took part in the FossilBlitz. Each individual or family group were given a 50 x 50 cm quadrat, which they were instructed to place randomly on a bedding plane of their choosing. With the aid of a fossil identification sheet and magnifying glass they then recorded the abundances of the different body fossils and trace fossils that they could see inside their quadrat. No *in situ* specimens were collected and no damage to the site took place. On hand to assist with the data collection and to answer any questions were a high-quality assemblage of palaeontologists from the British Antarctic Survey (Alistair Crame, Vanessa Bowman), the University of Leeds (Crispin Little, Alex Dunhill, Autumn Pugh, James Witts), the Natural History Museum, London (Richard Twitchett, Will Foster), BioGeoD (Alistair McGowan), and recent graduates James Brown (Plymouth University) and Bethany Allen (Durham University). Completed survey sheets were then exchanged for stickers and a certificate!

Data collection! William Foster confirms the identifications of a FossilBlitz citizen scientist as another Bed 29 quadrat is sampled. Photo by Alistair McGowan.

As the rocks are only accessible around low tide, the FossilBlitz lasted just six hours. In that time, *ca*. 1,600 fossils were counted in a total of 87 quadrats from eight beds spanning the Hettangian/Sinemurian boundary. Although primarily about outreach and engagement, the participants employed very similar data collection techniques to those used in published palaeoecological studies from the same locality (*e.g.* Barras and Twitchett 2007; Pugh *et al*. 2015), so the results should have some scientific value. Indeed, preliminary analyses show that despite the potential for misidentifications the relative proportions of the most common body fossils

are similar to those recorded by Pugh *et al*. (2015) for the same beds, which is very encouraging. The advantages of the FossilBlitz include an order of magnitude increase in the sampling of some beds, which should reveal the presence of rarer taxa and help to better constrain their stratigraphic ranges. A few brief results have been disseminated via the @FossilBlitz twitter feed, and it is hoped that soon all of the data will be made freely available.

Overall, our first FossilBlitz appears to have been very successful and incredibly well received by all the participants. Comments from members of the public were invariably positive and enthusiastic – "better than the Moon landings" said one! – and there is real enthusiasm to hold a similar event in the near future. If anyone fancies running their own FossilBlitz event then we would be happy to provide advice based on our experiences.

Richard J. Twitchett
Natural History Museum, London,
<r.twitchett@nhm.ac.uk>

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The Iguanodon Restaurant – fossil-fuelled fun for dino-enthusiasts!

In April, Emerald Ant received funding from the Palaeontological Association towards research and development of a new street show called "The Iguanodon Restaurant". This follows their very popular life-size, travelling pliosaur, Horace, who since 2012 has inspired family audiences at the Jurassic Coast. Emerald Ant is an arts company based on a sheep farm in West Dorset, where, when sheep are not being dipped, dinosaurs and giant sea lizards come to life. They have worked with the Jurassic Coast Team and palaeontologists for several years. Whilst touring Horace they learnt about the famous banquet of 1853 inside a concrete iguanodon at Crystal Palace Park in London. Inspired, Emerald Ant makers joined forces with Shanty Theatre Company and the Friends of Crystal Palace Dinosaurs, to research and create a performance around this scene. A meeting on 12th February at the Natural History Museum, London was the first step towards achieving the PalAss Engagement Grant.

Research has led to a fascinating narrative around the birth of geology. Featuring colourful characters Richard Owen, Gideon Mantell, William Buckland and Mary Anning, and set inside a

The Iguanodon Banquet of 1853, as reported by The Illustrated London News*, 7th January 1854.*

life-size installation of the Crystal Palace Victorian iguanodon, the story starts in 1812 in Lyme Regis with the Annings' discovery of an ichthyosaur. It travels at rollicking speed to Cuckfield and Maidstone to Mantell's discoveries, to the banquet in Crystal Palace Park, through the publication of *On the Origin of Species* in 1859, and culminates at the Oxford evolution debate of 1860, with giant bishops and smoke machines. Crammed full of trickery and surprise, we plan to offer exploding blancmange, pigeons flying from pies, a strata-Smith banqueting table, speaking portraits, and excessively long beards. The drama will show how fossils transcended from being mere curiosities in 1800 to the embodiment of prehistory by 1860, how scientists' interpretation of fossils has progressed over the years, and how the discovery of fossils led to theories of extinction and evolution that shocked the world.

The PalAss funds have enabled us to make initial touring plans. Our five-year tour will start on the Jurassic Coast and travel across the Sussex and Kent Weald to Crystal Palace. We hope to visit the North Yorkshire 'Dinosaur Coast' in 2018, and possibly Belgium. So far, around eight events have registered a desire to host us. Following in Horace's wake, we expect to tour music and science festivals, reaching audiences at Glastonbury, Larmer Tree, Latitude, museums and community events. Our schools programme will see us perform shows and deliver creative fossil interpretation workshops with palaeontologists and artists working together. This will be accompanied by an online Schools Pack, available to all schools, containing fossil guides, guided walks, scientific information and creative activities for engaging children in Earth science. In south London the work will be carried out in partnership with the Friends of Crystal Palace Dinosaurs, ensuring that local children learn about the dinosaurs and raising awareness of their need for restoration. In the southwest, schools within 30 minutes' drive of the Jurassic Coast who have not yet benefited from educational programmes will receive teachers' inset sessions.

Our research has brought in scientists and historians at the Natural History Museum, London and UCL, in particular Dr Ellinor Michel and Professor Joe Cain. We have visited iguanodon discovery sites in Cuckfield and Maidstone, and gauged local communities' knowledge about the amazing discoveries on their doorsteps. Working with Shanty Theatre Company, we have devised structure and content for a very funny, fast and furious 20-minute show. Our model 'Iggy' is pictured below. We are now waiting to hear from the Arts Council and Heritage Lottery Fund regarding funding for the build and tour. We are truly grateful to the PalAss for giving this exciting project a real kick-start, and look forward to working with science events over the next few years.

Sarah Butterworth
Emerald Ant

Find out more at <**www.emeraldant.com**>or contact Sarah Butterworth by e-mail at <**sarah@emeraldant.com**>.

Emerald Ant's scaled model for their new 'Iguanodon Restaurant' street theatre show, featuring Richard Owen, Gideon Mantell, William Buckland, Mary Anning and Charles Lyell.

>>***Future*** Meetings of Other Bodies

The Micropalaeontological Society Annual General Meeting 2015
University of Liverpool, UK *16 – 17 November 2015*

This year's annual meeting in Liverpool has the theme "Rock to Clock: the importance of microfossils". The importance of microfossils in fundamental and applied biostratigraphy, looking into biodiversity, evolution and geological indicators, will be discussed by the keynote speakers including Phil Gibbard, Vanessa Bowman, Simonetta Monechi and Mike Simmons. Open session talks and posters are particularly encouraged from students and early career researchers.

For more information see the website <**http://www.tmsoc.org**>.

Biotic Response to Environmental Change
Flett Theatre, Natural History Museum, London, UK *27 November 2015*

This meeting includes keynote lectures from Camille Parmesan (Plymouth University & University of Texas at Austin) 'Responses to anthropogenic climate change: predicting the future requires knowing the past', and Richard Primack (Boston University) 'The effects of climate change on the plants, birds, and insects of Thoreau's Concord using museum specimens, historical and modern observations, citizen science networks, and experiments'.

Many of the presentations throughout the day have a palaeontological basis and include Richard Twitchett (NHM, London) 'Shrinking shellfish and marine ecosystem function during past episodes of global climate change', and Erik van Sebille (Imperial College London) 'Chasing water: why ocean currents matter to plastic, plankton and palaeoproxies'.

This meeting is free to attend, but registration is essential.

For more information and to register see the conference website:

<**http://www.eventbrite.co.uk/e/biotic-response-to-environmental-change-insights-from-natural-history-collections-tickets-18737348915**>

17th International Bryozoology Association Conference
Melbourne Museum, Victoria, Australia *10 – 15 April 2016*

The IBA Conference is a multidisciplinary meeting that includes morphology, phylogeny, geochemistry, taxonomy, palaeontology, ecology and genetics of the Phylum Bryozoa. Keynote speakers will be Tim Flannery 'Australia: an introduction for scientists', and Michele Prinsep, 'Current state of bioprospecting among bryozoans'. There will be a pre-conference excursion (Tasmania) and a post-conference excursion (Great Ocean Road to Adelaide), which will include a lot of geological

and fossil sites. Manuscripts are welcome to be brought to the conference for submission for the proceedings volume.

For more information and to download the final circular, see the website at <**http://iba2016.org/**>, or e-mail <**info@iba2016.org**>. *Early bird registration deadline: 1st February 2016.*

European Geosciences Union General Assembly 2016
Austria Center Vienna (ACV), Vienna, Austria *17 – 22 April 2016*

The EGU General Assembly 2016 will bring together geoscientists from all over the world for a meeting covering all disciplines of the Earth sciences, including palaeontology. The EGU aims to provide a forum where scientists, especially early career researchers, can present their work and discuss their ideas with experts in all fields of geoscience.

Proposed sessions supported by the PalAss include: "Biomineralisation in the fossil record" and "Experimental solutions to deep time problems in palaeontology". Other palaeontological sessions in the skeleton programme include "Conservation & stratigraphic palaeobiology: deep-time to Recent", and other proposals are welcome.

Abstract submission is now open; see <**http://www.egu2016.eu/**> for details.

9th Fossil Preparation & Collections Symposium
Doubletree by Hilton, Colorado Springs, USA *20 – 23 April 2016*

The Association for Materials & Methods in Paleontology (AMMP) would like to invite you to the 9th Annual Fossil Preparation & Collections Symposium.

Look for registration and travel logistics coming soon to AMMP's website at <**www.paleomethods.org**>, and through social media outlets.

7th International Conference on Fossil Insects, Arthropods and Amber
National Museum of Scotland, Edinburgh, UK *26 April – 1 May 2016*

Registration is now open for this conference on the scientific study of non-marine arthropods and amber. ,The Conference is usually held every three years and this is the first time that it will be held in the UK. ,It comprises a reception at the Royal Society of Edinburgh, three days of lectures at the National Museum of Scotland, and two optional days of field-work to Palaeozoic non-marine arthropod sites.

For more information about the meeting and how to register please e-mail Dr Andrew Ross (<**a.ross@nms.ac.uk**>). *Deadline for abstract submission is 31st December 2015.*

4th International Congress on Ichnology (Ichnia 2016)
Idanha-a-Nova, Portugal *6 – 9 May 2016*

Ichnia 2016 is jointly organised by the International Ichnological Association, the Geopark Naturtejo da Meseta Meridional, UNESCO Global Geopark, and the National Museum of Natural History and Science of the University of Lisbon. Pre-, intra- and post-congress field-trips are proposed to ichnosites throughout the Iberian Peninsula.

Oral and poster presentations are both welcome! Ichnia 2016 call for abstracts opens on 15th August 2015; for details see <**http://ichnia2016.org/**>.

9th International School on Foraminifera
Urbino, Italy *6 –– 25 June 2016*

The 9th School on Foraminifera is designed to provide an overview of the taxonomy, ecology, biodiversity and geological history of benthic and planktonic foraminifera. This intensive course is intended for students interested in micropalaeontology, palaeoceanography, palaeoecology, climate history, biology, and environmental applications. The aim is to provide a primer on the study of foraminifera and examples of how foraminifera can be used as (palaeo)environmental and (palaeo)oceanographical proxies. We will review the current classification schemes of foraminifera, discuss their ecology and life history, review their usefulness for biostratigraphical applications, and use case studies to investigate the geological history of the group with lab and practical sessions. The entire course consists of approximately 60 hours of lectures and 60 hours of practical work. Four distinct courses are planned: Foraminiferal Introduction (7–11 June), Larger Benthic Foraminiferal Course (12–15 June), Planktonic Foraminiferal Course (17–21 June) and Smaller Benthic Foraminiferal Course (22–25 June).

To register please submit an application form that can be downloaded from the website at: <**http://isf.tmsoc.org**>, or e-mail <**isf@tmsoc.org**>. *Registration deadline 6th May 2016.*

6th Symposium on Mesozoic and Cenozoic Decapod Crustaceans
Villers-sur-Mer, France *14 – 18 June 2016*

The symposium will be held at the Paleospace-l'Odyssee, Museum of Palaeontology and the cinema, both located in the centre of Villers-sur-Mer. Poster and oral presentations will be followed by field-trips to the Callovian–Oxfordian cliffs of the "Vaches Noirs", Bajocian stratotype and Bathonian Confessionnaux, parts of the Normandy landings locations, a trip to the Cenomanian hard-grounds of Petreval, and the Etretat cliffs which attracted Courbet and Monet. English and French will be the official languages of the Conference. Talks will be 30 minutes long including discussion. The area is popular with tourists, so accommodation should be booked early.

For more information, please see the conference website at <**http://geosoc.fr/manifestation/agenda-des-reunions-colloques-sgf/event/218-6th-symposium-on-mesozoic-and-cenozoic-decapod-crustaceans.html**> or e-mail the organiser, Sylvain Charbonnier (<**scharbonnier@mnhn.fr**>).
Registration payment deadline 1st February 2016. Abstract deadline 1st March 2016.

XIV Annual Meeting of the European Association of Vertebrate Palaeontologists (EAVP)
Haarlem, The Netherlands *6 – 9 July 2016*

More information will be available soon. Please check the EAVP website for updates, at <**http://www.eavp.org**>.

Palaeo Down Under 2 (PDU2)
Adelaide, Australia *11 – 15 July 2016*

A full conference programme is proposed, covering all aspects of palaeontology and associated disciplines. Dedicated symposia on the Ediacaran and Cambrian systems will be a highlight of the programme, under the auspices of the respective International Subcommissions on Stratigraphy, focusing on recent rapid advances in our understanding in these areas. The Conference will include guest keynote lectures, general and thematic sessions, symposia and posters.

The Conference will be preceded by a field excursion to Ediacaran and Cambrian fossil localities in the renowned Flinders Ranges to the north of Adelaide, and will also feature the Emu Bay Shale Konservat-Lagerstätte on Kangaroo Island, south of Adelaide. A half-day mid-conference field excursion will be arranged to a location of international geological interest in the vicinity of Adelaide. A post-conference camping-style excursion to Mesozoic and/or Cenozoic fossil localities in the arid Lake Eyre Basin is also under consideration, pending number of interested participants.

For further information, please see the conference website at <**http://aap.gsa.org.au/PDU2.html**>.

9th International Meeting of the Society of Avian Paleontology and Evolution
Diamante, Argentina *1 – 5 August 2016*

The Meeting will be hosted by and held at the Centro de Investigaciones Cientficas y Transferencia de Tecnologia a la Produccion de Diamante (CICYTTP-CONICET). It will be dedicated to Larry Martin (USA), in order to honour his memory and his outstanding palaeornithological contributions. The schedule includes a fossil identification session, and pre- and post-conference excursions.

Please see the conference website for more information, at
<**http://www.cicyttp.org.ar/sape2016.html**>.
Registration deadline 29th February 2016. Abstract deadline 30th June 2016.

Joint Meeting of the TSOP, AASP and ICCP
Houston, Texas, USA *18 – 23 September 2016*

This is the first joint meeting of these three related geological, geochemical and biological societies: The Society for Organic Petrology (TSOP), The Palynological Society (AASP), and the International Commission for Coal and Organic Petrology (ICCP).

The purpose of this joint meeting is to discuss the close relationships between organic petrology and palynology, to foster thoughtful discussion, and to address issues that may be of benefit to furthering the respective sciences. Key themes to be addressed during joint activities include palynofacies and source rock assessment. Proposed symposia include: Palynofacies and Kerogen, Palynofloral Contributions to Source Rocks, and (tbc) an Alfred Traverse Symposium, Palynostratigraphy and Global Biozonations, Forensic Palynology, and Wetlands Through Time. Pre- and post-conference field trips are planned.

More details will be available in the near future. Please see the TSOP and AASP websites for updates: <**http://www.tsop.org/index.htm**> and <**http://www.palynology.org**>.

XIV International Palynological Congress and the X International Organization of Palaeobotanists Congress (IPC XIV / IOPC X 2016)
Salvador, Brazil *23 – 28 October 2016*

This will be the first time that both the International Palynological Congress (IPC) and the International Organisation of Palaeobotany Conference (IOPC) will gather together in the southern hemisphere. Several field-trips are being planned in Bahia State and to the Tocantins Fossil Trees Natural Monument (Bielândia/Filadélfia, Tocantins State).

More details will be available in the near future.

DINO11: 11th International Conference on Modern and Fossil Dinoflagellates
EPOC Laboratory, Bordeaux University, France *Mid July 2017*

More details will be available in the near future. Please see the conference website for updates, at <**http://www.laplf.org/dino11/calquedino11.htm**>.

Please help us to help you! Send announcements of forthcoming meetings to <**newsletter@palass.org**>.

Meeting REPORTS

Conservation & Stratigraphic Palaeobiology: Deep-time to Recent
European Geosciences Union General Assembly 2015, Vienna, Austria
14 April 2015

This Symposium brought together palaeontologists and marine biologists interested in exchanging new concepts and ideas in the fields of stratigraphic palaeobiology and conservation palaeobiology, with contributions on taphonomy, palaeobiogeography and macroevolution. It was organized by a cohort of European palaeobiologists, including James Nebelsick (University of Tübingen, Germany), Paolo Albano and Martin Zuschin (University of Vienna, Austria), Adam Tomašových (Slovak Academy of Sciences, Slovakia), Wolfgang Kiessling (University of Erlangen, Germany), Andrzej Kaim (Polish Academy of Sciences, Poland) and Silvia Danise (Plymouth University, UK, and University of Georgia, USA). Comprising eleven oral presentations and fifteen posters, the Symposium was attended by a large number of scientists, an excellent result for a palaeontological session held at the EGU General Assembly, so much so that the Division on Stratigraphy, Sedimentology and Palaeontology have asked the organizers to convene it again next year.

After an introduction given by James Nebelsick, the Symposium started with three talks focusing on the integration of sequence stratigraphy and palaeobiology in understanding the distribution of fossils in time and space. **Steven Holland** (University of Georgia, USA), funded by the Palaeontological Association to attend the meeting, gave a keynote on the stratigraphic palaeobiology of mass extinctions. He focused on the stratigraphic distribution of fossils across extinction events and, using numerical models and field-study examples, showed how the last occurrence of fossils does not generally indicate the time of extinction but is instead controlled by stratigraphic architecture (*e.g.* the presence of subaerial unconformities, flooding surfaces, surfaces of forced regression and condensed horizons). He concluded that many interpretations on the tempo of extinction based on stratigraphic patterns of last occurrences need to be re-interpreted in light of the sequence stratigraphic record. The second speaker, **Stefano Dominici** (University of Florence, Italy), presented a study on the stratigraphic distribution of large marine vertebrates and shell beds in the Pliocene of Tuscany. Integrating facies analysis and stratigraphy, palaeogeography, and quantitative palaeoecological data, Dominici and co-authors concluded that the more abundant and diverse accumulations of large vertebrates took place in settings under the influence of coastal upwelling, and compared the Pliocene of Tuscany to the modern Ligurian Sea that sustains a rich and diverse cetacean population. **Daniele Scarponi** (University of Bologna, Italy) showed how the concepts

Photo: Stefano Dominici

Steven Holland in the audience.

of Stratigraphic Palaeobiology can be applied to implement the definition of Global Boundary Stratotype Section and Points (GSSPs), presenting a study on a candidate GSSP section for the Late Pleistocene in the Taranto Area (Italy).

Uwe Balthasar (Plymouth University, UK) discussed the still poorly-understood influence of seawater composition on the evolution of the calcareous skeleton of marine invertebrates. Using data from $CaCO_3$ precipitation experiments, he proposed a new model to explain the increase of aragonite over calcite skeletal composition in calcifying organisms over the course of the Phanerozoic. **Rafal Nawrot** (University of Vienna, Austria) then compared body-size patterns of modern and Pliocene Mediterranean bivalves with those of the present day Red Sea, to test the hypothesis that invasion of Red Sea taxa following the opening of the Suez Canal reflects the presence of an empty ecological space in the Mediterranean, left following decimation of warm-water fauna during the Late Pliocene–Early Pleistocene climatic cooling. He found that the similarity between Pliocene and modern Red Sea bivalve size-distributions, completely different from those of modern day Mediterranean bivalves that are characterized by smaller sizes, could explain the successful migration of tropical species.

The second part of the Symposium focused on taphonomy and conservation palaeobiology. **Breandán MacGabhann** (Edge Hill University, UK) analysed the taphonomy of fossil eldonids, a Cambrian to Devonian clade of non-mineralized asymmetric discoidal basal or stem deuterostomes, mostly preserved as siliciclastic moulds and casts, and discussed their utility in reconstructing ambient conditions at the time of fossilization, and assessing the interaction between environmental change and the fossil record. **Mathias Harzhauser** (Natural History Museum Vienna, Austria) showed how the use of high-resolution digital surface models can enhance our understanding of ecological and taphonomic pathways during the formation of multiphase time-averaged shell beds. Harzhauser and co-authors applied this pioneering technique to an Early Miocene oyster reef, a shell accumulation covering an area of 400 m^2 with thousands of specimens.

Photo: Stefano Dominici

Mathias Harzhauser describing an Early Miocene oyster reef, a shell accumulation covering an area of 400 m^2.

Adam Tomašových (Slovak Academy of Sciences, Slovakia) proposed a new model to assess how age-frequency distributions of shell beds, known to capture information on the elapsed time since death of individuals on the landscape or seabed, can provide decadal- to millennial-scale windows into the processes that lead to skeletal production, disintegration and burial. Tomašových and co-authors applied this new model to the deposit-feeding bivalve *Nuculana taphria* from the southern Californian continental shelf, and found that an onshore–offshore gradient in time averaging is dominated by a gradient in the timing of production, corresponding to the tracking of shallow-water habitats during a sea-level rise. Model estimates of the timing of past production are in good agreement with an independent sea-level curve.

Paolo Albano (University of Vienna, Austria) opened the section of the Symposium dedicated to conservation palaeobiology with a talk on the impact of oil platforms on benthic assemblages in the Persian (Arabian) Gulf, a semi-enclosed basin that currently hosts the highest concentration of infrastructures for oil and gas extraction in the world. He showed how the comparison between death assemblages (which represent archives of species composition and community states over time and are inert to recent changes) and living assemblages can be used to reconstruct the degree of recent, anthropogenic, community disturbances. **Ivo Gallmetzer** (University of Vienna, Austria) then presented a study on the ecological changes of molluscan communities in the northern Adriatic Sea during the last 500 to 1,500 years, with the aim of clarifying the timing of major ecological changes in the past and defining pristine benthic communities as references for future conservation and management efforts. The northern Adriatic Sea, with its densely populated shoreline, is among the most degraded of marine ecosystems worldwide and is therefore particularly suited to study ecosystem modification under anthropogenic pressure.

Mairi Best (Ocean Observing Consultant, Canada) closed the Symposium with a talk on deep sea taphonomy in gas hydrate environments, showing an example from the Barkley Canyon, Canada. She showed data from ongoing observations of experimentally-deployed specimens (fresh shells and cellulose) using a remotely controlled crawler with camera and sensors, made with the aim of elucidating the formation and evolution of gas hydrate deposits, their distribution through time, and the ecological and taphonomic feedbacks that they generate.

Silvia Danise
Plymouth University and University of Georgia

5th Polar Marine Diatom Workshop
University of Salamanca, Spain *19 – 24 July 2015*

The 5th Polar Marine Diatom Workshop (PMDW) was hosted by María Angelas Bárcena and hosted 46 participants from 15 nations. The Workshop included the presentation and discussion of ideas and issues in taxonomy, terminology and identification. Collaboration in this series of workshops is pivotal in shaping the direction of future research in the field. While many PMDW attendants are specialists, this community is also focused on increasing student attendance through incentives such as travel grants. These are in addition to the inherent incentives of receiving training and advice from leading diatom specialists, and gaining insight into current research from leaders in the polar marine diatom community. More information about the PMDW is available at <**http://www.polarmarinediatomworkshop.org**>.

Since the first PDMW in 2005, hosted by Richard Jordan at Yamagata University, Japan, attendance has grown substantially. The 5th meeting consisted of 14 microscope-based taxonomy sessions, 11 lectures and 20 poster presentations. A primary objective of the PMDW is the transfer of knowledge and skills to the next generation of researchers. The Salamanca workshop was immensely successful in this regard, where nearly 70 per cent of attendees were graduate students. Students attended presentations on the use of diatoms in answering key questions about Earth history, and received first hand training in taxonomy and morphology from fellow students and established diatom specialists through lecture and microscope sessions (Figure 1). Lectures afforded the opportunity to see various methods currently employed in their respective fields that are useful to data analysis and interpretation of palaeoclimatic and palaeoceanographic conditions, and towards understanding palaeobiogeographic relationships.

Figure 1. Microscope sessions, like this one led by Leanne Armand (standing), provided useful training in the identification of morphological characteristics used to characterize different modern and fossil diatom species. Photo by Itsuki Suto.

Presented topics ranged between studies of modern and of Paleogene materials. The slide sessions and lecture presentations can be divided into four general themes:

1) *Taxonomy/morphology*: surface water diatoms from the Sabrina Coast, East Antarctica (**Armand**); detailed observations on *Thalassiosira spp.* from the North Pacific (**Stroynowski**); three species of *Thalassiosira* from the Bering Sea (**Caissie**); fossil Diatom assemblages from the Sabrina Coast, East Antarctica (**Leventer**); a comparison of the two marine planktonic diatoms *Denticulopsis praedimorpha* and *Thalassionema umitakae* (**Akiba**); changes in resting strategies of diatoms across the Eocene/Oligocene boundary (**Suto**); Antarctic fossil and modern *Fragilariopsis* (**Harwood**); morphological variation of *Fragilariopsis kerguelensis* between glacial and interglacial periods (**Kloster**); and evolution of *Thalassiosirales* (**Jordan**).

2) *Biogeography*: biogeographical patterns of Arctic and Atlantic diatoms in the sub-Arctic Labrador Sea (**Fragoso**); seasonal and geographical distribution of diatom species in the Southern Ocean and their role in the biological pump (**Rigual-Hernandez**).

3) *Palaeoclimate*: siliceous microfossil response to climatic and palaeoceanographic changes across the Eocene–Oligocene transition, East Antarctica (**Harrison**); diatom biostratigraphy and biosiliceous marine organisms response to changes in the Kerguelen Plateau (**Tolotti**); the importance of astrochronology in palaeoceanographic or palaeoclimatic reconstructions (**Sierro**); and Middle Eocene sea ice diatom assemblages from the central Arctic Ocean (**Abe**).

4) *Palaeoceanography/oceanography*: Holocene Antarctic diatom mats (**Pike** and **Allen**); subarctic marine diatom assemblages off the Faroe Islands (**Hoff**); Southern Ocean phytoplankton community dynamics sampled using a remote automated sampler (**Eriksen**); North Pacific SST reconstructions based on diatom transfer functions (**Lopes**); and diatoms as recorders of environmental conditions off Kerguelen Island during the last 40 ka (**Crosta**).

While a larger proportion of presentations were from studies on Recent material, those studies are key to palaeontology. A robust understanding of modern diatom connections to climatic and environmental parameters is essential for understanding the environmental conditions of past organisms, especially those organisms whose extinctions occurred long before humans could make direct observations. Studies of morphological characteristics of extant species are also crucial to providing information to interpret palaeontological and palaeobiological characteristics of extinct species and their taxonomic classifications.

To end the workshop, participants took part in a half-day field-trip into Sierra de Francia (mountains in the southern Province of Salamanca), stopping first in Monsagro, a town with many impressive examples of Paleozoic trace fossils built into the façades of the buildings and houses. The open-air museum has *Rusophycus*, *Skolithos* and other trace fossils dating back 430 million years (Figure 2).

Figure 2: The open air museum in Monsagro. Building stones contain magnificent trace fossils, remnants of the 430 Ma sea that deposited sediments in the region. This image shows a stone containing a large Cruziana *with smaller* Skolithos *burrows going through and around it. Photo by Raffaella Tolotti.*

The second stop was the Nuestra Señora de la Peña de Francia Sanctuary (The Sanctuary of Our Lady of the Rock of Francia), which offered an amazing view of the structural characteristics of

the mountains. The final stop was the Viñas del Cámbrico winery, where owner Fernando Maillo, a biologist, led a vineyard tour and discussed how regional geology and mineral-rich soils play a key role in the development of the grapes used in Cámbrico's wines. As the Salamanca workshop ended, participants returned to their research with new experiences, new knowledge and a network of new colleagues to help advance the collective understanding of polar marine diatoms and their application to environmental problems.

Michael Harrison
University of Nebraska-Lincoln

Raffaella Tolotti
University of Genoa

Acknowledgement: We are grateful for the Palaeontological Association grant (ref. PA-GA201502).

Evolution and Development of the Vertebrate Dentition: a symposium in honour of Moya Meredith Smith
Gordon Museum, King's College London, UK *18 June 2015*

What is the mark of a successful career? Numbers of papers published? The number of research fields influenced? The number of students you've influenced in their own careers? Add to this the number of UK and international researchers willing to speak at a Symposium or Festschrift in your honour, and the number of friends and colleagues attending this Symposium, and you can begin to understand the esteem in which Moya Meredith Smith is held, and the impact she has had on the field of early vertebrate evolution. Moya's career has spanned over five decades, incorporating both developmental biology and palaeontology, amply reflected by those attending her symposium and the talks presented. The Symposium was held at the Gordon Museum of Pathology, King's College London, the perfect venue being a teaching museum filled with jars of interesting, if sometimes confronting, specimens, with balconies looking down on the meeting below. We held our coffee breaks and post-meeting drinks in the associated Life Sciences Museum, again a fantastic, older-style museum, with cabinets filled with a wonderful array of specimens for attendees to study, while enjoying a drink and vibrant discussions.

We assembled an outstanding schedule of speakers (the meeting programme is available online at <**http://www.kcl.ac.uk/dentistry/newsevents/events/eventsrecords/festschrift-programme.pdf**>) from the UK, USA and Europe, including morning and afternoon plenary talks from **Jukka Jernvall** (University of Helsinki) and **Mike Coates** (University of Chicago), respectively. Presentations were on a wide range of topics related to the evolution and development of vertebrate dentition, reflecting Moya's varied research interests. A short, but fascinating introduction to Moya's career, provided by her friend **Barry Berkovitz**, set the tone for the whole meeting. Following Barry were talks on conodonts, Notch signalling pathways, evolution of bony fish dentitions, sawshark rostra and associated dentitions, tooth replacement and contributions of ectoderm and endoderm to tooth development. Athena Swan provided support for two young female speakers, **Sophie Sanchez** (Uppsala University) and **Elodie Renvoise** (University of Helsinki) to attend. Moya has always been strongly supportive of other women in science, so this was a very important component of the meeting.

Barry Berkovitz gives the introductory talk outlining Moya's career. Photo by Alex Riley.

Although only a one-day meeting, the quality of presentations and speakers was comparable to a top-level Evo-Devo conference, and attended by many students who may not necessarily attend such conferences, who could also talk to some of the top researchers in the field. As organisers, we were thrilled with the results, as was Moya. At the end of the meeting, **Diane Rekow**, Executive Dean of the Dental Institute at King's College London, gave a short presentation reflecting on Moya's achievements over her career. As we crowded into the Life Sciences Museum for drinks, I think we realised that we had all participated in something unique and special that day, and again we would like to thank our sponsors, including the Palaeontological Association, for making it all possible.

Zerina Johanson
Natural History Museum, London

Abigail Tucker
King's College London

Anthony Graham
King's College London

Moya Meredith Smith and Abigail Tucker. Photo by Martha Richter.

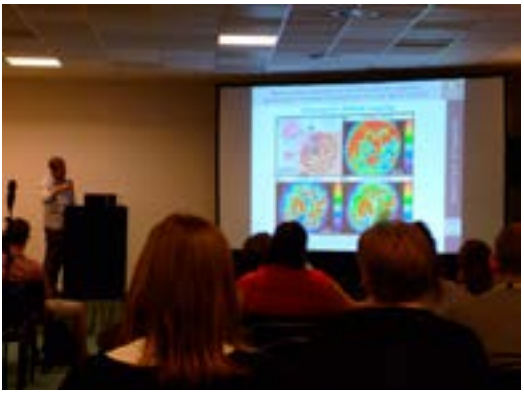
Goldschmidt Conference 2015
Prague Congress Centre, Czech Republic *16 – 21 August 2015*

Goldschmidt is the largest international geochemistry conference and is organized annually by the Geochemical Society and the European Association of Geochemistry. This year's Prague edition lived up to its reputation with over 4,000 attendees, and included 26 different session themes with up to 12 sub-sessions, each containing oral and poster presentations. With such a breadth of topics covered, many were related to palaeontology and particularly the environmental conditions affecting fossil life and vice versa. In this report I focus on some of the palaeontological research using geochemical techniques that was presented throughout the week.

Shelled invertebrates and microfossils make up a majority of the fossil record, and the process of biomineralization was the subject of a number of talk sessions. I particularly enjoyed session 15d that discussed both the biological aspects as well as the geological impacts of these organisms. Interesting talks included the identification of different versions of fossil polysaccharides in coccolithophores that could be controlling shell architecture (**Renee Lee**), and the measurement of shell nacre thickness to reconstruct seawater temperature (**Pupa Gilbert**). Session 08c on the last day also focused on using carbonate shells for various environmental isotopic proxies, with research ranging "From Culturing Experiments to Archives and Diagenetic Alteration", mainly in foraminifera and coccolithophores. However, biomineralized fossils are not the only source of climatic proxies, and session 09a ("Using Palaeoclimate Archives to Better Understand the Earth's Climate System") discussed algal, vascular plant and microbially-derived biomarkers. These biological markers are important to obtain direct information about terrestrial conditions, and talks included the use of oxygen isotopes from European Holocene speleothems (**Michael Deiniger**) and late Neogene mummified wood from Antarctica (**Rhian Rees-Owen**), and the analysis of bacterial membrane lipids (in this case brGDGTs) in fossil peat to reconstruct land temperatures (**David Naafs**). In addition to this session, **Ann Pearson** gave her insights on organic geochemical proxies (particularly TEX_{86}, a lipid palaeothermometer) in a plenary talk. This was one of five fascinating presentations organized to celebrate this 25th anniversary of Goldschmidt, whereby prominent researchers highlighted the greatest achievements and future perspectives within their research area.

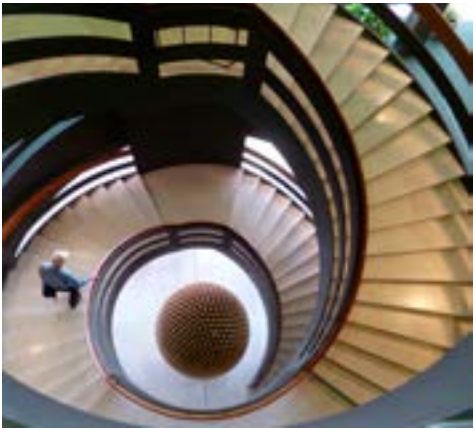
The Prague Congress Centre in a rare moment when the rain stopped. Photo by Jo Hellawell.

Multiple sessions at Goldschmidt were aimed at geological history before the Phanerozoic, and I attended session 22e on the environmental conditions necessary for the emergence of life on Earth. What stood out was the use of some interesting techniques, including computer simulations of Miller-like experiments (**Antonino Marco Saitta**) and secondary ion mass spectrometry (the most sensitive way to analyse surface material) to measure oxygen isotopes of organic compounds in Archaean cherts (**Romain Tartèse**). In session 9c **Jean Yves Storme** showed that even in such early Earth rocks it is possible to identify specific organic compounds – in this case pigments of cyanobacteria – by the way in which they absorb UV/visible light, and scatter light (Raman spectral analysis). The interesting session 22b on "The co-evolution of microbial life and environments in the Precambrian" included a talk by **Jochen Brocks**, on eukaryotic biomarkers from different basins of the supercontinent Rodinia, who revealed a new sterane, cryostane. Brocks suggested that the origin may be the function to protect organisms against their own membranolytic toxins, with implications for the proliferation of eukaryophagy at that time. A talk by **Nick Butterfield** on the overlooked oxygenating effects of bioturbation of seawater by sponges closed that session; he showed fantastic videos of using dyes to show the rapid water movement through modern sponges (see YouTube), suggesting that similar bioturbation could have had a large impact on the Proterozoic oceans.



Jean-Yves Storme suggests that UV-screening pigments evolved in early cyanobacteria as a protective strategy. The ability to detect them using Raman spectroscopy makes them potential biosignatures for cyanobacteria on the early Earth. Photo by Jo Hellawell.

In addition to the great oral and poster presentations given at Goldschmidt, there was the possibility to attend a variety of workshops, and join the mentor programme. In the mentoring scheme, students and early career scientists were matched with experienced researchers to help them navigate the conference, and I found it a great way to discuss future career plans in an informal setting. Details of this scheme, as well as the complete programme, can be found on the conference website at <**http://goldschmidt.info/2015/**>.



Sculpture in the Congress Centre, which was originally built as the 'Palace of Culture' in 1981 for large exhibitions, concerts and Communist Party gatherings. Photo by Jo Hellawell.

Edine Pape
University of Leeds

SVPCA 2015
National Oceanography Centre, Southampton, UK
29 August – 4 September 2015

The annual Symposium for Vertebrate Palaeontology and Comparative Anatomy was held in Southampton this year, a city with a thriving harbour, excellent university and world-leading (and very welcoming) Vertebrate Palaeontology Group. The reception and conference took place at the National Oceanography Centre (NOC). This modern, airy building is one of the largest bases for marine science, deep-sea research and technological development in the UK. Thanks to the Jones-Fenleigh Memorial Fund, I was able to attend SVPCA to present my own work, as well as to find out about the latest research by fellow vertebrate palaeontologists. The week began with an evening reception at the NOC; Gareth Dyke opened sessions the following morning.

Alexander Kellner was tasked with the first in a series of pterosaur presentations, discussing the surprise second egg discovered inside Chinese pterosaur, *Hamipterus tianshanensis*. Later, **Darren Naish** recapped the major finds and reinterpretations from Romania's Hateg Basin, then delighted us with a flying turtle, a Cretaceous super-owl, and his ability to pronounce tongue-twisting nomenclature (pyramicephalosaurine polyglyphanodontid borioteiioids, if you please). **Cindy Howells** talked about the exciting new theropod from Lavernock Point in Wales: "don't ever mention *Tyrannosaurus rex* if you don't really mean it," she warned with some exasperation, "that's all the press will ever say!" A montage of media headlines confirmed her point. However, the success of the outreach work surrounding this British discovery is undeniable.

After refreshments, **Daniel Vidal** shared *Spinophorosaurus* tail motion models and implications for tail adornment. **Michael Taylor** *et al.*'s anatomical observation of *Star Wars* Starfighter-shaped brontosaur vertebrae led them to suggest that brontosaurs had spikes along the length of the neck, perhaps for intra-species competition. We returned from lunch to hear **Diane Johnson** sharing the fossil finds of ancient Egypt. Thought to be offerings to the god Seth, their archaeological context is yet to be fully explored. We enjoyed **Vincent Beyrand**'s beautifully animated presentation on correlations between bird brain morphology, ecology and locomotion. Peruvian penguins came next with **Ursula Göhlich**, and then the convergent loss of flight – or as **Nicholas Chan** pointed out: the reacquisition of terrestrialism – in birds.

Marco Castiello kicked off day two with a plea to palaeoartists to "please draw more fish!" **Timothy Smithson**'s presentation on the position of the entepiconylar foramen in basal tetrapods presented a tantalising way to assess their transition onto land. **Eduardo Ascarrunz** took us forwards to the origins of lissamphibians and an amazing Madagascan *Triadobatrachus massinoti* specimen, splayed out like pot-bellied Triassic roadkill. **Donald Henderson**'s fieldwork in Alberta – a province that would swallow the UK many times over and still have room for an after-dinner mint – has recovered amazing Late Cretaceous dinosaur trackways, including a single Tyrannosaur footprint. Crocodylomorphs dominated the after-lunch presentations: **Mark Young** presented a marine crocodylomorph from the Mid Jurassic/Early Cretaceous, while **Davide Foffa** described the UK's first teleosaurid mandibular material from the Corallian Gap. *Pholidosaurus* came next, re-described by Southampton postgrad **Thomas Smith**. **Max Stockdale** rounded off these sessions with an examination of crocodylomorph evolutionary patterns and diversity.

Posters were displayed in an adjacent hall by earliest career researchers to seasoned palaeontologists. There was a constant crowd around a 3D-printed poster, but my personal favourite was by Sophie Regnault *et al.* on the puzzling evolution of the ossified mammal kneecap. Back in the theatre, we travelled into the ear canal of mammals with **Joanna Baker**, and surveyed the cranial ontogeny of basal synapsids with **Maren Jansen**. The final talk of the day was from **Mark Witton**, whose palaeoart sets a gold standard for reconstruction. He highlighted the way images resonate with the public and influence our ideas for decades. Yet unfortunately there is also rampant copying, and a lack of recognition for those original artists who spent hours researching the palaeontologically-accurate images that bring our science to life. I'll certainly be budgeting for good-quality palaeoart in my own future research. Several such artworks were included in the auction that evening: a runaway success that generated £1,942 to help fund future SVPCA attendees.

On the final day, it was my turn to take to the stage with an overview of my MSc project looking at Carnivora ankles, before **Jamie MacLaren** showed us his tapir limbs. **Chris Basu** was sporting a home-made "Giraffid Park" T-shirt during his *Sivatherium* body-mass presentation, and **Gertrud Rössner** examined the earliest antlers (~19 Ma) to answer questions about the evolution of shedding cycles. We returned from a refreshment break to the subject of mammal teeth. **Christine Janis** then turned from teeth to elbow rotation in *Thylacoleo carnifex*, with a potentially pivotal role in hunting and killing strategy. I was excited to hear about **Elis Newham**'s research on endothermy in Mesozoic mammals, explored through reconstruction of tooth cementum using synchrotron scans. We plunged headlong into a fishy session containing the funniest set of talks of the conference. **John Clarke** compared the rise of Holosteans and Teleosts to the British Empire and the present day United States. The unforgettable **Jeff Liston** continued the laughter during his presentation on pachycormid suspension feeders, somehow getting the work of Francis Bacon into his slides alongside comedy palaeoart (commissioned the night before). Southampton's own **Jessica Lawrence-Wujek** presented her comprehensive work on ichthyosaurs, before another Southampton student, **Luke Muscutt**, used his engineering background to explore plesiosaur hydrodynamics. The final talk was by **Nick Longrich**, presenting the recently-described Early Cretaceous snake. Controversies aside, he talked us through the specimen's snake synapomorphies, before discussing the behavioural implications of the limb anatomy.

The field-trip the next day transported delegates to Mesozoic England: the Wealdon of the Isle of Wight. The delegates zealously beachcombed from Chilton Chine to Compton Bay, examining Cretaceous ornithopod footprints and enjoying the clement weather. They spent time at the Dinosaur Isle Museum in Sandown and enjoyed a hearty pub lunch, before returning to the mainland to recover and prepare for next year's sojourn into the world of vertebrate palaeontology and anatomy. SVPCA 2016 will be held in Liverpool – check out <**www.svpca.org**> for the latest information (details and dates TBC). To find out what people were saying at the SVPCA 2015 and more about the recent discussion of the future of SVPCA, take a look at #SVPCA on twitter.

Elsa Panciroli
University of Edinburgh
<@gsciencelady>

Field-trippers on the beach on the Isle of Wight. Photo by Laura Säilä.

A Cretaceous ornithopod footprint on the Isle of Wight. Photo by Laura Säilä.

Yorkshire Fossil Festival
Scarborough, UK *18 – 20 September 2015*

Following the ongoing success of the Lyme Regis Fossil Festival in recent years, September 2014 saw the first appearance of an equivalent in the north of England: the Yorkshire Fossil Festival, held at the historic Rotunda Museum in Scarborough. Organised by the Scarborough Museums Trust in conjunction with the Palaeontological Association, the event is designed to run along similar lines to its older cousin on the south coast, bringing geology and palaeontology to the masses through a wide range of outreach activities run by different fossil-loving organizations. For the second running of the Festival, over a long and uncharacteristically (for Scarborough!) sunny weekend in September 2015, volunteers from the universities of Leeds and Hull were joined by representatives from the PalAss, the Natural History Museum in London, York Museums Trust, Dinosaur Isle, the Geological Curators Group, the Geological Society of London, and Oxford Museum of Natural History among others. As at Lyme Regis, the Friday of the Festival was given over to visits from groups of local schoolchildren, whilst on Saturday and Sunday the site opened to the general public.

The range of activities on show this year was particularly impressive. In a single tent you could learn about the varied delights and uses of coprolites and trace fossils, examine specimens of fossil plants and animals from the Yorkshire Coast alongside examples of their nearest living relatives, and discover the huge importance of microfossils. There was also an opportunity to view 'Alan the sauropod' (Yorkshire's newest dinosaur described this summer by a team from the University of Manchester), learn more about William Smith and his pioneering geological map, and even take on the role of curator and curate your own fossil finds. Several interactive public talks held at Scarborough Library also helped to keep the crowds entertained. **David Bond** (University of Hull) gave an overview of the cause and effects of various Phanerozoic mass extinction events, while **Alex Dunhill** (University of Leeds) spoke about the dinosaur footprints that can be found on the Yorkshire coast, and what these can tell us about the animals that made them.

The PalAss contribution to the Festival was the same activity that we used at this year's Lyme Regis Fossil Festival (see meeting report by Gemma Benevento in *Newsletter* **89**), a 'voyage back in time' to four different time periods; a Silurian reef, a Carboniferous coal swamp, a shallow Jurassic sea, and Pleistocene 'tundra'. Painted reconstructions of these environments are joined by a wide selection of representative fossils, and information on what they can tell us about the myriad ways that the Earth has changed through the Phanerozoic. The real appeal of this activity for me lies in explaining how you can take what, to the uninitiated member of the public, initially looks like a rather uninspiring lump of rock or fragment of a fossil, and use it to gain useful information about what the environment was like millions of years ago – be it sea level, water or air temperature, or even the composition of the ancient atmosphere. Although palaeoenvironmental reconstruction using rocks and fossils is something we may take for granted, this is still an under-appreciated side of our science for most of the general public, who are fascinated to learn of the variety of ways we can use fossils beyond just describing new species of long-dead organisms. The activity is also helped by its 'hands-on' nature as visitors are encouraged to pick up and handle the fossils. Although this has led to a few dented ammonites and even disappearing trilobites at past events, I am happy to report there were no such casualties on this occasion.

The Palaeontological Association's contribution to the Festival, a 'voyage back in time' to four different time periods. Photo by James Witts.

A team of PalAss volunteers, including undergraduate and postgraduate students, curators and academics (and even the Newsletter Editor and Publications Officer) were on hand to staff the stall, and we were once again joined by palaeoartist **James McKay**. James challenged younger visitors to complete a fact sheet describing their favourite UK fossil by talking to various experts around the Festival. Once completed, they returned the sheet to James who would then paint a picture of the animal. This led to a great variety of fantastic reconstructions, ranging from giant Carboniferous dragonflies to *Baryonyx*, and even that most charismatic of UK fossils, the humble *Gryphaea*! Beyond the more academic side of the Festival, there were also regular performances by 'Horace the Travelling Pliosaur Cinema', and a group of artists producing a musical about the life and times of William Smith. Meanwhile, down on the beach an impressive school of plesiosaurs, some giant ammonites, and even a PalAss-inspired trilobite appeared on the sand courtesy of a team of professional sand sculptors, ably assisted by enthusiastic members of the public.

A beached plesiosaur basking on the sand in sunny Scarborough. Photo by James Witts.

There were also numerous reports that a live *T. Rex* was to be found menacing the shoppers in Scarborough town centre in the direction of the Rotunda.

The Rotunda Museum in Scarborough and some of the Yorkshire Fossil Festival activities, including Horace the Travelling Pliosaur Cinema and a 'blown-up' version of William Smith's original 1815 map on the lawn made using different coloured pebbles. Photo by James Witts.

Many of the exhibitors chose to emphasise the bicentenary of the publication of William Smith's geological map of England and Wales, helped by the connection to the Rotunda Museum, which Smith had a hand in designing during the time he lived in Scarborough. One of the most popular of these activities, organised by volunteers from the University of Leeds in connection with local artist **Sue Lawty**, involved recreating a 'blown-up' version of Smith's original 1815 map on the lawn outside the Rotunda using different coloured pebbles collected from the beaches of the Yorkshire coast. Another testament to the popularity of any outreach activity where you can get your hands dirty – quite literally! By Sunday afternoon it was obvious that the weekend had been another huge success, with Rotunda staff reporting that 10,553 people had visited the site over the three days. It is hoped that the Yorkshire Fossil Festival can become a popular annual event in a similar way to that at Lyme Regis, whilst at the same time offering something a bit different. For anyone interested in volunteering in the future, it is a thoroughly rewarding experience and a huge amount of fun, and our contribution always generates the PalAss a considerable amount of goodwill and good publicity. I hope I speak for everyone who visited or took part this year when I say a huge thank you to all those people who helped put the Festival together. See you in 2016!

Dave Bond and son helping fill in the pebble version of William Smith's map, watched over by artist Sue Lawty. Photo by James Witts.

James Witts
University of Leeds

——OBITUARY——

David M. Raup 1933 – 2015

David M. Raup as many of us remember him. Photo courtesy of Rochester Democrat and Chronicle *(Rochester, New York, USA).*

David M. Raup was a central figure in the 'palaeobiological revolution' of the 1960s and 1970s that forever changed the field of palaeontology. His innovative work profoundly shaped how we analyse the history of life on Earth and the interaction of life and physical processes. As Stephen Jay Gould stated, "If Dave has any motto, it can only be 'Think the unthinkable (and then make a mathematical model to show how it might work); take an outrageous idea with a limited sphere of validity and see if it might not be extendable to explain everything.' … Of a handful [of colleagues] who have inspired me and pushed me to consider dangerous novelty … Dave Raup is the best of the best". Or as Steven M. Stanley put it when Raup was presented the Paleontological Society Medal: "Dave has always been an iconoclast who has perversely – but often justifiably – doubted conventional wisdom, and because of the highly original research born with this scepticism, palaeontology will never be the same". Raup was the very first recipient of the Schuchert Award of the Paleontological Society in 1973, and his 1997 Paleontological Society Medal made him the first individual ever to have received both awards.

There are a number of areas in which Raup made seminal contributions during his nearly fifty-year career as a palaeontologist. He made detailed quantitative analyses of the fossil record, laying the groundwork for a research programme that has been a major component of palaeontological research to the present day. In particular, he brought to our attention the numerous factors that might bias our understanding of biodiversity change over time. Raup was the chief proponent of the importance of considering random processes in our understanding of evolutionary patterns, and argued that causal explanations may not be needed if random processes could produce the same patterns. He summarised his ideas in the popular book *Extinction: Bad Genes or Bad Luck?* (1991).

Raup also quantified mass extinctions and, together with the late J. John Sepkoski Jr., he recognised the five major extinction events that now provide the starting place for any discussion of future biodiversity loss, including the widely quoted number that the end Permian extinction killed more than 95% of all marine species. The pair identified an apparent 26 million-year periodicity in the record of extinctions. This result ignited a firestorm of interest and criticism, and inspired a tremendous amount of further research and analyses. Raup documented the history of this controversy in his highly readable popular book *The Nemesis Affair: A Story of the Death of Dinosaurs*

and the Ways of Science (1986), the same year he delivered the Palaeontological Association Annual Address, a transcript of which was published early in 1987. Raup also pioneered the use of computers to simulate the forms of organisms, including mollusc shells, echinoids and trace fossils. The latter of these, working together with Dolf Seilacher, was one of the very first examples of 'artificial life' research.

Raup's ground-breaking textbook with Steven Stanley, *Principles of Paleontology* (1971) has been used by generations of young palaeontologists. It was the first palaeontology textbook to be solely about the science of palaeontology, rather than the fossils themselves. In fact, Raup, as well as other 'palaeobiologists', was often the target of criticism for his lack of interest in the traditional descriptive aspects of the field. Dave was actually somewhat proud of this, however; in his Presidential Address to the Paleontological Society (1978), he stated "I feel in a somewhat strange position today as the first president of the Society who has never described a species".

Raup was a superb teacher. Many of our leading younger palaeontologists studied with Dave at either the University of Rochester or later at the University of Chicago. His intellectual impact can be seen in any issue of *Paleobiology* or *Palaeontology*. Raup was also an excellent writer and I use his papers as an example to students of how to write a scientific paper – Dave was the Hemingway of palaeontologists; always brief and to the point! When I describe my own career, I modestly call myself a "Raupian". More than anyone else, he has influenced how I look at science, in particular with going outside the conventional boundaries of the discipline to look for ideas. I feel privileged having known and studied under him and he will be long missed.

Roy E. Plotnick
University of Illinois at Chicago

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Research Grant REPORTS

Evolution of biofouling and bioerosion in the Early Palaeozoic of Baltica

Olev Vinn
Department of Geology, University of Tartu

Introduction

Biofouling and bioerosion are two important but opposite processes shaping organic and inorganic hard substrates in the modern oceans. Biofouling or encrustation (sometimes termed bioconstruction) is economically important as it affects artificial substrates in the ocean such as dock facilities and boat hulls. Bioerosion is the chemical and/or mechanical degradation of hard substrates by organisms, whereas encrustation is the accretion of organisms (mostly calcium carbonate) on top of both organic and inorganic substrates. The geological history of biofouling and bioerosion is relatively well known (Taylor and Wilson 2003). The Ordovician was a time of great diversification of both hard substrate communities and bioerosion trace fossils (Taylor and Wilson 2003; Wilson and Palmer 2006), the latter being a function of the Ordovician radiation of marine invertebrates and termed the Ordovician Bioerosion Revolution (Wilson and Palmer 2006).

Ordovician and Silurian bioerosion is relatively well known in North America (*e.g.* Tapanila *et al*. 2004), and several studies have been devoted to the Early Palaeozoic of Sweden (Nield 1984; Ekdale and Bromley 2001). Likewise, some encrusting communities of Ordovician and Silurian hard substrates have been well-documented (Taylor and Wilson 2003; Nield 1984). However, there has, until now, been very little data available on the encrusting communities or bioerosion of the Ordovician and Silurian of the eastern Baltic, although they are thought to have assembled in the Early and especially the Middle Ordovician. Using the Research Grant from the Palaeontological Association I was able to carry out extensive fieldwork and laboratory investigations to try and elucidate the patterns of encrustation and bioerosion throughout the Ordovician and Silurian of eastern Baltica.

The environmental and biological controls on the biofouling and bioerosion in modern oceans have recently been thoroughly studied (see Lescinsky *et al*. 2002). The eastern Baltic is an excellent region for testing the possible environmental and biological controls on the evolution of biofouling and bioerosion in the Early Palaeozoic because its stratigraphy, facies zones, faunal composition and faunal distributions are among the best known in the world (see Raukas and Teedumäe 1997). The Baltic also has an excellent record of palaeoclimatic data that can be compared with biofouling and bioerosion data.

Encrustation of hard substrates of Baltica

The Middle Ordovician hardground faunas of Baltica are not diverse, including only bryozoans and echinoderms. Among the bryozoans, both domical colonies and stalked colonies (possible ptilodictyids) occur (Vinn and Toom 2015) (Figure 1), whereas echinoderms are represented by at least three different stemmed forms (*i.e.*, eocrinoids or crinoids).

Figure 1. Encrusted hardground from the Darriwilian of northern Estonia. 'br': ptilodictyid bryozoan holdfast, 'ech': echinoderm holdfast.

All studied samples derive from relatively shallow water environments and no obvious bathymetric or sedimentological trends can be established for the Ordovician of Baltica (Raukas and Teedumäe 1997). However, there is a stratigraphical trend in the taxonomic composition of hardground encrusters in the Ordovician of Estonia (Vinn and Toom 2015). The first hardground encrusters appeared in the Dapingian of Baltica, including bryozoans (possibly trepostomes), and echinoderm holdfasts (*i.e.*, eocrinoids or crinoids) (Vinn and Toom 2015). During the Darriwilian, ptilodictyid bryozoans appeared, but in general the early Middle Ordovician and late Middle Ordovician hardground faunas were similar. In the Late Ordovician (early Katian), edrioasteroids (*i.e.*, *Cyathocystis*) and cornulitids (*i.e.*, *Cornulites*) appeared (Vinn and Toom 2015). Most notable is the late appearance of edrioasterioids in the Ordovician hardground communities of Estonia. Similarly, cornulitids are known from the late Darriwilian of Estonia, but they colonized hardgrounds later in the early Katian (Vinn and Toom 2015). There seem to be no remarkable stratigraphic trends in encrustation intensities in the Ordovician of Estonia, which is surprising considering the great climatic change in Baltica (Raukas and Teedume 1997) while moving from the temperate zone to the tropics, coupled with the diversification of faunas during the Great Ordovician Biodiversification Event (GOBE) (Webby *et al*. 2004).

Typical Ordovician–Silurian hardground associations are, in general, similar and dominated by bryozoans and echinoderms (Taylor and Wilson 2003). One would expect the early Silurian associations to be very similar to the Ordovician ones. However, the taxonomic composition of an early Silurian hardground community from Estonia is rather different from characteristic Silurian associations, being dominated by tabulate corals, while bryozoans and echinoderms played a more

minor role (Vinn and Toom in press *a*). This domination of tabulates in the hardground fauna is surprisingly Devonian-like, where the tabulates form an important part of hardground associations. Somewhat similar is a community of stromatoporoid encrusters from the late Sheinwoodian of Saaremaa, Estonia (Vinn and Wilson 2012). These stromatoporoids also had an unusually high number of encrusting corals (*e.g.* rugosans and tabulates). Bryozoans occur in all other hard substrate associations described from the Silurian of Estonia, as do crinoids (Vinn and Toom in press *a*).

Bioerosion of hard substrates of Baltica

The earliest bioeroded inorganic hard substrates in the Ordovician of Baltica appear in the Dapingian and are also known from the Sandbian and Katian (Vinn *et al*. 2015). Most of the bioerosion occurs as the boring *Trypanites* Mägdefrau, 1932 (Figure 2) along with some possible Gastrochaenolites borings (Vinn *et al*. 2015).

Figure 2. Trypanites *borings in a hardground from the early Katian of Estonia.*

North American hardground borings are more diverse than those in Baltica; in contrast to a worldwide trend of increasing boring intensity, the Estonian record seems to show no increase during the Middle and Late Ordovician (Vinn *et al.* 2015). Bioerosion is mostly associated with carbonate hardgrounds, but cobbles and pebbles broken from the hardgrounds are also often penetrated by *Trypanites* borings. The general diversity of boring ichnotaxa in Baltica increased from one ichnospecies in the Cambrian to seven by the end of the Ordovician, showing the effect of the GOBE on bioeroding ichnotaxa; however, the diversity of inorganic hard substrate borers increased by only two times. This difference can be explained by the wider environmental distribution of organic compared to inorganic substrates in the Ordovician seas of Baltica and their more continuous temporal availability, which may have caused increased specialisation of several borers. The inorganic substrates may have been bioeroded only by the generalists among boring organisms (Vinn *et al*. 2015).

There seem to be no trends in the ichnotaxonomical diversity and bioerosion intensities in the Silurian of Baltica (Vinn and Toom in press *b*). Only *Trypanites* occurs in the hardgrounds of the Silurian of Baltica. The ichnological diversity of bioeroded organic hard substrates, containing *Trypanites*, *Palaeosabella* and *Osprioneides*, is higher than that of inorganic substrates (Vinn and Toom in press *b*). The small number of bioeroded inorganic substrates may indicate that these substrates were less important than the organic hard substrates for the development of seafloor ecological niches in this area (Vinn and Toom in press *b*). The average Baltic bioerosion intensities of the hardgrounds are relatively high, but not unusual for the Silurian (Vinn and Toom in press *b*).

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Evolution of early Sauropodomorpha: phylogenetic and biogeographic patterns in southern Pangea

Cecilia Apaldetti
CONICET, Museo Paleontológico Egidio Feruglio, Trelew, Argentina

The early Mesozoic (Late Triassic–Early Jurassic) was a crucial transitional period during which several of the most important vertebrate groups appeared, evolved, and dominated the terrestrial ecosystem for millions of years. One of the most successful groups to appear during those times were the sauropodomorphs, a dinosaur clade that appeared at the end of the Triassic and subsequently evolved into the largest terrestrial vertebrates of the planet, declining at the end of the Mesozoic. The basal forms of Sauropodomorpha, known as 'prosauropods', represented the first large radiation of herbivorous dinosaurs that dominated the faunal assemblage of Pangea for more than 40 Ma (Galton and Upchurch 2004; Upchurch *et al*. 2004). Although the fossil record of this group is diverse and broadly distributed worldwide, many aspects of its history, such as phylogenetic and biogeographic relationships, remain uncertain. Most phylogenetic studies show novel biogeographic patterns among basal sauropodomorphs from southern Pangea (*e.g.*, Upchurch *et al*. 2007; Yate *et al*. 2010; Apaldetti *et al*. 2011, 2013; Otero and Pol 2013; Otero *et al*. 2015), which represent key points in evolution leading towards the first steps of the origin of Sauropoda.

This project focuses on the anatomy of non-sauropod sauropodomorphs recorded in the Triassic and Jurassic of the Southern Hemisphere, with the aim of incorporating new information into a biogeographic analysis, utilizing the evolutionary relationships of basal sauropodomorphs within a phylogenetic framework. In this context, the Whittington Award from the Palaeontological Association gave me the opportunity to travel to South Africa to visit different palaeovertebrate collections, where the most relevant basal sauropodomorphs from the Upper Triassic–Lower Jurassic of the Elliot Formation are housed. At the Evolutionary Studies Institute (formerly the Bernard Price Institute for Paleontological Research, BPI), University of the Witwatersrand, Johannesburg, I studied the principal specimens known from the Early Jurassic of the Upper Elliot Formation, which include several individuals of *Massospondylus*, and the holotypes of *Antetonitrus*, *Aardonyx* and *Arcusaurus*. At the Transvaal Museum (TM) in Pretoria I was able to study the holotype of *Eucnemesaurus*, and at the National Museum (NMQR), Bloemfontein, I examined the skull and postcranium of *Melanorosaurus*. Finally, I visited the South African Museum (SAM, Iziko) in Cape Town, where I was able to study all of their specimens of basal sauropodomorphs that included, among others, the holotypes of *Massospondylus kaalae*, *Melanorosaurus*, *Blikanasaurus* and *Plateosauravus*. Most of the specimens are well preserved and many of them have an almost complete skeleton, which allowed me to obtain detailed information (morphological features) from cranial and postcranial elements.

The most important objective to be resolved in this project focused on a detailed comparison between South American and South African sauropodomorph taxa. During my visit to the fossil collections I gathered enough information to predict new evidence that links new basal sauropodomorph taxa from South America with those from South Africa. Additionally I was able to detect distinctive anatomical details for these groups that will be very useful for future phylogenetic studies.

The preliminary results show some new evidence that relates undescribed specimens from the Late Triassic of Argentina (*e.g.*, PVSJ2012-11, 2013-24) to some of the known South African taxa (*e.g.*, non-sauropods *Aardonyx*, or *Melanorosaurus*; possibly basal sauropods *Blikanasaurus*, or *Antetonitrus*). In this context, PVSJ2012-11 is an almost complete robust specimen with some sauropod-like features closely related to the most basal sauropod forms, such as *Antetonitrus*. The most relevant similarities are based on the presence of a strongly robust and short first metacarpal with asymmetrical distal condyles, and a gracile ulna with a well-developed olecranon process (Figure 1).

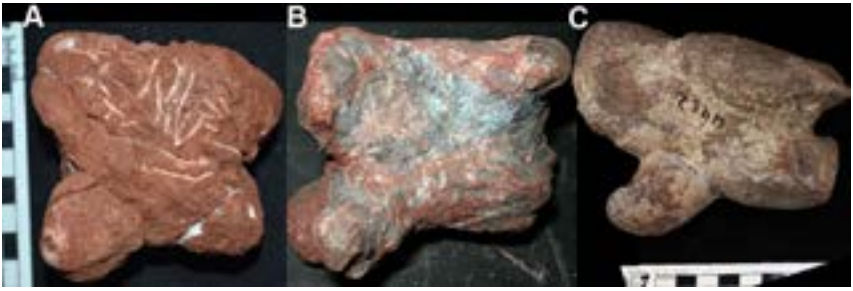

Figure 1. First metacarpals in dorsal view of different sauropodiform specimens from the Late Triassic of the Southern Hemisphere. A, right metacarpal of an undescribed specimen (PVSJ2012-11) from Marayes Basin of NW Argentina. B, left metacarpal (inverted) of Lessemsaurus *(PVL4822/56) from Los Colorados Formation of NW Argentina. C, right metacarpal of* Antetonitrus *(BPI4952) from the Lower Elliot Formation of South Africa.*

On the other hand, PVSJ2013-24 is a gracile basal specimen with sauropodiform-like features that in general resembles the *Melanorosaurus* condition, although its femur is more similar to the South American *Lessemsaurus* than that of South Africa (Figure 2). These affinities are based on the presence of a slightly sigmoidal femur with a semilunate fourth trochanter situated halfway along the length femur, which is more similar to that of *Lessemsaurus* (Figure 2A-D).

Figure 2. Femora of different sauropodiform specimens from the Late Triassic of the Southern Hemisphere. A, B, right femur of an undescribed specimen (PVSJ2013-24) from the Marayes Basin of NW Argentina. A, medial view. B, posterior view (inverted). C, D, right femur of Lessemsaurus *(PVL4822/65) from the Los Colorados Formation of NW Argentina. C, medial view. D, posterior view (inverted). E, F, left femur of* Melanorosaurus *(NMQR1551) from the Elliot Formation of South Africa. E, medial view (inverted). F, posterior view. G, H, left femur of* Antetonitrus *(BPI4952) from the Lower Elliot Formation of South Africa. G, medial view (inverted). H, posterior view.*

These findings provide new information that helps to clarify a particularly important region of the phylogenetic tree, the basal sauropodiform taxa (Figure 3), which represent the first steps towards the origin of Sauropoda.

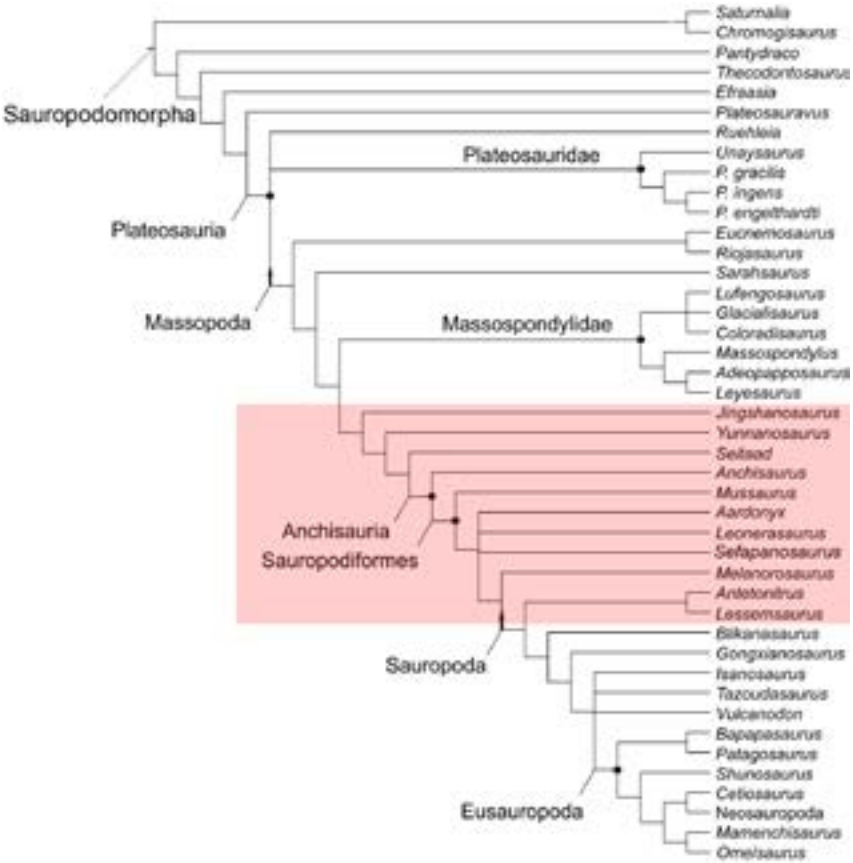

Figure 3. Phylogenetic tree of Sauropodomorpha showing (in red colour) the relationships and placements of Sauropodiforms. Tree modified from Otero et al. *2015.*

In this context, with the objective of understanding the phylogenetic relationships of Sauropodomorpha – and together with my colleagues from Argentina, Alejandro Otero (Museo de La Plata) and Diego Pol (Museo Egidio Feruglio) – we are performing a comprehensive phylogenetic study that includes all known basal sauropodomorph taxa around the world. Hence, all of the information collected from South African taxa is currently being processed to complete the new phylogenetic dataset on which we are working.

The most crucial points discovered during the development of our phylogenetic work include the detection of anatomical features not currently considered in phylogenetic analyses, as well as certain phylogenetic characters which are currently expressed in different ways, but that are measuring the same feature(s). From these data we are debugging the available phylogenetic information of

Sauropodomorpha in order to build a more comprehensive dataset, which will lead to novel and more coherent phylogenetic interpretations. Partial results of our studies will be shared during the next Latin American Congress of Vertebrate Palaeontology (V CLAPV; Apaldetti *et al*. accepted) where the phylogenetic relationship of basal Sauropodomorpha, with relevant information at the base of Sauropoda, will be proposed. For the short term, we are investigating different ways to release all of the gathered information with different perspectives regarding the evolution of Sauropodomorpha.

Acknowledgements

I wish to thank the PalAss and Whittington Award Committee for giving me the opportunity to travel to South Africa in the context of this project. I am also very grateful to the people who allowed me access to the collections under their care: B. Zipfel and S. Jirah (BPI), H. Fourie (TM), E. Butler (NM), R. Smith and Z. Erasmus (SAM).

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Pterosaur body mass, pneumaticity and flight mechanics

Elizabeth Martin
Ocean and Earth Science, University of Southampton

Introduction

True powered flight has evolved only three times in vertebrates: in birds, bats and pterosaurs. Of these, pterosaurs had the widest range of body sizes (with wingspans of 0.2–11 m), the largest overall size (the largest extant bird has a wingspan of 4 m, largest extinct was 7 m), and were the first to fly, initially in the Late Triassic. Despite being known in the fossil record for over 200 years, basic questions on pterosaur biology and biomechanics such as reliable body mass estimates and flight abilities are unknown or remain controversial. Body mass is one of the most basic and essential features affecting the locomotor capabilities of an animal, and is even more important with respect to flying animals as an animal's mass is directly proportional to its ability to take off and achieve lift. As the largest animals ever to fly, pterosaurs pushed the limits of aerodynamics, with much debate around whether or not the largest pterosaurs could indeed fly, making accurate mass estimates vital. Previous mass estimates have varied drastically depending on the methods used. For example, one of the largest pterosaurs, *Quetzalcoatlus northropi,* has been estimated at an improbably light 70 kg (Chatterjee and Templin 2004), more reasonable middle ground of 250 kg (Witton 2008), and very heavy 544 kg (Henderson 2010).

Fortunately, modern imaging technology has given us a way of accurately estimating bone mass using computed tomography (CT) scans. With relatively uncrushed pterosaur skeletons, bone volume can be estimated from CT scans, which can easily be converted into mass. Finally, after the bones have been reconstructed digitally, soft tissue mass can be estimated by estimating approximate muscle and tissue volumes. This should give a more accurate estimate of pterosaur total body mass, which is one of the main goals of my PhD. CT scans can also give us an idea of the degree of skeletal pneumaticity (air space present within the bones, caused by air-filled pouches invading the skeleton) found in specimens, which allows for comparison between different elements and species through the Air Space Proportion (ASP) of a bone. This can also be done using images of cross-sections through the bone, but that does not provide as accurate a measurement as CT scans throughout the entire bone (Martin and Palmer 2014). Pneumaticity is also found in birds, some theropod dinosaurs and in sauropod dinosaur necks. ASP gives a quantifiable measurement of the pneumaticity, which has implications for the biomechanics of an animal as it directly affects the stiffness of a bone. Additionally, CT scans can be used to look at the neural canal of vertebrae, in particular in the pelvis where the vertebrae are fused into a sacrum. Information about the size of the neural canal has been used in the past to gain information about locomotion in extinct animals (*e.g.* Giffin 1995), but has never before been applied to pterosaurs.

Aims

As part of my PhD research, I have been travelling to museums around Germany, the UK and North America to photograph and study as many pterosaur specimens as possible, and CT scan them where given the option. I have visited four museums in Germany, two in the UK, one in Canada, and two in the US: the Natural History Museum of Los Angeles County and the American Museum

of Natural History (AMNH) in New York. My trip to the AMNH was made possible thanks to the Sylvester-Bradley Award from the Palaeontological Association. I spent two weeks in the collections in January, during and just after the special exhibit on pterosaurs, so I could view some of the material in the exhibit. The goal of this trip was to study the *Pteranodon* material at the AMNH and document pneumatic features, as well as getting general ideas for the proportions of these animals, and to look at the additional material in the collections. In particular, I wanted to view an exquisitely preserved *Anhanguera* (AMNH 22555; Figure 1), a near complete wing of *Santanadactylus* (AMNH 22552), and a partial skeleton referred to as *Brasileodactylus* (AMNH 24444). Additionally, I hoped to obtain CT scans from as many of these as possible.

Figure 1. Anhanguera santanae*, AMNH 22555, on display. Additional material from the wings and legs is in the collections.*

Preliminary Results

Initial study of AMNH 22555 has proved very interesting. This is a partial skeleton consisting of both the pectoral and pelvic girdles, all preserved in 3D and mostly still articulated, which is very rare for pterosaurs. Low resolution CT scans of the specimen made in 2003 (provided to me by Patrick O'Connor of Ohio University) have revealed a very small neural canal in the sacrum in comparison with the sacrum of *Vectidraco*, a much smaller pterosaur from the Isle of Wight, UK. Preliminary study and comparison of these specimens suggests that *Vectidraco* was more terrestrially adept (large spinal cord for more innervation of the hindlimbs) than *Anhanguera* (small spinal cord). Previous studies have suggested that ornithocheirids like *Anhanguera* would have been poor locomotors on land, and were primarily flyers, while azhdarchoids like *Vectidraco* were strongly terrestrial, which is further supported here. The gross morphology of AMNH 22555 also supports this theory, as it has a much more robust pectoral girdle and a small pelvis.

Other preliminary results include visible trends in ASP (or MSP – marrow space proportion) in different sizes of pterosaurs. Non-pterodactyloid pterosaurs currently show no evidence of

appendicular pneumaticity (postcranial pneumaticity is limited to the axial column, as documented by others (*e.g.* Butler *et al*. 2009; Claessens *et al*. 2009), and therefore their long bones were likely full of marrow rather than air. This is also true for smaller pterodactyloids like *Pterodactylus*. Both of these groups are generally much smaller than the large, heavily pneumatised pterodactyloids. One trend that is becoming apparent is that smaller pterosaurs have proportionally higher bone volume when compared to space, meaning that the ASP or MSP is much smaller in these than in the larger pterosaurs (Figure 2). This is directly relevant to the bending stiffness of a long bone, and the effects of this are currently being studied. This does suggest that there is a minimum thickness required in pterosaur long bones, regardless of how small the pterosaur is, and cortical thickness does not scale uniformly with size.

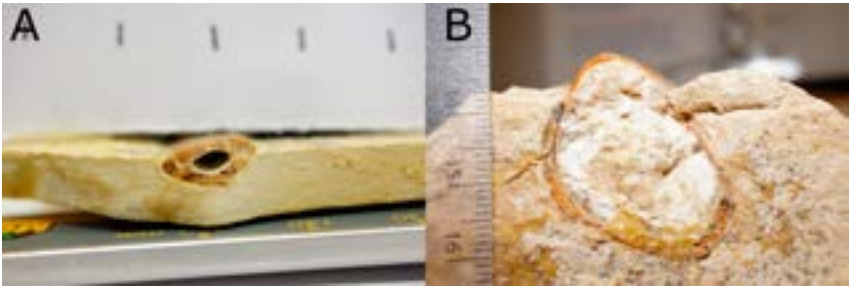

Figure 2. Images showing varying degrees of internal space compared to external cortex in pterosaur bones. A) a wing phalanx cross-section of a Rhamphorhynchus *with small MSP (Staatliches Museum für Naturkunde, Stuttgart, 59421), B) a larger wing phalanx cross-section from an ornithocheirid with large ASP (AMNH 22572).*

Future Work

These data are going to be essential in my continuing PhD research. First, I would like to further investigate the question of neural canal size and locomotion, and compare the values found with additional pterosaur taxa, expanding this to include the pectoral girdle as well. I also need to look at the effect of ASP and MSP on bending stiffness and study the trends seen in pterosaurs to see what this means about the difference in flight modes, or why there might be a minimum thickness required. Does anything come close to that minimum thickness? After CT-scanning a large number of specimens from a museum in Germany, I should be able to create a 3D model of most of a skeleton, ideally with some idea of soft tissue volume as well, in order to estimate a reasonable body mass. Some material from AMNH 22555 has been CT-scanned at a higher resolution more recently, and I have been given those scans to look at in the future. This is mainly just the cervical vertebrae, and will allow for study of pneumatic cavities and pneumatic volumes. Finally, some data I have collected from my visit to the AMNH that I have not yet looked at include data on wing bone sizes. In addition to the near complete *Santanadactylus* (AMNH 22552) wing, there is a nearly complete (although crushed) *Pteranodon* wing (Figure 3), with all elements isolated which meant that I could photograph it easily. Comparing these nearly-complete wings to the specimen that has been CT-scanned could provide more insight into how the proportions of different pterosaurs change, and how the mass distributions are different. These can further be compared to specimens of *Pteranodon* I was able to study in Los Angeles. This is something that will be done at the end of my PhD if time permits.

Figure 3. Near-complete wing of Pteranodon *(AMNH 4906) with some elements of the other wing as well. Image formed from three images stitched together.*

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I would like to thank the Palaeontological Association for making my trip to the AMNH possible; Carl Mehling and Mark Norell from the AMNH for helping and showing me around the collections; the Geological Society of London for funding my trips to Germany; the Natural Sciences and Engineering Research Council of Canada (NSERC) and the Graduate School of the National Oceanography Centre of Southampton for funding my PhD; my supervisors Gareth Dyke, Colin Palmer, Mike Habib, Emily Rayfield and Philipp Schneider for help and assistance; and many other people who have helped in this research.

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Undergraduate Bursary REPORTS

Early Cambrian embryos from the Kuanchuanpu Lagerstätte, China

Holly Betts
School of Earth Sciences, University of Bristol

The discovery of fossils of early animal embryonic developmental stages opened a new dimension of the fossil record, promising insights into developmental evolution during the establishment of animal body plans. However, palaeontologists were unprepared for the discovery since nothing was known concerning the taphonomy of these fragile stages; many subsequently over-interpreted the phases of diagenetic mineralisation within the fossils as representing preserved biological structure (Schiffbauer *et al*. 2012; Xiao *et al*. 2012). Experimental decay of embryonic and larval stages of living animals has revealed that physical structure can be maintained post-mortem on a timescale compatible with the establishment of conditions required for soft tissue mineral replication. However, comparatively little effort has been expended in understanding the fossilization history of fossil animal embryos to determine whether these new insights are relevant. Cunningham and colleagues previously studied the taphonomic history of embryo-like fossils from the Ediacaran Doushantuo Formation, which have disputed phylogenetic affinity (Bailey *et al*. 2007a, b; Cunningham *et al*. 2012 a, b; Huldtgren *et al*. 2011, 2012). I decided to undertake a comparative study of undisputed animal embryos from the Cambrian Kuanchuanpu Formation, another exceptional preservation site in South China, as well as those of the Doushantuo Formation.

The Cambrian Kuanchuanpu Lagerstätte preserves a range of fossils in calcium phosphate including tomotiids, anabaritids, chancelloriids, as well as embryos including the cnidarian *Olivooides* and the putative bilaterian *Pseudooides* (Bengston and Zhao 1997). These occur in association with cleavage-stage embryos and are surely related, although their precise attribution is unclear. I studied the mineralisation history of cleavage embryos comprised of tens to hundreds of component cells and characterized these non-invasively using synchrotron radiation X-ray tomographic microscopy (SRXTM), which allowed me to observe the structure of fossils. The differential attenuation of the synchrotron X-radiation reflects differences in the atomic structure of the materials, and this is reflected in the greyscale levels in the resulting radiographs. To establish the sequence and style of the phases of mineralisation then required invasive analysis of the texture and chemistry in the fossils. To do this, I embedded the fossils in epoxy resin, ground the resin to the level of interest predetermined using the SRXTM data, and then analysed these surfaces using backscattered electron (BSE) imaging, and electron probe microanalysis (EPMA) – the same methods used to elucidate the taphonomy of the embryo-like Doushantuo fossils.

The BSE and EPMA images show that the fossilized embryos exhibit a range of preservational states and polarisation of preservation within embryos themselves (Figure 1). Their preserved biological structure is limited to the cell membranes of the component blastomeres. Four different phases of mineralisation were identified within the Kuanchuanpu embryos, each of which has a specific

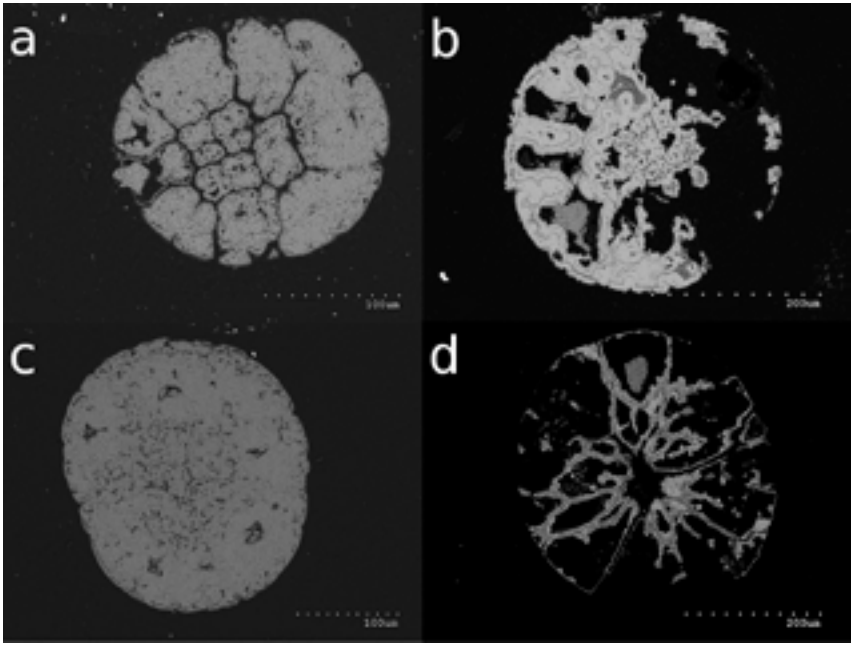

Figure 1. Backscattered electron (BSE) images of Kuanchuanpu fossil embryos. (a) embryo with distinct blastomeres composed of large, homogeneous crystals, no cell membrane preserved; (b) aligned crystals in a highly degraded specimen; (c) homogeneous mass of crystals with blastomere shape preserved only at the exterior edge; (d) degraded, mainly hollow embryo, with preservation of the cell wall in a dark, microcrystalline phase.

texture and chemistry (Figure 2) ranging from large, blocky and homogeneous to microcrystalline. A combination of preservation types were found in different areas of the fossil embryos. The preservation of the blastomeres ranges from complete, extending internally through to just the outlines between adjacent cells at the embryo edge. More often than not, the membrane is not preserved and instead there is only a hollow void in its place; possible reasons for this include potential infilling with calcite that was subsequently dissolved out during extraction. No intracellular structures are preserved in any embryos.

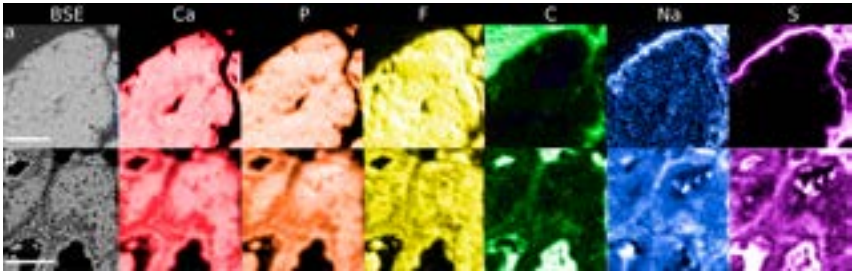

Figure 2. Backscattered electron (BSE) images of an area of two different embryos (a) and (b) and electron probe microanalysis (EPMA) images of the relative abundance of calcium (Ca), phosphorus (P), fluorine (F), carbon (C), sodium (Na) and sulphur (S). Scale bar in each case equals 20µm. Brighter areas show a higher abundance of the element relative to dark areas.

Since there is polarisation of mineralisation in an inward direction, we can infer that the preservation may have occurred from the outside in. The absence of a cell membrane, but the clear structure that many of the embryos exhibit, likely indicates that cell membrane preservation was essential for the replication of cell structure. The variation in the extent of biological structure preserved, such as the more or less distinct boundaries between component cells, suggests that the embryos were in variable states of decay when they were mineralized. The limited range of preserved structure is not entirely compatible with the results of taphonomy experiments, which revealed that the microscopic physical structure of embryos and their component cells can be maintained as substrates for mineral replication. Indeed, the Kuanchaunpu cleavage embryos do not directly preserve any biological structure and cell membranes can only be inferred to have been present based on the centripetal mineralisation within the cell lumens. However, experiments and fossil taphonomy may be reconciled by a model in which the mineral grows away from the substrate, rather than impregnating and replicating it. The taphonomic history of the Kuanchuanpu cleavage embryos differs from that of the Ediacaran Doushantuo embryo-like fossils as, in Doushantuo, but not Kuanchuanpu, intracellular structures are preserved. In both, cell membranes are not directly preserved. These similarities and differences may reflect the possibility that the Doushantuo embryo-like fossils are actually fossilized animal embryos, or it may merely reflect generic aspects of cellular preservation.

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Multiple sulphur isotope studies of pyritized microbially induced sedimentary structures, Neoarchaean Ghaap Group, South Africa

Nicolette Meyer
Department of Earth & Environmental Sciences, University of St Andrews

Introduction

The rock record is sparse in terms of evidence for the earliest forms of microbial life – the challenge for geobiologists is to use the morphology of stromatolites, microbially-induced sedimentary structures (MISS) and microfossils as well as stable isotope data to interpret microbial modes of life (Noffke *et al.* 2013). We coupled petrographic electron microprobe analysis (EPMA) and sulphur isotope secondary ion mass spectrometry (SIMS) on extraordinarily well-preserved MISS from the 2.65-2.50 Ga Lokammona Formation, Ghaap Group, South Africa, to investigate sulphur cycling in a Neoarchaean microbial mat. The disseminated pyrite SIMS data show low $\Delta^{33}S$ values, which suggests the sulphur was not exposed to mass independent fractionation (MIF) through atmospheric photolysis and is therefore likely to be of hydrothermal origin. The $\delta^{34}S$ values show a high spatial variation of 18‰ on a mm-cm scale, which is analogous to the sulphur isotope trends seen in modern microbial mats (see Fike *et al.* 2009). Therefore, we propose that the pyritized MISS and its complex $\delta^{34}S$ sulphur signal represents an ancient microbial mat community living in relative proximity to a seafloor hydrothermal vent, utilising the redox potential to support sulphur-based Neoarchaean life forms.

Description and interpretation of microbial structures

Textural analysis of the pyrite-rich black shale MISS sample from the Lokammona Formation, BH1-SACHA core, using a super-resolution digital microscope (VHX-2000) and EPMA (Jeol JCXA-733 Superprobe) at the University of St Andrews shows evidence of microbial origin. Crinkly and wavy lamina composed of pyrite and detrital grains (predominantly quartz and clay minerals) with an approximate wavelength of 500 µm and a height of 200 µm were observed (Figure 1). Such structures may form as a result of ductile deformation of a surface composed of detrital grains bound by microbially-produced extracellular polymeric substances (Noffke, 2009; Schieber, 2007), or be due to the abiological compaction of phyllosilicates. The cohesive nature of the surface is further highlighted by the presence of roll-up structures, where thin microbially-bound layers were overfolded (Noffke *et al.* 2006; Schieber, 2007). Furthermore, solitary 80 µm detrital clay mineral grains 'floating' between pyrite-rich laminae were identified (Figure 2). The long axes of the grains are parallel to the mat layer. This is a feature seen in modern microbial mats, where biofilms separate detrital grains (Noffke *et al.* 2006). In the Neoarchaean MISS sample, the carbon-rich laminae that separate the detrital grains have been replaced by pyrite.

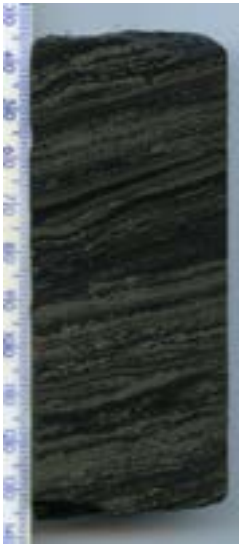

Figure 1. Pyritized MISS from the Lokammona Formation, Ghaap Group, South Africa.

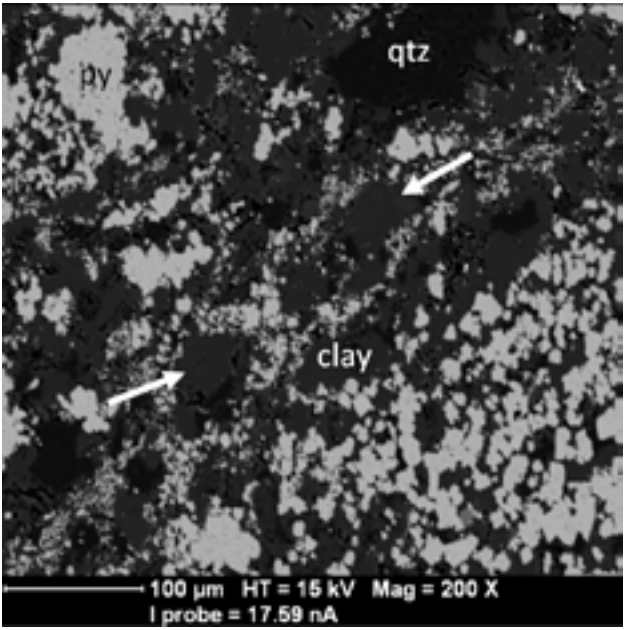

Figure 2. Backscatter electron image of detrital clay mineral grains (arrows) "floating" between pyrite-rich laminae. py = pyrite, qtz = quartz, clay = clay minerals.

This suggests that the pyrite may have formed due to mat decay mineralisation during diagenesis (Schieber 2007), where dissimilatory sulphate reducers oxidize organic matter, forming hydrogen sulphide that combines with Fe^{2+} to produce pyrite (Seal 2006).

Sulphur isotope data

I used the CAMECA IMS 7f-GEO SIMS in the Department of Earth and Planetary Sciences at Washington University in St. Louis to measure multiple sulphur isotopes ($\delta^{34}S$, $\delta^{33}S$, $\Delta^{33}S$) of the MISS sample. 10 µm x 10 µm spot analyses were performed in pyrite-rich areas to show spatial differences in sulphur isotope ratios on a µm-mm scale. A variation of 18‰ and 8‰ in $\delta^{34}S$ and $\Delta^{33}S$, respectively, was noted throughout the sample. This is comparable to the sulphur signature in modern microbial mats, where there are high spatial differences in $\delta^{34}S$ between laminae (Fike *et al.* 2009). An overprinting, later, hydrothermal process by an exotic H_2S would have homogenized the $\delta^{34}S$ values during transport (Kakegawa and Nanri 2006), and therefore the data from this study suggest a syndepositional/early diagenetic origin of the pyrite.

Sedimentary rocks older than the Great Oxidation Event (GOE) at 2.4 Ga show a MIF signal (MIF = $\Delta^{33}S \neq 0$). MIF occurs through the atmospheric photolysis of SO_2 in the absence of an ozone layer (Seal 2006). Due to SO_2 photolysis, pre-GOE pyrites show a linear correlation between $\delta^{34}S$ and $\Delta^{33}S$ (Figure 3; Ono *et al.* 2003). However, the disseminated, anhedral pyrite crystals in the MISS studied here consistently have $\Delta^{33}S$ values close to zero and thus do not exhibit a MIF signal. This suggests that the sulphur source was not exposed to the atmosphere, and thus a deep-sea hydrothermal origin is likely.

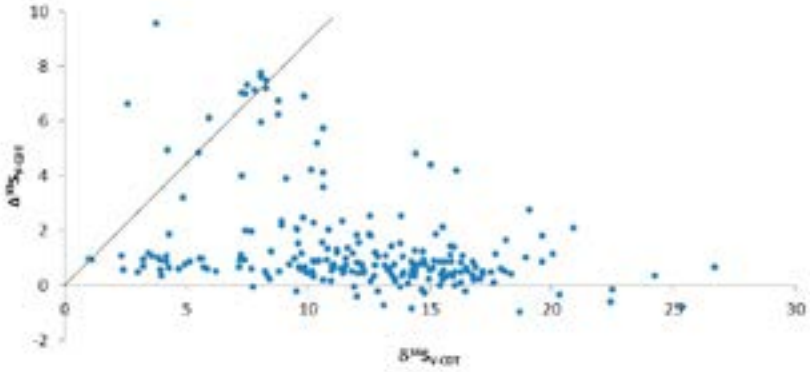

Figure 3. SIMS sulphur isotope data on the Neoarchaean MISS sample from the BH1-SACHA core, Lokammona Formation. The line represents the Archaean seawater sulphate and elemental sulphur isotope composition due to atmospheric photolysis (Ono et al. *2003). The low $\Delta^{33}S$ values suggest that the sulphur source did not undergo MIF and therefore its origin is likely hydrothermal rather than atmospheric. The high spatial variation in $\delta^{34}S$ indicates that the sulphur source was syndepositional/ early diagenetic (Kakegawa and Nanri 2006) and was likely caused by biological MDF processes in a closed system.*

Overall, the data suggest that the pyritized MISS represent a fossilized microbial mat close to a deep-sea hydrothermal source where microbes with a sulphur-based metabolism utilized the steep redox gradients to respire. Biological mass-dependent fractionation (MDF) processes such as dissimilatory sulphate reduction and sulphur oxidation (Reysenbach and Cady 2001) in a closed system could have caused the high $\delta^{34}S$ variation measured in the MISS sample.

Conclusion

Textural evidence has shown strong indication for a biological origin to the Neoarchaean wavy, crinkly MISS. A hydrothermal sulphur source and biological MDF processes in a closed system could explain the observed µm-mm scale variation in $\delta^{34}S$ and a $\Delta^{33}S$ signal close to zero, respectively. Further scanning electron microscopy work will help to explain isotope data outliers (particularly those that fall close to the Archaean reference line (Figure 3), constraining the pyritized MISS sulphur source and therefore helping our understanding of ancient microbial communities at hydrothermal vents.

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3D photogrammetric imaging and re-analysis of unique Late Carboniferous footprint assemblages from Shropshire and the West Midlands, UK

Luke Meade

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

The Late Carboniferous to Early Permian was an interval of major global environmental change, with increasing global aridity leading to the collapse of the previously widespread humid, tropical rainforests (the 'Coal Forests'). This environmental transition is hypothesized to have driven major changes in terrestrial tetrapod communities (Sahney *et al*. 2010), with the amphibians that dominated ecosystems of the Carboniferous being replaced by early amniotes ('reptiles'). A tetrapod track assemblage from the Alveley Member of the Salop Formation at Alveley, southern Shropshire, is the most extensive collection of footprints known from the Late Carboniferous of Europe and provides a unique ichnological insight into tetrapod communities and palaeoecology during this interval (Tucker and Smith 2004). Another less extensive but still remarkable set of tracks come from Hamstead, around 6 km northwest of Birmingham city centre, from the Enville Member of

the Salop Formation. These latter footprints date from slightly later in the Carboniferous and have been substantially less well studied in the scientific literature (Hardaker 1912; Haubold and Sarjeant 1973).

This project aimed to use 3D photogrammetric imaging to create high-resolution 3D models of the footprint slabs, allowing the number and diversity of trackways to be documented in great detail so that new data on trackway dimensions and morphology could be identified. The aim was to generate more refined identifications of the trackmakers and perhaps a new outlook on trackmaker locomotion. The best preserved, most abundant and impressive ichnological specimens were digitized first, as modelling all available slabs (over 200) was not possible in the timeframe. For each slab, approximately 30–50 photographs were taken from a range of different angles using a digital SLR camera (Nikon D5100) with a fixed 50 mm lens and a tripod, and with slabs illuminated by artificial light. These photographs were then imported to the software Agisoft Photoscan (Professional Edition). Photoscan software was used to combine these photographs into high-resolution 3D photogrammetric models. Subsequently, the freeware software CloudCompare was used to render these models as digital 3D reliefs with coloured contour intervals (Figure 1; methodology from Romilio and Salisbury 2014), as well as in the form of images with areas of steeper gradient (*i.e.* the edge of a footprint) highlighted (Figure 2).

During the course of the project, the focus shifted from the Alveley material to that of Hamstead. Due to the limited previous study, it was decided that focusing on documentation of the Hamstead material in its entirety would provide more scientifically important results, as new insight into these tracks was more likely. The analytical results generated from models and rendered images of the Hamstead tracks are currently being written up for publication, and provide an important comparison to the earlier Alveley material, indicating ecological and environmental changes occurring during the Late Carboniferous.

The first study of the tracks from Hamstead (Hardaker 1912) identified 11 distinct track types amongst the footprints. Ten of these types were assigned to the ichnogenus *Ichnium* and a solitary example of *Ichnotherium cottae* was identified. When the material was partially revisited by Haubold and Sarjeant (1973) the taxonomic assessment of seven of the Hamstead track types was revised, with two being assigned to *Ichnotherium cottae*, another two to *Dromopus lacertoides*, and a further three types being identified as *Gilmoreichnus brachydactylum*, *Anthichnium salamandroides* and *Dromopus lacertoides*. The material was briefly mentioned by Tucker (2003), who found no evidence of *Ichnotherium cottae*, stating instead that the slabs were dominated by very large *Limnopus vagus* tracks along with *Dimetropus leisnerianus*, *Hyloidichnus bifurcatus*, *Limnopus salamandroides*, and *Dromopus lacertoides*.

As part of this project, I have revised this taxonomy. A range of large and small tracks have been assigned to *Limnopus* isp. (made by early amphibians; Figure 1) with a series of smaller and slightly morphologically different tracks being assigned to *Batrachichnus salamandroides* (also made by early amphibians). *Dromopus lacertoides* (made by the lizard-like araeoscelids) and *Dimetropus leisnerianus* (made by early synapsids) were identified as present and no evidence was found of *Hyloidichnus bifurcates* or *Ichnotherium cottae*. The presence of such large *Limnopus* trackways (in some cases reaching a length and width of over 10 cm) along with the presence of *Dromopus*, typical of semi-arid and coastal environments, suggests noticeably different palaeoenvironments

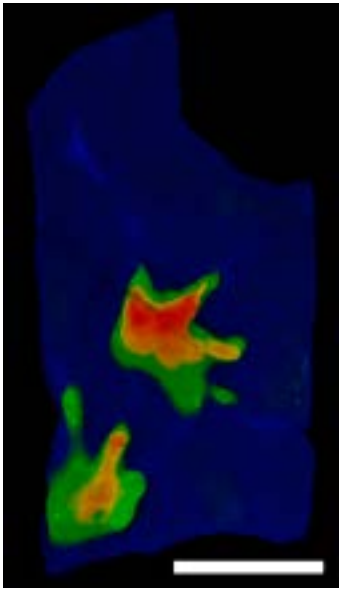

Figure 1. Rendered image of a sandstone slab from Hamstead highlighted topographically to show a Limnopus *manus-pes pair. Scale bar is 10 cm.*

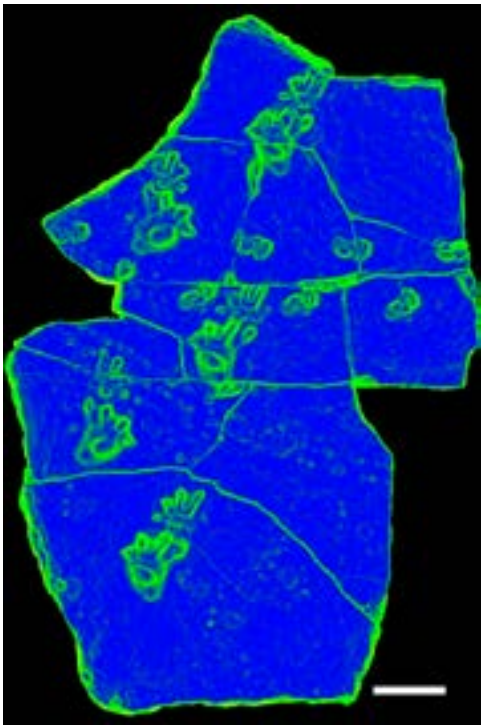

Figure 2. Rendered image of a large sandstone surface from Alveley highlighting areas of steeper gradient, and including trackways of Ichnotherium willsi *(larger trackway moving from bottom to top) and* Limnopus vagus *(smaller trackway moving from left to right). Scale bar is 10 cm.*

and faunas between the Hamstead material and the earlier Alveley material, which features much smaller *Limnopus* tracks, includes large *Ichnotherium* tracks (made by reptilomorphs; Figure 2) and lacks *Dromopus*. The project also produced many high-quality digital models and rendered images from the Alveley material and succeeded in digitising the Hamstead material in its entirety. The models and images will form part of a permanent display in the newly redeveloped Lapworth Museum of Geology at the University of Birmingham. Some models will be downloadable to view as part of a new iPhone app for Museum visitors.

I would like to thank the Palaeontological Association for making this study possible, and Dr Richard Butler and PhD student Andy Jones for their support and supervision.

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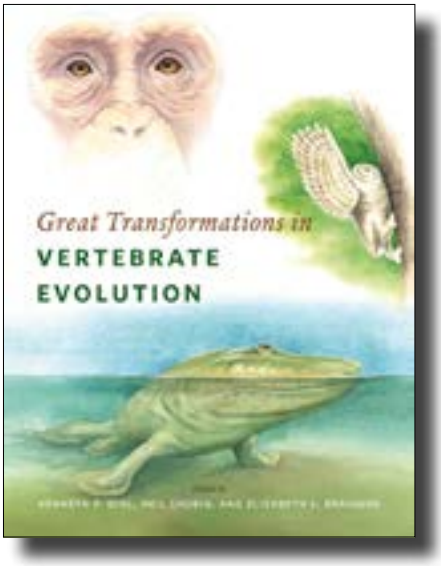
Book Reviews

Great Transformations in Vertebrate Evolution

Kenneth P. Dial, Neil Shubin and Elizabeth L. Brainerd (eds.). 2015. The University of Chicago Press. 424 pp. £31. ISBN-13: 978-0-226-26825-5.



Great Transformations in Vertebrate Evolution is a broad yet in-depth look at some of the most radical and fascinating changes in vertebrate anatomy and biology over the course of their evolutionary history. With contributions from 35 authors, this book greatly benefits from a range of expertise and many years of scientific research. The book is split into two main parts with part one entitled "Origins and Transformations", comprising 15 chapters. Each chapter focuses on the evolution of a particular trait or associated traits from various vertebrate clades from across evolutionary history. These include the origins of the jaw and teeth in gnathostomes, hind-limb posture in archosauromorphs, and the placenta in therian mammals. In each of these chapters, the original theories for the evolution and function of these respective feature(s) are first presented before reviewing how these hypotheses now stand up in the light of recent research. One very appealing aspect to all of these chapters is that the authors draw evidence from a vast range of disciplines, from 'good old-fashioned' taxonomy, to genetics, to biomechanical modelling. Such an approach favourably shows vertebrate palaeontology as an area of interdisciplinary scientific research, at the forefront of applying state-of-the-art and insightful techniques.

The second part of *Great Transformations*, entitled "Perspectives and Approaches", comprises eight chapters. In this section, research methods are the main focus of each chapter with vertebrate taxa acting as illustrative case-studies. Chapters include morphological innovation in archosaurs, as well as the derivation of new and altered structures in teleost fishes from their underlying genetic diversity. All of these chapters highlight the exciting fact that there is always more to discover about the evolutionary history of these extraordinary animals, emphasising that we need to continue to utilise an ever-expanding range of techniques in our scientific arsenal, not strictly to make new discoveries of taxa *per se,* but for "identifying the important questions to ask". This is exemplified in chapter 6 "Anatomical Transformations and Respiratory Innovations of the Archosaur Trunk" and warrants a more detailed description. The authors first review differences in morphology and function in the trunk of the only two surviving groups of archosaurs, crocodilians and aves.

Stemming from this, they then question whether trunks of extinct archosaurs, such as dinosaurs and pterosaurs, can be representatively reconstructed based on their extant relatives. This attitude towards solving scientific problems is important for preventing untestable hypotheses being formulated and for determining how best to answer the testable questions. In this instance, the authors conclude that subjecting more archosaur fossils to advanced imaging techniques is a promising future direction. Such an approach to solving palaeontological scientific problems in this manner is one of the great strengths of this book.

Great Transformations gives a brilliant overview of the huge diversity of topics on vertebrate evolution whilst maintaining depth for each subject. Some of these in-depth chapters, such as "Microevolution and the Genetic Basis of Vertebrate Diversity" and "Placental Evolution in Therian Mammals", also contain a useful glossary allowing non-specialists to get a foothold in these topics. However, I feel that a glossary could have been provided in all chapters in order to further broaden the audience, to include non-specialist readers in the other topics. The authors acknowledge that this book does not provide the final say on long-standing scientific questions, and readily encourages readers to explore the literature further and come up with their own conclusions. This is of course aided by the majority of chapters containing an extensive and up-to-date reference list, allowing readers to easily immerse themselves further in any of the topics or research techniques as they so choose.

Great Transformations also benefits from an abundant range of figures, many of which are adapted from previous papers mentioned in the respective chapters, which are mostly easy to interpret. I say mostly because there are a few anatomical diagrams in chapters "Flexible Fins and Fin Rays as Key Transformations" and "The Evolution of the Mammalian Nose" which are in black and white and are thus a little harder to interpret than they would have been in colour. Having said that, the book is complemented with several excellent pencil illustrations by Robert Petty, which do a fine job of depicting the dynamic nature of animal movement.

I would have personally liked a chapter on the actual origins of vertebrae and the Vertebrata. In my opinion, this could be argued as one of the biggest transformations of vertebrate evolution, so seems rather peculiar to be absent from this book. In addition, for all the vertebrate clades featured in *Great Transformations*, it is perhaps a little unsurprising that some get a little more coverage than others. Page space dedicated to archosaurs, especially birds for example, is plentiful whereas key clades such as Chondrichthyes and Squamata only get brief mentions. Of course this bias is very unlikely to have been intentional from the authors, more likely a reflection of how intensively studied particular taxa have been in recent years. Overall, *Great Transformations* is an engaging and thorough book explaining not only what we know about vertebrate evolution, but, perhaps more importantly, the evidence behind what we know. Furthermore, it is also relatively cheap for its content and size, making it a great asset for any PhD student entering the realm of vertebrate palaeontology, and for any professional researcher wishing to keep up to speed with the latest advances in vertebrate evolution.

Jordan Bestwick
University of Leicester

Macroevolution – Explanation, Interpretation and Evidence

Emanuele Serrelli and Nathalie Gontier (eds.). 2015, Springer. 403 pp. ePub £86 / hardcover £108 ($119.00 / $159.00). ISBN: 978-3-319-15044-4.

This book is the second in Springer's *Interdisciplinary Evolution Research* series and the most relevant to a palaeontological audience. It stems from a series of Darwin bicentennial lectures given at the University of Chicago in 2009 and subsequent meetings, schools and public events. The editors are both philosophers of science and the book is accordingly more a collection of essays than papers. This makes for a more unusual focus than other collected volumes, but one that benefits from a didactic approach by its authors. The book contains twelve chapters split into an introductory synthetic chapter, then two parts (*Macroevolutionary Explanations and Interpretations* and *Evidencing Macroevolution with Case Studies*) of six and five chapters, respectively. The introductory chapter is one of the best of its kind I have encountered. Here the editors clearly spent considerable time reading and digesting the eleven other contributions, and draw out multiple themes, linkages, and questions which enhance the reading of the rest of the book.

Douglas Futuyama's chapter opens the book proper and re-opens the debate of whether microevolutionary processes can explain macroevolutionary patterns. Here the focus is on the evolutionary synthesis and some apparent palaeontological objections to it (*e.g.* punctuated equilibria). He concludes that the synthesis remains "fairly intact", but acknowledges the importance of these robust criticisms in its development. Folmer Bokma's chapter effectively disagrees. He points out that "… evolutionary theory fails to predict when and where and to what extent evolution will take place", and goes on to argue that molecular evidence actually supports punctuated evolution and more broadly that "macroevolution is not microevolution writ large". More specifically he argues "long-term stasis is caused by traits exerting selection on each other", and suggests that macroevolution is thus a largely autonomous process, but one driven more by internal trait selection than abiotic factors.

Emanuele Serrelli's chapter focuses on visualising macroevolution, with a particular focus on adaptive landscapes. Here, landscapes from Simpson to Dawkins are presented alongside a Sepkoski diversity curve and various morphospaces. Stanley Salthe's chapter focuses on 'energy flows', in contrast to the more dominant information perspective in biology. I found this unusual approach interesting, and he shows that both information and energy (measured as energy

throughput per unit mass) broadly increase over geologic time, culminating in modern society (and our own insatiable appetite for energy and its unfortunate climatic consequences). Within this framework, species are irrelevant (they are informational constructs) and thus his use of the term macroevolution refers to the more general perspective.

Ilya Tëmkin and Niles Eldredge's chapter does an excellent job of delineating biological networks and hierarchies, and sets up a framework within which questions concerning the status of macroevolution as an emergent phenomenon can be addressed. They argue that biology can be split into two main hierarchies (economic and genealogical), and more broadly that the complexity of biological systems may help buffer against external perturbations, echoing Bokma's chapter as a potential explanation for stasis. They conclude by noting that hierarchical approaches to biology are still in their infancy and that there is much work still to do. Nathalie Gontier's chapter – on uniting microevolution and macroevolution into an extended synthesis – was my least favourite. However, she does make an interesting argument: that, in practice, microevolution and macroevolution can be considered two separate paradigms (*sensu* Kuhn), and hence are comparable to the wave-particle nature of light.

The second part of the book is opened by Lutz Becks and Yasaman Alavi's chapter, which also concerns the integration of micro- and macroevolution, but here they concentrate on the differences between sexual and asexual organisms. They begin by nailing their colours to the mast (macroevolution is just microevolution scaled up) and go on to note interesting aspects of asexual taxa. Specifically, they are 'twiggy' in their phylogenetic distribution, rare, and recent (Pleistocene or younger). Interestingly they seem to thrive in highly variable environments (*e.g.* high altitude or latitude), which at least partially explains their lack of persistence. Sexual taxa are thus by contrast more diverse, longer lived, and more common in stable environments. Alycia Stigall's chapter is the most directly palaeontological, focusing on three case studies from the North American fossil record: the Late Ordovician Richmondian invasion, the Late Devonian biodiversity crisis, and the Miocene equinid radiation. Here, biogeographic patterns are examined where turnover can lead to shifts in the prevalence of slowly speciating but widespread taxa, and faster speciating taxa, with narrow ranges and downstream effects on diversification rates. Contrary to Bokma, the importance of abiotic factors (tectonics, sea level) is emphasised, although she agrees that macroevolution is a distinct phenomenon.

Alessandro Minelli's chapter concerns morphological outliers ("misfits") and how they might relate to developmental biology. Many examples across the tree of life are provided and some criteria by which they can be further subdivided are suggested. Here he argues that explanations for their existence must begin by correctly placing them in the tree of life, something that molecular data are likely to be much more effective at than morphological. Finally, he presents multiple developmental explanations (modularity, evolvability, heterochrony, heterotopy, and heterometry) that may explain their existence. Bernard Wood and Mark Grabowski's chapter concerns macroevolution in our own clade (the Homini). They make the important point that macroevolution is sensitive to taxonomic differences in a way that microevolution is not. Hominins are particularly contentious in this regard, with classifications differing between workers and over time. For example, phylogenetics has changed perceptions of broader ape phylogeny, but largely failed to provide a consistent tree for fossil taxa. They go on to argue for a "splitters" taxonomy and favour the use of grades (paraphyletic taxa) within the Homo stem, noting that understanding hominin macroevolution is plagued by issues beyond taxonomy.

The final chapter of the book – by Elena Casetta and Jorge Marques da Silva – focuses on the present biodiversity crisis and, specifically, conservation priorities. Here they simply point out that speciation and extinction are macroevolutionary phenomena, and at their extremes represent adaptive radiations and mass extinctions. Evidence that we are headed into the 'Big Sixth' is based on modern extinction rates, and they discuss important issues such as how modern extinctions should be declared and conservation priorities set. Importantly, they argue that ethics should also be considered, *e.g.* if malaria were endangered should it be conserved? They conclude by criticising current U.S. (Endangered Species Act) and E.U. (Habitats Directive) legislation.

This book has relatively few negatives. Perhaps the greatest one is the steep price, which may be fatal for some readers. Those on a budget should therefore check whether their institution has access through SpringerLink, or recommend a hardcopy to their librarian. More personally, I was hoping for a greater phylogenetic perspective as I feel that is where quantitative macroevolution has really developed in recent years. However, that is more of a personal gripe and a different Springer title (*Modern Phylogenetic Comparative Methods and Their Application in Evolutionary Biology*) already has most of those topics covered. Aside from that my ePub review copy had some issues with figure quality, particularly those reprinted from older works in the Serrelli chapter, and there are minor English issues in places.

Overall, though, I really enjoyed this book. I got something from every chapter and was impressed by how 'integrated' it felt. Specifically, there was real linkage between the chapters, and it really felt that each author was aware of every other's chapter. The book would make ideal reading for a macroevolution class and a great starting point for a discussion on whether macroevolution is a distinct phenomenon. There is also a great mix of history (I learned that the term 'macroevolution' was actually first coined by the Russian geneticist Filip**č**enko), novel ideas (the Bokma chapter), and frameworks for future study (the Tëmkin and Eldredge chapter). I would thus heartily recommend this book to anyone interested in this important palaeobiological topic.

Graeme Lloyd
Macquarie University

Ordovician Trilobites of Southern Ontario, Canada and the surrounding region

Philip A. Isotalo. 2015. 224 pp, 165 colour illustrations, mainly photographs. £21 (softback). ISBN: 978-0-9929979-1-5. Available direct from the publisher at <**http://www.siriscientificpress.co.uk**>.

This is an enchanting book, and a welcome addition to any trilobite-lover's library. It is basically an illustrated guide to the trilobites of a classic region of North America, with all the photographs in colour, some being full-page. But it is also a useful introduction, written by a keen and truly knowledgeable amateur palaeontologist, as to what trilobites actually are, their history through time, some aspects of their anatomy, ontogeny, biology and behaviour, their discovery, and their classification. And, of course, there are sections on the Palaeozoic geology of southern Ontario, and especially the Ordovician, illustrated by appropriate geological maps.

The main part of this book is a photographic survey, systematically arranged, of 64 species, illustrated by intact or nearly complete specimens. Several of these are represented by numerous

photographs of different individuals; there are 142 photographs altogether, some illustrating stages in the preparation of a trilobite and other practical matters. Additional species represented only by fragments are noted though not illustrated; the total number of Ordovician trilobite species in Ontario amounts to 89, more than enough to show the amazing diversity of trilobite morphology during this period. Of particular interest are 13 or so tasteful reconstructions of the animals themselves or of the undersea communities of which they formed a part. These were evidently prepared specially for this guidebook. Although there are no Konservat-Lagerstätten in Ontario, there are two just over the USA border in New York State: Beecher's Trilobite Bed and Walcott-Rust Quarry. These are described here, and their spectacular trilobites illustrated. The final part of the book is a practical guide to collection, equipment, preparation, photography, and storage of specimens. There is a list of Internet resources and a bibliography.

It is now 36 years since the publication of Rolf Ludvigsen's admirable *Fossils of Ontario Part 1: The Trilobites*, and as David Rudkin notes in his Foreword, many additional species from Ontario have been collected, described and illustrated since then. The time was ripe for another book on the trilobite treasure-trove of southern Ontario, and this fulfils all expectations. Both amateur palaeontologists and professionals less familiar with the region can benefit greatly from it. It is nicely written and clearly presented. Some photographs are a little better than others, but on the whole they are very good, and they are all in colour. The number of professional palaeontologists working on trilobites in museums and universities is sadly decreasing fast; in Europe and the USA most who retire and finally depart this life are not being replaced. Trilobitology will increasingly lie in the capable hands of well-informed amateurs such as Phillip Isotalo, and if the resulting product is as good as this fine book, then we can all breathe collective sighs of relief.

Euan N. K. Clarkson
University of Edinburgh

REFERENCE

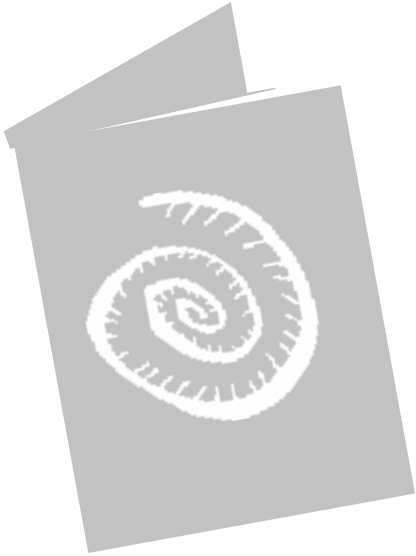
LUDVIGSEN, R. 1979. *Fossils of Ontario Part 1: The Trilobites*. Royal Ontario Museum, Toronto. 96 pp.

Books available to review

The following books are available to review. Please contact the Book Review Editor, Tom Challands (e-mail <**bookreview@palass.org**>), if you are interested in reviewing one of them.

- *British Polacanthid Dinosaurs*, by W. T. Blows.
- *Solving the Mystery of the First Animals on Land: the Fossils of Blackberry Hill*, by K. Gass.
- *Ammonoid Paleobiology: from Anatomy to Ecology*, by C. Klug, D, Korn, K. De Baets, I. Kruta and R. H. Mapes (eds.), 2 vols.
- *Dinosaur Footprints and Trackways of La Rioja*, by F. Pérez-Lorente.
- *Treatise on Invertebrate Paleontology, Part E (Revised), Volumes 4 and 5: Hypercalcified Porifera*, by P. A. Selden (ed.).
- *Techniques for Virtual Palaeontology*, by M. Sutton, I. Rahman and R. Garwood.
- *Mammoths and the Environment*, by V. V. Ukraintseva.

Dr Tom Challands
PalAss Book Review Editor,
School of GeoSciences,
The University of Edinburgh,
Grant Institute,
The King's Buildings,
James Hutton Road,
Edinburgh
EH9 3FE
UK



Careering off course!

Inspirational palaeontologists

Richard Price is a biostratigrapher and geologist with Robertson, a CGG company based in North Wales. The company is a longstanding, large geoconsultancy business for the oil and gas industry, employing a wide range of specialists, including micropalaeontologists, palynologists and nannopalaeontologists. Richard has spent the last 11 years working both on- and offshore, primarily as a nannopalaeontologist (Jurassic–Pleistocene), at diverse locations around the world, helping oil companies to age-date the rocks they are drilling through and interpret the stratigraphy at any given location. Richard started his career by studying the plant kingdom as a horticulturalist for the National Trust before embarking on a degree in Plant Biology (Hons) at Bangor University in 1999, where he was first introduced to palynology. An MSc in Taxonomy followed in 2002–2003 at the University of Edinburgh, where he studied further aspects of palaeontology and palynology.

Describe yourself in three words.
Reliable, focused, hardworking.

How did you first get interested in palaeontology?
When I was a child my father, a civil engineer, taught me about rocks and fossils and we had a small collection at home. I don't think I really got interested until I went to Bangor University and studied rocks and fossils as a part of my degree course, in the context of plant evolution.

What are the main responsibilities of your job?
The main responsibilities are to accurately analyse fossil assemblages in rock samples using a microscope and to provide high-quality biostratigraphy reports for oil companies on time and on budget, as well as supplying accurate real-time data during offshore drilling.

What is your favourite fossil and why?
Probably one of the Discoasteraceae such as *Discoaster signus*, a beautiful nannofossil with a wonderfully descriptive Latin name that translates as 'daisy wheel' and is also a useful marker fossil restricted to the Middle Miocene.

In an average week, how many hours do you work?
This varies enormously. Standardly, we are contracted to work a regular 37.5 hour week during normal office hours, but this increases to 84 hours a week whilst working offshore doing 12 hour shifts (day or night) for up to four weeks at a time.

How many people do you work with on a daily basis?
Our departmental team of biostratigraphers totals around 26 at present, made up of micropalaeontologists, palynologists and nannopalaeontologists, but we also work closely with the other geoscientists on site including sedimentologists, geophysicists and geochemists, plus technicians and support staff, so around 200 people in all.

What are the worst things about your job?
Having to do lots of form filling, quality control paperwork, compulsory health and

safety courses *etc*. These things just eat into your time for doing the more interesting stuff like looking at fossils under the microscope. Planning your home life can also be frustrating if working offshore as you can be constantly on call and may need to travel at short notice for undetermined lengths of time.

Do you get to do much overseas travel for work and do you do much fieldwork?
There are lots of opportunities to travel the world in this profession, either whilst working offshore or on associated promotional trips. I have been fortunate to visit a wide range of countries that I would never have dreamed of going to 15 years ago.

Has there been a paper or book that has influenced your career?
The first two palaeontology books that inspired me were both PalAss publications acquired as an undergraduate at Bangor University. They were *Plant Fossils of the British Coal Measures* (Cleal & Thomas) and *Fossil Plants of the London Clay* (Collinson).

Who have been the most important mentors in your career so far?
Dr Adrian Bell (Bangor University) for having the faith to accept me onto the undergraduate course in Plant Biology as a mature student lacking in formal qualifications. Also Nigel Brown (Bangor University): his knowledge of the natural sciences is immense and he introduced me to palynology and palaeobotany as an undergraduate.

What skills does it take to be successful in your job?
Logical thinking and problem solving are essential, as are being able to work under pressure and alone with a microscope for long periods, away from family and friends. The rest is down to lots of hard work training and self-learning all of the fossils and their names.

Do you have any tips for students who would like to take a similar career path?
A higher degree is essential. I would say try and focus on one discipline that you like and find out as much as you can about it before taking the plunge, especially if you are thinking of doing a PhD. As a multidisciplinary MSc graduate, switching disciplines very early in your career is not usually a problem as extensive training is always beneficial.

Are there any major obstacles to being successful in a career like yours?
Around the time I graduated there had been a general decline in all plant sciences including the demise of the MSc in Palynology at the University of Sheffield, followed not long after by the MSc in Micropalaeontology at UCL. Things have now improved with a new MSc course at the University of Birmingham providing students with an excellent grounding and postgrad job opportunities. However, the current oil price crash has seriously affected recruitment opportunities for new people entering the oil industry for the first time in many years.

What's the best thing about your job?
Travelling the world to strange and exotic places.

If you could have dinner with a famous palaeontologist (living or dead), who would you choose?
Charles Darwin. He was seeing the bigger picture when he came up with his theory of evolution and he challenged conventional wisdom. These are important factors for good science and all scientists in academia and industry should remember these.

For biostratigraphy jobs the following websites may be useful, as well as individual company websites:

<**https://www.oilandgasjobsearch.com/**>

<**http://www.earthworks-jobs.com/**>

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Virtual Palaeontology Issue 4: Arthropod papers of enduring influence

Palaeontology has published many papers that deserve to have a long citation life. Unlike many of the physical sciences, work done well in palaeontology continues to be the source of data for subsequent hypotheses, while past reviews offer new students the chance to build their expertise with confidence – eventually to discover the flaws that serve to advance the science. My list includes papers on trilobites in particular, but with a reference to a paper that has contributed to the larger question of how the trilobites sit within the Arthropoda as a whole.

Richard Fortey
Natural History Museum, London

CLARKSON, E. N. K. 1979. The visual system of trilobites. *Palaeontology*, **22**, 1–22.

Euan Clarkson is the doyen of trilobite vision, having spent much of his life exploring the functioning of the calcified lens system of the arthropods. This 'state of the art' review is a summary of what was known at the time, and written with the author's customary clarity. Subsequent reviews have greatly advanced the understanding of the biology of the visual system as compared with living arthropods, but the volume 22 review remains the best introduction to the subject.

WHITTINGTON, H. B. 1980. Exoskeleton, moult stage, appendage morphology and habits of the middle Cambrian trilobite *Olenoides serratus*. *Palaeontology,* **23**, 171–204.

H. B. Whittington's detailed description of the Burgess Shale trilobite *Olenoides* was seminal in describing the appendage morphology of trilobites. Whittington's attention to detail is always exemplary. This description remains important today in all codings for cladistic treatments of arthropod phylogenetics.

BRIGGS, D. E. G. and COLLINS, D. 1988. A Middle Cambrian chelicerate from Mount Stephen, British Columbia. *Palaeontology,* **31**, 779–798.

An important paper from the 'Whittington school', the description of *Sanctacaris* as a stem chelicerate was germane to the arguments aired by Stephen Jay Gould in his bestseller *Wonderful Life* of 1989 examining the Cambrian evolutionary 'explosion'. *Sanctacaris* has subsequently continued to be a significant animal in the phylogenetic analyses of the Cambrian arthropod radiation – including, naturally, arguments on the affinities of the Trilobita. The basic data remains in this paper.

FORTEY, R. A. and CHATTERTON, B. D. E. 1988. Classification of the trilobite suborder Asaphina. *Palaeontology*, **31**, 165–222.

This was, I believe, the first cladistic phylogenetic analysis of a wholly fossil group – it was carried out on the mainframe at Imperial College as PAUP required more computing power than the Natural History Museum had at the time. Some of the results would now be debatable because the original selection of taxa was made on the assumption of monophyly of a few defining characters, but most of the subgroups remain robust.

RUSHTON, A. W. A. 1988. Tremadoc trilobites from the Skiddaw Group in the English Lake District. *Palaeontology*, **31**, 677–698.

The links between geology, stratigraphy and palaeontology have been somewhat sidelined by some palaeobiologists, but fieldwork directed towards solving correlation problems often leads to important new finds. The discovery of Tremadocian trilobites in the English Lake District not only served to recalibrate the regional biostratigraphy, but also afforded the earliest example of a deep water trilobite fauna in the Ordovician.

FORTEY, R. A. and OWENS R. M. 1999. Feeding habits in trilobites. *Palaeontology*, **42**, 429–465.

This is a personal favourite among my own papers – an attempt to account for some of the huge morphological variation in trilobites in terms of various adaptations for sediment grazing, predation, filter chamber feeding or pelagic habits. It should continue to provide a springboard for future critiques helping to elucidate the life habits of these extraordinarily successful arthropods.

Virtual Palaeontology Issue 5: Annual Symposium – The photosynthesis revolution

The five papers of this virtual issue of *Palaeontology* were developed from presentations to the 58th Annual Meeting of the Palaeontological Association Thematic Symposium, which was entitled 'The photosynthesis revolution: how plants and photosynthetic micro-organisms have bioengineered the planet' (see *Newsletter* **86** for the Symposium details).

WELLMAN, C. H. and STROTHER, P. K. 2015. The terrestrial biota prior to the origin of land plants (embryophytes): a review of the evidence. *Palaeontology,* **58** (4), 601–627.

SCHIRRMEISTER, B. E., GUGGER, M. and DONOGHUE, P. C. J. 2015. Cyanobacteria and the Great Oxidation Event: evidence from genes and fossils. *Palaeontology,* **58** (5), 769–785.

MORRIS, J. L., LEAKE, J. R., STEIN, W. E., BERRY, C. M., MARSHALL, J. A., WELLMAN, C. H., HILLIER, S., MANNOLINI, F., QUIRK, J. and BEERLING, D. J. 2015. Investigating Devonian trees as geo-engineers of past climates: linking palaeosols to palaeobotany and experimental geobiology. *Palaeontology,* **58** (5), 787–801.

EDWARDS, D., CHERNS, L. and RAVEN, J. A. 2015. Could land-based early photosynthesizing ecosystems have bioengineered the planet in mid-Palaeozoic times? *Palaeontology,* **58** (5), 803–837.

BUTTERFIELD, N. J. 2015. Proterozoic photosynthesis – a critical review. *Palaeontology,* **58** (6), 953–972.

Overseas Representatives

Argentina: Dr M. O. Manceñido, Division Paleozoologia invertebrados, Facultad de Ciencias Naturales y Museo, Paseo del Bosque, 1900 La Plata, Argentina.

Canada: Professor R. K. Pickerill, Dept of Geology, University of New Brunswick, Fredericton, New Brunswick, Canada E3B 5A3.

China: Dr Z. Zhonge, Institute of Vertebrate Palaeontology and Palaeoanthropology, Academia Sinica, P.O. Box 643, Beijing 100044.

France: Dr J. Vannier, Centre des Sciences de la Terre, Université Claude Bernard Lyon 1, 43 Blvd du 11 Novembre 1918, 69622 Villeurbanne, France.

Germany: Professor F. T. Fürsich, GeoZentrum Nordbayern, Fachgruppe Paläoumwelt, Universität Erlangen-Nürnberg, Loewenichstrasse 28, D-91054 Erlangen, Germany.

New Zealand: Dr R. A. Cooper, GNS Science, P.O. 30368, Lower Hutt, New Zealand.

USA: Professor P. Selden, The Paleontological Institute, University of Kansas, Lawrence, Kansas, 66045, USA.

Professor N. M. Savage, Department of Geology, University of Oregon, Eugene, Oregon 97403, USA.

Professor M. A. Wilson, Department of Geology, College of Wooster, Wooster, Ohio 44961, USA.

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This publication is not deemed to be valid for taxonomic/nomenclatural purposes [see Article 8.2 of the International Code of Zoological Nomenclature (4th Edition, 1999)].

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The Palaeontological Association has its own pages on the World Wide Web, including information about the Association, and copies of the *Newsletter*. Internet Officer Alan R. T. Spencer can be reached by e-mail at <**webmaster@palass.org**>. The locator is <**http://www.palass.org/**>.

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