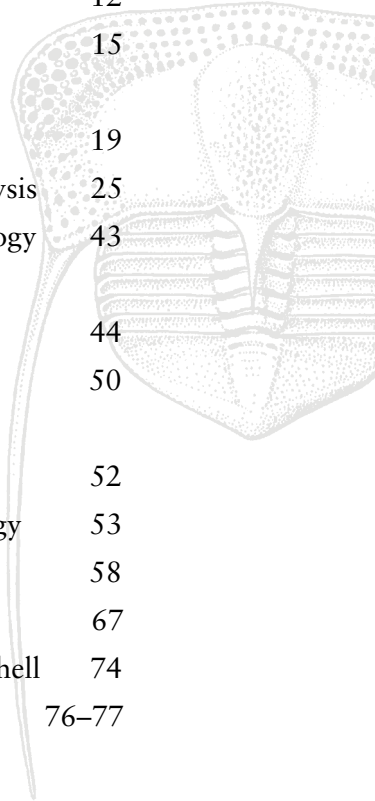


The Palaeontology Newsletter

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Reminder: The deadline for copy for Issue no 77 is 13th June 2011.

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Association Business

Nominations for Council

The following vacancies will occur on Council at the AGM in December 2011:

President Elect
Vice President
Chair of the Publications Board
Secretary
Editor Trustee
Book Review Editor
Newsletter Editor
Meetings Co-ordinator
Two ordinary Members

Nominations are now invited for these posts. Please note that each candidate must be proposed by at least two members of the Association and that any individual may not propose more than two candidates. Nomination must be accompanied by the candidate's written agreement to stand for election and a single sentence describing their interests.

All potential Council Members are asked to consider that:

'Each Council Member needs to be aware that, since the Palaeontological Association is a Registered Charity, in the eyes of the law he/she becomes a Trustee of that Charity. Under the terms of the Charities Act 1992, legal responsibility for the proper management of the Palaeontological Association lies with each Member of Council'. Responsibilities of Trustees can be obtained from <secretary@palass.org>.

The closing date for nominations is **1st October 2011**. They should be sent to the Secretary: Dr Howard A. Armstrong, Department of Earth Sciences, University of Durham, Durham DH1 3LE; e-mail <h.a.armstrong@durham.ac.uk> or <secretary@palass.org>.

The following nominations have already been received:

President elect: Council nomination Prof. M. J. Benton
Vice president: Council nomination Dr H. A. Armstrong
Chair of the Publications Board: Council nomination Dr P. Orr
Editor Trustee: Council nomination Dr P. Barrett
Book Review Editor: Council nomination Dr C. Jeffrey-Abt
Newsletter editor
Meetings Co-ordinator
Two ordinary Members: Council nomination Prof. Smith



Grants, awards and prizes

Lapworth Medal

The Lapworth Medal 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 in choosing suitable candidates.

Nominations must be supported by a resumé (single sheet of details) of the candidate's career, and further supported by a brief statement from two nominees. A list of ten principal publications should accompany the nomination. Council reserves the right not to make an award in any one year. Details and nomination forms are available on the Association Website and in the *Newsletter*. The deadline is **1st May**. The Medal is presented at the Annual Meeting.

Grants in Aid

The Palaeontological Association is happy to receive applications for loans or grants from the organisers of scientific meetings 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. Such requests will be considered by Council at the March and the October Council Meetings each year. Enquiries may be made to <secretary@palass.org>, and requests should be sent by **1st October** or **1st March**.

Grants-in-Aid: Workshops and short courses

The Palaeontological Association is happy to receive applications for loans or grants from the organisers of scientific workshops or 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. Such requests will be considered by Council at the March and the October Council Meetings each year. Enquiries may be made to <secretary@palass.org>, and requests should be sent by **1st October** or **1st March**.

Awards and Prizes, AGM 2010

Lapworth Medal: Dr L. R. M. Cocks

Richard Fortey writes: Robin Cocks has been a force for good in palaeontology for forty years. He has given of his time most generously to the Association, serving as Publications Secretary when much of the routine of publishing was handled on a purely voluntary basis, and later as an effective President.



Scientifically Robin has made significant and lasting contributions in several different fields. Those of us who know him are amazed by his capacity to turn out papers even while carrying heavy administrative loads at the same time. We attribute it to preternatural organisation skills. Brachiopods, of course, have been at the centre of his activities, but from that base he has contributed to a wide range of geological problems. Certainly it is for these latter achievements that he is most widely known in the scientific world as a whole. He has spent most of his working life at the Natural History Museum, where he continues to carry on with his output unabated. It is possible to divide his work rather arbitrarily into several categories. These are:

1. Systematics. More than half of Robin's output (in terms of published pages, rather than papers published) has been systematics of one kind or another. Since his PhD in 1965 he initially focused on Silurian brachiopod faunas, and produced standard accounts of the British faunas, including his big paper on the Plectambonitacea in 1970. He has extended his interests subsequently into the Ordovician, and recently documented huge faunas in several places – China, Taimyr and Kazakhstan – with appropriate co-authors. His contribution to the recent revision of the Brachiopoda *Treatise* was considerable, entailing a detailed revision of the Strophomenida, partly the result of happy collaboration with his Chinese colleague Rong Jia-yu. Probably his most-thumbed work is the summary of all the brachiopods of the British Isles in his Synoptic supplement to Davidson, published by the Palaeontographical Society (1978). To stratigraphers and those non-specialists who wish to update their nomenclature this work is truly invaluable – I understand an update on this useful work will be published soon, so he will be repeating the benefit to all once again.

2. Stratigraphy. From the first Robin was involved with description of Silurian stratigraphy and elucidating correlation problems. Many of his shorter papers are of this kind, with notable contributions on Llandovery (1971), the Girvan District (1973), the Ordovician–Silurian boundary in Scandinavia (1982) and many papers with W.S. McKerrow (his former supervisor) in Newfoundland. Additional subsequent forays into China, the Malay Peninsula, South Africa, *etc.*, show his global spread. He became closely involved with the standardisation of the Ordovician–Silurian boundary, volunteering as Secretary of the IUGS Working Group on the problem, and edited a vast Bulletin of the BMNH (1988) summarising the results. Partly as a result of this assiduousness, the GSSP for the boundary stayed in Britain (at Dob's Lin). Coupled with the efforts of Charles Holland, Robin also helped retain the British names for the first three subdivisions of the Silurian System, and with his co-authors wrote the revision of the *Correlation Chart of the Silurian Rocks of the British Isles* (1992). Like his Davidson revision this is a much-thumbed publication. Many more people use it than acknowledge the fact in formal reference.

3. Palaeogeography. This is probably the work for which Robin is most well-known globally. It started early with his thesis work with Zeigler on Silurian brachiopod “communities” in the Welsh basin, and then broadened out over the years to embrace the whole Palaeozoic and the whole world. Faunal ‘provinces’ in the 1970s became re-interpreted in terms of plate/continent distributions. The paper he co-wrote in (1982) postulating the



OBVERSE



REVERSE



independence of Baltica as a continent in the Ordovician and the existence of 'Tornquist's Sea' became one of the 'citation classics' of the Geological Society. It resulted in a reconsideration of tectonic history which has had an enduring influence. Subsequent ones that should be mentioned include the recent (2003) hefty summary of Lower Palaeozoic faunal evidence for continental distributions for *Earth Science Reviews*. Recently, Robin has teamed up with the brilliant Norwegian palaeomagnetician Trond Torsvik for a whole series of Cocks & Torsvik papers (sometimes the other way round) (2002, 2004, 2006, 2007) which have firmed



up the position of palaeocontinents in the Palaeozoic. These reconstructions have become the standard ones used in international symposia that I have attended over the last few years. His use of faunal mapping in interpreting palaeogeography is now fairly standard practice, but it should be remembered where it came from. We should probably put his work with Stuart McKerrow (*e.g.* 1986) on determining the site of the main sutures in Lower Palaeozoic Iapetus in this category.

4. Administration. Robin is the only living person (maybe ever?) to have held the Presidency of all the major geological/palaeontological societies in Britain: to wit, The Palaeontological Association 1986–88, the Palaeontographical Society 1994–98, the Geological Society of London 1998–2000, and the Geologists Association 2004–06. I might say that these presidencies followed upon service to all of the societies in various other capacities, which would take too much space to enumerate. But just to list one example I know about, he was instrumental as Publications Chairman at the Geological Society in the eighties at the time when it was proposed to set up the Publications House as an independent entity. Robin pushed hard for this, succeeded, and it has been one of the major factors in turning around the fortunes of that society.

At the same time he rose through the ranks at the Natural History Museum to become Keeper of Palaeontology in 1986 until 1998, when he formally 'retired' at 60. This is actually a full time job, so the wonder is that he managed, not only to run the Department, but also keep all his other activities going – both administrative and research. As Keeper he is remembered for his efficient operation ("Never use more than one side of A4" was his motto). During his period in charge the Department went from strength to strength – for example, we had two FRSS for the first time since the 1940s. Just to add to the list, he was also a Commissioner for the ICZN 1982–2002 and a Visiting Professor at Imperial College 1992–2002. He has been on the Silurian Subcommittee of the IUGS for a very long time indeed.

Formal recognition. Robin has received a measure of formal recognition for his achievements, beginning with a DSc from Oxford University in 1984. He was given the OBE in 1999. He received the Coke Medal of the Geological Society, which is awarded for a combination of 'community service' and scientific excellence, in 1995, and the Dumont Medal of *Geologica Belgica* in 2003.



President's Prize: Dr N. Butterfield

Nick Butterfield has made a major contribution to palaeobiological research over the past 20 or so years. He has made key contributions in a number of areas: (1) Investigation of Mesoproterozoic and Neoproterozoic fossil Lagerstätten, (2) Discovery and study of recurrent Early–Middle Cambrian assemblages of microfossils dominated by disarticulated organically-preserved non-mineralizing animals (“micro-Burgess Shales”), (3) Analysis of exceptional fossil preservation in “Burgess Shale-type” biotas – with important implications for resolving the original histology and phylogenetic affiliation of various problematic fossils, (4) Reassessing and applying the Proterozoic–Cambrian acritarch record to test molecular clock estimates for the origin of animals and other major ecological/evolutionary innovations, (5) Investigation of the macroecological and macroevolutionary implications of early metazoan evolution.



Nick is also actively involved in research on events at the Precambrian–Cambrian boundary. His primary focus has been on trophic relations and productivity, integrating his extensive knowledge of modern ecosystems. His list of citation statistics is impressive: it includes at least two papers with more than 100 citations, at least ten with 60+ citations, and at least 15 that have been cited more than 40 times. Many of his papers have been published in leading academic journals; including *Nature*, *Science* and *Geology*.

Hodson Award: Dr T. V. R. Vandenbroucke

Thijs's palaeontological training is in chitinozoan taxonomy and biostratigraphy, commencing his



studies with the classic Lower Palaeozoic succession of the Girvan District under the careful guidance of Euan Clarkson. His grounding in taxonomy and biostratigraphy – resulting in a Palaeontographical Society Monograph – has given him solid foundations by which to judge the quality of Early Palaeozoic global plankton datasets. With this basic, but absolutely fundamental palaeontological training, he is now developing ground-breaking new techniques that allow the distribution patterns of Early Palaeozoic plankton to be interrogated as a proxy for latitudinal climate belts, as tools for ground truthing climate models, and, perhaps more fundamentally, to estimate Early Palaeozoic atmospheric CO₂.



In the past year Thijs has authored three 'state of the art' studies. The first two (in *Paleoceanography* and *Palaeo3*) have showed how macro- and microplankton biotope patterns define a steep surface temperature latitudinal gradient for the early Late Ordovician oceans, and have thus questioned long-standing views that this was a greenhouse world. Furthermore, Thijs was able to demonstrate, for the very first time, similarities between modern and Early Palaeozoic zooplankton biotope patterns. Building on this work in the third paper (recently published in *PNAS*), Thijs used plankton biotopes to track changes in the position of the southern polar front in the Late Ordovician between glacial and interglacial states. He showed the polar front moving in a similar pattern to that of the Quaternary and was thus able to provide a revised and quite radical reinterpretation of Late Ordovician $p\text{CO}_2$ and its control on glaciation. Thijs' *PNAS* paper also demonstrated a marked contraction in surface ocean biotopes during the glacial maximum of the Late Ordovician, and provides a possible causal mechanism for end Ordovician extinction.

Thijs' work crosses the boundary between palaeontology and palaeoclimatology, and he is in the vanguard of attempts to get these different disciplines working together. He recently chaired the IPC3 session on 'Palaeozoic Climates' in London, and he has formulated a dedicated session on biological proxies for palaeoclimate analysis at the Annual Palaeontological Association Meeting (that he also organised) in Ghent last December. Thijs marries together his palaeoclimate work with his more 'traditional' biostratigraphical work with aplomb. He is, for example, a member of the American Geophysical Union, whilst at the same time a voting Member of the International Subcommittee on Ordovician Stratigraphy (ISOS). For a young researcher he already has a formidable publication record (20 papers), and as previously mentioned many of these are in high-impact journals. Thijs is already recognised to be at the cutting edge of his subject, and I believe he has great potential to be a world leader in the interpretation of Early Palaeozoic palaeoclimate, and indeed to improve our understanding of the links between climate change and biodiversity more generally.

Mary Anning Award: Mr Daniel Vizcaino



Mr Daniel Vizcaino, although an agricultural scientist by profession, has been working on Cambrian and Ordovician fossil palaeontology, stratigraphy and palaeogeography for more than 30 years. His studies and collaborations are largely based on the Lower Palaeozoic fossiliferous successions in the Montagne Noire (southern France), SW Europe and NW Africa. He has successfully combined stratigraphical and palaeontological approaches to provide key data for interpreting the first metazoan-dominated benthic communities in Northwest Gondwana, and has collaborated in more than 50 published papers with a wide range of research workers (mainly palaeontologists and stratigraphers) from Argentina, Australia, Belgium, Czech Republic, France, Germany, Italy, Spain, UK, and USA.

Mr. Vizcaino follows in the footsteps of an impressive list of amateur palaeontologists from Languedoc. He was introduced to Palaeontology by Abbé Robert Courtessole, the priest of Carcassonne, who published in 1973 a formidable monograph focused on the Middle Cambrian Palaeontology and Stratigraphy of the Montagne Noire for which he was awarded a Doctorate



Honoris Causa from the University of Würzburg (Germany) some years afterwards. After Courtessole's death in 1990, Mr. Vizcaïno's house has become the home for all amateur and professional palaeontologists and geologists who wish to visit the Montagne Noire. Several generations of junior and senior palaeontologists have enjoyed his hospitality and freely studied numerous brachiopod, trilobite and echinoderm collections collected by him over many years. His collections are magnificent, precisely located and well prepared; they have always been open to any student or researcher interested in any aspect of Palaeontology. As a result, many of his collections are housed in many institutions and Museums of Europe and America. He is generous too with information, willingly taking colleagues to key localities, many discovered by him.

Mr. Vizcaïno is one of the very best of the traditional amateur generation of European palaeontologists. His home has become a real 'Institute of Palaeontology,' and his kindness and legendary hospitality are known by any researcher devoted to the 'Cambrian explosion' and the 'Ordovician biodiversification'. Since 1981, and despite the numerous papers in which his name occurs in the section named 'Acknowledgements', he has maintained a high publication rate (*h-index* = 8!). We have all met him in Carcassonne or at one of the International Cambrian–Ordovician field conferences co-organized by himself in southern France. He more than extravagantly fulfils the criteria for the Palaeontological Association's 'Mary Anning Award.'

Sylvester Bradley Awards AGM 2010

Council agreed that the following applicants should receive awards: L. Cotton, T. Halliday, M. Koot, L. O'Brien and M. Young. As part of the selection process, Council noted that a number of good quality applications had been received either incomplete or that had not followed the guidelines and that these applications had had to be rejected.

Larger benthic foraminifera extinctions across the Eocene–Oligocene transition at Fuente Caldera, Spain Laura Cotton (University of Cardiff)

A number of long-ranging and widespread larger foraminifera are known to have suffered extinction during the E–O climate transition. However, detailed shallow carbonate records across the E–O transition are rare because global sea level decreased, leaving many sections incomplete with hiatuses at the boundary. So far my PhD work has focused on three cores from Tanzania that span the E–O transition. These comprise hemipelagic clays with secondary limestone beds. The cores contain a detailed record of larger foraminifera that has been tied to planktonic foraminifera, nannofossil and stable isotope data, allowing correlation to plankton stratigraphy and the global isotope curve. In doing this it has been found that the larger benthic extinctions are coincident with the extinction of Hantkeninidae, and not the maximum $\delta^{18}\text{O}$ shift and sea level drop as previously thought. The purpose of this project is to compare the Tanzanian site with an analogous site to determine if the event is globally synchronous. The Fuente Caldera section in Spain is reported to contain larger benthic-rich limestone layers, within well-correlated marl sequences, however no detailed work on the larger benthic foraminifera has been carried out. I plan to undertake field sampling of the Fuente Caldera sequence and use the pre-existing planktonic biostratigraphy to constrain the timing of the larger benthic extinctions in the Tethys Ocean. The results will be compared with my existing data from Tanzania.



Goniopholidid Crocodylians from Central Asia **Thomas Halliday (University of Bristol)**

Crocodylians were an important clade during the Mesozoic; a major group was the Jurassic Goniopholididae, well known in Europe but also present across Laurasia. The Central Asian forms are not particularly well described, and this project aims to integrate four taxa (*Sunosuchus shartegensis*, *Kansajsuchus extensus*, *Turanosuchus aralensis* and *Karatausuchus sharovi*) housed at the Paleontological Institute (PIN, Moscow) into cladistic analyses of crocodylians, relating the results to palaeobiogeography. *Karatausuchus* is particularly controversial (Buscalioni and Sanz 1988, *Historical Biology*): the type specimen is a juvenile, and the characters which have linked it to the adopsaurids are possibly simply a result of the juvenile state (lack of dermal armour, small size). Key characters of these controversial and poorly-described species will be rigorously described in the context of the European goniopholidids, and coded. Based on Andrade's (2011, *Zoological Journal of the Linnean Society*, in press) cladistic analysis of the European and North American goniopholidids, phylogenetic positioning will be resolved. Techniques such as DIVA and TRA will be used to relate the species to the palaeobiogeography of the Mesozoic.

Permian–Triassic elasmobranchs from the Oman Mountains and Batain plain **Martha Koot (University of Plymouth)**

This proposal is part of an ongoing investigation and sampling of key Permian–Triassic sections worldwide, which is aimed at enhancing the knowledge on shark distribution and diversity, and to reconstruct the patterns of survival and extinction in sharks and related changes in their ecology. Most of our current knowledge comes from studies of boreal localities, such as East Greenland and northwestern Canada, but based on results from preliminary work, more southern localities may be of importance. It is therefore proposed to undertake fieldwork in the Oman Mountains in northern Oman and the Batain area in the eastern coastal region of Oman. A Middle Permian–Late Cretaceous cyclic shallow-water carbonate series was deposited on the Arabian Platform along the Neo-Tethys continental margin following a thermal subsidence induced transgression that covered most of Oman. A number of pilot samples from the Jabel Akhdar region (Saiq Fm), the Saih Hatah and the Batain plain have already been obtained. The processing of these samples is in the final stages and preliminary results show that the shark presence in Oman is limited to local areas. The focus of this proposed work will therefore now be on those localities that have yielded shark remains and to reconstruct more detail. The sample material will be processed using buffered formic acid. This method leaves the phosphatic elasmobranch microremains intact, which are picked from the residue and studied and analysed further.

Palaeoenvironmental analysis of a new Burgess Shale locality **Lorna O'Brien (Natural History Department, Toronto, Canada)**

Early to Middle Cambrian (545 to 500 Mya) Burgess Shale-type deposits are critical for our understanding of the evolution and palaeoecology of early animals in the aftermath of the Cambrian explosion. The 505 million-year-old Burgess Shale (Yoho National Park, British Columbia) is the best known of these exceptionally preserved sites. Most Burgess Shale fossils come from two



localities on Fossil Ridge, the Walcott and Raymond quarries. Less well known are several new Burgess Shale-type deposits discovered by the Royal Ontario Museum (ROM) in the 1980s outside the type localities. Perhaps the most important of these localities is the 'S7' site on Mount Stephen found in 1983. The current collection comprises 2,038 slabs, with at least 10,000 specimens that were collected in subsequent expeditions. The proximity of Burgess Shale localities to the Cathedral Escarpment has traditionally been thought to play a key role in their preservation. Although no direct proximity to the Escarpment has been found at the 'S7' locality, it is seen elsewhere on Mount Stephen, and 'S7' is interpreted as being more distal when compared to the Walcott Quarry. The primary goal of this project is to gain an understanding of the palaeoenvironmental setting at the 'S7' locality and how palaeoenvironmental factors (*e.g.* benthic geochemistry, bioturbation, frequency of burial events) might have affected the community composition. This study will also allow more confident palaeoecological comparisons with other Burgess Shale localities.

Quantifying the evolution of super-predatory behaviour in metriorhynchid crocodylomorphs

Mark Young (University of Edinburgh)

Metriorhynchid crocodylomorphs did not possess the most extensive marine adaptations within Archosauria, but they evolved a range of sophisticated feeding behaviours and bizarre skull shapes. How more than three species could be contemporaneous in one ecosystem challenges our understanding of ecosystem carrying capacities and population ecology (as no more than two crocodylian species are sympatric today). This project aims to quantify evolutionary trends in metriorhynchid dentition, investigating how differences in tooth shape relate to feeding adaptations, and the evolution of super-predatory behaviour. How did metriorhynchids exploit the potential range of tooth shapes available to them? Are peaks in form and/or mechanical diversity related to novel feeding behaviours and peaks in biodiversity?



news



‘Geology Matters’ website shows history of Earth

A new website gives visitors an insight into the rich geological heritage of the Black Country and the UK. *Geology Matters* – www.geologymatters.org.uk – shows images of a wide range of fossils, rocks and minerals which are found in museum collections in the Black Country.

Collectively the Black Country geology collection forms one of the largest collective collections in the UK, with specimens housed in Dudley Museum & Art Gallery, Wednesbury Museum & Art Gallery and Wolverhampton Art Gallery. These 30,000 specimens include some rare fossils such as soft-bodied worms to more common fossils including the ‘Dudley Bug’ trilobite. Dudley has the largest collection with almost 18,000 specimens.

The website has almost 3,000 records of geology specimens from across these museums, with almost 2,000 of these records having high-quality images showing a variety of views of the objects. Information provided with each specimen tells the story of where it was found and its age. The collections range over the full geological history of the UK, from the Precambrian through to the present day.

The *Geology Matters* blog introduces people to the basics of geology, including how fossils form and how to care for geological collections. This is done through a series of short articles written by local geologists, and includes videos featuring the current Keeper of Geology at Dudley Museum & Art Gallery, Graham Worton. The blog is constantly being updated with new content.

Find out about key people in history who have used the Black Country as a base for their geological knowledge, including Sir Roderick Murchison who used fossils found at the Wrens Nest in his book on the ‘Silurian System’ in the early 19th Century. The website also offers a brief overview of the collectors who have made the collections special and unique in the geological world.

The site is aimed at people with very little geological knowledge. Everyone visiting the site will learn something new and find something interesting which they may not have seen before. Both professional and amateur geologists will find this a useful resource.

Many of the specimens are in permanent storage with dedicated displays at Dudley Museum & Art Gallery. Visitors wishing to see specimens will find information on where the specimen is stored and how to see it by using the information on the website.

Geology Matters has been funded by the Museums, Libraries and Archives Council through its ‘Renaissance in the Regions’ programme. It includes information from Dudley Museums Service, Sadwell Museums Service and Wolverhampton Arts and Museums Service.

For more information go to <<http://www.geologymatters.org.uk/>>.



ASSOCIATION MEETINGS



55th Annual Meeting of the Palaeontological Association

University of Plymouth 17 – 20 December 2011

The 55th Annual Meeting of the Palaeontological Association will be held at the University of Plymouth, organised by Richard Twitchett and colleagues in the School of Geography, Earth and Environmental Sciences.

The meeting will begin with a symposium on Saturday 17th December, followed by a drinks reception. The conference proper will commence on Sunday 18th December with a full day of talks and posters, the Association AGM and the Association Annual Address, which this year will be given by Prof. Paul Pearson of Cardiff University and entitled 'Climate and evolution in the Cenozoic oceans'. In the evening there will be a drinks reception followed by the Annual Dinner. Monday 19th December will be a full day of talks and poster sessions. The time allocated to each talk will be 15 minutes; if too many abstracts of sufficient quality are submitted then shorter slots of 10 or 12 minutes are envisaged to avoid the need for parallel sessions. A dedicated poster session will be scheduled. The meeting will conclude on Tuesday 20th December with a field excursion to the English Riviera Global Geopark (<<http://www.englishrivierageopark.org.uk/>>), to take in local exposures of the marine Devonian and a visit to Kents Cavern.

Venue and travel

The conference will take place on the campus of the University of Plymouth (<www.plymouth.ac.uk/>) right in the city centre of Plymouth.

Transport into Plymouth can be achieved via a variety of means: rail, road, air and sea. Travel by train from London Paddington to Plymouth takes between three and four hours depending on the time of day and the number of stops. The cheapest fares are available by booking in advance, e.g. through the First Great Western website (<www.firstgreatwestern.co.uk/>). There are currently direct air links into Plymouth from Aberdeen, Bristol, Cork, Dublin, Glasgow, Guernsey, Jersey, Leeds Bradford and Manchester airports (<www.airsouthwest.com/>). In addition, many national and international airlines fly into Exeter airport. Exeter is one hour away from Plymouth by train. Ferries link Plymouth to France (Roscoff), Spain (Santander), and Cornwall. National Express coaches link Plymouth with all major UK cities and London airports. Plymouth University is situated a few minutes' walk from the train station, coach/bus station, and a number of hotels, guesthouses and other accommodation.

Plymouth is an historic and vibrant city that overlooks one of the world's great natural harbours. Best known for its rich maritime heritage, Plymouth is also home to the oldest gin distillery in the UK, which has been in operation since 1793 and is housed in a 15th century former monastery in the historic Barbican district. The Barbican is a short ten-minute walk from the University campus and is famous for its Elizabethan buildings and for being the final departure point from which the Pilgrim Fathers set sail on the Mayflower to the New World in 1620. Its cobbled streets also house a number of restaurants and pubs, which are situated a stone's throw from the National Marine Aquarium where the opening night's reception will be held. On the hill above the Barbican sits



Plymouth Hoe, with its iconic lighthouse (Smeaton's Tower), the imposing Royal Citadel fort and the Sir Francis Drake bowling lawn, amongst other attractions.

Accommodation

Rooms in a variety of hotels and guest houses at a range of different prices can be reserved through the usual channels. In addition, we have organised discount rates at some of the major city centre hotels that are closest to the University campus. The city also has a number of cheaper hotels and hostels. More information on these and alternative accommodations will be provided in the next edition of the *Newsletter* and on the website in due course.

Registration and booking

Registration and booking (including abstract submission) will commence in July 2011. Abstract submission will close on Monday 5th September 2011 and abstracts submitted after this date will not be considered. Registration after this date will incur an additional administration charge of approximately £20, with the final deadline of Friday 18th November 2011. Registrations and bookings will be taken on a strictly first come first served basis. No refunds will be available after the final deadline.

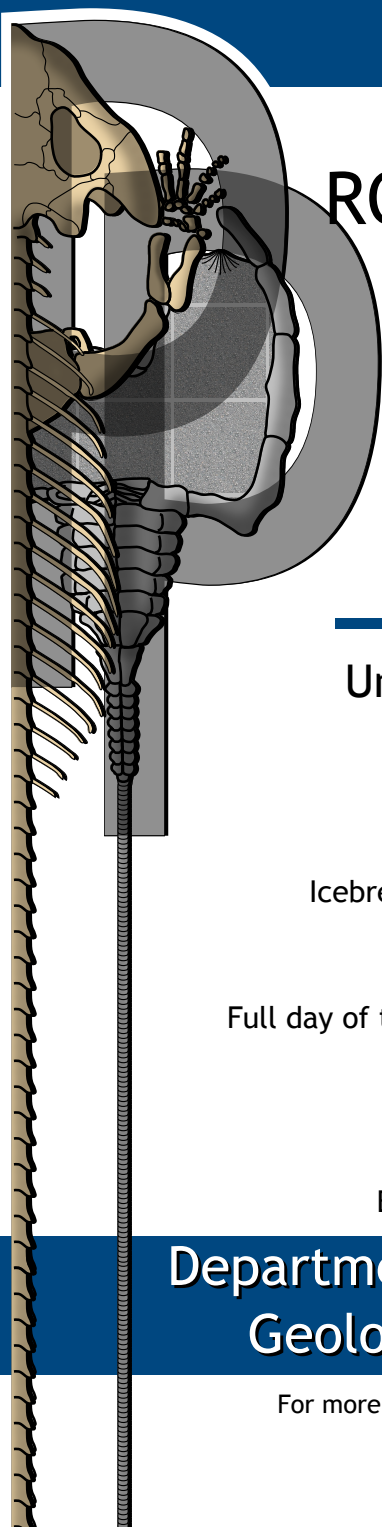
Registration, abstract submission, booking and payment (by credit card) will be from online forms available on the Palaeontological Association website (<<http://www.palass.org>>) from July 2011. Accommodation must be booked separately; details will be placed on the website.

Draft Programme

- Saturday 17th December 2010
 - Symposium
 - Reception (National Marine Aquarium).
- Sunday 18th December 2010
 - Scientific sessions: talks and posters
 - AGM
 - Annual Address by Prof. Paul Pearson (Cardiff)
 - Reception and Annual Dinner
- Monday 19th December 2010
 - Scientific sessions: talks and dedicated poster session
 - Presentations of awards
- Tuesday 20th December 2010
 - Field excursion to the English Riviera Global Geopark.

Travel grants to student members

The Palaeontological Association runs a programme of travel grants to assist student members (doctoral and earlier) to attend the Annual Meeting in order to present a talk or poster. For the Plymouth meeting, grants of less than £100 (or the € equivalent) will be available to student presenters who are travelling from outside the UK. The actual amount that will be payable is dependent on the number of applicants and the distance travelled. Payment of these awards is given as a disbursement at the meeting, not as an advance payment. Students interested in applying for a PalAss travel grant should contact the Executive Officer, Dr Tim Palmer (e-mail <palass@palass.org>) once the organisers have confirmed that their presentation is accepted, and before 1st December 2011. Entitle the E-mail "Travel Grant Request". No awards can be made to those who have not followed this procedure.



PROGRESSIVE PALAEOLOGY

LEICESTER, MAY 2011

University of Leicester (UK)

Provisional Programme

Wednesday 4th:

Icebreaker reception in the New Walk Museum

Thursday 5th:

Full day of talks and posters in the Department of Geology

Annual dinner

Friday 6th:

Excursion to a local fossiliferous site

Department of
Geology



University of
Leicester

For more information: Laurent Darras (ld101@le.ac.uk)
David Riley (dar13@le.ac.uk)

And on www.palass.org



>>**Future** Meetings of Other Bodies



Chemosymbiotic molluscs and their environments: from intertidal to hydrothermal vents

Natural History Museum, London *7 April 2011*

The discovery of hydrothermal vents in the 1980s triggered an enormous biological interest in chemoautotrophic organisms dependent on previously unknown symbioses with sulphide and methane oxidising bacteria. Molluscs, particularly bivalves, are the most diverse and widespread group of chemosymbiotic animals, ranging from the intertidal to hadal depths. Talks at this meeting will review their biology, diversity, evolution, host-symbiont interactions and habitats.

The meeting, which runs from 10am to 6pm, is organised by John Taylor and Emily Glover on behalf of the Malacological Society of London and Department of Zoology, The Natural History Museum, London.

There is no registration fee, but for catering purposes please inform the organisers if you plan to attend. For further details and information please e-mail <j.taylor@nhm.ac.uk>.



XI International Ichnofabric Workshop (11th IIW)

Museo del Jurásico de Asturias, Colunga, Spain *1 – 5 July 2011*

The forthcoming XI International Ichnofabric Workshop (11th IIW) will be held in the MUJA (Museo del Jurásico de Asturias, <<http://www.museojurasicoasturias.com/>>), from 1st to 5th July 2011. Abstracts concerning any ichnofabric aspect will be accepted. As pointed in the first circular (<<http://www.dinoastur.com/IIW>>), the abstract deadline is 31st March 2011. The second circular, with detailed information about expenses, accommodation and workshop schedule, will be distributed during March 2011. Please send us (e-mail <iiwasturias@gmail.com>) the pre-registration form (pre-registration deadline is 15th January 2011). All additional information concerning the 11th IIW is on the web page (<<http://www.dinoastur.com/IIW>>).



XVII International Congress on the Carboniferous and Permian

Perth, Western Australia *3 – 8 July 2011*

International congresses on the Carboniferous and Permian run every four years – the previous one was in Nanjing in 2007. The venue for the 2011 congress will be the University of Western Australia. The hosts are UWA and the Geological Survey of Western Australia.

Perth lies in the central Perth Basin which is one of a series of basins extending from Timor in the north that formed part of the East Gondwana rift system. We will be running excursions to the Canning, Carnarvon and Perth basins in Western Australia and to Timor Leste. As well as highlighting Permian and Carboniferous exposures, we will be visiting the World Heritage Shark Bay



(with the famous stromatolites), Ningaloo Reef – an exceptional modern coral reef that has been nominated for World Heritage listing – and the Devonian reefs of the Canning Basin.

We invite you to participate in the Congress and to join us on one or more of the associated field excursions. Full information on the Congress is provided at <http://www.iccp2011.org/>.



6th Symposium of IGCP 507

China University of Geosciences, Beijing, China 15 – 20 August 2011

We are pleased to announce that the China University of Geosciences will organise the 6th Symposium of the International Geoscience Program IGCP 507, which will be held on 15–20 August 2011, in Beijing, China. The symposium aims to create an opportunity to discuss the Cretaceous biodiversity, faunal change, environments and climate in Asia based upon the studies of palaeontology, palaeoecology, stratigraphy and sedimentology.

The symposium will include two days of oral and poster presentations including a half-day main workshop on “the Early Cretaceous Jehol Biota of China”. It is followed by regular sessions on palaeoenvironments, stratigraphy, palaeontology and tectonics. In regular sessions there will be a variety of talks and posters on regional geology, stratigraphy, vertebrate and invertebrate fossil faunas and environments in the eastern part of the Asian continent during the Cretaceous.

A post-symposium field excursion will be organized to observe the non-marine Cretaceous deposits in Western Liaoning, which contain abundant mega- and micro-fossils. In a four-day long post-symposium field excursion, we will visit some important sites for the Cretaceous Jehol Biota, stratigraphy, and depositional environments in Western Liaoning.

Dr Guobiao Li
School of Earth Sciences and Resources,
China University of Geosciences (Beijing),
Xueyuan Lu 29, Haidian District, Beijing -100083,
China P R
tel: +86-10-82321040 (office),
fax: +86-10-8232-1040
e-mail: liguobiao@cugb.edu.cn; shaowuren@tom.com



21st Canadian Paleontology Conference

Vancouver, British Columbia, Canada 19 – 22 August 2011

The 21st Canadian Paleontology Conference will be held in Vancouver in August 2011. The website for this meeting is at <http://132.156.108.208/cpc/>. The meeting will end with Field Trips to the Coast Mountains and Gulf Islands.



Specific Dates and Venues:

19th August 2011: Registration, Reception, Meetings

20th August 2011: Conference and Banquet

21st August 2011: Field trip 1: Harrison Lake

22nd August 2011: Field trip 2: Saltspring Island

The CPC will be held at the University of British Columbia with accommodation available on campus. The Reception will be held in the Pacific Museum of the Earth, part of UBC's brand new Earth Sciences Complex. The intention is that the Conference will be held in the Irving K. Barber Learning Centre, and the Banquet (and optional music jam session) in the magnificent Beaty Biodiversity Museum and Research Centre. The anticipated Registration Fee (including the banquet) will be approximately \$200 (student and public rate will be less than half this amount); firm rates will be posted in March 2011.



The 15th International Symposium on Dental Morphology

Northumbria University in Newcastle upon Tyne, UK 24 – 27 August 2011

The 15th ISDM will be held on 24–27 August 2011 at Northumbria University in Newcastle upon Tyne, sponsored by the Newcastle University School of Dental Sciences. This symposium will bring together scholars from around the world to present research in all aspects of dental morphology. The range of presentations will be broad and include topics such as dental anthropology, dental evolution, dental function, growth and development, dental tissues, and the genetics and clinical aspects of dental morphology. For information, registration, and accommodation bookings, please visit our website at <<http://www.ncl.ac.uk/dental/ISDM/index.htm>> or for other queries, e-mail <Wendy.Dirks@ncl.ac.uk>.



8th International Triassic Field Workshop 2011

Toulon area, Southern France 4 – 8 September 2011

During the highly successful 2010 Triassic Workshop in the Dolomites it was suggested to hold the 2011 workshop in Southern France. The Triassic of the Toulon area provides a unique opportunity to study the transition between the Germanic and the Tethyan facies. Our colleagues Marc Durand (Nancy-Laxou), the co-organiser of the 3rd Workshop, Jean-Paul Caron (Marseille) and Hans Hagdorn (Ingelfingen) will organise and guide the workshop between 4th and 8th September 2011.

You are kindly requested to pre-register as soon as possible.

So far we had the following field workshops with mostly 20–30, and up to 70, international participants: 2004 England, 2005 Central Germany, 2006 Eastern France, 2007 Western Poland, 2008 Hungary, 2009 Southern Germany, 2009 Central Germany, 2010 Dolomites.

The 2012 Field Workshop is planned in the Lombardian Alps (Andrea Tintori, Milano).



The aim of the field workshops is to demonstrate stratigraphy and facies of the Triassic in the respective area. Participants pay for their own travel, accommodation and food. Transport is normally by private or department cars.

For further information please visit <<http://paleo.cortland.edu/sts/>> (Meetings) and <<http://www.stratigraphie.de/perm-trias/>> (Triassic Field Workshops, and contains guidebooks from earlier workshops, too).



SVP 71st Annual Meeting

Las Vegas, Nevada, USA 2 – 5 November 2011

Esteemed Friends and Colleagues of the Society of Vertebrate Paleontology, the 71st Annual Meeting of the Society of Vertebrate Paleontology will be held in fabulous Las Vegas, Nevada!

The Host Committee consists of individuals from a number of institutions, with expertise in many facets of southwestern vertebrate palaeontology, and we look forward to highlighting this information-rich region to you. During the course of the meeting, there will be field trips to Palaeozoic and early Mesozoic marine units, terrestrial Mesozoic units in southern Nevada and Utah, and famous Cenozoic deposits in and around the Las Vegas Valley. We sincerely hope that you will be able to join us on one of these fantastic trips that we have in the works. In addition to the offered field trips, we have made arrangements with several known regional institutions for comparative collections visits.

We sincerely hope you are able to join us and we can't wait to be your hosts for this showcase of the Southwest!

For more information please visit <<http://www.vertpaleo.org/meetings/2011annualmeeting>>.

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



From our Correspondents

The varnished truth

In this crowded world of ours, we're forever surrounded by the ordinary. The people around us are, mostly, roughly our size – so when Jonathan Swift invented Lilliput and Brobdignag, the effect on our imaginations bit deep – and those mental toothmarks have remained, across the generations. Cats are mostly cat-sized – and that very feliformity allowed Mikhail Bulgakov to reprise Swift with Behemoth, the six-foot tall, gun-toting, wise-cracking mog in *The Master and Margarita*. Dogs – well, dogs run more variously, but that's mostly because humans have cheated, taking some unfortunate medium mutts and forcing the various benighted existences of Chihuahua and St. Bernard, dachshund and chow chow, on their offspring.

That's perhaps why records fascinate us – the biggest, the largest, the fastest, the oldest. *The Guinness Book of Records* was something, as a child, I pored over endlessly, to encounter cheetahs and viruses and blue whales and giant redwoods, as well as impossibly long moustaches, never-ending sneezing fits and ridiculous numbers of students in bubble cars or in telephone boxes. Well, this age of innocence is over, and what was a simple thick square book has now evolved, I see, into an infinitely more commercially savvy franchise. No matter: away from the hoopla, there's still some innocent pleasure to be had.

It's nice to know, for instance, that the longest graptolite – still, I think, the 1.45 metre-long *Stimulograptus halli* found by David Loydell in the Aberystwyth Grits – is just *miles* taller than the smallest dinosaur (the newly-discovered Chinese *Microraptor*, perhaps, at less than a metre long, a touch more petite than the venerable *Compsognathus*¹). And the smallest trilobite (*Acanthopleurella*) would be nobbut a flea on the back of the largest one (that mighty newcomer *Ogyginus forteyi* from Portugal having, it seems, elbowed that formidable Manitoban *Isotelus rex* to second on the podium).

But among long-dead animals and plants, gigantic and diminutive, it's their habitat that I have a particular fascination for – the strata that have entombed them for so long. Ordinary rock layers averaging the thickness of a hand's-breadth, for instance, the sort of thing that's ten a penny in cliffs and quarries. That may well be a standard turbidite layer, which settled in a flurry of mud and sand over the sea floor as sediment poured in from shallower waters, all in a few hours of early Palaeozoic time, start to finish. Let's give it a run-out distance of a hundred kilometres and an average width of twenty kilometres and an average thickness of 10 cm – a very modest Welsh turbidite, thus, and small by global standards. That is still an approximate volume of two hundred million cubic metres and a weight of some 500 million tons (or about a third of a million Eiffel Towers, to choose an appropriately Gallic comparator). Let's say that a sample of it will yield 100 acritarchs and other microfossils per gram. In that single modest turbidite there will therefore be some 50,000 trillion individual microfossils² – enough to challenge even the most assiduous of palynologists.

¹ Yes, I know that *really* the smallest dinosaur is a humming-bird, but deep down we know that dinosaurs are meant to be scaly and scary, ever ready to crunch down a human at one gulp or, if vertically challenged, to viciously shred your shoelaces.

² And the odd graptolite, too, if we're lucky.



So we may turn, driven by our insatiable pursuit of drama, back to the record books, and find the world's largest turbidite layer – so far discovered, of course. Well, I'm not sure if it has been stoutly declared official, but the Herodotus Basin Megaturbidite is at least a candidate, the estimated 400 cubic kilometres of this sedimentary giant³ covering some 40,000 square kilometres of seafloor to a depth of up to 20 metres. And as for entombed and resedimented microfossils – well, it must contain *lots*.

In some places many successive turbidites can pile up thick and fast, and here it's not the individual size that usually amazes, but the rate at which they accumulate on the sea floor. I'm not sure what the record is, but those greywacke beds of the bleak hills of the Southern Uplands might well be contenders. Being washed off the growing Laurentian mountains straight into the ocean trench of the late Ordovician or early Silurian, up to 5 kilometres thickness⁴ of strata could pile up in the order of a graptolite zone – say, a million years or so.

That's sedimentation as an all-action, Hollywood-esque phenomenon, as mountains are reduced to rubble and flow into the ocean depths. But it's the other side of the coin that exerts the greater fascination for me: those parts of the sea floor where nigh-well intangible particles of almost nothing-at-all collect, ever so slowly but *ever* so continuously but *almost* imperceptibly for quite unimaginable stretches of time. These produce those thin but time- and event-rich stratal successions that geologists call condensed sequences. So – as thousands of metres of muddy sand poured into the Southern Uplands ocean trench, something quite different was taking place on the ocean floor above, barely a few hundred kilometres away. In those still depths, there accumulated – perhaps a thousand times more slowly – that mixture of fine mud and organic goo that went on to become black shales, often packed full of the fossilized remains of those remarkably durable plankton, the graptolites.

Here, each graptolite zone, of the order of a million years in duration, can be just a metre or two thick. That's thin, but still a little bulked up by occasional mud clouds drifting across from that busily infilling ocean trench next door. There are the remnants of more isolated parts of sea floor – I've seen examples in the Czech Republic, and in Poland, where graptolite zones (complete, as far as can be judged) are under a metre thick.

Now, that is therefore (on average) one millimetre of stratum resulting from each elapsed millennium. Let us allow generously for those strata having since been squeezed both flat and dry, losing 80% of their volume in the process. That would still be half a millimetre of original sediment per century. It's a vision of eternity almost and – one might be tempted to add – eternal dullness. But in that tedium lies a question: with rates of sedimentation – and therefore of burial – so infinitely slow, just how could any organism get preserved at all? They obviously did, in the starkest of empirical fashions, for even the most condensed of these black shales abound in graptolites – which might be flattened but which look remarkably well preserved otherwise.

Here one might note that the preserved parts of graptolites, the tubes they lived in, seem to have been collagenous, and were likely reasonably tough (the consistency of a bird's feather perhaps?). And, that those sea floors were typically starved of oxygen, effectively keeping out multicellular

³ A baby giant, though, temporally, being merely of Late Pleistocene age.

⁴ And for good measure, one individual turbidite encompassed, if I recall, some 40 metres thickness. The giants of those days may have been gianter.



scavengers and aerobic bacteria. That improves the odds – but still, the average graptolite, the size of a matchstick, would seem to be lying at the surface for a couple of centuries before being buried with even a skim of mud – while the spiral ones, the size of a thimble or larger, would rest there for millennia. Now their collagen might be a bit on the chewy side (think pork scratchings or beef jerky) and the microbes would have been those anaerobic ones, perhaps slower on the uptake than their oxygen-metabolizing cousins – but nevertheless, that was *food* out there, on an ocean-sized plate.

That still seems mysterious to me. One partial solution dropped into place a few years back, as Helen Jones, then a Leicester undergraduate student, investigated the preservation of those wonderful spiral graptolites, to wit *Spirograptus turriculatus*, and why they are often preserved – not just wonderfully, but also flattened on to a single 2D lamina, as though they had been wrapped in clingfilm prior to burial and sedimentary compaction. Conjuring up a well-nigh Shakespearian mixture of passion flower tendrils (as body doubles for those spiral graptolites, you see), powdered Oxford Clay (as Silurian mud) and pond slime (the organic goo), Helen discovered that the pond slime is the key ingredient in preserving their shape. That Silurian sea floor, at that moment, changed within my imagination from being a sea of mud with fallen graptolites sticking out here and there, into something more akin to one of those central European delicacies, with various cuts of meat embedded in aspic⁵ – the latter being some concoction of microbial mats and fallen-in organic debris, the ‘everlasting fall’ of marine snow, as Rachel Carson once called it. Like the aspic⁶, perhaps this organic matrix (that was to disappear almost completely, eventually, as the sediment was buried and heated), was the medium that smuggled so many fossils across from one era into another.

So it’s great stuff, is mud, and quite obviously the blacker, the slimier, the smellier, the *slower* it is the better, for the best of academic reasons. But in terms of our search for a record-breaking stratigraphic slouch, we need to go elsewhere. Our destination is now far away from that deep Silurian sea floor, in space as well as in time. One needs, in fact to re-trace footsteps that both Alexander von Humboldt and Charles Darwin took – puzzled and curious men, both, when they encountered this phenomenon. And the trail goes further still – to Mars, in fact, as the smooth and glistening contours of yet another target in the exopalaeontological hunt.

It was 1799 when something strange caught Humboldt’s eye, while on his epic journey through South America. Granite surfaces around Santa Barbara, in Venezuela, near the mouth of the Orinoco river, had a particular shimmer in the bright sunlight, a shimmer that he saw was due (as he came closer) to dark, lustrous crusts on the surfaces of granite blocks and exposures. These, he noted, were ‘0.3 of a line in thickness’. Some strange kind of weathering, of chemical decay, perhaps? Not for nothing did Humboldt have a reputation as one of the great observers of natural phenomena. He saw that, here and there, pink, unaltered feldspar crystals rose above the black crusts and – just for good measure – he took his hammer and smote a boulder, to see unaltered granite beneath the crusts. These were, then, dark coatings of material *added* to the rock surface, and not some sort of weathering residuum.

The 29th of February, 1832, had been delightful for Darwin. And delight itself – as he noted – ‘is a weak term to express the feelings of a naturalist who, for the first time, had wandered by

⁵ Or a particularly wobbly lasagne, perhaps.

⁶ Or béchamel sauce



himself in a Brazilian forest'. He admired the elegant grasses, the strange new parasitic plants, the luxuriance of the vegetation – not even a violent tropical downpour could dampen his enthusiasm (instead he noted that, taking shelter under a tree, after a few minutes 'a little torrent flowed down the trunk'). Yet even amid these biological riches, he took note when he caught sight, by the shore, of 'that subject discussed by Humboldt' – pale syenitic rocks, burnished with a black layer of extreme thinness 'as if polished by plumbago'. He was intrigued enough to have specimens chemically analysed 'by Berzelius', to show that the black layers were made up of oxides of iron and manganese – yet that did not come any closer to establishing just how these layers formed. Desert varnish (or rock varnish), this stuff has been called subsequently – Darwin's coastal deposit being a bit of an outlier. It has been found in all of the deserts of the Earth, as thin, lustrous coatings of iron-manganese oxides. But just how did these form?

Neither Darwin nor Humboldt had at their disposal scanning electron microscope or X-ray fluorescence spectrometer, energy dispersive analysis or electron microprobe. Subsequent work has shown that these coatings contain silica too (and sometimes the coatings are of little else, and in this form they are clear and glass-like) and also, often, a little titanium and magnesium. The more metallic versions are, in normal microscopic thin section, opaque – but when ultrathin sections are cut, then the coatings – almost never more than a fifth of a millimetre thick – are typically seen to be finely laminated, with alternating more and less metal-rich layers, each less than a thousandth of a millimetre thick.

Could they in sum be, in effect, a fossil – the desert equivalent of a stromatolite? In this scenario, championed by such as Dorn and Oberlander in 1981, fine dust particles would be plucked out of the desert wind by resource-hungry microbial colonies that would then, over millennia, transform these minerals into exceedingly thin layers of metal oxides and silica. Now, if these coatings need microbes to enable them to form, the plot becomes exceedingly thick – for images from around the spacecraft landing sites on Mars have shown surfaces that look for all the world⁷ to show desert varnish coating the surfaces of boulders (DiGregorio 2001; Murchie *et al.* 2004). So, is the surface of the red planet literally coated in microbial gunk and, to find a fossil, a future astronaut doesn't have to do any more than to reach out and pick up the first Martian pebble?

Alas, the interpretation of desert varnish as an obligate biological phenomenon seems not to be so. Later work showed that, firstly, microbes (perhaps unsurprisingly) are not terribly common on exposed rock surfaces in hot arid environments and, secondly, one can make varnish-like coatings in the laboratory in an entirely non-biological setting, as Randall Perry and Mark Sephton (2008) did recently. Here, it seems that silica is the key, with alternate episodes of wetting (dew formation, perhaps?) and drying creating a thin film of evaporated gel of silicic acid on the rock surface that can then capture and react with particles of wind-blown dust to produce metal oxide films.

So – a purely non-biological process on Earth as on a dead red planet? At heart, so it seems. But there is a lustrous lining to this story. One of the reasons that the microbial mechanism was so eagerly suggested was revealed by the wonders of scanning electron microscopy. For the varnish can act as a kind of sticky fly paper, to make up some sort of Lilliputian lagerstätte. Trapped within its layers, there can be entombed the remains of bacteria, fungi, diatoms – and organic

⁷ For all of *that* world, of course.



molecules such as amino acids too (Perry and Sephton 2008). So, even if it is not itself a fossil, such varnish might preserve the microscopic outlines of life, whether Earthly or Martian.

Or it might preserve not just life, but time too – compressing more of our mysterious fourth dimension into its tiny confines than any other material on Earth. It was Tanzhuo Liu and Wallace Broecker – the latter taking a busman’s holiday from his life’s work of seeing how ocean currents and climate are interlinked – who tried to work out quite how much time a varnish layer can encompass. They chose varnish samples from rock surfaces that had been independently dated – by, for example, cosmogenic dating, or by being on a surface relating to some known glacial or volcanic event. The fastest rate they found was 40 microns per thousand years, and the slowest was less than one micron per thousand years – or, to put it another way, less than one millimetre per million years. If one could grow a varnish layer at this rate for the whole history of the Earth, it would be four and a half metres thick. Grow it on some distant planet that formed at the beginning of the universe and it would be but thirteen metres thick by now.

That puts our condensed Silurian black shales looking as bulky as a quarryful of gravel. Yet, there’s more to time than mere extent, or even topological compression. Liu and Broecker worked further on those varnish layers in the drylands of western North America and found that the dark and light bands within them formed a consistent pattern – indeed, a stratigraphy – that could be correlated as far as the Greenland icesheet. Pale microlaminae, poor in manganese and barium, formed in drier, millennial-scale spells, while darker ones, richer in those elements, formed in intervening wetter intervals.

The pattern seemed almost spookily reminiscent of the old pluvial–interpluvial idea – the notion that deserts bloomed during glacial phases and desiccated during interglacials. That simple notion was scotched once it was shown that the Sahara desert was larger than today at the height of the last Ice Age. But Liu and Broecker suggest that this idea might be resurrected, at least in some regions, at a fine, millennial scale.

However the detailed interpretation pans out, it’s a remarkable archive. How far does it extend? The literature on desert varnish suggests that it is strictly contemporary, going back up to a fifth of a millimetre in distance and some tens of thousands of years back in time. Can it become truly geological, as it were, and go back into deep time? One unknown here is what happens to an iron-manganese oxide film away from the Earth’s surface, once it is buried. The prognosis is not good. Burial takes desert varnish into the anoxic realm, where iron and manganese become reduced and, alas, more soluble. So, what built up over many millennia can simply, and quickly, dissolve into porewaters and just vanish, along with all the stories of climate and microflora that it held within its tiny compass. Perhaps, though, in places such stories can be sealed from that most efficient of solvents, water, by an early cement of a different kind, be it silica or carbonate or phosphate.

That has more than likely been the case, here and there, one suspects. But who would look? These varnish layers are thin and, once away from the modern Earth surface where their peculiar nature can shine a signal to researchers from Humboldt onwards, they would be cryptic – more so because their telltale laminae can only be revealed by ultra-thin sections of rock, and not just the standard thin sections made for optical microscopic analysis. One would have to look for



them, scrupulously and determinedly, in just the right kind of strata and geological setting (and be ready for many disappointments before hitting that El Dorado of a desert varnish from the Permian⁸, or the Devonian, or even the Proterozoic).

For true antiquity, the varnish layers of Mars (if that is what they are) may be, paradoxically, a better bet, for all the difficulty of actually getting there and sampling them. For Mars is now essentially dry, so those layers might have been initiated, perhaps, in those times of Mars's history when its axial tilt (so much more crazily changeable than that of our Earth) was at a high level, sometime in what is to us, on this planet, the Pliocene. Or perhaps, among those freeze-dried landscapes, some patches of varnish may even date back to the Hesperian period, some three and a half billion years back in that planet's history. Then, true (if perhaps ephemeral) rivers flowed to produce point bars as good as any on the present-day Mississippi river, and the squally Martian winds might – perhaps! – have carried microbes as well as dust particles.

To track those times and disputable lives, would we need, then, to venture into the world of the hyper-small, and encourage picrostratigraphy to trump microstratigraphy? It's something to bear in mind, perhaps, as one day another, more fortunate, Beagle fossicks among the distant landscapes of Mars. There might, too, be pickings closer to hand among, say, terrestrial Red Sandstones both Old and New. It is satisfying to break any record, of course – but to break a stratigraphic record would be a bit special.⁹

Jan Zalasiewicz

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⁸ The Ed. tells me that Permo–Trias desert varnish has indeed been recorded, from the likes of the Budleigh Salterton Pebble Beds and such. Now there's a chance to unearth a story or two...

⁹ Stop the presses! Just as the last corrections are in... a serious rival for all-time sedimentary sluggard hoves into view: deep-sea iron-manganese crusts. Oda *et al.* in this issue of *Geology* (2011, v. **39**, pp. 227–230) recognize, amazingly, palaeomagnetic reversals in this stuff. These show that it grew – down there, amongst the giant squid and the angler fish – at 5 mm per million years.



PalaeoMath 101

Semilandmarks and Radial Fourier Analysis

The last column completed our extended discussion of landmarks and landmark analysis methods. You now have at your disposal the entire array of mathematically sophisticated and commonly used tools that originally were placed under the general heading of ‘geometric morphometrics’. But just as there’s more to analytical geometry than plotting discrete points in a Cartesian coordinate system, most morphometricians have come to realise that there must be more to geometric morphometrics than the simple analysis of sets—I often refer to them as ‘constellations’—of landmarks.

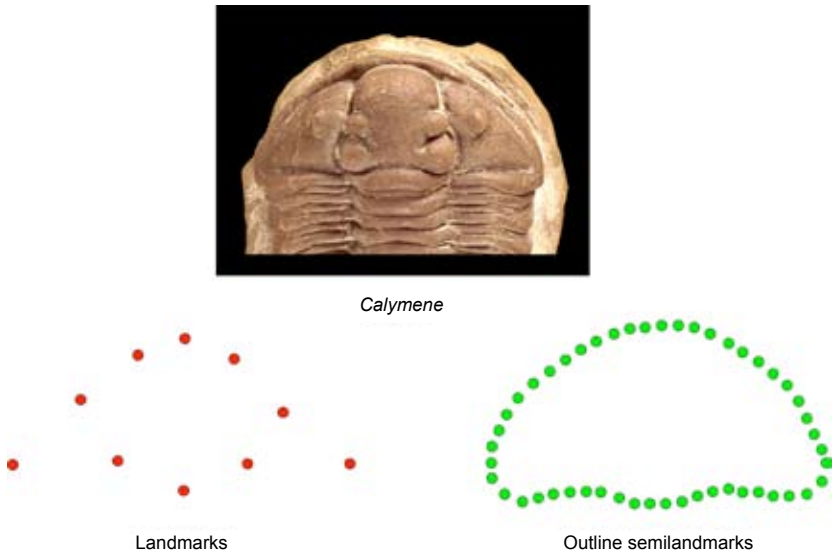


Figure 1. Alternative morphometric representations of the Calymene cranidial form. Original image (top), landmark-based representation (lower left), semilandmark-based representation (lower right). Both representations are ‘correct’ insofar as both accurately express the positions of various cranidial features. However, both are also very different in terms of their geometric form and information content. Which representation is the more appropriate for a particular investigation depends on the objectives of the investigation.

The basic problem with landmarks is illustrated in Figure 1. Landmarks are specific point locations on a biological form, or image of a form, located according to some rule. Dependence relations among the rule sets used to locate landmarks give rise to the landmark type classification system.



Type I landmark: a mathematical point whose [topological] homology is provided by biologically unique patterns on the form (*e.g.*, juxtaposition of tissue types, small patch of some unusual histology).

Type II landmark: a mathematical point whose [topological] homology is provided only by geometric, not biological or histological, criteria (*e.g.*, point of maximum curvature along a boundary).

Type III landmark: a mathematical point having at least one coordinate that's 'deficient' in the sense that its location is logically dependent on the location of other landmarks and/or the orientation of the specimen as a whole (*e.g.*, either end of a longest diameter, or the bottom of a concavity).

Despite their inherent biological ambiguity these are, nevertheless, fairly stringent definitions. Even in the best of circumstances it is typically the case that a relatively small number of such points can be located on any set of forms. Landmark identification is maximized when all forms of interest represent the same or closely related species whose morphologies are composed of the same parts. Regardless, and as will be well appreciated by those with even a cursory experience of systematics and taxonomy (not to mention ecology, biogeography, phylogenetics), this imposes a rather severe constraint on the range of problems that can be considered under a solely landmark-based morphological sampling scheme.

Prior to the advent of the geometric morphometric paradigm, a school of morphometrics developed a set of form-sampling protocols and data-analysis tools that provided all morphometricians with the ability to assess variation in the outlines of biological forms. This approach to biological form/shape analysis was developed alongside the inter-landmark distance-based approach that is usually referred to as multivariate morphometrics (Blackith and Reyment 1971; Pimentel 1979). Owing to (1) the necessary and compelling limitation of multivariate morphometric datasets to comparisons of features that could be regarded as being comparable in some meaningful biological sense and (2) the comparative ease by which the landmarks used to define the inter-landmark distances could be collected, multivariate morphometrics became the dominant approach to the quantitative analysis of biological form throughout the 1960s, 1970s, and 1980s. Nevertheless, owing to its inherently more geometric character, outline morphometrics developed a stronger tradition of shape modelling and a wider range of applications than did multivariate morphometrics.

Although the utility of analyzing the geometry of boundary outlines has long been recognized in a variety of applied geometric contexts, this approach has remained a sparsely populated sub-domain of morphometrics. This lack of popularity occurred for two reasons. First, some prominent morphometricians raised theoretical issues with regard to the idea of comparing sequences of outline coordinates that might fall on structures that were non-comparable in any biologically meaningful sense (see Bookstein *et al.* 1982). The second, and much more practical, reason that many found outline morphometrics difficult to apply was that most morphometricians lacked access to the types of boundary outline sampling systems that were needed to pursue such analyses. To an extent, outline morphometrics suffers from the former criticism still and, as a result, this approach is not considered an option for morphometric analysis designs, even in situations where it would clearly be advantageous to do so.



Irrespective of this somewhat contentious history, during the 1990s recognition of the contributions boundary outlines can make to the resolution of a number of outstanding biological problems forced both their reassessment as a primary morphometric data type and the development of tools that effectively brought the analysis of outlines into the corpus of the morphometric synthesis. At the same time, sophisticated and comparatively low-priced software programs designed to extract boundary outline coordinates from digital images of specimens appeared and began to be used by a greater range of morphometricians and students of morphological variation. As a result, outline morphometrics now represents not only a fully justifiable choice for a wide range of morphometric analysis situations, but in many instances the only reasonable choice for evaluating a wide array of complex and information-rich biological forms. Over the next several essays I intend to explore the data, tools and concepts that lie behind this highly useful, but presently underutilized, branch of morphometrics.

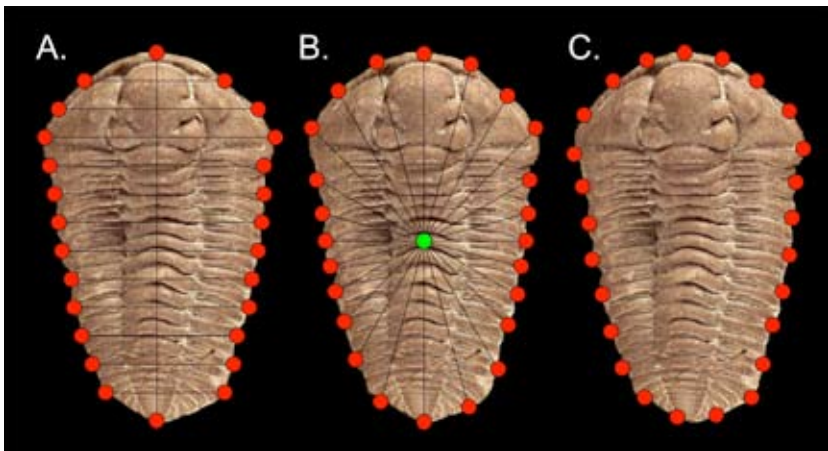


Figure 2. Alternative boundary outline semilandmark placement protocols. A. Equally spaced transverse chords along a maximum diameter. B. Equal angles from the object centroid. C. Equal spacing around the object periphery.

At the heart of the analysis of boundary outlines under the geometric morphometric paradigm is the concept of the semilandmark (Fig. 2). Bookstein (1996a,b) defined this term as referring to a series, or sequence, of landmark coordinates used to represent the form of a curve. Individually, semilandmark points usually conform to the definition of Type 3 landmarks insofar as their positions reference a series of criteria external to the form itself (e.g., orientation of the specimen, placement of the starting point and/or end-point of the boundary). However, the reason why semilandmarks are treated as being ontologically distinct from Type 3 landmarks has more to do with their sequential nature than with their definitional dependence relations.

Semilandmarks are always sequences of mathematical points, usually defined by some sequence-based criterion in addition to the form-based criteria used to define Type 3 landmarks. These criteria include equal spacing along the length of the curve, equal spacing of horizontal or vertical grid lines along the length of a maximal diameter at the points that intersect the boundary of a curve, or intersections between a set of equiangular radius vectors emanating



from a closed form's centroid at points that intersect the boundary of interest. In this essay we're going to take a close look at the oldest of the boundary outline analysis methods, classic radial Fourier analysis (RFA) which utilizes the equi-angular sequence-based sampling criterion.

Fourier analysis and the Fourier series are fundamental mathematical concepts that lie at the nexus of calculus and number theory. While working in the early 1800s on a physical problem relating to the flow of heat between two bodies, the French mathematician Joseph Fourier solved a complex differential equation by using the sine and cosine functions¹ to decompose the equation into a series of simpler components. On the basis of his success Fourier postulated that any continuous or discontinuous function can be represented to any desired level of accuracy by an infinite series of sine and cosine functions. Unexpectedly, this postulate over the nature of functions has not only remained controversial from Fourier's day to our own, but has gone on to inspire research in areas of mathematics well beyond the (already large) domain for which it was formulated originally.

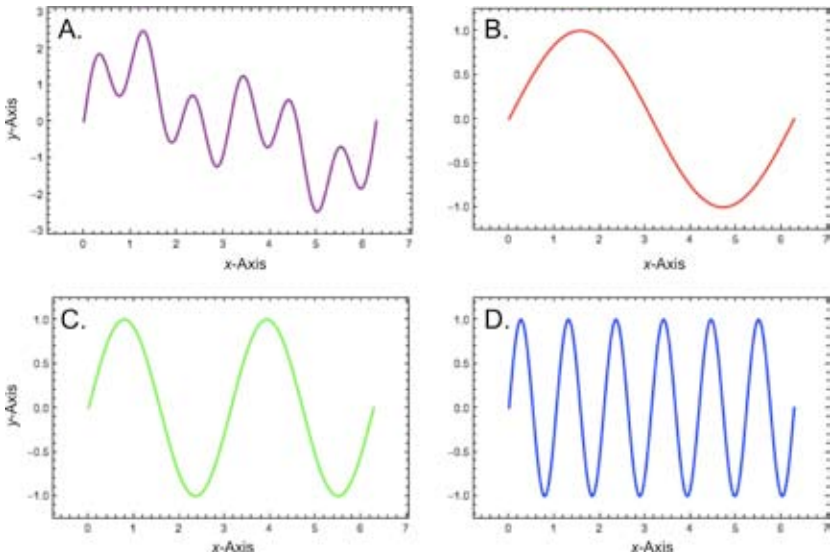


Figure 3. Decomposition of a complex boundary curve in a Cartesian coordinate space (A) into a set of component curves based on the sine function: $y = \sin(1t)$ (B), $y = \sin(2t)$ (C), and $y = \sin(6t)$ (D), where t is allowed to vary continuously between 0.0 and 2π .

The basic method of Fourier analysis is simple enough to demonstrate. Take a complex mathematical function such as that shown in Figure 3A. This curve was formed by adding the three simple sine functions shown in figures 3B-D together. Fourier's contribution was to devise an infinite series of functions that could be used to represent or 'decompose' any complex empirical curve like this into a set of simpler component curves that resemble those shown in figures 3B-D.

Note that, in order to describe the empirical curve, it is not necessary for the decomposition to recover the same curves that were used to construct the complex curve. Indeed, it will usually

¹ A function is a mathematical relation that uniquely associates the members of one set with the members of another set.

be the case that the empirical curve is either not constructed out of a set of known curves and/or that the set of curves that contribute to its assembly is very large. From the standpoint of curve description, the recovery of the original generating curves—even if that were possible—is irrelevant. All we need is a method to find a set of component curves that can be used to describe and quantify aspects of the complex curve of interest and that, when combined with other descriptors of the curve, can reproduce the complex original to any desired level of accuracy. Of course, it also helps with interpretability if the series of curves used to describe the complex curve have known and simple geometric relations with one another. This is precisely what Fourier's series provides.

Before we dive into the mathematics of Fourier analysis, let's take care of a little relevant detail. It probably hasn't escaped your notice that the curves shown in Figure 3 don't look very much like the outlines of organisms. Why are these curves—and by implication why is Fourier analysis—of any interest to people like us? The answer is to be found in altering the manner in which we draw the curves shown in Figure 3.

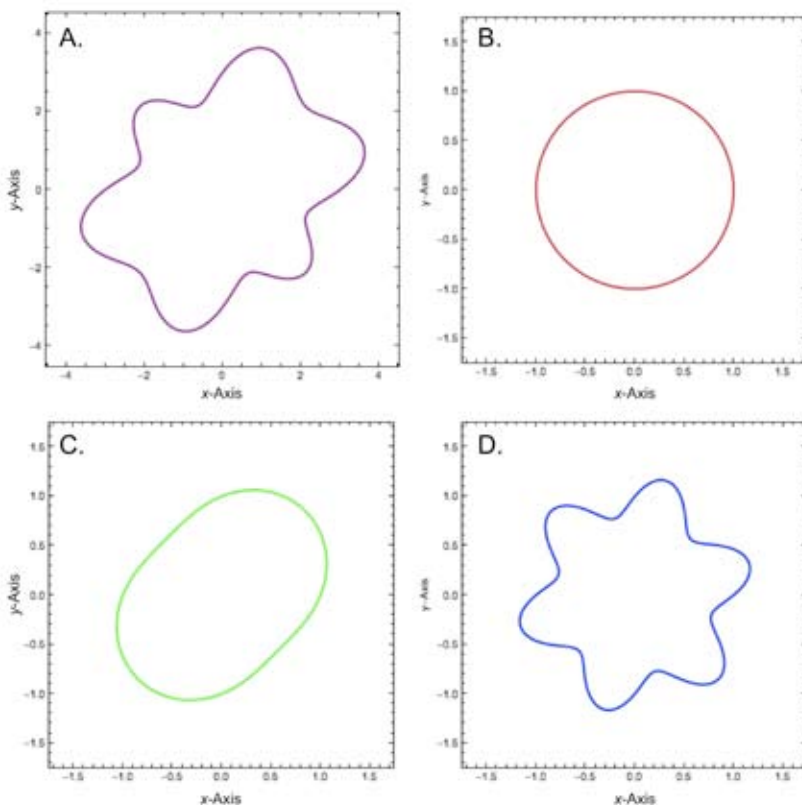


Figure 4. Decomposition of a complex boundary curve in a polar coordinate space (A) into a set of component curves based on the sine function: $y = \sin(1t)$ (B), $y = 1+0.5 \sin(2t)$ (C), and $y = 1+0.5 \sin(6t)$ (D), where t is allowed to vary continuously between 0.0 and 2π .



Take a look at Figure 4. These are the equivalents of the equations used to plot the curves in Figure 3 produced this time as polar (rather than Cartesian) coordinates. Recall that polar coordinates use two numbers to locate points within a linear coordinate system in the same way as Cartesian coordinates, but polar coordinates achieve this location by specifying the angle of a vector from a reference axis and the distance of the point from the coordinate system's origin. The curves in figures 3 and 4 are equivalent representations of the same sine and cosine functions. Fourier analysis can operate on the complex curves show in figures 3A and 4A in exactly the same manner. However, it's obvious that the polar form of a boundary outline curve can be used to represent a wide variety of biologically interesting outline shapes.

The canonical expression of the Fourier series is usually given as follows.

$$r(\beta) = \bar{r} + \sum_{j=1}^k [a_j \cos(j \cdot \beta) + b_j \sin(j \cdot \beta)] \quad (22.1)$$

Where:

r = length of radius vector in polar coordinate system

β = angle of radius vector in polar coordinate system

\bar{r} = average of all radius vectors

j = Fourier harmonic number

k = total number of harmonics in Fourier series

a_j = amplitude of the cosine term for the j th harmonic

b_j = amplitude of the sine term for the j th harmonic

This equation can be used to calculate the position of any point in the polar coordinate space that satisfies the equation's conditions. Each term in the summation specifies a geometric figure whose size is determined by the mean radius vector term (\bar{r}) and whose shape is determined by the a_j and b_j coefficients. These control the amplitude of the sine and cosine functions. We can have a look at the shapes that comprise the radial (= polar coordinate) Fourier series by ignoring the summation, holding a_j and b_j constant, specifying different values for the harmonic number (j), evaluating the resulting expression for a continuous set of β -values between 0.0 and 2π (= 360°), and plotting the result. Plots of the first six harmonic shapes for amplitude coefficient values of 0.1 and a mean radius of 1.0 are shown in Figure 5.

There are several things to note about this set of figures. First, the harmonic number refers to the number of 'lobes' in the shape. The amplitude coefficients control the degree of lobe differentiation. High amplitude values specify deep indentations, low values shallow indentations. These values also control the orientation of the lobes as they can be varied in the manner of weighting coefficients to 'pull' the figure in the direction of the sine or of the cosine components of the curve. Also note that, since k can be given any integer value, the scope of the series is infinite. A $k = 60$ Fourier harmonic figure will have 60 lobes that (for this set of amplitude coefficient values) would be arranged to 'wave' back and forth within a deviation envelope of 10 percent about the unit circle (Fig. 6).

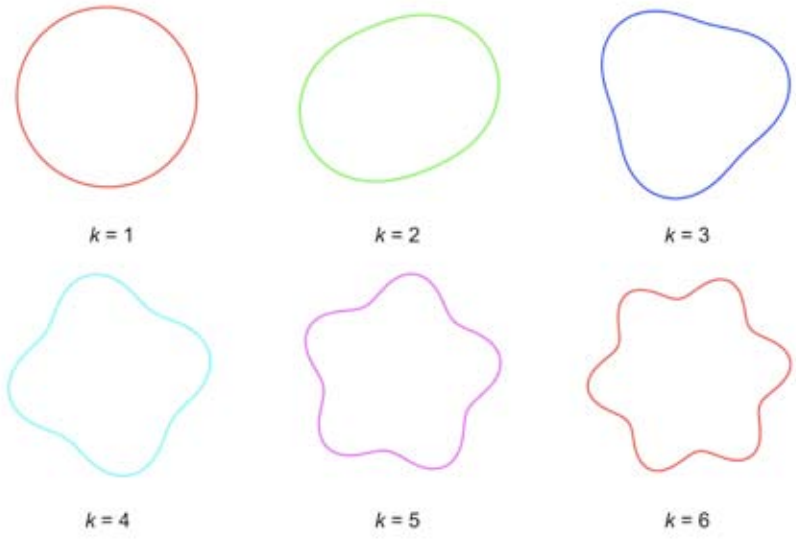


Figure 5. The first six radial Fourier harmonic shapes for the series defined by a mean radius value of 1.0 and amplitude coefficient values of 0.1.

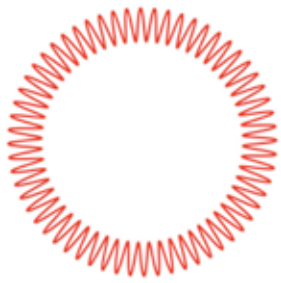


Figure 6. The 60th Fourier harmonic shape for the series defined by a mean radius value of 1.0 and amplitude coefficient values of 0.1.

These fancy mathematical graphics are all well and good, but the real purpose of the Fourier series lies in using the Fourier harmonic figures as variables that describe aspects of shape. Thus, the $k = 1$ harmonic can be thought of as an index of circularity, the $k = 2$ harmonic regarded as an index of ‘elongatedness’, the $k = 3$ harmonic an index of triangularity, and so forth.

How do we describe shapes using the radial Fourier harmonic series? Essentially we fit—in the sense of a regression analysis—the empirical shape to the set of harmonic figures one-by-one, by adjusting the values of the amplitude coefficients a_j and b_j . This is accomplished using the following equations (22.2).



$$a_j = \frac{2}{n} \sum_{i=1}^n r_i \cos(j \cdot \beta_i) \quad (22.2)$$

$$b_j = \frac{2}{n} \sum_{i=1}^n r_i \sin(j \cdot \beta_i)$$

Where:

n = total number of points in an empirical curve.

r_i = distance between i^{th} point and the curve centroid.

j = Fourier harmonic number.

β_i = angle of the i^{th} radius vector in polar coordinate system

The resulting amplitude coefficients measure the closeness of fit between the outline as expressed by the n points used to sample the outline and each of the j Fourier harmonic figures. Since each figure in the Fourier series is independent of, and uncorrelated with, all other figures in the series, a set of Fourier harmonics represents a set of j independent and uncorrelated shape variables. In this sense the set of Fourier harmonics are similar to the shape variables produced by an eigenanalysis of the covariance matrix calculated for a distance or landmark data set. However, since the Fourier series is derived from the sine and cosine functions which, unlike covariances, are the same for any sample, Fourier shape descriptors are invariant. In other words, each shape has its own, unique set of Fourier harmonic descriptors—often termed a Fourier spectrum—that can be compared with one another irrespective of what sample they belong to or what other shapes they are associated with in any analysis.

Two last points need to be made regarding Fourier analysis computations before we move on to an example computation. The first is the observation that the maximum number of Fourier harmonics that can be used to describe a shape is set by the number of coordinate points used to describe or sample the shape. This number (k) is determined by the following relation.

$$k_{\text{Maximum}} = \frac{n}{2} - 1 \quad (22.3)$$

Since k must be an integer, this means that the maximum number of non-zero harmonic amplitudes that can be extracted from any curve represented by n points is one less than half of n . It is perfectly acceptable to calculate the maximum number of Fourier harmonic amplitudes possible for a set of shapes, but then only use a subset of these for further analysis. The only way to increase the number of Fourier shape descriptors above the maximum for a particular dataset, however, is to resample the boundary outline shapes at a higher resolution.

The second point is that it is often inconvenient to work with two separate amplitude-based shape descriptors. Fortunately, there's no need to do this since Johnson (1944) determined that the radial Fourier series can also be expressed in the following manner.

$$r(\beta) = \bar{r} + \sum_{j=1}^k [c_j \cos(j \cdot \beta + \phi_j)] \quad (22.4)$$

Where:

$$c_j = \sqrt{(a_j)^2 + (b_j)^2} \quad (22.5)$$

$$\phi_j = \tan^{-1}(b_j/a_j) \quad (22.6)$$

The c_j term includes all the harmonic scaling information present in the separate a_j and b_j terms of equations 22.1 and 22.2. The ϕ_j term (known as the ‘phase angle’) contains information about the best-fit rotation of the harmonic figure to a position of maximum correspondence with the observed boundary outline. Because of the formulation of the arctangent (= \tan^{-1}) function, the following rules should be used to determine the true phase angle.

- If $a_j > 0.0$ and $b_j > 0.0$, $\phi_j = \phi_j$ (22.7)
- If $a_j < 0.0$ and $b_j > 0.0$, $\phi_j = \phi_j + 180^\circ$
- If $a_j < 0.0$ and $b_j < 0.0$, $\phi_j = \phi_j + 180^\circ$
- If $a_j > 0.0$ and $b_j < 0.0$, $\phi_j = \phi_j + 360^\circ$
- If $a_j = 0.0$ and $b_j > 0.0$, $\phi_j = 90^\circ$
- If $a_j = 0.0$ and $b_j < 0.0$, $\phi_j = 270^\circ$

Care must be taken when programming these correction rules as some computer systems and/or programming code compilers report the arctangent value in different ways. Let’s now turn our attention from developing to using this mathematical tool. Figure 7 shows three foraminiferal species that exhibit very different outlines.

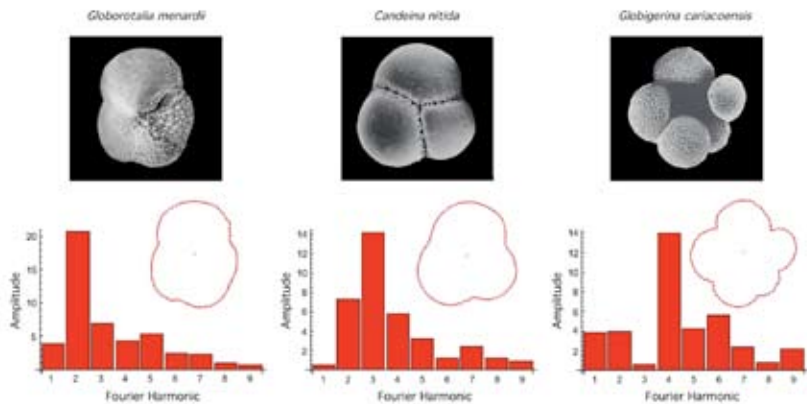


Figure 7. Images, boundary outlines, and Fourier harmonic spectra for three planktonic foraminifer species. SEM images modified from Saito et al. (1981).



The bar graphs at the bottom of this figure illustrate the values of c_j for a nine-harmonic Fourier analysis of these species' boundary outlines. Note how each harmonic spectrum reflects the specimen's outline shape. Although the terminal whorl of *Globorotalia menardii* is composed of three chambers, the general aspect of its outline is that of an ellipse with three prominent subsidiary lobes and two smaller lobes located to the right of the aperture. The geometry of this species' shape is reflected in the very high amplitude of harmonic 2 and relatively high amplitudes for harmonics 3 and 5. The *G. menardii* spectrum contrasts strongly with that of *Candeina nitida*, which is characterized by a high amplitude value for harmonic 3—reflecting the strong triangularity of this species' test in umbilical view—with subordinate components of elongation (harmonic 2) and quadrateness (harmonic 4). Finally, the shape of *Globigerina cariacensis* strongly reflects the final four chambers of the ultimate whorl (harmonic 4) with subordinate and subequal components of circularity (harmonic 1), hexagonality (harmonic 6), septagonality (harmonic 7), and nonagonality (harmonic 9). The point, of course, is that the radial Fourier series can be used to describe, characterize, and distinguish between different classes of boundary outline shapes with very high levels of precision.

Note also that these amplitude spectra remain the same regardless of the rotational orientation of the specimen. Information about this aspect of each specimen's pose is contained in the phase angle spectra (not shown). However, if rotational orientation is not a parameter you happen to be interested in, a geometrically valid analysis can be achieved in a rotation-invariant description of shape by ignoring the phase angle data altogether. To be sure, the decision as to which data are needed to answer any biological question must always be made with care. But this useful and mathematically elegant option is a characteristic feature of Fourier analysis.² Naturally, the conversion of the original x,y coordinate values to polar coordinate values has already taken care of outline translation via centroid superposition, while sequestering of the object's size as the mean radius vector effectively normalizes each outline for size differences.

Once a set of boundary outline shapes has been represented, or 'decomposed', into a series of amplitude values, the matrix of these shape descriptors can be subjected to standard multivariate analysis. Figure 8 shows a series of images of 18 Recent planktonic foraminifer species. Table 1 contains the amplitude spectra for the first nine Fourier harmonic decompositions of the species' boundary outlines. Finally, Figure 9 shows a scatterplot of the distribution of these shapes in the space of the first two principal components of the Fourier harmonic-shape covariance matrix.

² If phase angles are to be included in a secondary analysis of a set or sample of Fourier harmonic spectra (see below) it's usually a good idea to represent these angles as radians rather than degrees to make their magnitudes more comparable to those of the harmonic amplitude term c_j .

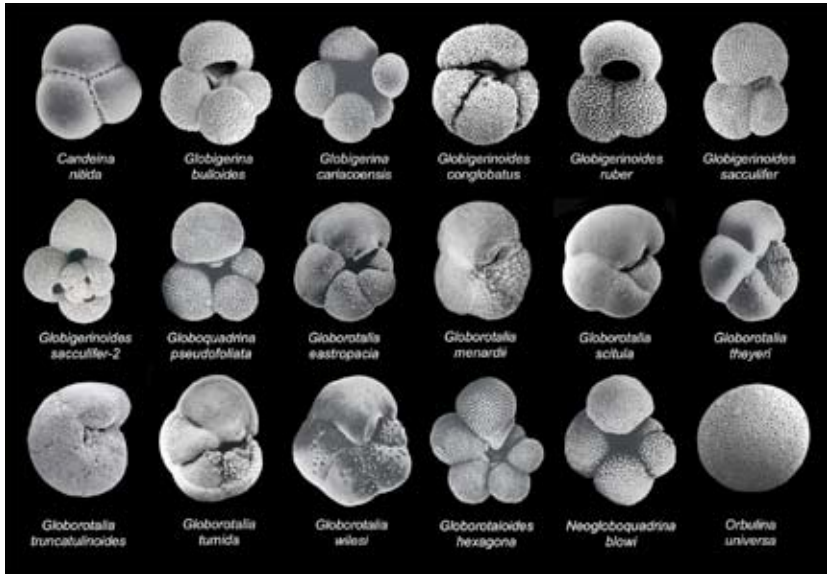


Figure 8. Images of planktonic foraminifer species used in the example radial Fourier outline analysis (modified from Saito et al. 1981).

Table 1. Harmonic amplitude values for the boundary outlines of the foraminiferal species shown in Figure 8.

Species	Fourier Harmonic Amplitudes								
	1	2	3	4	5	6	7	8	9
<i>Candeina nitida</i>	0.49	7.31	14.20	5.83	3.19	1.20	2.38	1.25	0.86
<i>Globigerina bulloides</i>	4.63	14.00	12.99	5.06	8.01	5.40	1.20	3.96	0.51
<i>Globigerina cariacensis</i>	3.86	3.97	0.64	13.96	4.29	5.66	2.41	0.88	2.22
<i>Globigerinoides conglobatus</i>	6.49	13.39	4.28	5.32	6.83	1.54	3.87	2.44	3.51
<i>Globigerinoides ruber</i>	2.31	22.25	12.77	8.75	5.04	1.20	2.56	1.79	1.52
<i>Globigerinoides sacculifer-2</i>	1.89	23.55	21.14	10.11	1.32	2.29	1.71	3.03	2.51
<i>Globigerinoides sacculifer</i>	0.46	25.06	6.09	7.67	2.05	2.65	1.36	0.25	0.63
<i>Globoquadrina pseudofoliata</i>	4.03	17.54	17.94	6.55	6.45	5.42	3.71	2.80	0.63
<i>Globorotalia eastropacia</i>	2.20	14.69	8.56	3.33	6.94	2.91	0.58	2.07	0.93
<i>Globorotalia menardii</i>	3.88	20.65	6.88	4.36	5.27	2.35	2.30	0.97	0.67
<i>Globorotalia scitula</i>	4.63	10.64	5.07	6.11	1.14	3.71	1.57	1.50	1.05
<i>Globorotalia theyeri</i>	6.03	17.43	10.69	4.01	3.37	1.49	2.90	0.70	2.13
<i>Globorotalia truncatulinoides</i>	7.82	12.30	9.45	6.22	4.58	2.86	2.42	1.79	1.66
<i>Globorotalia tumida</i>	4.11	15.65	7.01	2.14	4.14	0.46	0.61	1.18	0.80
<i>Globorotalia wilesi</i>	3.69	8.86	8.67	2.49	4.55	1.88	2.29	0.93	0.99
<i>Globorotaloides hexagona</i>	11.13	26.59	14.82	17.50	8.18	11.31	4.34	0.76	4.08
<i>Neogloboquadrina blowi</i>	3.96	14.56	9.77	10.97	5.19	1.71	1.51	2.84	1.52
<i>Orbulina universa</i>	2.57	5.39	1.12	0.78	0.40	0.06	0.18	0.33	0.48

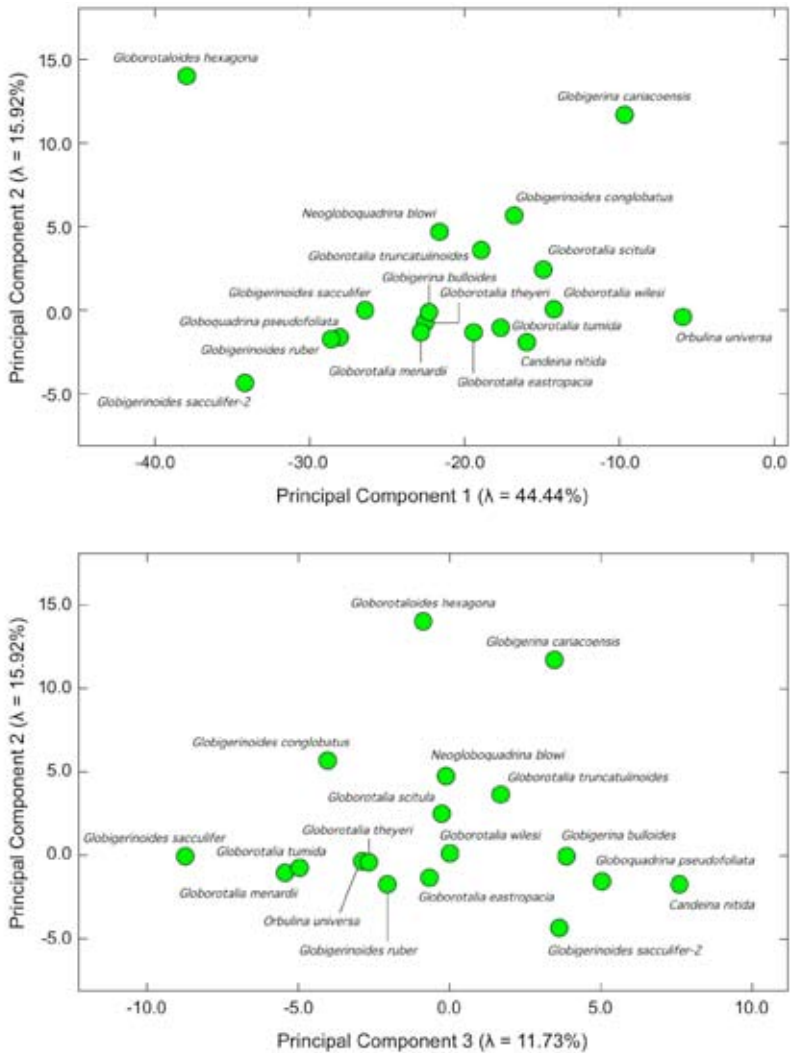


Figure 9. Scatterplots of the projections of planktonic foraminifera species' boundary outline shapes into the planes formed by the first three principal components of the Fourier harmonic-shape covariance matrix. See text for discussion.

Despite the fact that they represent a subordinate shape variation trend in the example foraminifer dataset, *Globorotaloides hexagona* and *Globigerina cariacensis* clearly represent shape outliers with respect to this particular species set. A quick inspection of Figure 8 shows these are the two species in the dataset with the most lobulate peripheries. In terms of their Fourier amplitude spectra, both are characterized by relatively high amplitudes for intermediate-level harmonics (e.g., harmonics 5–7, see Fig. 10). This contrasts strongly with the amplitude

spectra for species that plot low on the second principal component of the combined amplitude and phase angle spectra (e.g., *Globigerinoides sacculifer*, *Candeina nitida*, *Globigerinoides ruber*), all of which are characterized by quite low amplitudes in this intermediate region of the harmonic spectrum.

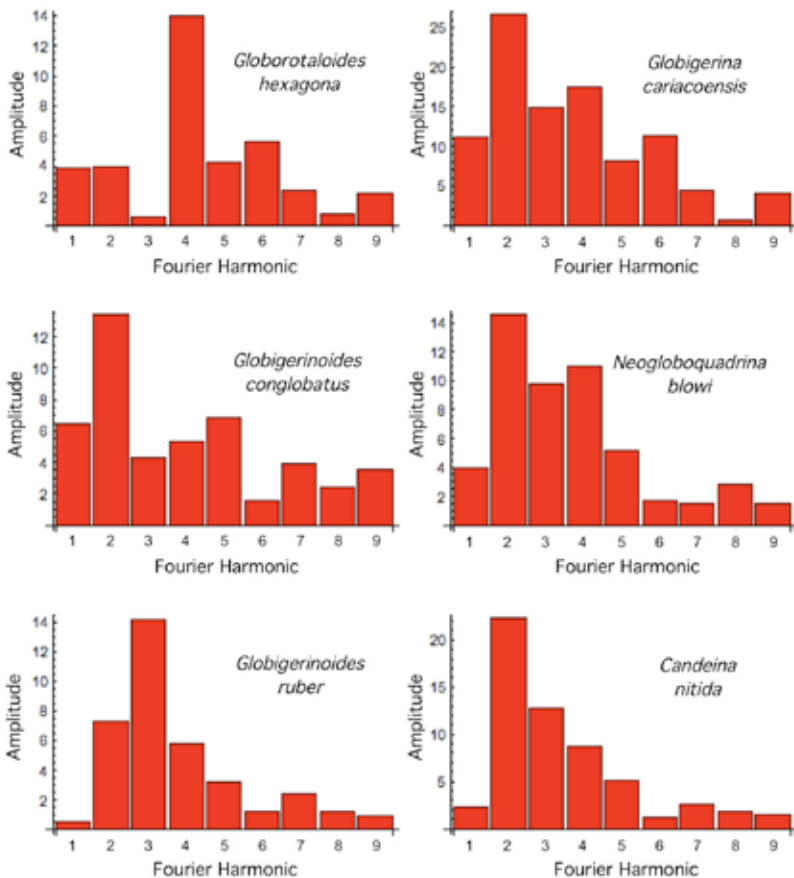


Figure 10. Fourier amplitude spectra for selected foraminifer taxa in the example dataset. Note the drift of middle-range harmonic amplitudes for those shapes that plot at lower (bottom plots), intermediate (middle plots), and high (upper plots) positions along PC-2. See text for additional discussion.

Interestingly, the species whose shapes are most intermediate along this axis (e.g., *Globigerinoides conglobatus*, *Neogloboquadrina blowi*) exhibit amplitude spectra that are markedly higher in the lower portion of this intermediate harmonic range (harmonics 3–5). Thus, along this secondary shape variance axis we appear to be seeing the effect of a progressive drift from low values in the intermediate harmonic levels, to a raising of the amplitudes in the low range of this intermediate level that finally culminates in either a broadly elevated, plateau-like spectrum (*Globorotaloides*



hexagona) or a distinctly bimodal spectrum (*Globigerina cariacensis*). Of course, the difference between these end-member harmonic geometries is responsible for the separation of these two shape outliers in the PC-1 vs. PC-2 space.

Turning now to the major, but far more subtle, shape variation trend in our example dataset, the difference between *Globigerinoides sacculifer-2* (a commonly seen variant morph of the typical *G. sacculifer* characterized by a large, but incompletely inflated, ultimate chamber) and *Orbulina universa* is both clear and compelling (see Fig. 8). In terms of the Fourier amplitude spectra for these two taxa the contrast is equally striking (Fig. 11). The other non-outlier species form a quasi-continuous distribution of shapes between these two end-member taxa along PC-1, forming a complex, but quasi-continuous shape variation sequence.

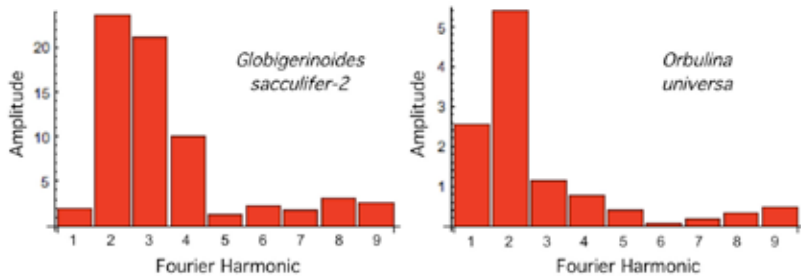


Figure 11. Fourier amplitude spectra for two foraminifer shapes that plot at the extremes along PC-1 and at broadly comparable positions along PC-2. Note the virtually reciprocal pattern of amplitude values characterizing all Fourier harmonics except harmonic 2. Note also the broad discrepancy between the amplitude scales for the two shapes. See text for additional discussion.

While it is possible to make interpretations of the geometric meaning of a Fourier harmonic-based principal component space using a qualitative analysis of extreme taxa, as we have seen above, this task is made much easier and much more precise now that we have access to, and can compare, the harmonic spectra of individual shapes. These shape variables are complex in the sense of being able to summarize a much greater amount of geometric information than inter-landmark distance variables or Procrustes shape coordinate variables. But at the same time the geometric regularity of the radial Fourier series makes fine interpretation both tractable and intuitive.

Still, we don't need to stop or be satisfied with solely qualitative, or even semi-quantitative, interpretations of these Fourier harmonic-based principal component spaces. In the same way that we were able to use simple matrix algebra to develop a tool that allowed us to obtain precise geometric models of any point in a PCA ordination plot in terms of the original variables (see MacLeod, 2009), we can apply that same technique to provide us with the means to visualize any point, or model any transformation series, within the Fourier harmonic-based principal component spaces. This is a very under-exploited approach to the interpretation of Fourier analysis and one that, because of the richly geometric nature of the radial Fourier series, yields insights that simply cannot be matched by most landmark-based approaches to morphometric analysis, much less those based on inter-landmark distance data. In order to operationalize this technique the data matrix submitted to the PCA must consist of either the a_j and b_j coefficients of



the standard Fourier decomposition both harmonic amplitudes and phase angles (see equations 21.1 and 21.2), or the composite harmonic amplitude a_j and associated phase angle ϕ_j (see equations 22.4, 22.5, 22.6). Either will do since equations 22.1 and 22.4 are equivalent.

In order to demonstrate the utility of PCA-based radial Fourier shape models, a transect of five shape models was calculated along the mean transects of each of the first three PC axes, with the extremes placed at the extreme positions of the data point cloud and the remaining three models placed as equally spaced positions along each transect. Figure 12 shows the three sets of back-projected shape variation models that, together, express the geometry of shape variation along these axes within the PC-1 – PC-2 – PC-3 subspace in a precise geometric manner. Figure 13 overlays each of the three model sets in the manner of a ‘strobe’ plot (see MacLeod 2009) so that the regions and directions of shape variation along each transect can be assessed and compared in an easy-to-understand manner. Note how much more definite, information-rich, and biologically informative the shape modelling approach to the interpretation of these morphometric data is, as well as how much easier it is to use them to communicate the results of such an analysis to non-quantitative colleagues and students.

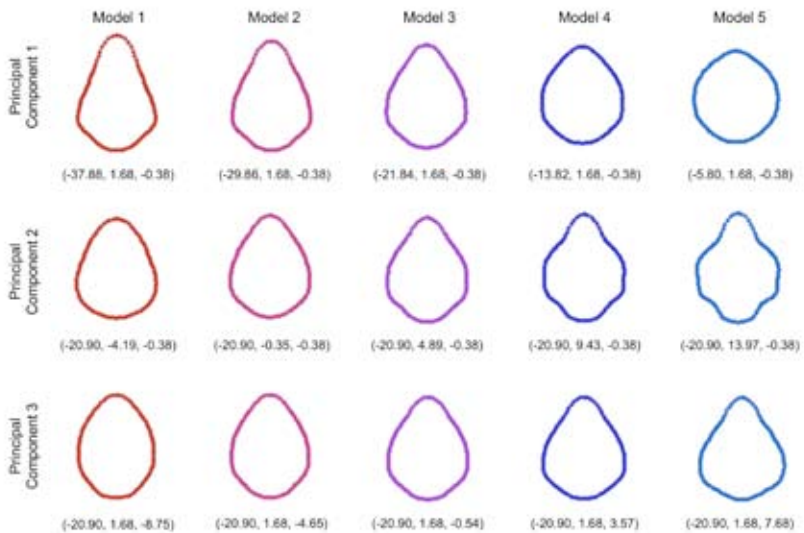


Figure 12. Shape models that correspond to a series of mean transects through the data point cloud shown in Fig. 9. Coordinates of the modelled positions in the PC-1 – PC-2 – PC-3 subspace are shown below each model. These models were determined using the back-projection method described in MacLeod (2009). Note how much more geometrically precise explicit shape models of the PCA space can be than the (standard) qualitative approach based on extreme objects. See text for further discussion.

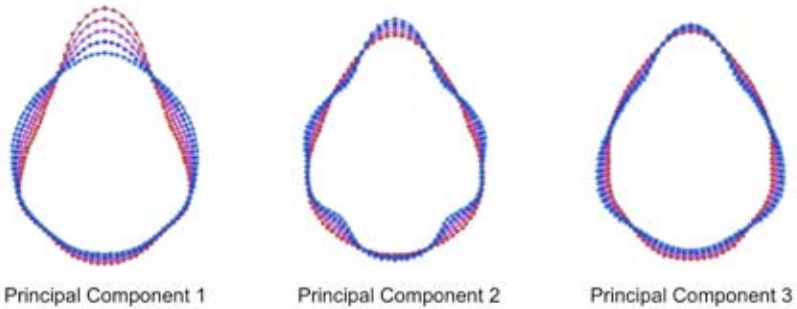


Figure 13. Overlay or 'strobe' plots of the along-axis shape models shown in Fig. 12. These plots are useful for identifying which parts of the outline are moving relative to which other parts as positions within the ordination space change, as well as the relative directions of movement. Colour codes as in Fig. 12.

In the past many have criticized the use of semilandmark points in any sort of biologically valid morphometric analysis because, with the exception of the starting and/or ending points of the curve, their definition rests wholly on geometric rather than biological criteria. But this stance was always plainly inconsistent with the fact that these same authors advocate the use of Type 3 landmarks which are defined—to all intents and purposes—on the same criteria. Moreover, semilandmark-defined boundary curves provide a strategy for quantitatively representing the form and shape of curves that systematists, taxonomists, ecologists, biogeographers, phylogeneticists, *etc.* use routinely both to characterize and to distinguish between individuals and groups in the normal course of their qualitative investigations. Indeed, many taxa are defined—in whole or in part—on the basis of precisely such curves. It has always struck me as odd to regard the analysis of such geometries as perfectly acceptable so long as the analysis remains qualitative, but to disallow it if any attempt is made to quantify the results despite the fact that the mathematical tools required to support such quantification and quantified analysis are not only available, but have been proven time and time again to yield interesting and important results; results unachievable by any other qualitative or quantitative analytic approach.

This is not to say that the use of RFA should be advocated in all instances and/or blindly. Far from it. Radial Fourier analysis is inherently limited, at least in its classic formulation. It can only be used to analyze closed curves and is dependent on accurate location of the curve centroid. The latter limitation is more complex than it appears due to the fact that the calculation of k harmonics requires the specification of $2k+1$ equiangular radius vectors, the estimation of which requires an initial estimate of the outline's centroid. Unfortunately, the centroid of the outline points specified by the resulting interpolated radius vectors may, or may not, coincide with the initial estimate of the raw outline's centroid, depending on geometric interactions between the number of boundary outline points used to quantify the curve and the shape of the boundary outline curve itself. In those cases in which the centroids estimated from the original data and from the radius vector do not coincide, imprecision will be introduced into the Fourier calculations. There are strategies to correct this problem, but these will not lead to centroid convergence in all cases.



Even more worryingly, classic RFA can only be applied to single-valued outlines, which are those in which all radius vectors cross the boundary curve just once. Many interesting biological outlines violate this single-value condition. Indeed, this problem is what required substitution of foraminifer for our standard trilobite dataset as the subject of the example calculations. Furthermore, there are even many foraminiferal species that exhibit multi-valued outlines; classic RFA could not even be used as a generalized approach to the analysis of the geometry of planktonic foraminifera. We'll be taking a look at the solutions to some of these problems in the next column. Regardless, RFA is a very efficient tool to use if your curves of interest are single valued and it represents an obvious starting point for our discussion of the morphometric analysis of outlines.

As for software, surprisingly few computer applications are available for performing this procedure. A fully worked example of all the calculations presented above is provided in the *PalaeoMath 101-2* spreadsheet. This can be used for simple problems. I have developed Wolfram *Mathematica*[™] notebooks for radial Fourier analysis and would be happy to share these with any *Mathematica* users. Øyvind Hammer's PAST program package for PC computers (<<http://folk.uio.no/ohammer/past/>>) includes a radial Fourier analysis routine. It is likely that public-domain radial Fourier routines also exist for MATLAB, R, and Maple software platforms, but I am unaware of any particularly appropriate or widely used examples. Fortunately, the calculations involved are quite simple and straightforward. If you need a 'quick-and-dirty' analysis, or just want to play around with the equations to confirm your understanding of the technique, the spreadsheet should suffice.

Norman MacLeod

Palaeontology Department, The Natural History Museum

<N.MacLeod@nhm.ac.uk>



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Don't forget the *PalaeoMath 101-2* web page, at:

<http://www.palass.org/modules.php?name=palaeo_math&page=1>



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Meeting REPORT



54th Annual Meeting of the Palaeontological Association

Ghent, Belgium 17 – 20 December 2010

In the unusually white December of 2010, palaeontologists from across Europe and beyond struggled through the snow to gather in the Aula, a monumental building in the historical centre of Ghent in Belgium, for the 54th Annual Meeting of the Palaeontological Association. The Aula is used as the official ceremonial hall by Ghent University, who hosted this year's meeting. The registration desk was located here and we were provided with our conference pack, nicely presented in a sturdy bag, which contained a programme and a very useful map of Ghent, as well as free tickets to a local exhibition on WWII. Everyone was then directed through into the main lecture theatre for the Palaeoclimatic Thematical Symposium starting at 13:45.

The symposium was entitled 'Biological proxies in climate modelling, or *why palaeontologists and climate modellers should be thick as thieves*'. The first half of the symposium included talks on understanding Silurian climate by **Axel Munnecke** (Universität Erlangen-Nürnberg), the early Palaeozoic climatic trend by **Yves Goddérís** (LMTG-Observatoire Midi-Pyrénées), as well as a comparison of four climate models with Eocene palaeodata by **Daniel J. Lunt** (University of Bristol) and a global biome reconstruction and data model comparison for the late Neogene by **Ulrich Salzmann** (Northumbria University). After this very interesting first half and a well-earned coffee break, everyone settled back into their seats for the late afternoon presentations of the symposium. The second half included talks on the Mid-Piacenzian Warm period by **Alan Haywood** (University of Leeds), a new combined proxy for environmental change in the Pliocene and Early Pleistocene by **Martin J. Head** (Brock University), followed ultimately by biological proxies for Holocene climate reconstruction by **Dirk Verschuren** (Ghent University).

Once the concluding remarks had been made, everyone exited the main lecture theatre and made their way into the main hall for the welcome reception, where wine, beer and a wide variety of canapés were served and very uniquely presented (for instance a fish purée on a silver spoon). These refreshments were welcomed by the attending members of the Association and service continued as the socialising got into full swing. After some time, people started to become peckish and went off to find places to eat. The historic centre was suggested as the best place to go as it has a wide range of quaint little eateries to choose from, especially on the Korenmarkt and the Groentenmarkt, and the areas were festive and spectacularly lit up by Christmas lights.

Through the night, unbeknown to everyone, heavy snow had fallen across Ghent, as well as the rest of northern Europe and the whole of the UK, so everyone awoke to a very white, picturesque-looking Ghent. The snow left Ghent looking like a typical scene on a holiday greetings card with a Christmas market, which we admired as we walked to the start of the day's talks. The venue for all the talks and poster presentations was 'Het Pand', the University's official conference centre, which was built as a hospital in the 13th century and soon became a Dominican monastery.



Welcome reception inside the Aula.

The day began with session 1, which included a wide range of talks, starting with **Joanna M. Wolfe** (Yale University) who discussed chelicerate tagmosis and mechanisms of development in extinct taxa. This was followed by a talk on predator–prey interactions between durophagous fishes and camerate crinoids following the Hangenberg mass extinction by **Lauren Cole Sallan** (University of Chicago) and a talk on Holocene morphospace of *Bellamyia* gastropods as evidence for punctuated morphological change by **Bert Van Bocxlaer** (Ghent University). The final three talks of the session included computational simulation of macroevolution by **Russell J. Garwood** (Imperial College London), experimental taphonomy of *Xenopus laevis* tadpoles by **Ragna Redelstorff** (University College Dublin) and to end the session, a talk on morphological decay experiments and the fossil record of non-biomineralised vertebrates by **Robert Sansom** (University of Leicester). During the following coffee break, everyone was able to mingle and look at the posters that were being presented around the building (those up for the poster prize were in a separate area) and catch up with old friends.

Everyone was soon called back into the main hall for the start of the second session, which kicked off with three talks on ammonoids: a discussion on insights into the Triassic ammonoid radiation from time-sliced cladistic analyses by **Alistair J. McGowan** (University of Glasgow), the Hunsrück Slate, origins and evolutionary development of ammonoids by **Kenneth De Baets** (Paläontologisches Institut und Museum), and Devonian pearls and ammonoid–endoparasite co-evolution by **Christian Klug** (Paläontologisches Institut und Museum). The second half of the session consisted of talks on belemnite sclerochronology by **Elizabeth V. Nunn** (University of Mainz), and cameral deposits in a sublethally damaged Pennsylvanian *Pseudorthoceras* sp. by **Barbara Seuß** (Universität Erlangen-Nürnberg). Lunch was then supplied by the conference organisers so it was unnecessary for us to brave the cold and snow in search of food; discussions about the latest research would have continued well into the next session had we not all been called back to our seats.



Winter in Ghent after all the snow fell on Friday night.

The third session was based around climate change, and started with the ecological impacts of global warming and investigating community change during past climate change by **Amelinda Webb** (Yale University). The session continued with a discussion of the Carboniferous ostracod freshwater colonization event driven by climate change by **Carys E. Bennett** (University of Leicester), Late Cretaceous climates of Antarctica by **Jane Francis** (University of Leeds), and the response of marine biota during the Paleocene–Eocene thermal maximum by **Robert P. Speijer** (K.U. Leuven). The session was rounded off with a further talk on the PETM about Neritic foraminiferal responses to a runaway greenhouse by **Peter Stassen** (K.U. Leuven), and Pliocene climate of the southern North Sea Basin by **Anne Marie Valentine** (University of Derby). Another coffee break followed, to refresh people for the final session of the day.

The final session included four talks, followed by the Annual General Meeting and then the Annual Address. The four talks at the end of the day's oral presentations included two on Ediacaran biota, firstly based on the life cycle of putative embryos by **John A. Cunningham** (University of Bristol) and then the role of microbial mats in ash-based conception-style preservation by **Marc Laflamme** (Yale University). The penultimate talk looked at trophic interactions, clues to investigate fossil assemblage complexity and the implications for Early Cambrian ecosystems by **David Casenove** (University of Tokyo) and then we moved on to a discussion on macro vs. micro Burgess Shales and early Palaeozoic life by **Nicholas J. Butterfield** (University of Cambridge).

The Saturday session of oral presentations was rounded off by the annual address, entitled *Ancient origin of the deep sea fauna: new evidence from the fossil record*. It was given by **Andrew S. Gale**, Professor in Geology at the University of Portsmouth. He introduced the audience to his topic by sketching the history of deep-sea research, which gained interest in the nineteenth century when technical advances opened up possibilities in man's exploration of the natural world. As deep-sea



research became an established scientific field, human curiosity about the origin and potential antiquity of this new and undiscovered world increased. Generations of scientists have attempted to answer these questions. A Mesozoic or even Cenozoic date of origin for the modern fauna has been considered in recent hypotheses, which involved the eradication of pre-existing communities by anoxic or cooling events. However, definite conclusions have as yet been elusive, due to the near absence of direct fossil evidence; the origin of the modern deep-sea fauna therefore remains highly speculative. But don't despair! A well-preserved body fossil assemblage of Lower Cretaceous echinoderms from NE-Atlantic bathyal sediments may provide a glimmer of hope, since it shows how the community composition is similar to modern deep-sea echinoid communities. Supported by evidence from crustacean and other arthropod groups, this suggests how at least some of the modern deep-sea fauna is much older than previously thought. Prof. Gale skilfully engaged the listeners in this active scientific field, and if their attention fluttered, it soon returned due to his stylish, yet very sparkly waistcoat.

A short walk away (in heavily falling snow) from where the conference was being held, the annual dinner was hosted in St Peter's Abbey. The abbey is also an arts centre and was the venue for the exhibition of photography from WWII, for which free tickets were distributed to attendees. The abbey is situated directly beside the majestic Our Lady of St Peter's Church, which was open to the public, and there was a winter festival in the adjoining square with a skating rink. The drinks reception commenced at 19:00 and the annual dinner followed at 20:00. After the annual dinner, everyone moved on to the abbey's crypt bar for the opportunity to try out the finest Belgian beers that were on offer.

The final day started bright and early and we received news that further snow had fallen overnight across Europe, which was now less welcome because it caused many transportation

networks to grind to a halt. This affected a large number of people who were planning on leaving the conference at the end of the day, as many airports across Europe and the UK were shut to incoming flights, even though Brussels airport was open. As a consequence, the Eurostar was flooded with people and therefore suffered major delays. Even so, the conference went ahead as scheduled, starting with a poster session that lasted an hour and a half, during which delegates were asked to stand by their posters and answer questions for those interested. During this time, refreshments and a light breakfast was available, which included some very delicious pastries.

The oral presentations commenced at 10:30, and due to the quantity of presentations accepted, two sessions were run in parallel. The first of these two sessions discussed here is session 6, which focused on plants. **Alan Channing** (Cardiff University) started the session with a talk on data confirming the dominance of wetland ecology throughout the Phanerozoic record of hot spring



The outside of St. Peter's Church and Abbey where the conference dinner was held.



floras, which was followed with a talk by **Paul Strother** (Boston College) on the palaeobiology of a nonmarine Precambrian shale. The session continued with resetting the clock on the origin of land plants by **Wilson A. Taylor** (University of Wisconsin-Eau Claire), the oldest flora of the South China Block in northern Vietnam by **Paul Gonez** (University of Liege), and palynological evidence for Pennsylvanian vegetation change in a British coal field by **Janine L. Pendleton** (University of Sheffield). The final two talks of the session included topics about Palaeogene flora of Svalbard and its climatic significance by **Abigail Clifton** (University of Leeds), then Late Miocene global vegetation reconstruction by **Matthew J. Pound** (University of Leeds / British Geological Survey).

Running parallel, session 7 commenced with a talk on the evolution of mantis shrimp-like predators in the Cambrian by **Joachim T. Haug** (University of Ulm), followed by **David A. Legg** (Imperial College London) who discussed the phylogeny of marrellomorph arthropods. The next three talks all focused on trilobites. The first was about what cuticle ornamentation tells us about trilobite segmentation by **Javier Ortega Hernandez** (University of Cambridge). The second was on morphological variability of the trilobite digestive system by **Rudy Lerosey-Aubril** (Senckenberg Research Institute), and the final trilobite talk by **Kenneth J. McNamara** (University of Cambridge) discussed segmentation polarity during their regeneration. The final two talks of the session covered a discussion on the visual strategy of a Cambrian predator by **Brigitte Schoenemann** (University of Bonn), and on crustaceans from a bitumen clast in Carboniferous glacial diamictite by **Paul A. Selden** (University of Kansas), before a well-earned lunch break.

A lunch of sandwiches and refreshments was again provided by the conference organisers, and this was the first opportunity to discuss the morning's talks while it continued to snow outside. For the afternoon's sessions we all moved back in to the main hall, as there were no more parallel sessions. The afternoon commenced with an entire session on vertebrate research, kicked off with Paleocene–Eocene evolution of beta-diversity among ungulate mammals in North America



The poster session on the Sunday morning.



by **Simon A.F. Darroch** (Yale University). This was followed by two specifically Early Eocene based talks, firstly on insights in the mammal faunas from Indo-Pakistan by **Pieter Missiaen** (Ghent University) and secondly, on a new specimen of the enigmatic perissodactyl-like archaic ungulate mammal *Olbitherium* by **Thierry Smith** (Royal Belgian Institute of Natural Sciences). The next talk, by **Chloe L. Marquart** (University of Cambridge), discussed the use of skulls of extant crocodylians for inter and intraspecific variation. This was followed by **Laurent Darras** (University of Leicester) who discussed reconciling form and function of fossil fishes. The final talk of the session before the coffee break was on integrating new results from the *Iguanodon*-bearing Wealden facies of the Mons basin by **Johan Yans** (FUNDP, University of Namur). The half-hour coffee break allowed everyone to stretch their legs and discuss the exciting talks they had just heard.

The final session of the day and of the conference started at 15:30; one talk was unfortunately cancelled. The first talk was on new data from the tropics in Tibet by **David A.T. Harper** (University of Copenhagen). This was followed by a discussion on the palaeobiology of the Tentaculitoids from the Lower Devonian by **Heike Drapatz** (Steinmann-Institut), which preceded a talk on microfossil memory of ancient artefacts by **Mark Williams** (University of Leicester). The final three talks of the day included looking at the arachnid fossil record by **Jason A. Dunlop** (Humboldt University Berlin), comparing deep sea and land-based palaeobiodiversity by **Graeme Lloyd** (Natural History Museum), and finally to end the conference a talk on modelling the longevity of Early Jurassic crinoids floating wood colonies by **Aaron W. Hunter** (Petronas University of Technology).

With the scientific sessions concluded, all that was left on the programme was the fieldtrip on Monday. This was scheduled to include morning excursions to two quarries in the Mons Basin in southern Belgium, then on to the Royal Belgian Institute of Natural Sciences in the late afternoon. Due to the snow, one of the quarries was completely covered and had become inaccessible for any vehicles, so that visit had to be scrapped; the rest of the excursions went ahead as planned.

We would like to congratulate the Department of Geology and Soil Sciences at Ghent University for running a very successful and enlightening conference. We would also like to thank everyone who presented posters and gave talks, and in particular **Andrew S. Gale** (University of Portsmouth) for his fascinating annual address. We now look forward to seeing you all again in December 2011 at the 55th Annual Meeting of the Palaeontological Association at the University of Plymouth, United Kingdom.

Nikita Jacobsen and Martha Koot
University of Plymouth



MYSTERY FOSSIL 21

Our Mystery Fossil series comes of age with a pretty little ‘unidentified problematicum’ sent in by **Ed Jarzembowski**. MF 21 (Fig. 1) is preserved in three dimensions in sideritic ironstone concretions from Smokejack’s Brickworks, Surrey, UK. The stratigraphic unit is the Upper Weald Clay, which is Early Barremian in age. Ed writes ‘opinions vary from petal to scale – they are associated with insects and shark egg cases (*Spirangium*). I favour a vertebrate origin – which is why I can’t identify them!’



Figure 1.

If you can identify MF 21 please send in your answers to me at <newsletter@palass.org>. As an added incentive, Ed tells me that this problematicum is featured in the forthcoming Palaeontological Association Wealden Field Guide, and is the only unidentified fossil in the entire publication. Ed promises that the first person to send in a correct identification ‘will get rapid recognition in print!!’



Update on Mystery Fossil 20

One suggestion has been received for MF 20, which was sent in by **Jan-Peter Duda** (Bremen), and which was discovered in samples of Upper Jurassic–Lower Cretaceous carbonates of the Neuquen Basin, Argentina (Fig. 2).

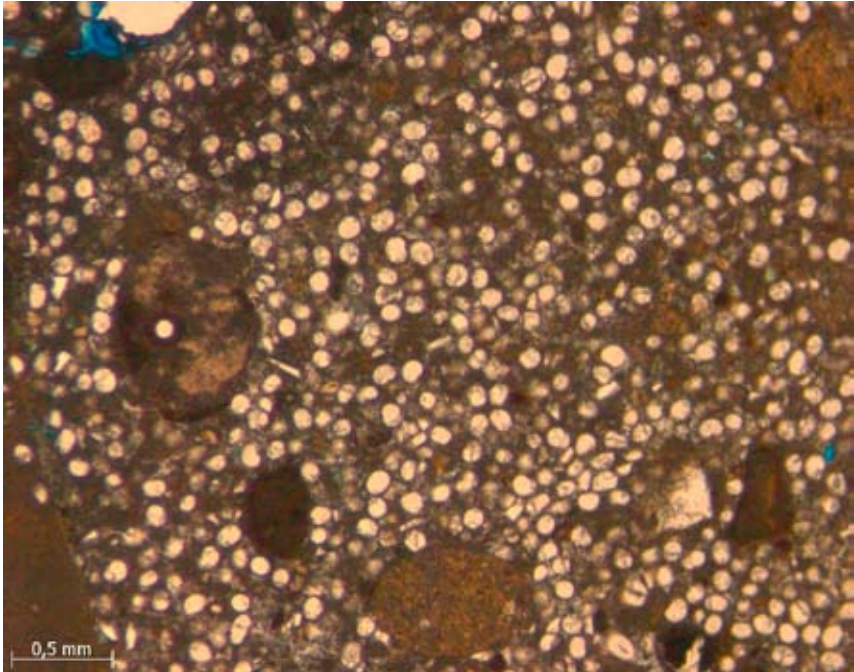


Figure 2.

Nigel Trewin writes ‘These appear to be spicules of a Rhaxellid sponge, they have the typical siliceous wall structure and display spherical and kidney shapes. They are, however, smaller than typical *Rhaxella* of the Upper Jurassic of the UK (e.g. Oxfordian Ardassie ‘limestone’, of Brora, Sutherland, and the Oxfordian Alness Spiculite of the Moray Firth). The modern sponge *Geodia* has similar spicules and ranges back to the Cretaceous. *Rhaxella* sponges colonised wide areas of sea floor, building up a spicule-rich fine sand from decay of sponges; *Geodia* does the same today. The thin section showing a high spicule content [Fig. 2 above] is typical of the spiculites produced by these sponges.’

Unless anyone disagrees with this identification, Nigel Trewin is hereby awarded full honours for his suggestion.

Richard Twitchett



—OBITUARY—

Raphael G. Martins-Neto

19?? – 2010

Raphael Martins-Neto was the most prolific palaeoentomologist in South America. With a publishing career spanning more than 30 years, he described and named more than one hundred different species of fossil insect, mainly from the Cretaceous of Brazil. His most important works centred on the neuropterans, lace wings and allies, and the orthoptera, grasshoppers and crickets, from the famous Crato Formation of the Araripe Basin in north east Brazil. Although essentially a systematist, Raphael also researched the taphonomy and palaeoecology of the Crato Formation entomofauna. He was an ardent supporter of palaeontological conservation, and this occasionally got him into conflict with museum curators and foreign scientists. He began his scientific career in Sao Paulo, working his way northwards to Juiz de Fora, Minas Gerais, and finally to the Universidade Regiaonal do Cariri (URCA) in Crato, Ceará. During this time he published 60 papers on the Crato Formation entomofauna as well as several on the vertebrates, including the first evidence of Mesozoic birds in South America. Although his death was premature, it is perhaps fitting that he died where he was at home surrounded by the insect-rich forests and fossil-rich strata of the Chapada do Araripe.



A nearly complete bibliography of the works of Raphael Martins-Neto can be found in:

BECHLY, G. 2007. *Insects of the Crato Formation*, 142–426. In MARTILL, D. M., BECHLY, G. and LOVERIDGE, R. F. (eds). *The Crato Fossil Beds of Brazil*. Cambridge University Press, Cambridge.

Dave Martill
Portsmouth



The Public Perception of Palaeontology, part 2: Poetry

It's all well and good me asking colleagues for a perspective on science in the media, but we're inherently biased. We have our own specialist subjects, and they're *always* communicated incorrectly if we're not the one doing the presenting (and sometimes, even then). To get a sense of how palaeontology really comes across to the public, therefore, we need to engage with non-scientists of all kinds, and establish just what is understood about fossils.

So, having begun this series by interrogating a palaeontological friend who now works as a journalist, I decided to move into completely different territory, and interview a poet. Poetry might not seem a common means of spreading the palaeontological word, but there is a long history of poets being palaeontologists and vice versa. Indeed, Ralph O'Connor's book *The Earth on Show: Fossils and the Poetics of Science* (2008) examines how 19th century writers used poetry to bring palaeontology to the masses. Perhaps most significantly, if you extract the poet from our subject, you are left with the unheralded discipline of alanology.

The poet in question here – Don McKay – is one who has a love of geology, but, as he has no formal training in the subject, I was interested to find out his experiences of the science.

Described recently by *The Walrus* magazine as Canada's 'greatest living poet', Don was born and raised in Ontario. He studied at Bishop's University, Quebec, and the University of Western Ontario, before moving to the University of Wales in Swansea to begin a PhD. There, studying the poetry of Dylan Thomas, Don found that one of the best spots for writing was St Helen's, the Swansea home of Glamorgan County Cricket Club, where no-one would ever think of looking for a Canadian. After completing his PhD, Don returned to Western Ontario, where he remained until 1990, when he moved to the University of New Brunswick to teach on its creative writing programme. In 1996, Don retired from teaching, and relocated to Vancouver Island to concentrate on his writing. He has twice won the Governor General's Literary Award, in 1991 and 2000, and in 2007, the year he came to live in St John's, Newfoundland, his book *Strike/Slip* won the Griffin Poetry Prize. In 2008, Don was made a member of the Order of Canada.

This interview arose very much by chance. I went to a literary festival in Newfoundland last Winter where Don was one of the writers giving a reading. It had been a very enjoyable (but decidedly non-geological) day, when Don took to the stage to give the last talk and introduce the audience to some new poems. Having never heard him read before, and not being familiar with his work, I wasn't sure what to expect, but it certainly did not include the name-checking of Cambrian arthropods. So I was rather surprised when both *Paradoxides* and *Opabinia* made an appearance.

Don was probably equally surprised to be accosted by a palaeontologist immediately after speaking, too, but he hid his shock well, and was very happy to talk about fossils. It quickly became apparent that he was keen to go out fossil-hunting too, and once the Newfoundland Winter was over (mid-June), we went off trilobite chasing in the famous Manuel's River Formation. A few weeks later, Don accompanied me and a group of Memorial University postdocs and



postgrads on a day trip to see some Snowball Earth deposits (and then eat bacon sandwiches at the Bacon Cove unconformity). And just before I fled back to Britain, I managed to grab him for this interview. I began by asking Don when geology first grabbed him, and how.

"Although there were many pre-tremors of rock fever," Don told me, "the big surge came when I moved to British Columbia from New Brunswick, and simultaneously retired from teaching. The move presented me with a landscape very much overwritten by tourism with its commodified sublime ('Super Natural British Columbia' [as the provincial tourist board would have it]) so I was looking for an entry into its forms and energy apart from that well-trodden path.

"The Loss Creek-Leech River Fault at the southern end of Vancouver Island offered such an entry – a beautiful but unheralded landform that gave me access to the dynamics of plate tectonics on the one hand, and the forestry practices (it's been severely clear-cut) on the other. I decided to walk it end to end (60 km of lovely, shorn, canyon) and learn whatever it presented to me – geologically, of course, but also all other areas of natural history, as well as the cultural history of BC's logging and mining industries. I read an introductory text, *Earth System History*, along with Marcia Bjornerud's *Reading The Rocks*, as primers. Chris Yorath also has an introduction to the area's geology for beginners. It was like the fault prescribed homework and mystical exercises at the same time."

This tectonic trek led Don to write *Deactivated West 100*, a mix of prose and poetry that takes its name from one of the region's abandoned roads, and the poetry collection *Strike/Slip*, which went on to win the prestigious Griffin Poetry Prize. The latter includes such poems as *Varves*, *Quartz Crystal* and *Devonian*, where

the light that fell so softly through the depths was
intercepted by the lobe-finned fishes

Deactivated West 100, meanwhile, features *Between Rock and Stone: a geopoetic alphabet*. In this piece, Don contemplates everything from the origin of vertebrate jaws to the DNA of Neanderthals, all in the context of geopoetry, a term coined by Harry Hess when the idea of plate tectonics had yet to be supported by the evidence. It was made redundant once the evidence did come to light, but Don petitions the reader to consider its general usefulness. What phrase could be better, he asks, "for those moments of pure wonder when we contemplate even the most basic elements of planetary dwelling, and our words fumble in their attempts to do them justice? What else but 'geopoet' should we call Xenophanes, as he stands with a fossil of a seashell in his hand, in his mind the wild notion that the quarry he stands in once lay under the sea?"

Geopoetry was also a movement in the USSR in the 1950s, begun by a group of students at the Leningrad Mining Institute. Though most went on to become professional geologists, these "pochveniks" (poets of the soil) were often far more famous for their poems than their science, and constituted an important movement in 20th century Russian poetry (Belasky 2009). I wondered if Don thought more geologists should attempt poetry.

"I don't think scientists *need* to do anything different as far as the practice is concerned," he says. "Indeed, there is great beauty in having the mind stretch to its limit in the exercise of reason, observation and analysis. It's the quite separate attitude that relegates other modes of knowing to decorative status or worse that's pernicious. But, as may be the case, practising (not just writing) poetry might well lead to an embrace of betweenity. I've seen it happen."



For those of us who have never knowingly embraced betweenity, I asked Don to explain what he meant by the term. It was apparently coined by Horace Walpole in 1760, in reference to a building that was neither Gothic nor Palladian but somewhere in between, but in this case, Don described it as “what poetry can bring to science as an addition to its ‘normal’ reliance on hard and/or definable fact.”

“Betweenity,” Don adds, “is the condition of metaphorical knowing. Metaphor, by relying on resonance between entities rather than reduction, and by being at once true and false, is betweenity’s primary exemplar in language. Of course, scientists use it all the time, as an instrument of thought and not only a method of explanation. Some, such as Richard Dawkins, tend to be worried about this helpful, but rogue, vehicle, whilst others, for example James Lovelock, tend to embrace it as a legitimate mode of knowing, and a complement to analytic reason.”

Don discussed betweenity at greater length in his 2010 Pratt Lecture – *The Speaker’s Chair: Field Notes on Betweenity* – at the Memorial University of Newfoundland, a talk which focused on the ‘Two Cultures’ hypothesis of C. P. Snow. As that rare beast, a physicist who wrote novels, Snow was uniquely positioned to assess both science and the arts. He famously argued that, for the western world, a combination of factors – but primarily an inflexible education system unable to adapt to the Industrial Revolution – had led to two polarized cultures: literary intellectuals and physical scientists. Many scientists, Snow lamented, regarded Dickens as ‘the type-specimen of literary incomprehensibility’, whilst he could find barely a writer who knew the Second Law of Thermodynamics.

“The situation we generally live with [is one] in which the faculties are divided into separate spheres, regarding each other with distrust and competing for attention, funds, power and social dominance.” Don, however, regards this separation as a false dichotomy, and one which needs



Our intrepid Reporter with Don McKay and the postdocs and postgrads of Memorial University enjoying the aptly named Bacon Cove (photo Alex Liu).



to be broken down. I ask him how he, as an artist, finds the scientific world. “It is a mistake,” he tells me, “to think of artists as utter devotees of either the emotional life or beauty. Rather than pursuing these exclusively, artists (I’m thinking of an ideal here, not necessarily what you find) are concerned with an *integration* of faculties, a condition in which reason, emotion, imagination and instinct all play their parts.”

More broadly, Don argues that, “far from mutually excluding one another, the empirical and poetic impulses are symbiotic. Why wouldn’t they be? The condition of astonishment produced by the Ediacaran fauna at Mistaken Point ... [is] a primary stimulus for poetry and poetic attention. And conversely, poetry brings to scientific fact and data the gifts of linguistic energy and metaphorical flex.”

Don visits Mistaken Point frequently, and I ask him if these are the fossils that interest him the most. “Well, since I’ve not had to specialize academically, I’ve focused on the fossils and periods suggested by the landscape I’m in. At present, because of living in Newfoundland & Labrador, Ediacaran fossils and period (incarnate at Mistaken Point) and the *Paradoxides* fossils of the mid-Cambrian are absorbing interests.”

I wondered if this meant that palaeontologists or geologists had become interested in his work, but Don tells me that if they are, they’re keeping it fairly quiet. “A few geologists – often the partners of poets or artists – have approached me after readings,” Don says. “And, for a few weeks before he died, [the geologist] Hank Williams thought we ought to collaborate on a paper entitled ‘Newfoundland, the Holy Ground of Plate Tectonics’. I think it will always be a deep regret that we didn’t get the chance to pull that off.”

In reverse, I wonder if using scientific terminology in his poems goes down well with non-scientific audiences. “I’m not sure about audience response to terms,” Don replies, “but I am sure that poetry’s lexicon ought not to be constrained or policed by preconceptions about what’s ‘poetical’. If you can hear the music of the Latin mass, you can hear the music of the corresponding, agglutinative language of geology in its rich academic formations, full of ‘upraised Neoproterozoic strata of volcanoclastic sediment’ and the like.”

Don then asks whether there is any truth to his suspicion “that the geological English, while tending to its Latin and Greek roots in formal papers, may tend to its Anglo-Saxon ancestry in the field.” Having once spent a field season in Death Valley referring to virtually everything as buff-coloured fubarite, I can only say that, from my perspective at least, there is.

Finally, I ask Don whether part of the problem in communicating palaeontology is the fact that earth scientists are too comfortable with geological time, a concept that can be bewildering to the general public. He isn’t sure this is a problem. “Don’t you think it is necessary to get blasé about deep time if you’re going to do work in ancient rock? A surgeon can’t be exclaiming over the wonders of the circulation system as he accomplishes the bypass. But it is entirely possible to be utterly technical in the moment, coldly exercising observation and reason, while, in the larger scheme, embracing the wonder of the lifeform and all that it implies – the *Paradoxides* fossils gathering formations from widely separated regions into ancient Avalonia being a case in point. Hank Williams’ technical writing did not prevent him from contemplating the wonder of the ‘Holy Ground of Plate Tectonics’, did it?”



“In my view,” Don concludes, “outreach activities are crucial.” Whether well-produced popular science programmes – one of his favourites is the CBC radio show ‘Quirks and Quarks’ – or more local activities, these, he says, “will do far more to increase a wide ecological awareness – with its consequent ethical shifts – than any amount of moral harangue from Al Gore.”

And with that, I’m off to write some geopoetry. I encourage you to do the same, and if you send your efforts my way, I’ll set aside the next column for the best contributions and ask Don to assess their quality. Type “The Paleontologist’s Blind Date” into Google if you’re in need of inspiration.

Liam Herringshaw

<lgh865@hotmail.com>

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Sylvester-Bradley REPORTS

Anatomy and phylogenetic relationships of Gracilisuchus stipanicorum and its bearing on the origin of Crocodylomorpha

Agustina Lecuona

CONICET – Museo Paleontológico Egidio Feruglio (MEF), Trelew, Chubut, Rep. Argentina

The basal archosaur *Gracilisuchus stipanicorum* Romer 1972 is a small taxon of approximately 28cm presacral length that is nowadays very controversial in terms of its affinities within Archosauria.

Gracilisuchus is known from several specimens recovered in outcrops of the Los Chañares Formation (~Ladinian age, Middle Triassic; Spalletti *et al.*, 1999; Rogers *et al.*, 2001) in the Ischigualasto–Villa Unión Basin, NW Argentina, by Dr Romer and Dr Bonaparte from 1964 to 1972. Six incomplete specimens were recovered of this taxon, which is represented mainly by skulls and axial material, but also an almost complete pelvic girdle and hind limb. The fossil remains of *Gracilisuchus* are now deposited in different collections in Argentina (Museum of the University of La Rioja, La Rioja, PULR; Lillo Institute, Tucumán, PVL) and United States (Museum of Comparative Zoology of Harvard University, Massachusetts, MCZ).

The phylogenetic affinities of *Gracilisuchus* have been a longstanding problem in archosaur systematics since it was firstly described (Romer 1972). In this original description, Romer allied it with the enigmatic *Ornithosuchus*, an idea followed posteriorly by Bonaparte (1975). One of the milestones in the understanding of *Gracilisuchus* was given by an analysis focused on tarsal and cranial morphology (Brinkman 1981) that reinterpreted this taxon as a member of the crurotarsal line of archosaurs. This interpretation was later reached by several cladistic analyses focused on basal archosaur relationships (*e.g.*, Benton & Clark 1988; Sereno 1991; Parrish 1993; Juul 1994). The interesting point is that among these studies *Gracilisuchus* varied greatly in position, from very basal within Crurotarsi (*e.g.*, Li *et al.* 2006) to different positions within Suchia (*e.g.*, Benton and Clark 1988; Parrish 1993). In spite of these highly variable results, *Gracilisuchus* is currently interpreted as one of the closest sister taxa to Crocodylomorpha and thus used as outgroup in multiple phylogenetic analyses of this clade or more inclusive ones (*e.g.*, Sereno and Wild 1992; Clark 1994; Clark *et al.*, 2000; Clark and Sues 2002; Benton and Walker 2002; Sues *et al.* 2003; Pol and Gasparini 2009).

Unfortunately the published information of *Gracilisuchus* is very limited. The original description is brief and only gives a general account of its anatomy, and more recent studies – tending to solve phylogenetic relationships among basal archosaurs – have included limited information in their character scorings for *Gracilisuchus*. The lack of detailed anatomical studies creates several



problems for any kind of analysis when the specimens cannot be studied at first hand by the researchers, thus leading to different interpretations and results among authors.

The main focus of my PhD project is to redescribe in detail the anatomy of *Gracilisuchus stipanicorum* and reevaluate its phylogenetic affinities through a cladistic analysis based on a broad taxon and character sampling. This project is supported by a PhD scholarship of the Argentinean National Council (CONICET) and being developed in the Museo Paleontológico Egidio Feruglio (MEF) in Patagonia. In order to test the varied phylogenetic hypotheses, the taxonomic scope of the analysis is necessarily extensive, ranging through basal archosauriforms, basal dinosauriforms, phytosaurs, ornithosuchids, aetosaurs, rauisuchians, and crocodylomorphs. Among the latter, some basal crocodyliforms protosuchians and living representatives are included, but special attention is given to the basal Crocodylomorpha, the non-crocodyliform crocodylomorphs namely “sphenosuchians”, a group of questioned monophyly (e.g., Sereno and Wild 1992; Clark *et al.* 2004). An exhaustive sampling was performed of the ‘sphenosuchians’ taxon that has particular implications for determining the suitability of *Gracilisuchus* as outgroup of Crocodylomorpha.

It is important for the accurate scoring of the characters and taxa of the data matrix to examine first-hand the taxa included in the analysis. In addition to the specimens housed in collections of South America, many of the taxa in my phylogenetic analysis are lodged in USA collections, although others are in European, African and Asian collections. The Sylvester-Bradley Award has offered me a valuable opportunity to visit several collections in USA, being able to examine many taxa of my taxonomic framework, such as basal archosauriforms (e.g., *Chanaresuchus*, *Proterochampsia*, *Doswellia*), phytosaurs (e.g., *Rutiodon*, *Smilosuchus*), rauisuchians (e.g., *Postosuchus*), sphenosuchians (e.g., *Dromicosuchus*, *Hesperosuchus* [Fig. 1]). It was also important for my research to study and describe carefully the referred material of *Gracilisuchus* lodged in the Museum of Comparative Zoology (Fig. 2), comparing them and integrating them with the specimens housed in the Argentinean collections. As a preliminary result of these observations, the taxonomic assignment of the cranial material of the referred specimens to *Gracilisuchus* could be confirmed, whereas some discrepancies have arisen regarding the postcranial material, suggesting the presence of another suchian taxon.

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Figure 1: Specimen of *Hesperosuchus agilis* (CM 29894).



Figure 2: Cranium of a referred specimen of *Gracilisuchus stipanichorum* (MCZ 4117). Courtesy of the Museum of Comparative Zoology, Harvard University.



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Global patterns of Cretaceous forest composition and productivity

Emiliano Peralta Medina

Royal Holloway, University of London, Egham, Surrey TW20 0EX, UK

Email: <emiliano@es.rhul.ac.uk>

In the course of my Sylvester-Bradley work, I analysed global patterns of Cretaceous forest composition and productivity through the construction of two comprehensive fossil wood databases. This research forms part of my ongoing PhD studies on Cretaceous biomes supervised by Dr Howard Falcon-Lang at Royal Holloway, University of London.

To ascertain forest composition I constructed a database of Cretaceous fossil wood comprising 2,211 records from 73 countries and 497 localities worldwide (Figure 1). To ascertain forest productivity, I constructed a second database of mean tree-ring width data ($n = 259$). In each case, data were mined from published literature, existing databases (e.g. InsideWood – <insidewood.lib.ncsu.edu>; Paleobiology Database – <paleodb.org>), and the inventories of major museums. The Sylvester-Bradley award funded trips to the Natural History Museum, London, Sedgwick Museum, Cambridge, and collections in Paris and Lyon to view and measure the fossil wood collections stored there and to contribute data to the two databases.



Figure 1. Compiled data of Cretaceous fossil woods.

Material and methods

Fossil woods were classified by botanical affinity (ferns, cycadeoids, ginkgos, angiosperms, and conifers, the latter subdivided, where possible, into superfamily groups). Records were plotted on palaeomaps showing Cretaceous rock distribution, and targeted searches were made to fill geographic data gaps. Searches continued until the daily hit-rate diminished towards zero.

The global patterns of forest composition and productivity that I have collated are based on a near-complete compilation of Cretaceous fossil wood, synthesizing >150 years of data ranging from



individual species descriptions to regional reviews (e.g. Bamford and Philippe 2001; Oh *et al.* 2010; Philippe 2011). As such, my work builds on the many earlier attempts to analyze the nature of Cretaceous terrestrial biomes and climates using fossil floral and faunal databases (e.g., Florin 1963; Creber and Chaloner 1985; Markwick 1998), but takes a more quantitative approach within the limits imposed by the fossil record.

Results

Results confirm previous conjecture that araucarioid and podocarpoid conifers were globally co-dominant in Early Cretaceous times, especially in humid (para)tropical biomes, but drastically reduced in numbers and range during the Late Cretaceous. Cupressoid conifers, which were most common in seasonally dry mid-latitudes, and pinoid conifers, which were restricted to more temperate conditions at higher northern latitudes, also declined at the same time, though less markedly (Figure 2). Loss of conifer forests was directly linked to the rise of angiosperms, with the modern relictual pattern of conifer distribution largely established by the latest Cretaceous (Campanian–Maastrichtian) when angiosperm trees attained global forest for the first time.

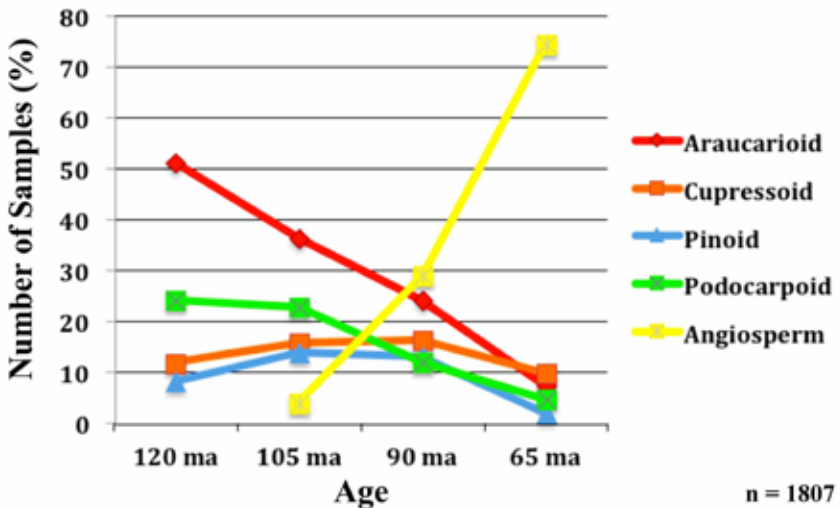


Figure 2. Trends of the main groups of plants through the Cretaceous

Comparison with modern data shows that Cretaceous forest productivity was greatly elevated in low-latitudes, and to a lesser extent in mid- to high-latitudes. In addition, results imply a broader humid tropical belt and a significant poleward displacement of the temperate belt. These findings are consistent with climate-vegetation models (Beerling *et al.* 1999; Brentnall *et al.* 2005; Sellwood and Valdes 2006) and support the hypothesis that extreme greenhouse warmth and/or CO₂ fertilisation significantly influenced terrestrial biomes. As such, findings have general implications for a better understanding of the medium- to long-term (500–1,000 years) effects of future global warming.

Overall, my forest composition and productivity data provide strong quantitative verification of the results of Cretaceous climate-vegetation models, with implications for better understanding the medium- to long-term effects of future global warming.



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Sclerochronological analysis of the belemnite Acroteuthis lateralis: a new technique for understanding ontogeny and ecology

Elizabeth V. Nunn

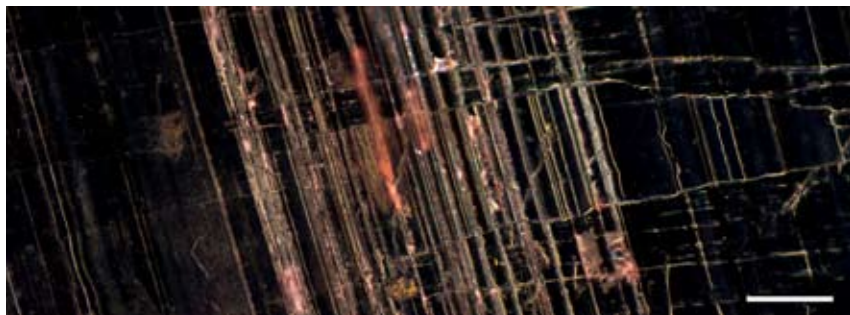
Department of Applied and Analytical Palaeontology, University of Mainz, Germany

<nunn@uni-mainz.de>

Since the earliest days of oxygen isotope analysis in biogenic carbonates, belemnite rostra have been used to reconstruct palaeoclimatic and palaeoenvironmental conditions (e.g., Urey *et al.*, 1951). This has been done, however, with no true understanding of belemnite ontogeny or ecology. How long did belemnites live for? Where did they live (shallow/deep waters; bottom/surface dwellers)? Were they active swimmers? Did they migrate extensively (vertically and/or laterally) during their lives? Preliminary investigations into some of these questions have already been undertaken, however such studies are typically based on very limited and equivocal data, and, consequently, definitive answers remain elusive. This presents a major problem because both ontogenetic and ecological factors significantly influence the fractionation of certain isotopes and trace elements into biogenic calcite, and as long as these factors remain unknown in belemnites it will remain impossible to accurately reconstruct past environments and climates from belemnite-derived geochemical data.

Acroteuthis lateralis (Phillips, 1835) was endemic to the Late Jurassic–Early Cretaceous Boreal Realm and it is one of the largest and most robust belemnite species known (Saks & Nal'nyaeva, 1966). The adult rostra typically exceed 50 mm diameter in the stem region, and the apex, apical canal and phragmocone are all strongly ventrally displaced. Together, these features result in a belemnite that is ideal for sclerochronology (the study of incrementally growing fossil hard parts), because the section of the rostrum between the apical canal and dorsal margin is significantly expanded. This provides an excellent opportunity to investigate growth-increment, stable isotope and trace element variability in the rostrum at an extremely high resolution.

Receipt of a Sylvester-Bradley Award allowed me to analyse an *A. lateralis* specimen that was collected a few years ago in Arctic Russia. Two cross-sections were cut from the belemnite rostrum. The first was stained with Alizarin red-S and K-ferricyanide (as per Dickson, 1965) in order to assess



Dark field photomicrograph of the Acroteuthis lateralis belemnite rostrum showing seasonal variations in growth increments. Scale bar represents 200 μ m.



the preservation of the specimen and to highlight the fine structural detail of the carbonate for microincrement analysis. The second was prepared for stable isotope ($\delta^{18}\text{O}$ and $\delta^{13}\text{C}$) and trace element analyses (Mg/Ca and Sr/Ca ratios, and Fe and Mn concentrations), with samples taken along a transect from the apical canal to the rostrum margin.

The combined growth-increment and geochemical investigation of *A. lateralis* provided a valuable insight into the belemnite's mode of life. The data suggest that this specimen was probably spawned in relatively warm waters and then experienced fluctuating temperatures, most likely on a seasonal basis, throughout the rest of its life. This would indicate a life span of approximately 2.5 years, with growth slowing after the first year. Speculative palaeotemperature calculations strongly suggest that *A. lateralis* was, for the most part, nektobenthic, although the belemnite may have intermittently migrated to warmer surface waters for spawning during the Summer months. Ultimately, the information generated from this study will considerably improve our understanding of the belemnite mode of life, and consequently this research has the potential to significantly advance and refine future palaeoclimatic and palaeoenvironmental investigations based on this fossil group.

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Book Reviews

Cambro-Ordovician Studies III

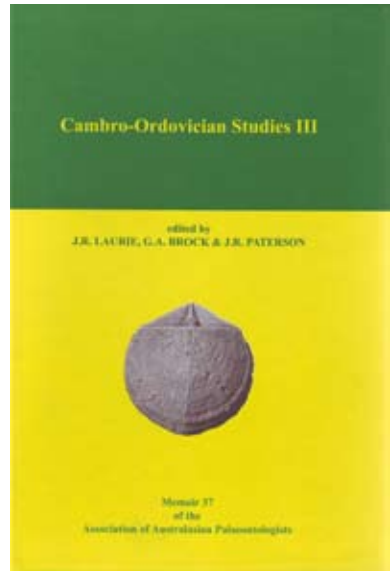
John R. Laurie, Glenn A. Brock and John R. Paterson (eds) (2009) *Memoir 37 of the Association of Australasian Palaeontologists*. Canberra. 716pp. ISBN 978-0-949466-35-8. ISSN 0810-8889. AUS\$175 from Geological Society of Australia Inc (<www.gsa.org.au/publications.html>).

As the title suggests, this is the third in a series of publications covering Cambro–Ordovician faunal studies, the previous volumes being published as *Memoir 30* (Laurie 2004) and *Memoir 32* (Paterson & Laurie 2006). There are a total of 32 papers comprising this latest volume, covering a broad faunal and geographic range. This is a well-illustrated publication, keeping up the trend from the earlier two volumes, with high-quality photographs.

There is enough to keep a range of workers happy as the papers in this volume cover a variety of faunal groups although, perhaps not surprisingly, trilobites (17 papers) dominate. There are four papers on other arthropods, three each on brachiopods and conodonts, two on Scalidophora and one on small shelly fossils. There is good coverage of both periods, with 18 papers discussing aspects of Cambrian faunas and 14 covering the Ordovician. The volume provides a broad geographic spread, with six papers from Australia the largest number from any one country. Other areas include a range of lower Palaeozoic areas from Laurentia (USA), Baltica (Sweden), Siberia, Kazakhstan and various other areas around Gondwana (Argentina, China, Iran, Morocco, Antarctica, Iran, New Zealand).

Trilobite faunas described include Argentinean faunas from the middle Cambrian (Tortello) and lower Ordovician (Waisfield and Vaccari), Chinese Ordovician cyclopygid faunas (Zhiyi and Zhiqiang), a Cambrian fauna from Antarctica (Bentley *et al.*), middle Ordovician faunas from central Kazakhstan (Mansoureh Ghobadi Pour *et al.*), a low-diversity leiestegiid association from Iran and China (Mansoureh Ghobadi Pour and Turvey) and a new, small fauna from the late Cambrian of Australia (Sun and Jago).

Detailed systematic reviews of trilobite taxa include a review of the systematics and biostratigraphic significance of *Xenocheilos* (Westrop and Adrain), systematic revision and consideration of biostratigraphic implications of new occurrences of *Bathynotus* (Webster), revision of *Lotagnostus trisectus* (Rushton), description of a new giant asaphid from the Lower Ordovician (Fortey), re-description of *Ogygites collingwoodensis* (Wright), and a new plimerid genus from the lower





Ordovician of Utah (McAdams & Adrain). In addition, the trilobite biostratigraphy and its implications for the bases of Ibexian (Lower Ordovician) stages in the western USA are described by Adrain *et al.*, while Vokac *et al.* describe exceptional preservation of agnostid trilobites entombed within hyolith conches, providing evidence of a benthic lifestyle for the agnostid genus *Peronopsis*.

Linguliform brachiopods are represented by descriptions of a Late Cambrian fauna from Iran (Popov *et al.*) and a well preserved lingulate fauna from the Middle Ordovician of New Zealand (Percival *et al.*). Rhynchonelliform brachiopods are covered by description of a *Martiella* association from the Ordovician of Iran (Percival *et al.*).

Late Cambrian and early Ordovician conodonts from Siberia are described by Tolmacheva & Abaimova whilst Zhen *et al.* describe the Darriwilian fauna from New Zealand. Zhen *et al.* describe a new family of conodonts (Serratognathidae) from eastern Gondwana and discuss the biogeographic and biostratigraphic implications.

Fortey & Rushton revisit the aglaspidid arthropod *Tremaglaspis* based on new topotype specimens, Schallreuter & Schallreuter describe the phylogeny of Phosphatocopa, and Gibb *et al.* describe Ordovician arthropod ichnofossils from the *Cruziana* ichnofacies, including three new ichnospecies, from Australia. New bradoriids are described from Australian core samples by Jones & Kruse who also include a census of Australian Bradorrida and Phosphatocopida.

Other groups covered include the small shelly fossils described from the lower Cambrian of south Australia by Topper *et al.*, a new species of Scalidophora based on larval specimens (Maas *et al.*) and a new species of *Markuelia* both from the Middle Cambrian of Australia.

In addition to the faunal descriptions outlined above, there are papers reviewing the depositional environment of the Cambrian (Series 2–Series 3 Boundary) Kaali formation of China (Lin) and the faunal and sedimentological evidence for a late Cambrian transgression in the Appalachians (Taylor *et al.*).

Overall then, this is an excellent, broad-ranging compilation of specialist papers focused on Cambrian and Ordovician faunas. Whilst it won't have a broad appeal to the general reader, it would seem extremely useful to those who specialise in lower Palaeozoic palaeontology.

Paul Winrow

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Plants in Mesozoic time: Morphological Innovations, Phylogeny, Ecosystems

Edited by Carole T. Gee (2009). Indiana University Press. 424 pp. ISBN: 978-0-283-35456-3. US\$89.95.

Plants in Mesozoic time is an edited volume to honour the career contributions of Ted Delevoryas (Professor emeritus, University of Texas, Austin) to the field of palaeobotany. Consequently, this



volume is not a textbook, nor anything resembling an introductory text on the Mesozoic flora. Instead, it is intended as a testament to Ted Delevoryas' career, his impact on the understanding of fossil plants, and also to his teaching, since all the contributors are academically related to Ted (students he supervised and their subsequent students) and displays their latest research. There are 14 papers split very unequally in to three broad themes: the key innovations of Mesozoic plants, plant phylogeny, and Mesozoic ecosystems.

The time span, around 180 million years or so, is vast, and the plant groups covered are very diverse. The usual Mesozoic suspects are fairly well represented and discussed in this volume: the ginkgophytes, cycads, bennettitaleans, conifers and flowering plants, as well as a rather more unexpected modern-looking horsetail. The geographical span is quite impressive too, from

Antarctica and Argentina to North America, provided that you remember the focus of this volume is based on the work of Delevoryas.

This is an eclectic mixture of papers; from a detailed study on the reproductive structure of a Middle Triassic sphenophyte and the micromorphology of the walls of the spores within this cone, to studies on the reconstruction of the Late Jurassic vegetation from the Morrison Formation, and on fossil lianas (vines) from Late Cretaceous deposits in Utah and New Mexico. There are also useful and up-to-date reviews of key groups. In the middle of the volume, and distractingly two pages into a paper, there are 16 well-produced colour plates, in addition to the well-presented plates and figures included in each paper.

In the first part of the book, which deals with morphological innovations, seven papers look at the key innovations of the Mesozoic flora, from a broad discussion about why the flora looked so different to that of today and the potential biochemical and developmental control of shoot growth underlying these growth patterns, to describing a flora from the famous and very fossiliferous Howe Ranch (USA) sauropod locality (Morrison Formation, Late Jurassic). The role of animals in plant evolution is examined, either as pollinators and dispersal agents in flowering plant evolution or as potential insect predators/pollinators in bennettitaleans, an investigation that is in part based on studies of tiny coprolites preserved inside the plant tissues. In contrast to the broader papers there are two papers that detail exquisite examples of anatomically preserved plants, a horsetail and a bennettitalean. An attempt to integrate Cretaceous fossil evidence into modern evolutionary developmental biology (evo-devo) studies of flowering plant organ delimitation (how is a flower made and controlled?) is particularly interesting. It fits with the quietly growing body of evidence that the earliest flowering plants had flowers that were far more morphologically and developmentally variable than is inferred from molecular data garnered from today's flowering plants.



The second theme, phylogeny of Mesozoic plants, has five papers which cover representatives of the major plant groups and include: the earliest vine-line flowering plants, the rare ginkgoalean remains of the three very widely separated Late Triassic localities in North America, an up-to-date review and phylogeny of the cycadophytes (cycads and bennettitaleans) from Argentina, and Early Cretaceous conifers of Western Gondwana. Another paper reviews and attempts to test critically the disputed placement of the bennettitaleans within seed plant phylogeny, and sounds a note of caution over interpretations of their morphology and potential homologies with cycads and other plants. This paper does, however, indicate where potential future investigative focus might be beneficial and makes the case for continued morphological and anatomical work in living and fossil plants. This section of the book gives a broad, but detailed perspective on some key Mesozoic plant groups; many other plant groups are neglected, but Ted himself couldn't investigate every plant group throughout the Mesozoic!

The final part is the smallest, consisting of just two papers on the rather large subject of ecosystems. Palynological sampling shows quite a different floral composition to that recorded in the macroflora of the Late Jurassic Morrison Formation. These preliminary results are possibly due to the low sampling carried out on a North–South transect across North America, so facies differences and other effects are unclear. The second paper, on dinosaur herbivory, is a well-constructed synthesis of different lines of evidence (skeletal and dental remains/microwear, digestive tract remains, coprolites, trackways, modern herbivore analogues and fermentation experiments) in trying to assess which plants were really eaten by the sauropods. Interestingly, it is suggested that, contrary to popular ideas, the cycads and typical tree ferns were unlikely to be nutritious enough or fast enough at regeneration to have been preferentially eaten, so instead horsetails, some ferns and conifers were much more likely to have been food for hungry herbivores.

This is a very mixed set of papers that are interestingly disparate, but brought together to form a personalized volume. Some papers are thorough review articles, others instead detailing specific palaeobotanical specimens, and there are also preliminary results given. It must be remembered that this is a dedication volume and not an exhaustive textbook or proceedings. It is not really suitable as an introduction for a general audience, nor was it intended to be, but it is an appealing book for specialists, with excellent plates and diagrams; the colour plate section, although placed slightly awkwardly, is a lovely addition when stumbled across.

Leyla Seyfullah

Georg-August-Universität Göttingen, Germany

Introducing Palaeontology: A Guide to Ancient Life

Patrick N. Wyse Jackson. September 2010. Dunedin Academic Press. 152pp. £9.99. ISBN978-1-906716-15-8.

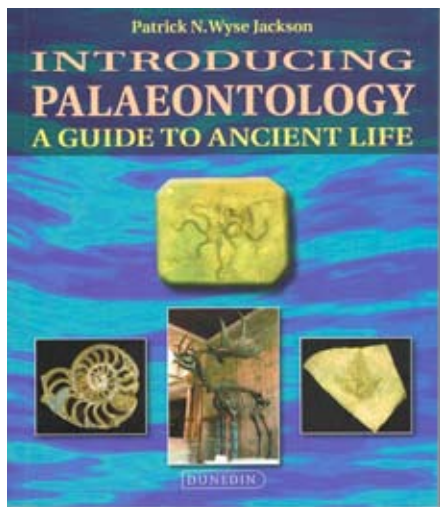
Well known for their Earth Science and Geology publications, this is the second book in Dunedin Academic Press's current series. Whether you are a member of the public, a student, or an amateur palaeontologist, this book offers a thorough, basic grounding in the subject. As a first-year geology student at the University of Liverpool myself, this volume has already become an invaluable source of reference.



Thankfully, this book is not just another guide to identifying fossils in the field, but rather is a pocket-sized (A5) 152 page volume, beautifully illustrated in colour, with photographs, annotated line drawings and diagrams throughout. This book is also excellent value for money at only £9.99, so well within even the poorest student's budget.

As you pick the book up for the first time you are immediately struck by its soft-feel, matt-finished cover and its user-friendly design. It is not daunting or overpowering in any way, but inviting. Taking you on a whistle-stop tour of the many aspects of palaeontology, this book certainly fills a gap in the market.

The first few pages of the book contain suggested additional reading and further information, along with notes on the illustrations and acknowledgements. The remainder of the volume is divided into two parts.



Part 1 introduces the science of palaeontology. It covers everything from 'What is a fossil?' to the risky business of fossilization itself, explaining in reasonable detail the whole series of factors that need to be just right for fossilization to occur. It describes the different types of fossil preservation, trace fossils, recrystallization, moulds and casts. There is a practical section on the tools required for collecting fossils, and methods of preparing, classifying and studying your finds. A nice inclusion in this section is the Code of Conduct for fossil collectors, not often found in books of this sort. Also covered within this section is taxonomy – how to classify and identify fossils correctly. The author has been careful to offer guidance for beginners concerning the process of identification from Kingdom right down to subspecies.

The book covers in some depth how fossils can be used to study the palaeobiological history of life on Earth. It explains how fossils can be used to trace mass extinction events and interpret ancient environments. This book doesn't just skim over the subjects but gives suitably detailed descriptions and illustrations to help the reader understand.

Part 2 covers the fossil groups themselves. Each group is illustrated by several detailed images and annotated diagrams. Important words and fossil names are highlighted in bold type. Each section is clear and concise, offering all the information you need, without the need to read pages and pages. The fossil groups covered are algae and vascular plants, unicellular animals, sponges, cnidarians, bryozoans, molluscs, brachiopods, echinoderms, arthropods, graptolites, conodonts, fish and tetrapods including reptiles, birds, mammals and hominoids. Trace fossils are also described.

The volume is rounded off with a valuable specialist glossary, necessary for the beginner in the field, given the fact that palaeontology seems to have spawned a completely different language only distantly related to English.



In conclusion, this book never underestimates the reader's geological and palaeontological experience or intelligence, but is accessible and written in clear, understandable English. I have no doubt that this book will soon become a recommended read for first and second year geology / palaeontology students around the world. For anyone interested in studying fossils, it is well worth the very reasonable price tag, and I whole-heartedly recommend it.

Emma Prince

University of Liverpool



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Dr Charlotte Jeffery Abt
Book Review Editor,
Department of Earth & Ocean Sciences,
School of Environmental Sciences,
University of Liverpool,
4 Brownlow Street,
Liverpool L69 3GP,
UK
tel: 0151 794 5178
e-mail <chj@liv.ac.uk>





**Special Papers in Palaeontology 84:
Evolution and development of the brachiopod shell**

Foreword and an appreciation of Howard Brunton. *By* FERNANDO ALVAREZ *and* GORDON B. CURRY.

Variation in the shell morphology of *Compsothyris* (Brachiopoda, Recent): An example of the problems associated with the compilation of data matrices for phylogenetic analysis and the preparation of electronic databases. *By* FERNANDO ALVAREZ, GORDON B. CURRY, COVADONGA BRIME *and* NURIA ANADÓN.

Upper Permian brachiopods from the Nesen Formation, North Iran. *By* LUCIA ANGIOLINI *and* LAURA CARABELLI.

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Shell development in thecidellinine brachiopods with description of a new Recent genus. *By* JANA HOFFMANN *and* CARSTEN LÜTER.

Microbially induced phosphatization of intercrystalline soft tissue in the Late Ordovician brachiopod *Plaesiomys*, Anticosti Island, eastern Canada. *By* JISUO JIN *and* PAUL COPPER.

Observations on recruitment, growth and ecology in a diverse living brachiopod community, Doubtful Sound, Fiordland, New Zealand. *By* DAPHNE E. LEE, JEFFREY H. ROBINSON, JON D. WITMAN, SANDRA E. COPELAND, ELIZABETH M. HARPER, FRANZ SMITH *and* MILES D. LAMARE.

Endoskeletal plate development in the Recent Indo-Pacific brachiopod genus *Jolonica* Dall, 1920 (Terebratulida: Laqueoidea). *By* DAVID I. MACKINNON *and* NORTON HILLER.

A review of crural types, their relationships to shell microstructure, and significance among post-Palaeozoic Rhynchonellida. *By* MIGUEL O. MANCENÍDO *and* NEDA MOTCHUROVA-DEKOVA.

Adaptations to hard substrates in Pennsylvanian productides (Brachiopoda) from the Cantabrian Mountains (North-West Spain). *By* MARÍA-LUISA MARTÍNEZ CHACÓN *and* COR F. WINKLER PRINS.

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Evolution and development of the brachiopod shell

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