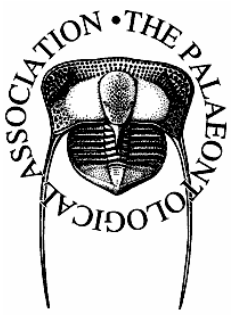
15 – 16 June

Conference programme and abstracts



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ABSTRACTS FOR ORAL PRESENTATIONS

(an asterisk indicates the speaker if multiple researchers are named)

Walking and jumping with Palaeozoic insects

Nicholas J. Minter
Department of Earth Sciences, University of Bristol, Wills Memorial Building, Queen's Road, Bristol, BS8 1RJ, UK <N.J.Minter@bris.ac.uk>

The Lower Permian Robledo Mountains Formation of southern New Mexico, USA, contains one of the most diverse and abundant Palaeozoic terrestrial trace fossil assemblages in the world, comprising trackways and other traces of both vertebrates and invertebrates. One of the most common traces is the insect jumping trace *Tonganoxichnus robledoensis*, which can be attributed to monurans, an extinct group of archaeognathan apterygote insects. The jumping behaviour of monurans is compared to that of the bristletail *Petrobius*, an extant machilid archaeognathan. Monurans appear to have been capable of forward progression via a linear succession of jumps of several times the body length, as well as a faster jumping gait of about one body length. *Petrobius* also employs such a fast jumping gait, but its longer jumps are used as an escape reaction, rather than for directed locomotion, and are essentially random in terms of their direction and degree of rotation of the body. The mechanism for the long forward jumps in monurans appears to have been modified during the evolution of *Petrobius* in order to enable the random escape jumps. Trackways preserved preceding, or following on from several *T. robledoensis* traces demonstrate that monurans used a variety of gaits ranging from very slow and stable gaits following jumps, to fast gaits preceding jumps. Archaeognathans are the most primitive group of true insects, and the presence of these similar types of jumping behaviours in monurans and machilids suggests that they were a primitive method of insect locomotion.

Linking shell morphology & larval ecology in a species-rich Neogastropod (*Turridae: Polystira)* from the Tropical West Atlantic.

Karl T. Bates[1*], Jonathon A. Todd[2] and Timothy A. Rawlings[3]

[1] School of Earth, Atmospheric & Environmental Science, University of Manchester, M13 9PL, UK <karl.t.bates@student.manchester.ac.uk>,

[2] Dept. of Palaeontology, The Natural History Museum, London, SW7 5BD, UK <J.Todd@nhm.ac.uk> and [3]Dept. of Biological Sciences, Florida International University, Miami, FL 33199, USA <rawlings@fiu.edu>

We report the results of a study into the links between larval shell morphology and ecology in Recent morphospecies of the neogastropod genus *Polystira* (Oligocene-Recent) in the Tropical West Atlantic (TWA). Our aim was to identify a suite of morphological characters in larval conchs that can be linked to larval ecology. In addition to measurements of size and number of whorls, this involved evaluation of microsculpture and lip shape using scanning electron microscopy.

Plotting the diameter of the embryonic protoconch against the number of larval whorls in Recent morphospecies reveals a bimodal distribution, corresponding to visually discriminated multispiral and paucispiral forms. Multispiral protoconchs strongly suggest planktotrophic and paucispiral forms non-planktotrophic larval development. Multispiral morphospecies have a well-developed sinusigera ridge and notch at the protoconch-teleoconch boundary, associated with large velar lobes used in active larval swimming. Interspecific variance in protoconch characters in paucispiral taxa suggests some variation in larval strategy. Other microsculptural features (e.g. tubercles) are not obviously associated with larval strategy in *Polystira* and require further study.

Many studies have linked larval ecology with geographic range-size and abundance in benthic gastropods, in which alternative modes of larval development (planktotrophic versus non-planktotrophic) convey very different dispersal potential. Preliminary analysis indicates that adult *Polystira* with inferred planktotrophic larva are among the most abundant and widespread morphospecies in the TWA, leading to a marginally significant correlation of mean geographic range-size and abundance with larval ecology across the genus. This has serious implications for our interpretation of biogeographic and evolutionary patterns in fossil *Polystira*.

Enigmatic fossils from the Soom Shale Lagerstätte, South Africa

Rowan J. Whittle [1*], Richard J. Aldridge [2] and Sarah E. Gabbott [3]
[1,2,3] Dept. Geology, University of Leicester, University Road, Leicester LE1 7RH, UK
[1] <rjw@le.ac.uk>, [2] < ra12@le.ac.uk >, [3] < sg21@le.ac.uk >

The Soom Shale is an example of a conservation Lagerstatte; a fossil deposit where the exceptional preservation of soft tissues occurs, providing much more information than is typically found in the fossil record. For example, entirely soft-bodied animals are preserved in exquisite detail, allowing a more complete view of community diversity.

As well as fossils such as orthocones, eurypterids, trilobites and brachiopods, the Soom Shale preserves several entirely soft-bodied fossils that are currently enigmatic in affinity. Enigmatic fossils provide insights into the anatomy and relationships of organisms known only from hard part morphology, or organisms otherwise unknown form the fossil record. Taxonomy and taphonomy are being employed to assign these fossils to their respective phyla. Results are compared to other Lagerstätten, such as the Cambrian Chengjiang and Burgess Shale biotas, and other groups of extinct and extant organisms.

Preliminary results add several arthropods and a possible medusoid to the list of organisms already identified from this site. Future results should increase this list and elucidate the evolutionary significance of these organisms.

Graptolite Shales and Silurian sea-level: some thoughts.

Alex Page[1*], Jan Zalasiewicz[1], Mark Williams[2], Phil Wilby[3] & Barrie Rickards[4]

[1] Department of Geology, University of Leicester, Leicester, LE1 7RH, UK

[2] British Antarctic Survey, Cambridge, CB3 0ET, UK

[3] British Geological Survey, Keyworth, Nottingham, NG12 5GG, UK

[4] Department of Earth Sciences, University of Cambridge, Cambridge, CB2 3EQ, UK

There is a clear bias graptolite fossil record: its vast majority occurs in dark-coloured, well-laminated, organic-rich mudrocks, deposited in oxygen restricted waters beneath the pycnocline. However, certain graptolites, such as *Stimulograptus sedgwickii*, may be found in demonstrably oxygenated shallow facies, meaning anoxia is not necessary for their preservation. However, graptolites are extremely rare in bioturbated facies, though comminuted fragments may occasionally be found. Detailed examination of the transitions from graptolite-bearing to graptolite-free strata has been undertaken using thin sections and palynological preparations. The presence of a bioturbating infauna, itself a function of sediment oxygenation, appears sufficient to preclude the preservation of graptolites.

In the early Silurian the deposition of graptolitic mudrocks is a function of sea-level. UK successions show that anoxic intervals, i.e. periods precluding the presence of burrowing infauna, are coincident with transgressions. In Wignall's (1991) model, sediment starvation during transgressions leads to rapid deepening and deposition of shelf facies in oxygen depleted waters. Whereas, regressions, such as the *sedgwickii* s.s. biozone, see graptolite faunas rarely recovered in shelf settings (Miller et al., in prep). If the deposition of graptolitic mudrocks is the dominant form of CO_2 burial in this interval, then this may provide a negative feedback mechanism limiting greenhouse-driven melting and therefore modulating transgression-regression cycles.

MILLER, M., ZALASIEWICZ, J.A., WILLIAMS, M, PAGE, A.A. & BLACKETT, E.J. *submitted*. Early Silurian (Llandovery) graptolites from central Saudi Arabia: first definitive record of Telychian faunas from the Arabian peninsula. Geoarabia

WIGNALL, P.R., 1991. A model for transgressive black shales? *Geology*, **19**, 167-170.

Simulations of Fossil Record Quality and the Probability of Early Origins

Alexei A. Rivera
Palaeontology Research Group, Department of Earth Sciences, University of Bristol, Queen's Road, Bristol BS8 1RJ, United Kingdom
E-mail: ar2754@bristol.ac.uk

The fossil record has long been regarded as biased and incomplete, but how poor must it be in order for evidence of early taxonomic origins to disappear? A data set consisting of 36,380 fossil marine genera (Sepkoski, 2002) was analysed using randomised bootstrap resampling. Computer simulations demonstrate that the fossil record would need to lose over 99.9% of taxonomic information in order for early origins, defined here as the appearance of genera by the Early Cambrian, to disappear in at least half of the replicates. Similar results were obtained at reduced sampling intensities for early genera, at higher taxonomic levels (up to the phylum), and in simulations incorporating the terrestrial fossil record. Despite the assumption of random information loss, these preliminary results support the view that the fossil record is surprisingly robust to degradation.

The characterisation and evolution of phyla

Jonathan B. Antcliffe* and Martin D. Brasier
Department of Earth Sciences, University of Oxford, Parks Road, Oxford, OX1 3PR, UK. <jonathan.antcliffe@earth.ox.ac.uk>

The way in which we discriminate higher taxa is a profound question for evolutionary theory. Many key debates that have taken place in palaeobiology over the last twenty years have revolved around a void: the lack of a formal framework for the description of higher taxa. We find it difficult to isolate the differences between phyla, not least because they differ so greatly with respect to those features we consider at, say, the species level. It is easy to agree that there is something mollusc-like about all molluscs and something arthropod-like about all arthropods, yet it is harder to decide just what this might be. Here we outline a set of features that can be discussed meaningfully at the level of the phylum, from which we deduct that homologies can take a nested structure consistent with taxonomic hierarchy. That is to say, such features will probably be present within every member of a phylum and also vary between phyla, while a feature that can discriminate between species will not be relevant between phyla. This theory of nested homologies not only provides a justification of character-weighting within cladistic analysis but also informs how the characters should be weighted. Consideration of phylum-level characters allows us to gain an insight into the development of higher taxa and principally, therefore, into the Cambrian Explosion. Furthermore, the concept can be developed into a tool that will allow fossils of uncertain affinities to be finally affiliated. Not the least of these enigmatic fossil groups is the Ediacara biota of the late Neoproterozoic, so providing a window to view evolutionary events in the critical period before the Cambrian.

Calcareous nannoplankton dynamics through the Eocene-Oligocene boundary – a new record from the western equatorial Indian Ocean.

Dunkley Jones, T[1*], Bown, P.R[1], Pearson, P.N[2] and McMillan, I.K[2]

[1] Department of Earth Sciences, University College London, Gower Street, London, WC1E 6BT; UK <tom.dunkleyjones@ucl.ac.uk>

[2] School of Earth, Ocean and Planetary Sciences, Cardiff University, Main Building, Park Place, Cardiff, CF10 3YE, UK <Paul.Pearson@earth.cf.ac.uk>

We present initial results from an exceptionally well-preserved upper slope section through the Eocene-Oligocene boundary (~33.7Ma) from recent drilling in Tanzania. The period from the latest-Eocene to earliest-Oligocene witnessed the most significant climatic transition of the Cenozoic, with the growth of continental ice-sheets and global cooling culminating in the rapid Oligocene Ice Building Event (Oi1 ~33.55Ma). A long-term decline in atmospheric carbon dioxide levels, the development of the Antarctic Circum Polar Current and orbital forcing have all been proposed as mechanisms of global cooling but the immediate cause of the transition is still poorly constrained. In order to understand the context of the Oi1 event it is vital to have detailed records of the state of the earth system during the latest Eocene and earliest Oligocene.

A well-preserved and diverse calcareous nannofossil assemblage was recovered from a 147 m section of hemipelagic clay, from which we present a ~5kyr-resolution record of relative abundance and diversity through the Eocene-Oligocene boundary. A series of extinctions and a decline in diversity are recorded suggesting significant environmental instability through this period. Future work will combine this data with high-resolution stable isotope records and foraminiferal bioevents to further constrain climatic and oceanographic change.

A new Eocene conifer flora from Seymour Island, Antarctica

Rosemary S Stephens[1*] J.E. Francis[1], J.A. Crame[2], A.Haywood[2]

[1] School of Earth Sciences, University of Leeds, Woodhouse Lane, Leeds LS29JT

[2] Geosciences Division, British Antarctic Survey, Madingley, Cambridge CB30ET

*<rosiest@earth.leeds.ac.uk>

Exceptionally well preserved plant material has been collected from new floras in Eocene strata (approximately 50Ma) on Seymour Island, Antarctic Peninsula. The plants are preserved in concretions within the La Meseta Formation, in sediments that formed in a marine shallow shelf environment.

The flora is dominated by well preserved conifer branches, preserved in three dimensions with their leaves still attached. Several types of angiosperm leaves are also present, but are fragmented and not as well-preserved as the conifer material. Some of the material occurs as impressions and casts but much of it has been permineralised by calcite, coating the fossils and preserving fine leaf features, including cellular detail and stomata. The conifer fossils include intact isolated leaves, cone scales, and woody fragments, as well as the three-dimensional leafy branches. The conifers are members of the Araucariaceae. The coniferous material has been identified as fossil relatives of the extant *Araucaria araucana*, the Monkey Puzzle tree, which is native to southern Argentina and Chile, and these fossils thus provide important links in the biogeographic and evolutionary history of this genus.

The recently developed Neutron Tomography technique has provided a unique opportunity to study these fossils in their original three-dimensional arrangement without destroying the specimens. This technique has never before been used on fossils of this type, and allows computer-generated reconstructions of the conifer fossils to be made.

The fine detail that is visible in this exceptionally well-preserved conifer flora will provide new information and lead to a better understanding of the vegetation of Antarctica during the Eocene - the last global greenhouse period. Data collected from the fossil material can be used to infer palaeoclimate and palaeoenvironment in the Antarctic Peninsula region, and also has important implications for the evolution and biogeography of the ancient Araucariaceae conifer family, and for the palaeogeography of West Antarctica in the early Tertiary.

Morphometric analysis of the conodont skeleton: a new multi-element approach

David Jones[1*]; Mark Purnell[1]; Peter von Bitter[2]

[1] Department of Geology, University of Leicester, University Road, Leicester, England LE1 7RH. <doj2@le.ac.uk>

[2] Royal Ontario Museum, 100 Queen's Park, Toronto, Ontario, Canada M5S 2C6. <peterv@rom.on.ca>

Conodonts possess a superb fossil record and occupy a key phylogenetic position within the vertebrate clade, thus representing an invaluable tool for investigating both evolutionary patterns and the acquisition of vertebrate characters. A rigorous understanding of morphology is required to exploit this potential; however, as with many vertebrates, conodonts are rarely preserved as articulated skeletons, typically occurring as isolated skeletal elements. Consequently, previous investigations into element morphology have been conducted outside the context of the skeleton, examining single element types in isolation. Whilst analysis of morphological trends within these elements remains informative, consideration of the entire skeletal apparatus allows testing of additional hypotheses regarding the nature of variation within the skeleton, including functional aspects of the apparatus, ontogenetic changes, and the correct identification of element homology. The latter is of particular importance as it is fundamental to phylogenetic reconstruction. Homology has traditionally been recognized exclusively through qualitative description of the morphology of disarticulated elements; yet hypotheses of homology based on articulated skeletons may contradict those derived from the morphology of isolated elements alone. Determining whether element morphology is an accurate guide to element position will produce more reliable primary hypotheses of homology, increasing the robustness of phylogenies; interpretations of evolutionary processes, such as heterochrony, can then be made more confidently. The Eramosa fossil *lagerstätte* from Ontario, Canada, preserves hundreds of articulated skeletons and isolated elements, so providing a unique opportunity to utilise morphometric analysis to examine the pattern of element covariation within the conodont apparatus.

Tooth microwear as a tool for investigating trophic ecology of fossil fishes: reconstruction of niche differentiation in extinct groups.

David C.Baines[1*], Mark. A. Purnell[1], Paul J. B. Hart[2] and Michael A. Bell[3]
Departments of Geology[1] and Biology[2] University of Leicester, Leicester LE1 7RH UK, <dcb14@le.ac.uk, map2@le.ac.uk, pbh@le.ac.uk>
[3] Department of Evolutionary Biology, State University of New York, Stony Brook, NY. USA, <mabell@life.bio.sunysb.edu>

The alleviation of competition for resources by niche differentiation through character displacement is one of the key paradigms for the formation of new species. One of the chief resources that organisms compete for is food, and the different foods they exploit can be reflected in their trophic morphology. However does a change in diet precede an alteration in physical characteristics or does morphology precede niche shift? This can be hard to discern in fossils. Quite often a fossil's trophic niche is determined by examination of the trophic morphology, a circular argument. However for vertebrates tooth micro-wear may be able to tell us something of a population's trophic ecology. If there is a continuous sequence of specimens before, during and after any changes in morphology the role of resource competition can be discovered. Previous work has focussed on three-spine sticklebacks (*Gasterosteus aculeatus*), comparing tooth micro-wear of control animals in the lab with wild populations in an effort to assess whether trophic ecology could be determined by micro-wear. This work successfully proved this correlation and work is underway investigating fossil populations of stickleback (*Gasterosteus doryssus*). The technique seems to work in derived teleosts but what about less derived and extinct groups of actinopterygians? To make the phylogenetic leap from stickleback to more basal groups, tooth micro-wear investigations are being carried out on bowfin (*Amia calva*) to see if they are comparable to results obtained so far. If interpretations of micro-wear patterns are the same in both species, the data can be used to try and work out the role of competition speciation events.

What lies beneath: internal bracing in a new plesiosaur skull from the Early Jurassic of England.

Mark Evans[1, 2]

[1] Department of Geology, University of Leicester, University Road, Leicester, LE1 7RH <me42@le.ac.uk>, [2] New Walk Museum, 53 New Walk, Leicester, LE1 7EA <evanm003@leicester.gov.uk>

A new specimen of plesiosaur (Reptilia: Sauropterygia) from the Pliensbachian of Gloucestershire represents a previously undescribed taxon, which fills a gap in our knowledge of the Early Jurassic radiation of this group. The skull is notable for the relatively large sub-circular parietal foramen and a V-shaped facial ridge bridging the suture between the premaxillae and frontals.

Although incomplete, the skull displays a mix of gracile features with structures adapted to resist stress. In particular, the internal relationships of the discrete bony elements of the skull as revealed through natural breaks show that in certain regions the bones are tightly interlocked. This observation has been confirmed by the use of Computer Aided Tomography (CAT) which has also shown a surprising degree of internal asymmetry. Specifically, a large spur of the left parietal crosses the midline, and continues anteriorly, surrounded by the right frontal. Interpretations of these observations inform hypotheses of the functional morphology of the skull and possible way of life of the new taxon.

Important Plesiosaurs in the National Museum of Ireland (Natural History)

Adam Stuart Smith
Department of Zoology, University College Dublin, Belfield, Dublin 4
<adam.smith@ucd.ie>

The type material of the ferocious Jurassic marine predator *Rhomaleosaurus* has a long and convoluted history, but it is now in storage in the National Museum of Ireland (Natural History). This complete skeleton (*R cramptoni*) is of vital importance in resolving the taxonomy and understanding the evolution of plesiosaurs, particularly the typically short-necked 'pliosaurs'. However, the current state of the type material is poor and parts of the specimen as mounted are erroneous. The specimen is now in the process of being cleaned, prepared and described. Two additional rhomaleosaurid specimens tentatively listed in the museum records as *Eurycleidus arcuatus* and *Rhomaleosaurus megacephalus* (=*E. arcuatus*?) are also being treated and described, with the latter appearing to represent a new species. Finally these species will be applied to phylogenetic analyses to secure a sound systematic basis for the future development of plesiosaur palaeontology.

Upper limits on the mass of land animals estimated through the articular area of limb-bone cartilage.

Michael P. Taylor
School of Earth & Environmental Sciences. University of Portsmouth UK, PO1 3QL
<dino@miketaylor.org.uk>

Unlike mammals, dinosaurs did not have shaped articular surfaces to their limb bones, but flat, rugose surfaces that bore thick cartilage caps in life. Many workers have felt that this cartilage would not have been strong enough to support the masses of large sauropods on land, and that sauropods must therefore have been aquatic. I test this assumption by measuring the areas of the articular surfaces of sauropod limb bones and using life-mass estimates from the literature to calculate the compressive stress operating on the cartilage. For *Brachiosaurus altihorax*, assuming a mass of 35000 kg, this method yields an estimated compressive stress of 706 KPa at rest if the whole surface areas of the proximal humerus and femur were in articulation with the glenoid and acetabulum. Assuming that only about half of the area was in contact at any time, and that locomotory stress was about twice static stress, the stress would be 2.8 Gpa. The compressive strength of hyaline cartilage is variously reported, but it seems to sustain about 5 Gpa before the onset of plastic deformation. The safety factor of 1.8 is close to the limit of safety factors exhibited during vigorous locomotion by extant animals, suggesting that cartilage stress may have limited the athletic performance of *B. altithorax*.

The inferred evolutionary history of integumentary sense organs in crocodylomorphs

David J. Allen
Department of Biological Sciences, Northern Illinois University, DeKalb, IL 60115, USA. <dallen4@niu.edu>

Five senses enable vertebrate animals to assess their surroundings. In addition to these senses, many vertebrates have evolved novel sensory mechanisms that convey improved hunting ability, and indirectly lead to enhanced fitness relative to other taxa. Examples include electroreception in the platypus and infrared detection in snakes.

Extant crocodilians possess small domed structures known as Integumentary Sense Organs (ISOs) that are hypothesized to have a mechanosensory role, although the mechanism of reception is poorly understood. ISOs are restricted to the head in alligatorids, but are also present on postcranial regions in other crocodilians.

The distribution of ISOs on the faces of extant crocodilians corresponds well with the distributions of jawbone foramina. These foramina supply ISOs with nerves and blood vessels, and may be used as indicators for the presence of these structures in extinct forms.

It is suggested that crocodilian ISOs first evolved late in the Triassic period. The first crocodilians to possess these structures would not have exhibited the complex ISO distributions seen in extant taxa. These earlier forms would have shown a more modest distribution of ISOs along jaws, and had fewer foramina. Several phases in crocodylomorph evolution are identified, leading up to the modern condition.

Cranial biomechanics and feeding in a basal ornithischian dinosaur

Laura B. Porro

Department of Earth Sciences, University of Cambridge, Downing Street, Cambridge, CB2 3EQ <lbp24@esc.cam.ac.uk>

Since its discovery and initial description, *Heterodontosaurus tucki* has remained a problematic animal in terms of its cranial biomechanics during feeding and its phylogenetic position within the ornithischian dinosaurs. This small, herbivore from the Early Jurassic Elliot Formation of South Africa features a closely packed magazine of cheek teeth with oblique occlusal surfaces. The wear facets on the teeth suggest that *H. tucki* processed plant matter using a transverse power stroke. Because diapsid jaw musculature does not allow a side-to-side motion of the lower jaw against the upper jaw, several fundamentally different theories have been put forward to explain how *H. tucki* chewed. These include rotation or scissoring of the dentaries against the predentary, propaliny, and lateral rotation of the cheek region. I am currently utilizing FEA (Finite Element Analysis—an engineering technique capable of deducing stress and strain in a structure under load) to approach the problem of cranial biomechanics and feeding in *H. tucki* in a way that will allow the various proposed hypotheses to be tested. CT scans from the cranium of *H. tucki* have been used in the ongoing construction of a three-dimensional FE model. Forces simulating those encountered during each of the proposed feeding mechanisms will be applied to the model upon its completion. Stress and strain patterns generated by different feeding strategies will then be analysed to determine which mode of mastication best corresponds to skull morphology. In addition, elucidating the cranial biomechanics of *H. tucki* may yield clues as to the relationship between *H. tucki* and other early ornithischians.

The phylogeny and evolutionary history of the ornithischian dinosaurs

Richard J. Butler[1, 2]

[1] Department of Earth Sciences, University of Cambridge, Downing Street, Cambridge, CB2 3EQ <rbut02@esc.cam.ac.uk>

[2] Department of Palaeontology, The Natural History Museum, Cromwell Road, London, SW7 5BD, UK.

Ornithischia represents a hugely diverse, abundant, and important, clade of dinosaurs. Yet a full understanding of ornithischian evolution is hampered by an absence of rigorously tested global phylogenies for the clade. In order to reassess prevailing views of ornithischian phylogeny and evolution a 'total-evidence' approach was taken. Nine higher-level and 42 species-level taxa were selected, representing all known valid ornithischians. The validity of all previously utilised characters was assessed, and direct examination of taxa allowed the identification of further characters. Data was analysed using a range of techniques including safe taxonomic reduction, reduced consensus methods and various measures of support.

The general structure of ornithischian phylogeny is supported; however, positions of certain taxa differ significantly from previous analyses. The Heterodontosauridae form the sister group to Genasauria and may represent the basalmost known ornithischians, a position concordant with stratigraphy. Strong evidence supports hysilophodontid paraphyly, with some Middle Jurassic taxa (*Agilisaurus*, '*Yandusaurus*' *multidens*) clading as sister-taxa to Cerapoda (Marginocephalia + Ornithopoda).

Far greater congruence with stratigraphy is present than in previous phylogenetic hypotheses, suggesting that the early ornithischian record may be better than generally believed. New time-constraints are placed on evolutionary events. For example, previous hypotheses require a Late Triassic date for the Ornithopoda-Marginocephalia split; this phylogeny predicts a Mid-Late Jurassic date for the same event, obviating the need for an extensive marginocephalian ghost-range. This analysis highlights both the necessity of rigorously testing the ornithischian tree, and the areas in which efforts should be concentrated.

ABSTRACTS FOR POSTER PRESENTATIONS

Acanthodian dentition and the origin of vertebrate teeth

Simon Neil Atkinson
Department of Earth Sciences, Wills Memorial Building, The University of Bristol, Queen's Road, Bristol. BS8 1RJ. <sa4739@bristol.ac.uk>

It has long been held that teeth have a single origin within the vertebrates. However, recently this model of homologous dentition throughout the gnathostome clade has been questioned by the proposal that teeth may have evolved independently within the major gnathostome lineages from pre-existing pharangeal denticles. The Acanthodii represent a little studied basal group of gnathostomes that are amongst the earliest vertebrates to possess teeth borne by a jaw. Unfortunately our current understanding of the dentition of this group is extremely limited despite its broad significance to our understanding of how this model developmental system has evolved throughout vertebrate phylogeny. This study concentrates on the Ischnacanthida, an order of predatory acanthodians provided with dermal jawbones to which their teeth are ankylosed. Using a combination of dental wear and histological examination of thin sections of ischnacanthid dentigerous jawbones from the Devonian of Canada and the Silurian of Sweden this study demonstrates the existence of differential occlusial wear in the upper and lower jaws and helps to elucidate how these earliest jawed vertebrates used their teeth. Further results clarify how tooth addition occurred through ontogeny and the relationship of the acanthodian dentition with that of their extant sister-group, the osteichthyans.

Ocean Climate and Ecology in the Middle Eocene at 55°South, New Zealand

Cat Burgess
Cardiff University, School of Earth, Ocean and Planetary Sciences, Main Building, Park Place, Cardiff <BurgessCE@cf.ac.uk>

The development of the Southern Ocean plays an important role in changing ocean circulation and therefore has a key impact on climate. A section containing exceptionally well preserved foraminifera and calcareous nannofossils in South Island, New Zealand allows the quantitative investigation of a range of aspects of climate and ocean ecology of the Southern Ocean during the Middle Eocene. The Middle Eocene is a period of warm but gradually cooling climate and is known to contain at least one transient warm event thought to be represented in the New Zealand section as the brief appearance of the foraminiferal species *Hantkenina australis*. This work will generate high-resolution records of this transient climate event using geochemical proxies ($\delta^{18}O$, $\delta^{13}C$, $\delta^{11}B$ and Mg/Ca) to increase understanding of the impacts and drivers of the rapid climatic warming and associated ecologic change. The section also records cyclic sedimentation, and a further multiproxy investigation aims to understand whether these high latitude, greenhouse period cycles are climate-driven.

The geochemical taphofacies of the Jardim Assemblage, Santana Formation, Brasil.

Jennifer Morris[1], Tom J. Challands[2], Howard A. Armstrong[3]

[1-3] Earth Sciences Department, University of Durham. [1] <j.l.morris@dur.ac.uk>, [2]<t.j.challands@dur.ac.uk>, [3]<h.a.armstrong@dur.ac.uk>

The Chapada do Araripe (Brazil) is a Cretaceous basin, which formed during the opening of the South Atlantic Ocean. The Santana Formation represents a period of marine incursion and is recognised as a world famous lagerstatten. Typically the fossils are preserved within carbonate concretions.

The majority of studied specimens belong to the Santana assemblage (northern basin) and previous work has proposed that preservation occurred by phosphatisation, in a sub oxic and low pH environment (Martill 1988). In this study the taphonomic history of an elopomorph fish from the coeval but distinct Jardim assemblage (eastern basin) has been elucidated.

Histological analysis shows good preservation of bone and scales, although no soft tissue is present. FTIR spectroscopy indicates the preservation of bones and scales occurred through calcification, resulting in an increase in Ca/P ratios, an increase in carbonate content, and an increase in crystallinity. Chemical alteration occurred by ion exchange: carbonate substituted phosphate in the apatite structure (B-type substitution). Normalised REE patterns indicate the microenvironment around the carcass was reducing and alkaline, allowing carbonate saturation.

The difference in geochemical taphofacies between the Jardim and Santana assemblages may be related to 'local' factors most likely differences in water depth and oxygenation of bottom waters.

Investigating the Platycopid signal

Ellen L. Weavers
Department of Earth and Environmental Science, University of Greenwich, Pembroke, Chatham Maritime, Kent, ME4 4TB <we32@gre.ac.uk>

Although much research has centred on the identification of sedimentological, geochemical and faunal proxies for dysoxia, little work has been done on the direct comparison of this range of indicators. In 1991, Whatley suggested a relationship between low oxygen conditions, and high percentages of Platycopina within ostracod faunas. He suggested that this was related to the mode of life of this sole remaining group of filter-feeding ostracods. Whatley et al. (2003) provided a numerical scale by applying work on modern ocean environments to Upper Cretaceous sediments. By comparing the varying ostracod faunas in Mid-Cretaceous marine clays with a range of geochemical and sedimentological proxies, it is possible to assess the reliability of the Platycopid signal as an indicator of dysoxia.