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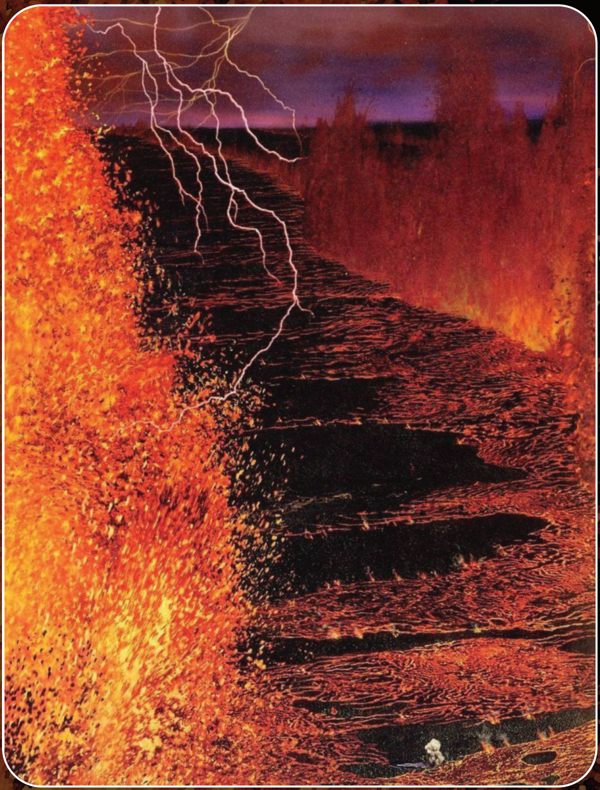
Lyell Meeting 2018

Mass extinctions: understanding the world's worst crises

7 March 2018 The Geological Society, Burlington House



Convenors:

Paul Wignall (University of Leeds, UK)
Dave Bond (University of Hull, UK)

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CONFERENCE PROGRAMME

Wednesday 7 March 2018	
09.00	**Registration & tea & coffee (Main foyer and Lower Library)**
09.30	**Biosedimentology of Mass Extinctions** David Bottjer (University of Southern California, USA)
09.45	**Searching for mass extinction drivers: common cause or lost cause?** Mark Puttick (University of Bath, UK)
10.00	**The functional consequences of extinctions: from giant sharks to small mollusks** Catalina Pimiento (Museum fur Naturkunde and Smithsonian Tropical Research Institute)
10.15	**The Devonian mass extinction: new geochemical and geochronological insights** Lawrence Percival (University of Lausanne, Switzerland)
10.30	**The Terrestrial Record of the End Devonian Mass Extinction Event** John Marshall (University of Southampton, UK)
10.45	**Tea, coffee and refreshments and posters (Lower Library and Arthur Holmes room)**
11.15	**The Carnian Pluvial Episode: Carbon-cycle disruption, extinction, and LIP volcanism in the early Late Triassic** Jacopo Dal Corso (University of Leeds, UK)
11.30	**Using mercury to link Large Igneous Province volcanism to environmental perturbations during the End-Triassic extinction and Early Toarcian Oceanic Anoxic Event** Tamsin Mather (University of Oxford, UK)
11.45	**Boron isotope data show ocean acidification in the aftermath of the end-Triassic mass extinction** James Rae (University of St Andrews, UK)
12.00	**Strong seasonality in the shallow Tethys across the end-Triassic mass extinction** Sarah Greene (University of Birmingham, UK)
12.15	**Lunch and Posters (Lower Library and Arthur Holmes room)**
13.30	**KEYNOTE: 'Under the Volcano' – environmental and biotic responses to massive volcanism during the end-Triassic mass extinction** Sofie Lindstrom (Geological Survey of Denmark and Greenland)
13.50	**Considering the impact of SO2 on plants across the Triassic-Jurassic boundary** Karen Bacon (University of Leeds, UK)
14.05	**Testing biotic recovery from the early Toarcian (Lower Jurassic) extinction event** Jed Atkinson (University of Leeds, UK)
14.20	**The early Toarcian mass extinction in the eastern epicontinental Tethys (NW Bulgaria)** Autumn Pugh (University of Leeds, UK)

14.35	**Modelling the ecological determinants of extinction across Mesozoic hyperthermal events** Alexander Dunhill (University of Leeds, UK)
14.50	**Strong avian ecological selectivity across the K-Pg: Evidence from lifestyle and body size** Daniel Field (University of Bath, UK)
15.05	**Tea, coffee and refreshments and posters (Lower Library and Arthur Holmes room)**
15.35	**Near coincidence of maximum Deccan volcanism with the Cretaceous-Paleogene boundary: evidences from U-Pb geochronology and mercury anomalies** Thierry Adatte (University of Lausanne, Switzerland)
15.50	**The role of ocean acidification in the marine extinctions at the Cretaceous/Paleogene boundary** Malcolm Hart (Plymouth University, UK)
16.05	**The recovery of marine phytoplankton cell size and biovolume in the aftermath of the Cretaceous-Paleogene mass extinction** Hojung Kim (University College London, UK)
16.20	**Re-building the ocean ecosystem after the K/Pg mass extinction event** Sarah Alvarez (University of Bristol, UK)
16.35	**KEYNOTE: Recovery of life from the greatest mass extinction of all time** Mike Benton (University of Bristol, UK)
16.55	**Concluding remarks** Paul Wignall (University of Leeds) and Dave Bond (University of Hull)
17.00-18.00	**Drinks reception (Lower Library)**

POSTER PROGRAMME

Archosauromorph extinction during the Triassic-Jurassic mass extinction was not related to body size Bethany Allen (University of Leeds)
Photic zone euxinia at the end-Triassic mass extinction event: a study of sediments from Felixkirk Borehole in the Cleveland Basin, North Yorkshire. Sarah Beith (University of Southampton)
Modelling the effect of spatial fossil bias and its impact on dinosaur palaeodiversity estimates in the latest Cretaceous of North America Alfio Alessandro Chiarenza (Imperial College, London)
Ectothermic vertebrate diversity dynamics across the K-Pg boundary Terri Cleary (Natural History Museum)
Redox constraints and sulphur cycling across the Permian–Triassic transition in the southern margin of the Boreal Ocean Laura Crick (University of St Andrews)
Reconstructing trophic networks across the early Toarcian Ocean Anoxic Event (Lower Jurassic) Alexander Dunhill (University of Leeds)
Red Queen ousts Court Jester: Decreasing environmental influence on the Phanerozoic success of marine calcifiers Kilian Eichenseer (Plymouth University)
Lithium isotopes as a proxy for weathering intensity during the Late Devonian Ronald Guthrie (University of Oxford)
Effects of the end Triassic mass extinction event on insect diversity and ecology Richard Kelly (University of Bristol)

ORAL ABSTRACTS
(in programme order)

Biosedimentology of Mass Extinctions

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Biosedimentology focuses on biological processes that produce sedimentary structures and fabric. In marine environments this includes reefs as well as microbial structures and bioturbation. Mass extinctions exert a profound influence on biosedimentological processes. That mass extinctions are defined by their effect upon metazoans implies they can have a strong affect upon reefs and bioturbation. The microbial record has been documented through the sedimentary structures which they produce, such as stromatolites in carbonates and wrinkle structures in siliciclastics. Marine environmental processes that cause mass extinctions and thus affect biosedimentology include changes in seawater temperature, carbonate chemistry and oxygen content. Changes in bioturbation due to mass extinctions are more likely caused by the negative affects of environmental changes that restrict bioturbators than extinction of bioturbators. Mass extinction processes that restrict bioturbators can affect development of the surface mixed layer and thus lead to changes in biogeochemical cycling. If there are changes in normal marine carbonate microbialites as well as siliciclastic wrinkle structures, then biosedimentological changes for a particular mass extinction are not just due to changes in ocean carbonate chemistry. Comparison can be made of changes in biosedimentology due to the end-Permian and end-Triassic mass extinctions, both caused by the environmental effects of large igneous provinces. Biosedimentological changes for microbial structures and bioturbation are greater in end-Permian than end-Triassic mass extinctions, while for both of these mass extinctions metazoan framework reefs were lost. Understanding these past episodes of environmental stress on biosedimentological processes will help to manage for future environmental change.

NOTES

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Mass extinctions have shaped the course of evolution but it is still debated whether these events share a set common causes or if they are a response to a more unpredictable set of drivers. Periodicity of mass extinction would be indicative a potential common mass extinction driver, but there has not been conclusive evidence of mass extinctions occurring at regular intervals. Some extinction drivers may be more unique, such as the bolide impact at the Cretaceous-Palaeogene boundary. However, many mass extinction events correlate with periods of warming: the Permo-Triassic mass extinction, the Cretaceous-Palaeogene, and others occurred alongside Large Igneous Province (LIP) activity. Furthermore, many events correlate with continent aggregation. We hypothesise that extinction risk resulted from climate warming due to LIP activity increasing levels of atmospheric carbon dioxide, and continent aggregation reducing carbon dioxide release through factors such as low silicate weathering rates. Here we take a statistical approach by analysing rates of extinction through time alongside these potential drivers of mass extinctions. We analyse a large-scale metazoan invertebrate database spanning the Phanerozoic and simultaneous account for vagaries in fossil record preservation. This approach can highlight if mass extinctions events are predictable, and thus understand if macroevolution is predictable in response to climactic changes.

NOTES

The functional consequences of extinctions: from giant sharks to small mollusks

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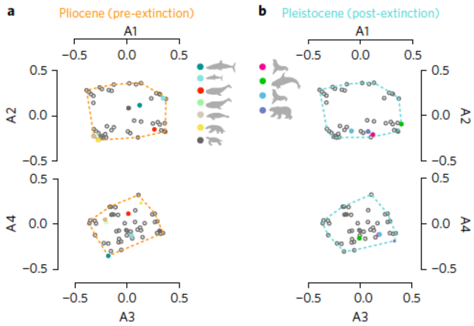

The end of the Pliocene marked the beginning of a period of great climatic variability and sea-level oscillations. Although it has been proposed that these environmental changes triggered the extinction of benthic communities in the Caribbean, large marine vertebrates are usually assumed to have remained globally resistant. We overturn this assumption by reporting a previously unrecognized extinction event in the Pliocene, in which 36% of the marine megafauna genera were lost. We used a functional diversity approach to evaluate the potential impacts of this extinction for ecosystem functioning, and found that seven out of 49 (14%) functional groups (unique trait combinations) disappeared, along with 17% of functional richness (volume of the functional space). This contrasts with previous studies that have reported negligible functional changes after the extinction of marine invertebrates. We further compared the functional diversity loss after the newly reported marine megafauna extinction and the well-known Caribbean mollusks extinction. We found that small, speciose mollusks are functionally redundant (large number of taxa filling functional groups), and consequently resilient, whereas large megafaunal taxa are functionally unique and their communities highly vulnerable. Our results suggest that functional redundancy is a key determinant of the consequences of extinctions for marine ecosystems.

NOTES

The Late Devonian mass extinction: new geochemical and geochronological insights

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The Late Devonian marked a time of numerous successive environmental perturbations and biotic crises, collectively considered one of the 'Big Five' mass extinctions of animal life in the Phanerozoic. The Frasnian–Famennian boundary (~372 Ma) and Devonian–Carboniferous boundary (~359 Ma) represent the two largest and best known of these crises, with several smaller scale events (e.g. the Late Famennian Annulata Event: ~363 Ma) spread over a 20 million year period. However, despite representing a period of substantial floral and faunal turnover, there remains little consensus as to the cause of these crises, either individually or collectively, with large scale volcanism, one or more meteorite impacts, marine anoxia, global temperature changes, and increased continental weathering all mooted as possible contributors towards the Frasnian–Famennian extinction and the other Late Devonian crises.

In this study, we present new geochemical and geochronological data from multiple locations in Europe and Australia to investigate a number of the processes proposed above. Of particular interest is the potential role played by increased continental weathering rates, and the impact on nutrient influx to the marine realm which may have promoted anoxic conditions inferred from numerous sedimentary records of this time. The possible influence of volcanic activity is also of interest due to the established correlation between large scale volcanic events and extinctions/climate perturbations in the Mesozoic. Constraining the potential impact, and timing, of such processes with respect to the Late Devonian crises will play a key role in the ongoing studies of these events.

NOTES

The Terrestrial Record of the End Devonian Mass Extinction Event

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The End Devonian Mass Extinction (EDME) is often referred to as the 6th mass extinction. However, EDME differs from most of the Big 5 as it was driven by a short intense glaciation and deglaciation. As such it remains our best analogue for extinctions that will accompany a collapse of the present glacial system. However, EDME still remains poorly understood and particularly its terrestrial expression. We report on sections from East Greenland- the interior of the Old Red Sandstone Continent. Here the D-C boundary is marked by a deep, wide anoxic lake that formed during the insolation maximum when the monsoonal system reached into the continental interior. Below the D-C boundary lake the palynological assemblage is dominated by *Retispora lepidophyta*, a very distinctive spore that was globally distributed, but restricted to the very latest Devonian. Immediately below the boundary the spore diversity increases markedly as the climate became less arid and the lake encroached. The spore record then disappears in the amorphous organic matter dominated part of the lake. Above the lake spores return, but as a very simple assemblage following the extinction of many long lived Devonian forms. *Retispora lepidophyta* disappears (the ultimate ruderal plant) which indicates the ecological severity of the crisis. We have integrated a palaeobotanical record by counting the abundance and size of plant stems. These show the disappearance of large forest trees coincident with the boundary and the change in spore assemblage also show loss of the understorey vegetation. It was the loss of these keystone taxa that collapsed the terrestrial ecosystem.

NOTES

The Carnian Pluvial Episode: Carbon-cycle disruption, extinction, and LIP volcanism in the early Late Triassic

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In the Carnian (early Late Triassic) a climate change from arid to markedly humid conditions, known as the Carnian Pluvial Episode (CPE), is recorded in stratigraphic sections worldwide. In marine sedimentary basins, the arrival of huge amount of siliciclastic material, the establishment of anoxic conditions, and a sudden change of the carbonate factory on platforms mark the CPE. The CPE is closely associated with biological turnover among marine groups, for example: important groups of crinoids either completely disappeared or severely declined during the CPE; 70% of conodont genera became extinct; the dominant ammonoid group (*Trachyceratinae*) almost disappeared. On land, a major turnover of the vertebrate fauna is observed. Palaeobotanical data suggest a floral shift from xerophytic to hygrophytic associations at different latitudes, the most severe decline in flora diversity after the end Permian mass extinction, and widespread resin production. The CPE is also linked to the first major radiation of dinosaurs, the appearance of abundant calcifying plankton, and the radiation of modern conifers and benettitaleans. New organic carbon-isotope records from the Southern Alps (Italy) and the Transdanubian Range (Hungary) confirm multiple negative □^{13}C excursions during the CPE, suggesting repeated perturbations of the global carbon-cycle. This together with a refined biostratigraphy give the opportunity to understand the links between the carbon-cycle perturbations and the palaeoclimatic and biological changes that mark the CPE. As it stands the eruption of the Wrangellia Large Igneous Province is the most likely cause of the geochemical, sedimentological, and palaeontological changes observed during the CPE.

NOTES

Using mercury to link Large Igneous Province volcanism to environmental perturbations during the End-Triassic extinction and Early Toarcian Oceanic Anoxic Event

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Mass extinctions and other episodes of palaeoceanographic and palaeoclimatic upheaval, such as Oceanic Anoxic Events (OAEs), have punctuated global climate throughout the Phanerozoic Eon. Several such events have been suggested to be causally linked with the formation of Large Igneous Provinces (LIPs), which represent the geologically abrupt emplacement of millions of cubic kilometres of (chiefly) mafic volcanic material. Evidence for such a relationship comes from the coincidence in the determined ages of many LIPs with the apparent age of an extinction/climate perturbation; and from the sedimentary record, where stratigraphic horizons recording palaeoclimatic events commonly show perturbations in sedimentary proxies for volcanism.

In this context, Hg/TOC (mercury/total organic carbon) excursions in sedimentary archives recording extinctions/environmental perturbations have been used to support a precise temporal link between many such events and the formation of LIPs, as volcanic outgassing is one of the main natural sources of mercury to the modern environment. Here, the Hg/TOC records of two Mesozoic events, the end-Triassic mass extinction and Toarcian OAE, are presented. The mercury trends are compared with other geochemical proxies for weathering rates and atmospheric CO_2 levels. These comparisons indicate a strong correlation in increased atmospheric mercury and CO_2 at the onset of both events, likely resulting from volcanogenic processes. For the Toarcian, these perturbations are also broadly correlative with an increased sedimentary $^{187}Os/^{188}Os$, suggesting enhanced continental weathering. Taken together, these observations strongly support a model of increased atmospheric CO_2 resulting from volcanogenic processes, with the excess CO_2 subsequently drawn down through one or both of enhanced continental silicate weathering and organic-carbon burial.

NOTES

Boron isotope data show ocean acidification in the aftermath of the end-Triassic mass extinction

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Ocean acidification driven by the emplacement of the Central Atlantic Magmatic Province (CAMP) has been suggested as a kill mechanism for the end-Triassic mass extinction. Although preferential extinction of heavily calcified groups and changes in shallow carbonate deposition hint at acidification as a causal mechanism, these observations can also result from factors other than acidification. Furthermore, depending on the rates of volcanic input and the efficiency of buffering by the carbonate system, volcanic emissions may not result in appreciable carbonate undersaturation. Here we present the first pH reconstruction over the Triassic-Jurassic boundary to test whether ocean acidification was a feature of environmental change at this time. These data, generated on well-preserved fossil oyster shells, reveal a pronounced acidification pulse in the aftermath of the end-Triassic extinction, coincident with input of isotopically light carbon and ocean warming. This signal is consistent with ocean acidification due to pulses of volcanic carbon input from the CAMP, supporting the hypothesis that ocean acidification was an important component of large igneous province-associated mass extinctions.

NOTES

Strong seasonality in the shallow Tethys across the end-Triassic mass extinction

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The end-Triassic mass extinction coincided with the emplacement of the Central Atlantic Magmatic Province, a large igneous province responsible for the massive atmospheric input of potentially climate-altering volatile compounds and a sharp rise in atmospheric CO_2. The precise extinction mechanism is debated, with both short-term cooling due to sulfur aerosols and long-term warming due to CO_2 emissions — essentially opposite hypotheses — among the suggested triggers. Until now, no temperature records spanning this crucial interval were available to provide a baseline or to differentiate between these hypothesized mechanisms. Here, we apply clumped-isotope paleothermometry to shallow marine microbialites from the uppermost Triassic of the southwestern UK to reconstruct palaeoclimate at the extinction horizon. We find mild to warm ocean temperatures during the extinction event and evidence for repeated temperature fluctuations of ~15ºC — swings too large to be attributable to global secular climate change. Via comparison with a general circulation climate model, we instead interpret our temperature reconstruction as a record of strong seasonality. We resolve no apparent evidence for short-term cooling or initial warming across the 1-40 kyr duration that our record captures, implying that the initial onset of the biodiversity crisis may necessitate another mechanism.

NOTES

"Under the volcano" – environmental and biotic responses to massive volcanism during the end-Triassic mass extinction

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During the past decade, several advances in geochronology have helped tune the timescale across the Triassic–Jurassic boundary (TJB; 201.35 Ma). Radio-isotopic (U/Pb) ages of ash beds in ammonoid-bearing successions have helped to constrain the onset of the end-Triassic mass extinction (ETE) to 201.56 Ma. Recently published high precision U/Pb dating of intrusives and extrusives of the Central Atlantic magmatic province (CAMP) have shown that the volcanism occurred in at least four pulses over approximately 600.000 years, and commenced ~100.000 years prior to the ETE with intrusive activity. This, together with a newly proposed correlation of TJB successions based on a combination of biotic (palynology and ammonites), geochemical ($\delta^{13}C_{org}$) and radio-isotopic constraints, has an impact on the chain of events during and after the ETE. The biotic crisis is generally explained by massive input of CO_2 and/or methane to the atmosphere from the CAMP. Indeed, both calcareous and organic $\delta^{13}C$-records across the TJB indicate that large scale emissions of isotopically light carbon to the atmosphere took place at that time. Stomatal proxy data of terrestrial plant fossils, as well as loss of calcifying marine organisms point to intense global warming and ocean acidification across the TJB. However, there are other known environmental stressors that may also have been emitted during the CAMP volcanism, e.g. SO2, flourides, PAH, and heavy metals. By investigating proxy records and the temporal development across the ETE, we explore whether these potentially lethal substances also played a part in the extinction scenario.

NOTES

Considering the impact of SO_2 on plants across the Triassic–Jurassic boundary

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Sulphur dioxide is increasingly linked to several mass extinction events in the Phanerozoic as a potential causal mechanism, or at least an excesserbator. However, due to its transient nature, it is difficult to find evidence of its action in the fossil record. Two recently developed plant proxies (leaf shape changes and cuticle scarring patterns) have recently been used to provide potential evidence of SO_2 action across the Triassic–Jurassic boundary in a well-preserved fossil flora from East Greenland. Simulated palaeoatmospheric controlled environment experiments (control: CO_2 380 ppm; elevated SO_2: CO_2 380 ppm and SO_2 200 ppb; simulated TJB: CO_2 1500 ppm, SO_2 200 ppb) also reveal significant shifts in leaf mass per area and other aspects of plant development. These experiments revealed that exposure SO_2 promotes clear shifts in plant function and leaf mass per area (fig 1 below) for a series of Mesozoic nearest living equivalent taxa. All species showed a statistically significant (at least $p < 0.01$) decrease in LMA on exposure to elevated SO_2 and a general rebound to greater LMA values in the simulated TJB treatment, but still usually lower than in the control treatment. These changes in LMA, triggered by variations in atmospheric composition, may be tracked in the fossil record, potentially providing an additional tool for identifying the action of SO_2 on fossil floras. Together these techniques highlight that SO_2 was likely to have had a non-trivial role on local to regional plant-responses across this mass extinction boundary, and this may have implications for interpreting other periods of climate change in the Phanerozoic.

(a) (b)

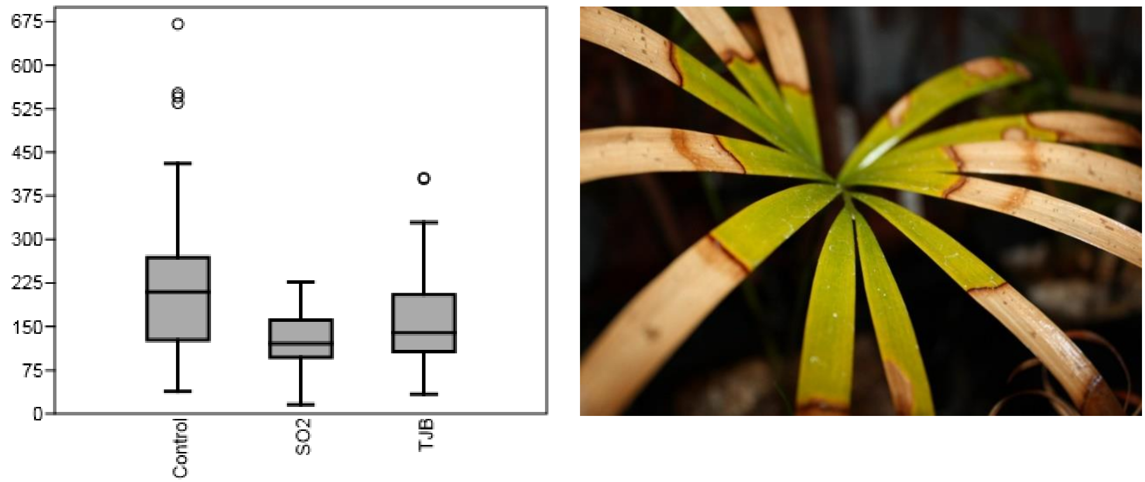

Figure 1: (a) Example leaf mass per area responses of nearest living equivalnet (*Agathis australis)* taxa when exposed to control, elevated SO_2 and simulated TJB palaeoatmosphere (b) visible leaf damage to *Lepidozamia hopei* when exposed to elevated SO_2

NOTES

Testing biotic recovery from the early Toarcian (Lower Jurassic) extinction event

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The Toarcian Oceanic Anoxic Event (TOAE) and associated marine mass extinction have attracted a great deal of research effort, focusing primarily on the causal mechanisms. In contrast, there is less known of the patterns of biotic recovery following this mass extinction (and others). Yet such recoveries are of interest as they record how surviving organisms radiate into newly vacated ecospace. The Cleveland Basin, North Yorkshire, has one of the most expanded Toarcian rock sections. Previous studies have presented a limited view of the recovery interval as the upper Toarcian sequence across much of the basin was truncated by a period of erosion during the Middle Jurassic. However, the Ravenscar coastal section preserves all of the upper Toarcian stratigraphy. We sampled 45 m of this section and recorded 24,006 benthic and nektic macrofossils, giving us new range data, and allowing, for the first time, a full evaluation of the biotic recovery from the TOAE. Results show that the recovery interval was overprinted by a regressive marine sequence with pre-extinction levels of diversity attained and exceeded around 5 million years after the extinction horizon.

NOTES

The Early Toarcian mass extinction in the eastern epicontinental Tethys (NW Bulgaria)

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The early Toarcian was characterised by severe environmental perturbations, notably the development of an Ocean Anoxic Event (T-OAE) and potentially ocean acidification, and extinction event amongst marine invertebrates. Despite the global nature of these environmental changes, the majority of supporting geochemical and palaeontological records come from the Western European epicontinental sections. Here we present the most easterly European record of environmental change using new stable carbon and oxygen isotope record from Lower Jurassic sections in the Balkan Mountains, NW Bulgaria, which record conditions from a range of settings spanning the inner shelf to deep basins. We also present the first record of the early Toarcian Mass extinction event in Bulgaria.

The Bulgarian $\delta^{13}C$ and $\delta^{18}O$ profiles from belemnites show similar trends through the Lower Jurassic to coeval European sections, suggesting that Bulgaria was directly linked to global palaeoclimatic and palaeooceanographic conditions during this time. Analysis of the $\delta^{13}C_{bel}$ record reveals a positive shift of 3‰ in the Early Toarcian that correlates with a similar excursion seen in many locations at this time. However, the characteristic negative shift in $\delta^{13}C$, often record in the organic C record, is not evident in Bulgaria. Our ongoing work aims to assess $\delta^{13}C_{org}$ during the T-OAE to identify if a negative excursion occurred in this part of the Tethys Ocean. The Bulgarian $\delta^{18}O_{bel}$ isotopes record a cooling in the late Pliensbachian and then a rapid warming event, through the E-TOAE, marked by a 2‰ negative shift.

Facies analysis in the Bulgarian sections shows only a weak manifestation of dysoxia and only in deeper basinal areas, coincident with peak TOC contents of 1.2% in the *falciferum* Zone. Although the early Toarcian extinction often coincides with the spread of anoxia, this link is not clearly seen in Bulgaria. Other factors such as rapid warming may have been more important in this central Tethyan region.

NOTES

Modelling the ecological determinants of extinction across Mesozoic hyperthermal events

Alexander M. Dunhill

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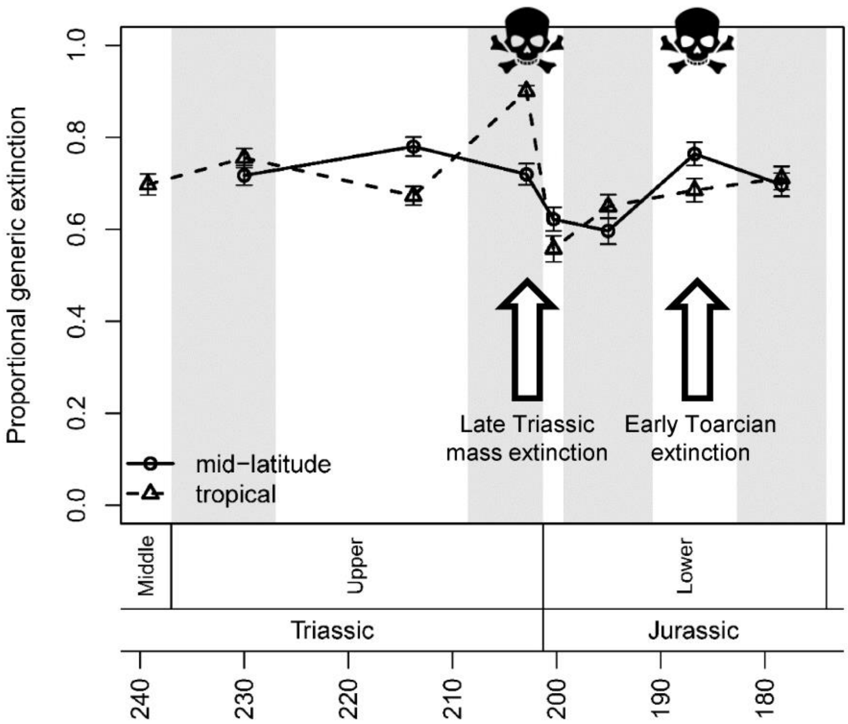

The Mesozoic Era witnessed a number of rapid warming events, known as hyperthermals, which are associated with Large Igneous Province eruptions. During the time of the supercontinent Pangaea, hyperthermals consistently result in mass extinctions as a direct consequence of warming, anoxia and acidification in the oceans. Here, I model determinants of extinction across two hyperthermal extinction events, the Late Triassic mass extinction and the early Toarcian extinction, in comparison to periods of background extinction during the Late Triassic and Early Jurassic. The Late Triassic mass extinction and the early Toarcian extinction resulted in a change in macroevolutionary regime that was not simply an intensification of background extinction rates. During the Late Triassic mass extinction, organisms living at tropical latitudes were predominantly affected as well as organisms inhabiting reef environments with predatory, suspension-feeding, or photosymbiotic lifestyles. During the early Toarcian extinction, photosymbiotic organisms and organisms residing in reef environments in the Tethys Ocean were highly prone to extinction. Despite the differences between Mesozoic and modern oceans, these results highlight the vulnerability of tropical reef ecosystems in a rapidly warming world.

NOTES

Strong avian ecological selectivity across the K-Pg: Evidence from lifestyle and body size

Daniel J. Field[1], Antoine Bercovici[2], Vivi Vajda[3], Jacob S. Berv[4], Jacques A. Gauthier[5]

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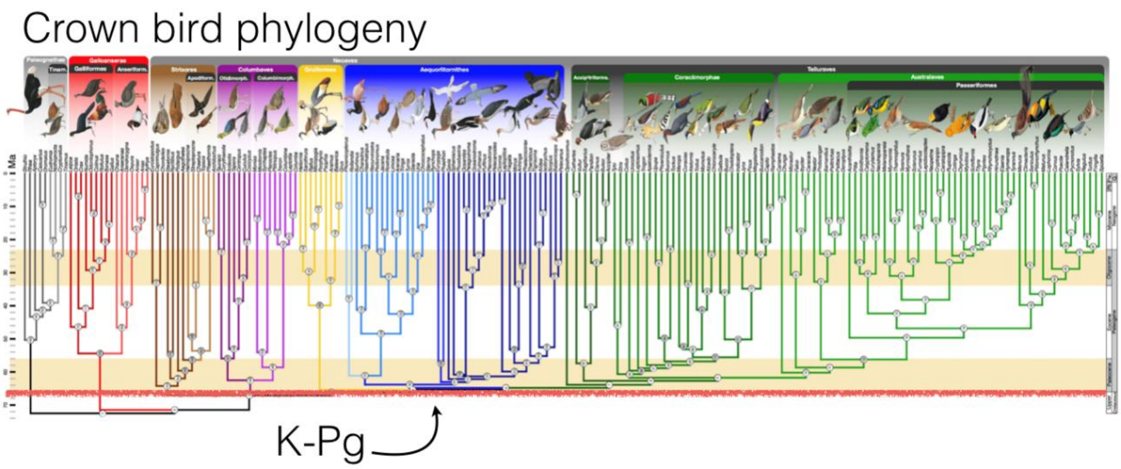
[5]*Yale University*

The fossil record and molecular divergence time analyses support a rapid diversification of crown birds in the earliest Cenozoic, following a limited initial diversification in the Late Cretaceous. These findings generate important questions regarding the mechanisms responsible for the survival of the deepest lineages within the avian crown across the K-Pg, as this mass extinction completely eliminated even the crownward-most members of the avian stem group. At the same time, a sparse early Paleocene fossil record demands an integrative approach to shed light on how and why crown birds made it through the K-Pg transition. We combine allometric approaches, ancestral state reconstructions, sedimentological data, and avian ecomorphology to reveal strong selective biases among birds across the K-Pg boundary. These approaches provide a unified model of avian ecological selectivity coincident with the K-Pg, supporting a short-lived but macroevolutionarily significant Lilliput Effect and strong selectivity for predominantly terrestrial lifestyles among avian mass extinction survivors. This filtering has left a discernable, though cryptic signature in avian macroevolutionary datasets. Our integrative approach emphasizes how tenuous avian survivorship was in the aftermath of the K-Pg, and provides the clearest picture yet of the mechanisms underlying the Cenozoic bird radiation.



NOTES

Near coincidence of maximum Deccan volcanism with the Cretaceous-Paleogene boundary : evidences from U-Pb geochronology and mercury anomalies

Thierry Adatte[1], Gerta Keller[2], Eric Font[3], André Mbabi Bitchong [4], Blair Schoene[2], Kyle Samperton[5] and Michael P. Eddy[2]

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(2)Department of Geosciences, Princeton University, Guyot Hall, Princeton, NJ 08544, USA
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Mercury (Hg) as indicator of large-scale volcanism in marine sediments provides new insights into relative timing between biological and environmental changes, mass extinctions and delayed recovery. The bulk (80%) of Deccan Trap eruptions occurred over a relatively short time interval in magnetic polarity C29r. U-Pb zircon geochronology reveals that the onset of this main eruption phase around 250 ky before the Cretaceous-Paleogene (KPg) mass extinction and continued into the early Danian suggesting a cause-and-effect relationship. We investigate the mercury (Hg) contents of 15 KPg sections. In all sections, results show Hg concentrations are more than 2 orders of magnitude greater during the last 100ky of the Maastrichtian up to the early Danian P1a zone (first 380 ky of the Paleocene). These Hg anomalies are correlative with the main Deccan eruption phase. At Gams (Austria), Bidart (France) and Elles (Tunisia), Hg anomalies correlate with high shell fragmentation and dissolution effects in planktic foraminifera indicating that paleoenvironmental and paleoclimate changes drastically affected marine biodiversity. Hg isotope data from Bidart support a direct fallout from volcanic aerosols. PGEs data from Mishor Rotem (Israel) from the KPg transition provide some important clues about the Hg deposited in the KPg layer, which appears to be more linked to volcanism than impact, suggesting a major pulse of Deccan activity just before and at the KPg that resulted in rapid climate warming and ocean acidification, increasing biotic stress that predisposed faunas to eventual extinction at the KPg.

NOTES

The role of ocean acidification in the marine extinctions at the Cretaceous/Paleogene boundary

Hart, M.B.[1], Leighton, A.D.[1], Hampton, M.[2] & Smart, C.W.[1]

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Planktic foraminifera, calcareous nannofossils and the early chambers (protoconchs) of ammonites were affected by the end-Cretaceous extinction event in a way that implies a near-surface water acidification event coincident with the Chicxulub impact. Analysis of astronomically-driven cycles across the boundary in the Brazos River area shows that this acidification event was short-lived and that recovery began ~30,000 years after impact and that significant recovery of the water column biota had occurred around 80,000–85,000 years after the impact (Figure 1). It was only the surface waters that were affected as 1) benthic foraminifera living in 50–75 m water depth show no signs of dissolution or fragmentation, 2) deeper-living nautiloids were unaffected and 3) the low pH surface waters would have begun mixing after around ~30,000 years allowing improvements in water quality and the recovery of the surviving planktic groups. Organic-walled microfossils, across the same interval, were not affected.

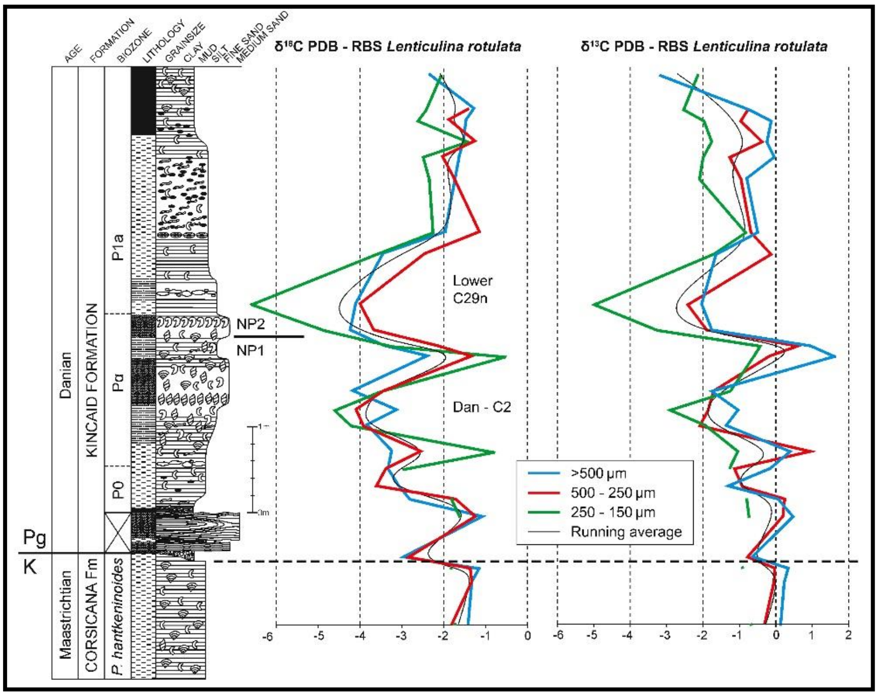

Figure 1. Stable isotope analysis of monospecific samples of foraminifera across the K/Pg boundary at Riverbank South (Figure 2). Early Paleocene hyperthermals are indicated as Dan-C2 and Lower C29n. From Leighton *et al*., 2017, *Journal of Foraminiferal Research*, **47**, 229–238.

This information has been obtained from an investigation of the Brazos River area of Texas. The Cretaceous/Paleogene boundary has been studied in the main river near the Rt. 413 road bridge, Cottonmouth Creek, Darting Minnow Creek and a significant, recently described, exposure known as Riverbank South (Figure 2). Samples from the latter exposure have been investigated for foraminifera, calcareous nannofossils and dinocysts and these provide a comprehensive database on which to investigate both the rate of extinctions and recovery and the impact of ocean acidification at the boundary.

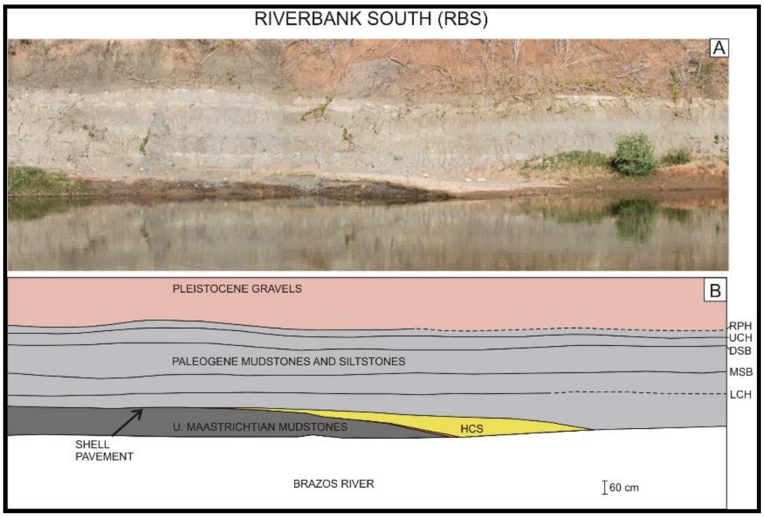

Figure 2. Photograph (A) of the K/Pg boundary exposed on the west side of the Brazos River at Riverbank South, with an interpretation (B) of the succession below.

NOTES

The recovery of marine phytoplankton cell size and biovolume in the aftermath of the Cretaceous-Paleogene mass extinction

[1]**Hojung Kim**, [2]Paul Bown, [3]Sam Gibbs, [4]Sarah Alvarez (Née O'Dea) and [5]Rosie Sheward

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[3]*University of Southampton*
[4]*University of Bristol*
[5]*Mount Allison University*
[1]*Hojung.kim.09@ucl.ac.uk*

The Cretaceous-Paleogene mass extinction eliminated over 70% of marine biota (Raup and Sepkoski, 1982) and the coccolithophores, one of the key marine phytoplankton groups, lost more than 90% of exisiting species. Their recovery in the early Danian was an important part of rebuilding of the marine ecosystem both in increasing biodiversity but also restoring ecosystem function, and, especially, the production and export of organic carbon. Here we focus on the record of coccolithophore lith and cell size because one of the most striking characteristics of the incoming Danian coccolithophore species is their unusually small size, producing coccoliths of around 1-3µm compared with the extinct Cretaceous taxa with average coccolith size of 8µm. The data come from a new K/Pg section from the North Atlantic Ocean- IODP Expedition 342 Sites U1403 and U1403 – that includes an intact spherule layer and a Danian succession with good microfossil preservation. Using observations of coccolith size and coccosphere geometry we document the trends and rates of cell size increase and recovery during the Danian. Furthur, by integrating cell size and population data we are able to reconstruct coccolithophore community biovolume and compare this with other proxies of recovering ecosystem function.

NOTES

Re-building the ocean ecosystem after the K/Pg mass extinction event

Sarah Alvarez (née O'Dea)[1*], Paul R. Bown[2], Samantha J. Gibbs[3], Hojung Kim[2], Andy Ridgwell[1]

*[1]University of Bristol, [2]University College London, [3]University of Southampton. *sarah.alvarez@bristol.ac.uk*

The Cretaceous/Paleogene boundary bolide impact triggered extinctions across all ecosystems but was rapidly followed by the emergence of many of the clades that underpin modern biodiversity. In the oceans, calcareous plankton were particularly hard hit, with their near-elimination a key part in the global collapse of marine primary productivity, loss of stable food webs and cascading extinctions. The robust, continuous and prolific fossil record of the keystone calcareous nannoplankton provides one of the most complete archives of this post-extinction world and allows us to quantify ecosystem reconstruction in the recovering marine environment. Here we present an unprecedented millennial-scale long-time-series nannoplankton population dataset, spanning 13 million years at ODP Site 1209 (Pacific Ocean). We use these data to assess long-term population variability using a suite of analytical approaches, including summed coeffiecient of variation, diversity and evolutionary rates metrics, and community cell size structure. The exceptional nature of the recovery interval is highlighted by the intensity of population variability that stands far above all other Paleogene biotic change. The post-extinction community is characterized by low diversity, high dominance plankton populations with successive acmes of short-lived, incoming taxa which, in the absense of any significant environmental forcing suggests an ecosystem driven by intrinsic biotic factors. Ecosystem stability is restored alongside increasing diversity, disparity and community cell size, and the eventual appearance of new specialized, oligotrophic populations. Our data document the process of re-building population and ecosystem resilience following near-annihaltion at the K/Pg boundary, and the eventual role of abiotic forcing in driving ecosystem and evolutionary dynamics throughout the remainder of the Paleogene.

NOTES

RECOVERY OF LIFE FROM THE GREATEST MASS EXTINCTION OF ALL TIME

Mike Benton
University of Bristol

The aftermath of the great end-Permian mass extinction, 252 million years ago, shows how life can recover from the loss of >90% species globally. The initial causes of the catastrophe continued to devastate Early Triassic environments and slowed the biotic recovery. Huge attention is currently focused on the exceptional Permo-Triassic rock successions in China, which document the recovery step-by-step. In addition, novel phylogenetic-macroevolutionary methods are being applied to this greatest-of-all 'adaptive radiations'. How did the successful post-extinction clades respond to the opportunity, and build up the fundamentals of modern ecosystems?

- Benton, M.J., Forth, J., and Langer, M.C. 2014. Models for the rise of the dinosaurs. *Current Biology* 24, R87-R95 (doi: 10.1016/j.cub.2013.11.063).
- Benton, M.J., Zhang, Q.Y., Hu, S.X., Chen, Z.Q., Wen, W., Liu, J., Huang, J.Y., Zhou, C.Y., Xie, T., Tong, J.N., and Choo, B. 2013. Exceptional vertebrate biotas from the Triassic of China, and the expansion of marine ecosystems after the Permo-Triassic mass extinction. *Earth Science Reviews* 123, 199-243 (doi: 10.1016/j.earscirev.2013.05.014).
- Chen, Z.Q. and Benton, M.J. 2012. The timing and pattern of biotic recovery following the end-Permian mass extinction. *Nature Geoscience* 5, 375-383 (doi: 10.1038/ngeo1475).
- University of Bristol: http://palaeo.gly.bris.ac.uk/PTB/

NOTES

POSTER ABSTRACTS

(in alphabetical order)

Archosauromorph extinction during the Triassic-Jurassic mass extinction was not related to body size

Bethany J. Allen[1,2], Mark N. Puttick[2,] Thomas L. Stubbs[2] and Michael J. Benton[2]

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Previous mass extinctions destroyed swathes of standing diversity but many of the evolutionary patterns during these events are not known. Currently, it is not clear whether species' traits or lifestyle made them more vulnerable to extinction during these events, or if mass extinctions were random killers that did not act according to the rules of background selection. Most evidence indicates previous mass extinction did not act on body size, but in modern vertebrates larger species have greater extinction risk. We investigated whether body size selectivity played a role in the survival and extinction of Archosauromorpha during the Triassic-Jurassic mass extinction. Using a novel approach, we estimated a new archosauromorph maximum likelihood supertree that incorporates phylogenetic uncertainty. We used phylogenetic comparative methods to test if more closely-related species were more likely to go extinct during the Triassic-Jurassic event, and if larger species were more prone to extinction. We found that there was a significant phylogenetic signal in extinction during the Triassic-Jurassic mass extinction, but that there is no correlation between body size and extinction. Previous mass extinctions did not act under body size selectivity, and current extinction risks may differ from those in deep time.

Photic zone euxinia at the end-Triassic mass extinction event: a study of sediments from Felixkirk Borehole in the Cleveland Basin, North Yorkshire.

Sarah Beith[1], Jessica Whiteside[1], Darren R. Gröcke[2], John Marshall[1]

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The end-Triassic mass extinction event (ETMEE) ~202 million years ago was plausibly triggered by CO2 release from giant flood basalt eruptions and associated intrusions of the Central Atlantic Magmatic Province. In this study, we use a multi-proxy approach based on lipid biomarkers and published palynological data to reconstruct a continuous high-resolution geochemical record of environmental conditions preceding the ETMEE, during the extinction event and during the recovery phase. In particular, fossil derivatives of the specific pigment isorenieratene (derived from green sulphur bacteria, Chlorobiaceae) are used in conjunction with a suite of redox-sensitive biomarkers. This study was designed to test the hypothesis that nutrient cycle disruption and water column stratification produced widespread photic zone euxinia during the ETMEE, potentially acting as an oceanic global kill mechanism.

Samples of Rhaetian sediments from Felixkirk Borehole were studied, which is located on the western margin of the Cleveland Basin, North Yorkshire. This borehole provides a nearcontinuous sedimentary record across the ETMEE. Carbon isotope analysis of bulk sedimentary organic matter (□13Corg) show a sudden large negative carbon isotope excursion (CIE) from –23.34‰ to –28.77‰ at a borehole depth of 288.94 m. This excursion has previously been recognised in many global sedimentary sections, hence confirming the presence of the Triassic-Jurassic boundary as defined by the carbon cycle. Preliminary biomarker data shows the presence of isorenieratane and aryl isoprenoids in abundance, along with gammacerane. From this we infer that the depositional environment of the ETMEE at Felixkirk Borehole was euxinic.

Modelling the effect of spatial fossil bias and its impact on dinosaur palaeodiversity estimates in the latest Cretaceous of North America

Alfio Alessandro Chiarenza[1], Philip D Mannion[1], [2]Dan Lunt, [3]Sarah-Jane Kelland, [1]Peter A Allison

[1]Imperial College London; [2]University of Bristol; [3]GETECH Plc; a.chiarenza15@imperial.ac.uk

Analyses of dinosaur diversity patterns through time have offered different interpretations of important biotic events, such as the lead up to the Cretaceous/Paleogene (K/Pg) mass extinction. Although the general consensus suggests a sudden extinction at the K/Pg boundary, some studies have proposed a slow diversity decline of up to tens of millions of years. One of the main methodological obstacles when interpreting these diversity analyses is the estimation of the impact of spatial bias. Ecological niche modelling, using species occurrences and climatic data to reconstruct habitat distribution through space, offers a possible solution for interpolating biogeographic patterns in the presence of fragmentary information, helping to integrate models of distributional patterns from unsampled areas. We combined latest Cretaceous dinosaur occurrences with a high-resolution palaeogeographic atlas. A time series analysis of North American species distribution models was developed from the early Campanian to the late Maastrichtian. The ecological niches modelled on available outcrop area through time show a decline for non-avian dinosaur clades, mirroring the diversity trends based on previous analyses. However, when continental projections are considered (incorporating unsampled regions), the pattern shifts dramatically, showing an overall increase in niche suitability from the Campanian to the Maastrichtian. These results hint at a hidden diversity of dinosaurs in the Maastrichtian, and support the view that dinosaurs were unlikely to have been in decline prior to the K/Pg boundary. We suggest that tectonic and eustatic drivers might be the major causes of the geological biases affecting the latest Cretaceous North American dinosaur record.

Ectothermic vertebrate diversity dynamics across the K-Pg boundary

Terri J. Cleary, Philip D. Mannion and Paul M. Barrett

Natural History Museum, University College London and Imperial College London (t.cleary@nhm.ac.uk)

The K-Pg boundary has been the focus of a wealth of studies because of its severe and wide-reaching impact on both terrestrial and marine life. Many analyses have examined its effect on the taxonomic richness of various animal groups, but often fail to account for the inherent biases in the fossil record. We examined the generic richness of non-marine ectothermic vertebrates (lepidosaurs, turtles and crocodiles) across the boundary, using Shareholder Quorum Subsampling (SQS) to ameliorate problems with uneven sampling. Unfortunately, after applying SQS, the only continuous signals we recover are from North America. Lepidosaurs were the most severely affected: larger-bodied forms became extinct, and richness decreased across the boundary and recovered slowly. Crocodiles and turtles were less affected, and we recover a rise in richness for both groups. Turtles in particular appear to have flourished in the earliest Paleogene of North America. Variation in responses likely corresponds to differences in each taxon's ability to cope with the dramatic climatic changes caused by the event, and their ability to colonise newly empty niches. It is possible that lepidosaurs initially struggled to compete with mammalian taxa for similar niche spaces compared to the other two ectothermic groups. Given our lack of detailed data from other continents, it is important that we continue to look for fossil ectotherm taxa outside of North America from either side of the boundary (but particularly from the Paleogene), in order to investigate if ectotherm responses to the K-Pg event were globally homogeneous.

Redox constraints and sulphur cycling across the Permian–Triassic transition in the southern margin of the Boreal Ocean

Laura Crick*†, Colin Mettam†, Aubrey L. Zerkle† and Richard J. Twitchett‡

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The latest Permian to earliest Triassic transition marks a cataclysmic extinction and protracted recovery. One mechanism that has been proposed in recent decades as a contributing factor for such a large-scale disaster is a change in the redox state of the oceans. Here, we applied the iron (Fe) speciation and sulphur isotope ($\delta^{34}S_{pyr}$) redox proxies to ancient sediments from East Greenland that record water column conditions in an isolated embayment of the Boreal Ocean. The well-established Fe speciation proxy allows the distinction between oxic and anoxic water column conditions and can further subdivide anoxia into ferruginous (Fe^{2+}-rich) or euxinic (sulphide-rich) depositional settings. Our results show persistently ferruginous conditions present throughout the section following marine ecosystem collapse and into the earliest Triassic. In addition, sulphur isotope ($\delta^{34}S_{pyr}$) analyses on extracted pyrite are mostly consistent with microbial sulphate reduction (MSR) with limited reoxidative sulphur cycling, supporting expanded local anoxia in late Permian seas. These data - in comparison with recently published records of dynamic redox conditions in the Neo-Tethyan Ocean[1] - indicate that this region of the Boreal Ocean was more strongly influenced by local rather than global environmental changes due to the embayment's isolated nature. We suggest that the protracted recovery from the Permian-Triassic extinction could have been due to continuing environmental instability in the earliest Triassic, with implications for the spread of anoxic zones and modern marine ecosystems today.

[1] Clarkson M. O., Wood R. A., Poulton S. W., Richoz S., Newton R. and Kasemann S. A. (2016) *Nat. Commun.* **7**, 1–9.

Reconstructing trophic networks across the early Toarcian Ocean Anoxic Event (Lower Jurassic)

Karolina Zarzyczny[1], Jed Atkinson[2], Crispin T.S. Little[2], and **Alexander M. Dunhill[2]**

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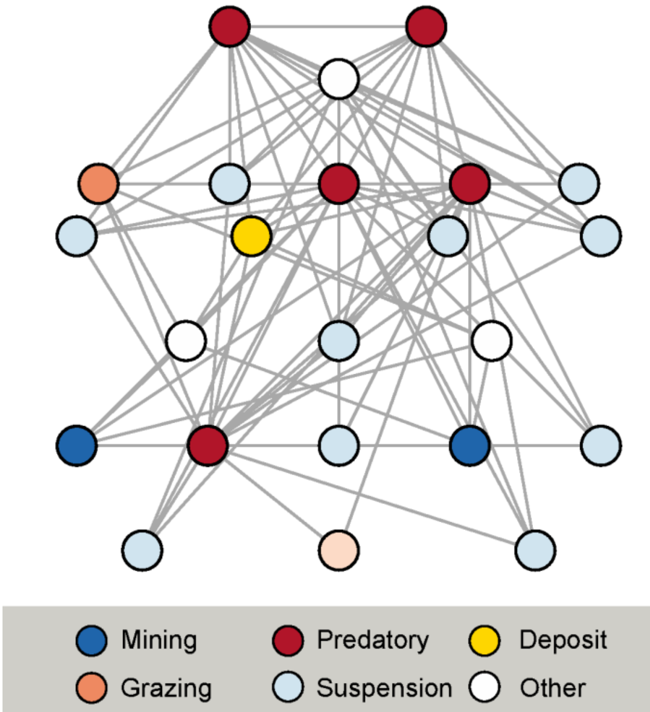

Trophic guild diversity, connectivity, and robustness of trophic networks decreases across the Early Toarcian Ocean Anoxic Event. We focus on the reconstruction of trophic network dynamics across the early Toarcian extinction event; which is thought to have been driven by an Ocean Anoxic Event. The analysis is based on a field database collected from the Pliensbachian-Toarcian of the Yorkshire Coast, with 162 macrofossil species assigned to trophic guilds using the Bambach ecospace model. Although there is limited evidence for the decoupling of pelagic and benthic ecosystems, there is a major loss of motile, metabolically demanding benthic fauna. Network connectivity is greater in the late post-extinction recovery than in pre-extinction, although the number of guilds remain equal. This is likely due to the appearance of new predatory guilds that display a high degree of centrality, i.e. well connected to other nodes, in the networks. The results suggest that the early Toarcian extinction event was likely a top-down extinction with metabolically demanding benthic guilds, such as motile predators, disappearing during the Ocean Anoxic Event, as they were more sensitive to dysoxic and anoxic conditions than stationary benthic faunas with lower metabolic demands.

Red Queen ousts Court Jester: Decreasing environmental influence on the Phanerozoic success of marine calcifiers

Kilian Eichenseer[1*], Uwe Balthasar[1], Christopher Smart[1], Julian Stander[2], Wolfgang Kiessling[3]

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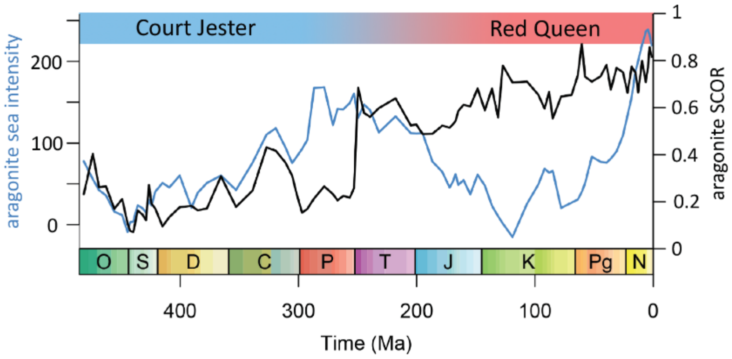
**presenting author, E-mail address: kilian.eichenseer@plymouth.ac.uk*

Environmental influences on macroevolution are apparent in the fossil record, but their relative importance may have changed through time. We investigate this hypothesis using the vast Phanerozoic fossil record of marine calcifiers. Calcifying organisms build their shells from calcite and/or aragonite, and the metabolic cost of shell secretion is influenced by the interplay of mineralogy and environment. Mg:Ca ratio and temperature control whether abiotic calcium carbonate is precipitated as calcite or aragonite, and variations in those conditions are likely to have affected calcifying organisms throughout Earth history. Here, we combine a model of seawater Mg:Ca ratio with $\delta^{18}O$ temperature reconstructions to quantify calcite-aragonite sea conditions from the Ordovician – Pleistocene. We correlate calcite-aragonite sea conditions with the ecological success of aragonitic taxa at stage resolution, calculated as Summed Common species Occurrence Rate (SCOR) based on genus-level occurrences from the Paleobiology Database. Calcite-aragonite sea conditions significantly co-vary with the ecological success of aragonitic taxa in the Palaeozoic, but correlation ceases in the Mesozoic (see figure). We attribute this to the escalation of marine life through time: The end-Permian mass extinction and subsequently the Mesozoic Marine Revolution led to the prevalence of increasingly mobile, metabolically active, and predatory taxa. Consequently, a Palaeozoic Court Jester world, in which environmental constraints shaped the success of marine calcifiers, gave way to the modern Red Queen world, where biotic interactions reign. We expect that this shift also increased the resilience of marine communities to environmentally induced mass extinctions.



Aragonite sea intensity (blue) and the relative success, SCOR, of aragonitic taxa (black) in 85 Ordovician – Pleistocene stages. Correlation is significant in the Palaeozoic (Court Jester world), but not in the Meso- Cenozoic (Red Queen world).

Lithium isotopes as a proxy for weathering intensity during the Late Devonian

Ronald Guthrie, Stuart Robinson, Hugh Jenkyns, Mel Murphy

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The Late Devonian was an interesting interval of time in which complex vegetation was evolving throughout the terrestrial realm, periodic anoxia associated extinction was occurring in the world's oceans, along with a presence of magmatism from the Viluy Traps. It is therefore of interest to understand how weathering intensity changed over this period and the effect this would have had on palaeoclimate, as the long term carbon cycle removes CO_2 from the atmosphere and stores it as sedimentary rock. Using lithium isotopes as a proxy, it is possible to determine whether the intensity of weathering is related to congruent weathering (transport limited) or incongruent weathering (chemically limited). Preliminary lithium isotope data from Frasnian-Famennian carbonates of Kowala quarry, Poland, and Steinbruch Schmidt, Germany, will be presented to demonstrate how weathering intensity varied over this period.

Effects of the end Triassic mass extinction event on insect diversity and ecology

Richard S Kelly, Mike Benton and Andrew Ross
University of Bristol and the National Museum of Scotland, Edinburgh

The fossil record is not a perfect record of past life but it does give us important insights into how specific events affected the diversity and evolution of organisms through time. Insects are one of the most diverse and important groups of animals in terrestrial ecosystems and this is thought to have been true throughout their evolutionary history. The main aims of this project were to develop understanding of insect assemblages through the Late Triassic and Early Jurassic to analyse the effects of the end Triassic mass extinction on insect diversity and ecology. Global collections of fossil insects were assessed but most of them are not suitable and require further stratigraphic work. British deposits provide well aged and abundant fossils from around the event and so were the focus of the project. Museum collections were utilised to construct the first taxonomically revised species level dataset of insect occurrence from this time. This dataset allowed us to reconstruct insect assemblages from before and after the event and to compare them to assess the impact of the mass extinction on insects.

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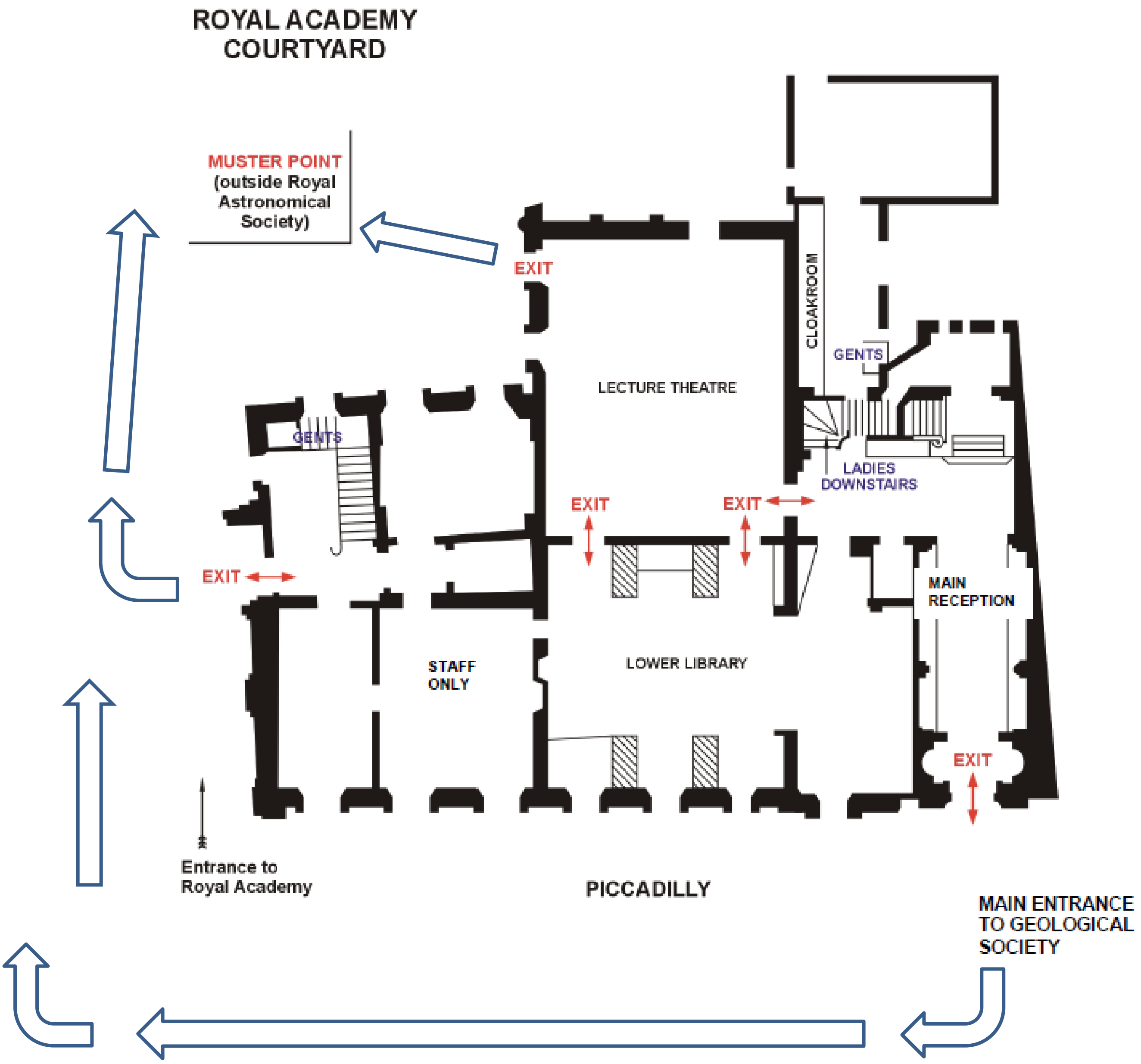
Ground Floor Plan of the Geological Society, Burlington House, Piccadilly



Geological Society 2018 Conferences

Date	Title	Location
09-10 April	Lithium: From Exploration to End-User	Burlington House
29-30 May	Eastern Mediterranean —An emerging major petroleum province	Burlington House
June	William Smith: Mineral resources at the frontier	Burlington House
05-07 June	Advances in Production Geoscience as an enabler for maximising economic recovery and ensuring a future for the UKCS	Aberdeen
08-09 October	Interplay of heatflow, subsidence and continental break-up: a case study workshop	Burlington House
10-11 October	Seismic Characterisation of Carbonate Platforms & Reservoirs	Burlington House
24-25 October	Geology of Fractured Reservoirs	Burlington House
31 October — 01 November	Marine Minerals: A New Resource for the 21st Century	Burlington House
November	Geological Society Careers Day	Nottingham
November	Geological Society Careers Day	Edinburgh
07-08 November	Operations Geoscience Adding Value	Burlington House

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https://www.geolsoc.org.uk/Events/Society