Contents

This meeting is a contribution from the Joint Committee for Paleontology for the Geological Society's 'Year of Mud'.

We gratefully acknowledge the financial support of the following organizing partners and sponsor for making this meeting possible:

Organising Partners:

Sponsor:

Acknowledgements: We would also like to thank Jess Aries and Naomi Newbold in the conference office at the Geological Society for their considerable help and expertise in organising the logistics for this meeting.

Lyell Meeting 2015: Mud, glorious mud and why it is important for the fossil record

Image source: Angela L. Coe

Bositra radiata, an opportunistic bivalve that survived the environmental change associated with the onset of the Toarcian Oceanic Anoxic Event, from Yorkshire, UK. Scale=12 cm across.

Introduction

Mudrocks provide an unrivalled medium for the preservation of fossils. This exceptional preservation has in turn enabled significant scientific advances in the functional morphology and evolution of biota throughout life history and a high resolution record of the ways in which biota adapt and evolve during environmental change.

It has long been observed that mudrocks yield abundant, diverse and well-preserved micro- and macro-fossils. Almost all of the strata yielding fossils with soft parts preserved are also from mud-grade deposits. More recent studies have discovered that the seawater chemistry at the time of deposition remains largely unaltered in shells preserved in mudrocks. This enables these fossils to be used as proxies for important Earth surface parameters such as water temperature, salinity, ice volume, rate of chemical weathering and pH.

The role of mudrocks in providing an ideal medium for understanding life throughout geological time also applies to lake deposits where terrestrial palynomorphs provide us with records of vegetation change in response to climatic fluctuations. The relative stratigraphical completeness of most mudrock successions makes them ideal for high-resolution studies and hence for understanding the rock record on biological timescales.

Angela L. Coe (The Open University, UK) and
Alan Lord (Senckenberg Naturmuseum, Germany)

Linked Public Lecture

Geological Society London Lecture Series

The Cambrian Alum Shales of Scandinavia and their remarkable trilobites
Tuesday 10 March 2015

Euan N.K. Clarkson – University of Edinburgh, UK

During the Cambrian the large continent of Baltica (including modern Scandinavia) lay isolated in the southern hemisphere. The Lower Cambrian of Baltica consists mainly of sandstones, but in the Middle and Upper Cambrian (Furongian) a muddy sequence known as the Alum Shales were deposited. Whereas the Middle Cambrian carries a rich and diverse trilobite fauna, oxygen levels dramatically decreased thereafter, and the uppermost Middle Cambrian bears a fauna consisting only of a single species of agnostoid, *Agnostus pisiformis.* In the following Furongian, the faunas were dominated by the olenid trilobites, adapted to dysoxic conditions. The Furongian of southern Sweden forms a superb natural laboratory for studying processes and patterns of evolution in the olenids. The rapid turnover of species and superb preservation of the fossils, both in shales and in carbonate concretions, allows evolutionary changes to be assessed both at the micro- and the microevolutionary scale. Also, the dynamics of the evolving faunas can be assessed and their relations with environmental fluctuations established by bed-by-bed collecting and analysis. Moreover since all trilobite growth stages often occur along with the adults, it is possible to establish the complete or partial ontogeny (individual development from the larval stages onwards) of many species, and to explore the relationships between ontogeny and phylogeny. All these separate dimensions will be considered here and particular attention will be given to adaptations of various olenids, and the functions, for example of the extreme spinosity which characterises some genera. Information gained from various lines of evidence from the faunas can be used, along with geochemical approaches to build up a coherent picture of an extinct muddy environment and its inhabitants (which include brachiopods at certain levels, and superbly preserved agnostoids and small phosphatised arthropods). The olenids persisted to the end of the Ordovician but lost their dysoxic adaptations and became part of the normal trilobite fauna.

Biography
Professor Emeritus Euan Clarkson graduated from Cambridge University in 1960, and subsequently continued as a PhD student on trilobite functional morphology, graduating in 1964. Meanwhile he had obtained a lectureship in palaeontology at Edinburgh University in 1963, rising to Reader in 1981 and Professor in 1998, retiring in 2002. His textbook 'Invertebrate Palaeontology and Evolution' ran to four editions, the last being 1998. He continued to work on trilobites, especially vision, functional morphology, ontogeny and taxonomy throughout his career, but also on the Lower Palaeozoic faunas and environments of the Midland Valley of Scotland and Ireland, and two crustacean-bearing Carboniferous Lagerstätten near Edinburgh (in one of which the first conodont animal was found in 1982). As well as several field guides on Scottish geology he produced two books with his igneous colleague Brian Upton 'Edinburgh Rock. The Geology of Lothian' (2006) and 'Death of an Ocean; A Geological Borders Ballad' (2010) both published by Dunedin Press. His main work at present is on Cambrian faunas and environments in Scandinavia, with colleagues from Lund University, Sweden and the visual systems of early arthropods, with Cologne-based physiologist Brigitte Schoenemann. He holds a DSc from Edinburgh and is a Fellow of the Royal Society of Edinburgh.

Programme

09.00	Registration, tea and coffee
09.25	**Opening remarks**
09.30	**The Kimmeridge Clay and the Etches Palaeontological Collection: A treasure trove of Jurassic biodiversity** David Martill (University of Portsmouth)
10.00	**Mudrocks as sanctuaries for enhanced preservation of skeletal morphology and mineralogy in fossil bryozoans** Paul Taylor (Natural History Museum)
10.30	**KEYNOTE:** **Mud, microbes and mineralisation: Mediating exceptional fossil preservation over geological time** Derek Briggs (Yale University)
11.15	Tea, coffee and poster session
11.45	**Toarcian mudrock biofacies: Where palaeontology meets geochemistry** Crispin Little (University of Leeds)
12.15	**Computational and human classification of pollen grains** Luke Mander (University of Exeter)
12.45	Lunch break and posters **(no lunch provided for delegates)**
14.00	**Mudrocks and plant fossils: Exploring a rich archive** Volker Wilde (Senckenberg Naturmuseum)
14.30	**Organic matter in mudrocks: Another form of exceptional preservation** John Marshall (University of Southampton)
15.00	**Revealing terrestrial environmental change: Big lakes, multi-proxies and challenges** William Gosling (University of Amsterdam)
15.30	Tea, coffee and poster session
16.00	**Exceptional preservation of carbonate microfossils in clay: Implications for palaeobiology and palaeoclimate** Paul Pearson (Cardiff University)
16.30	**From Cells to Species: Using exceptionally preserved coccolithophores to reconstruct biology and biogeochemistry** Samantha Gibbs (University of Southampton)
17.00	**Mud: Food for thought** Nick McCave (University of Cambridge)
17.30	**Closing remarks**
17.35	Drinks reception

Speaker Abstracts

The Kimmeridge Clay and the Etches Palaeontological Collection: A treasure trove of Jurassic biodiversity

David M. Martill

School of Earth and Environmental Sciences, University of Portsmouth, Burnaby Road, Portsmouth, PO1 3QL, UK

The Upper Jurassic Kimmeridge Clay Formation is economically the most important geological resource in the UK being the major source of hydrocarbons in the North Sea sedimentary basins. Consequently, it has been subjected to considerable scientific scrutiny by stratigraphers, sedimentologists, geochemists (organic and isotopic) and palaeoecologists, amongst others and has *de facto* become the ‘typical’ organic-rich mudrock to which all others are compared and contrasted. Preservation of its fossils, as well as its hydrocarbons can be exquisite, and exposures on the Dorset Coast are rapidly being recognised as a fossil Konservat Lagerstätte. However, its vertebrate palaeontology has been somewhat neglected after an initial flurry of interest in the late 19^{th} century. This is remarkable considering the initial diversity recognised by such great 19^{th} Century workers as Sir Richard Owen, who documented several species of gigantic marine reptiles, dinosaurs and even pterodactyles.

For the last 30 years, amateur palaeontologist Mr Steve Etches MBE has been collecting Kimmeridge Clay fossils, mainly from along the Dorset Coast and has assembled the largest and most diverse collection from the formation in the country. Containing over 2000 accessions, the Etches collection represents an unrivalled resource for researches investigating the vertebrate and invertebrate palaeontology of the UKs most famous marine Jurassic formation. Among the collections’ treasures are brood cases with eggs of ammonites, a new genus and species of pterodactyle and fossil cirripedes that confirm Charles Darwin’s arguments on the origin of cemented barnacles.

In 2014 Mr Etches bequeathed the collection to the Kimmeridge Trust, a charitable body established to conserve, develop and curate the collection to exploit its educational and recreational potential. The Trust has received valuable support from The National Lottery Heritage Fund, Dorset County Council, Perenco, the Smedmore Estate and several private sponsors. The project will inject around £5 million into the local economy and includes the construction of a new, purpose built palaeontological museum. Work on the museum, and the development of a computer data base has begun, with opening scheduled for early 2016.

Kimmeridge Bay has always been an important locality for petroleum geologists and geology students to examine first hand a rock that they usually only see in seismic profiles, as chipping from boreholes, or have read about in case studies. From 2016 the Etches Collection will provide a unique opportunity to examine and be wowed by the fauna and flora of the UKs most valuable geological resource.

Mudrocks as sanctuaries for enhanced preservation of skeletal morphology and mineralogy in fossil bryozoans

Paul D. Taylor

Department of Earth Sciences, Natural History Museum, London, SW7 5BD, UK

Email: p.taylor@nhm.ac.uk

The Bryozoa is a phylum of benthic, colonial invertebrates abundant in shallow marine settings at the present-day. The rich fossil record of bryozoans extends back to the Early Ordovician. Most of the *c*. 2100 described bryozoan genera biomineralise elaborate calcareous skeletons that furnish nearly all of the characters employed in the taxonomy of both living and fossil taxa. A majority of these characters are at the level of the individual zooid (or below) and many involve structures as small as 10 µm in size. Palaeozoic bryozoans comprise predominantly extinct orders, tend to be found in well-lithified sediments and are usually studied in thin section. However, post-Palaeozoic bryozoans, which belong to two extant orders (Cyclostomata and Cheilostomata), demand adequate surface preservation for taxonomic study. Because of the pervasive growth of epitaxial cements and frequent neomorphism of the skeleton, specimens collected from carbonates and coarse-grained clastics seldom preserve pristine colony surfaces, whereas those from clays usually do.

The importance of mudrocks in preserving details of surface morphology is increasingly apparent in the light of molecular sequence data showing that subtle morphological differences can be key to recognizing clades, for example in diaperoeciid cyclostomes from New Zealand. A major reason for our poor knowledge of bryozoans in the post-Palaeozoic tropics is the impact of intense diagenesis on the preservation and visibility of small encrusting species. Muddy reefs, such as those found in the Miocene of East Kalimantan (Indonesia), consequently offer crucial windows on Cenozoic tropical bryozoan diversity. The routine preservation of aragonite in mudrocks means that they also provide the only way of tracing the evolution of aragonite biomineralization in cheilostome bryozoans, which are primitively calcitic but evolved aragonitic or bimineralic skeletons in several clades. Surprisingly, aragonite in cheilostomes first appeared in the calcite sea of the Late Cretaceous, and a study of cheilostome mineralogy in Eocene–Oligocene deposits of Mississippii and Alabama failed to show the expected increase in aragonite biomineralization at the time when aragonite sea conditions are believed to have appeared.

Mud, microbes and mineralisation: Mediating exceptional fossil preservation over geological time

Derek E.G. Briggs

Department of the Geology and Geophysics, Yale University, USA

Email: derek.briggs@yale.edu

Exceptional fossil preservations (Fossil-Lagerstätten) provide critical data on events in the evolution of life. The information we glean from them, however, is subject to bias depending on the processes involved in fossilization. The controls on soft-tissue preservation are hierarchical, ranging from global factors, to the depositional environment in a sedimentary basin, the chemistry of the entombing sediment, and the nature and composition of the organisms. Mud plays diverse roles in this hierarchy. At the global level sediment distribution and sea water composition promoted soft tissue preservation in the Cambrian and early Ordovician and may have impacted the Neoproterozoic fossil record. At the environmental and chemical levels mud affects the formation of authigenic minerals which replicate tissues and contribute to the formation of concretions. And experiments indicate that some clays inhibit the decay of soft tissues. Such considerations yield an overview of the influence of mud on the fossil record of the history of life.

Toarcian mudrock biofacies: Where palaeontology meets geochemistry

Crispin T.S. Little, Robert J. Newton and Ifeoma Agbi

School of Earth and Environment, University of Leeds, Leeds LS2 9JT, UK

The Toarcian-aged (Lower Jurassic) mudrocks of the Cleveland Basin form specular cliff exposures from Whitby to Robin Hood's Bay on the North Yorkshire coast. They comprise 90 metres of heterogeneous mudrocks, ranging from bioturbated silty grey shales to organic-rich (up to 20% TOC) laminated black shales, and host calcitic, pyritic and sideritic concretions of various sizes. The exposures are considered to be the 'type section' of the Toarcian Oceanic Anoxic Event (TOAE), which is intimately linked to one of the smaller scale mass extinction events in the Phanerozoic. Over the past few decades much effort has been expended analysing the Cleveland Basin Toarcian mudrocks geochemically, with studies based on bulk samples (e.g. TOC, iron speciation, pyrite framboid sizes, Th/U, $\delta^{13}C_{org}$, organic biomarkers, $\delta^{98/95}$Mo and Mo concentration, $^{187}Os/^{188}Os$) and belemnites (e.g. $\delta\ ^{18}O_{carb}$, $\delta^{13}C_{carb}$, $\delta\ ^{34}S$, $^{87}Sr/^{86}Sr$). These geochemical proxies record sediment and water column anoxia, warming, freshening, and increased continental weathering during the TOAE in the Falciferum Zone, and also a significant negative carbon isotope shift. The latter is the regional signature of a global phenomenon, that has been linked to the eruption of the Karoo-Ferrar Large Igneous Province (~183 Ma).

In the Cleveland Basin, the black shale representing the main anoxic event is preceded in the Tenuicostatum Zone by three thin pre-cursor black shale events (the Sulphur Bands) which record brief excursions into anoxia prior to the main event. These each record a negative excursion in $\delta^{13}C_{org}$ and show subtle differences in their style of anoxia. Interestingly, only one of the three minor organic carbon isotope excursions (at the Pliensbachian-Toarcian boundary) has been identified in existing regional scale records. In addition to belemnites, the Cleveland Basin Toarcian mudrocks are rich in trace fossils, macrofossils and microfossils. Together with lithological and geochemical data, these have been used in a series of studies to define biofacies schemes that record the biotic response to decreasing oxygen content in sediments and the water column during the TOAE. We will review these biofacies schemes in this talk and show that there are interesting short-duration events in the Falciferum and Tenuicostatum Zones where geochemical proxies appear to conflict with palaeontogical data; this may be explained by temporal scale effects.

Computational and human classification of pollen grains

Luke Mander

College of Life and Environmental Sciences, University of Exeter, Prince of Wales Road, Exeter, Devon, EX4 4PS, UK

Email: luke.mander@gmail.com

Fossil pollen and spores can be hugely abundant in mudrocks, and they have provided valuable information on subjects ranging from the nature and timing of evolutionary events, such as the origin and radiation of flowering plants, to the relationship between vegetation and climate. Such palynological research into the history of Earth's vegetation is underpinned by the classification of pollen and spores into taxonomic groups, which allows scientists to investigate changes in vegetation diversity and composition in time and space. The vast majority of palynological studies are currently undertaken by human analysts. Typically, the analyst examines by eye the sizes and shapes of attributes that are thought to have taxonomic significance, and then uses these attributes to compare unknown specimens to classified reference material. Recently, there have been efforts to move away from this manual approach and to develop computational methods to classify pollen and spores. In this talk I outline a computational classification of modern grass pollen collected from herbarium sheets. The approach I describe is rooted in the accurate description of morphology, and aims to improve the taxonomic resolution of pollen and spore records of Earth's vegetation. I place the results of this computational classification in context by describing the results of an experiment designed to measure the accuracy and consistency of human classification of the same grass pollen specimens. I show images of fossil grass pollen derived from mudrocks to explore how the computational methods I outline might be applied to fossil material. I conclude with a discussion of the role of the human analyst in the present era of computational classification.

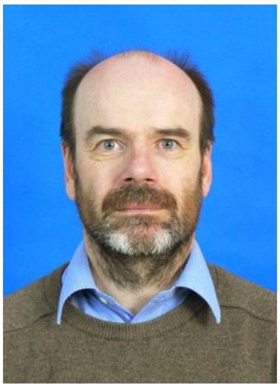
Mudrocks and plant fossils: Exploring a rich archive

Volker Wilde

Senckenberg Forschungsinstitut und Naturmuseum, Sektion Palaeobotanik, Senckenberganlage 25, 60325, Frankfurt am Main, Germany

Mudrocks are widely distributed in geological time and space. They are quite diverse in origin and composition, especially with regard to organic matter. Thus they present a rich archive for plant fossils ranging from fully terrestrial (lacustrine, fluvial, volcanic, karstic) to marginal marine (deltaic, estuarine, lagoonal) and into fully marine (basinal) settings. According to the different settings and the plant material subject to embedding, the amount and preservation of plants in mudrocks varies considerably. Many of the classic palaeofloras may be assigned to terrestrial or marginal marine settings, but preservation can be exceptional in fully marine sediments. The talk will illustrate the potential of mudrocks for the preservation of plant fossils by using selected examples, such as plant accumulations from the Upper Carboniferous and from the Wealden-facies of Germany which may serve as examples for fluvial to deltaic situations. The oil shale of Messel (UNESCO World Nature Heritage Site) which formed in an Eocene maar lake is an exceptional and well-studied example for a lacustrine setting. It has not only a wealth of plant macrofossils preserved, but palynological studies of the laminated oil shale allow deciphering of astronomical cyclicity under the Eocene greenhouse climate. Another example are karstic depressions (dolines) of Early Cretaceous age in Central Germany which have been found to be filled with mud rich in extremely well preserved charred plant remains. Siliceous muds of volcanic or marine origin may contain permineralized plant remains. The first case is represented in the Early Permian (Rotliegend) of Germany, and the latter in radiolarites of Lower Carboniferous age from the Rheinisches Schiefergebirge.

Organic matter in mudrocks: Another form of exceptional preservation



John E. A. Marshall[1] and Olga P. Tel'nova[2]

1. University of Southampton, National Oceanography Centre, European Way, Southampton, SO14 3ZH, UK
2. Institute of Geology, Komi Scientific Center, Ural Branch, RAS, Pervomaiskaya, 54, Syktyvkar, 167982 Russia

Email: jeam@noc.soton.ac.uk

Exceptional preservation is generally taken to mean preservation of soft-part macrofossils (lagerstätten) with well known examples being the Burgess Shale, Hunsrück Schiefer and the Solenhofen Limestone. But in these instances the preservation of organic matter is simply woeful, the first two deposits being low grade meta-sediments, the latter a micrite generally devoid of organic matter. However, there are deposits, analogous to lagerstätten, where there is exceptional preservation of organic matter, i.e. both relatively undegraded and at a low level of thermal maturation. What controls this is the combination of sedimentary environment and the subsequent burial history. As regards thermal maturation, it is clearly the cumulative effects of burial. This means that older deposits are more likely to have undergone deeper burial. Preservation is controlled by sedimentary environment and again contrasts with lagerstätten as the latter typically form in more distal environments with stratified water columns that have relatively fewer palynomorphs (often diluted by amorphous organic matter) which show wall degradation plus damage from framboidal pyrite.

There is now a well established and growing sequence of Phanerozoic lagerstätten. In contrast, the record of exceptionally preserved organic matter remains sporadic and particularly so in the Palaeozoic. We will describe well preserved organic matter from a borehole drilled through a Frasnian-Famennian boundary section (372 Ma) at Sosnogorsk, near Ukhta, in the Komi Republic, Russia. This revealed a remarkably well preserved 8 m thick interval of unconsolidated grey mudstone which contains pristine carbonate crystals preserved in a clay matrix. Spores show this mudstone interval to be equivalent to the Upper Kellwasser Mass Extinction level and hence a record of land plant extinctions through the event. The mudstone interval can be easily disaggregated to release separate fractions of the palynomorphs, amorphous organic matter, carbonate crystals, pyrite framboids and clastic grains. TOC and calcite contents reveals a pattern of orbital forcing and hence a time framework. Isotope analysis gives an integrated record of stable $\delta^{13}C_{org}$, $\delta^{13}C_{CaCO3}$ and $\delta^{18}O_{CaCO3.}$ Additional isotope analysis of separated kerogen components (spores and AOM) from single samples integrated with the pyrite framboid measurements and %S content enables us to identify when upwellings of euxinic water occurred. Analysis of the palynological record shows a progressive impoverishment of spore diversity and abundance through the event. These data combine to give a new model for understanding the Frasnian-Famennian Mass extinction.

Revealing terrestrial environmental change: Big lakes, multi-proxies and challenges

William D. Gosling

Palaeoecology & Landscape Ecology, Institute for Biodiversity & Ecosystem Dynamics, University of Amsterdam, The Netherlands

Most extant species on Earth had evolved by the start of the Quaternary (c. 2.6 million years ago). The Quaternary period, in geological terms, is considered as an "icehouse" with extensive glaciers expanding from the poles for the majority of the time. Quaternary "glacial" conditions have however been periodically punctuated by warmer (c. +4-6^{o}C) "interglacial" conditions concomitant with variation in the Earth's orbital configuration (on c. 40,000 or 100,000 year timescales). These major climate perturbations (glacial-interglacial cycles) resulted in the repeated reorganization of ecological communities on a global scale, and played a major role in determining modern biogeographic patterns.

An insight into how terrestrial ecosystems were perturbed by glacial-interglacial cycles can be obtained from the study of fossil records from lake sediments. However, lake sediments old enough to provide information from beyond the current warm interglacial period are globally scarce, and logistically difficult to obtain. Comparison of evidence for past vegetation change (fossil pollen) obtained from multiple lakes spanning at least one full glacial-interglacial cycle reveals: (i) the uniqueness of assemblage compositions of each interglacial period, (ii) the highly dynamic nature of vegetation assemblages during individual interglacial periods, (iii) the similarity of trajectories of change between interglacials, and (iv) the consistency in the patterns of change at different altitudes and latitudes. The heterogeneity of the past ecological records highlights the spatial complexity of ecosystems response to high magnitude rapid global climate change.

Exceptional preservation of carbonate microfossils in clay: Implications for palaeobiology and palaeoclimate

Paul Pearson

School of Earth & Ocean Sciences, Cardiff University, Main Building, Park Place, Cardiff, CF10 3AT, UK

Email: PearsonP@cardiff.ac.uk

Microfossils such as foraminifera and calcareous nannoplankton have an exceptionally rich fossil record, especially in the Cretaceous and Cenozoic, where they are widely used for biostratigraphy, evolutionary palaeobiology and palaeoclimatology. Isotopic and trace element analysis of foraminifer tests has provided us with an ever-increasing variety of climatic and environmental proxies; classically, for seawater temperature and global ice volume, but also pH, pCO2, biological productivity, water mass tracing, and so on. Nannofossils are also frequently analyzed geochemically, usually as the main carbonate constituent of bulk sediment, but more recently as concentrated aliquots of specific taxa. However it has become increasingly apparent that carbonate oozes and chalks, which are often full of microfossils, tend to suffer from substantial diagenetic alteration, especially recrystallization on the micron scale. This obscures fine morphological features and even destroys the record of the more delicate species of nannoplankton, and it can seriously bias geochemical proxies. Clays, on the other hand, can provide exceptional preservation of morphology with astonishing fidelity well below the micron scale. The reason for this is not fully understood but is presumably related to their very low permeability and suppression of the diagenetic effects of migrating pore fluids. In this lecture I review how clay-rich facies have provided us with extraordinary new insights into the taxonomy, biomineralization and biodiversity of calcareous microfossils; and I show how geochemical data from clays have revolutionised our understanding of past warm climate states. I propose an outline conceptual model for the recrystallization process and how it affects some proxies more than others.

From Cells to Species: Using exceptionally preserved coccolithophores to reconstruct biology and biogeochemistry

Samantha Gibbs, Paul Bown, Rosie Sheward and Alex Poulton

University of Southampton, Ocean and Earth Science, National Oceanography Centre Southampton, University of Southampton Waterfront Campus, European Way, Southampton, SO14 3ZH, UK

In the last few years muddy sediments have revolutionized the way we look at fossil coccolithophores, as they have for calcareous microfossils in general. For the first time, the remarkably preserved fossils that they contain allow us to truly think about coccolithophore fossils as individual cells and to explore how these crucial organisms interact, respond to and potentially modify their environment. Modern calcifying nannoplankton (coccolithophores) build exoskeletons from individual calcite plates (coccoliths), which cover the cell surface and form a protective barrier (coccosphere). While the coccolithophore fossil record typically comprises disarticulated single coccoliths, muddy sediments are yielding exceptionally high numbers of coccospheres, in effect providing us with fossil 'cells'. These coccospheres preserve invaluable information about the original living cell, including its size, levels of particulate organic carbon and inorganic carbon, ontogeny, and growth phase – information that tells us about their reproductive success and their potential role in local biogeochemical cycling, and crucially we can directly compare them with their living counterparts. Fossil coccospheres provide us with case studies of community variability alongside environmental change, over both long timescales of greenhouse to icehouse climate states and also more abrupt events such as the Paleogene hyperthermals. By better understanding these individual cells, we can ultimately explore the link between individuals and the success of the species to rationalise how single celled organisms, that only live for a day but have a global impact on biogeochemical cycles, ultimately 'respond' to climate change.

Mud: Food for thought

Nick McCave

Godwin Lab for Palaeoclimate Research, Dept of Earth Sciences, University of Cambridge, UK

The operative word here is 'food' because mud is highly nutritious and supports most benthic life. It owes this to its sorptive capacity based on a large specific surface area. This can be as high as 100 m^2 per gram for fine montmorillonite but even 15 m^2/g for coarser illite with a monomolecular layer of adsorbed organic carbon allows about 1% by weight organic carbon, a significant source of fuel for benthos. Most of the organic matter in marine sediments comes from surface primary productivity. This is at a maximum in the coastal zone and wind-driven upwelling areas where sediments generally contain much more than 1% organic carbon. The rapid delivery of this material to great depths via the 'faecal express' and marine snow provides both food and cues for seasonal reproduction well away from any variation in light intensity. Once in the seabed mud this organic matter fuels a huge range of organisms from bacteria to vertebrates. All (well nearly all) life is here, and much of it has a fossil (and trace fossil) record. This is all illustrated by deep-sea photographs, X-radiographs of marine sediments, and images of marine snow from near bed suspensions.

Poster Abstracts

-1-

The role that clay minerals play in organic fossil preservation: Insights from the Zavkhan terrane, Southwestern Mongolia

Ross P. Anderson[1], Francis A. Macdonald[2], Nicholas J. Tosca[3], Tanja Bosak[4], Uyanga Bold[2], and Derek E. G. Briggs[1]

[1]Department of Geology and Geophysics, Yale University, 210 Whitney Avenue, New Haven, CT, 06511, USA
[2]Department of Earth and Planetary Sciences, Harvard University, 20 Oxford Street, Cambridge, MA, 02138, USA
[3]Department of Earth Sciences, University of Oxford, South Parks Road, Oxford, OX1 3AN, UK
[4]Department of Earth, Atmospheric, and Planetary Sciences, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA, 02139, USA

Clay minerals have been posited to enhance the preservation of organic tissues in mudrocks in both Phanerozoic macroscopic metazoans (Butterfield 1990) and microscopic eukaryotes that extend deep into the Proterozoic (Butterfield et al. 1994). It is hypothesized that clays enhance preservation either by deactivating autolytic enzymes (e.g. Butterfield 1990), or by precipitating directly onto the organic tissue and providing an impermeable protective layer (e.g. Orr et al. 1998).

In this study we re-examine the role of clay minerals in the preservation of organic tissues. We present preliminary stratigraphic records of clay mineralogy and microfossil eukaryotic abundance for ~400 m of Neoproterozoic (~660 - ~640 Ma) carbonate rocks from Mongolia (Taishir Formation, Tsagaan Olom Group) that range between the Cryogenian “snowball Earth” ice ages.

Clay mineralogy is analysed through X-ray diffraction of the <2 μm fraction of the carbonate insoluble residue. Microfossil abundance is obtained from rock maceration and bedding perpendicular petrographic thin-sections. Clay mineral assemblages vary stratigraphically from berthierine (lowest ~150 m) through to talc (middle ~25 m) and kaolinite (highest ~225 m). Initial results suggest that shifts in fossil abundance coincide with changes in the clay mineral assemblages. Understanding the taphonomic biases in the organic fossil record is important to understanding the factors influencing changing diversity of the fossil record – are changes in fossil diversity real evolutionary events or are they an artifact of changing preservation potential? Few fossils have been described from the critical interval between the Cryogenian “snowball Earth” ice ages in the Mongolian sections and the barren nature of this interval has been attributed to extinction due to the proliferation of biologically unfavorable environments. Our preliminary data suggest a role for taphonomy in explaining the paucity of fossils from this interval.

-2-

Characterisation of the organic content of Arnsbergian (Serpukhovian, early Namurian) mudstones from the Widmerpool Gulf, UK Pennine Basin

Jan Hennissen[1], Ed Hough[1], Chris Vane[1] and Mike Stephenson[1]

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

The composition and amount of organic matter in shales and mudstones determines the quality and influences the quantity of hydrocarbons contained in shale reservoirs. The kerogen fraction in Serpukhovian-aged Carboniferous mudstones in the south-eastern part of the Pennine Basin includes up to 95% amorphous organic matter (AOM), mostly heterogeneous material of unknown origin lacking a distinct morphology. A better understanding of the amount and origin of AOM allows predictions to be made regarding the hydrocarbon potential of these rocks and is therefore relevant to both industry and government in understanding this currently unexploited source of indigenous energy.

Here we present the preliminary palynological and geochemical results of the Edale Shale from the Carsington Dam Reconstruction Borehole C3 located in the Widmerpool Gulf depocentre (Derbyshire). Deposition occurred in a series of inter-linked basins and half-grabens in water depths of several hundred meters, as a mudstone-dominated turbiditic succession. The Namurian successions of this region are characterized by a remarkable cyclicity thought to represent repeated interglacial sea level highstands associated with Southern Hemisphere glaciations. The base of each successive cycle is defined by dark-coloured marine mudstones which are typically overlain by siltstones.

The investigated interval from the Carsington C3 Borehole can be divided into two major parts representing a sea-level lowstand at the base and a transgressive systems tract to high stand in the upper part of the cored succession. The lower part represents an episode with a restricted exchange of waters from the main open ocean. This succession is characterized by higher levels of phytoclasts and gelified AOM and generally lower % Total Organic Carbon (TOC), typically around 2%. The upper part of the core consists mostly of carbonate cemented mudstones with very high levels of granular AOM and somewhat higher TOC values (~ 4%). This observation suggests that higher granular AOM counts are linked to higher %TOC and may represent intervals of elevated hydrocarbon generative potential. Further palynological investigations are required to clearly delineate the different AOM phases and to understand how these different phases affect hydrocarbon prospectivity. This could then be applied to understanding broader trends in Carboniferous Shales in the U.K. and can be integrated into models to characterize and identify zones of richer hydrocarbon potential.

-3-

Large-scale changes in the microfossil assemblages from the mudrocks representing Toarcian Oceanic Anoxic Event

Alice E. Kennedy[1], Angela L. Coe[1], William D. Gosling[1,2], Encarni Montoya[1]

[1]Department of Environment, Earth and Ecosystems, The Open University, Walton Hall, Milton Keynes, MK7 6AA, UK
[2]Institute of Biodiversity & Ecosystem Dynamics (IBED), University of Amsterdam, P.O. Box 94248, 1090 GE Amsterdam, The Netherlands

Mudrocks are associated with exceptional preservation of fossils throughout geological history. The organic-rich mudrocks representing Toarcian (Early Jurassic) Oceanic Anoxic Event (TOAE) are no exception.

The TOAE is characterised by pronounced changes in geochemical proxies; a $\delta^{13}C$ excursion consisting of four abrupt shifts interpreted as four pulses to the C cycle (e.g. Kemp *et al*. 2011); a shift in $\delta^{16}O$ interpreted as a 7 to 13°C rise in global temperatures (e.g. Dera *et al*. 2009); fluctuations in Os- and Sr-isotope compositions indicating enhanced rates of chemical weathering (Cohen *et al*. 2004) and a change in $\delta^{98}Mo$ interpreted as periods of increased areas of deoxygenation (Pearce *et al*. 2008). The marine invertebrates record extinctions and significant changes during this period (Caswell & Coe 2013).

Here we present the foraminifera and palynomorph response to the TOAE using mudrocks from the Yorkshire coast, UK. Microfossils have been used because of their highly sensitive response to the impacts of environmental change. The microfossil samples have been collected every 2.5 cm at the same localities and stratigraphic positions as high resolution geochemical proxies (Kemp *et al.* 2011, Pearce *et al.* 2008) and macrofossil data (Caswell *et al.* 2009, Caswell & Coe 2013). Our data demonstrate a significant turnover in marine microfossil assemblages from a diverse 'normal' assemblage to one dominated by sphaeromorphs. High resolution data has more tightly constrained ranges of dinoflagellates. Application of the freeze-thaw technique to extract the foraminifera (Kennedy & Coe 2014) has yielded new foraminiferal occurrences and extended known ranges in Yorkshire. Comparison of the foraminiferal and palynomorph occurrences with the high-resolution geochemical data set demonstrates changes in the microfossils are directly associated with geochemical proxies.

Caswell, B.A. & Coe, A.L., 2013. Geology, 41:1163-1166
Caswell, B.A. *et al.*. 2009. J. Geol. Soc., 166: 859-872
Cohen, A.S. *et al*.. 2004. Geology, 32: 157-160
Dera, G. *et al.* 2009. EPSL., 286: 198-207
Kemp, D. B. *et al.* 2011, Paleoceanography, 26:1-17.
Kennedy, A.E. & Coe A.L. 2014. J. Micro., 33: 193-203
Pearce, C.R. *et al.* 2008. Geology, 36: 231-234

Burlington House
Fire Safety Information

If you hear the Alarm
Alarm Bells are situated throughout the building and will ring continuously for an evacuation. Do not stop to collect your personal belongings.

Leave the building via the nearest and safest exit or the exit that you are advised to by the Fire Marshall on that floor.

Fire Exits from the Geological Society Conference Rooms
Lower Library:
Exit via main reception onto Piccadilly, or via staff entrance onto the courtyard.

Lecture Theatre:
Exit at front of theatre (by screen) onto Courtyard or via side door out to Piccadilly entrance or via the doors that link to the Lower Library and to the staff entrance.

Main Piccadilly Entrance:
Straight out door and walk around to the Courtyard.

Close the doors when leaving a room. **DO NOT SWITCH OFF THE LIGHTS**.

Assemble in the Courtyard in front of the Royal Academy, outside the Royal Astronomical Society.

Please do not re-enter the building except when you are advised that it is safe to do so by the Fire Brigade.

First Aid
All accidents should be reported to Reception and First Aid assistance will be provided if necessary.

Facilities
The ladies toilets are situated in the basement at the bottom of the staircase outside the Lecture Theatre.

The Gents toilets are situated on the ground floor in the corridor leading to the Arthur Holmes Room.

The cloakroom is located along the corridor to the Arthur Holmes Room.

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