Symposium I – Keynote

Peering into the crystalline eyes of trilobites

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Phacopid trilobites saw the Palaeozoic oceans through eyes containing calcite lenses. These ancient but highly sophisticated „schizochroal" eyes have fascinated palaeontologists ever since Ewan Clarkson and Ricardo Levi-Setti suggested that each lens had a doublet structure so that it focused light in a similar way to lenses developed in the 17th century by Des Cartes and Huygens. Although long heralded as a triumph of biological design, this elegant explanation has recently been challenged; alternative models include focusing of light using a graded density of organic inclusions (the GRIN model; Bruton & Haas 2003), or directing light to banks of photoreceptors using bundles of subgrains acting like optical fibres (Schoenemann & Clarkson 2008). Any resolution of this debate requires an understanding of the composition and microstructure of these lenses *in vivo*, which is challenging owing to the potentially obscuring effects of post mortem alteration. Using a range of high-resolution electron imaging and analysis techniques we have attempted to 'see through' the diagenetic overprint to reveal the original internal structure and composition of these lenses.

Of the twenty species examined nearly all have lenses that are richer in magnesium than the enclosing exoskeleton, and this magnesium is concentrated in dolomite crystals. The dolomite formed by early diagenetic recrystallization of magnesium calcite, thus demonstrating that the Phacopids simultaneously crystallized calcite exoskeletons and magnesium calcite lenses. The crystallization of magnesium calcite is surprising owing the low Mg/Ca ratio of the Ordovician to Devonian 'calcite seas' within which these animals lived, and such specialisation of biomineral compositions suggests that magnesium was critical for lens function. As the magnesium calcite imposes an inbuilt susceptibility to diagenetic alteration, it may be expected that primary lens microstructures would have been lost, but in fact original crystallographic orientations were preserved by secondary calcite owing to the very fine scale of the replacement reactions. All lenses contain calcite subgrains, and just beneath the curved outer surface of the lens they are arranged into a three-dimensional mesh of curved fibres, presumably to direct light to the lens centre and then photoreceptors beneath. These „radial fringes" have an exceptionally intricate geometry that was constructed by 'bending' crystals as they grew. It is difficult to envisage how such microstructures could have formed, especially given the need to rapidly develop eyes after moulting. Surprisingly terrestrial earthworms provide a good analogy as they can form granules of calcite of similar size and microstructure to the lenses, and all in less than one day.

Results of this work have enabled us to confidently reconstruct the *in vivo* chemical composition and microstructure of the lenses of schizochroal trilobite eyes. We are now completing optically modelling to elucidate how light moved through the calcite and was directed to the photoreceptors, so that we can understand better the palaeobiology and palaeoecology of these fascinating animals.

Bruton, D. L. & Haas, W. (2003): The puzzling eye of *Phacops*. – Special Papers in Palaeontology, 70: 349–361.
Schoenemann, B. & Clarkson, E. N. K. (2008): Did the trabecula in Phacopid lenses act as light guides? – Proceedings of the fourth international trilobite conference, Toledo, 4: 351–354.

Symposium K – Vortrag/oral presentation

Is the Ordovician explosion in the diversity of life related to climate cooling and glacial intervals?

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For several decades, the Early Palaeozoic was regarded as a long-lasting greenhouse period with stable climate conditions, and exept for the „Cambrian Explosion" there was nothing particularly spectacular with respect to the evolution of life. However, there is an extreme increase in diversity, especially during the Middle Ordovician, which was documented in detail over the last couple of years and already well visible in the classic Sepkoski curves. Since the „Webby Book" on Ordovician biodiversity was published in 2004, discussions focused on Ordovician radiations and their triggers. The Ordovician System spans about 70 million years and - as discussed in the frame of this Symposium by Thomas Servais et al. - is the geological period when the real exlosion of life occurs, termed the GOBE or Great Ordovician Biodiversification Event. Major radiations and the establishment of complex ecosystems were triggered by long-lasting physico-chemical and biological processes such as changes in palaeogeography, intensity of volcanism, climate and trophic networks.

$\delta^{18}O$ data from biogenic (conodont) apatite provide the reliable tool to infer temperature changes. There is a clear cooling trend throughout the Ordovician. Together with facies data from different palaeocontinents, the $\delta^{18}O$ record suggests the existance of at least two glaciations prior to the famous Hirnantian Glacial. There is evidence for a short-lived glacial already in the uppermost Sandbian, and for a second glaciation in the middle Katian. The peaks in Ordovician biodiversity in the curves of Sepkoski, the curves of specific faunas published in Webby et al. (2004), together with the appearance of highly complex reef systems coincide with the late Middle though Late Ordovician cold periods or glacials. Diversity peaks seem to coincide with the cold intervals and drops in diversity with intermittent warmer periods during early Palaeozoic times. It is plausible that changes in climate played an important role in early Palaeozoic extinctions and radiations and highly influenced macro-evolution.

Symposium D – Vortrag/oral presentation

Ant-Fungal Parasitism - Ancient Death-Grip Leaf Scars from the Eocene of Central Europe

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Unusual insect behaviour and its consequences occasionally are preserved in the fossil record, but previously have not implicated parasites as agents of behavioural modification. Many fungi manipulate insects to bite leaves in a similar manner to *Ophiocordyceps unilateralis* and so this type of manipulation is a likely candidate to be captured in the fossil record through the examination of fossil leaves. Here, we report physical evidence for „death-grip" scars on damaged leaf tissue, induced by stereotypical control of ant behaviour by fungal infection.

1. The new discovery supports previous biogeographical enigmas. Recently, evidence from middle Eocene sites in Europe, especially from somewhat younger Baltic Amber (44.4 Ma) indicates considerable sharing of plant and insect taxa, and now associations, with modern Southeast Asia. The current study adds to that growing list, suggesting that the forests of Thailand may be the closest extant analog to Lake Messel of the mid Eocene (47.8 Ma).

2. The new use of fossil leaf-damage data support to understand parasitism in the fossil record. Typically such rare parasitic or parasitoidic associations between insects and fungi occur in amber. However, this association occurs on compression material, indicating a newfound use of distinctive, stereotypical damage that mirrors associations that are documented, often meticulously, from modern material.

3. It is a rare example of a tritrophic association using stereotypical and highly distinctive fossil leaf-damage. Elucidation of a tritrophic interaction involving (1) a plant host, (2) an ant clade, and (3) the ant's fungal parasite is rare in the fossil record of leaf damage. Another, albeit undocumented, example is a galled Patagonian leaf taxon with galls that contain several parasitoid emergence holes. Our discovery indicates that the fossil record of plant-insect associations can cascade up and down three trophic levels.

4. The dating of this unique parasitic association minimally to the mid Palaeogene, indicating a deep-time origin for this phenomenon. The modification of a fungally-induced behaviour in this ant taxon now has an origin occurring when many modern ant lineages were diversifying. This indicates that this highly specialized interaction is relatively ancient

Symposium B – Poster

Bivalve-dominated macrobenthic assemblage from the Upper Cenomanian (Cretaceous) of Saxony, Germany

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During the Early Late Cretaceous transgression, vast formerly emergent areas were flooded and transferred in shallow epi- and peri-continental shelf seas. In Saxony (Germany) this global transgression is documented by the onlap of shallow-marine sandstones of the lower Upper Cenomanian Oberhäslich Formation onto Palaeozoic basement rocks of the eastern Erzgebirge, a part of the Mid-European Island. The units were deposited as shallow-marine sand sheets and provided widespread firmgrounds with environmental conditions favourable for macrobenthic communities. Based on field observations south of Dresden (Gebergrund, Goldene Höhe, Welschhufe) and the study of collection material hosted in the Museum für Mineralogie und Geologie of the Senckenberg Naturhistorische Sammlungen Dresden, a reconstruction of the macrobenthic assemblage of the Oberhäslich Formation is intended.

The macrobenthos of the Oberhäslich Formation is dominated by relatively large bivalves, most notably *Inoceramus* ex gr. *pictus* (*I. pictus pictus* Sowerby, *I. pictus bannewitzensis* Tröger) (48%), *Rastellum cariantum* (Lamarck) (13%), *Rhynchostreon suborbiculatum* (Lamarck) (8%), *Gervillaria*? *neptuni* (Goldfuss) (8%), *Pinna cretacea* (Schlotheim), and *P. cottai* Geinitz (3%). Less common are smaller bivalve taxa such as *Neithea (N.) aequicostata* (Lamarck) (6%), accompanied by rare *Gervillia solenoides* Defrance, *Plagiostoma sowerbyi* (Geinitz), *Modiolus siliquus* (Matheron) and other modiolines. Gastropods are very rare to absent. Non-mollusc benthic invertebrates are likewise very rare and represented by irregular (*Holaster* sp., *Hemiaster* sp., *Catopygus*? sp.) and regular echinoids (spines of cidarids) as well as siliceous sponges (*Siphonia* sp. and reticulate morphotypes). As a rarity, the zonal index ammonite *Calycoceras naviculare* (Mantell) has been found, indicating an early Late Cenomanian age (*C. naviculare* Zone). Further nektonic components are nautiloids [*Cymatoceras elegans* (Sowerby)] and shark remains. Conspicuous large *Thalassinoides* and *Ophiomorpha* burrows indicate that crustaceans have been an important part of the infauna, associated with irregular echinoids and polychaetes. Bored wood remains point towards the presence of a vegetated hinterland. All body fossils are preserved as steinkerns in fine-grained, well sorted quartz arenites.

The benthic assemblage of the Oberhäslich Formation is moderately diverse, consisting of ~25 taxa, and is dominated by semi-infaunal (bakevelliids, modiolines, pinnids) and epifaunal (resp. epibyssate) suspension-feeding bivalves (inoceramids, oysters, pectinids, limids). (Deep-)infaunal bivalve taxa are missing. The large size of many of the bivalves suggests very good environmental conditions concerning food supply and oxygen availability (in contemporaneous fine-grained off-