Preface

Mesozoic ecosystems – climate and biotas

This issue of Palaeogeography Palaeoclimatology Palaeoecology is devoted to papers on Mesozoic ecosystems and is an outcome of the International Geoscience Program (IGCP) 632. IGCP is a joint operation by UNESCO and the International Union of Geological Sciences (IUGS), which promote interdisciplinary Earth science research among scientists internationally. Since its formation in 1972, IGCP has supported over 500 projects in about 150 countries.

IGCP-632 “Continental Crises of the Jurassic: Major Extinction events and Environmental Changes within Lacustrine Ecosystems” was initiated in 2014 and aims to provide insights into the timing and causes of major perturbations in the evolution of life on Earth, covering the entire mid-Mesozoic, from the end-Triassic mass extinction event to the development of Early Cretaceous lake systems in China and elsewhere. The geographical coverage is global. By attaining an updated stratigraphy, particularly focusing on the much needed correlation between the marine and continental realms, a major leap will be taken forward providing the basis for interpretation of paleoclimate data and paleoenvironments. It further aims at clarifying the causal mechanisms behind two major events in the Earth history; the Triassic–Jurassic mass extinction event and the Toarcian anoxic event, which occurred 183 million years ago. The project finally covers the Jurassic–Cretaceous boundary at 145 million years ago focusing on freshwater deposits.

The issue “Mesozoic ecosystems – climate and biotas” has been extended to include the entire Mesozoic and the 12 contributions contained in this issue particularly focuses on the biota, including plants, invertebrates and vertebrates in both marine and continental settings (Fig. 1). The new data in all contributions are developed to also enhance understanding of the Mesozoic climate, ecosystems, mass extinction events and atmospheric composition.

1. The Mesozoic world

The special issue *Mesozoic ecosystems – climate and biotas*, takes the reader through the Mesozoic, bracketed between two mass extinction events and incorporating some of the most amazing evolutionary steps in the history of life (Fig. 1). The Mesozoic saw the evolution of the dinosaurs, early birds, the first mammals and the flowering plants (Kear et al., 2016). The Mesozoic (251–66 Ma) initiated in the aftermath of the most massive extinction event in the history of life—the end-Permian event, which closed the Paleozoic (Algeo et al., 2011; Vajda and Bercovici, 2014).

1.1. The Triassic

The reader is introduced to the Early Triassic predators that inhabited the polar areas of the Southern Hemisphere following the great extinctions. Based on analyses of vertebrate fossils and coprolites from the Sydney Basin, Australia (Niedzwiedzki et al., 2016) the authors

reconstruct the Early Triassic (Olenekian) faunas and the coastal river ecosystems, adding to knowledge of the aquatic and possibly, terrestrial carnivorous reptiles that inhabited the ecosystems close to the southern polar circle following the end-Permian mass extinction event.

Abdolmaleki and Tavakoli (2016) continue on the topic concerning the ecosystems in the wake of the end-Permian biotic crisis with records of so called anachronistic facies (facies that were commonly represented in the early Earth's ecosystems (Fraiser and Bottjer, 2007)). Various microbial facies, comprising, e.g., stromatolites and oncoids are described from Lower Triassic sequences within four giant gas fields in the Persian Gulf region, and a new model for ocean geochemistry related to the production of these microbial facies is presented.

We continue into the Upper Triassic successions of Hopen Island, Svalbard (Paterson et al., 2016), an island well known for preserving fossil biota (Strullu-Derrien et al., 2012). New palaeoenvironmental interpretations based on a broad range of microfossils, including pollen, spores, dinoflagellates, foraminifera, radiolarians and ostracods are presented. By this multidisciplinary approach, the authors link the microbiota and the vegetation signals to the existing stratigraphy, providing an improved palaeogeographic understanding of the Late Triassic ecosystems in the present Barents Sea region.

The reader is subsequently taken to the Triassic–Jurassic boundary successions of the Shanghai–Altay Mountain Ranges, including parts of southern China (Sha et al., 2016-in this issue) and the contribution provides a review of the peculiar bivalve genus *Waagenoperma* that thrived in various ecosystems, from fresh-water lakes to brackish, and fully marine environments. This has given them the status of “Rosetta stones” for chronostratigraphical correlation between different ecosystems in this area, linking the Jurassic marine and continental deposits. The analysis further shows that *Waagenoperma* was a successful survivor of the end-Triassic event, possibly owing to its ability to adapt to different ecological conditions.

The publication by Bacon et al. (2016) contributes to the ongoing scientific debate regarding the interpretation and understanding of preservational biases in the fossil record. More specifically, the relation between CO₂ levels in the atmosphere and leaf mass (thickness) as this has a bearing on the fossilization potential. The authors hypothesize that changes in leaf thickness could lead to an increased or decreased preservational potential of plant fossils and test the effects by simulating Mesozoic atmospheres in a set of gymnosperms. Their pioneering results indicate that atmospheric composition is an important taphonomic filter of the fossil leaf record.

The topic returns to fully continental ecosystems with paleoclimate and paleogeographical interpretations based fossil wood, yet another approach to the analysis of fossil plants (Vajda et al., 2016a, 2016b). Here the authors investigate fossil wood from Late Triassic (Norian to Rhaetian) successions of northern Sichuan Basin, southwestern China (Tian et al., 2016). The authors give insights into the evolution and geographical

Fig. 1. Stratigraphic distribution of the papers included in this special issue. Blue boxes around titles indicate that the focus is on marine successions whereas brown boxes signify continental materials. Left margin: international chronostratigraphical chart, 2016. <http://www.stratigraphy.org/index.php/ics-chart-timescale>.

distribution patterns of *Xenoxylon*, an enigmatic group of gymnosperms endemic to the Triassic–Lower Cretaceous of Far-East Asia. The wood anatomy in general, and more specifically, the growth rings of the fossil wood reveal a short-term cooling bracketed within otherwise warm and wet climatic conditions. The cooling event in Sichuan is further linked to a similar cooling at the western rim of Tethys (Tian et al., 2016).

1.2. The Jurassic

The Jurassic spans the interval during which dinosaurs became the dominant land vertebrates, new conifer types flourished in the wake of the end-Triassic extinction event and major changes in paleogeography took place as Pangea started its disintegration, and a continental configuration more like the modern world began to emerge (McLoughlin, 2001). As the Atlantic took shape, vast shallow marine basins were formed where biota accumulated and fossilized. The Jurassic climate was a stable greenhouse environment with high CO₂ levels (Beerling and Brentnall, 2007; Gomez and Goy, 2011; Steinthorsdottir and Vajda, 2015).

Scientists have recently discovered that microbial ecosystems flourished also after the end-Triassic event (Ibarra et al., 2014), as in the aftermath of the end-Permian event. Peterffy et al. (2016) describe newly discovered microbial mats formed by cyanobacteria in Lower Jurassic near-shore deposits of southern Sweden, providing the first record of Mesozoic wrinkle structures from that region. Pollen analyses from the same deposits reveal a typical Early Jurassic vegetation represented by ferns and Cupressaceae, together with extinct conifer families. Although the terrestrial ecosystems had seemingly recovered, Peterffy et al. (2016) interpret the microbial mats in the nearshore deposits as indicating decreased benthic activity, such as grazing in shallow marine environments.

The end-Triassic event has been linked to the Central Atlantic Magmatism (Akikuni et al., 2010) and the volcanic activity persisted during the Early Jurassic also in Scandinavia (Bergelin, 2009). In southern Sweden, this is evident from a multitude of volcanic necks in the otherwise subdued landscape (Bergelin, 2009). The rapid entombment of biota by the pyroclastic flows has in some cases resulted in exceptional preservation of biota (Bomfleur et al., 2014). McLoughlin and Bomfleur (2016) provide a case study of animal-fungal-plant interactions with an exceptional Early Jurassic (Pliensbachian) fern rhizome. The study highlights the potential of permineralized fern rhizomes with persistent leaf/root mantles to capture a picture of the myriad of biotic interactions in the understorey of Jurassic forests, especially when entombed rapidly by volcanoclastic sediments.

In the paper “The rise and demise of *Podozamites* in east Asia – an extinct conifer life style”, Pole et al. (2016) present a comprehensive review of the *Podozamites*, importantly including data from Russian, Chinese and other eastern Asian publications, which are generally difficult to access. *Podozamites* is a common Mesozoic plant fossil with nearly global distribution, although, due to its thin cuticle generally found only as an impression. *Podozamites* appears to have been little-affected through the Triassic–Jurassic transition, but responded to climate changes later in the Jurassic. By the late Albian angiosperms had arrived in many areas and risen to dominance (Halamski et al., 2016) and *Podozamites* became extinct shortly after (Bugdaeva, 1995). The new observations will have broader applicability in understanding Mesozoic ecosystems, such as the distribution of deciduous vegetation and fire, as well as contributing to an understanding of why angiosperms have mostly succeeded over conifers.

1.3. The Cretaceous

The Cretaceous covers the period in which angiosperms rose from their murky origins, and rapidly expanded in extent, biomass and biodiversity (Wing and Boucher, 1998), while various more typical Mesozoic

plants, such as the Bennettitales, dwindled to extinction (McLoughlin et al., 2011). This was a huge step towards the modern biota. However, dinosaurs remained the most prominent land vertebrates dominating mammals in both size and numbers. The Cretaceous was also a period of very high sea levels, with consequences including widespread paralic and lacustrine deposits (Vajda and Wigforss-Lange, 2006). Understanding of the commonly abundant fossils from these deposits suffers from a lack of high resolution with the marine record but where international palynological efforts within IGCP are showing great potentials.

The Lower Cretaceous Jehol Biota encountered within the Liaoning Province, China, is world famous for hosting unique fossil assemblages including feathered non-avian dinosaurs, birds, pterosaurs, mammals and importantly, the oldest flowering plants (Sun et al., 2002). The nomenclature of the sedimentary successions hosting the Jehol Biota and the underlying Yixian and Tuchengzi formations is however inconsistent, hampering accurate correlations. Wang et al. (2016) studied three continuous cores within the Sihetun area that penetrate these deposits and the authors present a lithostratigraphic nomenclature for the Sihetun Sub-basin describing the lithology and the fossil content in each of the members and units outlined. This refined stratigraphic nomenclature of the Yixian Formation has provided a better understanding of the sequence of facies and environments in which the fossils accumulated and paves the way for correlation with other coeval basins in China.

Nearly coeval to the Jehol Biota are the continental successions hosting the vertebrate bone-bed at Ariño in Teruel, Spain (Alcalá et al., 2012). An international team has studied coprolites recovered from this bone bed (Vajda et al., 2016a, 2016b) attributing the droppings to carnivorous dinosaurs. This is based on morphology of the coprolites, the presence of bone fragments within them and on the high content of calcium phosphate. Palynological analysis of the coprolites and the host sediments allow a dating of both to the Albian, also revealing that the coprolites were preserved in situ and deposited in continental wetlands. Taxodiaceae pollen produced by cypress-related trees dominate the coprolite samples, whereas the sediment samples have a slightly higher relative abundance of fern spores. Importantly, significant portions of charcoal are found in the coprolites, revealing an Early Cretaceous ecosystem with habitual wild fires.

The final paper in this issue takes us to the close of the Mesozoic, to the Cretaceous–Paleogene extinction event seen from a Southern Hemisphere (New Zealand) perspective but with global applications (Steinthorsdottir et al., 2016). The authors use fossil laurel leaf cuticles recovered from three New Zealand assemblages, which collectively span the latest Cretaceous to mid-Paleocene. Leaf cuticles are commonly used to reconstruct atmospheric carbon dioxide concentrations (pCO₂) by applying stomatal density analysis, which was first developed by McElwain and Chaloner (1995) and this method is employed by Steinthorsdottir et al. (2016). The results, which represent the first Southern Hemisphere stomatal density data spanning the K–Pg boundary, are consistent with previously published pCO₂ records from the Northern Hemisphere. The study further reveals that plants responded to significant changes in pCO₂ across the K–Pg by changing the stomatal density of their leaves. The Cretaceous ended with an asteroid impact that caused widespread ecological disruption, culminating in major, but seemingly targeted, extinctions (Schulte et al., 2010). These extinctions (non-avian dinosaurs for example) cleared the way for the modern world. The Mesozoic had ended and the Cenozoic begun.

2. Future advances

Palaeontology's great contribution to the current issues facing the Earth is to show how different it can be. It is only when the complex models that researchers use to predict the future can replicate the past that we will know that we have a firm understanding of the processes involved. The Mesozoic, as its name implies, is an ideal time to test these issues. On the one hand, aspects of it seem so modern (angiosperm forests for example) but at the same time, so alien (dinosaurs, extremely high

atmospheric carbon dioxide, but enigmatic reports of continental ice). Thus, there is the opportunity to keep one foot on firm (model) ground, while exploring with the other. However, underlying the 'big' questions is a fundamental field – taxonomy. A critical need in any of this research is to be clear just what time is being spoken about. Detailed biostratigraphy based on good taxonomy is essential, and climatic and environmental interpretations are often no better than the taxonomy that underpins them. The need for taxonomy to be taught, and therefore well-funded, remains essential to understanding how the Earth works.

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