

## P R E F A C E

# Multidisciplinary studies of global Carboniferous stage boundaries: towards a better definition and global correlations: an introduction

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Earth was very dynamic during the Carboniferous with major components of the Pangea supercontinent being assembled from late Famennian to latest Pennsylvanian times, although maximum consolidation occurred during Late Permian – Early Triassic time. During the Carboniferous Period, our planet also underwent at least three major icehouse periods. The first two, in late Famennian – early Tournaisian and late Visean – Bashkirian times, indicate the onset of the Late Palaeozoic Ice Age (LPIA) with ice sheets being confined to the alpine regions of southern Gondwana. The third icehouse regime during Gzhelian – Early Permian time represents the main episode of the LPIA when a continental ice sheet developed on the Australian, Antarctic and southern African components of southern Gondwana. During the Tournaisian equatorial areas in Euramerica were occupied by extensive arid belts, in which massive carbonate deposits formed on vast platforms in that time. From the late Tournaisian into the Visean and Serpukhovian much of the equatorial belt developed into a humid-tropical realm and the former arid belt split and shifted to higher latitudes. Shelf-carbonate deposition continued over extensive areas of the continental shelves and western Palaeo-Tethys but coal swamps were developing in the forelands of the rising Appalachian and Variscan orogens. The late Serpukhovian – early Bashkirian interval saw the closure of the Rheic Ocean and a continent–continent collision between Euramerica (Laurussia) and Gondwana to form Pangea. As a consequence, a marked transition from Visean carbonate deposition to the development of coal swamps and deposition of siliciclastics during the Serpukhovian Stage occurred in many regions.

Marine biotas have suffered two second-order mass extinctions, namely the latest Famennian/Hangenberg and mid-Carboniferous mass extinctions (Bambach, 2006). In contrast, the Tournaisian – Visean interval also saw biotic radiation/recovery from the Late Devonian mass extinctions in the sea; maximum diversity was found during late Visean time. Most reef-forming organisms became extinct during the Late Devonian. Waulsortian, stromatolitic, and thrombolitic carbonate mounds dominated the reef and mound settings during most of the Mississippian but a diversity of buildups including those constructed by *Palaeoaplysina*, phylloid algae, and aragonitic radial-fibrous cements developed in the Late Mississippian and Pennsylvanian.

Terrestrial ecosystems were characterized by the pronounced diversification of terrestrial plants, the establishment of vast lowland forests (coal swamps) in low- to medium-latitude regions and the evolution of reptiles from amphibians in the late Mississippian and Pennsylvanian. In particular, terrestrial plants colonized extensive low-lying non-marine settings during Late Devonian time. Forests became much more extensive throughout the Carboniferous Period when terrestrial floras were dominated by plants that reproduced by spores (sphenopsids, pteropsids and lycopsids) and were characterized by the common presence of seed ferns and the establishment of seed-bearing gymnosperm upland forests.

Accordingly, the Carboniferous Period was critical for the evolution of Earth life and formation of the Pangea supercontinent. Few stage boundaries of the Carboniferous have been precisely defined however, although the biostratigraphy of this period has been studied since the late nineteenth century. To date, only the Global Stratotype Section and Points (GSSPs) of the Devonian–Carboniferous (D–C; = Famennian–Tournaisian), Tournaisian–Visean

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and mid-Carboniferous (= Serpukhovian–Bashkirian) boundaries have been established at the La Serre section of the Montagne Noire of SE France, the Pengchong section, Guangxi, South China and the Arrow canyon section, Nevada, USA, respectively.

In July 2011, more than 200 geoscientists assembled in Perth to present their new research results focusing on all aspects of Carboniferous–Permian geology, palaeontology and palaeoclimatology at the XVII International Congress on Carboniferous and Permian (ICCP 2011). From the papers presented at this conference, we selected eight papers addressing multidisciplinary studies on the stage boundaries within the Carboniferous for this special issue of *Geological Magazine*.

Recent studies show that an evolutionary lineage of key conodont species previously defining the D–C boundary is absent from the GSSP La Serre (Kaiser, 2009). The D–C boundary (also the base of the Tournaisian) therefore requires a re-definition (Aretz, 2011). Here, Kumpan *et al.* (2014) documented a high-resolution multiproxy stratigraphic analysis of the D–C boundary sections from the Czech Republic and attempted to correlate them with the same boundary successions worldwide. To provide a better definition of the D–C boundary in conodont-barren facies successions, Mottequin *et al.* (2014) recommended several shallow-water facies brachiopod species as the markers defining this boundary, based on intercontinental correlations of those brachiopod elements. Belgium records one of the most complete Early Carboniferous successions in the world. Poty *et al.* (2014) presented their detailed definitions of the stage and substage boundaries of both the Tournaisian and Viséan based on Belgian stratigraphic records and suggested that those Belgian substage boundaries can be a basis for an international chronostratigraphic division of those two stages, which are unusually long.

Both Sevastopulo & Barham (2014) and Qi *et al.* (2014a) documented detailed conodont zones defining the base of the Serpukhovian based on fossil records from NW Europe and South China, respectively. Those two studies provide the most up-to-date biostratigraphic correlations for the basal boundary of the Serpukhovian Stage. Kulagina *et al.* (2014) documented the detailed biostratigraphic and lithostratigraphic changes across the mid-Carboniferous boundary from southern Urals, Russia, which provide a better understanding of the mid-Carboniferous boundary mass extinction and associated climate change and environmental stress. Sungatullina (2014) described conodont faunas and index zones across the Bashkirian–Moscovian boundary from the Volga region, Russia. Qi *et al.* (2014b) reported complete Carboniferous conodont zones from the southern Guizhou area, South China with emphasis on the definition of the Pennsylvanian (Late Carboniferous) stage boundaries.

Such a special issue on Carboniferous biostratigraphy is timely given the growing research interest in

Carboniferous palaeoclimate and life evolution which, however, lacks a fine timescale. Accordingly, we hope that this special issue of *Geological Magazine* will provide some new insights into the establishment of GSSPs of stage boundaries and a fine timescale of the Carboniferous Period.

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