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ScienceDirect

Palaeoworld 24 (2015) 5–15

Palaeoworld

www.elsevier.com/locate/palwor

Global climate, sea level cycles, and biotic events in the Cambrian Period

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Received 19 November 2014; received in revised form 19 February 2015; accepted 25 March 2015
Available online 3 April 2015

Abstract

The developing high-resolution chronostratigraphy of the Cambrian provides an updated age model for various geologic and biotic events that occurred during this critical period of Earth history. Broad, time-specific patterns of lithofacies, such as organic-rich deposits, and biofacies appear to be consistent across all Cambrian paleocontinents. Records of important evolutionary events including first appearances of certain metazoan taxa, migrations, and extinctions, tend to coincide with changes in eustatic sea level, as do the positions of many Konservat-Lagerstätten, concretion horizons, agnostoid-rich beds, and other sedimentary features. Most of these events or horizons also show a relationship to perturbations in the global carbon cycle. The positions of organic-rich deposits bear strong relationship to both paleogeographic position and sea level history. Cambrian strata show evidence of cyclicity at multiple scales. Synchronous or near-synchronous global cyclicity is inferred to be associated with oceanographic and climatic cycles characteristic of glacial expansion and deglaciation.

Keywords: Cambrian; Chronostratigraphy; Glacioeustasy; Paleoclimate; Black shale

1. Introduction

New, well-resolved chronostratigraphy of the Cambrian (summarized in Peng et al., 2012a) provides an intercontinental framework for age interpretation of myriad geologic and biotic phenomena. Although a high-resolution chronostratigraphy is still evolving (Babcock et al., 2011b; Peng et al., 2012a), global patterns could not have been recognized prior to the time that good, synchronous, intercontinental marker horizons were identified (Geyer and Shergold, 2000) and some internal subdivisions of the Cambrian System were defined (Peng et al., 2004b, 2009, 2012b; Babcock et al., 2005, 2007; Babcock and Peng, 2007). Using a combination of well-constrained biostratigraphic, chemostratigraphic, and other techniques, together with extrapolation between points where numerical age constraints have been obtained, we are now able to correlate intercontinentally with a high degree of certainty and precision, and we have a new understanding of both the rates and patterns of some important global phenomena.

Refinement of the Cambrian timescale has resulted in fundamental changes in our understanding of Cambrian events. The four Cambrian epochs/series (Fig. 1) correspond broadly to significant steps in Earth's biological and chemico-physical development recognizable from stratigraphic evidence. The Terreneuvian Epoch (Landing et al., 2007) approximates the time of early expansion of a bilaterian trace fossil record (e.g., Mángano and Buatois, 2014) and early expansion of a skeletal body fossil record (e.g., Li et al., 2007; Steiner et al., 2007; Rozanov and Varlamov, 2008). Epoch 2 (provisional name until defined by a ratified GSSP) witnessed widespread early diversification of marine animal clades, most notably among the arthropods.

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http://dx.doi.org/10.1016/j.palwor.2015.03.005
1871-174X/

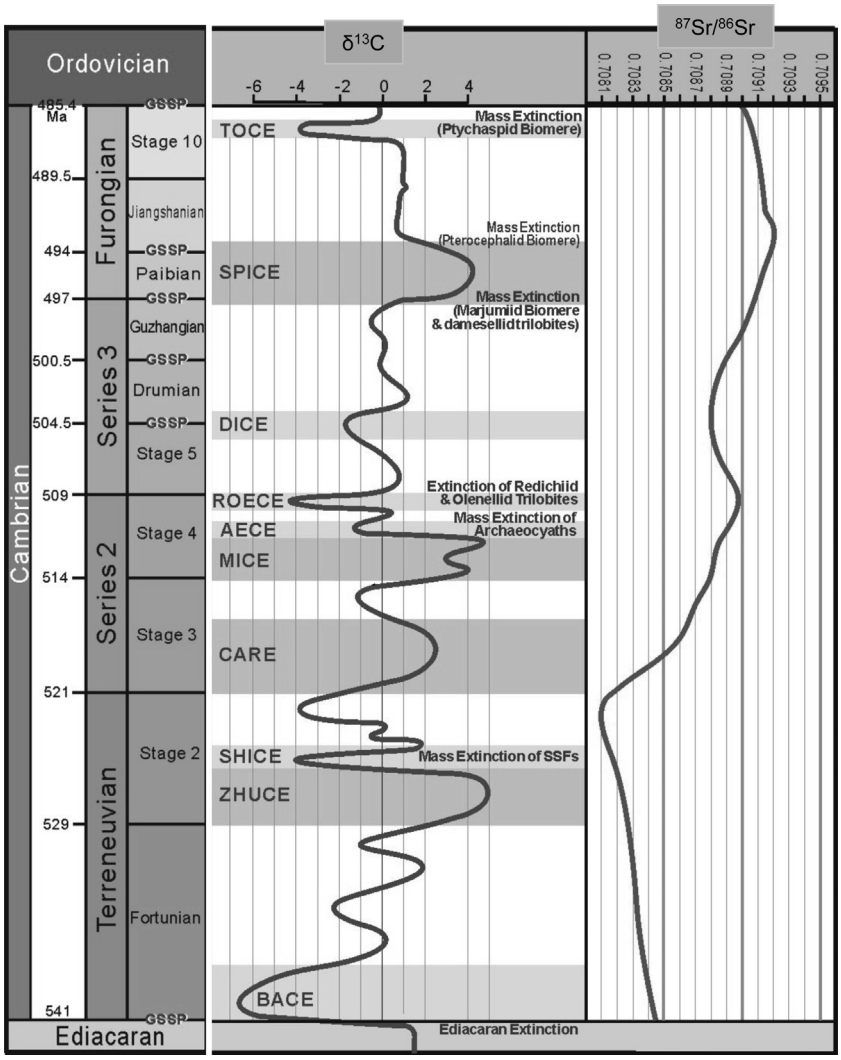

Fig. 1. Late Ediacaran–Cambrian timescale (left) compared with chemostratigraphic profiles ($\delta^{13}C$, center, and $^{87}Sr/^{86}Sr$, right) and timing of some important bioevents such as the first appearances of some major taxa and biomere extinction events recorded in Laurentia. Stages and series defined by ratified GSSPs are indicated on the timescale. Provisional stages and series, indicated by numbers, do not yet have ratified boundary positions. Modified from Peng et al. (2012a).

The epoch's beginning approximates the onset of the Cambrian Arthropod Radiation Event (Zhu et al., 2006). The transition from Epoch 2 to Epoch 3 (provisional name) is marked by major biotic turnovers exemplified by the extinctions of archaeocyath sponges followed by olenelline and redlichiid trilobites, and by transition of chemical cycling in the ocean from a 'Proterozoic style' characterized by numerous, large positive and negative excursions to a 'Phanerozoic style', characterized by few large excursions (Zhu et al., 2006; Peng et al., 2012a; Shields-Zhou and Zhu, 2013). Epoch 3 and the Furongian Epoch were times of major intraclade expansion of bilaterians, especially calcifying arthropods (principally agnostoids and polymerid trilobites; e.g., Peng and Robison, 2000 and references therein; Ahlberg et al., 2004; Robison and Babcock, 2011; Zhao et al., 2011; Ahlberg and Terfelt, 2012; Peng et al., 2012a; Robison et al., 2015) and non-biomineralizing arthropods (e.g., Briggs et al., 1994; Fortey et al., 1996; Robison et al., 2015). During Epoch 3, marine ecosystems were characterized by relative stability comparable to an ecological-evolutionary subunit of the middle Paleozoic (see Brett and Baird, 1995; Brett et al., 1996), and evolutionary expansion of cosmopolitan marine arthropods (e.g., Peng and Robison, 2000; Peng et al., 2012a; Álvaro et al., 2013). The Furongian Epoch (Peng et al., 2004b) was a time of substantial change in physico-chemical conditions of the world ocean (e.g., Saltzman et al., 2000; Peng et al., 2004b; Kouchinsky et al., 2008; Ahlberg et al., 2009; Dahl et al., 2014), leading to punctuation of marine evolutionary processes. A succession of extinctions and/or rapid faunal replacements dominates the fossil record of the Furongian (Palmer, 1965b, 1984; Stitt, 1975; Westrop, 1988; Taylor, 2006).

The proposed 10 ages/stages of the Cambrian (Fig. 1; Peng et al., 2012a) are or will be delimited by horizons that can be correlated globally using multiple chronostratigraphic tools, including biostratigraphic events, which coincide with the horizon or closely approximate that position. Some relationship among, or coordination of, biologic and physico-chemical