Evidence of global climatic and sea level cycles in the Cambrian

Babcock, Loren; Peng, Shanchi; Brett, Carlton E.; Zhu, Maoyan; Ahlberg, Per; Bevis, Michael

Published in:
IGCP 591 Field Workshop 2014, Kunming, China, 12-21 August 2014, Extended Summary

2014

Evidence of global climatic and sea level cycles in the Cambrian

Loren E. BABCOCK[1,2], PENG Shanchi[3], Carlton E. BRETT[4], ZHU Maoyan[3], Per AHLBERG[2] and Michael BEVIS[1]

[1] *School of Earth Sciences, The Ohio State University, Columbus, Ohio, 43210, USA <babcock.5@osu.edu>*

[2] *Department of Geology, Lund University, SE-223 62, Lund, Sweden*

[3] *State Key Laboratory of Stratigraphy, Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, Nanjing 210006, China*

[4] *Department of Geology, University of Cincinnati, Cincinnati, Ohio 45221, USA*

New, well resolved chronostratigraphy of the Cambrian provides an intercontinental framework for age interpretation of myriad geologic and biotic phenomena. The precision of correlation on a global scale now available (Peng *et al*., 2012) greatly exceeds that available prior to one decade ago, when the first internal subdivisions of the Cambrian System were ratified. Using a combination of well-constrained biostratigraphic, chemostratigraphic, and other techniques, a number of correlation issues have been resolved over the past decade. The newly available chronostratigraphic record shows broad time-specific patterns of lithofacies and biofacies that appear to be consistent across all Cambrian paleocontinents. The best intercontinental record of evolutionary events key to correlating globally has come from outer shelf facies, commonly dark, organic-rich shales and limestones. Some taxa preserved in these strata, including some agnostoid, pelagic polymerid, micromollusk, conodont, acritarch, and other species, have widespread or cosmopolitan distributions, particularly around continental margins. Important evolutionary events including radiations, migrations, and extinctions, tend to coincide with perturbations in the global carbon cycle (Zhu *et al*., 2006), so the secular pattern of $\delta^{13}C$ provides a good baseline for constraining correlations even in situations where traditional biostratigraphic criteria are absent or ambiguous. Even in low latitude paleocontinents where there is commonly great disparity between faunas of the outer shelf and the more restricted inner shelf, carbon isotope chemostratigraphy has proven valuable for correlation.

In this preliminary report we call attention to lithofacies and biofacies attributes of Cambrian and genetically related lowermost Ordovician strata that reveal evidence of synchronous or near-synchronous global cyclicity in sedimentary patterns. We infer that these patterns are linked to oceanographic and climatic cycles characteristic of glacial expansion and deglaciation.

One striking aspect of Cambrian stratigraphy is the coincidence of biotic events with shifts in the $\delta^{13}C$ cycle (Zhu *et al*., 2006; Peng *et al*., 2012). Evolutionary events, such as the radiation of archaeocyaths and various arthropod clades, as well as significant extinction events such as the extinction of archaeocyaths and the extinction of trilobite and other taxa at biomere boundaries, line up closely with shifts in $\delta^{13}C$. Understanding the interplay of biotic factors and $\delta^{13}C$ history provides a semi-independent means of assessing time relationships in the Cambrian, and providing a check on biostratigraphic interpretations.

Another striking aspect of Cambrian stratigraphy, particularly in the upper two series, is in the zonation of agnostoids (reflecting the evolution of new species and rapid global migration; Peng and Robison, 2000; Peng *et al*., 2012; Fig. 1), and repeated extinctions of polymerid trilobites followed by recovery and radiation, or biomeres (Palmer, 1965; Stitt, 1975; Fig. 1). One of the most readily recognizable sedimentary horizons in the Cambrian is the position marking the base of the *Ptychagnostus gibbus* Zone. Generally this horizon is a disconformity, and in low paleolatitudes it is commonly marked by shales containing *P. gibbus* overlying a carbonate platform succession. It is interpreted as a major marine flooding surface, one of the most substantial in the Paleozoic. Above this position, there is a good record of outer-shelf facies, and a commensurate record of cosmopolitan agnostoid taxa. The agnostoids provide one of the best tools for precise intercontinental correlation

from the *P. gibbus* Zone through the Lower Ordovician (Tremadocian). There is a regular, repeating pattern of species appearances in open-shelf facies, where agnostoid zones seem to have a time duration of about one to two million years each. The appearances of agnostoid species is closely linked to lithofacies patterns (Babcock *et al.*, 2007; Peng *et al.*, 2012), resulting in zonal boundaries slightly above the bases of transgressive systems tracts.

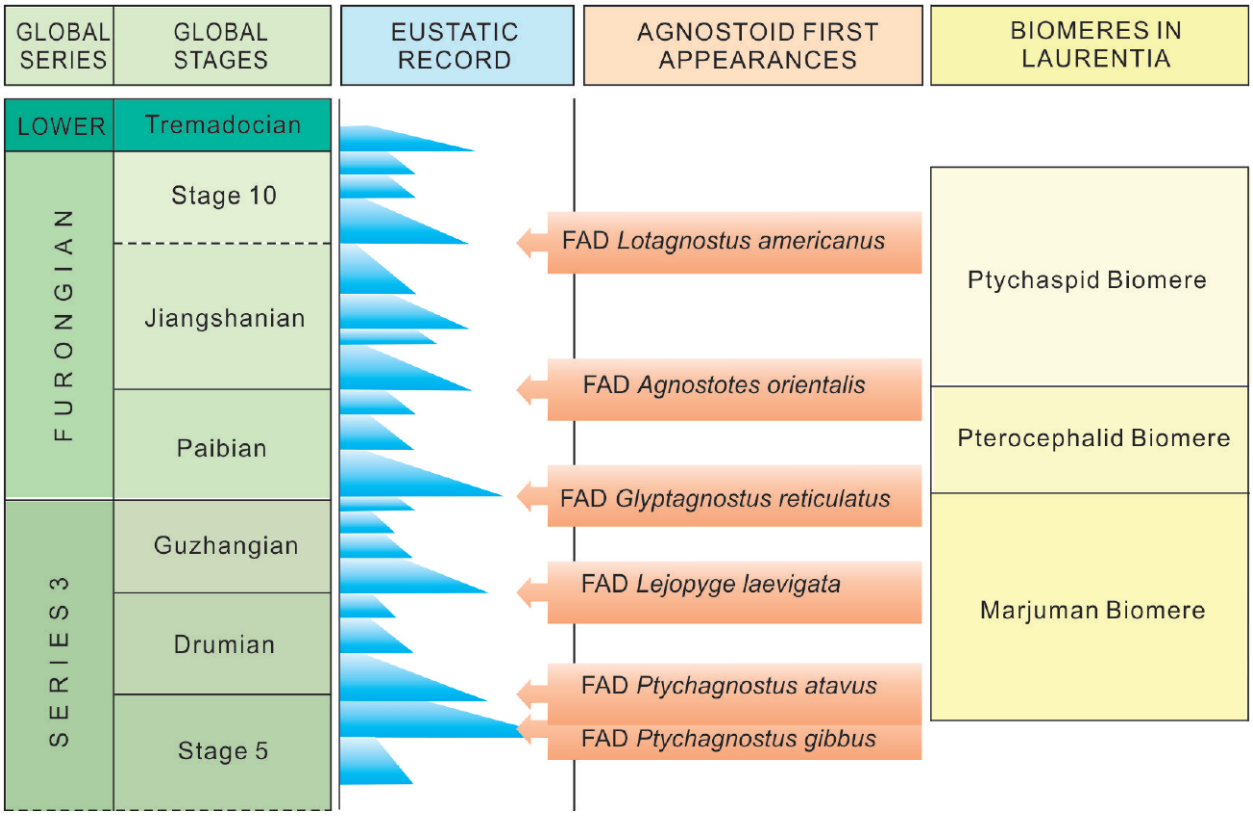

Fig. 1. Inferred eustatic record in the upper two series of the Cambrian System (Series 3 and Furongian Series) compared with the first appearance datums (FADs) of cosmopolitan agnostoids, and biomere intervals recorded in Laurentia.

Multiple lines of evidence suggest that water temperature was a controlling factor on marine biota of the latter part of the Cambrian. In low latitude regions, disjunct shelf (warm water) and deeper slope-basinal (cool water) trilobite faunas have been documented from Series 3 (Babcock, 1994) and the Furongian Series (Taylor and Cook, 1976). By way of analogy with the Quaternary, such a distribution of marine arthropods implies a stratified water column, with warm water near the surface in the tropics and cooler water of polar origin below (Taylor and Cook, 1976). In the Quaternary, a temperature-stratified water column in which warm and cool water masses have different circulation patterns, is a function of the presence of continental glaciers in polar regions. A similar forcing mechanism has been hypothesized for the Cambrian (Babcock, 1994), and this is supported in part by the interpretation that large portions of southern Gondwana lay astride the south polar region (Peng *et al.*, 2012).

Biomere extinctions have commonly been attributed to the transgressive rise of deep, cool waters onto shallow shelf platforms, followed by extinction or displacement of most shelf trilobites, and their replacement by taxa whose ancestors were cool-water adapted (e. g. Stitt, 1975). Two biomere boundaries mark the bases of Cambrian stages (Drumian and Paibian), and reflect significant turnovers in shelf-dwelling polymeroids coincident with the arrival of agnostoid taxa used for global correlation (Fig. 1). The first appearances of these agnostoids are just above the bases of major

transgressive surfaces, suggesting that deglaciation associated with icehouse-to-greenhouse transitioning supplied quantities of cool water to polar shelf areas of Gondwana sufficient to induce eustatic rise. The cool water likely circulated northward toward the equator below warmer surface waters. Accompanying the trangresssions, agnostoids and cool-water-adapted polymerids arrived onto outer shelf areas of low latitude continents.

A variety of sedimentologic signals, recognizable on a global scale in the same stratigraphic positions, tend to reinforce the inferred eustatic pattern, or alternatively, to suggest pulses of water mass movement of global consequence. Among these, hash beds of agnostoids, notably in the dysaerobic facies of the Furongian Stage, suggest temporary pulses of oxygenation of the sea floor. Pulses of oxygenation are likely the result of oxygen-rich cool water arriving from polar deglaciation. Coquinas of agnostoids, notably in the lower Drumian Stage and in various positions within the Furongian Series, suggest lag deposition related to sediment starvation during late transgressive phases or highstands. In the Furongian, slide deposits along continental slopes, comprising carbonate material of shelf-edge origin, imply lowstand intervals. Carbonate concretion horizons, known best from the Alum Shale Formation (e.g. Calner *et al.*, 2013), seem to correlate near-globally, although the concretions are not always of the same large size as the famous 'orsten' concretions of Scandinavia. Dissolution of the upper surfaces of some concretions in Scandinavia suggests sediment starvation and removal through corrosion. In dysaerobic or anaerobic facies, some concretionary horizons feature cone-in-cone calcite, and the positions of these horizons correlate near-globally.

Selected references

Babcock, L. E. 1994. Biogeography and biofacies patterns of Middle Cambrian polymeroid trilobites from North Greenland: palaeogeographic and palaeo-oceanographic implications. *GrØnlands Geologiske UndersØgelse Bulletin*, 169, 129 – 147.

Babcock, L. E., Robison, R. A., Rees, M. N., Peng Shanchi and Saltzman, M. R. 2007. The Global boundary Stratotype Section and Point (GSSP) of the Drumian Stage (Cambrian) in the Drum Mountains, Utah, USA. *Episodes*, 30, 85 – 95.

Calner, M., Ahlberg, P., Lehnert, O. and Erlström, M. (eds). 2013. The Lower Palaeozoic of Southern Sweden and the Oslo Region, Norway. Field Guide for the 3rd Annual Meeting of the IGCP Project 591. *Sveriges geologiska undersökning*, *Rapporter och Meddelanden*, 133.

Palmer, A.R. 1965. Biomere—a new kind of biostratigraphic unit. *Journal of Paleontology*, 39, 143 – 153.

Peng Shanchi, Babcock, L.E. and Cooper, R.A. 2012. The Cambrian Period. *In*: Gradstein, F.M., Ogg, J.G., Schmitz, M.D., Ogg, G.M. (eds), *The Geologic Time Scale* 2012. *Volume* 2. Amsterdam, Elsevier BV. 437 – 488.

Peng Shanchi and Robison, R. A. 2000. Agnostoid biostratigraphy across the Middle-Upper Cambrian Boundary in China. *Paleontological Society Memoir*, 53, 1 – 104.

Stitt, J.H. 1975. Adaptive radiation, trilobite paleoecology and extinction, Ptychaspidid Biomere, Late Cambrian of Oklahoma. *Fossils and Strata*, 4, 381 – 390.

Taylor, M.E. and Cook, H.E. 1976. Continental shelf and slope facies in the Upper Cambrian and lowest Ordovician of Nevada. *Brigham Young University Geology Studies*, 23(2), 181 – 214.

Zhu Maoyan, Babcock, L.E. and Peng Shanchi. 2006. Advances in Cambrian stratigraphy and paleontology: integrating correlation techniques, paleobiology, taphonomy and paleoenvironmental reconstruction. *Palaeoworld*, 15, 217 – 222.

IGCP Project 591 Field Workshop 2014

in conjunction with

International Subcommission on Silurian Stratigraphy (ISSS)
International Subcommission on Ordovician Stratigraphy (ISOS)
and
International Subcommission on Cambrian Stratigraphy (ISCS)

Extended Summary

Edited by

ZHAN Renbin and HUANG Bing

Nanjing University Press

IGCP Project 591 Field Workshop 2014 *in conjunction with* **ISSS, ISOS and ISCS**

"Geologic and biotic events and their relationships during the Early to Middle Paleozoic"

Kunming, China; 13 - 21 August 2014

Organizing and Scientific Committee:

ZHAN Renbin (chair), Nanjing Institute of Geology & Palaeontology
HOU Xianguang (vice-chair), Yunnan University, Kunming
ZHANG Yuandong (vice-chair), Nanjing Institute of Geology & Palaeontology
WANG Yi (secretary), Nanjing Institute of Geology & Palaeontology
HUANG Bing (secretary), Nanjing Institute of Geology & Palaeontology
FENG Zhuo (secretary), Yunnan University, Kunming
Mike MELCHIN (ISSS), St. Francis Xavier University, Canada
David HARPER (ISOS), Department of Earth Sciences, Durham University, UK
ZHANG Xingliang (ISCS), Northwest University, Xi'an
CONG Peiyun, Yunnan University, Kunming
WU Rongchang, Nanjing Institute of Geology & Palaeontology
YANG Qun, Nanjing Institute of Geology & Palaeontology
LIU Yu, National Natural Science Foundation of China
Brad CRAMER, University of Iowa, USA
Jisuo JIN, Western University, Canada

Suggested reference format:

Cramer, B.D, Vandenbroucke, T.R.A. and Ludvigson, G.A. 2014. Asking old rocks new questions: high-resolution event stratigraphy (HiRES) and the quantification of stratigraphic uncertainty. 24-25. In: Zhan Renbin and Huang Bing (eds), IGCP 591 Field Workshop 2014, Kunming China, 12-21 August 2014, Extended Summary. Nanjing, Nanjing University Press. 246 pp.

Zhan Renbin and Huang Bing (eds). 2014. IGCP 591 Field Workshop 2014, Kunming China, 12-21 August 2014, Extended Summary. Nanjing, Nanjing University Press. 246 pp.

Explanations of cover photos:

Cover: upper—a ventral internal mould of brachiopod *Saucrorthis* sp. (~x15) from the Shihtien Fm (Darriwilian, Middle Ordovician) of Laojianshan, Baoshan; down—graptolite *Lituigraptus glomeratus* Ni (~x5) from the lower Jenhochiao Fm (upper Aeronian, middle Llandovery) of the same section as above.

Back cover: a complete specimen of *Anomalocaris saron* (~17cm) from the lower Yu'anshan Mb of the Heilinpu Fm (Cambrian Stage 3) of Maotianshan, Chengjiang, eastern Yunnan.

ISBN 978-7-305-13559-0

Preface

IGCP Project 591 is dedicated to investigating the "Early to Middle Paleozoic Revolution". Indeed, the geological interval from Cambrian to Devonian was full of *revolutionary* events, both in the organic and inorganic realms, and their interactions triggering the macroevolution of Earth ecosystems as well as the solid Earth itself. The well known Cambrian Explosion, the first macroevolutionary radiation of ecosystem, comprises several episodes from its prologue (represented by the Ediacara Biota), through the first (the Small Shelly Fauna) and the main stages (the Chengjiang Biota) to the epilogue (the Burgess Shale Fauna, the Kaili Fauna etc.). The great Ordovician biodiversification event (GOBE), i.e. the Ordovician radiation, spanned tens of million years, highlighted by several diversity acmes, and established the basic framework of the Paleozoic Evolutionary Fauna that dominated the marine ecosystems for more than 290 Ma. The end-Ordovician mass extinction was the first catastrophic event in life history. It is now known not to be ranked as one of the Big Five, and the marine ecosystem did not collapse at all during this mass extinction. None of these major biotic events are regional in scale, not to say local, although all of them were closely related with local, regional and global tectonic movements, paleogeographic and paleoclimatic changes and apparently some sedimentary innovations (e.g. the Substrate Revolution in Cambrian and Ordovician), as well as some other geological activities such as vocanic eruptions, comets collisions, Milankovich cycles, etc. To investigate these Early to Middle Paleozoic revolutionary events and their dynamics, geoscientists in the world need a common language, i.e. the GSSPs and the establishment of regional and global chronostratigraphic frameworks, which have been some of the major tasks of each Subcommission of ICS for several decades.

On behalf of the Organizing Committee, we would like to take this opportunity to thank all 151 experts who have co-authored the 66 abstracts, summaries and extended summaries in this Extended Summary volume for this meeting. The scope of these papers covers all the above-mentioned topics dealing with the Early to Middle Paleozoic revolutionary events and their triggering factors. Among the 151 contributors, nearly half of them are graduate students or young researchers who brought great vitality to this meeting as well as the IGCP Project. We also want to thank the three keynote speakers, Michael Melchin (ISSS), David Harper (ISOS) and Loren Babcock (ISCS), who prepared both extended summaries and reviewed presentations for this meeting.

Many thanks to the following institutions for their financial support: the National Natural Science Foundation of China (NNSFC: 41221001, 41290260 and another special project); the Nanjing Institute of Geology and Palaeontology (NIGP) of CAS; the State Key Laboratory of Palaeobiology and Stratigraphy (LPS); and the Yunnan Key Laboratory of Paleobiology (YLP) attached to the Yunnan University.

Zhan Renbin and Huang Bing
On behalf of the Organizing Committee

Contents