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Foreword/Avant-propos

The Cambrian explosion: Its timing and stratigraphic setting

L'explosion cambrienne : chronologie et signification stratigraphique

1. English version

1.1. Introduction

Even if Ediacaran–Cambrian times might have been a major turnover point in greening of the terrestrial landscape (see e.g., Álvaro et al., 2003; Strother et al., 2004; Retallack, 2008, 2013; Horodyskyj et al., 2012), this time-interval is mostly known for the diversification of the marine counterpart of the biosphere. This bioevent, commonly named "the Cambrian explosion", is one of (if not the most) dramatic radiations in the history of life on Earth, now also regarded as the emergence of complex, benthic-demersal, metazoan dominated, marine ecosystems (e.g., Vannier et al., 2007; Klug et al., 2010) with no Precambrian counterpart. After some decades of intensified research, the topic of the "Cambrian explosion" has feed an abundant literature focusing on its biodiversity and phylogenetic patterns (e.g., Alroy et al., 2008; Erwin et al., 2011; Aberhan and Kiessling, 2012; Na and Kiessling, 2015) and their complex, interacting abiotic (e.g., climatic, atmospheric, tectonic and change in marine chemistry; Lyons et al., 2014; Maruyama et al., 2014; Santosh et al., 2014; Xiao, 2014) and biotic (genetic vs ecological; Erwin et al., 2011; Na and Kiessling, 2015) triggers. A high-resolution chronostratigraphic and correlative scheme for the Cambrian System is required for Earth scientists to decipher the ultimate triggers of the Cambrian bioevents and in particular their global versus local patterns and processes. However, the Cambrian is the only system of the lower Palaeozoic where series and stage boundaries have not been completely defined. Development of such a global stage/series-level chronostratigraphic subdivision of the Cambrian System, and erection and publication of regional and global correlation charts are the two main objectives of the International Subcommission of Cambrian Stratigraphy (ISCS) since its founding in 1962.

1.2. Current chronostratigraphic subdivision of the Cambrian System and ratified Global boundary Stratotype Sections and Points (GSSPs)

Peng and Babcock (2011) and Peng et al. (2012) extensively reviewed the history of the Cambrian stratigraphy and the last advances in bio-, chrono-, magneto-, chemo-, and sequence stratigraphy of this system. After about four decades of background, extensive investigations and meetings, five Cambrian boundaries, in addition to the basal boundary of the overlying Ordovician System (Cooper et al., 2001) have been ratified and defined by a Global boundary Stratotype Section and Point (GSSP). Briefly summing-up (Fig. 1), the GSSP for the base of the Cambrian System, conterminant with the base of the Phanerozoic Eonothem, the Terreneuvian Series and the Fortunian Stage, was ratified in 1992 and the latter series and stage named in 2007. It coincides with the first appearance known, at the time of ratification, of the trace fossil *Trichophycus pedum* in the Fortune Head section, eastern Newfoundland, Canada (Brasier et al., 1994; Landing et al., 2007). This marked an acceleration in the pace on decision on both provisional and ratified boundaries, but also extended the system downward by including to the former "Lower Cambrian" a large pre-trilobitic interval bearing ichnofossils and recording the "biomineralization event" or appearance of polyphyletic skeletonised microfossils (traditionally named "Small Shelly Fossils" or SSFs according to the expression introduced by Matthews and Missarzhevsky, 1975, and major members of the short-lived "Tommotian Evolutionary Fauna"; Sepkoski, 1992; Li et al., 2007). As a consequence, the consensus of opinion that the system should be subdivided into four series representing subequal time-spans emerged in September 2004 at the IX International Conference of the Cambrian Stage Subdivision Working Group in Suanbo Spa, South Korea. The lowermost series would represent the Cambrian pre-trilobitic interval whereas the first appearance of trilobites, traditionally considered a major biotic event with high chronostratigraphic potential, would mark the base of the provisional Series 2 and Stage 3 (Babcock et al., 2005). The ratified boundaries in the system define the bases of the Drumian, Guzhangian, Paibian and Jiangshanian stages. The Drumian (the 2nd stage of provisional Series 3) was ratified in 2006 (Babcock et al., 2007) at the first appearance datum (FAD) of the agnostoid arthropod *Ptychagnostus atavus* in the Stratotype Ridge section, Drum Mountains, northern Millard County, Utah, USA; the Guzhangian (the 3rd and uppermost stage of provisional Series 3) was ratified in 2007 at the FAD of the agnostoid arthropod *Lejopyge laevigata* in the Louyixi section along the Youshui river, northwestern Hunan, China (Peng et al., 2009a); the Paibian (base of the Furongian, uppermost Cambrian series) ratified in 2003 at the FAD of the agnostoid arthropod *Glyptagnostus reticulatus* in the Paibi section, northwestern Hunan Province, China (Peng et al., 2004); and the Jiangshanian (the penultimate Cambrian stage) ratified in 2009 at the FAD of the agnostoid arthropod *Agnostotes orientalis* in the Duibian B section at the base of Dadoushan Hill, northwest of Duibian Village, Jiangshan County, western Zhejiang Province, China (Peng et al., 2009b).

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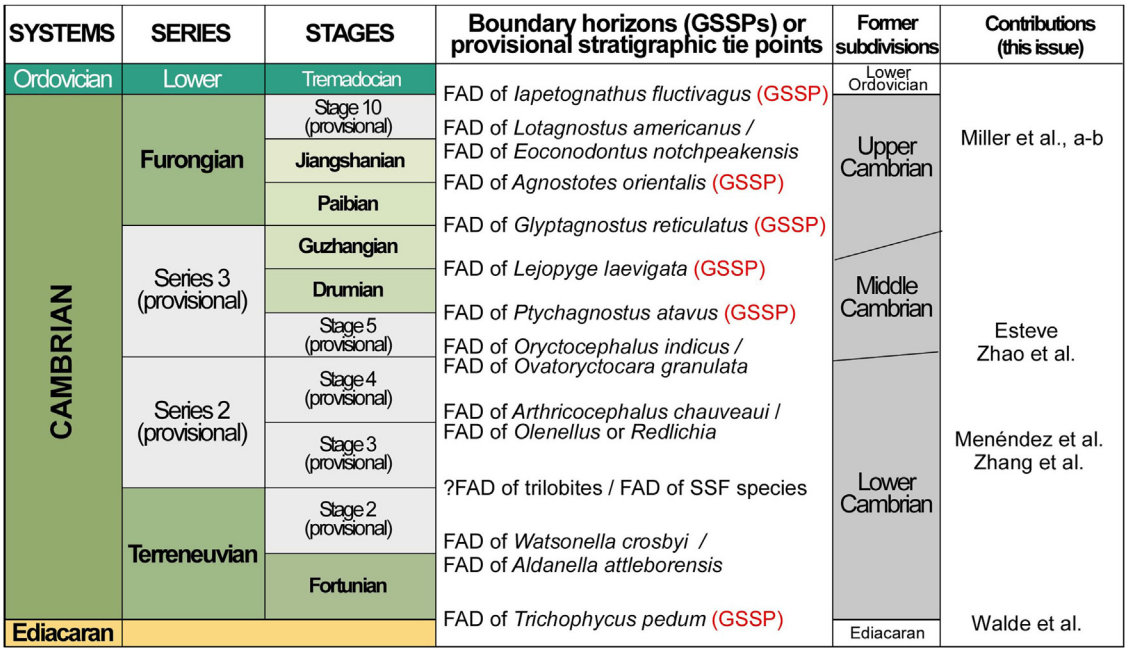

Fig. 1. Chart showing the current status of global chronostratigraphic subdivisions of the Cambrian System (updated from Peng and Babcock, 2011) and its correspondence with the former threefold Cambrian subdivision. Names of ratified series and stages are indicated in bold on a standard-colored background. Provisional units are numbered according to their stratigraphic rank in the system and shaded. Papers included in this issue are indicated in front of units they deal with (see text for details).
Charte montrant le statut actuel de la subdivision chronostratigraphique internationale du Système Cambrien (mise à jour d'après Peng et Babcock, 2011) et sa correspondance avec l'ancienne subdivision en trois séries. Les noms des séries et des étages ratifiés sont indiqués en caractères gras sur un fond de couleur standardisée. Les unités provisoires sont numérotées selon leur position stratigraphique dans le système et ombrées. Les articles inclus dans ce fascicule sont indiqués en face des unités dont ils traitent (voir texte pour détail).

1.3. Current discussions of Working Groups toward definition of remaining GSSPs and the 2014 meeting of the International Subcommission on Cambrian Stratigraphy, Ouarzazate, Morocco

A Working Group has been established for each boundary yet to be defined following the X International Field Conference of the Cambrian Stage Subdivision Working Group, held in Nanjing, China, in August 2005. Currently, the remaining undefined boundaries are the base of provisional Stage 2 (second and last stage of Terreneuvian Series), Stages 3 and 4 (the two stages of provisional Series 2), Stage 5 (also base of provisional Series 3) and Stage 10 (uppermost Cambrian stage of the Furongian Series). The main challenge has been and remains resolving issues of faunal provincialism, including taxa of stratigraphic value for global correlation.

The present special issue of *Annales de Paléontologie* comprises a set of papers that were originally presented during the joint meeting of the International Subcommissions on Ediacaran and Cambrian Stratigraphy that took place in Ouarzazate (Morocco) in September 2014. Along with other communications offered during the meeting (Álvaro, 2014; Devaere et al., 2014), they intend to provide some progress in the current discussions and topics held by both subcommissions, including documentation of Cambrian biodiversity and stratigraphy.

1.3.1. GSSP at the base of the Cambrian in question

The discovery of *Trichophycus pedum* below the GSSP in the stratotype (Gehling et al., 2001), along with problems in correlating this horizon at an intercontinental scale, pointed to the need of rediscussion and restudy of the definition of the GSSP for the base of the Cambrian System (Peng and Babcock, 2011; Babcock et al., 2014). A Working Group chaired by M. Zhu (China) has recently been assembled by the ISCS to provide a recommendation about whether or not options for redefining the GSSP should be considered. Walde et al. (2015, this issue) advocate for a revision of the Cambrian GSSP, with a change of the GSSP definition, point and horizon (one of the options listed by Babcock et al., 2014). They suggest, after a review of the Ediacaran-Cambrian transition in the State of Mato Grosso do Sul, Brazil, the FAD of a cloudiniid as a potential primary marker for a new Cambrian GSSP.

1.3.2. Terreneuvian Series, provisional Stage 2

Few biostratigraphic levels display good potential for intercontinental correlation in the upper part of the pre-trilobitic Cambrian (Terreneuvian Series). The Working Group devoted to Stage 2 GSSP, chaired by M. Steiner (Germany), emphasized the potential of the FAD of a few small shelly fossils. Among them, the FAD of the micromollusks *Watsonella crosbyi* and *Aldanella attleborensis* emerged as the best candidates, although no decision has been taken yet (see discussions in e.g. Rozanov et al., 2008; Zhu et al., 2008; Li et al., 2011; Parkhaev et al., 2011, 2012; Devaere et al., 2013; Parkhaev, 2014; Brock et al. *in* Devaere et al., 2014; Li *in* Devaere et al., 2014). One important task regarding this boundary is to support the recognition of potential levels with non-biostratigraphic correlation criteria such as chemostratigraphy, a still debated possibility (see e.g. Landing et al., 2013).

1.3.3. Provisional Series 2, Stages 3 and 4

The base of the provisional Series 2 and Stage 3 is considered to approximately coincide with the appearance of the first trilobite *sensu* Fortey and Whittington (1997) and Edgecombe and Ramsköld (1999), related to the calcification of its exoskeleton. This definition excludes different Terreneuvian ichnofossils attributed to trilobites. These ichnofossils are currently better considered as having been made by arthropods *sensu lato*. The earliest trilobites known so far include *Profallotaspis tyusserica* and *Profallotaspis jakutensis* from Siberia (Bushuev et al., 2014), *Hupetina antiqua* from Morocco (Geyer, 1996) and *Fritzaspis generalis* from Laurentia (western Nevada and eastern California; Hollingsworth, 2008). Their first appearances are often seen as nearly simultaneous (Hollingsworth, 2011; Bushuev et al., 2014), but still at slightly