Cretaceous Research 88 (2018) 90–99

Contents lists available at ScienceDirect

Cretaceous Research

journal homepage: www.elsevier.com/locate/CretRes

Ammonites and the mid-Cretaceous saga

Peter Bengtson [a, *], Mikheil V. Kakabadze [b]

[a] Institute of Earth Sciences, Heidelberg University, Im Neuenheimer Feld 234, 69120 Heidelberg, Germany
[b] A. Janelidze Institute of Geology, I. Javakhishvili Tbilisi State University, Polytkovskaja str. 31, 0186 Tbilisi, Georgia

ARTICLE INFO

Article history:
Received 6 May 2017
Received in revised form
9 September 2017
Accepted in revised form 1 October 2017
Available online 4 October 2017

Keywords:
Mid-Cretaceous
Series
Epochs
Stratigraphy
Ammonites
Taxonomic turnovers

ABSTRACT

Ever since the introduction of the Cretaceous System, nearly two centuries ago, the terms 'mid-Cretaceous' and 'middle Cretaceous' keep appearing in the literature, implying a three-fold division rather than the more generally accepted two-fold division of the system/period. The frequent and persistent use of these informal terms proves that they fulfil a need in stratigraphic communication; consequently, formalisation of a middle series/epoch of the Cretaceous System/Period is justified and desirable and will put an end to the present terminological confusion with respect to division of the Cretaceous. According to long-established practice, biotic turnover events (major extinctions and/or radiation events) of biostratigraphically significant fossil groups provide convenient, correlatable horizons for positioning chronostratigraphic boundaries. As a first step towards establishing a solid database for a formal proposal for a three-fold division of the Cretaceous, taxonomic turnover events at the level of family- and genus-group taxa (families/subfamilies and genera/subgenera) for the historically most important fossil group, the ammonites, have been analysed for the broad 'mid-Cretaceous' interval, ranging from base Barremian to base Santonian. The results provide little support for a series boundary at the traditional Lower–Upper Cretaceous boundary at the base of the Cenomanian. Instead, the most significant ammonite turnover event occurred at the Aptian–Albian boundary interval, which then emerges as a potential lower boundary of a middle Cretaceous series. Higher in the Cretaceous, no similarly distinctive turnover event is recorded for the ammonites, although the turnover at the Cenomanian–Turonian boundary interval is slightly more pronounced. For a formal proposal for a three-fold division of the Cretaceous, the ammonite data need to be integrated with data on other chronostratigraphically significant fossil groups, such as inoceramid bivalves, foraminifers, calcareous nannofossils and dinoflagellates, and with magnetostratigraphy, chemostratigraphy and cyclostratigraphy.

1. Introduction

Ever since the Cretaceous System was first introduced, by the Belgian geologist Jean-Baptiste-Julien d'Omalius d'Halloy (1822), it has been arbitrarily divided into two or three series, i.e. lower and upper Cretaceous or lower, middle and upper Cretaceous, respectively, a situation that continues unabated today to the obvious detriment of clarity in stratigraphic communication. Stability in scientific terminology and nomenclature is of utmost importance to guarantee accurate communication and avoid misunderstandings (e.g., Murphy and Salvador, 1999; U.S. Geological Survey Geologic Names Committee, 2009). For stratigraphy, the *International Stratigraphic Guide* (Salvador, 1994; Murphy and Salvador, 1999), the various national stratigraphic guides, and not least the regularly updated *International Chronostratigraphic Chart* (Cohen et al., 2017) provide rules and recommendations promoting stability. However, for some parts of the stratigraphic column, the terminology is far from stable, a prime example being the Cretaceous series.

With its *c.* 80 million years, the Cretaceous Period is by far the longest of the Phanerozoic periods. Dominantly high sea levels during the exceptionally warm Cretaceous resulted in vast epicontinental seas, which left their traces on all the continents. The Cretaceous saw the rise of the calcareous plankton (coccoliths and foraminifers), modern gastropods and the angiosperms, and at the end of the Cretaceous a major extinction event wiped out the ammonites, belemnites, inoceramid bivalves, rudists, the majority of the calcareous nannofossils and planktic foraminifers and the non-avian dinosaurs. The most extensive petroleum sources and reservoirs are found in Cretaceous rocks. Consequently, the Cretaceous System

* Corresponding author.
E-mail addresses: Peter.Bengtson@geow.uni-heidelberg.de (P. Bengtson), mishakakab@gmail.com (M.V. Kakabadze).

https://doi.org/10.1016/j.cretres.2017.10.003
0195-6671/

attracts a great deal of research. One would then expect that terminological problems in Cretaceous stratigraphy would have been settled long ago, and that Cretaceous workers would all speak the same language. Unfortunately, despite extensive efforts by the International Commission on Stratigraphy (ICS) and the Subcommission on Cretaceous Stratigraphy (SCS) with all its working groups and, not least, the IUGS Lower Cretaceous Ammonite Working Group, the 'Kilian Group' (Hoedemaeker et al., 2003; Reboulet et al., 2006, 2009, 2011, 2014) this is still not the case. In comparison with most other geological systems, few Cretaceous stage boundaries have so far been defined by GSSPs (*viz*., five out of twelve). There are also geographical differences, with regional or local stage names still in common use. Much of this disarray can be attributed to problems of correlation.

During the nearly two centuries since the Cretaceous System was introduced, a considerable amount of palaeontological and biostratigraphic data has been unearthed, providing a solid basis for formalising a practical division of the system. It is remarkable that in most stratigraphic charts, the excessively long Cretaceous Period is divided into only two epochs, with both the Early and Late Cretaceous each having a considerably longer duration than, for example, the entire Silurian Period, which is nevertheless divided into four epochs, the shortest of which (Pridolian) with merely a third of the duration of some of the Cretaceous ages. It is obvious that a coarse division of the Cretaceous into two 'overlong' epochs is far from practical. This explains the ubiquitous and seemingly ever increasing use of the terms 'mid-Cretaceous' and 'middle Cretaceous' (hereinafter referred to as 'mid-/middle Cretaceous') in stratigraphic communication. Formalisation of the Cretaceous series/epochs is long overdue, and there is convincing arguments for a threefold-division instead of the traditional two-fold division. To decide about the most practical boundaries for the mid-/middle Cretaceous requires analysis of the criteria for subdividing chronostratigraphic and geochronological units, applied to the Cretaceous System/Period.

Chronostratigraphic division is largely linked to palaeontological events manifested in the rock record. The historically and arguably still most important group for Cretaceous chronostratigraphy is the ammonites (e.g., Kennedy and Cobban, 1977; Kennedy, 1986; Lehmann, 2015). Taxonomic turnover events manifested in the rock succession provide a solid biostratigraphic framework, and the lowest occurrences of selected species in most cases indicate the most practical, correlatable positions when selecting GSSPs for stages. Major turnover events, reflected at the family- and genus-group level (families/subfamilies and genera/subgenera), may thus indicate suitable boundaries between higher stratigraphic categories, such as series. The use of ammonites as primary boundary criteria carries the additional advantage of these being determinable in the field, a quality shared with inoceramid bivalves and other stratigraphically significant macrofossils, whereas identification of microfossils and abiotic events generally requires laboratory processing and analysis.

The aim of the present study is to identify the major ammonite turnover events for the broadly conceived 'mid-Cretaceous' base Barremian to base Santonian interval. The next steps towards a proposal for a formalisation of a three-fold division of the Cretaceous will be to integrate the ammonite data with data on major taxonomic turnover events among other chronostratigraphically significant fossil groups, such as inoceramid bivalves, foraminifers, calcareous nannofossils and dinoflagellates, and with magnetostratigraphic, chemostratigraphic and cyclostratigraphic events. The data thus compiled is expected to indicate the overall most suitable series boundaries for a three-fold division of the Cretaceous System.

2. Historical background

The Cretaceous System was originally established by d'Omalius d'Halloy (1822) as a lithological term ("terrain crétacé", i.e., 'chalky ground'). Conybeare and Phillips (1822) divided the Cretaceous succession into "Beds between the Chalk and Oolite Series" and "Chalk Formation", which were later designated Lower and Upper Cretaceous (Lyell, 1851, p. 209). The boundary between the two units was then often placed at the base of the "Lower Green Sand" (Mantell, 1833, p. 66; Topley and Jukes-Browne, 1888, p. 455) or "Gault", Albian or "Upper Greensand and Gault" (Lyell, 1851, p. 209; Page, 1856, p. 202; Jukes-Browne, 1886, pp. 366–367; Jukes-Browne and Topley, 1888, p. 77), i.e., the Albian was included in the Upper Cretaceous. Initially, and well into the last decades, the terms 'Neocomian' and 'Senonian' have also been frequently used, although in highly variable ways (for the Neocomian, see Rutsch and Bertschy, 1955, Table 1). However, ever since the Cretaceous System was introduced, several authors favoured a three-fold division, commonly designated 'Neocomian', 'Gault' and 'Chalk' (e.g., d'Omalius d'Halloy, 1831, pp. 185–186; d'Archiac, 1839, p. 295; d'Orbigny, 1841, pp. 418–420; Leymerie, 1841, p. 295), "Crétacique inférieur", Crétacique moyen" and "Crétacique supérieur" (Renevier, 1897, p. 565) or "Infracretaceous", "Mesocretaceous" and "Supracretaceous" (Böse and Cavins, 1928), with "Eocrétacé", "Mésocrétacé" and "Néocrétacé" (Renevier, 1899, p. 44) for the corresponding epochs. A three-fold division was in frequent use in North America (e.g., Stevenson, 1875; Newberry, 1876; Böse and Cavins, 1928), and there were even advocates for a four-fold division (d'Archiac, 1846, p. 7).

At a meeting of the Commission for the Uniformity of the Nomenclature in Zürich, in 1883, despite a majority voting in favour of a three-fold division, the Cretaceous System was provisionally divided into two series (Dewalque, 1886, pp. 54, 61). Two years later, at the International Congress of Geologists in Berlin, in 1885, a two-fold division was accepted, although the French, Belgian, Swiss and Russian national committees advocated a three-fold division (Frazer, 1886, pp. 91–93, 105; Drushchits, 1966, p. 11). Though never formally ratified, the two-fold division has persisted until today, with the boundary between the Lower and Upper Cretaceous at the base of the Cenomanian Stage. For an exhaustive survey of the history of development of the Lower and Upper Cretaceous series, see Spath (1941) and Muller and Schenck (1943).

The terms 'middle Cretaceous' and 'mid-Cretaceous' can be found in the literature fairly soon after the introduction of the Cretaceous System, even in titles of publications. The first use of 'middle Cretaceous' in the title of a publication appears to be that of Conrad (1842) and of 'mid-Cretaceous' that of Osborn (1902). In the early 20th century, the terms 'middle Cretacic' and 'mid-Cretacic' were preferred by some authors (e.g., Grabau, 1913).

On the basis of ammonites, rudists, echinoids, belemnites and foraminifers, Haug (1911, pp. 1163–1171) explicitly proposed a three-fold division of the Cretaceous System, viz. (1) lower Cretaceous ("Groupe Éocrétacé"), comprising the Valanginian–Aptian stages, (2) middle Cretaceous ("Groupe Mésocrétacé"), comprising the Albian–Turonian stages, and (3) upper Cretaceous ("Groupe Néocrétacé"), comprising the Coniacian–Maastrichtian stages (including rudist-bearing "Danian", now referred to the upper Maastrichtian). Haug (1911) listed the characteristic families and genera for each series/epoch, with emphasis on the ammonites. Although Haug's data were limited in comparison with the current amount of data, they clearly support a three-fold division of the Cretaceous System.

It is somewhat surprising that the widely accepted Lower and Upper Cretaceous series have never been formally defined and ratified, contrary to common belief or even clear assertions (e.g., D.E. Owen, 1987, 2009; Kemper and Wolfart, 1989; Kennedy and Gale, 1996; Mortimore et al., 2001; J.G. Ogg, 2004; Scott et al., 2009; J.G. Ogg et al., 2016), including statements of the International Commission on Stratigraphy (G. Ogg, 2007: "Official