

High-resolution Late Cretaceous carbon isotope stratigraphy; Linking ocean and shelf-seas on a global scale

S. VOIGT^{1*}, O. FRIEDRICH², A. S. GALE³

¹ IFM-GEOMAR, Wischhofstr. 1-3, 24148 Kiel, Germany (*correspondence: svoigt@ifm-geomar.de)

² NOC Southampton (of2w07@noc.soton.ac.uk)

³ University of Portsmouth (a.gale@nhm.ac.uk)

Carbon isotope stratigraphy has evolved as a remarkable tool in Cretaceous stratigraphy. It overcomes problems inherent in biostratigraphy such as provincialism or diachronous first occurrence ages, which makes it useful for long-range correlation. New high-resolution carbon isotope stratigraphies from Upper Cretaceous pelagic carbonate successions resolve carbon cycle variations down to timescales of less than 100 kyr. Here we present case studies from Cenomanian-Turonian and Campanian-Maastrichtian times.

The Cenomanian-Turonian marks the peak warmth of the Cretaceous greenhouse with tropical sea-surface temperatures exceeding 30°C. In contrast, emerging evidence indicates dramatic eustatic sea-level changes and at least short periods of glaciation punctuating the warmth. The synchronicity of sequences is proven by high-resolution $\delta^{13}\text{C}$ correlation between sedimentary successions on different continental cratons. Throughout the middle Cenomanian-Turonian succession, the $\delta^{13}\text{C}$ curve shows numerous small-scaled positive excursions, which are of significance and appear to be cyclic. Results of spectral analysis of the $\delta^{13}\text{C}$ record show a frequency pattern that can be related to short and long eccentricity.

One of the most extreme carbon cycle perturbations in Earth's history occurred in the latest Cenomanian and is reflected by the widespread occurrence of organic-rich sediments (OAE 2). A new high-resolution carbonate $\delta^{13}\text{C}$ curve derived from the cyclic Wunstorf core succession resolves all known features of the OAE2- $\delta^{13}\text{C}$ anomaly and, based on high-resolution borehole geophysics and XRF core scanning, allows the development of an orbital age model. Two prominent oceanographic events occurred in shelf-sea environments and are related to eustasy and short eccentricity. A period of intensified circulation and shelf-sea cooling corresponds to the maximum rate of transgression and enhanced ventilation of the deep proto-North Atlantic Ocean, whereas widespread black-shale deposition corresponds to high sea level and the spread of partly anoxic oceanic surface waters onto the shelves. The close relationship between sea level and eccentricity suggests an orbital forcing of eustasy in periods of greenhouse climate conditions.

The Campanian-Maastrichtian was a period of long-term climate cooling succeeding the extreme warmth of the mid-Cretaceous. The causal mechanism of this cooling period is poorly understood to date. While some authors suggest mainly oceanographic changes such as progressive deep-water exchange between the deep oceanic basins, others supposed a short ephemeral glaciation as initial trigger. Mainly, the relative timing of oceanic $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ changes to eustatic sea-level changes is not proven yet. Likewise, the influence of plate tectonic changes as the opening of gateways or the subduction of mid-ocean ridges and/or of orbital forcing is poorly understood. A principle objection beside the sparse available data is the low temporal resolution of biostratigraphic zonations.

New carbon isotope correlations from Campanian-Maastrichtian sites of Boreal and Tethyan shelf seas in Europe and from the Shatsky Rise in the tropical Pacific improve the available stratigraphic framework. Of special importance are two negative carbon isotope excursions (CIEs) in the late Campanian and earliest Maastrichtian, which lasted about 0.8-1.5 million years, affected all ocean basins and correspond to an interval when the rise of marine strontium isotopes displays an increased slope. The CIEs correspond to a period when long-term sea-level fall resulted in the widespread exposure of continental shelves, which might have favoured increased rates of terrestrial and marine organic matter oxidation. However, available sedimentological data do not prove a temporal relation of the CIEs and major short-term regressions querying a glacioeustatic mechanism. Alternatively, changes in the mode and site of deep-water formation could have intensified the ventilation of the ^{12}C enriched deep-waters causing a reduction of $\delta^{13}\text{C}$ in the inorganic carbon reservoir.