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Late Cenomanian to Middle Turonian high-resolution carbon isotope stratigraphy: New data from the Münsterland Cretaceous Basin, Germany

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Abstract

New high resolution carbon isotope stratigraphies from two basinal pelagic carbonate successions in northern Germany (Halle and Oerlinghausen, Münsterland Cretaceous Basin) resolve late Cenomanian to early Mid-Turonian carbon cycle variations at timescales of less than 100 kyr. Beside the major carbon isotope excursion of the late Cenomanian oceanic anoxic event (OAE 2), 11 small-scale distinct features are precisely resolved in the $\delta^{13}C$ carbonate curve and related to boreal macrofossil zonations. The small-scale carbon isotope events correspond to secular $\delta^{13}C$ carbonate variations identified previously in the English Chalk. The boreal high-resolution $\delta^{13}C$ carbonate curve shows a detailed coincidence with two Tethyan $\delta^{13}C$ curves from Italy, what demonstrates the interregional significance of the $\delta^{13}C$ dates and allows their correlation within error limits of ±40 kyr. Furthermore, the new $\delta^{13}C$ curve enables the calibration of boreal and tethyan macro- and microfossil zonations. Accordingly, the Tethyan calcareous nannoplankton boundary NC13/NC14 corresponds to the boreal FO of *C. woollgari*, the index taxon for the Lower-Middle Turonian boundary. The cyclic appearance and the temporal spacing of the small-scale carbon isotope events suggest that orbital forcing exerted control on surface water productivity and organic matter preservation at the sea floor.
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Keywords: carbon isotope stratigraphy; Cretaceous; correlation

1. Introduction

The Cretaceous was a period of greenhouse climate, when polar ice was mostly absent and the tropics experienced unusual warmth. Numerous studies have demonstrated that marine sedimentation was influenced by orbital forcing, fast and repeated changes in sea level, the occurrence of oceanic anoxia, as well as sudden and large changes in sea surface temperature, ocean chemistry and marine biota documenting the high degree of Cretaceous climate variability [1–8]. In order to improve our knowledge about the temporal and spatial dimension of processes, it is of great importance to develop stratigraphic tools, which provide a high time resolution and can be applied on a global scale. Biostratigraphic zonations are regional useful stratigraphic tools, but long-range correlations are complicated by climate-zone

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related provincialism of biota, as well as differences in bathymetry and sedimentary facies. To date, large temporal uncertainties exist in the calibration of Late Cretaceous micro- and macrofossil zonations, which have a dimension from hundred thousands to millions of years [9,10].

Carbon isotope stratigraphy has proven as a remarkable tool in stratigraphic correlation, especially in mid-Cretaceous sedimentary successions, where no magnetic reversals can be detected [11–13]. It is shown in numerous studies that the Cenomanian–Turonian carbon isotope curve has significant features, which differ in their magnitude as well as in their long- and short-term variability. The most prominent carbon isotope event is the positive excursion in the Cenomanian–Turonian boundary interval, which is associated to the major oceanic anoxic event OAE 2. The δ^{13}C anomaly has a magnitude of 2–3‰, lasted about 400 kyr, and shows detailed features which occur synchronous in various sections worldwide (Western Interior Basin [14,15]; Eastbourne, England [16,17]; Gröbern, Germany [18]; Gubbio, Italy and Tarfaya basin, Morocco [19–21]). Further carbon isotope events, as the Mid-Cenomanian Event (MCE) in the early Middle Cenomanian [22,23] or the Pewsey and Hitchwood Events in the late Turonian [24], are distinctive geochemical marker, which are successfully used for long-range correlation, the detection of sedimentary hiatuses, and the overcoming of biogeographic differences [25–28]. More recently, secular carbon isotope variations are recognised to occur synchronously in geographically widely spaced sections of the English Chalk, and were used to develop a δ^{13}C carbonate reference curve for the Cenomanian–Campanian [29].

This study will focus on the recognition of secular carbon cycle variations in the late Cenomanian to early Turonian. The long-term trend of the δ^{13}C carbonate curve is characterised by the major positive Cenomanian–Turonian (C–T) excursion, the recovery phase in the earliest Turonian, and the ongoing aftermath in the early and Middle Turonian that is represented by a period of relatively high and stable background values terminated by a sharp decrease [25,28–31]. Here, we will present new high resolution δ^{13}C carbonate curves from two expanded basinal successions of the Münsterland Cretaceous Basin in northern Germany (Halle and Oerlinghausen), which recover a stratigraphic complete record of inorganic carbon cycle variations (Fig. 1). The δ^{13}C curve shows a distinct cyclicity that will be shown to be orbitally forced by the frequencies of long and short eccentricity. Independent biostratigraphic data based on boreal macrofossil zonation are available for both sections, which will provide the opportunity to calibrate biostratigraphic dates against distinct features in the δ^{13}C carbonate curve.

2. Methods

The basinal successions at Halle and Oerlinghausen provide a continuous sedimentary record of the late Cenomanian to Middle Turonian time interval. Both sections were detailed logged bed-by-bed and sampled in 20 cm intervals for measurements of carbonate and total organic carbon (TOC) content, and carbonate carbon and oxygen isotopic composition. In addition, the carbon isotopic composition of total organic matter was analysed for the black shale succession at Halle. The Halle section was sampled over a 20 m horizon from the Facies Change up to the last two prominent black shale beds associated by the acme occurrence of the inoceramid *Mytiloides mytiloides* (Fig. 2). The succession at Oerlinghausen begins with these two black shales, and was sampled from the base over a horizon of 40 m up to the base of the white limestones of the Weisse Grenzbank“ carbonate maximum, which lies ~6 m beneath the prominent marl layer M Teuto.

A split (750 mg) of powdered sediment samples was acidified by adding HCl in two steps, first a weak solution (~10%), second a stronger solution (~25%) and subsequently neutralized by dilution with deionised water. The percentage of $CaCO_3$ was determined by the dry-weight loss after decalcification, assuming that all carbonate comprised in the samples is calcite. The total organic carbon content is determined by measuring the thermal conductivity of the gaseous products of pyrolysis of a split of the acidified sediment sample (LECO carbon determinator) and the TOC values are calculated as weight percentage. The reproducibility of repeated standard measurements was better than 0.01%. A second split of the decalcified sample was analysed for carbon isotopic composition of organic matter by sample combustion at 950 °C and subsequent measurement of the released CO_2 gas with a Finnigan Delta S mass spectrometer (University of Cologne). The values are given relative to V-PDB and the reproducibility of repeated standard measurements was 0.1‰. Stable isotope analyses of carbonate bulk-rock samples were performed at a reaction temperature of 75 °C using a Finnigan MAT 252 (Erlangen University) with an online automated carbonate reaction Kiel III device. All values are reported in ‰ relative to V-PDB and reproducibility is better than 0.08‰ and 0.05‰ for oxygen and carbon.

Spectral analysis was performed for the carbon isotope record of the Oerlinghausen section. The data

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