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Paired carbon stable-isotope records for the Cenomanian Stage (100.5 -93.9 Ma): correlation tool and Late Cretaceous pCO_2 record?

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Carbon stable-isotope stratigraphy of marine carbonates (δ13Ccarb) provides remarkable insights into past variation in the global carbon cycle, and has become firmly established as a powerful global correlation tool. Continuous δ13Ccarb time series are becoming increasingly available for much of the geological record, including the Upper Cretaceous. However, our knowledge of stratigraphic variation in the carbon isotopic composition of sedimentary organic matter (δ13Corg) is much poorer, and is generally restricted to organic-rich sedimentary successions and/or key boundary intervals. Close coupling exists between the global isotopic composition of the reduced and oxidised carbon reservoirs on geological time scales, but the stratigraphic resolution of most long-term δ13Corg Mesozoic records is inadequate to identify leads and lags in the responses of the two reservoirs to carbon cycle perturbations.

Cenomanian times (100.5–93.9 Ma) represent perhaps the best documented episode of eustatic rise in sea level in Earth history and the beginning of the Late Mesozoic thermal maximum, driving global expansion of epicontinental seas and the onset of widespread pelagic and hemipelagic carbonate deposition. Significant changes occurred in global stable-isotope records, including two prominent perturbations of the carbon cycle – the Mid-Cenomanian Event I (MCEI; $\sim$96.5–96.2 Ma) and Oceanic Anoxic Event 2 (OAE2; $\sim$94.5–93.8 Ma). OAE2, one of two truly global Cretaceous OAEs, was marked by the widespread deposition of black shales, and a global positive carbon stable-isotope excursion of 2.0 – 2.5‰ δ13Ccarb, and up to 7‰ in the sulphur-bound phytane biomarker. MCEI, by contrast, shows a <1‰ δ13Ccarb excursion and no associated black shales in most areas.

Here, we present detailed paired δ13Ccarb and δ13Corg stable-isotope records for the entire Cenomanian Stage, based on an Upper Albian – Lower Turonian composite reference section from the Vocontian Basin of SE France. We compare the δ13Ccarb profile to new results from the English Chalk reference section at Folkestone, and correlate the carbon-isotope events between England, France, Germany and Italy. Comparison of the Vergons δ13Ccarb vs. δ13Corg profiles demonstrates similar medium-term stratigraphic variation, but significant differences in both short- and long-term trends. Potential causes of the similarities and differences are examined, and it is concluded that major deviations of the paired isotope trends offer insights into long-term atmospheric pCO_2 variation. The osmium 187Os/188Os isotope stratigraphy of the MCEI and OAE2 intervals provides evidence of varying volcanic CO_2 input, in-part driving climate change. Spectral analyses of the δ13Corg time series reveals a strong $\sim$100 kyr short eccentricity signal throughout the Cenomanian, with well-expressed $\sim$40 kyr obliquity and $\sim$20 kyr precession cycles in some intervals. A 400 kyr long eccentricity cycle is recorded in sedimentation rate changes and amplitude modulation of the 100 kyr cycle. The relative spacing of events, and comparison with the latest orbital solution La2011, further suggest that MCE I and OAE2 coincided with nodes in the $\sim$2.2-Myr eccentricity modulation.