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Coupled carbon-isotope records from the Cenomanian of SE France: a six-million year record of mid-Cretaceous pCO_2 change?

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The Late Cretaceous (99.6 – 65.5 Ma) provides perhaps the best example of how the Earth System may function under long-term extreme greenhouse conditions. Rapidly rising global temperatures indicate that we are heading 'back to the Cretaceous' within a few hundred years, so a better understanding of this time interval is essential. The Upper Cretaceous of the Vocontian Basin, SE France, provides excellent reference sections for studying the Cenomanian stage (99.6 – 93.6 Ma), a period of rapidly rising eustatic sea level and dramatic global warming.

In the vicinity of Vergons, a >400 m thick Cenomanian succession is developed in hemipelagic and pelagic facies. Rhythmically bedded calcareous muds and marls with ∼40% $CaCO_3$ in the Upper Albian, pass up into an interbedded marl - limestone succession with rising carbonate contents through the Cenomanian, into thin marls and thick limestones with >80% $CaCO_3$ in the Lower Turonian. Ammonites, inoceramid bivalves, planktonic foraminifera, organic walled dinoflagellate cysts (dinocysts) and calcareous nannofossils provide a basis for subdividing and dating the succession. The carbonate fraction is dominated by calcareous nannofossils; organic matter is overwhelmingly of marine origin, with palynomorphs assemblages yielding abundant dinocysts. Organic matter contents (TOC) fall from ∼1% in the Upper Albian to ∼ 0.08% in the Lower Turonian, but the 10 m-thick Cenomanian-Turonian boundary (CTB) interval, the Niveau Thomel, contains black shales with up to 3.5% TOC, the regional representation of Oceanic Anoxic Event 2 (OAE2).

Sections (500 m) have been logged, macrofossil occurrences recorded, and samples taken every 0.5 – 1 m for microfossil, isotopic and elemental geochemistry. This paper focuses on paired carbon stable-isotope chemostratigraphic records (δ13C) in coexisting bulk carbonate (δ13Ccarb) and bulk organic matter (δ13Corg) fractions. The δ13Ccarb record from Vergons may be correlated at high-resolution to corresponding curves from Italy, Germany and England. The δ13Corg curve broadly tracks the carbonate curve with the expected offset of approximately -28 per mil, expressed as the difference between paired isotope values, Δ13C.

A marked step increase in Δ13C occurs immediately above a large double positive δ13C excursion at the base of the Middle Cenomanian: Middle Cenomanian Event I. This offset is apparent in both marine and non-marine organic carbon records. The step of +0.5 per mil Δ13C indicates a major change in the global carbon cycle. Could increased isotopic fractionation during Middle and Late Cenomanian times be related to increased pCO_2, driven by increased volcanic outgassing on a global scale? We have argued previously that pCO_2 peaked during the Late Cenomanian with the emplacement of the Caribbean Large Igneous Province immediately prior to OAE2. Subsequently, the widespread deposition of organic matter caused pCO_2 drawdown, evidenced by a sharp fall in Δ13C and cooling, prior to a renewed pCO_2 increase and warming in the Early Turonian.

Factors influencing δ13Ccarb, δ13Corg and Δ13C trends in the Cenomanian will be discussed in the context of the palaeoceanographic and palaeoclimatic events that accompanied eustatic sea-level change in the earliest Late Cretaceous, culminating in OAE2 and the subsequent global climatic optimum.