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Cretaceous environmental change: lessons from the Cenomanian

I. Jarvis

School of Earth Sciences & Geography, Kingston University London, UK
(i.jarvis@kingston.ac.uk / phone +44 20 8547 7526)

The Cenomanian Stage (99.6 – 93.5 Ma) represents one of the periods of greatest environmental change in the geological record. Abnormally high rates of oceanic crust production and the formation of large igneous plateau led to high and rising levels of atmospheric CO_2 and increased hydrothermal fluxes to the oceans. Global warming progressed towards a post-Palaeozoic thermal maximum in the early Turonian. Rising eustatic sea-levels caused the flooding of continental interiors and the initiation of hemipelagic chalk sedimentation in extensive warm shallow epicontinental seas world-wide. Periods of oceanic anoxia are indicated by the widespread deposition of black shales in the ocean basins. Cenomanian sediments thus record a period of dramatic and rapid change in Earth's biogeochemical cycles.

The Cenomanian is uniquely well-suited to multiproxy studies of the causes and consequences of Cretaceous environmental change because high-resolution global correlation can be achieved using ammonites and inoceramid bivalves, while preserved oceanic crust and extensive onshore geological records facilitate detailed palaeogeographic reconstructions. The occurrence of orbitally bedded hemipelagic sediments containing ammonites is enabling the development of a biostratigraphically calibrated time scale with a resolution better than 50 kyr for some intervals. Sequence analysis of Cenomanian successions has defined up to 10 sequences and systems tracts within the Cenomanian that correspond to the long 400 kyr Milankovitch eccentricity cycle. Significant faunal and floral changes accompany sequence boundaries, transgressive surfaces and maximum flooding surfaces. Sequence stratigraphy provides a basis for interpreting changes in eustatic sea-level that can be compared with other palaeoenvironmental proxies.

Results from stable-isotope and elemental geochemical studies of Cenomanian chalk successions will be explored in this paper. Carbon isotope profiles from both bulk carbonate and organic matter broadly follow eustatic sea-level, with rising δ^{13}C accompanying transgression, and falling δ^{13}C accompanying regression. Large positive carbon isotope excursions at the (1) Albian / Cenomanian boundary, (2) base of the Middle Cenomanian, and (3) Cenomanian / Turonian boundary, associated with sequence boundaries and transgressive surfaces, and periods of major biotic turnover, reflect periods of increased organic carbon burial, particularly in the proto-Atlantic Ocean. Positive carbon excursions are linked with major transgressive events, but other factors such as changing rates of sea-level rise and fall, and varying partitioning between organic carbon and carbonate carbon reservoirs, complicate relationships.

Bulk sediment silica and trace-element (Ti, Zr) aluminium ratios peak around transgressive surfaces and maximum flooding surfaces, indicating pulses of increased siliciclastic input. Sr/Ca ratios and Mn contents also vary systematically with respect to sea-level change. Increasing Sr/Ca ratios during periods of sea-level fall indicate the release of Sr from aragonite dissolution and replacement in subaerially exposed platform carbonates. Falling Sr/Ca ratios accompanied the re-establishment of shallow-water carbonate factories during subsequent sea-level rise. Manganese minima occurring during low stands, and maxima located around maximum flooding surfaces, are tied to variations in the Mn depositional and diagenetic fluxes. It is concluded that during the Cretaceous eustatic sea-level change provided a major forcing mechanism of the global carbon cycle and many other biogeochemical cycles.