Early Cretaceous climate and paleoceanography as seen from a Tethyan perspective

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Tethyan Cretaceous sedimentary and geochemical climate archives contain a fascinating record of repeated perturbations of the global carbon cycling resulting in greenhouse pulses. Carbon isotope records are used as to trace the history of the carbon cycle. Pelagic and neritic sedimentary records provide information on evolutions of oceans and biota during greenhouse pulses.

One of the largest Mesozoic C-isotope excursions is dated as Early Aptian in age. It reaches values of up to + 5 per mil and has a duration of up to 3 million years. The Aptian C-isotope anomaly is preceded by a Barremian C-isotope excursion reaching positive C-isotope values of up to 3.0 ‰ marking the beginning of the unstable mid-Cretaceous C-isotope record. The formation of the Ontong-Java Igneous Province is considered as the cause of the Barremian-Aptian carbon cycle and climate perturbation.

Most remarkable is an excursion to low carbon isotope values at the base of the major Aptian positive excursion. The negative anomaly lasted less than a few 10^5 years and it possibly records a sudden addition of isotopically light carbon to the marine carbon reservoir. Methane stored in clathrates or thermogenic methane derived from organic-rich sediments is proposed as possible sources of light carbon. A major warming pulse observed at the time of the negative carbon isotope spike could have triggered the destabilisation of sedimentary gas hydrates and the sudden release of methane to the biosphere.

Changes in physical and chemical oceanography and in the biological carbon pump were a consequence of greenhouse warming. Accelerated burial of organic carbon formed an efficient negative feedback within the carbon cycle. Both, the Barremian and Aptian carbon isotope excursions coincide with episodic black shale deposition. The Aptian black shale time is known as “Oceanic Anoxic Event 1a” or as “Livello Selli”. Black shales formed in pelagic environments can be read as an expression of a “Cretaceous greenhouse ocean mode” with peculiar circulation pattern and elevated marine productivity.

Increased burial of organic carbon during the time of increasing carbon isotope values should have contributed to the stabilisation and later to lowering of atmospheric CO_2 concentrations. Available pCO_2 proxy data from Aptian successions in France and Italy do not yet show a clear greenhouse pulse preceding the positive carbon isotope excursion and coinciding with the negative carbon isotope values. However, CO_2 estimates based on varying fractionation between organic matter and carbonate carbon provide some evidence that atmospheric carbon dioxide levels were highest at the time of the negative carbon isotope spike followed by stepwise decrease in pCO_2 during the transition time to positive carbon isotope values.

The Aptian C-isotope anomaly was accompanied by a biocalcification crisis recorded in coastal and in pelagic environments of western Tethys. The crisis started before but culminated during the negative carbon isotope spike and it may have been triggered by pCO_2-induced changes in climate and in surface water chemistry. Elevated nutrient levels in river-influenced coastal waters and in upwelling regions further weakened marine calcification.

The Barremian-Albian was also a time of important plate tectonic reorganisation and of poorly understood anomalies in ocean chemistry. Barremian-Albian sulphur isotope values reached lowest Mesozoic values; sulphate concentrations in seawater were low, and the opening South Atlantic-North Atlantic seaway resulted in a new ocean circulation pattern. These data indicate that, in addition to volcanism, tectonic changes in ocean configuration had profound impact on mid-Cretaceous oceans and climate.