West to East in the Cretaceous – Greenhouse climate events and sea-level change

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The Cretaceous greenhouse climate interval was characterized by intervals of extreme hothouse climate that lead to environmental Earth System events like the Oceanic Anoxic Events. In addition, the potentially ice-free hothouse, besides high magmatic activity due to final Pangaea breakup, fostered maximum sea-level with prolonged highstands more than 250 m above today's sea level. The mid-Cretaceous interval, between OAE 1a (early Aptian) and OAE 2 (late Cenomanian), constitutes the time of most pronounced hothouse intervals leading to (nearly) global OAEs due to eutrophication of oceans, plankton blooms, expansion of oxygen minimum zones up to the photic zone, and down to the deep-sea bottom. This resulted regionally in black shale deposition and a minor extinction event of e.g. about 25% of planktic foraminifera.

Taking OAE 2 as a case study, which constitutes the Cretaceous Thermal Maximum interval of at least more than 30–35°C equatorial ocean surface temperatures, high-precision stratigraphy based on cyclostratigraphy, astrochronology and numerical dating, a 300 to 700 ka OAE carbon isotope excursion interval can be reconstructed, ending in a recovery phase up to 1 Ma. Cyclostratigraphy results in 100 ka and 405 ka eccentricty signals, most significant in Tethyan areas and other lower latitude realms. Obliquity signals may be present in higher latitudes and may relate to higher precipitation, humid-arid and megamonsoon cycles. However, also during OAE 2, a significant cooling event, the Plenus Cold Event, is present, and may have resulted in intermittent ice shields on Antarctica. This cold snap is still represented in southern Tethys sections such as Tunisia based on stable isotopes and faunal migrations.

Climate and temperature-have driven eustatic sea-level fluctuations, modulating the high sea level of the Cretaceous resulting from magmatic processes. During ice-free hothouse times, aquifer eustasy was the main process driving global sea level, at least on an amplitude of 30–50 m. Intermittent ice shields may conteract aquifer eustasy with higher magnitude glacial eustasy during cooler greenhouse phases like the Plenus Cold Event, but this is still under exploration. Major hothouse sea-level cycles have a cyclicity of about 1–1.2 Ma, showing precession- and eccentricity-modulated long-obliquity cycles in pelagic and shallow-water successions. This builds the basic sequence stratigraphy cycles during prominent greenhouse intervals of the Earth system, at least during the Mesozoic. Linking such greenhouse times models to our Anthropocene warming planet indicates a stronger hydrological cycle during warming and rising sea-levels.

eISSN 2353-3641 | ISSN 1731-0830