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A Cretaceous benthic foraminiferal stable isotope compilation: implications for paleoclimate and paleoceanography

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We produced new stable isotope data sets of Cenomanian to Santonian benthic foraminifera from the western equatorial Atlantic (ODP Leg 207) and from the tropical Pacific Ocean (DSDP Sites 305 and 463). Together with literature data our results are compiled into a global isotope compilation, resulting in a continuous benthic δ^{18}O record for the last 115 Ma. This compilation shows four main intervals during the Cretaceous: (1) increasing temperatures before 97 Ma and (2) a subsequent super-greenhouse which are both paralleled by increasing δ^{13}C values, (3) a long-lasting cooling and decrease in carbon isotopes (90-78 Ma), and (4) globally similar δ^{13}C and δ^{18}O values after 78 Ma. Increasing sea-surface temperatures sometimes exceeding 35˚C are well-known for Intervals 1 and 2. But our compilation shows, that deep-ocean temperatures were significantly warmer than today, especially in the proto- North Atlantic (20-28˚C). These high temperatures are explained by a lack of cold bottom-water formation, the restricted nature of the North Atlantic, and the formation of warm saline bottom waters that sporadically were formed within epicontinental seas. The parallel positive trend in δ^{13}C is believed to reflect massive storage of Corg during Cretaceous black shale formation. Interestingly, however, δ^{13}C values of the tropical Atlantic show a similar trend but more negative values. We propose that this reflects a combination of extensive remineralization of ^{12}C and a long residence time due to the sporadic formation of warm and saline waters. During the following interval 3, benthic δ^{18}O values of all ocean basins show similar values. This trend is interpreted to be the result of the beginning opening of the Equatorial Atlantic Gateway. This deepening and a parallel reorganization of the oceanic circulation with longitudinal water-mass and heat exchange may have favoured the observed cooling trend of interval 3. This explanation is supported by the global decrease in δ^{13}C, proposed to reflect a better connection of the former restricted North Atlantic that allows the oxidization of the organic-rich sediments formed in this basin. In contrast to the former intervals, the last 13 Ma of the Cretaceous are, on a global scale, characterized by similar values for both, oxygen and carbon isotopes. This is proposed to indicate a full connection between all ocean basins.

Comparison of the Cretacoeus stable isotope compilation with the one of the Cenozoic reveals the presence of three long-term ($\sim$30 Ma) cycles. Each of these cycles is characterized by greenhouse period (mid-Cretaceous, Eocene, Miocene) followed by a step-wise decrease in bottom-water temperatures and/or increased ice volume. Even almost similar in shape and magnitide, however, subsequent cycles are represented by cooler boundary conditions and therefore less pronounced greenhouse conditions.