Timing, Magnitude, Rate, and Drivers of Eustasy: A Review of the Cretaceous Period

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Isolating the eustatic signal from the sedimentary record remains challenging, yet much progress is being made toward understanding the timing, magnitude, and rate of eustasy on both long-term ($10^7$-$10^8$ yr) and short-term ($10^5$-$10^6$ yr) scales throughout the Phanerozoic. Knowledge of timing, magnitude, and rate, in turn, provides insights into driving mechanisms (tectono-eustasy vs. climatically mediated eustasy; e.g., glacio- or aquifer-eustasy). As an example, we review the current state of knowledge of Cretaceous eustasy. A literature-based review of sea-level change estimates has been conducted, and the results were evaluated against the different driving mechanisms. A further evaluation of driving mechanisms has been derived from a global geodynamic and associated paleoclimate model.

An analysis of short-term sea-level cycles reveals four broad episodes of magnitude change. Three of these episodes reflect trends of increasing sea-level change magnitudes from the Berriasian to early Hauterivian, late Hauterivian to Aptian, and Santonian to Maastrichtian. The fourth episode reflects a decreasing magnitude trend from the Albian to Coniacian. In addition, the maximum magnitude of sea-level change, at an approximate stage level, has been identified and categorised as slight (less than 10 m), modest (10 to 40 m), or significant (41 to 65 m). Significant magnitudes are inferred for the Valanginian, Aptian, Albian, and Maastrichtian; exclusively slight magnitudes are restricted to the Berriasian.

Because climatically driven eustasy is the likely cause of short-term sea-level change, an assessment of the characteristic maximum magnitude limits of the principal climatic drivers (thermo-, aquifer-, and glacio-eustasy) has been made. Such a comparison argues for glacio-eustasy as the driver of significant short-term sea-level change and is supported by climate proxy data demonstrating that the Valanginian, Aptian, Albian, and Maastrichtian are intervals of cooling.

While the mechanisms, frequency, and magnitude short-term sea-level cycles linked to thermo- and glacio-eustasy are understood, the likely contribution of aquifer-eustasy remains enigmatic and, for the most part, untested. To better understand the role of aquifer-eustasy, paleoclimate simulations aimed at assessing the spatio-temporal pattern of aridity and humidity under differing CO$_2$ forcing have been undertaken during time slices considered reflective of the differing Cretaceous climates and paleogeographic configurations (Valanginian, Turonian, and Maastrichtian). Only modest changes in the spatial extent of arid and humid zones are observed in
response to large changes in CO₂ forcing. The simulations also demonstrate that the greatest aquifer charge is more likely during lower CO₂/cooler intervals, indicating that aquifer-eustasy works in phase with both glacio- and thermo-eustasy in contrast to the aquifer-eustasy paradigm. Additionally, using information on modern water table depths, we estimate that aquifer eustasy would be unable to contribute significantly to Cretaceous sea-level change. Indeed, even in the most optimistic case, the largest possible total aquifer-eustasy response remains smaller than 7 m. Our results indicate that glacio-eustasy is the most likely driver of Cretaceous short-term eustatic cycles because aquifer-eustasy is unable to account for the estimated Cretaceous magnitudes.