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Greenhouse sea-level changes: Growing evidence for aquifer-driven eustasy

Wagreich, M.[1], Wendler, J.[2], Sames, B.[1] and Wendler, I.[2]

[1] University of Vienna, Department for Geodynamics and Sedimentology, A-1090-Vienna, Austria. *michael.wagreich@univie.ac.at*

[2] University of Bremen, Department of Geosciences, 28334 Bremen, Germany.

In contrast to glacial eustasy controlled mainly by waxing and waning of continental ice sheets, short-time sea-level changes during major greenhouse episodes of the Earth history are still poorly understood, and are often explained by the presence of ephemeral ice sheets even during extreme 'hothouse' phases such as the mid-Cretaceous. However, the possible effect of groundwater storage and release on sea-level change has been widely underestimated in its order of magnitude. It is considered to constitute a water volume that is about equivalent to today's ice volume, thus corresponding to a potential sea-level change of up to ca. 50 m, applying isostatic adjustment. Groundwater aquifer storage, including both freshwater and saline pore waters above sea level, exceeds lake and river storage capacities by several orders of magnitude. The term aquifer-eustasy was introduced by Wendler et al. (2011) and lateron elaborated by Wendler et al. (2014, 2016; see also Wagreich et al., 2014).

Evidence for aquifer-driven eustatic cycles during supposed ice-free periods of the mid-Cretaceous come from wet-dry weathering cycles and high-resolution stratigraphic correlations between marine and continental lake archives, i.e., lake-level and sea-level fluctuations that are recorded in an out-of-phase relation in such a way that a major marine sea-level lowstand corresponds to a lake-level highstand (i.e., water 'removed' from the sea and stored on the continents), and vice versa. Tests using the Turonian to Campanian Late Cretaceous record of the long-lived lacustrine Songliao basin in China indicate such an out-of-phase relation, and thus support this hypothesis (Wagreich et al., 2014).

Compelling evidence that aquifer charge/discharge could drive eustasy comes from the observation that pervasive astronomically-driven Cenomanian-Turonian sea-level cycles are linked to cycles in continental weathering and hence to systematic changes in precipitation. Presence of weathering sensitive minerals in transgressive phases suggests dry climate, while regressive to lowstand phases show minor amounts of weathering sensitive minerals consistent with humid climate (Wendler et al. 2014, Wendler et al., 2016).

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