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Cenozoic deep-ocean temperature and carbonate saturation jointly reconstructed from trace elements in benthic foraminifera

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The deep ocean mediates global climate and biogeochemical cycles by storing vast quantities of heat energy and dissolved carbon. Understanding the evolution of these parameters would help to reveal the mechanisms behind climate changes of the distant past. However, reconstructions of ancient carbonate chemistry, in particular, are still sparse and primarily consist of inferred changes in the carbonate compensation depth (CCD). Recently, core-top studies have demonstrated that the trace element composition (Mg/Ca, B/Ca, Sr/Ca) of benthic foraminifera is a function of both the ambient bottom-water temperature (BWT) and carbonate saturation state (Ω_c). This means that BWT and Ω_c can be jointly reconstructed from a given set of trace element ratios, as the observed trace element composition will be consistent only with a limited set of BWT and Ω_c values. Here, we present a new database of compiled trace element ratios of benthic foraminifera from multiple sediment cores spanning the Cenozoic (60 Ma to present) and use it to reconstruct BWT and Ω_c of the global deep ocean. We find that benthic trace elements replicate the long-term cooling observed in other temperature proxies but also document a concomitant rise in deep ocean Ω_c during the Palaeogene. Carbonate saturation peaks in the Oligocene at multiple sites, before slowly falling again to its present-day value over the Neogene. When combined with models for the concentration of seawater Ca^{2+}, the reconstructed changes in Ω_c imply a notable increase in the concentration of CO_3^{2-} over the Cenozoic. These results provide the first quantitative record of deep ocean carbonate chemistry that is independent of inferred changes in CCD and, together with pH proxies like $\delta^{11}B$, could shed light on the evolution of the oceanic carbon content through the Cenozoic.