The crux of interpreting oxygen isotope data with respect to Milankovitch-scale sea-level changes during greenhouse climates

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Oxygen isotope data from marine carbonates are routinely used to interpret fluctuations in temperature, continental ice volume and sea level for the glacial – interglacial periods of the Pleistocene icehouse climate. Such interpretation is fraught with difficulties for older records from greenhouse epochs such as the Cretaceous, especially the very warm middle Cretaceous, when cyclic Milankovitch-scale (3rd and higher -order) sea-level changes were most likely not forced by glaciation – deglaciation cycles. Instead, the higher temperatures cause stronger hydrological cycling and potentially a landward shift of the ocean – land water balance that would lead to falling sea level as temperatures rise and vice versa. This relationship is opposite to the positive correlation between sea level and temperature during icehouse climates. What does that mean for the interpretation of oxygen isotope records with respect to sea level? Apart from the well-known problems that hamper interpretation of deep-time $\delta^{18}O$ records, such as unknown pH and $\delta^{18}O$ value of the seawater and diagenetic alteration, a number of other factors need to be considered when relating $\delta^{18}O$ records to sea level in greenhouse climates.

Oxygen-isotope fractionation occurs through preferential removal of ^{16}O from seawater during evaporation and preferential removal of ^{18}O from the water vapor during condensation. The evaporative removal of water from the ocean and its storage on land, both as continental ice and as liquid water in aquifers, sequesters ^{16}O and increases the $\delta^{18}O$ value of the remaining water in the ocean (effect of ice volume and groundwater volume). However, because oxygen-isotope fractionation is temperature dependent and there is an opposite effect of temperature on the accumulation of terrestrial ice versus groundwater, the net fractionation effect for oxygen is different for icehouse and greenhouse climates. The presentation discusses the various influences on the $\delta^{18}O$ record such as latitudinal temperature gradients, number of precipitation steps, dynamics of terrestrial water storage, spatial salinity variations and the temperature effect itself.