# Paleoclimates, Ocean Depth, and the Oxygen Isotopic Composition of Seawater

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Oxygen isotope ratios in carbonates are routinely used to estimate paleotemperatures during the last few tens of millions of years. O isotope ratios from both carbonates and cherts have also been used to estimate paleotemperatures in the more distant past. Archean cherts are typically depleted in $^{18}$O by 10‰ or more; ancient carbonates show smaller, but still substantial, $^{18}$O depletions until as recently as a few hundred million years ago. Taken at face value, these isotope ratios suggest that Earth's mean surface temperature was 70±15$^{o}$C in the early Archean and remained significantly elevated until as recently as 350 Ma. While not impossible from a theoretical standpoint, such high temperatures are hard to reconcile with evidence for glaciation at 0.6, 0.75, 2.4, and possibly 2.8 Ga.

An alternative way of explaining the O isotope data is if the oxygen isotopic composition of seawater has varied with time. This possibility has been suggested numerous times over the past 40 years but has never garnered widespread support. The O isotopic composition of seawater is controlled primarily by water-rock interactions within the midocean ridge hydrothermal vents. Hot (>350$^{o}$C) interactions increase the $\delta^{18}$O values of seawater; interactions at lower temperatures decrease seawater $\delta^{18}$O. We suggest here that gradual changes in Earth's tectonic evolution have driven significant changes in this marine isotope control system. Specifically, higher geothermal heat flow in the distant past should have led to shallower oceanic ridges and lower water-rock interaction temperatures within hydrothermal vents. This, in turn, should have caused a corresponding negative shift in the O isotopic composition of seawater. All of this implies that the early Earth was warm, not hot.