C and O stable isotope compositions of Cenozoic Earth-surface carbonates of all sorts, Part II

The plot on Part I of this pair shows ranges of C and O stable isotope data from an arbitrary selection of Cenozoic, and largely Quaternary, carbonate materials that formed at Earth’s surface. Some things to note are that...

1) The overall range of data is huge: about 38‰ in δ¹⁸O and 32‰ in δ¹³C.

2) Continental carbonates (lacustrine carbonates, pedogenic carbonates, tufas, travertines, and speleothems) collectively have a huge range of data and commonly have large ranges within one set of data. This presumably reflects the variability of continental environments across small spaces (for example, edge to center of a lake basin, top to bottom of a soil profile and location in a soil catena, drip-site to wall of a cave) and through relatively short periods of time (for example, seasonal to millennial climate change).

3) Marine carbonates, in contrast, have a comparatively small range of δ¹⁸O and δ¹³C. This reflects the extent to which the oceans are a well-mixed mass because of their circulation (largely their deep thermohaline circulation) and a large mass that responds comparatively little to global climate change, compared to the swings in data from continental carbonates. Marine carbonates record the behavior of the difficult-to-disturb dog; continental carbonates record, or simply are, the tail that wags widely.

4) Data from non-travertine continental carbonates collectively, and commonly within sets of data, have a greater of δ¹³C than of δ¹⁸O. This is because there are multiples sources of carbon to these carbonates, ranging in δ¹³C from very small values generated by respiration and decay of C3 plants to large values in atmospheric CO₂.

5) Data from continental carbonates collectively, and within sets of data, show a broad correlation of δ¹³C and δ¹⁸O. This is largely because wetter settings allow more input of plant-mediated CO₂ and less evaporation of H₂O, giving smaller values of δ¹³C and δ¹⁸O. On the other hand, drier settings commonly allow less input of plant-mediated CO₂ and more evaporation of H₂O, giving greater values of δ¹³C and δ¹⁸O.

6) Among continental carbonates, material from high altitudes and/or high latitudes commonly has low values of δ¹⁸O, presumably because of rain-out effects in the transport of water vapor.

7) Carbonates precipitated at high temperatures typically have small values of δ¹⁸O because of the lessened fractionation between water and mineral. Travertines thus commonly have small values of δ¹⁸O.

8) Comments 6 and 7 combine to mean that carbonate deposits from hot springs in mountains at higher latitudes have very low values of δ¹⁸O, and the travertines from Mammoth Hot Springs at Yellowstone therefore fall far to the left on the plot.

9) Travertines and tufas occupy areas on the plot that overlap to some extent, but travertines generally have lesser values of δ¹⁸O and greater values of δ¹³C than tufas. The former can be explained by the higher temperatures at which travertines form, and the latter can be explained by the lesser involvement, or at least engulfment, of plants in the formation of travertines.

10) Marine carbonates have a small range of δ¹³C and δ¹⁸O compared to continental carbonates, but there are predictable variations within marine data sets:

10a) δ¹³C values in planktic carbonates are typically less than those in abyssal benthic carbonates because surface waters are variably warm but deep waters are invariably cold. Even within those sets of data, δ¹³C values are greater through time in glacial phases and less in interglacials (the “GM” and “IG” on the plot).

10b) Values of δ¹³C also vary from planktic to benthic, because photosynthetic removal of ¹³C from surface water typical gives greater δ¹³C in planktic carbonates, whereas oxidation of organic matter at depths gives lesser δ¹³C in benthic carbonates.

10c) δ¹⁸O of benthic carbonates also varies from the Atlantic to the Pacific, because younger deep water in the Atlantic has had less time to accumulate low-δ¹³C CO₂ from oxidation of sinking organic matter, but older deep water in the Pacific has had time to accumulate such CO₂ and thus gives benthic foraminiferal carbonate with lesser values of δ¹³C.

11) The range of δ¹⁸O values in marine carbonates would be even smaller were it not for the peculiarities of Quaternary glaciation. Both near-freezing bottom-water temperatures and glacial storage of ¹⁸O push the δ¹⁸O of benthic forams during glacial maxima to values more than +4 that would not be attained otherwise.