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The Cambrian SPICE event: perturbation of global carbon cycle or global diagenesis?

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The $\delta^{13}C$ of ancient shallow water carbonates records periods of instability, or Carbon Isotope Excursions (CIEs), many of which are demonstrably global and occur with magnitudes far exceeding noise in the data. CIEs have been interpreted to reflect global carbon cycle fluxes, such as organic C burial, in part because many coincide with changes in climate, oxygenation, or biodiversity. Alternative explanations for CIEs include global diagenesis events driven by eustasy, changes in aragonite/calcite, and/or water mass aging/restriction. The late Cambrian SPICE (Steptoean Positive Carbon Isotope Excursion; +5‰ VPDB above baseline) does not easily fit these alternative explanations because it: 1) did not occur during glacio-eustasy that can drive large scale changes in advective fluid flow through sediments (i.e., alternating sediment vs fluid buffered diagenesis) and 2) is largely facies-independent, recorded from >50 localities globally in depositional environments from supratidal/nearshore to open marine.

We test for global diagenesis using bulk carbonate $\delta^{44/40}Ca$, Sr/Ca, and $\delta^{13}C$ from the SPICE in shallow (Iowa) and deep water (China). $\delta^{44/40}Ca$ in Iowa (-0.75 to -0.86‰ SW; n=5) is relatively invariant spanning SPICE and lacks covariation with $\delta^{13}C$ (0 to +4‰) or Sr/Ca (0.22 to 0.37 mmol/mol). Uniformly high $\delta^{44/40}Ca$ and low Sr/Ca in our samples suggest that the entire stratigraphic column has undergone the same degree of diagenesis, which depends on whether the sediments were originally aragonite or calcite – if calcite, then less diagenesis is implied. Importantly, a uniform degree of diagenesis would not result in stratigraphic $\delta^{13}C$ change, such as the one observed during the SPICE.

The alternative hypothesis that platform $\delta^{13}C_{DIC}$ and/or $\delta^{13}C_{carb}$ increased worldwide, decoupled from global C cycle, is also not supported because facies show few or no changes during the SPICE. Facies can serve as a ‘proxy’ for water mass restriction/aging (e.g., fenestral/microbial/oolitic limestone can precipitate from DIC decoupled from the global ocean). In 50+ SPICE sections worldwide, facies changes towards restricted environments potentially decoupled from oceanic $\delta^{13}C$ are rare. Testable hypotheses for why platform water mass DIC would change globally to produce the SPICE absent a global carbon cycle perturbation are needed if an alternative explanation is warranted.