Large isotopic variability at the micron-scale in Shuram excursion carbonates from South Australia

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Ediacaran-aged (635-541 Ma) sediments record a large negative carbon isotope ($\delta^{13}C$) excursion, with marine carbonate $\delta^{13}C$ values reaching -12‰ (VPDB). Known as the Shuram excursion, many have interpreted the $\delta^{13}C$ record as an unprecedented perturbation to the global carbon cycle and have debated a causal connection to the rise of animal life. Other models interpret the $\delta^{13}C$ signal as a product of diagenesis. Discriminating between these hypotheses is important for understanding paleoenvironmental evolution during the early stages of metazoan diversification. Here, we present SEM imaging and in-situ $\delta^{13}C$ measurements made by secondary ion mass spectrometry (SIMS) to evaluate the origin of the Shuram excursion in the Wonoka Formation (South Australia). Results from the nadir of the excursion show that rounded sedimentary grains of detrital calcite have $\delta^{13}C$ values that range from -13 to -11‰. Post-depositional euhedral dolomite is also evident in the sample. The dolomite phase appears to have grown unimpeded in open sedimentary pore space, thereby suggesting an early burial diagenetic origin. The authigenic dolomites, however, have values of $\delta^{13}C$ that reach +5‰, requiring a formation fluid with a substantially different $\delta^{13}C$ value from implied, coeval basin waters or bulk sediment. Collectively, these results indicate no significant role for post-depositional diagenesis (i.e., carbonate cementation, dolomite formation) in producing $\delta^{13}C$ values as low as -12‰. The results, however, complicate interpretations of Shuram nadir values. The data suggest large carbon isotopic gradients in the surface environment, with shallow waters precipitating carbonates with very low $\delta^{13}C$ (down to -12‰) and deeper shelf and/or marine pore waters forming carbonate phases with more positive $\delta^{13}C$ (up to +5‰). Negative isotope excursions of similar magnitude, however, are found in widely dispersed Ediacaran basins, implying that a global process led to the Shuram excursion in shallow water strata.