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Uncovering the largest negative carbon isotope excursion in Earth history

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A deep understanding of carbon cycle's evolution is essential for our understanding of the evolution of our planet's habitability. The Ediacaran Period (635-539 Ma), which marked the transition from the Precambrian to the modern Earth system, witnessed the largest negative carbonate carbon isotope ($\delta^{13}C_{carb}$) excursion in Earth's history [i.e., the "Shuram Excursion" (SE) or "DOUNCE/EN3"]. The SE is globally characterized by a negative shift of >15‰ in $\delta^{13}C_{carb}$ and a duration of several million years (approximately from 575 to 565 Ma). The nature of the SE has long been debated. Two major competing categories of hypotheses have been proposed. The first argues a primary signal for the SE, usually interpreting the SE as a global oceanic oxygenation event, involving massive oxidation of organic matter, such as dissolved organic carbon (DOC) or hydrocarbon-rich fluids in the oceans and/or fossil organic matter on continents; The second argues a late-stage diagenetic or authigenic carbonate origin for the SE. Although many traditional sedimentary-stratigraphic observations and various geochemical records tend to support the primary nature of the SE, the nature of the SE is not more confidently uncovered until a few lines of direct, fingerprint or diagnostic evidence were recently provided. Here, we summarize them as: (1) Micron-scale *in-situ* carbon isotope analyses provide direct evidence confirming the primary nature of the SE; (2) Carbonate-associated sulfate (CAS) triple oxygen isotopes provide compelling diagnostic evidence that supports the SE as an oceanic oxygenation event; (3) Carbonate-associated phosphate (CAP) records offer direct and fingerprint evidence affirming that the SE fundamentally was also an event related to massive organic matter oxidation, most likely DOC oxidation. The uncovering of the SE nature confirms the uniqueness of the Neoproterozoic C cycle, resolves a longstanding debate on mechanistic connection between ancient ocean oxygenation and the evolution of early complex eukaryotic life (particularly early animals).