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Uranium-isotope records of global ocean deoxygenation during the Early Aptian Oceanic Anoxic Event (OAE 1a)

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The Phanerozoic Aeon was marked by a number of intense environmental perturbations, several of which were characterized by widespread seawater oxygen depletion, known as Oceanic Anoxic Events (OAEs). The Cretaceous Period featured multiple such anoxic episodes, one of the most severe of which occurred during the Early Aptian (OAE 1a, ~120 Ma). This environmental crisis is thought to have been triggered by major carbon emissions related to the volcanic formation of the Greater Ontong-Java Plateau. Stratigraphic records of OAE 1a around the world are characterized by a pronounced carbon-isotope ($\delta^{13}C$) anomaly, comprising a sharp negative shift and a pair of positive excursions recorded in the overlying strata. Several OAE 1a sites are also marked by the preservation of organic-rich laminated shales, indicative of oxygen-depleted conditions in the water column and at the sediment-water interface. However, the relative paucity of Early Aptian open-ocean sedimentary records means that the degree to which anoxic conditions spread throughout the global marine realm during OAE 1a remains poorly constrained.

Here, we aim to quantify the geographic extent of seawater oxygen depletion using uranium-isotope ($\delta^{238}U$) records of OAE 1a, based on four stratigraphic records. Under iron-reducing conditions, soluble U^{6+} is converted to insoluble U^{4+}, which is sequestered in organic-rich sediments. This chemical reduction is associated with a pronounced isotopic fractionation in favour of ^{238}U in U^{4+} ions; thus, the removal of U^{4+} via enhanced organic-matter burial (itself enhanced during OAEs), causes depletion of ^{238}U in the water column and a shift to an isotopically lighter $\delta^{238}U$ composition of seawater. Such a change in seawater $\delta^{238}U$ values is then recorded by carbonates precipitated in seawater, with pronounced negative excursions documenting widespread marine anoxia during the Late Devonian extinction, end-Permian extinction, and the Cenomanian–Turonian OAE. Consequently, stratigraphically correlating $\delta^{238}U$ trends with $\delta^{13}C$ records of OAE 1a (in combination with other geochemical data) enables better understanding of the onset and geographic extent of Early Aptian marine anoxia, together with its temporal relationship with the submarine volcanism thought to have triggered it.