

Supporting Information

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SI Text

Reproducibility of Uranium (U) Isotope Data. External reproducibility based on multiple runs of the U isotope standards SRM950a and CRM129a over the course of this study is shown in Fig. S1. The U isotopic compositions of the samples are reported as relative to the U isotope standard SRM950a. Sample data from all runs are shown in Table S1.

Discussion on Secondary Alteration. Due to the reactivity of carbonate sediments, diagenetic alteration of samples is a potential concern. Fluctuations of $\delta^{238}\text{U}$ values in samples immediately below the extinction horizon (EH) at Dawen may indicate instability in the redox state of the ocean preceding the end-Permian extinction (1); however because these fluctuations are not seen in the thorium/uranium (Th/U) ratios of the same samples, they could be the result of secondary processes such as addition of isotopically heavy U. Given our current understanding of the U isotope system, no secondary process is known to generate isotopically lighter $\delta^{238}\text{U}$ values in carbonates, although secondary redox precipitation of U would produce heavy $\delta^{238}\text{U}$ in diagenetically altered samples (2–4).

Although it is difficult to rule out diagenesis in carbonate samples, several considerations support our interpretation that variation in both $\delta^{238}\text{U}$ and Th/U at Dawen is mainly of primary origin. First, the major changes in both Th/U and $\delta^{238}\text{U}$ occur at, or immediately preceding, the EH. Data from $\delta^{238}\text{U}$ and Th/U are independent of one another, and both fit previously proposed models for isotopic and elemental response to ocean anoxia from other basins (5). The fact that the Dawen section displays a similar trend of U chemistry across the Permian-Triassic boundary as in Oman (5) argues for a global cause, rather than local diagenetic processes. Secondly, our current understanding of U chemistry in marine sediments argues against the local effects of diagenesis. The possibilities of altering the $\delta^{238}\text{U}$ and Th/U of the samples are primarily limited to (i) secondary precipitation of U, and (ii) removal of U from the system. In the first case, precipitation of U-containing calcium carbonate cement as a secondary process is generally an early diagenetic process (6) and would thus reflect seawater values as well. Precipitation of

uranium-bearing carbonate containing cements during late stage burial diagenesis could shift the isotopic values of the carbonate sediments; however, the conclusions that we are drawing would still be valid, even when assuming that the entire section has undergone some late burial cement precipitation, as the temporal trends should not change in a relative sense. In the second case, if U was leached from the Dawen samples during burial, only the Th/U ratio would be affected with $\delta^{238}\text{U}$ remaining unchanged. Unlike ^{234}U , which is concentrated in the aqueous phase by preferential leaching of alpha-recoil damage sites from the decay of ^{238}U (7), leaching of U has been shown not to measurably alter the $^{238}\text{U}/^{235}\text{U}$ ratio of sediments (3, 4, 8). Furthermore, it has been suggested that because U is incorporated into the calcium carbonate as a uranyl complex as part of a dilute solid solution, remobilization of U would require bulk dissolution (9, 10). This process should have no effect on the isotopic composition of the residual carbonate material as no leaching has taken place.

The carbonate $\delta^{13}\text{C}$ curve for Dawen shows good correspondence to $\delta^{13}\text{C}$ curves at other Permian-Triassic boundary sections, so it is unlikely that bulk carbonate $\delta^{13}\text{C}$ has been modified to any significant degree by diagenesis. Further, the carbonate sediment at Dawen appears to have stabilized early in the burial environment, as reflected in relatively heavy $\delta^{18}\text{O}$ values, which average $-4.6 \pm 1.7\text{‰}$ ($n = 75$). The absence of negative $\delta^{18}\text{O}$ outliers is also an indication of little, if any, late-stage diagenesis. These considerations are consistent with the idea that the carbonate $\delta^{13}\text{C}$ curve is a record of primary marine $\delta^{13}\text{C}$ values, adding confidence that U isotopes and Th/U signals are primary in origin.

The concentration of aluminum (Al) was obtained on the samples as an indicator of terrigenous input and is shown as U/Al. No correlation exists between U/Al and $\delta^{238}\text{U}$ or Th/U in these samples (Fig. S2), so it is unlikely that the large changes in $\delta^{238}\text{U}$ and Th/U across the EH were caused by terrigenous input of U. Similarly, lithology is unlikely to have controlled the $\delta^{238}\text{U}$ and Th/U of samples, as the degree of dolomitization shows no correlation with $\delta^{238}\text{U}$ and only a weak correlation with Th/U ratio ($R^2 = 0.24$).

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Table S1. Data table showing sample number, represented by distance from the EH in cm, $\delta^{238}\text{U}$ (in ‰) with associated uncertainty 2SD and number of runs (N), Th/U, U/Al, and %Dolomite in samples of this study

Sample (in cm from EH)	$\delta^{238}\text{U}$ (‰)	2SD	N	Th/U	U/Al	%Dolomite	$\delta^{13}\text{C}$
1,000	-0.63	0.23	5	0.35	0.76	0.76	-0.17
880	-0.64	0.21	5	0.16	1.15	1.88	-0.83
802.5	-0.59	0.15	5	0.37	1.75	1.62	-0.21
727.5	-0.47	0.17	5	0.64	1.03	2.98	-0.26
672.5	-0.70	0.11	5	0.48	3.15	1.86	-1.07
610	-0.63	0.14	4	0.25	1.19	4.85	-0.29
585	-0.77	0.26	5	0.35	1.80	1.47	-0.09
522.5	-0.49	0.19	5	0.31	2.28	0.77	-0.20
500	-0.72	0.20	5	0.26	2.26	0.60	-1.23
435	-0.79	0.12	6	0.26	2.98	1.12	-0.34
421.5	-0.70	0.17	6	0.28	1.35	4.10	no data
395	-0.62	0.14	6	0.24	1.51	6.45	-0.28
362.5	-0.62	0.14	5	0.55	1.09	5.18	-0.05
310	-0.71	0.15	6	0.26	1.63	9.35	-0.10
292.5	-0.75	0.12	4	0.95	0.23	30.69	-0.04
131.5	-0.57	0.12	6	0.63	1.28	37.20	1.02
124.5	-0.58	0.12	6	0.65	0.34	21.87	0.30
92	-0.68	0.21	6	0.66	0.68	27.21	0.27
76	-0.66	0.17	6	0.36	1.25	18.57	0.66
51	-0.64	0.13	6	0.13	1.20	11.66	-0.37
33	-0.73	0.21	6	0.54	0.87	45.70	1.38
23	-0.64	0.13	3	0.40	0.95	51.14	0.88
15	-0.78	0.22	6	0.39	2.56	39.68	1.67
10.5	-0.48	0.17	7	0.51	0.88	32.37	1.82
8.2	-0.77	0.13	7	0.35	0.34	22.52	0.73
2.5	-0.46	0.09	4	0.58	0.53	36.45	0.05
-4	-0.64	0.08	8	0.16	5.30	0.69	0.56
-40	0.15	0.06	6	0.04	19.52	0.63	1.72
-64.5	-0.24	0.12	6	0.03	14.58	0.51	0.52
-97.5	-0.58	0.03	6	0.04	16.67	0.38	1.92
-117.5	-0.76	0.25	6	0.04	4.84	0.27	1.82
-160	-0.36	0.19	6	0.13	12.87	1.20	2.36
-270	-0.48	0.17	4	0.06	0.96	2.56	2.80
-330	-0.04	0.13	7	0.02	3.84	2.03	1.15
-370	-0.45	0.18	7	0.03	9.92	1.32	1.28
-389.5	-0.39	0.19	4	0.03	38.75	2.25	2.57
-409.5	-0.30	0.11	7	0.10	2.23	0.57	2.95

The $\delta^{13}\text{C}$ values are from (11) and are included here for reference. "N", the number of runs, refers to the times the sample was run for U isotopes. Multiple samples were run as replicates for quality control from powder, and these replicates are included in "N" as the same sample.