LETTER

Onset of carbon isotope excursion at the Paleocene-Eocene thermal maximum took millennia, not 13 years

The Paleocene-Eocene thermal maximum (PETM) may represent the best paleo-analog for rapid and massive carbon release to the ocean and atmosphere. Thus, constraining the carbon release rate at its onset is critical. Wright and Schaller (1) use records from apparently rhythmically layered shelf sediments to argue that the layering is annual and that the onset of the carbon isotope excursion (CIE, fingerprint for carbon release) in the surface ocean was complete in 13 y. Using basic carbon cycle and climate considerations, we show this is not feasible. In fact, Wright and Schaller's isotope records indicate that the CIE onset took at least several millennia. This finding rules out a cometary origin of the carbon release.

For a near instantaneous release of carbon into the atmosphere, the magnitude of the CIE in the surface ocean directly following the release is

$CIE_{max} \cong \delta_i - (\delta_i M_i + \delta_s M_s)/(M_i + M_s)$, where M_s and M_i are the source and initial surface ocean + atmosphere carbon mass and δ's are isotope compositions (2). M_s = 3,000 Pg (following ref. 1) requires $\delta_s \cong -55‰$ to produce the recorded CIE of ∼3‰ in the entire exogenic (surface) carbon reservoir. With initial pCO_2 = 1,000 ppmv, δ_i = −3‰, and M_i = 3,200 Pg, $CIE_{max} \cong 25‰$. A surface ocean CIE of this magnitude would develop on a timescale of decades, before the signal is diluted through mixing with intermediate- and deep-ocean water. We quantify CIE_{max} mechanistically using the carbon cycle/climate models LOSCAR (Long-term Ocean-atmosphere-Sediment CArbon cycle Reservoir Model) (3) and GENIE (Grid Enabled Integrated Earth System Model) (4), yielding $CIE_{max} \cong$ 20–22‰ (Fig. 1*A*). Hence, if the sediment layering in Wright and Schaller (1) were annual, the measured surface CIE should have exceeded 20‰. This result contrasts the observed ∼3.5‰ at Millville (Fig. 1*A*).

The $\delta^{18}O$ records of Wright and Schaller (1) are indicative of warming at the PETM onset. Statistical analysis of the Millville $\delta^{18}O$ and $\delta^{13}C$ records (measured on the same samples) shows zero leads/lags within the data-resolution limit, implying that the full amplitude of surface warming must also have been completed within 13 y. However, the climate system's inertia (mostly ocean heat capacity) delays surface warming by up to centuries (5). The result is a substantial lag between $\delta^{13}C$ and warming as confirmed by our carbon/climate models (Fig. 1*B*), achieving only ∼50–60% of the final surface temperature anomaly (ΔT) within 13 y. We also forced our model (4) to produce a ∼3‰ CIE over 13 y (inverse approach). However, the associated temperature rise is negligible (Fig. 1*C*). Hence, a 13-y timescale for the completion of the surface carbon-cycle and climate response, as proposed in Wright and Schaller (1), is impossible, unless the Paleocene ocean's heat capacity was near zero. Additional model runs show that a minimum timescale of several millennia is required for the PETM onset to eliminate leads/lags between surface CIE and ΔT. Assuming layers are not a drilling artifact, we note that rhythmically layered shelf sediments, in which the layering neither represents primary sediment deposition nor annual deposition, form off modern river deltas, the paleoenvironment of the ancient New Jersey Shelf (6). We see nothing in Wright and Schaller's (1) measurements to conclude that the PETM onset was completed in 13 y, nor that a cometary impact could have materially contributed to the recorded global CIE.

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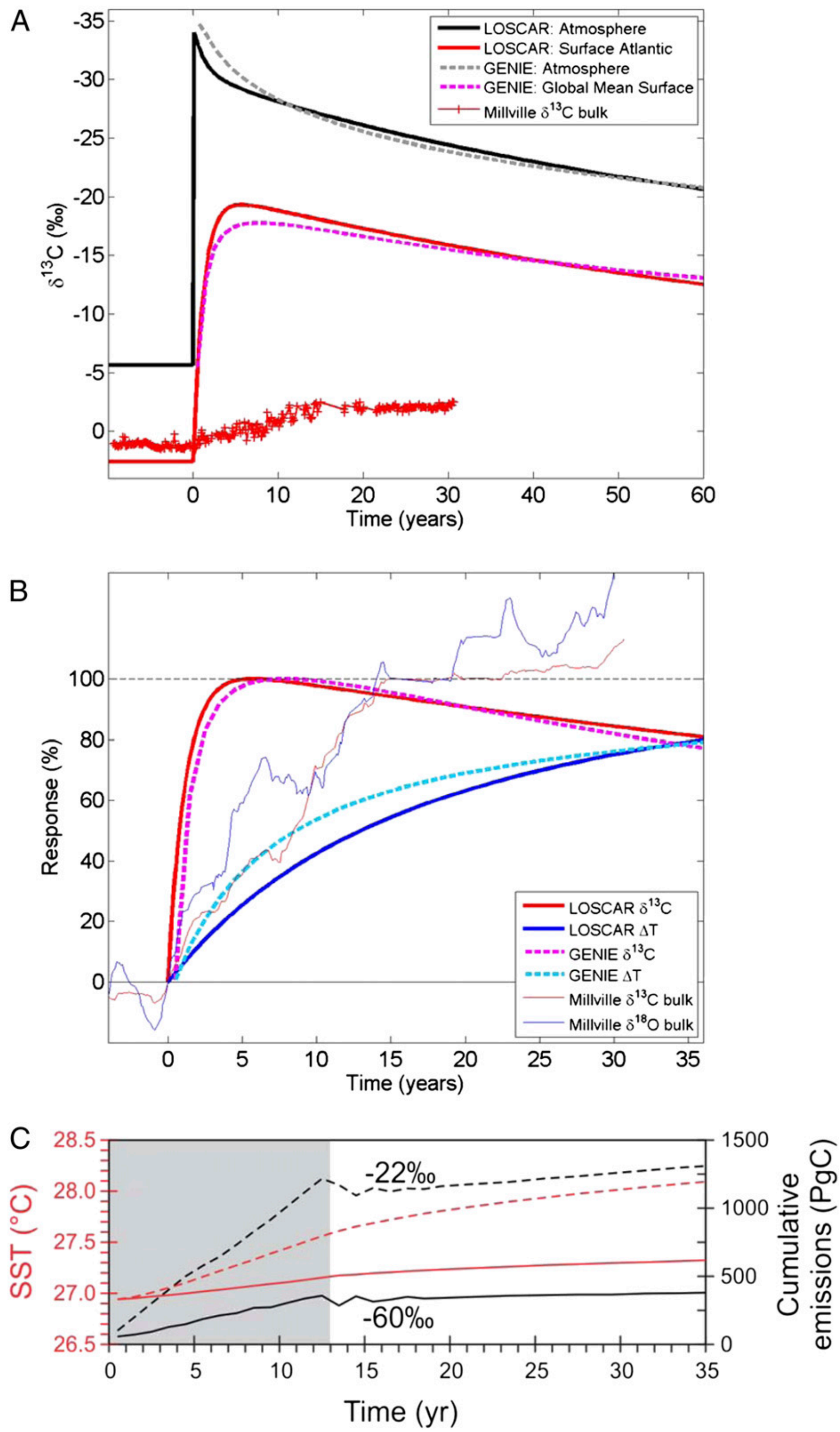

Fig. 1. Observed and modeled CIE (*A*), normalized CIE and climate response (*B*), and inverse modeling approach (*C*). Isotope data [Millville, IODP 174AX (1)] are plotted assuming near instantaneous carbon release and a 13-y timescale for the CIE onset as proposed by Wright and Schaller (1) (10-point running mean shown in *B*). Carbon release in LOSCAR (3), and GENIE model (4) is 3,000 Pg at $\delta^{13}C = -55‰$ over 1 mo in *A* and *B* to produce the final recorded 3‰ CIE in the total surface (exogenic) carbon reservoir and to simulate near instantaneous carbon input. All records and model output are normalized to percent response in *B*; ΔT = model surface temperature anomaly. (*C*) Diagnosed cumulative carbon emissions to the atmosphere required for a linear ~3‰ decline in the $\delta^{13}C$ of ocean surface dissolved inorganic carbon (black) over 13 y in GENIE (4) for −60‰ (solid) and −22‰ (dashed) carbon sources; resulting mean global sea surface temperature (SST) change shown in red.