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HOW LARGE WAS THE "TRUE" CARBON ISOTOPE EXCURSIONS AT THE PETM?

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The Paleoecene-Eocene Thermal Maximum (PETM) is a period of extreme and abrupt global warming that coincides with a pronounced negative carbon isotope excursion (CIE) in both terrestrial and marine carbonate and organic matter. Although the cause of the CIE is debated, all proposed mechanisms call for the rapid addition of ^{13}C-depleted carbon to the ocean-atmosphere-biosphere system. If processes that fractionate carbon isotopes operated in the same way during the PETM as before and after, then terrestrial and marine reservoirs should show a uniform shift in values of the same magnitude. Instead, terrestrial leaf wax lipids demonstrate a CIE of 5-6‰ or more, whereas the marine carbonate CIE is only 3-4‰.

One hypothesis is that the marine carbonates have been isotopically altered, and that the leaf wax lipid record demonstrates the true magnitude of the CIE (5-6‰) (Pagani et al., 2006). Ocean acidification during the PETM would have lead to non-deposition and dissolution of carbonate preventing the accumulation of marine carbonate at the base of the PETM (Zachos et al., 2005). In addition, reduced pH and carbonate concentrations at the base of the PETM would have lead to more positive carbon isotope ratios of marine carbonate, reducing the magnitude of the excursion by up to 0.5‰ until pH rebounded (Bowen *et al.*, 2004).

Here we examine this hypothesis by assuming that our leaf wax lipid record from the Bighorn Basin, WY, USA, represents the true magnitude of the CIE (5‰). We estimate the expected marine carbonate CIE by first calculating the carbon isotope signature of atmospheric CO_2 and then calculating the δ^{13}C values for calcite in equilibrium with atmospheric CO_2 (via dissolved inorganic carbon). Because the equilibrium fractionation factor between calcite and CO_2 is temperature-dependant, the warmer PETM causes the estimated marine carbonate CIE to be 6‰, even larger than that observed in leaf waxes. The largest CIE observed in marine carbonate is 4‰ (Fig. 1). If the leaf wax CIE represents the true CIE, the marine record would have to be enriched in ^{13}C by 2‰ throughout the entire PETM.

To date, no mechanism has been presented that can cause a sustained 2‰ enrichment in marine carbonates throughout the PETM. The effects of ocean carbonate and acidification would be concentrated at the beginning of the PETM and are estimated at 0.5‰. Therefore, we support the alternative hypothesis, that the leaf wax CIE is amplified relative to the true CIE through changes in carbon isotope discrimination by plants. Although the true CIE, meaning the net isotopic change in the combined ocean-atmosphere-biosphere reservoir, need not be that of marine carbonates (3-4‰), we have shown that it is even less likely to be that of leaf wax lipids (5-6‰) and is most likely somewhere in-between.

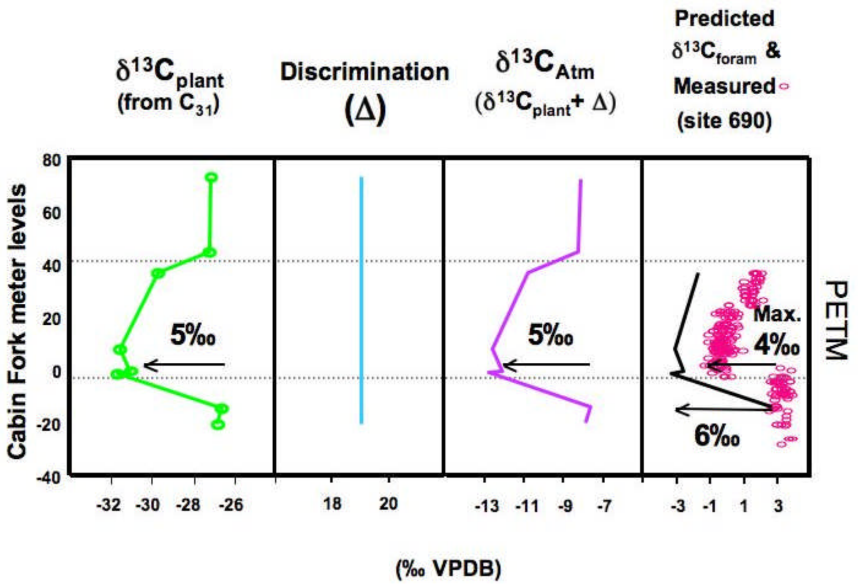

Figure 1 A) $\delta^{13}C$ of total plant tissue calculated from C_{31} *n*-alkane measured in the Bighorn Basin, WY, USA using ε = 4.94 ‰. B) ^{13}C-discrimination assumed. C) Predicted atmospheric CO_2 $\delta^{13}C$. D) Predicted $\delta^{13}C$ values for marine calcite (solid line) precipitated in equilibrium with atmospheric CO_2 following. Measured values from planktonic forams from site 690 (ovals) (Thomas et al., 2002). CIE magnitude indicated by arrows.

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