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Using coccolith chemistry to track coccolithophore productivity response to the PETM

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The Paleocene Eocene Thermal Maximum (PETM) was characterized by rapid and dramatic changes in the carbon cycle and climate. The response of the planktic ecosystems and productivity to the dramatic climate changes of the PETM has been difficult to document. Through culture, sediment core top, and sediment trap studies, we show that consistent positive relationships exist between coccolith Sr/Ca ratios and nutrient-stimulated changes in coccolithophore productivity. Futhermore, coccolith Sr/Ca ratios covary with independent indicators of export production over Quaternary productivity cycles. We exploit these relationships to examine productivity and ecological shifts in calcifying plankton over the PETM.

Sr/Ca ratios of latest Paleocene nannofossil genera exhibit a large degree of heterogeneity, comparable to the range in modern nannofossils. This suggests that the primary Sr/Ca of nannofossils has not been compromised by addition of secondary diagenetic calcite which would homogenize their chemistry. The thick shells of Paleocene nannofossil genera, up to twice as massive as modern coccoliths of comparable diameter, therefore are a primary feature of Paleocene biomineralization and not a consequence of secondary overgrowth. Their high degree of calcification may reflect overall high saturation state of Paleocene surface seawater as proposed by recent models.

The Sr/Ca productivity indicator documents increased overall productivity in the Atlantic sector of the Southern Ocean during the PETM. Rise in productivity of *Toweius* appears to precede the nannofossil CIE by a few ky, and is followed by transient rise in productivity by *Chiasmolithus* and gradual productivity increase in *Zygrhablithus.*

Discoaster and *Fasciculithus* show no productivity change although their relative abundance increases during the PETM, suggesting that their resistant shells were preferentially preserved during the dissolution of the PETM. For *Zygrhablithus* and *Chiasmolithus* elevated productivity ends prior to the surge in carbonate mass accumulation rates characterizing the PETM recovery. *Toweius* productivity remains elevated throughout the recovery. This suggests that the surge in carbonate accumulation during the recovery is likely due to excess carbonate ions supplied by enhanced silicate weathering, consistent with models, rather than to elevated calcareous nannoplankton production. Productivity changes in tropical Atlantic and Pacific sites during the PETM were comparable to background variability prior to the PETM. Despite acidification of the ocean there was not a productivity crisis among calcifying phytoplankton.

Application of the Pandora ocean box model suggests that given proxy and model evidence for decreased Southern Ocean overturning during the PETM, the increase in productivity there likely reflects increased nutrient inventories of the ocean, a consequence of climatically enhanced weathering. Concomitant enhanced burial of organic carbon may have contributed significantly to stabilization of climate and the carbon cycle.