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AN EXTENDED CRETACEOUS-TERTIARY (K/T) STABLE ISOTOPE RECORD: IMPLICATIONS FOR PALEOCLIMATE AND THE NATURE OF THE K/T BOUNDARY EVENT; Steven D'Hondt, Department of Geological and Geophysical Sciences, Princeton University, and Matthias Lindinger, Geologisches Institut der ETH-Zurich.

In order to obtain a detailed single site record of marine productivity and temperature across the Cretaceous-Tertiary (K/T) boundary, we measured both $\delta^{13}C$ and $\delta^{18}O$ values in paired surface and deep water microfossil and nannofossil samples of mid-latitude South Atlantic DSDP Site 528. Additionally, we determined the % sedimentary carbonate content of the rock samples from which the analyzed fossil samples were taken. The analyzed interval spanned the last ~1 million years of the Cretaceous (the Abathomphalus mayaroensis foraminiferal zone) and the first ~9 million years of the Tertiary (the Paleocene). Paired samples were analyzed every 150 cm of the entire 165 m sampled interval (1 sample per recovered DSDP section), every 20 cm for 2.0 m below and 2.5 m above the K/T boundary, and every 0.25 cm immediately below, at, and above the "K/T boundary clay".

At our sampled level of resolution, the Cretaceous-Tertiary boundary of this site is not preceded by any significant latest Cretaceous change in either surface-to-deep $\delta^{13}C$ and $\delta^{18}O$ gradients or in % sedimentary carbonate content. While a small shift in benthic $\delta^{13}C$ values begins slightly prior to the K/T boundary and lasts into the earliest Paleocene, this shift lies well within the range of upper Maastrichtian background $\delta^{13}C$ signal variation at DSDP Site 528.

The Cretaceous-Tertiary boundary and earliest Paleocene record of DSDP Site 528 is marked by at least two strong decreases in the surface-to-deep $\delta^{13}C$ gradient -- one at the K/T boundary (66.4 mybp[1]) and one approximately 150,000 to 200,000 years later. Both of these decreases co-occur with radical decreases in % carbonate content and appear to indicate not one, but two, strong decreases in marine primary productivity during the analyzed interval (Figure 1).

Both dominant planktic foraminiferal faunas and % carbonate content strongly covary with these changes in the earliest Paleocene surface-to-deep $\delta^{13}C$ gradient -- indicating that this stable isotope record is neither a function of post-depositional alteration nor a function of nannofossil or microfossil "vital effects". Similar isotopic and foraminiferal records at other sites indicates that these two productivity events are global in scale, although at least the second event may locally vary in magnitude.

The presence of at least two major decreases in global marine productivity has interesting consequences for K/T boundary extinction theories. Two successive productivity events require one of two endmember general models: either the Cretaceous-Tertiary boundary and earliest Paleocene are subjected to repeated causal events (i.e. multiple impacts or volcanic episodes) or the earliest Paleocene is characterized by extremely strong productivity feedback on the scale of 150,000 to 200,000 years following a single boundary event.

Throughout this earliest Paleocene interval, the $\delta^{18}O$ record closely varies with the $\delta^{13}C$ record: the surface water $\delta^{18}O$ signal decreases at both the Cretaceous-Tertiary boundary and at the earliest Paleocene decrease in the $\delta^{13}C$ gradient (Figures 1,2). These decreases in the surface water $\delta^{18}O$ signal appear to indicate warming of surface ocean waters coincident with the decreases in surface ocean productivity. At DSDP Site 528, the overall magnitude of these $\delta^{18}O$ shifts approaches 0.5 parts per mil. This magnitude is equivalent to approximately 2 or 3 degrees Celsius, assuming no ice volume effects or changes in the magnitude of microfossil vital effects. Unlike a previous study of nearby DSDP Site 524[2], no indication of cooling is seen in the DSDP Site 528 K/T boundary samples. This previously discovered apparent decrease in surface water temperature was based on a bulk rock $\delta^{18}O$ measurement and may have been due to either short term isotopic fluctuations not detected by the present study or to a bias from a strong benthic foraminiferal signal in these extremely low carbonate, high benthic K/T boundary samples. Significantly, an apparent cooling signal is seen in a mixed benthic foram sample from the largely dissolved Maastrichtian chalk in underlying contact with the "K/T boundary clay" at Site 528. This $\delta^{18}O$ signal is not seen in monogeneric benthic foram samples or in nannofossil samples from the boundary clay itself and appears to be a result of benthic foraminiferal vital effects.

As with the $\delta^{13}C$ excursions, the observable covariance between surface water $\delta^{18}O$ records and changes in the $\delta^{13}C$ record appears at other sites globally. For both the K/T boundary and earliest Paleocene $\delta^{13}C$ excursions, a possible cause of this correlation between the $\delta^{13}C$ and $\delta^{18}O$ records is a decrease in marine productivity leading to a covariant increase in atmospheric pCO_2 on geological timescales. Such increases in atmospheric pCO_2 would, in turn, lead to increased mean atmospheric and surface water temperatures.

Through the P1d foraminiferal subzone, the Site 528 early Paleocene stable isotopic record is characterized by a low and highly variable $\delta^{13}C$ gradient. The return to a new stable carbon isotopic gradient, paralleled by return to a new high stable level of % carbonate content, does not occur until well after the beginning of the P1d subzone (FAD Subbotina trinidadensis at 65.6 mybp), but prior to the upper P3 foraminiferal zone (FAD Morozovella pusilla pusilla at 62.8 mybp). P2 Zone sediments do not occur at DSDP Site 528, thereby preventing exact determination of the local timing and rate of return to new stable high productivity levels. Previous studies at other sites[3,4] indicate that full recovery occurred by the P2 foraminiferal subzone (FAD Morozovella uncinata at 64.6 mybp). By the time of full recovery, the dominant carbon system influence on climate and sea-surface temperature appears to have shifted from marine productivity driven ocean-atmosphere carbon partitioning (Figure 2) to longer term whole reservoir shifts in either land-ocean or sediment-ocean carbon partitioning.

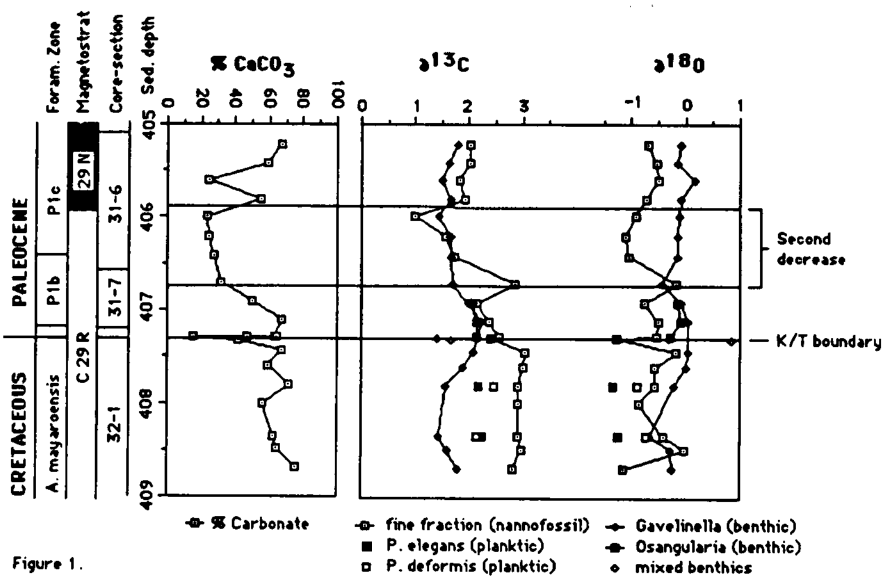
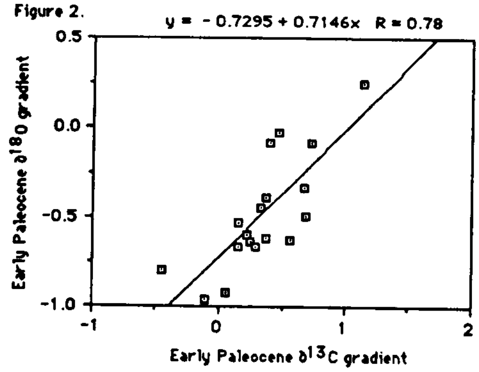


Figure 1.

Figure 2.



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