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The Dynamics of Rapid Greenhouse Warming: Insights from the Paleocene-Eocene Thermal Maximum

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The Paleocene-Eocene Thermal Maximum (PETM) was first indentified 20 years ago[1]. In the time since, significant progress has been achieved in detailing the primary features of this rapid and extreme global warming event, as well as impacts on marine and terrestrial environments. This includes quantification of the magnitude of global warming, 5 to 6°C, and the mass of carbon released, 4500 to 6000 Pg C. Evidence has also emerged for a dramatic shift in global precipitation patterns and intensity, and a transient reduction in oceanic overturn and deoxygenation. Chronostratigraphic constraints indicate the majority of these changes unfolded in less than 10 k.y., then reversed with recovery taking well over 100 k.y. The one exception is the reduction in oceanic overturn and deoxygenation which was transient 2. The overall impacts of the PETM on biota were substantial as evidenced by major shifts in species diversity and abundances in both marine and terrestrial environments.

Given the differences in boundary conditions (e.g., absence of large ice-sheets and associated feedbacks) and a more gradual rate of perturbation, it is evident that the PETM does not represent an ideal analog for future anthropogenic warming. There are, however, several key features of the PETM that can be used to test theory on greenhouse climate dynamics as well as carbon cycle dynamics. For one, observations of the PETM indicate a temperature sensitivity to CO_2 that is at the high end of current sensitivity estimates from models [(3,4)]. Second, the sequestration of carbon released during the PETM required well over 100 k.y., consistent with estimates for the lifetime of anthropogenic carbon. Finally, though the evidence is spatially limited and mostly indirect, particularly for continental settings, it appears the hydrologic cycle intensified during the PETM. Sedimentological and fossil evidence recovered from continental and coastal sections indicate increased precipitation, but with a shift toward seasonal extremes (i.e., brief, but intense wet season, long dry season), resulting in reduced vegetative cover, extreme flood events, and enhanced sediment erosion [(2,5)].

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