Isotopic fractionation of phytoplankton reveals Phanerozoic pCO_2 trend

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Past changes in atmospheric concentrations of carbon dioxide (pCO_2) have had a significant influence on earth system dynamics. Yet, reconstructing secular trends of past pCO_2 remains a prevalent challenge in paleoclimate studies. Based largely on the work advanced by John M Hayes, we apply the theory of photosynthetic stable carbon isotopic fractionation (ε_p) using the isotopic relationship between preserved molecular fossils and inorganic carbon to explore pCO_2 over the Phanerozoic. In order to reconstruct the longest single-proxy trend for pCO_2 currently available, a spatially and temporally ubiquitous compound throughout the geologic record is implemented: phytane, a diagenetic product of the primary pigment for photosynthesis.

The observed secular pCO_2 trend derived from phytane-based ε_p generally mirrors the available pCO_2 reconstruction compilations of the past 420 Ma, with the exception of two periods in which our higher estimates agree with the warm climate during those time periods. This possibly suggests that the phytane-based estimates for pCO_2 may have greater accuracy than the previous proxy compilation. We further test this concept on smaller timescales to assess the robustness of the proxy during periods of assumed smaller pCO_2 fluctuations, such as the past 17 Ma from the greenhouse conditions of the Middle Miocene Climatic Optimum (MMCO) into the icehouse world of today. The phytane-based estimates for pCO_2 during the MMCO are higher than previous records, showing a more steady decline in pCO_2, reflecting the similar decline in sea surface temperatures over this time period. This suggests that temperature and CO_2 were coupled over the past 17 Ma, a concept significant for understanding past systems as well as modeling future climates.