Climatic controls on Late Cretaceous through Paleogene ecosystems

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Climate change has long been considered a driver of marine invertebrate species extinction, origination, and compositional turnover, yet the nature of these relationships remains unclear. Here, we use shallow marine faunas dominated by mollusks from the late Cretaceous through Oligocene of the Gulf Coastal Plan (GCP) of the United States of America (Tennessee, Georgia, Alabama, Mississippi, Louisiana, and Texas) to determine whether and how climate affects the diversity and turnover of these assemblages. The GCP was a shallow subtropical shelf on a passive margin that remained at relatively constant latitude during the studied interval, making it an excellent natural laboratory in which to study these questions. Additionally, the GCP contains some of the world's best-preserved and most diverse Cretaceous and Paleogene mollusk faunas in the world. We have complied a large faunal dataset and a complementary dataset of temperature estimates derived from the oxygen isotopic composition of the fossils themselves. Faunal data consist of field and literature counts of 4,000 taxa (identified to the species level in about 90% of cases), tallied from over 1,700 samples and 280,000 occurrences. Temperature data are derived from mollusks, otoliths, and corals, and are often seasonally resolved records, providing minimum, maximum, and mean temperature. Temperature data result from our own work and the literature, and are comprised of over 7,000 isotopic measurements.

We use the ecological modeling technique capture mark recapture (CMR), modified for paleontological data, to analyze the effects of temperature on the origination and extinction of these assemblages. CMR has several advantages, namely, it can account for unequal time bin duration and the changing likelihood of observing a species in each time bin due to variable sampling intensity, preservation, and geographic spread of fossiliferous outcrops.

Temperature is found to significantly influence both origination and extinction, and exerts a much stronger influence than other potential controls, such as sea level. Specifically, the seasonal range of temperature (i.e., the degree to which temperature varies over a year) is the most significant temperature variable, followed closely by minimum temperature. When seasonal range is small, extinction and origination are low, and as seasonal range widens, both increase. This relationship is stronger for extinction than origination. These relationships result in relatively high and unchanging diversity for most of the Paleogene, until increasing seasonality and cooling caused a long-term diversity decline during the late Eocene through early Oligocene. Although there are no marine invertebrate faunas known from the Paleocene-Eocene Thermal Maximum (PETM), we can compare latest Paleocene faunas to those of the earliest Eocene to evaluate the long-term effects of the PETM. Extinction rate was relatively unchanged across the Paleocene-Eocene boundary, however, origination rate significantly dropped across it, indicating a slight effect of the PETM at this level of resolution. The effects of temperature on marine invertebrates described here could result from organisms encountering novel temperatures as seasonal range widened. Or, these results may arise from variables associated with seasonality, such as consistency and productivity of the planktonic food source.