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Stable isotope time series and dentin increments elucidate Pleistocene proboscidean paleobiology

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Investigations of stable isotope composition of mineralized tissues have added greatly to our knowledge of past climates and dietary behaviors of organisms, even when they are implemented through “bulk sampling”, in which a single assay yields a single, time-averaged value. Likewise, the practice of “sclerochronology”, which documents periodic structural increments comprising a growth record for accretionary tissues, offers insights into rates of growth and age data at a scale of temporal resolution permitted by the nature of structural increments. We combine both of these approaches to analyze dental tissues of late Pleistocene proboscideans. Tusk dentin typically preserves a record of accretionary growth consisting of histologically distinct increments on daily, approximately weekly, and yearly time scales. Working on polished transverse or longitudinal sections, we mill out a succession of temporally controlled dentin samples bounded by clear structural increments with a known position in the sequence of tusk growth. We further subject each sample (or an aliquot thereof) to multiple compositional analyses – most frequently to assess δ^{18}O and δ^{13}C of hydroxyapatite carbonate, and δ^{13}C and δ^{15}N of collagen. This yields, for each animal and each series of years investigated, a set of parallel compositional time series with a temporal resolution of 1-2 months (or finer if we need additional precision). Patterns in variation of thickness of periodic sub-annual increments yield insight into intra-annual and inter-annual variation of tusk growth rate. This is informative even by itself, but it is still more valuable when coupled with compositional time series. Further, the controls on different stable isotope systems are sufficiently different that the data ensemble yields “much more than the sum of its parts.” By assessing how compositions and growth rates covary, we monitor with greater confidence changes in local climate, diet, behavior, and health status. We illustrate the potential of this approach with case studies that reveal: season of birth and age of weaning in juvenile mammoths; age of maturation in male mastodons; season of musth in mammoths and mastodons; and season of death and tests of simultaneity of death in mammoths and mastodons. The data provided by histological and stable isotope analyses rarely reveal cause of death directly, but they can, in concert with other observations, affect perceptions of the likelihood of competing interpretations of cause of death. Most important, paleobiological inferences based on these studies can be integrated over broad geographic and temporal scales to show how specific paleobiological traits changed through time, prior to extinction. These studies have great power for investigating causes of extinction because contrasting patterns of change are expected under different hypothesized drivers of extinction.