

Intra-tooth mammal enamel phosphate oxygen isotope data from the Miocene of Kutch (Gujarat) indicates monsoon-like conditions

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The Indian monsoon system, provider of the majority of annual rainfall in the Indian subcontinent, is one of the most prominent climate systems in the South Asian region. A long-standing fundamental question regarding this phenomenon has been of the timing of its genesis and intensification. Wide-ranging estimates from various proxy and modelling-based studies, ranging from 55 Ma to 7.5 Ma, have been suggested for these events. While many of these studies converge around Middle/Late Miocene subepoch, little to no consensus exists regarding the precise timing. To help resolve this chronological disagreement, herein we offer an age estimate based on the robust enamel phosphate oxygen isotopic record from the Miocene deposits of western India. Oxygen in enamel phosphate of water dependent large-bodied mammals (megaherbivores) is known to reflect the isotopic composition of ingested and hence, meteoric water ($\delta^{18}\text{O}_{\text{mw}}$). Intra-tooth sampling along the growth axis reveals the variation in the rainfall signature over the course of mineralisation, a powerful tool for detecting patterns of seasonality in the ambient rainfall regime. In search of such patterns, a pristine rhinocerotid enamel remain from a Middle Miocene (~14 Ma) locality in western India (Kutch) was serially sampled. Analyses revealed a sinusoidal-like curve with an amplitude of up to 4.6 ‰, a strong signal for the presence of rainfall seasonality (Fig.1.). Based on this, we propose $\leq$ ~14 Ma as the age of development of monsoon system in the Indian subcontinent.

In addition, a comparison of the Middle Miocene $\delta^{18}\text{O}_{\text{mw}}$ range with the ones from other contemporaneous and modern localities in the Indian subcontinent indicated the prevalence of present-day Mumbai (Bombay)-like rainfall dynamics in western India. This implied similarity further strengthens the isotopic evidence for the existence of monsoonal conditions in western India by as early as 14 Ma, as the Mumbai region currently receives almost all of its annual precipitation during the summer months followed by little to no rainfall during the rest of the year, resulting in pronounced wet and dry seasons, a classic symptom of monsoonal precipitation dynamics.

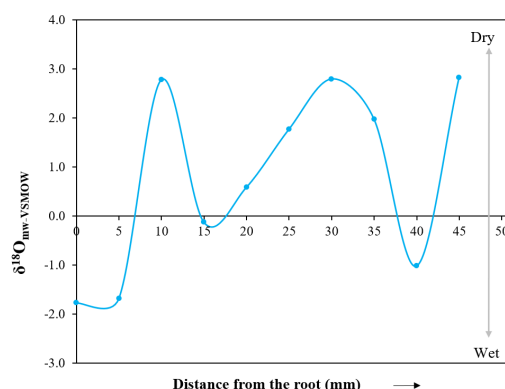


Fig.1. Measured $\delta^{18}\text{O}_{\text{mw}}$ variation across the serially sampled enamel growth axis transect (a proxy for time during the mineralisation period) in a rhinocerotidae sample (~14 Ma, Kutch) displaying a cyclical sinusoidal-like pattern with multiple alternating peaks and troughs indicating dry and wet periods, respectively.