Stable Isotopic Variations in Modern Herbivore Tooth Enamel, Plants and Water on the Tibetan Plateau: Implications for Paleoclimate and Paleoelevation Reconstructions

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Introduction

Stable isotope analyses of fossil teeth and other authigenic minerals have been used to reconstruct the paleoenvironment and paleoelevation of the Tibetan Plateau. The accuracy of such reconstructions is limited by the lack of a comprehensive modern comparative database from the region. In this study, we analyzed the carbon and oxygen isotopic compositions of modern herbivore tooth enamel, grasses and water samples collected from various elevations within the Tibetan Plateau to examine their relationships with modern environment/elevation.

Results

The $\delta^{13}C$ values of tooth enamel from modern herbivores reflect diets based primarily on C3 plants, consistent with the current dominance of C3 vegetation in the region. Although C4 grasses can be found in the warmest months at high elevations in southern Tibet, they are not a significant dietary component of modern herbivores due to their insignificant presence in local biomass. Our data show that the conservative "cut-off" $\delta^{13}C$ value for a pure C3 diet within the Tibetan Plateau should be -8‰ for modern herbivores and -7‰ (or even -6.5‰) for fossils if the Tibetan Plateau was in the past as arid as today. Carbon isotopic compositions observed within and between species primarily reflect the C isotopic variations of C3 plants available for consumption in local habitats. Oxygen isotopic compositions of tooth enamel varied widely within and between species. The mean $\delta^{18}O$ values of tooth enamel from yaks and horses show a strong positive correlation with water $\delta^{18}O$ values, confirming that the $\delta^{18}O$ of tooth enamel from large mammals that are obligate drinkers generally tracks the $\delta^{18}O$ of meteoric water. Serial isotopic analyses of individual teeth show that intra-tooth $\delta^{18}O$ variations primarily reflect seasonal variations in the $\delta^{18}O$ of meteoric water. Unfortunately, the $\delta^{18}O$ values of modern precipitation and of modern tooth enamel do not show strong correlations with elevation in this region.

Conclusions

In light of the large spatial and temporal variability of $\delta^{18}O$ values of meteoric water and the lack of a strong relationship between precipitation $\delta^{18}O$ and elevation in the Tibetan region, we caution against any quantitative reconstruction of the paleoelevation of the Tibetan Plateau using the $\delta^{18}O$ values of paleo-meteoric water estimated from tooth enamel and other O-bearing minerals. Although changes in the $\delta^{18}O$ values of authigenic O-bearing minerals in terrestrial environments most likely indicate changes in certain aspects of local climate, teasing apart the many factors (e.g., changes in elevation, temperature, precipitation amount, moisture sources, monsoon strength, etc.) that can have a local influence on the $\delta^{18}O$ of meteoric water without other independent constraints is practically impossible in this region with complex tectonic and climatic history.