Quaternary International xxx (2016) 1–7

Contents lists available at ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

The stable isotope record in cervid tooth enamel from Tantang Cave, Guangxi: Implications for the Quaternary East Asian monsoon

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ARTICLE INFO

Article history:
Available online xxx

Keywords:
Pleistocene
Southern China
Tantang Cave
East Asia monsoon
Stable isotopes

ABSTRACT

Studies have shown that stable isotope [oxygen (O) and carbon (C)] composition of mammal tooth enamel can provide information on a region's paleoclimate and paleoecology. Stable isotope analysis has been used to investigate the impact of the Qinghai–Tibetan Plateau uplift on the development and strength of the Asian monsoon. However, due to sparse data from southern China, a region dominated by the East Asian monsoon, O and C isotope analysis of mammal tooth enamel has been unable to fully inform on the impact of the monsoon environment in the region. Here, we present the results of the analysis of stable isotopes on a set of cervid tooth enamel from late Middle Pleistocene Tantang Cave in Bubing Basin, Guangxi, southern China and compare them with comparable isotope data from nearby early Early Pleistocene Mohui and middle Early Pleistocene Sanhe Caves. The results of the oxygen isotope analysis indicates that Tantang Cave (−8.70‰ to −6.39‰) is similar to Mohui Cave (−8.71‰ to −6.34‰), with both sites being more negative than Sanhe Cave (−4.77‰ to −1.20‰). We suggest the East Asian summer monsoon was stronger during the Tantang and Mohui mammal occupations and weaker during the lifetime of the Sanhe mammals. This result is indirectly corroborated by vertebrate paleontological evidence. Murid rodents, implying an open grassland and somewhat drier climate, are found in great numbers in Sanhe. The carbon isotope results from Tantang (−17.70‰ to −10.26‰), Mohui (−15.27‰ to −12.51‰), and Sanhe (−16.63‰ to −14.71‰) overlap extensively suggesting these various faunas primarily lived in a closed forest environment. The implications of these findings from stable isotope studies from Tantang are discussed in their broader context.

1. Introduction

The analysis of stable isotope (e.g., oxygen, carbon) ratios of vertebrate fossil tooth enamel has contributed tremendously to a better understanding of the paleoecology of different animals (including hominins) and the paleoclimate and paleoenvironment in which they lived (Wang et al., 1994; Cerling and Harris, 1999; Sponheimer and Lee-Thorp, 1999a). A good example of these contributions is a recent study of Australopith diet. Wynn et al. (2013), using *Australopithecus afarensis* samples from Hadar and Dikika, that are securely dated to between 3.4 and 2.9 Ma, found that *Au. afarensis* clearly relied heavily on a diet of C_4/CAM plants (foods common to tropical savannas and deserts). This was a major divergence from the known diet of the older *Au. anamensis* taxon, whose diet was focused on C_3 plants and indicates a significant change in the region's environment (Wynn et al., 2013). Thus, understanding stable isotope data can inform on important questions related to a species' paleodiet and paleoecology, and more generally, the paleoenvironment.

Oxygen isotopes in mammalian tooth enamel contain valuable information about paleoclimate, related directly to variables such as temperature, seasonality, and rainfall. Evaluating $\delta^{18}O$ values of meteoric water can contribute to a better understanding of aspects

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http://dx.doi.org/10.1016/j.quaint.2015.11.049
1040-6182/

like an animal's drinking water, habitat and mobility, as well as paleotemperature variation (Luz et al., 1984; Luz and Kolodny, 1985; Sponheimer and Lee-Thorp, 1999b; Dupras and Schwarcz, 2001). δ^{18}O of tooth enamel has been used as a proxy to study paleoclimatic changes during a tooth's growth stage (Luz et al., 1984; Bryant and Froelich, 1995; Sponheimer and Lee-Thorp, 1999b; Kohn and Cerling, 2002; Wang et al., 2008a,b). Further, at mid to high latitudes δ^{18}O is correlated with surface temperature (Dansgaard, 1964).

In general, different plants have different carbon isotope ratios. For instance, trees, most shrubs, and cool season grasses produce different carbon traces from warm season grasses. The former group (trees, most shrubs, and cool season grasses) are referred to as C_3 plants, while the latter group (warm season grasses) are referred to as C_4 plants. Because C_3 and C_4 plants produce different δ^{13}C values ($C_3 = -22$‰ to -35‰, avg. -27‰; $C_4 = -9$‰ to -17‰, avg. -13‰) understanding the carbon value can contribute to a better understanding of the types of plants that were common across time and space (O'Leary, 1981; Van der Merwe, 1982). As these distinct isotope ratios are passed up the food chain to the animals that consume these plants, identifying these values in fossil taxa can indicate what types of foods were available across different spatio-temporal facies. In other words, carbon isotope analysis of tooth enamel can inform what type of foods an animal consumed, which in turn contributes to reconstructions of a taxon's paleoecology (Cerling and Harris, 1999). In general, the carbon isotope composition of structural carbonate of tooth enamel is enriched by approximately 14‰ relative to the plants that compose the diet (Cerling and Harris, 1999).

Over the past several decades, many stable isotope studies in China have been conducted on a range of sites and materials dating from the Neogene to the Quaternary. Many of these studies have focused on questions related to the paleoecology, paleoclimate, and paleoenvironmental variation which have been influenced by the uplift of the Qinghai–Tibetan Plateau and/or the Loess Plateau in northern China (e.g., Deng and Xue, 1996; Dong and Deng, 1988; Wang et al., 1994, 2006, 2008a, 2008b; Deng, 1999; Deng et al., 2001; Li et al., 2003, 2006, 2009; Deng and Li, 2005; Wang and Deng, 2005; Biasatti et al., 2010; Zhao et al., 2011; Qu et al., 2014; Shao et al., 2014). For instance, Deng et al. (2011) analyzed 70 mammal tooth enamel samples from a series of sites from Quaternary northern China and found that the C_3-/C_4 ratio between northern China and Pakistan was noticeably different for the same time periods. Deng et al. (2001: 78) postulate that the reason for this environmental variation is primarily due to the uplift of the Qinghai–Tibetan Plateau, which reached an “influential height” sometime during the Late Miocene, in turn causing the development of monsoon variability (stronger and wetter south of the plateau, weaker and drier north of the plateau).

Traditionally, one of the problems with these reconstructions of the paleoecology, paleoclimate, and paleoenvironment of Quaternary China has been the paucity of similar data originating from regions outside of the Qinghai–Tibetan Plateau and the Loess Plateau in northern China. Understanding the paleoecology and paleoenvironment of southern China is equally important because the region sits squarely in the Oriental biogeographic zone, completely different from northern China which lies in the Palearctic biogeographic zone (Norton et al., 2010). Fortunately, an increasing number of studies are currently being conducted in southern China. For instance, in a recent comprehensive study of a series of sites and materials from the late Tertiary to the Quaternary in Yunnan, Biasatti et al. (2012) were able to observe a series of environmental fluctuations that were not previously identified. One of the major findings from their study is that they were able to show that the region changed from a heavily forested environment c. 8 Ma to a “mosaic of forest and grasslands” c. 4–3 Ma as reflected in the changing carbon and oxygen isotope data (Biasatti et al., 2012: 48).

Currently, stable isotope data exists from eight sites in southern China (Jianshi, Longgupo, Longgudong, Juyuandong, Chuifengdong, Mohui, Sanhe, upper Pubu Cave) that span the Quaternary (Wang

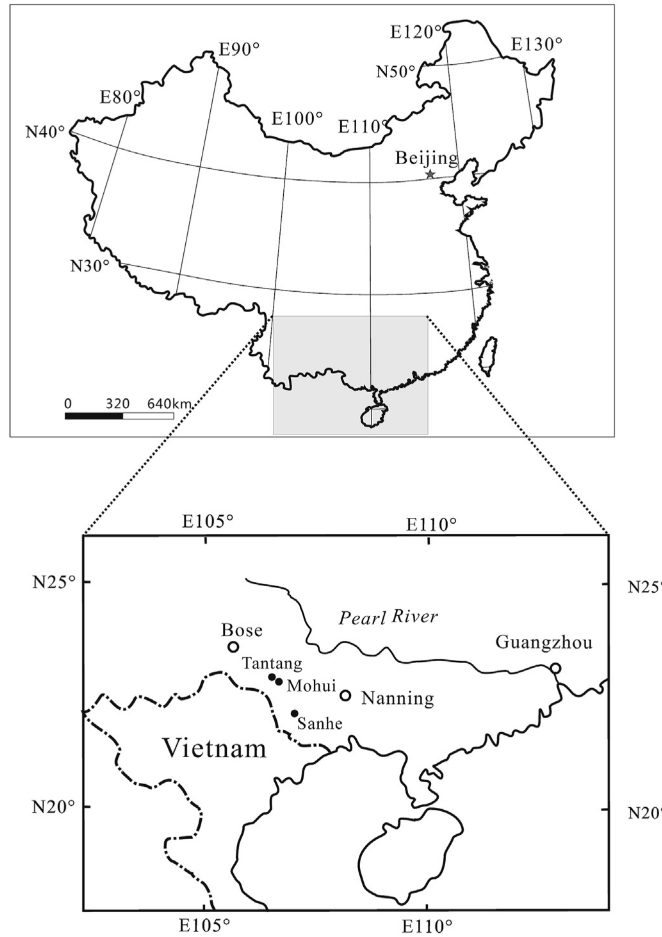

Fig. 1. Location of Tantang Cave.

Fig. 2. Landscape of Tantang Cave.

Please cite this article in press as: Li, D., et al., The stable isotope record in cervid tooth enamel from Tantang Cave, Guangxi: Implications for the Quaternary East Asian monsoon, Quaternary International (2016), http://dx.doi.org/10.1016/j.quaint.2015.11.049