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Expansion of open landscapes in Northern China during the Oligocene induced by dramatic climate changes: Paleoecological evidence

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ABSTRACT

The mammalian faunas of the Mongolian Plateau were affected by an important turnover at the Eocene–Oligocene transition, caused by a global cooling and a local aridification, which could have strongly affected the environment. However, paleoenvironmental indices remain scarce in this area during the Oligocene. The knowledge of the main paleoecological trends of mammals can thus constitute essential clues in order to better evaluate the impact of these climate changes on East Asian environment variations. As fossils of the primary consumer macro-mammals are unavailable to reconstruct past environments, we proposed to infer the feeding habits of well-described rodent communities by studying their dental microwear patterns. We assumed that their diet range reflected their past micro-habitats. 80 dental specimens of Cricetidae and Ctenodactylidae excavated from Ulantatal sites (Inner Mongolia, China) were investigated through the Oligocene period. Our results reveal that the main wear features observed in their dental patterns are fine scratches, which correspond to the ingestion of abrasive matter, such as grasses or dust present in herbaceous to shrubby layers. In addition to these plants, they could also have consumed insects. Feeding behaviors which included a high component of abrasive intakes were probably linked to important environmental changes that occurred between the Eocene and the Oligocene. That is stressed by the appearance and the relative expansion of open habitats involving mainly shrubs, and probably, to a lesser extent, grasses. These environmental changes are supported by some dental characteristics of the Oligocene mammalian paleocommunities of the Mongolian Plateau (e.g. high-crown). Similarly, Oligocene paleoenvironmental records of the North American Great Plains indicate the presence of woodlands and savannas at the same latitudes, including grasses. Although preliminary, these results concur with the assumption of the diversification of grasses in open landscapes well before their expansion during the Late Miocene.

1. Introduction

An important faunal turnover named the "Mongolian Remodelling" occurred at the Eocene–Oligocene boundary in an area located in Eastern Asia, which currently corresponds to the Mongolian Plateau (Meng and Mac Kenna, 1998). This event was assumed to be nearly synchronous with the "Grande Coupure" (Hartenberger, 1998; Kraatz and Geisler, 2010), a similar turnover that corresponded to the replacement of most of the European endemic faunas by Asian faunas (e.g. Stehlin, 1909; Thaler, 1966). The Mongolian event was closely linked to the dramatic global climate cooling starting from the Oligocene period (Liu et al., 2009), which also triggered aridification in Asia (Dupont-Nivet et al., 2007; Xiao et al., 2010), mostly in Northern China and Central Mongolia. This aridification was highlighted by a relatively high prevalence of micro-mammals (i.e. rodents and lagomorphs) in Mongolian and Chinese Oligocene faunas, more adapted to such climate conditions than the Eocene faunas which were dominated by larger mammals, mainly Perissodactyla (e.g. Brontotheriidae, Deperetellidae, Lophialetidae ; Meng and Mac Kenna, 1998; Wang et al., 2007). The transition between these so-called greenhouse and icehouse periods was also characterized by the substantial depletion of CO_2 atmospheric concentration, notably responsible for the onset and extension of the Antarctic ice caps (De Conto and Pollard, 2003; Pagani et al., 2005). These trends were amplified during the Oligocene by a reduced humidity caused by the fall of oceanic temperatures and by the retreat of the Paratethys Sea, which is related to the expansion of the Antarctic ice sheets and the collision between the Indian and Asian Plates (e.g. Fluteau et al., 1999; Zhang et al., 2007). The Himalayan orogenesis could only be marginally involved in these climate changes, since the Tibetan Plateau was slightly elevated at that time (nearly 1000 m against 5000 m 15 Ma ago) and it did not yet play the key role it did during the Miocene, involving the onset of the Monsoon in Southern and Southeastern Asia (Harris, 2006).

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In this context, it appears likely that Asian paleoenvironments have recorded important changes, which partly drove the Oligocene faunal turnover. During the Eocene, landscapes were composed of relatively dense vegetation favored by moister conditions, but forests were not so moist given the microphyllous nature of evergreen trees and the presence of some sclerophyllous elements (e.g. Collinson and Hooker, 2003). Unfortunately, accurate paleoenvironmental data from the Oligocene of the Mongolian Plateau are still missing, as in the whole of Eastern Asia (Strömberg, 2011), and the rare paleoecological evidence collected is strongly divergent. For instance, warm temperate deciduous broad-leaved forests were inferred for Northern China (e.g. Guo, 1990), while other studies hypothesized drier and more open environments. These latter authors proposed an environment incorporating broad-leaf deciduous and evergreen trees and sclerophyllous elements, with or without an herbaceous layer (Leopold et al., 1992; Janis, 1993), but excluding grasses in any case (Jacobs et al., 1999). The assumption of open environments and arid climate is supported by the paleoecological inferences deriving from the study of mammalian paleocommunities (Meng and Mac Kenna, 1998; Wang et al., 2007). They stressed drier and more open landscapes than previously suspected due to the appearance of open environment-like species having high-crowned teeth such as lagomorphs, rhinocerotids and some ruminants probably more adapted to the ingestion of abrasive and tough matter, such as grasses (Vislobokova and Daxner-Höck, 2002; Erbajeva, 2006). However, this kind of vegetation was not yet abundant in Oligocene landscapes (Edwards et al., 2010). Given these discrepancies, we aimed to test which of these vegetation models is the most accurate for the Mongolian Plateau during the Oligocene, and to discuss the influences of climate change on the evolution of environments and faunas.

We focused on a Northern Chinese area, Ulantatal (Inner Mongolia, Fig. 1), including the most diversified and abundant rodent faunas ever described from Asian Oligocene sites (Vianey-Liaud et al., 2006; Gomes Rodrigues et al., 2012). The interest in studying such micro-mammals is based on their more or less generalist feeding habits. Their diet could thus provide fine scale information on their micro-habitats, and more generally on the evolution of vegetations during the Oligocene. Dental microwear patterns were used to perform this investigation as they are generally produced by the communition of the last food items ingested by the animal (e.g. Teaford and Oyen, 1989). This way of investigation has revealed one of the most suitable and robust methods to determine the feeding habits of extinct vertebrates and to infer paleoenvironments as well (e.g. Walker, 1976; Grine, 1986; Solounias et al., 1988; Janis, 1990; Strait, 1993; Merceron et al., 2005a,b; Ungar et al., 2007; Goillot et al., 2009). Dental microwear analyses have only recently been used to determine the main food consumptions of extinct rodent groups (Nelson et al., 2005; Townsend and Croft, 2008; Gomes Rodrigues et al., 2009; Hautier et al., 2009; Firmat et al., 2010). Because the dental remains of primary consumer macro-mammals that are typically used for such studies are scarce or undescribed, the record of Ulantatal rodents appears suitable to infer the vegetal components of the Oligocene environments through their dental microwear patterns.

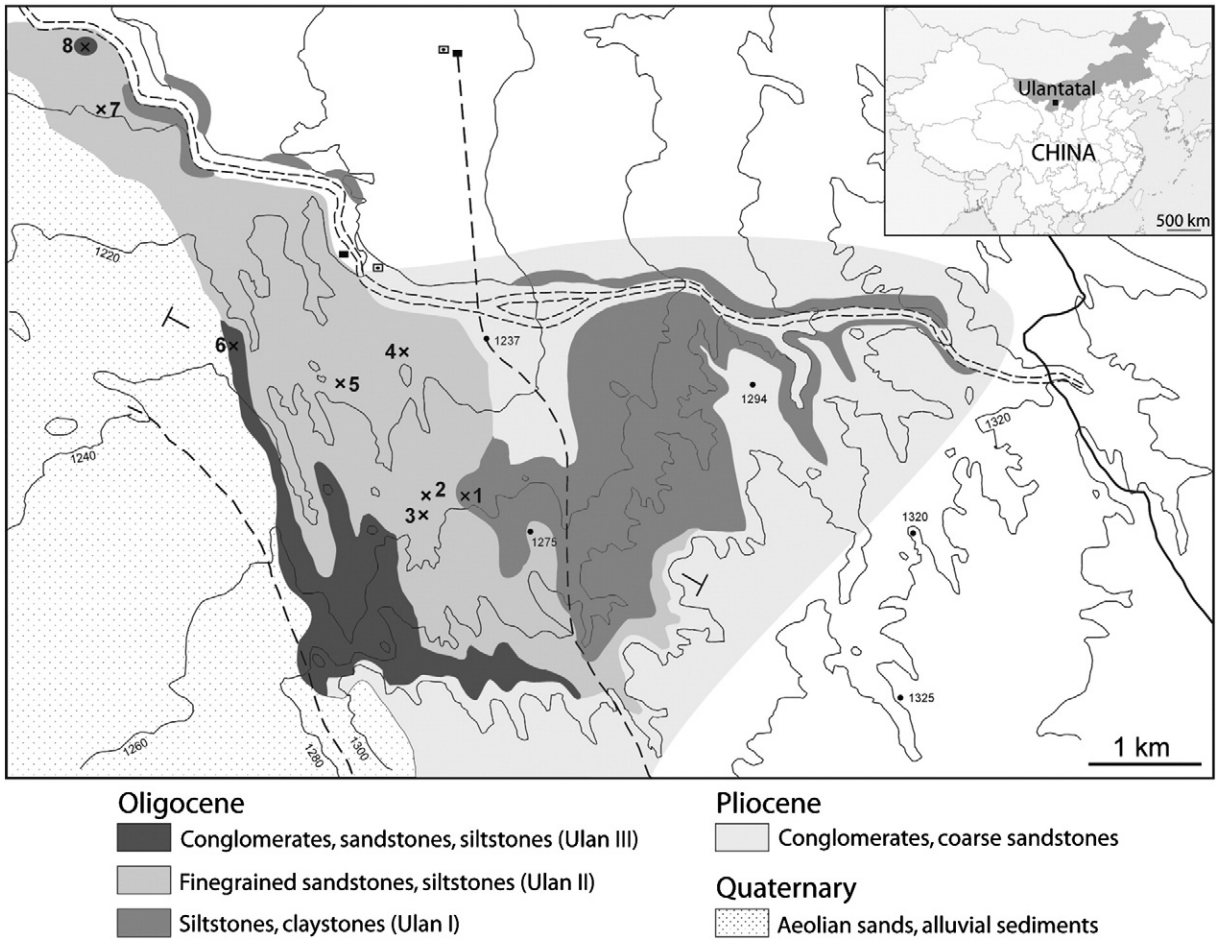

Fig 1. Map showing the location and the geology of the Ulantatal area.
From Gomes Rodrigues et al. (2012).