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Cenozoic xeromorphic vegetation in China and its spatial and temporal development in connection with global changes

Wei-Ming Wang *, Jun-Wu Shu

Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, Nanjing 210008, China

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Abstract

Remarkable angiosperm evolution and significant vegetation changes took place during the Cenozoic on earth. Specifically, Neogene is a crucial period in forming the framework of the current vegetation and in restructing earth ecosystem after the Eocene–Oligocene "greenhouse-icehouse" climate transition. Under the background of global changes, regional vegetation in China was synchronously developed. Some local changes had made extensive influences, such as the topographic changes, especially the uplift of the Qinghai-Tibet Plateau, and the changes in seasonal atmospheric circulation and precipitation, i.e., the initiation and evolvement of Asian monsoon system, along with other geographic changes in land and sea. The expansion of xeromorphic vegetation, represented by forest steppe, steppe and desert, played an ever-increasing role, which was closely related with the development of angiospermous xerophytes. The distributions of some representative angiospermous pollen types with their parent plants of xerophilous origination in the Cenozoic are summarized in the paper. Evidence shows that the origination and evolution of the angiospermous xerophytes underwent a series of developments, which were prompted largely by environmental variations. Pollen studies from some representative sites in China show that spatial and temporal development of Cenozoic xeromorphic vegetation is largely consistent with the global changes.

Keywords: Xerophytes; Vegetation; Global changes; Cenozoic; China

1. Introduction

The Cenozoic witnesses a series of extraordinary changes in land and sea, resulting in severe climate variations. The global warm climates had already begun a long and irregular slide into the glaciations, which characterized the late Cenozoic (Frakes, 1979). The Cenozoic climate was generally warm and stable in its early stage, and became deteriorated from the middle stage, with a worldwide glacier developed in the late stage (Berger, 1982; Shackleton et al., 1984; Barrett, 2003). The Eocene–Oligocene boundary, at about 33.5 Ma ago, marks the transition from "greenhouse-" to "icehouse-world" (Abelson et al., 2008). This changing tendency of the Cenozoic climate did not go straightforward, but was punctuated by periods of warmth, which were especially distinct during 19.5–16.5 Ma and 4.6–3.8 Ma (Kennett and von der Borch, 1985). Zachos et al. (2001) summarized the Cenozoic deep sea $\delta^{18}O$ temperature curve, changes in ice-sheets at Polar Regions, major global climatic, tectonic and biological events in their paper, which is widely recognized in the academic circle.

One of the major influences on the extant vegetation in China is the Asian monsoon system. The present East China is part of the Asian monsoon region. Geographically, taking the Daxing'anling, Yinshan, and Helanshan Mts. and the east border of the Qinghai-Tibet Plateau as an approximate boundary (Fig. 1), its southeast part is affected mainly by the Pacific Ocean monsoon, and its southwest part by the Indian Ocean monsoon, occupying about 47.6% of the whole Chinese territory (Zhang, 1989). There are many discussions on the initiation and development of the Asian monsoon in the geological past (Wang, 1984, 2009; Zhang, 1984, 1989; Liu, 1999; Sun and Wang, 2005; Wang et al., 2009), which is believed to be closely related with the intensified Cenozoic environment changes. Topographically, the formation of three macro-landform complexes in China, including some major mountain systems, numerous intermontane plateaus, basins, and plains, also played a great role.

* Corresponding author. Tel.: +86 25 83282222.
E-mail address: wmwang@nigpas.ac.cn (W.-M. Wang).

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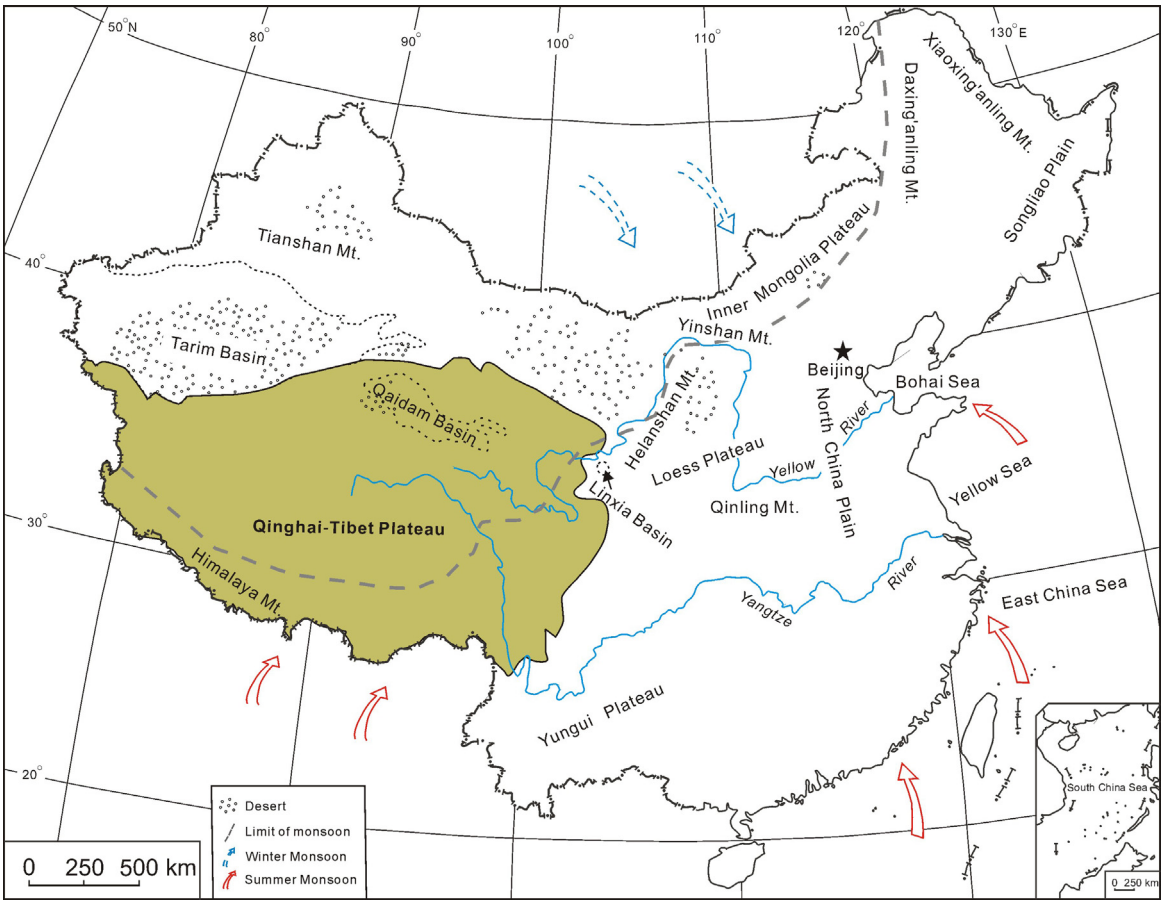

Fig. 1. Geographic map of China showing major topographic units and monsoon influenced regions.

In the Cenozoic of China, the temperate and warm temperate xeromorphic vegetation, such as forest steppe, steppe and desert played an increasing role. This paper aims at the major changing process of the Cenozoic xeromorphic vegetation in China under the background of the global changes. To better understand the vegetation changes, we also summarize the distribution of some representative angiospermous pollen types with their parent plants of xerophilous origination in the Cenozoic of China.

2. Evolution of main angiospermous xerophytes in the Cenozoic of China

The angiospermous xerophytes are well represented in the Cenozoic of China. Their families or genera have varying biostratigraphic significances in different time ranges (Song et al., 2004; Wang et al., 2006). The origination and evolution of xerophytes underwent a series of development, and were prompted largely by environmental variations, resulting in the formation of xeromorphic vegetation. Some of the xerophytes are especially representative, such as Chenopodiaceae, Nitrariaceae, Asteraceae, Poaceae, and Caryophyllaceae.

Chenopodiaceae was first recorded from the Cenomanian Qingshankou Formation in the Songliao Basin (Gao et al., 1999). It is widely distributed in the Cenozoic of China, especially in Northwest China. Pollen records from the Qaidam Basin show two distinct flourishing stages of the plant in the Oligocene and the Middle Miocene respectively (Zhu et al., 1985; Fig. 2). Currently, there are about 42 genera and 190 species of Chenopodiaceae, which are distributed mainly in deserts, and coastal and saline habitats in China.

Nitraria is a genus of halophilic in the family Nitrariaceae (previously assigned to the family Zygophyllaceae). The sometimes thorny shrubs have alternate and entire fleshy leaves, and are distributed mainly in Northwest China. *Nitraria* first occurred in the Late Paleocene upper part of the Qijiachuan Formation in Xining area, and fully developed in the Late Eocene–Early Oligocene as revealed by the pollen data from the Qaidam Basin (Zhu et al., 1985; Fig. 3).

There are four fossil pollen genera, related to Astereae, Tubuliforae, *Artemisia*, and Cichorieae respectively in Asteraceae. All of them were first recorded in the Qaidam Basin, with Astereae from the Eocene Lulehe Formation, Tubuliforae from the Eocene lower part of the Lower Ganchaigou Formation, and *Artemisia* and Cichorieae from the Oligocene Upper Ganchaigou Formation, respectively (Zhu et al., 1985). Although the origin of Asteraceae might be dated back to the Paleogene, it did not thrive until the Middle Miocene, and only became widely distributed in the Pliocene (Wang, 2004). Most members of Asteraceae are herbaceous, but a significant number of them are also shrubs, vines, and trees. This family has a worldwide distribution and is most common in the