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Miocene woods from the Qaidam Basin on northern Qinghai-Tibet Plateau with implications for paleoenvironmental change

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ABSTRACT

The Qaidam Basin with the most complete Cenozoic sedimentary preservation in northern Qinghai-Tibet Plateau is a key area for studying uplift and environmental change of the plateau. Three types of woods, *Ulmus* (Ulmaceae), Leguminosae (?) (angiosperm) and Cupressaceae (gymnosperm) were recognized from the large-scale preservation of fossil woods in late Miocene Shang Youshashan Formation in northern Qaidam Basin on the Qinghai-Tibet Plateau. Both investigations of their Nearest Living Relatives (NLRs) and previous grassland mammal evidences suggest that there have been temperate deciduous broad-leaved forest and needle-leaved forest with grass in northern Qaidam Basin during the late Miocene in contrast to the desert vegetation found there nowadays. The presence of the ancient forest steppe further implies that the southern part of the plateau used to be adequately low, so that the Indian and East Asian monsoons could approach the northern area and to accommodate the vegetation in late Miocene.

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1. Introduction

The Qinghai-Tibet Plateau with an average elevation between 4000 and 5000 m above sea level is well known as the "Roof of the World". It is the largest and youngest plateau all over the world. The formation and evolution of the plateau have had a profound impact on the Cenozoic climate and environmental changes in Asia, and even extending to the Northern Hemisphere for the aridification in central Asia and enhancement of monsoon in Asia. The uplifting of the plateau is considered as one of the most important reasons for late Cenozoic global climate change. Late Cenozoic environmental and climate change of the plateau has been a key issue attracting geologists and paleontologists (e.g. Xu et al., 1973; Li et al., 1979, 2001; Kutzbach et al., 1989; Ruddiman and Kutzbach, 1989; Ruddiman et al., 1989; Harrison et al., 1992; Molnar et al., 1993, 2010; Li and Fang, 1998; Fang et al., 1999; An et al., 2001; Guo et al., 2002; Spicer et al., 2003; Molnar, 2005; Harris, 2006; Zhou et al., 2007; Zhu et al., 2006; Royden et al., 2008; Song et al., 2010; Miao et al., 2012; Pan et al., 2012; Wang et al., 2012; Sun et al., 2015).

Plants are sensitive indicators of environmental and climate change. Well preserved plant megafossils provide direct evidences for investigating the Cenozoic vegetation and climate as well as estimating the amount of continental uplift of the Qinghai-Tibet Plateau. For example, based on the discovery of *Quercus* fossils in the Pliocene strata at 5700–5900 m above sea level on the northern slope of the Xixia Bangma Peak at Shigatse, Tibet, Xu et al. (1973) suggested that the uplift in the Himalayan region had been up to 3000 m since the Pliocene.

Although studies on plant megafossils started on the Qinghai-Tibet Plateau decades ago, reports on plant megafossils are relatively sporadic in literature partly due to the difficulties in collecting plant fossils under the tough conditions on the plateau. Researchers have previously paid special attention to the Cenozoic plant megafossils (e.g. fossil leaves) from the southern part of the plateau, including Paleogene fossils from Angren, Gar, Gonjo, Lhatse and Shigatse, and Neogene fossils from Gar, Markam and Namling, etc. (Li, 1995; Liu et al., 1996). However, from the northern part of the Plateau, only a few reports on Neogene plant megafossils are available from Zekog and Ulan Counties in Qinghai Province (Li and Guo, 1979; Liu et al., 1996) (Fig. 1). Recently, Sun et al. (2015) reported a fossil *Berberis* leaf from the early–middle Miocene sediments of Wudaoliang in Hoh-Xil Basin in northern Tibet at a present altitude of 4611 ± 9 m, and suggests that the Hoh-Xil Basin has been uplifted ~2–3 km in the last 17 million years. Unfortunately, the Cenozoic petrified woods, as important relics of ancient forests, have never been studied in-depth in the plateau before.

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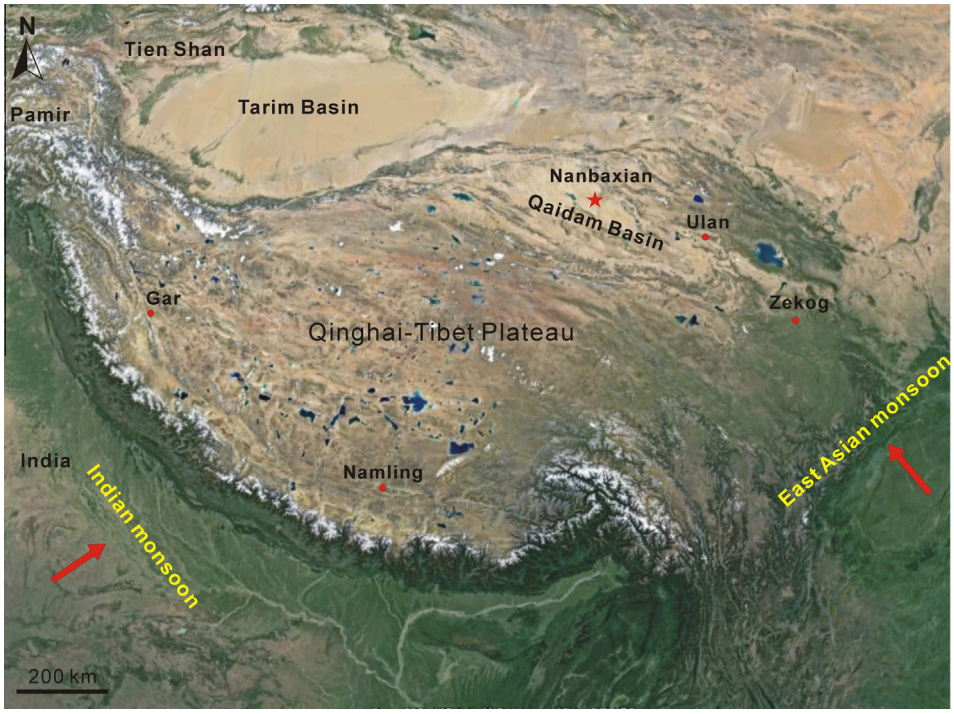

Fig. 1. Map showing location of the fossil sites including Nanbaxian village (wood, marked with star), Ulan, Zekog, Gar, and Namling (leaves, marked with solid circle) on the Qinghai-Tibet Plateau (from Google earth).

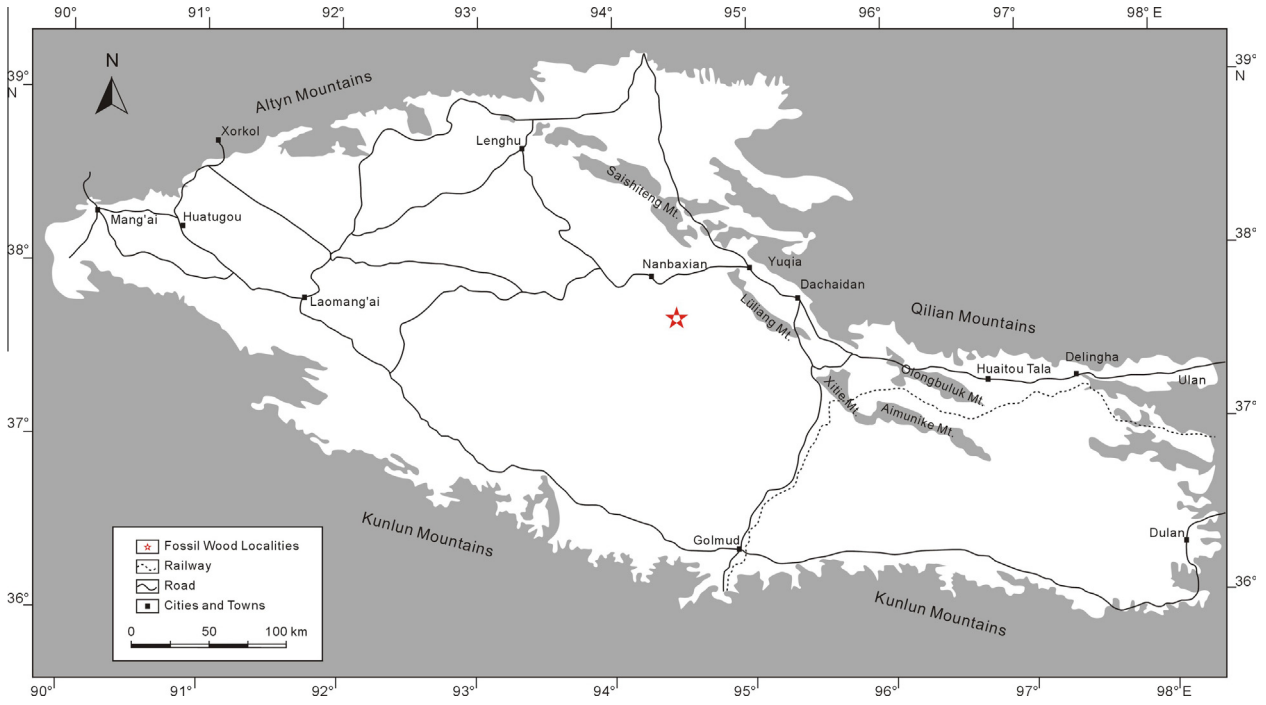

Fig. 2. Map showing detailed location of the fossil wood site (near Nanbaxian) in Qaidam Basin, Qinghai Province, China (modified from Wang et al., 2007).

In recent years, during a survey of geological heritage in and around the Qaidam Basin in northern Qinghai-Tibet Plateau, a large quantity of rare Miocene petrified woods have been discovered in the Yardang landform area near the Nanbaxian village, Dachaidan Town in the northern part of the Qaidam Basin, Qinghai Province, China (Fan and Wang, 2004). It is the first large-scale outcrop of the Cenozoic petrified wood flora discovered on the Plateau. This study reports three types of fossil wood, *Ulmus* (Ulmaceae), Leguminosae (?) and Cupressaceae from the Qaidam Basin, and sheds a light on the Neogene vegetation and paleoclimate of the northern plateau.

2. Geography and stratigraphy

The Qaidam Basin, located in the northern part of the Qinghai-Tibet Plateau, is surrounded by the Altyn Mountains to

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