Journal of Palaeogeography
2014, 3(3): 323−330
DOI: 10.3724/SP.J.1261.2014.00059

Biopalaeogeography and palaeoecology

Late Miocene wood flora associated with the Yuanmou hominoid fauna from Yunnan, southwestern China and its palaeoenvironmental implication

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Abstract The Upper Miocene Xiaohe Formation of the Yuanmou Basin in Yunnan Province, southwestern China, is famous for its hominoid fauna and is important for studying the Late Cenozoic human and mammal evolution. Abundant fossil wood was found associated with this fauna, which provided important evidence for palaeoenvironmental reconstruction of the basin. Among the fossil wood, two different taxa have been identified namely, *Quercoxylon* sp. (Fagaceae) and *Pterocarya* sp. (Juglandaceae). Based on the habitats of their Nearest Living Relatives (NRLs), it is suggested that upland subtropical evergreen broad-leaved forest dominated by *Quercus*/*Lithocarpus* was common around the basin, while a lowland deciduous broad-leaved forest dominated by *Pterocarya* was present on the river bank of the basin during the Late Miocene.

Key words fossil wood, *Quercoxylon*, *Pterocarya*, palaeovegetation, Late Miocene, Yuanmou Basin

1 Introduction

Several Miocene hominoid localities, namely Baoshan, Kaiyuan, Lufeng, Shangri-La, Yuanmou, and Zhaotong occur in Yunnan Province of southwestern China (Biasatti *et al.*, 2012). The fossil hominoids of Yunnan provide a unique temporal perspective on the evolutionary history of hominoids (Harrison *et al.*, 2002). Among these localities, the Yuanmou Basin is well known for its Pliocene fauna (Cheng *et al.*, 2005; Qian 1985; Qian and Zhou, 1991) and the Late Miocene hominoid fauna (He, 1997; Qi *et al.*, 2006), and might have been an important refuge for hominoids after they experienced extinction in the rest of Eurasia (Harrison *et al.*, 2002; Zhu *et al.*, 2005). The age and character of the Yuanmou hominoid fauna are similar to the Late Miocene Siwalik faunas of Pakistan, the Lufeng fauna of Yunnan and the Baode fauna of Shanxi, China (Johnson and Vondra, 1972; Flynn *et al.*, 1990; Pan and Zong, 1993; Quade and Cerling, 1995; Barry *et al.*, 2002).

The palaeoenvironment of the Yuanmou Basin has been reconstructed with the help of faunal statistics (Ni and Qiu, 2002; Qi *et al.*, 2006), palynological evidence (Qian and Ling, 1998) and stable carbon and oxygen isotopes (Biasatti *et al.*, 2012). According to the analysis of micromammals, the habitats of the Yuanmou hominoids and associated fauna were mainly mountainous forests, including some dense forests and transitional shrubberies, as well as some open flat valleys and rivers (Ni and Qiu 2002; Qi *et al.*, 2006). Palynological analysis indicates that the Yuanmou hominoid lived in sparse forest-grasslands in a

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Received: 2013−12−18 Accepted: 2014−04−13

warm and dry climate (Qian and Ling, 1998). Additionally, stable carbon and oxygen isotope studies show that a forest cover was present in the Yuanmou Basin during the Late Miocene (Biasatti *et al.*, 2012).

Although the aforementioned studies indicate the presence of either a dense or a sparse forest cover in the Yuanmou Basin, lack of direct plant megafossil evidence makes it difficult to decipher the faunal makeup of the forest.

According to geological and paleontological surveys (Qian and Zhou, 1991; He, 1997; Zhang *et al.*, 2002), abundant fossil wood fragments were discovered with the hominoid fauna in the Upper Miocene Xiaohe Formation of Leilao, Zhupeng and Xiaohe villages in the Yuannmou Basin, but the woods have not been previously investigated in detail. Based on a large number of fossil wood specimens, this study describes two taxa of fossil wood, viz., *Quercoxylon* sp. (Fagaceae) and *Pterocarya* sp. (Juglandaceae) from the Upper Miocene hominoid-bearing Xiaohe Formation of Leilao, Zhupeng and Xiaohe villages, Yuanmou County, Yunnan Province, China and throws light on the palaeovegetation and palaeoclimate of the region.

2 Materials and methods

The Yuanmou Basin, at an elevation of 1050 to 1380 m, is located approximately 110 km northwest of Kunming (provincial capital) in Yunnan Province of southwestern China (Figure 1). The north-south elongated basin is bordered by elevated regions of metamorphic rocks and granites of the Precambrian basement and Jurassic to Cretaceous sediments. The basin is mainly filled by a thick series of Late Cenozoic fluvial and lacustrine sediments that contain abundant mammalian fossils (Qian and Zhou, 1991; Pan and Zong, 1991; He, 1997; Harrison *et al.*, 2002; Qi *et al.*, 2006). The Upper Miocene hominoid-bearing Xiaohe Formation lies mostly in the northwestern section of the basin, and consists of 80 m of clays, silts, partially cemented fine sands, and gravels overlying the Jurassic to Cretaceous sediments. The formation also contains abundant hominoid and other mammalian fossils (He, 1997; Harrison *et al.*, 2002; Qi *et al.*, 2006) and fossil wood fragments (Qian and Zhou, 1991; He, 1997). This formation is dated between 7.2 and 8.1 Ma based on palaeomagnetic evidence (Qi *et al.*, 2006). Large fossil trunks were often found in association with gravels. The material for the present study was collected from the lower part of the Xiaohe Formation of Leilao, Zhupeng, and Xiaohe villages of Yuanmou County in Yunnan Province of southwestern China. Ground thin sections were prepared using standard techniques of cutting, grinding and polishing and different grades of carborundum powder were used for polishing (Hass and Rowe, 1999). Both the specimens and the slides have been deposited at the Geological Museum of China. Anatomical terms used in this paper follow the recommendations of the IAWA list of microscopic features for hardwood identification (IAWA Committee, 1989).

3 Systematic description

3.1 Fagaceae

Quercoxylon Kräusel, 1939

Quercoxylon sp. (Figure 2a−2e)

Growth rings are indistinct. Wood is diffuse porous. Vessels are exclusively solitary, circular to slightly oval in outline, showing a stream-like arrangement. The tangential diameters of the vessels range from 67 to 270 μm, with a mean of 196 μm, and the radial diameter of the vessels range from 55 to 229 μm, with a mean of 167 μm. The vessel frequency is 6−10 /mm^2. Perforation plates are simple. Intervessel pits were not observed. Vessel-ray parenchyma pits with reduced borders are horizontally to vertically elongate and variable. Tyloses are thin-walled and abundant. Vasicentric tracheids with distinctly bordered pits present around large vessels. Axial parenchyma is relatively abundant, diffuse to diffuse-in-aggregate, and also in 1−3 celled thick bands. Rays consist of two distinct types, uniseriate and multiseriate; multiseriate rays are exclusively compound, 289−833 μm, mean 516 μm wide, up to 6 mm high.

Samples: P2291 (ZP6), P2292 (ZP28), P2293 (LL22).

Locality: Zhupeng (ZP) and Leilao (LL), Yuanmou County, Yunnan Province, China.

Horizon and age: Lower part of the Xiaohe Formation, Late Miocene.

Repository: Geological Museum of China, Beijing, China.

Affinities: The important diagnostic features of the fossils, exclusively solitary vessels, vessel-ray parenchyma pits with reduced borders, horizontally to vertically elongate vasicentric tracheids, diffuse to diffuse-in-aggregate axial parenchyma, and uniseriate and compound rays, indicate its affinity with the Fagaceae, especially with evergreen species of *Quercus* L. and *Lithocapus* Bl. (Metcalfe and Chalk, 1950; Shimaji, 1962; Cheng *et al.*, 1992).

Kräusel (1939) instituted the genus *Queroxylon* to include fossil wood resembling *Quercus*/*Lithocarpus*. As reviewed by Kramer (1974a, 1974b), Wheeler *et al.* (1978), Gros