

Occurrences of Early Cretaceous fossil woods in China: Implications for paleoclimates

Xiao-Ju Yang^{a,*}, Yong-Dong Wang^a, Wu Zhang^b

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

^b Shenyang Institute of Geology and Mineral Resources, Ministry of Land and Resources, Shenyang 110032, China

ARTICLE INFO

Article history:

Received 17 October 2011

Received in revised form 13 May 2013

Accepted 15 May 2013

Available online 24 May 2013

Keywords:

Fossil woods
Early Cretaceous
Paleoclimate
China

ABSTRACT

The Chinese Early Cretaceous flora was divided phytogeographically into the Northern Floristic Province and the Southern Floristic Province. The “temperate–wet vegetations” and “tropic–subtropic xeric vegetations” were proposed to represent the two different vegetation types. About 52 species of fossil woods belonging to Cycadophytes (2 species), Ginkgoales (1 species) and coniferales (49 species) have been discovered in the two floristic provinces, mainly from the Northeast China. The biodiversity and anatomical characteristics, especially the growth ring feature analysis of fossil woods indicated climatic conditions with seasonal variation in both the Northern and Southern Floristic Provinces during the Early Cretaceous. It suggests that a tropic to sub-tropic semi-arid climate might dominate over southern China, while warm or temperate, and wet climate prevailed in northern China during the Early Cretaceous. The wood evidence is in accordance with that of the leaf fossils collected from the corresponding formations of the Early Cretaceous in China.

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1. Introduction

Studying of fossil woods is an important independent branch in paleobotany. In most cases only the secondary xylem of Mesozoic woods could be preserved. Wood fossils occur alone or associated with other fossils in the strata of various depositional facies and paleoecosystems. Well-preserved fossil woods usually show detailed cellular structure as in a modern specimen, revealing a great deal of information concerning past environments of growth (Chaloner and Creber, 1973; Creber and Chaloner, 1984). As one of the main organs of terrestrial plants, systematic studies on fossil woods also improve our knowledge of the composition of past vegetation. The growth ring patterns of fossil wood may provide key information regarding regional paleoclimate as well as a tree paleoecology and phenology in deep time (Creber and Chaloner, 1984; Falcon-Lang, 2005). Fossil woods occur throughout the geological past representing a unique paleoenvironmental data-store and could be considered as an important archive of data for paleoenvironmental reconstructions. In China over 180 species of fossil woods referred to 106 genera have been recorded from hundreds of localities, ranging from the Late Paleozoic to the Cenozoic (Zhang et al., 2008).

The Mesozoic strata yielding fossil woods are well developed in China (Sze et al., 1963; Zhang et al., 2008; Wang et al., 2009). In the early 20th Century, Chang and Sze made pioneering contributions and laid the foundation of the fossil wood study in China (Chang, 1929; Gothan and Sze, 1933; Sze, 1951). Sze investigated for the first time

fossil woods from northeastern China, including three taxa from the Early Cretaceous (Sze, 1951) and twelve years later he summarized gymnospermous fossil woods of China, mostly from the late Mesozoic (Sze et al., 1963). Since the 1980s considerable progress regarding the Cretaceous fossil woods was made and many new taxa have been erected in China. When studying Late Mesozoic plants from eastern Heilongjiang, Zheng and Zhang (1982) reported six taxa of the Early Cretaceous woods. He (1995) studied fusain woods from the Early Cretaceous of Huolinhe and Yimin coal mines located in Da Hinggan Mountains of eastern Inner Mongolia and described twelve species referred to eight genera, including seven new species. Vozenin-Serra and Pons (1990) reported some fossil woods from the Early Cretaceous of Tibetan region, which show a relationship with the Laurasian plant elements. Duan et al. (2002) reported an *Araucarioxylon*-type wood from the Early Cretaceous of Zhejiang Province, which represents an important record of Cretaceous woods in southern China.

In the last two decades many paleobotanists worked on fossil wood and a great number of the Early Cretaceous woods have been described (Du, 1982; Cui and Liu, 1992; Cui, 1995; Zhang and Shang, 1996; Zhang et al., 1999; Ding, 2000a, 2000b; Ding et al., 2000a, 2000b; Yang and Zheng, 2003; Li and Oh, 2007). To date about 52 species belonging to 26 genera have been published and most of them discovered from the Early Cretaceous of Northeast China. Fossil woods are rare in the South China (Fig. 1). One of the possible reasons for this phenomenon may be due to the insufficient specimen collection and investigation.

While fossil woods from various sedimentary rocks and strata of the Early Cretaceous in a vast area in China have been collected and studied, most works dealt with the taxonomy and anatomical details of individual specimens. Here we summarize fossil woods from the

* Corresponding author. Tel.: +86 25 8328 2239; fax: +86 25 8335 7026.

E-mail address: xjyang@nigpas.ac.cn (X.-J. Yang).

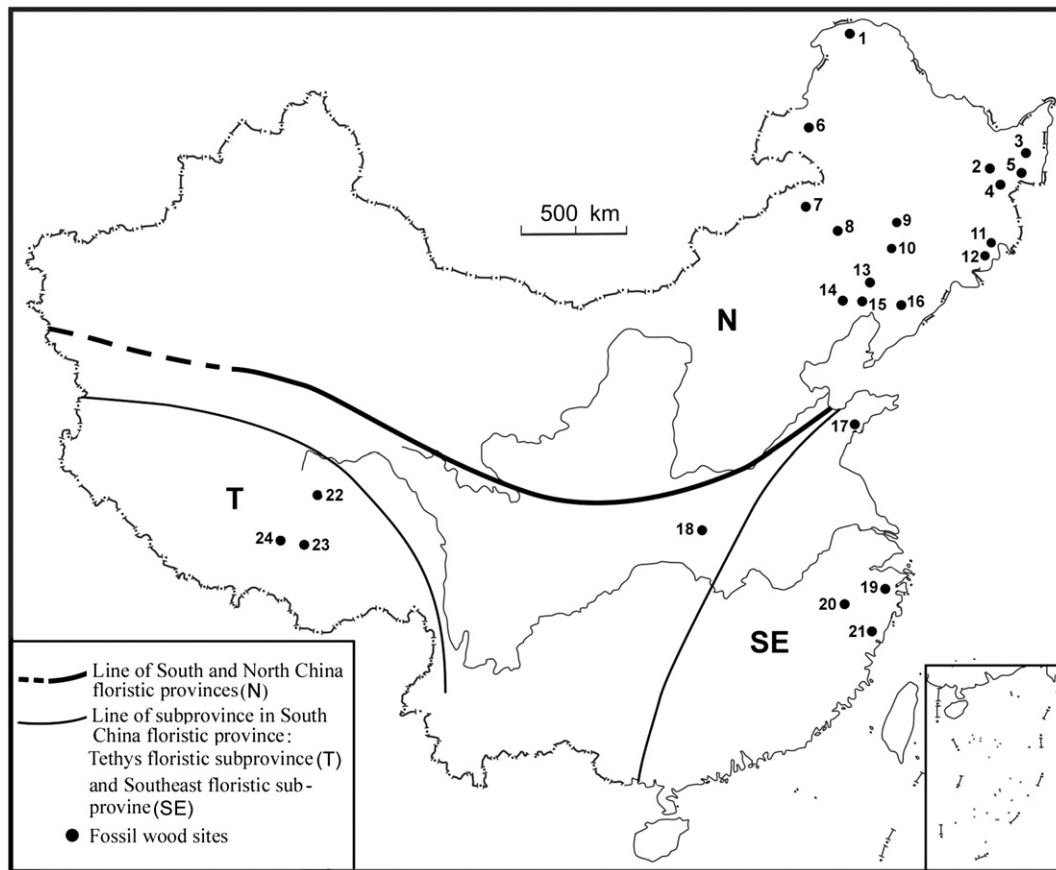


Fig. 1. Geographical distribution and major localities of Cretaceous woods in China. 1. Mohe, Heilongjiang 2. Boli, Heilongjiang 3. Baoqing, Heilongjiang 4. Jixi, Heilongjiang 5. Mishan, Heilongjiang 6. Ewenki, Inner Mongolia 7. Huolinhe, Inner Mongolia 8. Jarud, Inner Mongolia 9. Changchun, Jilin 10. Liaoyuan, Jilin 11. Yanji, Jilin 12. Helong, Jilin 13. Fuxin, Liaoning 14. Chaoyang, Liaoning 15. Yixian, Liaoning 16. Benxi of Liaoning 17. Jimo of Shandong 18. Xinyang, Henan 19. Xinchang, Zhejiang 20. Longyou, Zhejiang 21. Taishun, Zhejiang 22. Lalong, Tibet 23. Lamba, Tibet 24. Linzhu, Tibet.

non-marine Early Cretaceous deposits of China with special reference to their paleoclimatic implications.

2. Geological and geographical distribution of Early Cretaceous fossil wood

The Early Cretaceous continental deposits were developed in almost the whole of China except for southern Tibet, eastern Heilongjiang and westernmost Xinjiang, where there were some marine deposits (Chen, 2003). Under favorable geographic and climatic conditions, woody plants were very flourishing in China during that time (Cao et al., 1982; Sun et al., 1995). Available data show that Northeast (including East Inner Mongolia) China is a major source of fossil woods with diverse and well-preserved specimens (Zhang et al., 2008). The main localities are: Mohe, Boli, Baoqing, Jixi and Mishan of Heilongjiang; Ewenki, Huolinhe and Jarud of Inner Mongolia; Changchun, Liaoyuan, Yanji and Helong of Jilin; Fuxin, Yixian and Benxi of Liaoning; Jimo of Shandong; Xinyang of Henan; Xinchang, Longyou and Taishun of Zhejiang; and Lalong, Lamba and Linzhu of Tibet (Fig. 1). About 41 species have been described from Northeast China and only a few species of *Brachyoxylon*, *Lhassoxylon*, *Protopodocarpoxyton* (Vozenin-Serra and Pons, 1990) and an *Araucarioxylon* (Duan et al., 2002) collected from South China. To date, there are more than 24 main localities distributed in eight provinces in which fossil woods have been discovered. The geographical distribution of the Early Cretaceous fossil woods of China is shown in Fig. 1.

Stratigraphically, fossil wood specimens are mainly discovered from the Hauterivian to Aptian of the Early Cretaceous (Fig. 2). In northeast

China there are many inland depositional basins, such as the Jixi basin of Heilongjiang, the Huolinhe and Hailar basins of Inner Mongolia and the Fuxin basin of Liaoning. These basins mainly consist of conglomerate, sandstone, mudstone, siltstone and coal beds, yielding abundant fossil plants (Chen et al., 1988; Deng, 1995; Deng et al., 1997; Yang, 2003). In western Liaoning and Zhejiang the Early Cretaceous deposits containing fossil plants are generally characterized by fluvial to lacustrine sediments intercalated with volcanic rocks (Lin et al., 1989; Wang et al., 1989; Cao, 1999; Sun et al., 2001). The plant-bearing strata of Tibet were deposited successively on the marine beds of the Late Jurassic and covered by red clastic rocks and neritic pelite intercalated with limestone considered to be the Aptian to Albian in age (Wu, 1985).

3. Biodiversity of Early Cretaceous fossil wood

The Early Cretaceous fossil woods discovered in China are mainly preserved as silicified and fusainized types. Except for *Ginkgoxylon chinense* Zhang et Zheng (Zhang et al., 2000), *Araucarioxylon sidugawaense* Shimakura (Duan, 2000), *Lhassoxylon aptianum* Vozenin-Serra et Pons (Vozenin-Serra and Pons, 1990), *Phyllocladoxylon xinqiuensis* Cui et Liu (Cui and Liu, 1992), *Taxoxylon liaoxiense* Duan (Duan, 2000), and *Xenoxylon peideense* Zheng et Zhang (Zheng and Zhang, 1982) which have been reported with pith and primary xylem, and all others have only the secondary xylem preserved. In fact, most fossil woods are referred to morphogenera based only on characteristics of the secondary xylem. Although the Cretaceous coniferous plants on the whole have been extinct, a great number of them show affinities and similarities to the modern relatives in anatomical structures of the secondary xylem.

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