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Natural and anthropogenic forest fires recorded in the Holocene pollen record from a Jinchuan peat bog, northeastern China

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Abstract

Pollen and charcoal particles from a Jinchuan peat (northeastern China) were examined to investigate the fire origin and interaction between climate, vegetation, fire and human activity during the Holocene. Pollen results show that: (i) a broadleaved deciduous forest was dominant during the early Holocene; (ii) from ~5500 cal. yr B.P. there was a gradual increase in coniferous trees (mainly *Pinus*), and a decrease in broadleaved deciduous trees (e.g. *Quercus*, *Juglans*, and *Ulmus–Zelkova*); (iii) after ~4200 cal. yr B.P., the deciduous forest was replaced by a mixed forest of coniferous and deciduous trees; (iv) coniferous trees including *Pinus*, *Abies* and *Picea* further increased after ~2000 cal. yr B.P., reflecting a cooler and drier climate after ~5500–4200 cal. yr B.P. Two layers of abundant microfossil charcoal particles (250–10 μm) and the coexistence of macrofossil particles (>2 mm) suggest two local fires: fire event 1 (5120±66 cal. yr B.P.) and fire event 2 (1288±8 cal. yr B.P., AD 662±8). Charcoal layer 1, with a large amount of Monolete psilate spores, is superimposed on the long-term trend of vegetation changes, indicating a natural origin for fire event 1 that was probably facilitated by drying environmental conditions since the mid-Holocene. Cerealia-type pollen and a low percentage of Monolete psilate spores were observed in charcoal layer 2, indicating that fire event 2 was caused by clearing. We suggest that fire event 2 may be related to the spread of the Han farming culture accompanied by the territorial expansion of the Tang Dynasty to the studied area in AD 668.

Keywords: Pollen record; Fire; Vegetation; Human activity; Holocene; Northeastern China

1. Introduction

Fire is recognized as an important agent in ecological systems (e.g. Cochrane et al., 1999; Haberle et al., 2001; Whitlock et al., 2003). It also affects the global carbon cycle and climate through emissions of CO_2 and other greenhouse gases (Page et al., 2002; Kurtz et al., 2003). For example, the 1997 Indonesian fire caused by long-term droughts led to the destruction of the rainforest and establishment of pioneer species within the southeastern Asia and the New Guinea region (Haberle et al., 2001), and the greatest annual increase in atmospheric CO_2 of the past 50 years (Page et al., 2002). In addition to natural fire triggers such as droughts, human activities can also play an important role in the occurrence of fire. It is important to differentiate the origin of fire for an improved understanding of the interaction between vegetation, climate and human activity in the geological past (Edwards et al., 2007).

Fire used to play an essential role in the advancement of human civilization. It was used as a source of heat and light, and was also used for cooking and to fend off wild animals. In agriculture, fire was used to clear lands in preparation for planting (De Vries and Marchant, 2002). China ranks amongst the world's great centres of ancient civilization, with a recorded history of at least 5000 years. Archaeological findings have demonstrated that agriculture was first established in the Yellow and Yangtze valleys (Yasuda, 2002; Kong et al., 2003) (Fig. 1A), and then gradually spread out to the surrounding

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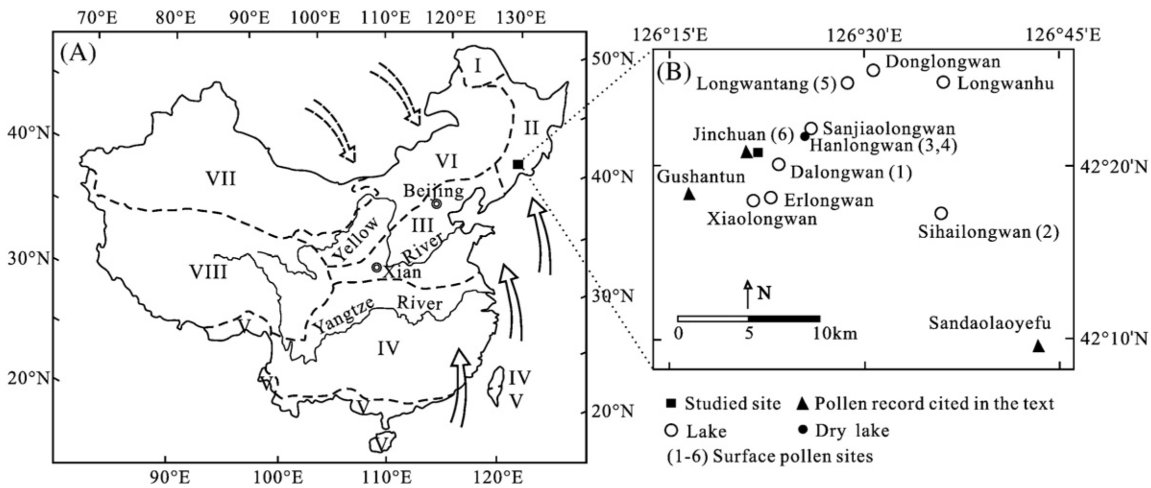

Fig. 1. (A) Modern vegetation zones in China (after Editorial Board for flora of China (1995) and Hou (2001)). I, Cold-temperate conifer forest; II, Temperate mixed conifer-broadleaved forest; III, Warm-temperate broadleaved deciduous forest; IV, Subtropical evergreen broadleaved forest; V, Tropical rainforest and seasonal rainforest; VI, Steppe; VII, Desert; VIII, Tibet–Qinghai cold and highland vegetation. The dashed and solid arrows indicate winter monsoon and the dominant direction of the summer monsoon precipitation belt, respectively. (B) Location of studied site and surface pollen sites.

areas. However, the pattern and pace of this agricultural spread remains unclear. Solutions to this problem largely depend on more high-quality historical documents and precisely-dated geological records.

Northern China is climatically influenced by the East Asian monsoon (Fig. 1A), where more than 0.4 billion people live (Ye et al., 2002). Agricultural activities, i.e. cultivation and herding, are closely linked to monsoonal precipitation. During years of extreme monsoon activity, severe disasters (dust storms, droughts and floods) resulting from the monsoon can impact hundreds of thousands of people. By contrast, excessive agricultural activities have led to desertification, soil erosion/degradation, and pollution (Ye et al., 2002). These impacts on the ecosystem are considerable and often even irreversible. Therefore, it is essential to achieve sustainable development through management of modern agriculture, which demands a better understanding of the complex interactions between human activities and the natural ecosystem. However, in the East Asian monsoon region, little is known about the relationship between human activity and the natural ecosystem (Dodson et al., 2006). Here we present records of pollen and charcoal, and high-resolution pollen assemblages in two radiocarbon-dated charcoal layers, from a peat bog in Jinchuan, northeastern China. Our aim is to separate the origin of fire events through high-resolution pollen analyses, and to explore the effect of climate and human activity on vegetation changes and fires.

2. Field and methods

2.1. Geographical background

The Jinchuan peat bog (42°22′ N, 126°26′ E, 662 m a.s.l.) is located to the west of Jinchuan village in Huinan County, Jilin province, northeastern China. The bog is nearly circular, with a diameter of ~1 km. It is believed that the Jinchuan bog grew in a hollow left by a maar (Liu, 1999) or from a barrier lake formed by volcanic activity (Hong et al., 2000). It sits on the western edge of the Longgang mountainous area, which is known for its Late Pleistocene and Holocene volcanic activity and especially its maar lakes (Fig. 1B), with a relief between ~400 and ~1200 m a.s.l. Approximately 150 km to the east of the studied site, the Changbai Mountains lie on the border of China and Korea (2691 m a.s.l., the highest peak on the Chinese side).

The climate of the region is sub-humid temperate, with a mean annual temperature of 3 °C. The mean temperature in January is −18 °C, whereas in July it is 20 °C (Sun and Yuan, 1990). The East Asian monsoon system brings warm and wet humid weather in summer and cold, dry weather in winter. Mean annual precipitation is ~700 mm. The mean January precipitation is less than 25 mm, the value for July is ~200 mm.

The region falls within a temperate mixed deciduous and coniferous forest zone (Editorial Board for Flora of China, 1995; Hou, 2001) (zone II on Fig. 1A). As the Longgang Mountains and Changbai Mountains lie to the east, the natural vegetation shows zonal distribution along the altitudinal gradient (Table 1).

Table 1
Vegetation distribution along the altitudinal gradient in the studied region (after Editorial Board for flora of China, 1995)

Altitude (m a.s.l.)	Vegetation zone	Main taxa
>2100	Alpine tundra	*Dryas octopetala*, *Salix rotundifolia*, *Rhododendron* spp.
1800–2100	Sub-alpine dwarf shrub	*Betula ermanii*
1100–1800	Coniferous forest	*Pinus koraiensis*, *Picea jazoensis*, *Picea koraiensis*, *Abies nephrolepis*
<1100	Mixed deciduous and coniferous forest	*Pinus koraiensis*, *Abies holophylla*, *Carpinus cordota*, *Ulmus propinqua*, *Acer mono*, *Quercus mongolica*, *Fraxinus mandshurica*, *Juglans mandshurica*, *Tilia amurensis, Betula costata*, *Betula platyphylla*