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Peatland evolution and associated environmental changes in central China over the past 40,000 years

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ABSTRACT

Central China has experienced stronger summer monsoon during warm periods such as Marine Isotope Stages (MIS) 1 and 3, and weaker summer monsoon during cool periods such as MIS 2. The evolution history of Dajiuhu subalpine peatland in central China can help investigate how the expansion and shrinkage of peatland were associated with monsoonal strength over the last glacial–interglacial cycle. Here we apply bulk organic carbon and molecular biomarkers (hopane and *n*-alkane) to reconstruct the evolution history for the Dajiuhu peatland over the past 40,000 yr. The results indicate fluctuations between lacustrine and peat-like deposition during MIS 3, steady lacustrine deposition during MIS 2, and peatland initiation and expansion during MIS 1 in the Dajiuhu peatland. Therefore, at the glacial–interglacial scale, warmer summer and cooler winter conditions in interglacial periods are crucial to trigger peat deposition, whereas reduced evaporation in glacial period instead of decreased monsoonal-driven precipitation would have played a predominant role in the regional effective moisture balance. However, within the Holocene (MIS 1), monsoonal precipitation changes appear to be the main controller on millennial-scale variations of water-table level of the Dajiuhu peatland.

Introduction

The Asian summer monsoon is an important atmospheric circulation system maintaining the living environment on the Asian continent. Climatic changes throughout the late Quaternary in the East Asia are characterized by alternations of the Asian summer monsoon strength (An, 2000). High-quality $\delta^{18}O$ records from cave stalagmites suggest that central China has experienced stronger summer monsoon during warm periods such as Marine Isotope Stages (MIS) 1 and 3, and weaker summer monsoon during cool periods such as MIS 2 (Wang et al., 2001, 2008). However, knowledge of climatic variations and their relation with ecosystem evolution in central China over the last interglacial–glacial cycle (MIS 1–3) remains incomplete, owing to limited high-quality paleoclimatic records available other than speleothem $\delta^{18}O$ records (Wang et al., 2001, 2008; Herzschuh, 2006).

Peatland serves as a good archive for paleoclimatic reconstruction, since expansion and shrinkage of peatland respond sensitively to climatic changes. Understanding how peatland development was associated with past climatic conditions would provide useful insights into projecting future environmental changes. Most previous peatland studies have focused on two major zones, high latitude regions (50°–70°N) and tropical regions (20°S–10°N; Zhao et al., 2014). Abundant peatlands in northern and tropical China, such as Hani (Zhou et al., 2010), Hongyuan (Zheng et al., 2007) and Dingnan bogs (Zhou et al., 2005; see locations in Fig. 1A) could offer important information on peatland histories in the mid-latitude region of the Northern Hemisphere (20°–50°N), connecting the two major peatland regions. The Dajiuhu peatland is a well-preserved subalpine peatland in the western Shennongjia Mountains in central China (~30°N). Thick and continuous peat deposits allow for the reconstruction of past environment and climate changes (Zhu et al., 2010). Because the nearby Sanbao Cave contains high-quality monsoonal records over the last glacial–interglacial cycle (Fig. 1A, Wang et al., 2008), records from the Dajiuhu peatland would provide a good opportunity to disentangle the relation between the peatland ecosystem evolution and monsoonal strength in this region.

Recent developments in organic geochemistry have introduced molecular biomarkers to paleoclimatic reconstruction (Eglinton and

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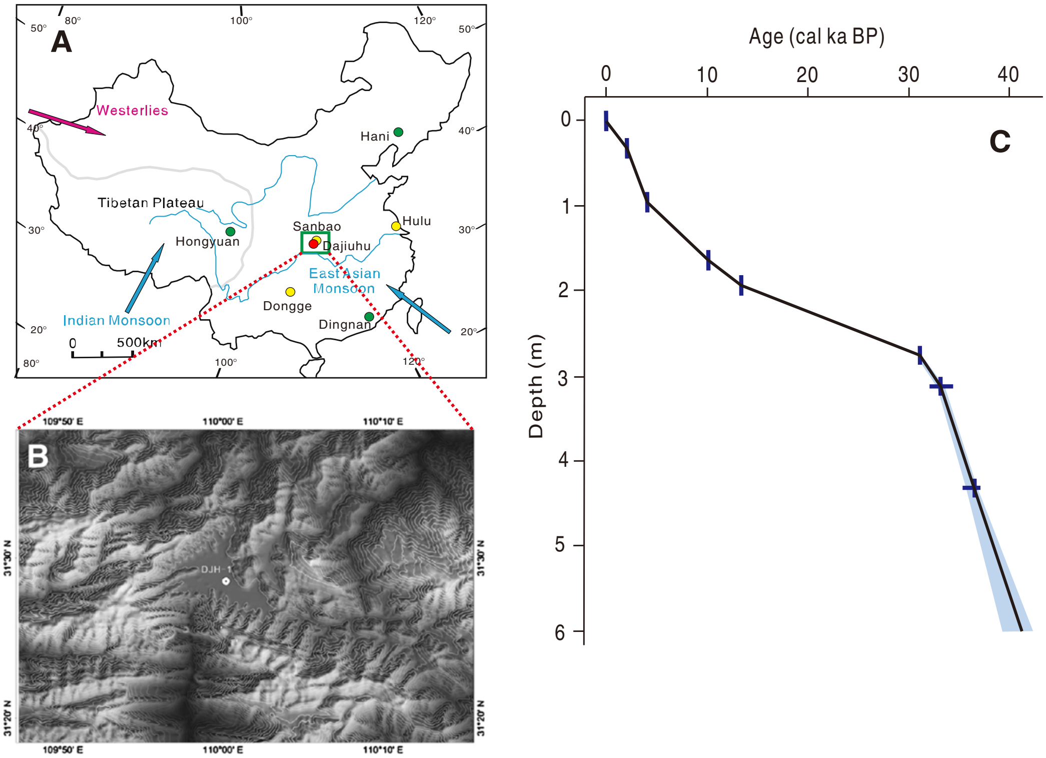

Figure 1. (A) Overview map showing location of the Dajiuhu (red dot), Hongyuan, Dingnan and Hani peat bog (green dots) and Dongge, Sanbao and Hulu Caves (yellow dots). (B) Coring site of core DJH-1. (C) Age profile for core DJH-1 based on seven AMS ^{14}C dates (Li et al., 2013).

Eglinton, 2008; Castañeda and Schouten, 2011). Many types of biomarkers have been utilized to infer climatic changes in the Dajiuhu region, including branched fatty alcohols (Huang et al., 2013a), hopanoids (Xie et al., 2013) and aromatic triterpenes (Huang et al., 2013b). However, none of these studies involve *n*-alkanes, a traditional biomarker for both lacustrine (e.g., He et al., 2014) and peatland studies (e.g., Bingham et al., 2010; Zhou et al., 2010). A set of *n*-alkane indices, including the average chain length (ACL, Poynter and Eglinton, 1990), the odd-over-even carbon preference index (CPI, Marzi et al., 1993) and the proportion of aquatic macrophytes (P_{aq}, Ficken et al., 2000) can be good supplementary indicators on vegetation composition variation and peatland evolution. On the other hand, previous studies (Huang et al., 2013a, 2013b; Xie et al., 2013) have only focused on climatic conditions over the past 13,000 yr when the peatland was fully formed, barely allowing for reconstructions at glacial–interglacial timescales. How the Dajiuhu peatland itself evolved and how its evolution was associated with climatic conditions over the last glacial–interglacial cycle largely remain elusive. In view of that, here we reconstruct bulk organic carbon and molecular biomarker (hopane and *n*-alkane) records obtained from a 6-m core taken from the Dajiuhu peatland at central China. Together with previously presented lithological, gray scale and pollen data from the same core (Li et al., 2013), we investigate the history of peatland evolution and regional environmental changes over the past 40,000 yr. Our objective is to infer the controlling mechanisms for the peatland formation over glacial–interglacial cycles and during the current interglacial period (i.e. the Holocene).

Materials and methods

The Dajiuhu peatland (110°00′E, 31°29′N, 1751 m above sea level) is located at the western Shennongjia Mountains, which belong to the eastern extension of the Daba Mountain Ranges of the upper-middle reaches of the Yangtze River, central China (Figs. 1A, 1B). At present, this area is marked by short warm–wet summers and long cold–dry winters due to the influence of the Asian monsoons. Modern mean annual rainfall in this region is ~1550 mm, with 40–50% falling in the summer, and potential evaporation varies from 500 to 800 mm (Li et al., 2013).

A 6-m core (DJH-1) was collected from the Dajiuhu peatland using a Russian-type peat corer (Fig. 1B). The age profile of core DJH-1 has been described previously in Li et al. (2013). Chronologies were established through seven accelerator mass spectrometry (AMS)-^{14}C dates on the bulk organic matter (Table 1). Dating samples were pretreated at Guangzhou Institute of Geochemistry, CAS and analyzed in the AMS Lab at Beijing University. All dates were calibrated to calendar years with the CALIB 6.0.1 software (Stuiver and Reimer, 1993) using the IntCal09 database (Reimer et al., 2009). The age model for core DJH-1 was established using the Clam software package (Blaauw, 2010) including extrapolations to the top and bottom of the core. The total organic carbon (TOC) content was analyzed by the Euro EA3000 elemental analyzer. A low resolution TOC record from core DJH-1 has been reported in Li et al. (2013), and here we report an updated higher resolution one.

A total of 187 peat/sediment samples with the thickness of 1 cm from core DJH-1 were selected for lipid analysis. Total lipids were ultrasonically extracted from freeze-dried sediments with organic solvents

Table 1
AMS-^{14}C dates for the core DJH-1 chronology.

Laboratory ID	Depth (cm)	Materials	^{14}C age (^{14}C yr BP)	Error (yr)	Calendar age (cal yr BP)	Error (yr)
XA6289	33	Peat	2025	24	1982	62
GZ3136	95	Wood	3669	26	4003	82
XA6290	163	Peat	8894	40	10,039	151
GZ3137	193	Peat	11,533	39	13,375	107
XA6291	276	Sediment	26,640	105	31,069	168
GZ3138	312	Sediment	28,665	98	33,085	406
GZ3139	431	Wood	31,936	119	36,522	258