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A 15,400-year record of climate variation from a subalpine lacustrine sedimentary sequence in the western Nanling Mountains in South China

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ABSTRACT

Multi-proxy records of a subalpine lacustrine sequence in Daping Swamp in the western Nanling Mountains provide evidence for exploring climate variability in the past 15,400 yr. Two dry and cool (15,400–14,500 and 13,000–11,000 cal yr BP) and one humid and warm interval (14,500–13,200 cal yr BP), which we correlate to Heinrich Event 1, the Younger Dryas and the Bølling-Allerød event respectively, are revealed. The early Holocene climate (11,000–8000 cal yr BP) was characterized by less humid and warm conditions, suggesting a weaker Asian summer monsoon (ASM) intensity. Our findings indicate that the Holocene optimum occurred between 8000 and 4500 cal yr BP, and the most intensified ASM appears from 8000 to 7000 cal yr BP. After 4500 cal yr BP, climate shifted to relatively cool and dry conditions. We speculate that five short dry and cool events centered at ~11,000, 9000, 8400, 6000, and 3500 cal yr BP were linked to the Holocene ice-rafting events detected in the North Atlantic. Migration of the ITCZ, and the oceanic–atmospheric circulations, particularly SST changes in the tropical Pacific may play a pivotal role in climate variation of the study region.

Introduction

The Asian summer monsoon (ASM) system is a thermodynamic atmospheric circulation induced by seasonal heating change of the Central Asian highlands, with its extreme lapse rates and resulting central Asian low-pressure system during summer. The monsoon contributes to the atmospheric heat budget in the Northern Hemisphere and hence, changes in the monsoon system have great potential to control global climatic change (Wang et al., 1999; An, 2000). Detailed understanding of past summer monsoon climate variation, especially the precipitation-related variations during the Holocene, is also essential for predicting regional climate change in the future. The Indian summer monsoon (ISM) and East Asian summer monsoon (EASM) are two important components of the ASM system, varying on both millennial and orbital time scales. However, several important questions on specific details of monsoon climate have not been fully answered: 1) Did the two monsoon systems behave similarly or differently in East Asia, and what forcings have driven changes in the two systems (Hong et al., 2005, 2010; Shinozaki et al., 2011; Stebich et al., 2011; Zhang et al., 2011)? 2) Is there an asynchronous Holocene optimum throughout the monsoon region? 3) Has rainfall in the EASM region been increasing since the early Holocene (Zhang et al., 2011)? To fully address these questions, more paleoclimate data from typical regions influenced by both monsoon systems are needed.

The Nanling Mountains (NLM) form an important geographic division between the middle and southern subtropical zones in China, and are located at the center of the area influenced by the tropical monsoon (Gao et al., 1962). Paleoclimate studies in the eastern NLM have demonstrated that the mountains present ideal paleo-monsoon geo-archives (Zhou et al., 2004; Xiao et al., 2007; Zhong et al., 2010a, 2010b). However, there have been few relevant studies in the western NLM, which are in the transitional belt between the EASM and ISM systems (Fig. 1a) (Qian et al., 2007; Zhang et al., 2011). Because the study region is influenced by both the ISM and EASM, detailed paleoclimate studies of this area would facilitate valuable understanding of the issues mentioned above. In this study, we present a new ~15,400-yr climatic record, derived from lacustrine sediments in Daping Swamp in the western NLM. We use these data to explore the history of ASM variations since the last deglaciation in the study region.

Material and methods

Site description

Daping, a sub-alpine intermontane basin, is in the Nanshan Pasture of Chenbu Miao Autonomous County in western Hunan Province of China. This region is in the southern Bashili Grand Mountains, part of the Xuefeng Mountains in the western NLM (Fig. 1). The current annual average temperature is 10.9°C and annual precipitation about 2000 mm. Local humidity and temperature conditions lead to flora that is

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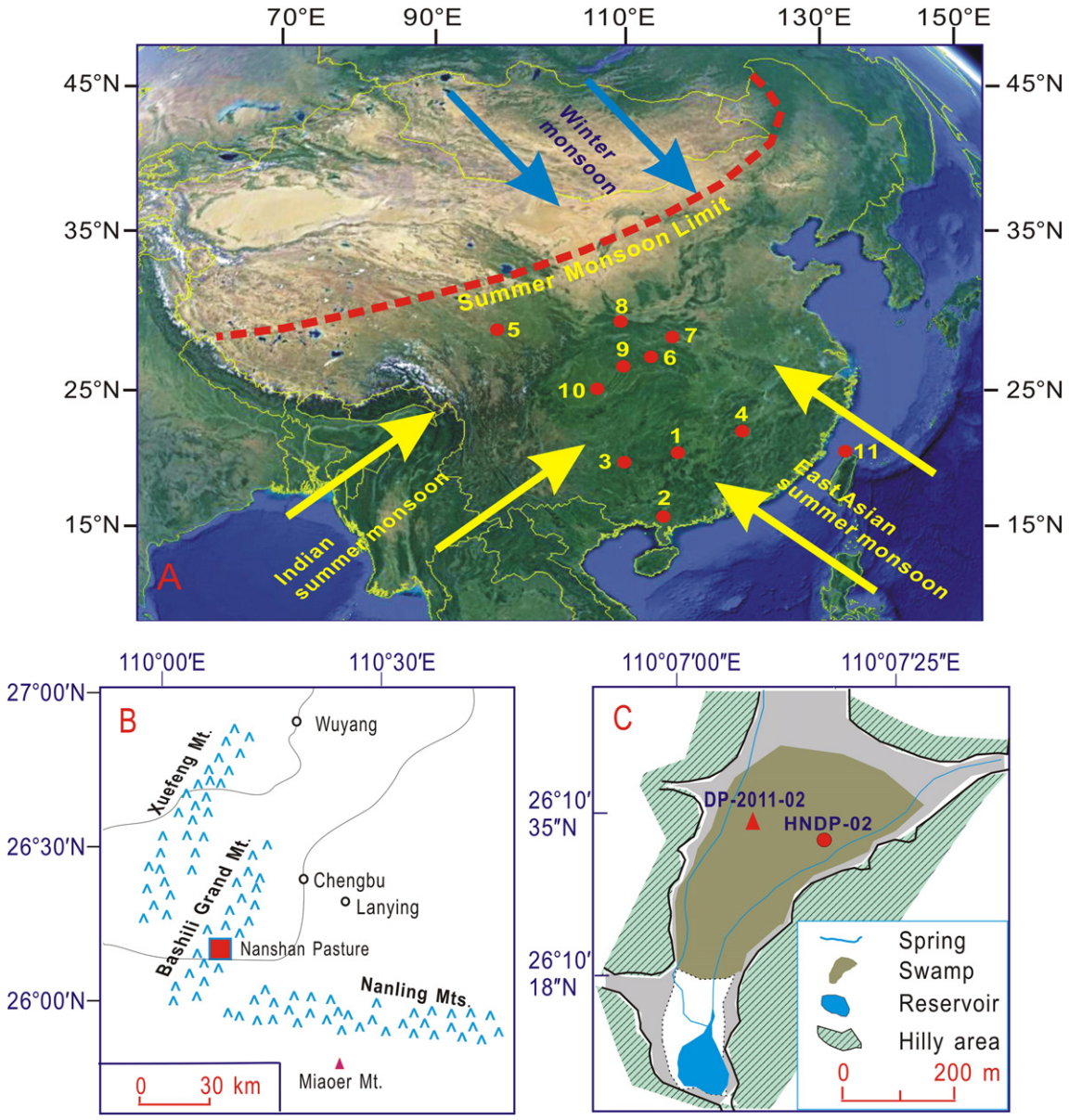

Figure 1. Climatic background of the sub-alpine Daping Swamp in the western Nanling Mountains. Dashed red line represents the averaged modern summer Asian monsoon limit. The locations of various Asian monsoon records in China referred to in the text are shown: 1, the location of Daping Swamp (B) and the core site (C) (this study); 2, Huguangyan Maar Lake in Leizhou Peninsula in South China (Yancheva et al, 2007); 3, Dongge Cave in southwest China (Wang et al, 2005); 4, Dahu Swamp in east Nanling Mountains (Zhong et al., 2010a); 5, Hongyuan peat on the eastern fringe of Tibetan Plateau (Hong et al, 2005); 6, Heshang Cave in Central China (Hu et al., 2008); 7, Sanbao Cave in central China (Wang et al., 2008a, 2008b); 8, Jiuxian Cave in central China (Cai et al., 2010); 9, Lianhua Cave in central China (Zhang et al., 2013); 10, Shigao Cave in southwest China (Jiang et al., 2012); 11, Retreat Lake in northeast Taiwan (Selvaraj et al., 2007). The red triangle indicates the location of core DP-2011-02 used in this study. The red circle indicates the HNDP-02 peat section which has been studied (Zhong et al., 2014).

dominated by evergreen and deciduous broadleaf forest, montane coppice such as *Machilus rehderi*, *Cyclobalanopsis*, *Fagus*, and *Alnus*, as well as shrub vegetation dominated by *Enkianthus* and *Rhododendron* and others (Xiao et al., 1986). Natural vegetation in the region has been substantially destroyed by modern anthropogenic activity. Present plants at the center of Daping basin are dominated by *Polygonum hydropiper*, *Juncus effuses*, *Eragrostis ferruginea*, and *Cyclobalanopsis* (*Thunb.*).

In Daping Basin, granite bedrock formed a near-surface aquiclude that trapped water and established favorable conditions for the development of Daping Swamp, which is about 300 m long and 150 m wide. This swamp has peaty sediments. Geologic investigation has revealed that buried peat accumulation there amounts to more than 100,000 m^3 (Sun and Zhang, 1984). In 1950s, a small reservoir was built in the swamp area.

Sampling and analyses

In September 2011, we recovered several cores at Daping Swamp (see also Zhong et al., 2014). A 236-cm-long core (core DP-2011-02; 26°32.02′N–110°08.03′E; ~1620 m asl) was selected for paleoclimatic investigation. In the field, the core was split lengthwise, photographed and described. Because the top 10 cm of the core had substantial modern plant roots, sample collection concentrated on 10–226 cm depths. Samples were taken at continuous 3-cm intervals for pollen measurement. Bulk dry density (DD), humification degree (HD), loss on ignition (LOI), and particle grain size fraction (PGSF) were analyzed for samples at continuous 2-cm intervals.

Eight bulk samples were measured for radiocarbon dating at the Key Laboratory of Western China's Environmental Systems (Ministry of