Palaeogeography, Palaeoclimatology, Palaeoecology 438 (2015) 344–351

Contents lists available at ScienceDirect

Palaeogeography, Palaeoclimatology, Palaeoecology

journal homepage: www.elsevier.com/locate/palaeo

Millennial-scale variability in biomass burning covering the interval ~41,000–7050 cal BP in the tropical Leizhou Peninsula (south China)

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ARTICLE INFO

Article history:
Received 19 September 2014
Received in revised form 23 July 2015
Accepted 28 August 2015
Available online 5 September 2015

Keywords:
Charcoal
Biomass burning
Last glaciation
Leizhou Peninsula

ABSTRACT

Here, we present a well-dated terrestrial charcoal chronology covering the interval ~41,000–7050 cal BP and identifying the millennial-scale variability in biomass burning for the tropical Leizhou Peninsula, south China. Our results show that changes in biomass burning closely followed regional temperature and precipitation variations on orbital timescales, i.e., more biomass burning occurred during the warm/wet Marine Isotope Stage (MIS) 3, and less biomass burning occurred during the cold/dry MIS 2. Superimposed on this general trend, our charcoal record shows millennial-scale variability in biomass burning corresponding to the rapid climate changes associated with Dansgaard–Oeschger (D–O) cycles, i.e., biomass burning increased during D–O warming events, whereas biomass burning decreased during intervals of rapid cooling terminated by Heinrich events. During the cooler/drier periods, low biomass burning can be explained by the decline of vegetation productivity, whereas the warmer/wetter periods are characterized by higher biomass burning related to increasing fuel availability. Therefore, climate control can be considered as the major forcing factor of biomass burning from 41,000–7050 cal BP on both orbital and millennial timescales in the northern Leizhou Peninsula.

1. Introduction

Charcoal particles resulting from incomplete combustion of plant debris during biomass burning episodes are reliable indicators of fire events and have therefore been widely used to reconstruct past changes in fire activity (e.g. Patterson et al., 1987; Long et al., 1998; Mohr et al., 2000; Power et al., 2011; Rius et al., 2012). Although changes in fire activity can be precisely reconstructed using high-resolution records and special techniques, most palaeorecords only provide an indication of relative changes in biomass burning, and these changes in biomass burning can be assumed to reflect changes in fire activity (Marlon et al., 2006; Daniau et al., 2010). In recent years, many sedimentary charcoal records from the Chinese Loess Plateau of north-central China (Huang et al., 2006; Tan et al., 2011), northeastern China (Jiang et al., 2008), and South China Sea (Sun et al., 2000; Luo et al., 2001) have provided valuable information on palaeofire, palaeoclimate, and landscape evolution for the late Pleistocene and Holocene. However, relatively little is known about the history of fire activity in south China.

Here, we present a well-dated micro-charcoal (<125 μm) record based on pollen-slide charcoal analysis from a peat core at the Xialu peatland in the tropical northern Leizhou Peninsula, south China, covering the interval ~41,000–7050 cal BP, with the aim of reconstructing the fire activity (defined here as biomass burning; e.g. Daniau et al., 2010). The reconstruction of biomass burning is then compared to vegetation and to climate proxy records from the same sediment core, which makes it possible to study how biomass burning responded to major climatic changes during intervals when human influence was negligible in the study region (Zheng et al., 2004). Furthermore, we compare our records with other regional climate proxy data in order to increase our understanding of the fire–climate–vegetation interactions of the Leizhou Peninsula from ~41,000 to 7050 cal BP.

2. Study region

The Xialu peatland is situated on the northern Leizhou Peninsula (Fig. 1), south China, where climate is controlled by the warm/humid East Asian summer monsoon (EASM) and to a lesser extent by the Indian summer monsoon (ISM) in the summer season and the cold/dry East Asian winter monsoon (EAWM) in the winter season. The peatland is located on the coast, with an elevation of approximately 5–8 m above sea level. To date, there is no evidence indicating a higher sea level that could have affected the sampling site since the last glaciation (Xue et al., 2014). The study area has a mean annual precipitation (MAP) of about 1600 mm, most of which occurs in summer (mainly from April to October) in association with the EASM, and mean annual temperature (MAT) of about 23 °C. Modern natural vegetation in the Leizhou Peninsula mainly consists of tropical semi-evergreen seasonal

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http://dx.doi.org/10.1016/j.palaeo.2015.08.037
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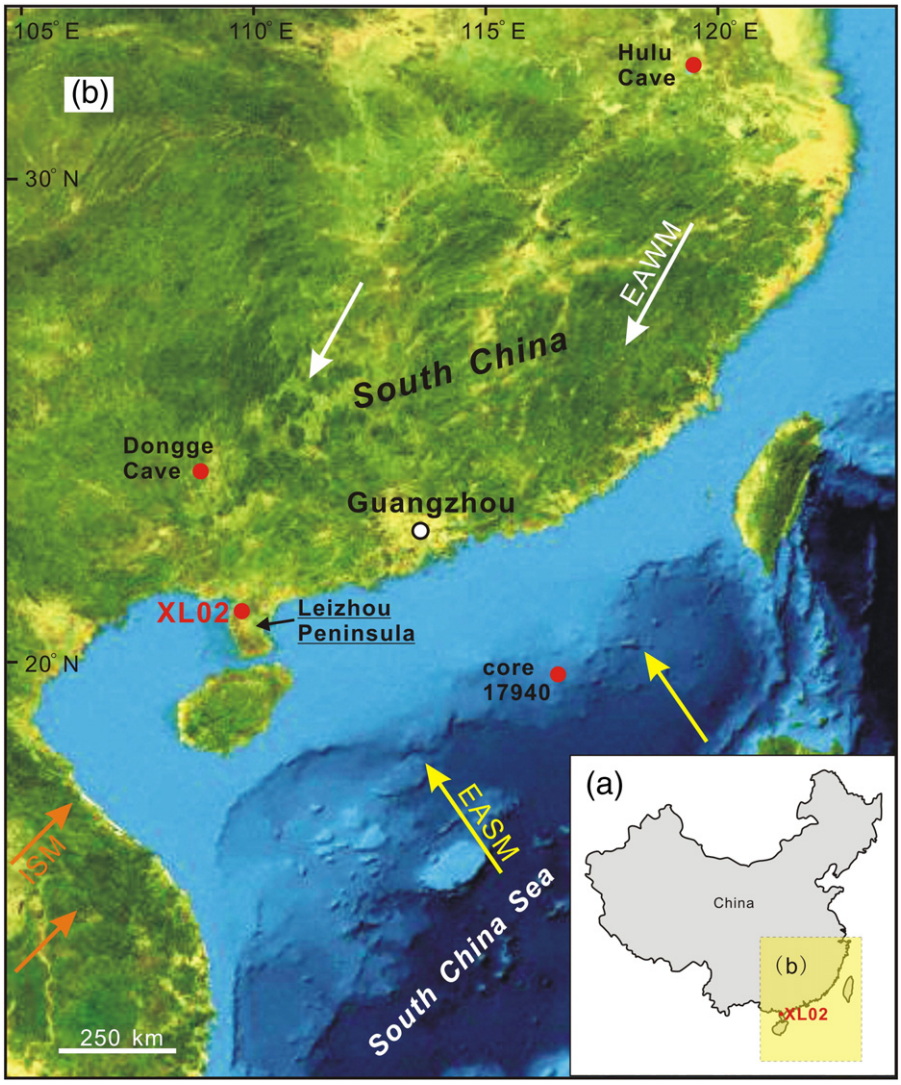

Fig. 1. Location of core XL02 in the northern Leizhou Peninsula, south China.

rain forest as well as tropical tree steppe (Zheng and Lei, 1999). On the dry land and hill slopes, open forests and tropical grassland are widespread, accompanied particularly by Poaceae and heliophytic ferns such as *Dicranopteris*. A few semi-natural forests standing on the hills, compose mainly of *Ficus*, *Syzygium*, *Elaeocarpus*, *Antidesma*, *Artocarpus*, and *Antiaris*. Due to strong human disturbances, there are only small relicts of the original flora left in this region at present. So far, the relationship between past fire activity and climate has never been fully investigated in the palaeorecords of the Leizhou Peninsula, in a region which today experiences a number of large natural (e.g. lightning strikes) and human-induced fires every year. However, as the present-day incidence and spatial distribution of fires resulting from lightning strikes is commonly restricted by human activities, natural ignitions may have had broader effects in the past.

3. Materials and methods

3.1. Sampling and lithology

In May 2006, several cores were recovered from the Xialu peatland (21°18′N, 109°49′E), using a Russian peat corer (chamber 500 mm long, 75 mm diameter). Twin boreholes were drilled at the same sampling site and the cores overlapped at least by 30 cm. The stratigraphy was recorded initially in the field and was described in further detail when they were opened for sampling in the lab. The studied XL02 peat core is mainly composed of two sedimentary units: Unit 1 (30–105 cm) consists of 75 cm of weakly humified yellowish- and light-brown-colored peat; Unit 2 (105–210 cm) consists of 105 cm of highly humified dark-brown-colored peat. Notably, many tree remains (small branches and/or bark) occur from 90 to 105 cm and from 165 to 180 cm.

3.2. Laboratory analysis

In this study, micro-charcoal particles (<125 μm) were counted simultaneously with pollen and spores in pollen-slides (Patterson et al., 1987). About 1 cm^3 of material was sampled at 3 cm intervals, and a total of 58 samples were analyzed from 30 to 200 cm of core XL02. Samples for pollen analysis were processed using heavy liquid separation (Nakagawa et al., 1998). In brief, the preparation procedures involve treatment with 10% HCl to remove carbonates, 10% KOH to remove humic components, heavy liquid floatation (a $ZnCl_2$ solution with a specific gravity of between 2.0 and 2.2), acetolysis to remove cellulose, followed by mounting the sample in a glycerin jelly. One tablet of *Lycopodium* marker spores was added to each sample for calculating total pollen and spore concentrations. At least 300 pollen and spores were counted for each sample. Pollen percentages were calculated based on the total terrestrial pollen sum. All samples were identified