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Palynological analysis of the late Early Pleistocene sediments from Queque Cave in Guangxi, South China

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ABSTRACT

Palynomorphs extracted from the sediments in Queque Cave of the late Early Pleistocene in Chongzuo, Guangxi Zhuang Autonomous Region were investigated to reconstruct the paleoenvironment in the study area. While the sediments are pollen-poor, they are sufficiently productive to carry out a paleoenvironmental analysis. The source vegetation reflected by the palynomorphs from the unfossiliferous layer was temperate to warm temperate deciduous and evergreen broadleaved forest while it was warm temperate to subtropical deciduous and evergreen broadleaved forest from the mammalian horizons. Climatic parameters obtained using the Coexistence Approach indicate that the unfossiliferous layer (MAT = 11.3–15.4 °C, MAP = 601.1–1076.1 mm) was cooler and drier than that from the mammal-bearing layers (MAT = 12.6–18.6 °C, MAP = 784.7–1523.1 mm).

1. Introduction

Cave deposits represent ideal settings for mammal fossil discoveries (e.g. Demirel et al., 2011; Terry et al., 2011; Haouchar et al., 2014), as many of the animals like to use caves as dens. The composition of the fauna can reveal part of the paleoenvironmental information. The sediment itself, on the other hand, is more suitable for extracting the whole story (Ford and Williams, 2007). Although cave pollen assemblages are sometimes considered to yield only limited paleoecological information (Coûteaux, 1977; Turner and Hannon, 1988), they usually provide enough data (Carrión et al., 1999). Palynology of karst caves is one of the potentially important sources of information for Quaternary plant paleoecology (Carrión et al., 1998).

A large number of fossil mammals, especially *Gigantopithecus blacki* and human, were discovered in the karst caves in Guangxi Zhuang Autonomous Region (Guangxi ZAR for abbreviation hereafter) (e.g. Han, 1982; Jin et al., 2007, 2008, 2009a,b, 2010, 2014; Wang et al., 2009a,b, 2010, 2014; Liu et al., 2010; Zhang et al., 2010, 2014; Dong et al., 2014; Harrison et al., 2014; Yan et al., 2014). However, no palynological studies from Quaternary cave sediments were carried out in this area previously. In the present contribution, we chose a karst cave, Queque Cave of the late Early Pleistocene in Guangxi ZAR (Fig. 1), where abundant mammalian fossils were excavated, to carry out paleovegetational and paleoclimatic studies based on pollen analysis. Such analyses should help to give more detailed snapshots of the paleoenvironment (vegetation, living environment of the mammals) in this area.

2. Site setting

Guangxi ZAR is very famous for its karst landforms (with an area of 9.7×10^4 km^2 or 41% of the territory of Guangxi) (Li et al., 2003). Queque karst cave (22°16′22″N, 107°30′22″E) is located on the southern slope of Wuming Mountain (311 m above sea level) in Chongzuo Eco-Park (Chongzuo Biodiversity Research Institute, Peking University), Jiangzhou District, Chongzuo City, in southwestern Guangxi. The altitude of the entrance is 196 m above sea level (a.s.l.) and it faces south. The cave is about 26 m long from northeast to southwest, with a maximum width of 8.2 m (Jin et al., 2014).

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The sediments in Queque Cave are ca. 7.5 m in thickness. The animal fossils were mainly discovered in Layers 4 and 5 (Fig. 2). The Queque fauna contains 26 species of large mammals and 38 species of small mammals based on preliminary identification (Jin et al., 2014). There are at least two species of apes, *G. blacki* and *Pongo weidenreichi* (Harrison et al., 2014) and three species of Old World monkeys, including the most complete skeleton of a fossil macaque in China (Zhang et al., 2010). The age of the sediments, according to the magnetochronological sequence of a 5.5 m section (at the depth of about 0.5–6 m of this study) (with a minimum interval of 10 cm sampling), was investigated by the Institute of Geology and Geophysics, Chinese Academy of Sciences (Sun et al., 2014). Based on the mineral magnetic results, three magnetozones were recognized in Queque Cave. The mammalian assemblages discovered in Queque Cave were also used for age determination. The *Gigantopithecus* fossils in Queque Cave, which are located in the Jaramillo normal subchron at the depth interval of 3.1–5.9 m in this study, are estimated to be ~1.0 Ma (Sun et al., 2014).

Sanhe Cave (~1.2 Ma) (Jin et al., 2014; Sun et al., 2014), which is 7 m above the Queque Cave, is more famous for its faunal feature. In total 32 species of large mammals and 52 species of small mammals were found (Jin et al., 2008, 2009a). The fauna indicates the presence of a tropical rainforest (Jin et al., 2008, 2009a).

The present climate of the study area is subtropical with a mean annual temperature of 22.4 °C (1957–1999) (Huang and Pan, 2010). As a typical karst region, the vegetation is seasonal rainforest under 700 m a.s.l. (Li et al., 2003; Su and Li, 2003). However, most of the original forests were cut during the last few decades, and have now been replaced by secondary vegetation of which *Sterculia nobilis* pure forest and a mixed forest of *S. nobilis* and *Pteroceltis tatarinowii* are the most common (Li et al., 2008).

3. Material and methods

In total, 16 samples (QQD-1–QQD-12, QQDK-1–QQDK-4) were collected from the sediments in Queque Cave, 12 of which were collected from about ten meters away from the entrance, among which 7 (QQD-1–QQD-7) from non-fossiliferous sediments and 5 (QQD-8–QQD-12) were collected from the mammal-bearing layer. The other 4 samples (QQDK-1–QQDK-4) were collected near the entrance as a supplement. The sediments consist of calcareous sandy conglomerate and calcareous mudstone. The locations of these samples are shown in Fig. 2.

Pollen grains and spores were extracted using the acid-alkali-free method (Moore et al., 1991; Li and Du, 1999). About 40 g of each sample were analyzed. Pollen slides were counted and photos were taken at ×400 on an Olympus CX41 microscope (Figs. 3 and 4). A single grain technique (Ferguson et al., 2007) was applied and SEM photos were taken under a JEOL 6700F scanning electron microscope (Figs. 5–7). The identifications of the palynomorphs were mainly based on monographs such as Pollen Flora of China (Wang et al., 1995) and Sporae Pteridophytorum Sinicorum (IB-CAS, 1976), and other relevant palynological literature (IBSCIB-CAS, 1982; Moore et al., 1991). Because of the limited number of pollen grains in Queque Cave, the entire residue extracted from the 40 g of material was utilized for counting.

For the paleoecological analysis, the Coexistence Approach (CA) (Mosbrugger and Utescher, 1997) was applied. Based on the pollen taxa of the assemblages, the nearest living relatives and their geographic distribution (Wu and Ding, 1999) were collated. The modern climatic variables used in the CA were taken from Surface Meteorological Data of China (1951–1980) (IDBMC, 1983a,b; 1984a,b,c,d). Seven paleoclimatic variables were obtained (MAT = mean annual temperature, WMMT = warmest month mean temperature, CMMT = coldest month mean temperature, DT = difference between temperature of the coldest and warmest months, MAP = mean annual precipitation, MaMP = maximum monthly precipitation, and MiMP = minimum monthly precipitation).

4. Results

4.1. Palynological assemblages

The 12 samples inside the cave yielded in total 317 pollen and spores belonging to 38 types of sporomorphs (Table 1), i.e. 1 gymnosperm, 33 angiosperms (of which 13 herbaceous), and 4 pteridophytes.

Table 1
List of palynomorphs from Queque Cave and their percentages.

	Unfossiliferous layer	Fossiliferous layer	In total	Samples near the entrance
Pinus	25.3	21.1	23.3	1.0
Juglans	2.9	0.7	1.9	\
Ulmus	0.6	1.4	0.9	1.0
Alnus	1.2	0.7	0.9	\
Betula	1.8	4.8	3.2	
Quercus	1.8	2.7	2.2	4.1
Castanopsis	4.1	3.4	3.8	\
Corylus	1.8	0.7	1.3	\
Carya	\	\	\	1.0
Terminalia	\	0.7	0.3	\
Ebenaceae	\	2.0	0.9	
Spiraea	0.6	0.7	0.6	\
Rhamnaceae	1.2	1.4	1.3	\
Leguminosae	\	2.0	0.9	
Meliaceae	\	0.7	0.3	\
Burseraceae	\	0.7	0.3	\
Theaceae	\	0.7	0.3	\
Anacardiaceae	0.6		0.3	\
Araliaceae	0.6	1.4	0.9	
Nitraria	0.6	\	0.3	\
Polygalaceae	0.6	\	0.3	\
Sapindaceae	0.6	1.4	0.9	\
Euphorbiaceae	1.2	2.7	1.9	\
Brassicaceae	1.2	1.4	1.3	2.1
Poaceae	5.9	8.8	7.3	5.2
Artemisia	3.5	2.0	2.8	17.5
Solanaceae	0.6	1.4	0.9	\
Ranunculaceae	2.9	2.7	2.8	\
Chenopodiaceae	1.2	5.4	3.2	10.3
Rosaceae	0.6	2.0	1.3	\
Moraceae	0.6	\	0.3	
Morus	\	1.4	0.6	\
Humulus/Cannabis	2.9	2.7	2.8	39.2
Asteraceae	0.6	1.4	0.9	3.1
Amaranthaceae	0.6		0.3	\
Hemionitidaceae	28.8	19.0	24.3	14.4
Athyriaceae	3.5	2.0	2.8	1.0
Lycopodiaceae	0.6		0.3	\
Botrychium	1.2	\	0.6	\

Pinus pollen, with a percentage of 23.3%, as the only gymnosperm, is the most abundant spermatophyte in the assemblages. Poaceae (7.3%) is the main angiosperm taxon. Hemionitidaceae is the predominant pteridophyte with its spore percentage of 24.3%.

Some differences between the palynomorphs in the samples from the unfossiliferous layer (QQD-1–QQD-7) and those from the mammal-bearing horizon (QQD-8–QQD-12) (Table 1) were observed. Although some thermophilous taxa, Araliaceae, Sapindaceae, Hemionitidaceae for example, exist in both layers, more typical subtropical to tropical taxa are present in the fossiliferous