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The Early Pleistocene *Gigantopithecus-Sinomastodon* fauna from Juyuan karst cave in Boyue Mountain, Guangxi, South China

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ABSTRACT

As one of the most important Quaternary mammalian faunas in southern China, the *Gigantopithecus-Sinomastodon* fauna has received much attention. The large-primate fossil teeth newly collected from Juyuan karst cave in Boyue Mountain, Guangxi Zhuang Autonomous Region of southern China, can be identified as *Gigantopithecus blacki*. The morphology and size of these *G. blacki* teeth differ from those of the middle Pleistocene *Gigantopithecus* teeth which hold evidently larger dental dimensions and more complex crenulations from Hejiang Cave also in Guangxi and Tham Khuyen Cave in Vietnam. However, the *G. blacki* teeth from Juyuan Cave are relatively similar to those from Early Pleistocene Mohui Cave and Liucheng *Gigantopithecus* Cave both in Guangxi, which suggests that the three cave sites have similar age. The Juyuan fauna associated with *Gigantopithecus blacki*, consisting of 45 mammalian species (such as *Sinomastodon yangziensis*, *Ailuropoda wulingshanensis*, *Stegodon huananensis*, and *Rhinoceros fusuiensis*), is a typical Early Pleistocene *Gigantopithecus-Sinomastodon* fauna of southern China. The Juyuan fauna is mostly similar to Mohui fauna, also implying their contemporaneity. Paleomagnetic analyses demonstrate that the fossil-bearing sediments in Juyuan Cave are dominated by normal polarity. Combining the faunal analysis and magnetostratigraphic evidence, the Juyuan sediments can be best correlated with the Olduvai normal subchron, giving an estimated age of 1.8 Ma.

1. Introduction

As the largest primate ever to have lived, *Gigantopithecus blacki* is an extinct giant ape and a typical member of the Pleistocene fauna known from southern China or, more broadly, mainland Southeast Asia. *Gigantopithecus blacki* was initially erected based on the isolated teeth collected from traditional Chinese pharmacies by the German paleontologist Von Koenigswald (1935). Since the first discovery of *G. blacki* from an *in situ* geological horizon in Guangxi Zhuang Autonomous Region (Guangxi ZAR) in the 1950s, there have been at least 16 sites found in southern China and northern Vietnam, all dating to early-middle Pleistocene (Woo, 1962; Huang and Fang, 1991; Ciochon et al., 1996; Zheng, 2004; Wang et al., 2005, 2007a, 2007b; Zhao et al., 2006, 2008, 2011; Wang, 2009; Jin et al., 2009, 2014; Zhao and Zhang, 2013; Zhang et al., 2014, 2015).

The initial *G. blacki* teeth were commonly found from the "Drugstore fauna" without stratigraphic control. Both Chow (1957) and Pei (1962) agreed that the fauna from Liucheng *Gigantopithecus* Cave was more primitive than the typical middle Pleistocene *Ailuropoda-Stegodon* fauna (*sensu stricto*) and was referred to as the *Gigantopithecus* fauna with an estimated age of Early Pleistocene. *Sinomastodon* (Proboscidea) was once prevalent, together with *Gigantopithecus*, during the Early Pleistocene and possibly became extinct at the end of the Early Pleistocene in southern China (Wang Y et al., 2012, 2014). The Early Pleistocene fauna from South China is suggested to be revised as the *Gigantopithecus-Sinomastodon* fauna (Wang Y et al., 2014).

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During the past decade, the most diverse and intriguing of *Gigantopithecus* fossils and other vertebrate remains have been discovered from a number of cave sites in the Chongzuo, Zuojiang River area of Guangxi ZAR, South China (Jin et al., 2009, 2014; Dong et al., 2010, 2014; Harrison et al., 2014; Takai et al., 2014; Wang Y et al., 2014 Yan et al., 2014; Zhang et al., 2014; Zhu et al., 2014, 2015). These newly discovered cave sites have estimated dates that span the early-middle Pleistocene, even possibly late Pleistocene (Sun et al., 2014; Zhang et al., 2014). For example, the early Early Pleistocene faunas from Baikong Cave of Liyu Mountain and Yanliang Cave of Gaoyan Mountain include some primitive species, such as *Sinomastodon jiangnanensis*, *Ailuropoda microta*, *Megantereon microta, Cervavitus ultimus*, and *Tapirus sanyuanensis* (Jin et al., 2014; Yan et al., 2014; Zhu et al., 2014, 2015). The middle Early Pleistocene faunas from Juyuan Cave in Boyue Mountain and Sanhe Cave in Wuming Mountain are characterized by the first appearance of *Sinomastodon yangziensis*, *Ailuropoda wulingshanensis* and *Tapirus sinensis* (Jin et al., 2009, 2014; Wang Y et al., 2014). The late Early Pleistocene fauna from Queque Cave of Wuming Mountain is characterized by the first appearance of *Stegodon orientalis* and *Bubalus brevicornis chowi* and the last appearance of *Sinomastodon* (Dong et al., 2014; Jin et al., 2014). The Middle Pleistocene fauna from Hejiang Cave of Mulan Mountain is characterized by the appearance of *Ailuropoda baconi* and *Stegodon orientalis* (Zhang et al., 2014). The fauna from Shuangtan Cave of Mulan Mountain also from Chongzuo including *Ailuropoda melanoleuca*, *Elephas maximus,* and *Megatapirus augustus*, possibly is late Pleistocene and awaits systematic research.

To date, the earliest record of *G. blacki* in Chongzuo area is from the early Early Pleistocene Baikong Cave of Liyu Mountain (2 Ma) (Jin et al., 2014; Sun et al., 2014), and the latest occurrence is from Hejiang Cave in Mulan Mountain (400–320 Ka) (Zhang et al., 2014). The geographic distribution of *G. blacki* is limited to the Oriental zoogeographic realm of southern China (south of the Yangtze River and Qinling Mountain) and northern Vietnam (Tham Khuyen Cave; Ciochon et al., 1996) associated with mesic tropical and subtropical climatic zones. In China, the northernmost limit is 30°51′N (Longgupo in Chongqing) (Huang and Fang, 1991; Wei et al., 2014) and the southern boundary is located at 22°16′N (Chongzuo cave sites, Guangxi) (Jin et al., 2014).

In 2004, Wenshi Pan discovered some large primate fossil teeth and other vertebrate remains from the cave sediments in Boyue Mountain in Chongzuo Ecological Park, Guangxi. The large primate fossil teeth were subsequently identified by Zhanxiang Qiu as *Gigantopithecus blacki*. It was the first discovery of *G. blacki* in Chongzuo area, so this site was called Juyuan Cave in Boyue Mountain ("Juyuan" in Chinese means "*Gigantopithecus*").

Since 2006, a research team co-organized by Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences (IVPP, CAS) and Peking University has carried out the systematic excavations in Juyuan Cave and has unearthed a plethora of higher primate remains, including *G. blacki*, *Pongo,* and *Macaca,* as well as other abundant associated mammalian fossils.

Jin et al. (2014) has provided a preliminary account of the Juyuan fauna. This paper conducts a systematic study on the *Gigantopithecus-Sinomastodon* fauna from Juyuan Cave of Boyue Mountain based on new faunal data and previously published paleomagnetic data of Sun et al. (2014). The present study aims at providing important new evidence regarding the evolutionary trends, taxonomic composition, biochronological stages and paleoenviromental context of *Gigantopithecus-Sinomastodon* fauna.

2. Geographical and geological background

Chongzuo Ecological Park is about 16 km southeast of the Chongzuo urban district and 120 km northeast of the China-Vietnam border. Juyuan Cave (22°17′21.9″N, 107°30′40.1″E) is located on the eastern slope of Boyue Mountain which is near the entrance of Chongzuo Ecological Park (Figs. 1 and 2).

Chongzuo was a part of the Tethys during the late Paleozoic, and subsequent late Mesozoic tectonic movement led to the deposition of multiple sedimentary layers. As a consequence of the continuous uplift of the area since the Pliocene, multiple horizons of karst caves have formed at different elevations. These show a degree of regularity in the relationship between elevation and time of cave formation. Generally, the higher the elevation of the cave, the older the age of its formation within its deposits.

A total of six horizons of karst caves have been recognized in the Chongzuo area (Fig. 3). The elevation of the sixth, highest, horizon is about 270 m above sea level, and that of the first, lowest, horizon is about 150 m above sea level, which is situated only a few meters above the valley floor, with a likely age of the Holocene. The sediments of the karst caves of the fifth horizon with an elevation of about 200 m above sea level (e.g., Sanhe Cave and Yangliang Cave) yield the typical fossil members of the Early Pleistocene of southern China, such as *Gigantopithecus*, *Sinomastodon*, *Stegodon huananensis*, and *Cervavitus fenqii* (Jin et al., 2009, 2014; Yan et al., 2014).

The northern tropical karst in this area include peak valleys and peak depressions. The height of the mountains is generally about 300 m above sea level. Hejiang River between Boyue Mountain and Liyu Mountain flows from west to east, and the river valley floor is about 145 m above sea level (Fig. 3). On the steep faces of the karst slopes, numerous caves and fissures of various dimensions have been formed. These caves or fissures are normally filled with yellowish-brown or red–brown clay with breccia, most of which contain fossils.

Juyuan Cave is an elongated slit-like cave oriented southeast to northwest. The natural entrance of the cave faces east. The maximum width of the cave is 3.6 m (Fig. 4a). The elevation of the cave entrance is 206 m above sea level, and is situated more than 60 m above the valley floor. The sediments of the cave are approximately 5.5 m in thickness, which can be divided into six layers from top to bottom (Fig. 4b). The *G. blacki* and associated mammalian remains were recovered from the first and fifth layers. Layer 1: yellow–brown silty conglomerates with relatively hard nodules and limestone breccias of 3–4 cm, containing abundant fossils (110 cm). Layer 2: brown calcareous silts with relatively hard nodules (50 cm). Layer 3: dark-brown lutaceous silts (108 cm). Layer 4: gray–white calcareous floor with crystallized carbonate (12 cm). Layer 5: maroon argillaceous silts, relatively unconsolidated, with few large limestone breccias but well-developed calcite and iron-manganese nodules, yielding abundant fossils (130 cm). Layer 6: red clays (140 cm, bottom unseen).

3. Paleontology

The mammalian assemblage discovered from Juyuan Cave of Boyue Mountain contains 8 orders, 24 families, 36 genera and 45 species, including 20 species of large mammals and 25 species of small mammals (Tables 1 and 2).

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