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Evolutionary trend in dental size in *Gigantopithecus blacki* revisited

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ABSTRACT

Previous analyses of dental size in *Gigantopithecus blacki* indicated marked sexual dimorphism and a trend towards increasing size through time. These studies were based on a sample of over 700 teeth from five localities excavated prior to 1990. Since then, 12 additional cave sites have been discovered in southern China, yielding hundreds of isolated teeth of *G. blacki*. Most of these sites are well dated by a combination of biochronology and absolute dating methods, so we now have a much better understanding of the chronology of *G. blacki*. Here, we reexamine the degree of sexual dimorphism and the question of dental size increase through time in *G. blacki* based on the expanded collections now available. Our results show that sexual dimorphism is not as marked as indicated in previous studies and confirm earlier analyses suggesting that the postcanine teeth of *G. blacki* tend to become larger through time from the beginning of the Early Pleistocene to the Middle Pleistocene.

Introduction

To determine the provenance and geological age of *Gigantopithecus blacki* after its initial discovery in Hong Kong drugstores (von Konigswald, 1935), surveys and excavations were carried out in Guangxi Zhuang Autonomous Region and Hubei Province starting in the 1950s by teams from the Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences. This resulted in the recovery *in situ* of three partial mandibles and more than one thousand isolated teeth from five cave sites (i.e., Longgudong, Liucheng, Nomoshan, Bulalishan, and Hei Cave; Fig. 1). Among them, *Gigantopithecus* Cave (Fig. 1), Liucheng, Guangxi, yielded the majority of the fossils. At the same time, several hundred isolated teeth of uncertain provenance were recovered from local drugstores in Guangdong, Guangxi, and Hubei. This major research effort led to a better understanding of the phylogenetic relationships and paleobiology of *G. blacki*, as well as its provenance and geological age.

Yinyun Zhang (1982, 1983) was the first to address the question of dental size change through time in *G. blacki*. He analyzed linear metric data of *G. blacki* teeth from the original five cave sites (data from Pei and Woo, 1956; Woo, 1962; Chang et al., 1973, 1975; Xu et al., 1974). He also included data from 32 drugstore teeth collected from Guangdong and Guangxi (data from Woo, 1962). Based on the understanding of the biochronology at that time, Yinyun Zhang (1982) divided the five cave sites into two chronological groups. The Early Pleistocene group comprised the specimens from the *Gigantopithecus* Cave, Liucheng (638 teeth), while the Middle Pleistocene group included those from Jianshi (five teeth), Bama (one tooth), Daxin (two teeth), and Wuming (11 teeth). The drugstore teeth were also included with the Middle Pleistocene group based on the assumption that they probably originated from caves close to the valley floor, which were most easily accessible to local collectors, and were therefore younger than Early Pleistocene. Yinyun Zhang (1982) concluded that the cheek teeth of the Early Pleistocene group were significantly smaller than those of the Middle Pleistocene group.

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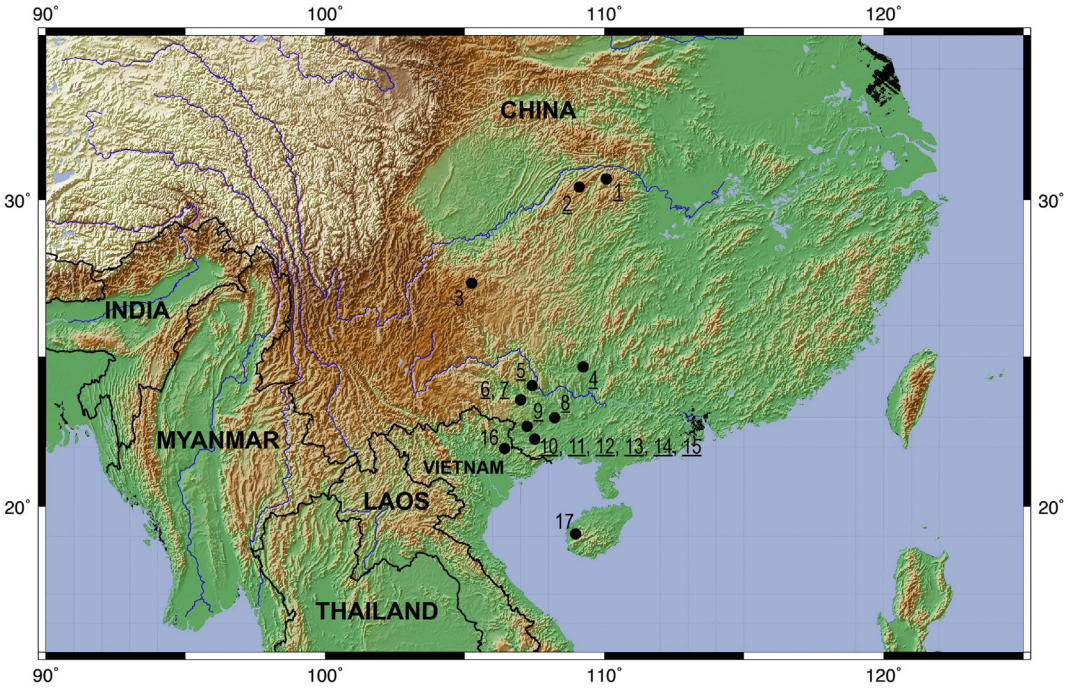

Figure 1. Map of *G. blacki* localities in southern China and Vietnam (underlined numbers indicate those localities for which metric data were analyzed in the present paper). 1. Longgudong, Jianshi, Hubei Province (Xu et al., 1974; Zheng, 2004); 2. Longgupo, Wushan, Chongqing (Huang and Fang, 1991); 3. Baeryan, Bijie, Guizhou Province (Zhao et al., 2006); 4. *Gigantopithecus* Cave, Liucheng, Guangxi Autonomous Region (Pei, 1957; Woo, 1962); 5. Nomoshan, Bama, Guangxi Autonomous Region (Chang et al., 1975); 6. Chuifeng Cave, Tiandong, Guangxi Autonomous Region (Wang, 2009); 7. Mohui Cave, Tiandong, Guangxi Autonomous Region (Wang et al., 2005); 8. Bulalishan, Wuming, Guangxi Autonomous Region (Chang et al., 1973); 9. Hei Cave, Daxin, Guangxi Autonomous Region (Pei and Woo, 1956); 10–15. Baikong Cave, Yanliang Cave, Boyue Cave, Sanhe Cave, Queque Cave and Hejiang Cave, Chongzuo, Guangxi Autonomous Region (Jin et al., 2009, 2014; Takai et al., 2014; Zhang et al., 2014a, 2014b); 16. Tham Khuyen Cave, Lang Son Province, Vietnam (Ciochon et al., 1996); 17. Xinchong Cave, Changjiang Li Autonomous County, Hainan Province (Chaorong Li, pers. comm.).

Yinyun Zhang (1983) re-measured all of the teeth himself to avoid inter-observer error and added 180 isolated teeth collected from drugstores in western Hubei to his original samples. The chronological groupings were the same as in Yinyun Zhang (1982), except that the age of the younger group was recognized as late Early Pleistocene, early Middle Pleistocene, or more recent. The drugstore teeth from Guangdong, Guangxi, and west Hubei were again assigned to the younger group based on two lines of evidence. First, according to Pei (1965) the systematic survey from 1956 to 1960 explored more than 300 caves in Guangdong and Guangxi, and only the *Gigantopithecus* Cave of Liucheng was considered to be Early Pleistocene. Second, caves with entrances at low elevations on the mountainside, which were correlated with the Middle Pleistocene, were easier for local people to access and collect fossils. Yinyun Zhang (1983) deduced, therefore, that the drugstore teeth were from younger deposits than the Early Pleistocene. Based on the expanded samples, Yinyun Zhang (1983) confirmed his earlier findings that the teeth of the younger group were significantly larger than those from the Early Pleistocene.

Since Yinyun Zhang's studies, twelve additional cave sites (see Fig. 1) and several hundred isolated teeth of *G. blacki* have been discovered *in situ* (Huang and Fang, 1991; Wang et al., 2005; Jin et al., 2009, 2014; Wang, 2009; Takai et al., 2014; Zhang et al., 2014a, 2014b). Most of these sites are well dated using biochronology and/or absolute dating methods, and we now have a much better appreciation of the chronology of *G. blacki* (Huang et al., 1995; Zheng, 2004; Rink et al., 2008; Jin et al., 2014; Shao et al., 2014; Sun et al., 2014; Zhang et al., 2014a, 2014b). The wealth of new fossil finds and the improved understanding of the chronology allows us to revisit the question of dental size change through time in *G. blacki*. The aim of the present paper is to analyze the metric data for almost all the available teeth of *G. blacki* in China in order to investigate evolutionary trends in dental size.

Materials and methods

Samples

Analyses of the metric data of *G. blacki* by Yinyun Zhang (1982, 1983) included over seven hundred isolated teeth of all tooth types from five *in situ* localities and two drugstore collections. We have added nine additional *in situ* localities in the present study. Since anterior teeth are less well represented in the collections than cheek teeth, our analysis only includes permanent postcanine teeth from fourteen *in situ* localities and two drugstore collections (Table 1). The sample comprises 1205 teeth re-measured by two of the authors (YZ and RTK), as well as thirteen teeth (two from Daxin, one from Bama, and 10 from Wuming) with measurements taken from the literature (Pei and Woo, 1956; Chang et al., 1973, 1975).

Chronological grouping of the localities

The twelve new *G. blacki* localities discovered since 1990 (all those listed in Fig. 1 except Longgudong, Liucheng, Nomoshan, Bulalishan, and Hei Cave), in conjunction with the application of absolute dating methods (Huang et al., 1995; Ciochon et al., 1996; Zheng, 2004; Rink et al., 2008; Jin et al., 2009; Shao et al., 2014; Sun et al., 2014; Zhang et al., 2014a, 2014b), have provided a better understanding of the chronology of *G. blacki*. Jin et al. (2014) developed a seriated chronology for 10 Early Pleistocene *G. blacki* localities in Chongzuo, Guangxi based on biochronology, geochronology, and magnetostratigraphy. Nine of these Early Pleistocene