



Biochronological framework of *Homo erectus* horizons in China



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ABSTRACT

A total of 15 sites yielding *Homo erectus* were discovered in China. Numerical age dating results vary from different authors. In an attempt to evaluate and possibly refine controversial dating results, the author proposes five stages as a biochronological framework for *Homo erectus* horizons in China by sequencing all hominin horizons according to fauna antiquity coefficients, faunal binary similarity coefficients, faunal extinction rates, and ecological composition similarities of the faunas. The first stage is associated with the arrival of *Homo erectus* in East Asia, and the last stage is associated with the decline and final disappearance of *Homo erectus* as well as arrival of *Homo sapiens* in East Asia. The faunas experienced some kind of critical transition or turnover in the third stage.

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1. Introduction

It is well known that *Homo erectus* (*s.l.*) is the earliest prehistory tool-maker human in East Asia. The systematic excavations during the 1920s and 1930s at the Zhoukoudian site in Beijing started a series of research on *Homo erectus* and related prehistory in China (e.g. Black, 1927, 1930; Zdansky, 1927, 1928; Pei, 1929, 1931; Teilhard de Chardin and Young, 1929; Breuil, 1931, 1939; Black et al., 1933; Andersson, 1934; Weidenreich, 1935; Teilhard de Chardin, 1941). More and more hominin localities were discovered and excavated since the systematic excavations at Zhoukoudian (Wu et al., 1999; Liu et al., 2014). Nevertheless, the numerical age dating results of hominin horizons vary. For example, the lower layer yielding the first skull-cap of *Homo erectus* at Locality 1 of Zhoukoudian was dated as 462 ka by Zhao et al. (1985) but 750 ka by Shen et al. (2009); that of Hexian Man was 150–190 ka by Chen et al. (1987) but 300 ka by Huang et al. (1995); that of Nanjing Man was 350 ka by Chen et al. (1996) but 500 ka by Wang et al. (2002); and that of Lantian Man at Gongwangling was 1.15 Ma by An and Ho (1989) but 1.7 Ma by Zhu et al. (2015). The most spectacular difference is that for Yuanmou Man, 700 ka by Hyodo et al. (2002) but 1.7 Ma by Li et al. (1976) and Zhu et al. (2008), with a difference of 1 My. The latter variance is not very significant for Paleozoic or even Mesozoic paleontology, but it is important for that of the Cenozoic, especially for Quaternary and human evolution research.

Well documented mammalian faunas associated with *Homo erectus* (e.g. Zdansky, 1928; Young, 1932; Li and Ji, 1981) tell us not only the probable diet components and paleoenvironments of the prehistoric humans, but also the relative ages of their horizons to calibrate the numerical age dating. The faunas were, however, mostly described alone and compared with a few related faunas (e.g. Zdansky, 1927, 1928; Hu and Qi, 1978; Lin et al., 1978; Li and Ji, 1981; Ji, 1999; Wang et al., 2007; Gong et al., 2014). Only a few comparisons were at larger scale such as those of North China (Qi, 1989) or South China (Han and Xu, 1989), or even the whole country (Dong et al., 2000). Here, a biochronological framework of *Homo erectus* horizons in China is proposed, by sequencing all faunas from the hominin horizons in the whole country, including those from Mohui and Hualongdong discovered and documented in the recent decades, based on faunal evolution. An attempt is made to evaluate and possibly refine the numerical ages with the proposed biochrons.

2. Regional setting

There are 15 sites yielding *Homo erectus* in China, since the discovery of the first skull-cap of Peking Man at Zhoukoudian in 1929. Besides these, the purported 16th site of *Homo erectus*, Xichuan Man site, remains unknown (Liu et al., 2014). Thirteen teeth of Xichuan Man were collected in 1973 from traditional Chinese medicine stores at Xichuan County in the same Nanyang Municipality as that of Nanzhao Man in Henan Province. The follow-up investigations at several potential localities were carried out but were fruitless (Wu and Wu, 1982). It is therefore impossible

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to include this unknown site in the present study. The geographic and geological settings of the 15 sites are as follows.

2.1. Yuanmou Man locality at Danawu

The site (GPS: 25°40′39.54″N, 101°54′42.42″E, 1284 m) is about 5 km southeast (heading: 128°) of Yuanmou downtown, near the middle part of eastern Yuanmou Basin in Yuanmou County, Yunnan Province (Fig. 1A). The type section of the Late Cenozoic Yuanmou Formation ranges from the eastern slope of Dongshan in southern Yuanmou County to Laoyatang by the Longchuan River. It consists of four lithostratigraphic members. Member 4, the top member with a total thickness of 122.2 m, is composed of fluvial and alluvial silty clays interbedded with sandy conglomerates, and it is further divided into 5 lithostratigraphic layers with Layer 28 on the top and Layer 24 at the bottom (Qian and Zhou, 1991). A pair of upper first incisors of *Homo erectus* were collected from Layer 25 near Danawu (Hu, 1973), and a left tibia of *Homo erectus* was collected from the southern slope of Guojiabao (Zhou, 1998) which might be equivalent to Layer 27. Mammalian remains from Layers 25–27 were considered as the same fauna (Lin et al., 1978).

2.2. Tiandong Man locality at Mohui cave

The cave (GPS: 23°34′49.76″N, 106°59′58.95″E, 215 m) is located halfway up a Permian–Triassic limestone hill in Bubing Basin, about 12.6 km west (heading: 258°) of Tiandong downtown in Guangxi Zhuang Autonomous Region (Fig. 1B). The cave deposits of roughly 6.5 m thick were divided into five lithostratigraphic layers (Wang et al., 2005). A complete right lower second molar of *Homo erectus* (*s.l.*) and abundant large mammal fossils were unearthed from Layer 3, which is composed of fossiliferous brown sandy clay with breccia, and its thickness measures 120 cm. A broken upper left first or second molar was collected from disturbed deposits in the cave (Wang et al., 2005).

2.3. Jianshi Man locality at Longgudong

Longgudong (“Dragon-bone cave” in Chinese) is a karst cave (GPS: 30°39′54.26″N, 110°4′35.15″E, 738 m) horizontally developed in the Early Triassic limestone with a length of about 110 m. It is about 34.5 km east (heading: 78°) of Jianshi downtown in southwestern Hubei Province (Fig. 1C) and about 245 km south (heading: 191°) of Yunxian Man locality at Quyuanhekou in northwestern Hubei Province, but only about 45 km southeast (heading: 119°) of Longgupo Site of Chongqing Municipality adjacent to Hubei Province. The cave developed from the east entrance to west exit as an irregularly shaped tunnel, and a secondary cave developed from the proximity of the west exit and extends northeastwards as a narrow chamber. The cave deposits were formed in different parts of the cave. Seven sections along the length of the cave were excavated from 1999 to 2000 (Zheng, 2004). The cave deposits with thickness of 2–5 m in the seven sections were divided into 5–17 layers according to lithostratigraphic character. The upper part of the deposits in all sections is characterized by calcareous flow-stone with varied thickness. The lower and main part of the deposits in all sections is composed of fossiliferous layers of clay, sub-clay and sandy clay with occasional breccia on the bottoms. Three *Homo erectus* (*s.l.*) teeth, an upper left third molar, an upper right third premolar and a lower right first molar were unearthed during the excavations from Layer 8 of Section A–A′ (with total 12 layers) near the east entrance, Layer 5 of Section G–G′ (with total 7 layers) in the west secondary cave and Layer 8 of Section C–C′ (with total 17 layers) in the center of the cave respectively (Zheng, 2004).

2.4. Yunxian Man locality at Quyuanhekou

The Quyuanhekou (“Quyuan River mouth” in English) locality (GPS: 32°50′2.21″N, 110°35′4.20″E, 203 m) is about 21.3 km west (heading: 269.7°) of Yunxian downtown and 56.4 km southwest (heading: 250°) of the Longgudong at Meipu of Yunxian County in northwestern Hubei Province (Fig. 1E). It is located on the north bank of the Han River and on the west bank of Quyuan River mouth which is a tributary of the Han. Two skulls of *Homo erectus* and associated fauna were unearthed from the deposits of the fourth terrace of the Han River over the Sinian metamorphic series bedrock. The fourth terrace deposits were divided into three parts based on sedimentary facies (Li and Feng, 2001). The lower part is mainly coarse sand and gravel bedload, the middle part is mainly channel margin fine sand and silt, and the upper one is alluvial silt and clay. The upper part was further divided into three layers. Layer 3, the lowermost one which yielded hominin skulls and associated fauna, is fossiliferous light brown silt clay with a large amount of calcareous concretion, and its thickness is 1.3 m (Li and Feng, 2001).

2.5. Yunxian Man locality at Meipu

Three teeth of *Homo erectus* were collected from the cave deposits in a karst cave (GPS: 33°0′6.49″N, 111°8′57.88″E, 263 m) called Longgudong (“Dragon Bone Cave”) in Yunxian County, Hubei Province (Fig. 1G). The cave was horizontally developed in a Sinian limestone hill named Zhailiangzi. It is about 37 km northeast (heading: 58°) of Yunxian downtown and about 56.4 km northeast (heading: 70°) of the Yunxian Man locality at Quyuanhekou in the same county. The cave deposits were divided into three layers (Xu, 1978). The upper one is a hard cemented layer with a thickness of 30 cm; the middle one is mainly yellow sandy clay with occasional breccia and gravels, its thickness ranges from 50 cm to 250 cm; and the lower one is cemented yellow sediments with some small limestone gravels. Only the middle layer yielded *Homo erectus* teeth and associated mammalian fossils (Xu, 1978).

2.6. Yunxi Man locality at Bailongdong

The site (GPS: 32°59′40.0″N, 110°31′33.6″E, 550 m) is located in Shenwuling Village of Anjia Town of Yunxi County in northwestern Hubei Province (Fig. 1I). It is only about 10 km east (heading: 89°) of Yunxi downtown, and about 18.6 km northwest (heading: 344°) of Yunxian Man locality at Quyuanhekou. Bailongdong (“White Dragon cave” in Chinese) is developed in the Pliocene Sha-ping Formation composed of breccia interbedded with calcilutites and marls. The cave deposits were lithostratigraphically divided into 8 layers (Wu et al., 2009; Liu et al., 2014). Layer 1 is loosely deposited yellowish brown clay with fragments of marls and mammalian bones and with a thickness of about 50 cm; its upper part was considered as disturbed sediments. Layer 2 measures 54 cm and is mainly brownish red fossiliferous clay with occasional calcareous concretions and gravels with a diameter of about 5 mm. An orange yellow sandy clay lens with gravels and with a thickness of 7–9 cm is interbedded in the layer. Layers 3–8 are mainly clay with varied scattered gravels and calcareous concretions and stratifications and no fossils were found. Altogether, eight *Homo erectus* teeth and associated mammalian fossils were unearthed from Layer 2 (Wu et al., 2009; Liu et al., 2014).

2.7. Lantian Man locality at Gongwangling

Gongwangling locality (GPS: 34°11′3.33″N, 109°29′23.90″E, 715 m) is located in southeastern proximity to Gongwang Village and on the northern slope of a hill among Gongwangling ridges at

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