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Middle to Late Pleistocene hominin occupation in the Three Gorges region, South China

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A B S T R A C T

The contributions of the Chinese Paleolithic record to broader ranging paleoanthropological debates – have long been difficult to decipher. The primary problem that hinders many contributions that include or focus on the Chinese record is that relatively few regions outside of the main flagship sites/basins (e.g., Zhoukoudian, Nihewan Basin, Bose Basin) have been intensively researched. Fortunately, systematic archaeological survey and excavations in the Three Gorges region, South China over the past two decades has led to the discovery of a number of important hominin fossils and Paleolithic stone artifact assemblages that have contributed to rethinking of ideas about hominin adaptations in Pleistocene China. This paper provides a detailed review of the results of recent paleoanthropological, particularly Paleolithic archaeological, research from this region.

The Three Gorges region is located in the transitional zone between the upper and middle reaches of the Yangtze River (Changjiang River). Vertebrate paleontological studies indicate that the faunas from this region belong primarily to the *Ailuropoda–Stegodon* faunal complex, a group of taxa representative of a subtropical forest environment. Systematic field surveys identified sixteen Paleolithic sites in caves and along the fluvial terraces of the Yangtze River. Based on geomorphology, biostratigraphy, and geochronology studies, these sites were formed during the Middle to Late Pleistocene. Follow up excavations at these sites led to the discovery of a large number of Paleolithic stone artifacts, Pleistocene mammal fossils, as well as some hominin fossils. Analysis of these materials has provided the opportunity to reconstruct hominin technological and mobility patterning in a restricted spatial point. The Paleolithic technology from the Three Gorges region is essentially an Oldowan-like industry (i.e., Mode 1 core and flake technologies) comprised of casual cores, whole flakes, fragments, and chunks as well as a low percentage of retouched pieces. The utilized stone raw material is primarily high sphericity cobbles and limestone, which were locally available along the ancient river bed and surrounding terraces. Most of the artifacts are fairly large in size. All flaking is by direct hard hammer in a single direction without core preparation. Unifacial choppers are the predominant core category, with fewer bifacial choppers, sporadic discoids, polyhedrons, and bifaces. The flake types demonstrate that the first stage of core reduction is represented by a low percentage of Type III and VI flakes. Some flakes are retouched unifacially by direct hard hammer percussion on the dorsal surface of the blanks. Archaic *Homo sapiens* and modern *H. sapiens* identified from some of the cave deposits are likely the hominins responsible for the production of the stone artifacts. Implications for Oldowan-like technological patterning in South China are discussed.

1. Introduction

It is generally accepted that the earliest hominins evolved in Africa, and then sometime after 2 million years ago dispersed into Eurasia (Bar-Yosef and Belfer-Cohen, 2001; Antón and Swisher, 2004; Norton and Braun, 2010; but see Dennell and Roebroeks, 2005 for alternative view). Following the important discoveries at Zhoukoudian in the early twentieth century, China has proven to be a key area for the study of human evolution and understanding the nature of hominin adaptation during the Pleistocene in a temperate/subtropical setting (Weidenreich, 1943; Aigner, 1981;

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An and Ho, 1989; Olsen and Miller-Antonio, 1992; Schick and Dong, 1993; Wu and Poirier, 1995; Etler, 1996; Hou et al., 2000; Zhu et al., 2003). The Chinese human fossil and archaeological records have greatly expanded over the past few decades (Shen and Keates, 2003; Wu, 2004; Shang et al., 2007; Norton and Jin, 2009; Bae, 2010; Liu et al., 2010). This new evidence has important implications for understanding the course of human evolution and Paleolithic trends not only in South China, a region well known for being distinctively different from North China (Olsen and Miller-Antonio, 1992; Gao and Norton, 2002; Norton and Jin, 2009), but also broader eastern Asia.

It has been suggested that a marked division of technological industries may exist between eastern Asia and large portions of the western Old World (Movius, 1944; Schick and Dong, 1993; Gao and Norton, 2002; Norton et al., 2006; Norton and Bae, 2009; Lycett and Bae, 2010; Lycett and Norton, 2010, among many others). Most notably, a low degree of standardization and lack of typical Acheulean (or 'Mode 2') handaxe technologies and Middle Paleolithic prepared core (i.e., 'Levallois' or 'Mode 3') industries is evidenced in eastern Asia (Movius, 1944). This geographic line of technological demarcation subsequently became known as the 'Movius Line' (Swartz, 1980). China is physically situated at the eastern end of the Eurasian landmass. The informality of the Early Paleolithic in China is one of its most interesting aspects (Clark and Schick, 1988; Norton and Jin, 2009). There are also casual cores and flakes with the focus of the "chopper-chopping tool" designation (Movius, 1948), a term, which now in large measure, has been discarded (Schick and Dong, 1993; Schick, 1994; Leng, 1998; Norton and Bae, 2009; Lycett and Norton, 2010).

It is generally accepted that there are two Paleolithic traditions in China. The first, a small, flake toolkit composed of microblades, a number of formal tools, and a bone industry, is recognized as the Flake Tool Tradition in northern China (Wang, 1998; Zhang, 2002). Some general characters of the Flake Tool tradition are: Most of the stone artifacts are small in size and less than 40 mm in length. The tools are mostly made on flakes and can be subdivided into scraper, pointed tool, awl, and chopper. Among them the scraper is the main type and the pointed tool is another important one. All tools are trimmed by hard hammer percussion and mainly retouched on the dorsal surface, therefore, they are not regular in shape and the working edges are zigzag (Zhang, 1999). The second tradition, occurring in southern China, continues the informal flake/core/chopper tradition made on cobbles. This technocomplex is referred to as the Pebble Tool Tradition (Wang, 1998; Zhang, 2002), with no noticeable changes until the Terminal Pleistocene (Olsen and Miller-Antonio, 1992; Gao and Norton, 2002; Norton and Jin, 2009; Norton et al., 2009). Some general characters of the regional stone tool industries are: 1) most of the stone artifacts are large, over 100 mm in length; 2) the tools mainly consist of choppers, and occasionally picks, bifaces, and cleavers; 3) a few scrapers and pointed tools are also contained in the assemblages; 4) all tools are crudely retouched by hard hammer percussion; and 5) tools are rather irregular in shape, the working edges are zigzag and the trimming scars are deep and broad in most cases (Zhang, 1999). The primary problem that hinders many reconstructions that include or focus on the Chinese record is that relatively few regions outside of the main flagship sites/basins (e.g., Zhoukoudian, Nihewan Basin, Bose

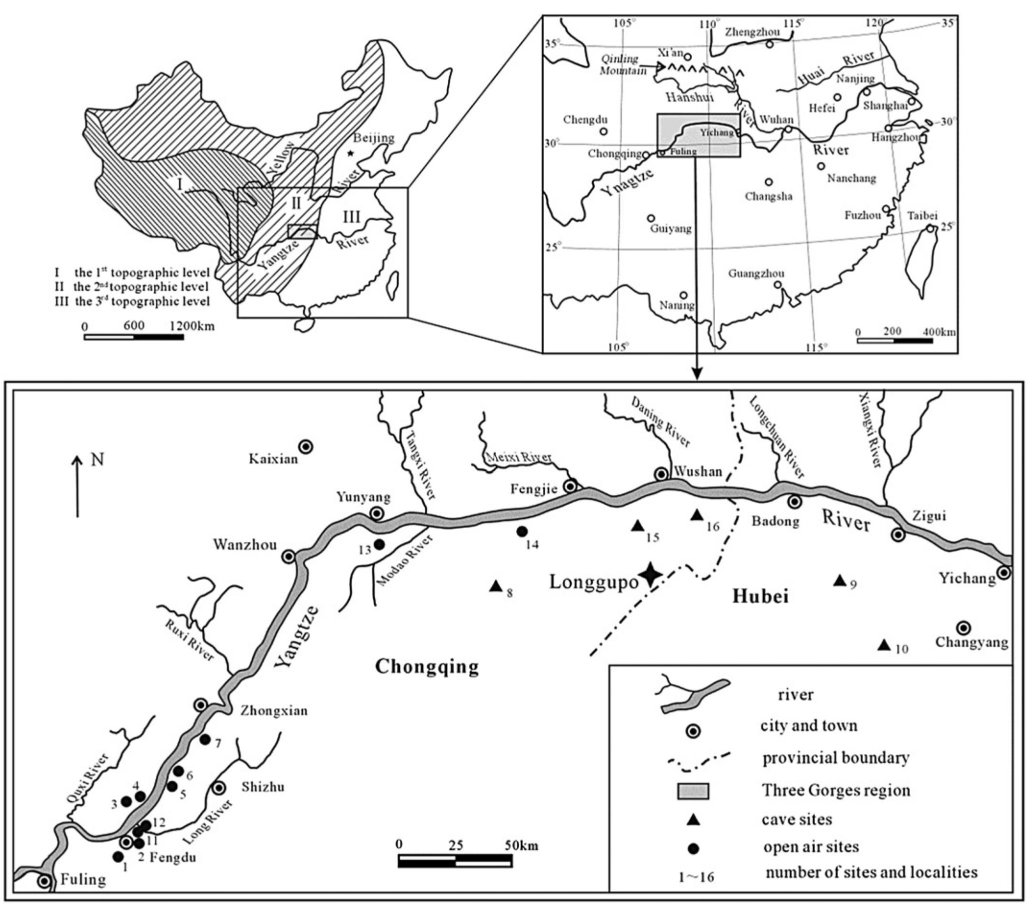

Fig. 1. Geographic location of major paleoanthropological and Paleolithic sites in the Three Gorges region. 1 Yandunbao 2 Miaogou, 3 Chibaling, 4 Ranjialukou, 5 Gaojiazhen, 6 Fanjiahe, 7 Wuyang, 8 Xinglong cave, 9 Sunjia cave, 10 Zhongjiawan cave, 11 Jingshuiwan, 12 Zaoziping, 13 Dadiping, 14 Outang, 15 Leiping cave, 16 Migong cave.

Basin) have been intensively researched (Norton and Braun, 2010).

The Three Gorges region, situated in East Chongqing National Central City and Southwest Hubei Province (latitude range 29°30′–31°30′N, longitude range 106°30′–111°30′E), is located in the transitional zone between the upper and middle reaches of the Yangtze River (Changjiang River). The Three Gorges region has always been considered an important region for the study of the origin and cultural development of ancient humans (Pei, 1937, 1955). It is also known as the region where the first Paleolithic archaeological investigations in China occurred. The earliest reported search for evidence of an early hominin presence in the region is from 1913, when J. H. Edgar discovered five lithic artifacts during field surveys carried out along the Yangtze River between Chongqing and Yichang (Edgar, 1933-1934). Between 1925 and 1926, N.C. Nelson collected about 20,000 Neolithic artifacts along the bank of the Yangtze River (Nelson, 1926). Bowles and Graham studied the stone artifacts and also claimed that some of the artifacts were Paleolithic remains (Graham, 1935). However, Pei Wenchong pointed out that some of the artifacts were not produced by hominins and some of them were Neolithic artifacts (Pei, 1955). In 1935, Chungchein Young and P. Teilhard de Chardin surface collected one lithic artifact from the river terrace west of Wanxian (Teilhard de Chardin and Young, 1935). In 1957, one hominin upper jaw fragment and one lower premolar were discovered from Zhongjiawan cave in Changyang County (Chia, 1957). In the spring of 1968 one "*Australopithecus*" tooth was collected from a local traditional medicine store in Badong, Hubei Province (Gao, 1975), which was later re-assigned to early *Homo erectus* by Zhang Yinyun in 1984 (Zhang, 1984). In 1984, one lower mandible fragment and an incisor of a purported early *H. erectus* [or an even earlier hominin (e.g., *Homo habilis*)] were found in association with an Early Pleistocene fauna (magnetostratigraphic dates range between 2.04 and 2.01 Ma) and two possible stone artifacts from Longgupo, a limestone cave in Miaoyu town, Wushan County (Huang et al., 1995; Huang and Hou, 1997). However, the mandible fragment may actually be the remains of *Lufengpithecus* or possibly a yet-to-be identified new ape (Schwartz and Tattersall, 1996; Etler et al., 2001; Etler, 2004; Ciochon, 2009; Norton et al., 2010a). The incisor has been ascribed to modern *Homo sapiens*, and it has been suggested that the tooth's position in the cave may be the result of a more recent secondary deposition (Wang, 1996; Etler et al., 2001; Etler, 2004). Later, a total of 26 stone artifacts from four levels (5–8 levels) were reported successively (Hou et al., 1999, 2002, 2006) from the second period excavation (1997–1998). The most recent stage of archaeological excavation at Longgupo (2003–2006) is being conducted by a Sino-France team which was carefully based on geological sequence (Boëda et al., 2011; Boëda and Hou, 2011a). Excavation has enabled recovery of 854 artifacts within 30 archaeological levels in the south sector and 11 in the north (Boëda and Hou, 2011b). Further, the artifactual nature of the stone tools from Longgupo has also been contested by recent research (e.g., Boëda and Hou, 2011a, b; but see Norton et al., 2010a and references therein).

For a long time, hominin fossils and stone artifacts deriving from unambiguous stratigraphic contexts had not been discovered in the Three Gorges Region. The breakthrough was due to the construction of the Chinese national government's initiative to build the Three Gorges Reservoir Dam. In the 1990s, a large scale Paleolithic reconnaissance was launched in this region as part of a salvage archaeological project, funded by the national government. Sixteen localities (fifteen new sites and the previously-identified Zhongjiawan cave, Changyang), that date to the Middle to Late Pleistocene, were further researched. Some of the better known sites include Migong cave (Huang et al., 2000), Leiping cave (Liu et al., 2006), Xinglong cave (Gao et al., 2004). Lithic artifacts and vertebrate fossils were also discovered on the fluvial terraces and caves along the Yangtze River (Wei et al., 1997; Wei, 2004; Pei et al., 2006a; Gao and Pei, 2010). Since 1995, a total of seven open-air sites and five cave sites were excavated by a joint archaeological team from the Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences ("IVPP") and the Chongqing Museum of Natural History.

This paper presents detailed findings of these recent archaeological field and laboratory initiatives in the Three Gorges Region. The focus is on the lithic assemblages recovered from seven archaeological sites, with discussion of the nature of hominin behavioral evolution during this spatio-temporal point.

2. Geological and environmental background

2.1. Geological context and chronological background

There are three major geomorphic levels in China (I, II, and III; Fig. 1 upper left). The highest one (I) is the Tibetan (Qinghai–Xizang) Plateau, located in western China, with an average elevation of about 4000–5500 m a.s.l. (meters above sea level). The second level (II) includes the Inner Mongolia Plateau, the Ordos Plateau, the Loess Plateau, and other plateaus in northwest and central China, with an average elevation of around 1000–2000 m a.s.l. The third level (III) consists mostly of hills, and plains, located in eastern China, with an average elevation below 200 m a.s.l. (Li et al., 1995). The Yangtze River is one of the largest rivers in the world. Originating from the Tibetan Plateau, the river flows eastward across the three major topographic levels eventually ending in the East China Sea. The Three Gorges region is located in the second transitional belt (Fig. 1.upper left), linking the upper rocky valley and the lower

Table 1
Chronology derived from the Three Gorges region and adjacent area (ages are listed from old to young).

Sample location	Geomorphic unit	Age (ka BP)	Dating methods	Sources
Chongqing-Fuling	T_7	1160.0	ESR	Li et al., 2001
Wushan County	T_7	950.0	ESR	Li et al., 2001
Chongqing-Fuling	T_6	860.0	ESR	Li et al., 2001
Chongqing-Fuling	T_5	730.0	ESR	Li et al., 2001
Chongqing-Fuling	T_4	490.0	ESR	Li et al., 2001
Yichang	T_4	310.49	ESR	Li et al., 2001
Sandouping (Yichang)	T_3	215.0	TL	Xie, 1990
Wushan County	T_3	147.8 ± 12	TL	Li, 1996
Ranjialukou(Fengdu County)	T_3	142.6 ± 11.6	OSL	Chen et al., 2004
Yichang	T_3	90.9 ± 4.5	TL	Yang, 1990
Fengdu County	T_3	81.34 ± 6.91	TL	Han et al., 2006
Ranjialukou(Fengdu County)	T_3	78.3 ± 4.1	OSL	Chen et al., 2004
Fengjie	T_2	75.13 ± 6.39	TL	Yang, 2006
Jingshuiwan (Fengdu County)	T_2	64.5 ± 4.1–75.8 ± 3.7	OSL	Pei et al., 2006a, b
Zhongxian County	T_2	61.93 ± 5.26	TL	Yang, 2006
Chongqing	T_2	45.92 ± 3.90	TL	Han et al., 2006
Fuling	T_2	38.33 ± 3.26	TL	Yang, 2006
Chongqing	T_2	28.3	TL	Han et al., 2006
Badong County	T_2	24.49 ± 0.84	^{14}C	Yang, 1988
Wushan County	T_1	13.4 ± 0.4	^{14}C	Yang, 1988
Zhongxian County	T_1	12.8	TL	Han et al., 2006
Fengjie County	T_1	102.86 ± 8.74	TL	Yang, 2006
Wushan County	T_1	9.1 ± 0.7	^{14}C	Li et al., 2001
Zhongxian County	T_1	7.22 ± 0.61	TL	Han et al., 2006
Badong County	T_1	6.64 ± 0.195	^{14}C	Xie, 1990
Yichang	T_1	6.57 ± 0.11	^{14}C	Xie, 1990

alluvial river channel and flood plain. The Three Gorges were formed primarily by episodic intense tectonic movement and river down cutting (Yang, 1988).

Early geological studies (e.g., Li, 1933; Barbour, 1935; Shen, 1965) proposed that the Yangtze River channelized through the Three Gorges region in the Neogene. Recent studies tend to place the timing of the formation of the Three Gorges region to sometime between 3.0 and 0.2 Ma (e.g., Yang and Chen, 1988; Wu, 1989; Tang and Tao, 1991; Zhao, 1996). Two planation surfaces, one erosional surface and seven terraces were developed in the Three Gorges region (Li and Xie, 1999). The higher planation surface (named the Exi Surface, 1800–2000 m a.s.l.) and the lower planation surface (1200–1500 m a.s.l.) were probably formed during the Neogene (prior to 3.4–3.6 Ma) (Yang, 1988). The erosional surface was developed during the Late Pliocene to Early Pleistocene. Yang et al. (2001) suggest that the ancestral Yangtze River began to restructure its drainage network after the last planation event. The erosional surface below these two planation surfaces is composed of valley basins, intermountain basins, and karst platforms, with altitudes ranging from 800 to 1200 m a.s.l. This surface occurs at different elevations in separate sub-drainage basins of the Yangtze throughout the Three Gorges. One electron spin resonance (ESR) date from the erosional surface (~1200 m a.s.l.) in the region suggests an age of 2.37 Ma (Li et al., 2001). Two other dates obtained by paleomagnetics and ESR from Longgupo (830 m a.s.l.) range between 2.01 and 2.04 Ma (Liu et al., 1988) and 1.8 Ma (Huang and Fang, 1991).

A series of alluvial terraces occur widely at different elevations in the Three Gorges region closely related to the uplift of the Qinghai-Tibetan Plateau. There are seven terraces (T_7–T_1, in

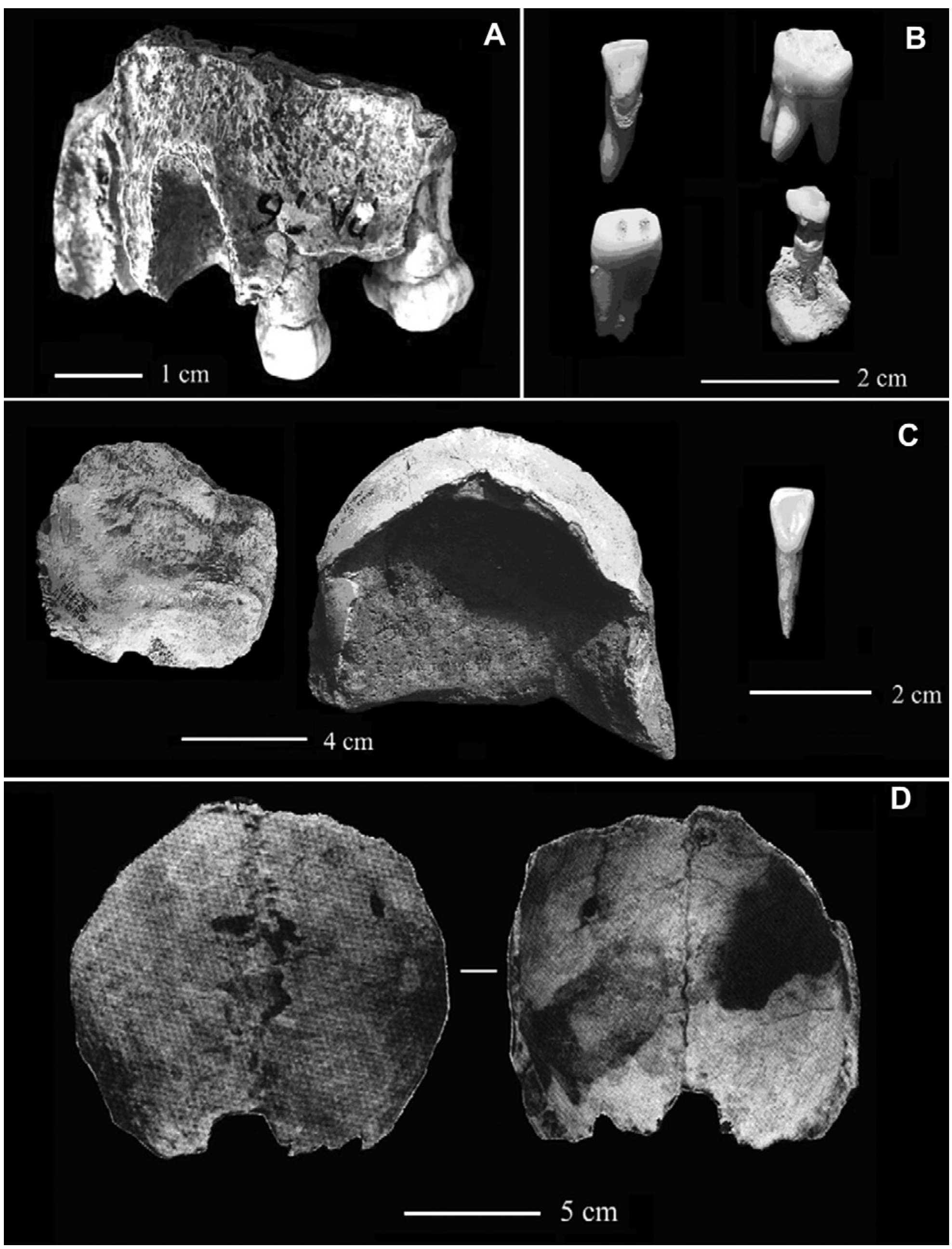

Fig. 2. Hominin fossils recovered from the Three Gorges region (re-edited after Wu et al., 2009). (A) maxilla from Zhaongjiawan cave, Chanyang, (B) hominid teeth from Xinglong cave, (C) huminid fossils from Leiping cave (left-parietal bone, middle-frontal bone, right-upper inciser), (D) parital bone from Migong cave (left-dorsal view, right-ventral view).

descending order from oldest to youngest) identified in the region. The presence of more resistant rocks and higher rates of tectonic uplift in the Three Gorges region impedes terrace development by vertical incision of river channel over lateral migration. In general, older and higher terraces are usually not well preserved due to tectonic activity, while younger and lower ones are widespread and well preserved. Recent investigations and comparisons about planation surfaces, erosional surface and seven terraces show that the terraces in the Three Gorges region are generally comparable in spatial and temporal settings to the terraces upstream east in the Sichuan Basin and downstream west in the Jianghan Basin (Li and Xie, 1999; Li et al., 2001). This serves to verify the evolution of the Yangtze River network during terrace development. The chronology for these terraces of the region is listed as follows.

Table 1 indicates that T_7–T_6 formed in the Early Pleistocene, T_5–T_4 in the Middle Pleistocene, T_3 in the late Middle to early Late

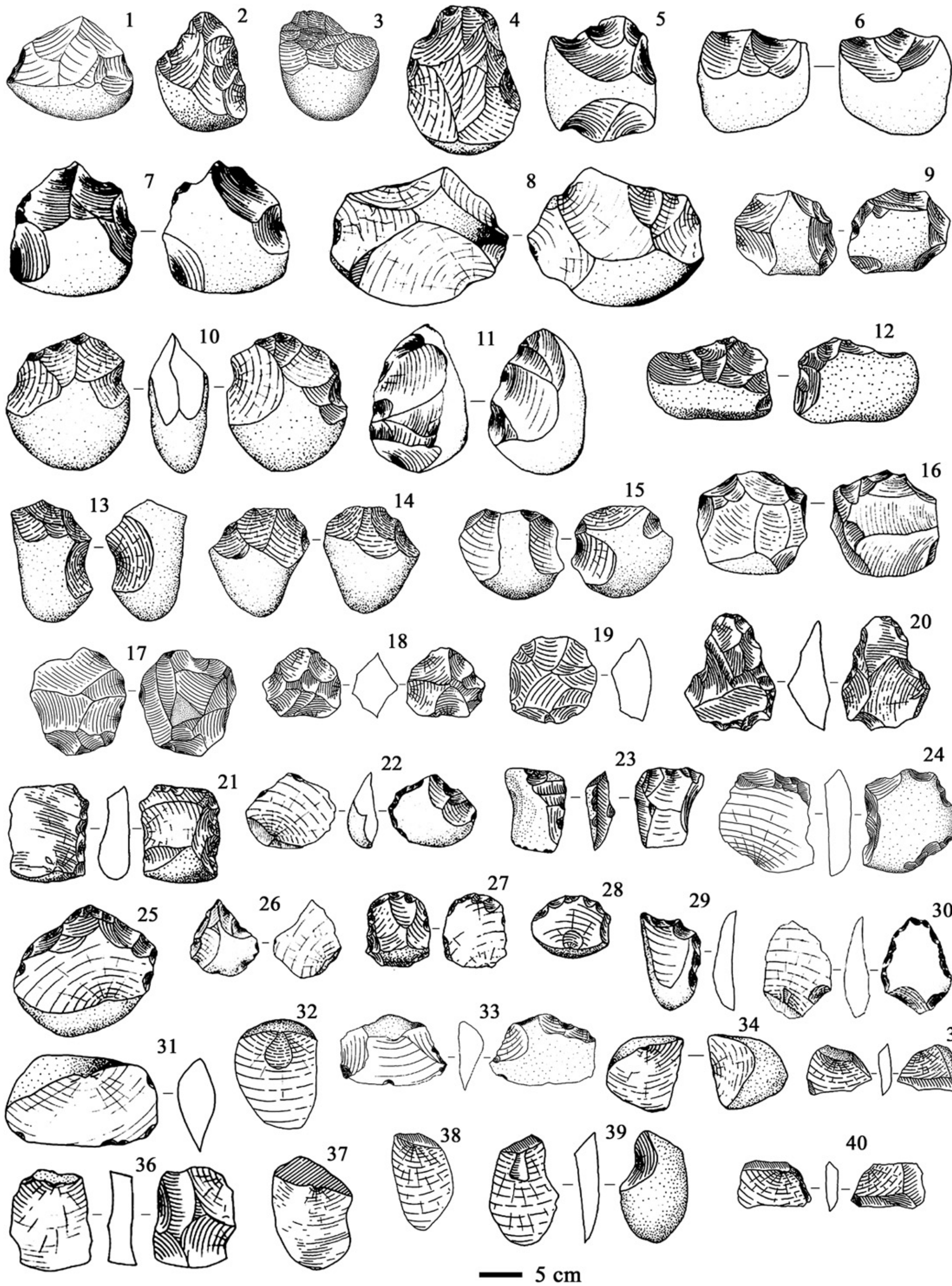

Fig. 3. Drawings of artifacts excavated from the Three Gores region (re-edited after Feng et al., 2003; Chen et al., 2004, Pei et al., 2004b, 2005, 2010; Ma et al., 2009; Peng et al., 2009). 1–5 unifacial choppers. 6–15 bifacial choppers. 16 polyhedron. 17–19 discoids. 20–21 bifaces. 22–30 retouched pieces. 31–40 complete flakes (1, 33) FJH, (2, 8, 12, 19–21, 27–28, 31, and 36) RJLK, (3, 24) CBL, (4–7, 11, 16, 23, 34, and 37) GJZ, (9, 18) ZZP, (10, 13–15, 22, 25–26, 29–30, 32, 35, and 38–40) JSW, (17) YDB. YDB, Yandunbao site; GJZ, Gaijiazhen site; FJH, Fanjiahe site; RJLK, Ranjialukou site; CBL, Chibaling site; JSW, Jingshuiwan site; ZZP, Zaoziping site.

Pleistocene, T_2 in Late Pleistocene, and T_1 most probably formed in the Early Holocene. The T_7–T_5 terraces belong to the base or erosional terrace type with few deposits preserved above the base surface, while T_4–T_1 all belong to the base terrace type with a thick layer of cobbles, sands, silt, and clay was preserved above the base surface. In the eastern part of the region, the bed rock is dominated by dolomite and limestone which resulted in the formation of karst caves. The deposits are usually dominated by cobble, sand, and silt laminae interbedded with many layers of carbonate concretions.

2.2. Environmental background

At the latitude of ca. 34°N, the Qinling Mountain Range – Huai River Line in central China is the traditional dividing line between the subtropical *Gigantopithecus* fauna of the Plio-Pleistocene and *Ailuropoda–Stegodon* fauna of the Middle to Late Pleistocene of South China and the Palearctic, temperate "Chinese Villafranchian" fauna or Nihewan fauna of North China (Aigner, 1981; Han and Xu, 1989; Pope et al., 1995; Norton et al., 2010b) (Fig. 1, upper right). The Three Gorges region belongs to the southeast warm-humid monsoon climate belt of the subtropical zone. It was generally dominated by a warm and humid climate intercalated with occasional periods of relatively dry-cold and dry-cool climate stages during the Quaternary (Han and Xu, 1985). The fauna unearthed from the caves of the Middle to Late Pleistocene belong to the *Ailuropoda–Stegodon* faunal complex, whose living environment was primarily restricted to subtropical wet-humid forests. The early Late Pleistocene fauna displayed transitional faunal features, and after the last glacial stage, the terminal Late Pleistocene showed no obvious differences from the present day. It should be noted that more detailed analyses of the *Stegodon–Ailuropoda* faunal complex in Bubing Basin, Guangxi Province has revealed that a great deal of temporal variation exists (Wang et al., 2007). It is likely that more detailed analyses of the Quaternary vertebrate paleontological remains from other regions of southern China will also indicate some degree of variability not previously recognized.

The spore-pollen analysis of the accumulations from the caves and different terraces indicate that this region was generally dominated by a humid and warm climate, which resulted in an environment dominated by evergreen broadleaf trees, coniferous trees, and mixed forest-prairie vegetation (Huang and Fang, 1991; Wang, 1998; Huang et al., 2000; Huang and Xu, 2002; Pei et al., 2004a).

3. Overview of the main sites from the Three Gorges region

One hominin upper jaw fragment and one lower premolar were discovered in Zhongjiawan cave, Changyang in 1957 (Chia, 1957). More recent fieldwork identified an additional 15 Paleolithic sites. The sites are cave and fissures and open-air localities (Fig. 1). The hominin fossils were generally found together with other faunas, but only a few stone artifacts in caves and fissures (Wu et al., 2009). The open-air sites are dominated by stone artifacts derived from buried alluvial terraces.

Table 2
Inventory of the stone artifacts and raw material exploitation of the Yandunbao site.

Artifact categories	Frequencies	Percentage	Volcanics		Quartz/quartzite		Others	
	N	%	*N*	%	*N*	%	*N*	%
Cores	147	13.2	39	3.5	107	9.6	1	
Retouched pieces	65	5.8	11	1.0	53	4.8	1	
Whole flakes	361	32.4	83	7.5	276	24.8	2	
Flake fragments	317	28.5	85	7.6	228	20.5	4	0.4
Chunks	218	19.6	74	6.6	140	12.5	4	0.4
Hammerstones	6	0.5	–	–	6	0.5	–	–
Total	1114	100	292	26.2	810	72.7	12	1.1

Table 3
Inventory of the stone artifacts and raw material exploitation of the Gaojiazhen site.

Artifact categories	Frequencies	Percentage	Volcanics		Quartz/quartzite		Others	
	N	%	*N*	%	*N*	%	*N*	%
Cores	379	52.7	220	30.6	154	21.4	5	0.7
Retouched pieces	46	6.4	12	1.7	34	4.7	0	
Whole flakes	111	15.4	63	8.8	45	6.3	3	0.4
Flake fragments	81	11.3	34	4.7	46	6.4	1	0.2
Chunks	102	14.2	43	5.9	56	7.8	3	0.4
Total	719	100	372	51.7	335	46.6	12	1.7

3.1. Cave sites

3.1.1. Zhongjiawan cave, Changyang

Zhongjiawan, developed in an area of Precambrian limestone, is located 1300 m a.s.l. on the southern slope of Guanlao mountain of Zhongjiawan, Huangjiatang, 45 km west of Chanyang, Hubei province. It was discovered in 1956 and test excavated in 1957 by archaeologists from the IVPP. The deposits of the cave consist of a fine, sandy dark yellow clay, with abundant limestone fragments and breccias interbedded in the deposits. Eighteen species of mammalian fossils were collected from the deposit and are attributed to the *Ailuropoda–Stegodon* faunal complex. Evaluation of the deposits suggests the materials are a secondary deposit. The hominin material consists of a partial left maxilla with two socketed teeth (P3 and M1) and one isolated left M2 (Fig. 2). The crowns and roots of these teeth are much larger and more complex in their patterns than those of modern humans, but smaller and simpler than the Zhoukoudian Locality 1 *H. erectus* (Chia, 1957). Based on biostratigraphy, the age of the hominin fossils is attributed to the late Middle Pleistocene (Chia, 1957).

3.1.2. Sunjia cave

Sunjia cave, developed in the Ordovician limestone, is located 820 m a.s.l. on the right bank of the Luogudong River, Erjia village, Lianghekou, 50 km southwest of Zigui County, Hubei province. It was discovered in 1994 by archaeologists from the IVPP. The cave is 60 m long, 3.5 m high, and 3 m wide. The deposits of the cave consist of yellow sandy clay and do not appear to be disturbed. Eight mammalian species were identifies and 17 stone artifacts were collected from the sediments. The paleontological remains have been assigned to the *Ailuropoda–Stegodon* faunal complex. Based on biostratigraphy, Sunjia dates to the late Middle Pleistocene (Dong, 1998). The lithic assemblage is comprised of 3 choppers, 6 retouched pieces, 6 flakes, one chunk, and one stone hammer.

Table 4
Descriptive statistics for variables measured on cores, retouched pieces, and whole flakes of Gaojiazhen.

Artifact categories	Statistics	Length (mm)	Breadth (mm)	Thickness (mm)	Mass (g)
Cores ($n = 379$)	Mean	184.8	142.4	79.2	3014.4
	SD	39.8	28.1	19.3	1807.9
	Range	96–305	61–219	38–159	455–17,000
Retouched pieces ($n = 46$)	Mean	122.4	110.3	43.8	937.7
	SD	29.3	30.7	22.1	478.1
	Range	51–191	63–197	10–98	110–3480
Whole flakes ($n = 111$)	Mean	100.5	94.8	36.8	511.4
	SD	31.8	27.6	15.2	493.9
	Range	21–182	36–156	6–84	8–3400

Table 5
Mean sizes of the stone artifacts from Fanjiahe site complex ($n = 86$).

Artifact categories	Length (mm)	Breadth (mm)	Thickness (mm)	Mass (g)
Cores ($n = 23$)	169.6	146.9	68.7	2572.9
Retouched pieces ($n = 9$)	111.2	100.4	31.1	472.8
Whole flakes ($n = 10$)	101.9	113.6	40.9	765.1
Flake fragments ($n = 2$)	69.0	63.5	30.5	211.5
Chunks ($n = 40$)	139.0	94.5	54.2	1431.4
Hammers tones ($n = 4$)	138.5	71.0	38.5	685.0

3.1.3. Xinglong cave

Xinglong cave was discovered and excavated in 2001 by Professor Wanbo Huang from the IVPP. It is located 1100 m a.s.l. at N108°45′-109°37′, E30°30′-30°55′ in Yunwu, Wushan County. The cave is developed in an area of karst landform, surrounded by karst basins and cliffs. The cave entrance, opening to the southwest and filled with deposits at the bottom, is currently less than 1.5 m high but is estimated to have been originally around 3 m high. The stratigraphic sequence of Xinglong is divided into six layers of breccias and sandy clay. The uppermost part of the cave deposits has been removed and disturbed, while the rest appears to be original deposition. The hominin fossils, archaeological and paleontological remains were identified in clear primary context in the lower part of the sandy clay, 60 cm in thickness, and between 15 and 35 cm from the base of the deposits. A total of 51 mammalian species were excavated from the archaeological layers. These are mainly from the *Ailuropoda–Stegodon* faunal complex. Similarity with the Yanjinggou Fauna (Colbert and Hooijer, 1953), a typical Middle Pleistocene fauna in South China, indicates that the archaeological level was formed during the Middle Pleistocene. Uranium series (U-series) dating on ancient animal bones and teeth from the archaeological level resulted in an age between 118 ± 7–154 ± 9 ka; thus, corroborating the relative age derived from the paleontology (Huang and Xu, 2002; Gao et al., 2004).

Four hominin permanent teeth were recovered during the 2001 excavation field season (Fig. 2). These hominin fossils have been tentatively assigned to archaic *H. sapiens*, though more detailed morphometric analysis is warranted.

Twenty lithic artifacts were excavated, including 13 choppers, 1 core, 1 flake, 1 point, and 4 scrapers. The primary raw material was locally available limestone, though a few flint chunks and debris were also found. Some of the choppers and flakes can be refitted and direct hard hammer percussion appears to have been the flaking method.

Fig. 4. A photo showing the stratigraphic section of Ranjialukou site of 2007(view from north).

Table 6
Inventory of the stone artifacts and raw material exploitation of the Ranjialukou site.

Artifact categories	Frequencies	Percentage	Volcanics		Quartz/Quartzite		Others	
	N	%	*N*	%	*N*	%	*N*	%
Cores	467	28.4	100	6.1	365	22.2	2	0.1
Retouched pieces	264	16.1	79	4.8	183	11.2	2	0.1
Whole flakes	382	23.3	98	6.0	281	17.1	3	0.2
Flake fragments	335	20.4	77	4.7	254	15.5	4	0.2
Chunks	193	11.8	45	2.7	147	8.9	1	
Total	1641	100	399	24.3	1230	74.9	12	0.7

3.1.4. Leiping cave

Leiping cave, developed in the Triassic Jialingjiang limestone, is located in Guandu town, Wushan County. It was discovered by Professor Wanbo Huang from the IVPP in 2004. Hominin fossils including one occipital, some fragments of skull, and a frontal bone of one juvenile, and one upper incisor were collected from the sediments and tentatively assigned to archaic *H. sapiens* (Fig. 2). In addition, some stone artifacts and over 10 species of mammalian fossils were also discovered. The paleontological remains belong to the *Ailuropoda–Stegodon* faunal complex. Based on biostratigraphy, Leiping appears to have been occupied sometime during the late Middle to early Late Pleistocene (Liu, 2006; Liu et al., 2006).

3.1.5. Migong cave

Migong cave is located at 165–258 m a.s.l. on the right bank of the Yangtze River and 75 km southeast of Wushan County at N 30°32′, E 108°52′. It formed in the Triassic Jialingjiang Formation limestone. The cave was discovered and excavated by Professor Wanbo Huang from the IVPP in 1999. The deposits of the cave consist of three parts: The upper part is breccia about 0.2 m in thickness. The middle part is about 1.5 m thick of brown sandy clay, and the lower part is mainly sediments of gravels and sands. Two partial hominin fossil bone, 23 stone artifacts, and over 40 species of mammalian fossils were unearthed from the lower part. The faunal assemblage is typical *Ailuropoda–Stegodon* fauna complex. A ^{14}C dating analysis on bones from the middle level yielded an age of 13,150 ± 0.19 ka, which indicates that the human activities at the cave most likely occurred during the Terminal Pleistocene (Huang et al., 2000).

The hominin fossils are two fragments of parietal bones which belong to one individual (Fig. 2) and can be assigned to modern *H. sapiens*. The stone assemblage includes 5 choppers, 3 retouched pieces, 3 core fragments and 12 chunks.

Table 7
Descriptive statistics for variables measured on cores, retouched pieces, and whole flakes of Ranjialukou.

Artifact categories	Statistics	Length (mm)	Breadth (mm)	Thickness (mm)	Mass (g)
Cores ($n = 467$)	Mean	147.1	118.5	68.1	1737.6
	SD	37.1	32.7	22.5	1311.2
	Range	53–291	50–212	21–151	100–6600
Retouched pieces ($n = 264$)	Mean	99.2	101.8	39.1	539.7
	SD	30.0	31.1	16.9	405.9
	Range	40–220	27–188	32–68	50–2300
Whole flakes ($n = 382$)	Mean	91.7	97.8	33.1	507.7
	SD	33.3	32.9	12.3	521.6
	Range	32–230	40–195	10–70	30–3000

Table 8
Mean sizes of the artifacts from Chibaling site complex ($n = 213$).

Artifact categories	Frequencies N	Percentage %	Length (mm)	Breadth (mm)	Thickness (mm)	Mass (g)
Cores	69	32.4	136.0	121.0	59.0	1366.0
Retouched pieces	17	8.0	92.7	104.1	39.4	510.0
Whole flakes	25	11.7	91.3	99.4	32.0	418.2
Flake fragments	32	15.0	81.4	71.7	23.9	221.5
Chunks	70	32.9	99.0	92.0	51.0	686.0

3.2. *Open-air sites*

Eleven Paleolithic sites were discovered from the 2nd to 4th terraces of the Yangtze River, of which seven have been excavated during the past 15 years. The most representative sites are described below.

Because there is no single standardized typology for the Chinese Paleolithic stone tool industries (for discussion see Jia et al., 1972; Gao, 2002; Gao and Norton, 2002), discussion relies primarily on the classification systems of Leaky (1971) and Toth (1985) that were developed to describe the African Oldowan industries. The artifact classification protocol used is as follows: artifacts were first divided into major categories (cores, retouched pieces, debitage, and percussors). Classification divided cores into unifacial choppers, bifacial choppers, discoids, polyhedrons, and bifaces. Debitage was divided into whole flakes, flake fragments, and chunks. Breakdowns of the following artifact classes are presented, as well as descriptive statistics where applicable: cores; retouched pieces; whole flakes; flake fragments; chunks. Whole flakes were classified into six flake types (type I ~ VI), based primarily on the technological information they retain on their platforms and dorsal surfaces with regard to prior flaking of the cores (Toth, 1985; Toth and Sckick, 2009).

3.2.1. *Yandunbao*

Yandunbao is situated 210–220 m a.s.l. on the 4th terrace of right bank of the Yangtze River at N 29°52′18″, E 107°43′41″. It is located in Sanhe town, Fengdu County. The site was discovered in 1994 and excavated in 1994, 1995, 1996, and 1998. The excavations exposed an area of more than 900 m^2. Four stratigraphic layers were identified at the site, with a total thickness of more than 3.8 m. A large number of stone artifacts (>1300) were unearthed from the 2nd to 4th layers of red fine sandy clay, 3.4 m in thickness (Feng et al., 2003). The site was relative dated based on its location on the 4th terrace, which is thought to date to the Middle Pleistocene. No paleontological fossils were discovered that could be used for chronometric or biostratigraphic dating. A representative sample of artifacts is presented in Fig. 3.Table 2 summarizes the contents of the lithic assemblage in terms of provenience, artifact categories, and raw materials.

The cores include 113 unifacial choppers, 31 bifacial choppers, and 3 discoids. The cores are large and heavy with average dimensions of 151.8 mm (length), 111.2 mm (breadth), 63.5 mm (thickness), and 1539.4 g (mass). Whole flakes forms the dominant debitage compared with the flake fragments and chunks. The maximum dimension of whole flakes ranges between 23 mm and 200 mm, with a mean of 76.6 mm. The mass ranges between 10 g and 1580 g, with a mean of 228.2 g. The majority of the flakes have cortical platforms (72.3%) (types I, II, and III), while flakes with non-cortical platforms (type IV, V and VI) comprise only 27.7% of the total. Type III ($n = 104$, 28.8%) is the most representative type of flake with cortical platforms, followed by type I ($n = 81$, 22.4%), and type II ($n = 76$, 21.1%), while type V ($n = 47$, 13.0%) is the major type of flake without cortical platforms, followed by type VI ($n = 35$, 9.7%) and type IV ($n = 18$, 5.0%). The retouched pieces are mainly flakes using unifacial hard hammer percussion.

3.2.2. *Gaojiazhen*

Gaojiazhen is situated at 178 m a.s.l. on the 3rd terrace of the right bank of the Yangtze River at N 30°00′16″, E 107°50′54″. It is located in the Guihuacun village, Gaojiazhen town, Fengdu county. The site was discovered in 1994 and excavated in 1995 and 1998, exposing an area of about 456 m^2. Four stratigraphic layers were identified at the site, with a total thickness of more than 9 m. The site was relative dated based on its position on the 3rd terrace, which is thought to date to the late Middle to early Late Pleistocene.

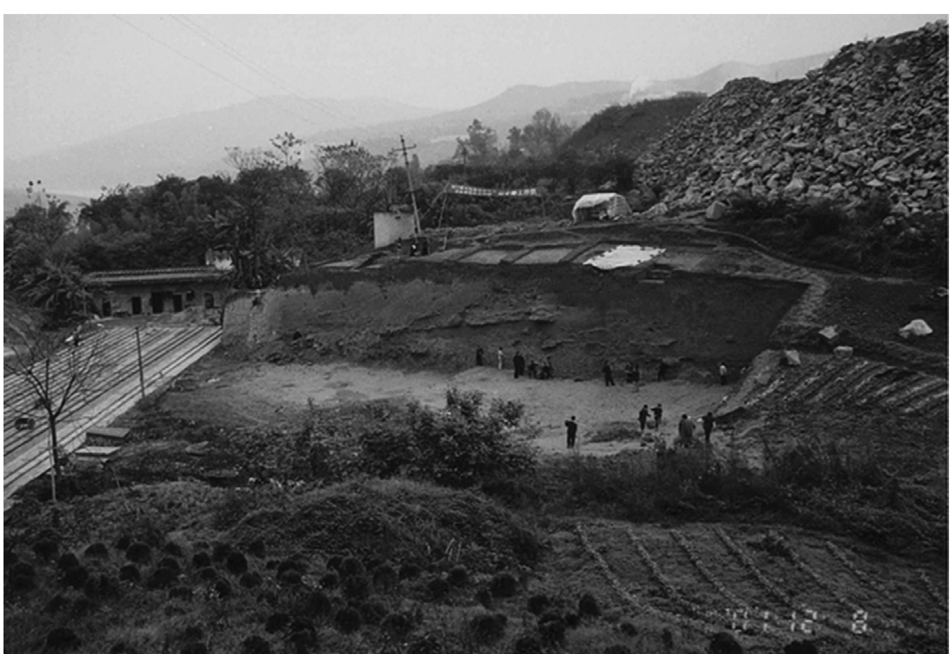

Fig. 5. A photo showing the Jingshuiwan excavation in 2001 (view from west).

Table 9
Inventory of the stone artifacts and raw material exploitation of the Jingshuiwan site.

Artifact categories	Frequencies	Percentage	Volcanics		Quartz/Quartzite		Others	
	N	%	N	%	N	%	N	%
Cores	329	36.2	142	15.6	182	20.0	5	0.6
Retouched pieces	93	10.2	31	3.4	61	6.7	1	0.1
Whole flakes	281	30.9	137	15.1	137	15.1	7	0.8
Flake fragments	101	11.1	52	5.7	47	5.2	2	0.2
Chunks	102	11.2	36	3.9	62	6.8	4	0.4
Hammerstones	4	0.4	–	–	4	0.4	–	–
Total	910	100	398	43.7	493	54.2	19	2.1

Stone artifacts were mainly unearthed from the top of the 4th layer, a layer of alluvial cobbles, ~210–215 cm in thickness, 174–178 m a.s.l. (Pei et al., 2005). Table 3 summarizes the stone artifacts and utilized raw materials. Table 4 presents the descriptive statistics for variables measured on the cores, retouched pieces, and whole flakes. The cores are classifiable as unifacial choppers ($n = 224$), bifacial choppers ($n = 150$), polyhedrons ($n = 3$), and discoids ($n = 2$). A representative sample of the Gaojiazhen artifacts is presented in Fig. 3. Most of the cores retain some cortex, with a range from 15% to 95% and a mean percentage of 66.0%.

A total of 111 whole flakes were excavated from Gaojiazhen. The first three flake types, those with cortical platforms (types I, II, and III), are the most abundant amounting to 22.5%, 54.1%, and 9.0%, while the last three flake types without cortical platforms (types IV, V, and VI) represent only 0.9%, 11.7%, and 1.8% of the collection. Forty six retouched pieces are mainly retouched on flakes using unifacial hard hammer percussion.

3.2.3. Fanjiahe

Fanjiahe is situated at 182 m a.s.l. on the 3rd terrace of the right bank of the Yangtze River at N 30°00′26″, E 107°51′32″. It is located in Fanjiahe village, Gaojiazhen town, Fengdu County. The site was discovered in 1994 and excavations conducted in 2007 exposed an area of 209 m^2. The upper section is composed of fluvial deposits about 9 m thick of sand and silt, intercalated with several lentoids of carbonate congregations. The site was relative dated based on its position on the the 3rd terrace, which is thought to date to the late Middle to early Late Pleistocene. Stone artifacts were unearthed from the top of the cobble layer (174–178 m a.s.l.).

A total of 86 stone artifacts were recovered during the excavation (Fig. 3). Quartz and quartzite (59.3%) are the major raw materials, followed by volcanics (37.2%), with only 3.5% produced on other raw materials.

Descriptive statistics of the stone artifacts are presented in Table 5. The length of most artifacts (59.3%) was between 100 and 200 mm, about 24.4% were 50–100 mm long, and 16.3% of the artifacts were >200 mm respectively. No artifacts less than 50 mm were collected. The cores are classifiable as unifacial choppers ($n = 20$) and bifacial choppers ($n = 3$). Ten whole flakes are classified as type I ($n = 8$) and II ($n = 2$). Nine retouched pieces were collected from Fanjiahe. The length of the retouched pieces varied from 55 to 230 mm, with a mean length of 111.2 mm. The mass of the retouched pieces varied from 140 to 1320 g, with a mean of 472.8 g.

Table 10
Descriptive statistics for variables measured on cores, retouched pieces, and whole flakes of Jingshuiwan.

Artifact categories	Statistics	Length (mm)	Breadth (mm)	Thickness (mm)	Mass (g)
Cores ($n = 329$)	Mean	127.5	105.4	60.6	1271.8
	SD	33.9	29.8	20.9	1124.4
	Range	57–270	44–200	21–155	100–8085
Retouched pieces ($n = 93$)	Mean	87.3	86.7	28.9	187.5
	SD	27.1	21.9	8.6	114.1
	Range	46–148	33–134	9–60	20–545
Whole flakes ($n = 281$)	Mean	92.2	97.9	31.6	438.6
	SD	32.5	36.1	13.9	520.3
	Range	23–190	31–220	5–95	5–2920

Table 11
Mean sizes of the stone artifacts from the Zaoziping site complex ($n = 101$).

Artifact categories	Frequencies N	Percentage %	Length (mm)	Breadth (mm)	Thickness (mm)	Mass (g)
Cores	23	22.7	99.6	80.1	46.2	487.4
Retouched pieces	12	11.9	62.6	61.5	20.3	83.7
Whole flakes	40	39.6	58.2	61.4	18.5	81.1
Flake fragments	16	15.9	50.3	41.6	14.2	52.8
Chunks	9	8.9	73.5	53.0	28.3	185.5
Hammerstone	1	1.0	109	75	65	750

3.2.4. Ranjialukou

Ranjialukou is buried at 176 m a.s.l. on the 3rd terrace of the left bank of the Yangtze River at N 29°55′14–16″, E 107°44′11–56″. It is located in the Ranjialukou village, Zhenjiang town, Fengdu County. The site was discovered in 1994 and excavated in 2000, 2001, 2005, and 2007. The excavations exposed a total area of about 3804 m^2. Five stratigraphic layers were identified, with a total thickness of more than 5 m (Fig. 4). A total of 1641 stone artifacts and several nonhuman mammalian teeth and bone fragments were excavated from the top of the 5th layer, a layer of alluvial cobbles 110–310 cm in thickness. Quartz grains from the fluvial sediments of the 4th layer of the 3rd terrace were dated using optically stimulated luminescence/single aliquot regenerative-dose technique (OSL) yielding an age of 78.3 ± 4.1–142.9 ± 11.6 ka (Chen et al., 2004; Gao et al., 2008; Peng et al., 2009).

Inventory of the stone artifacts and utilized raw materials are shown in Table 6. A representative sample of artifacts is presented in Fig. 3. Table 7 presents the descriptive statistics for the cores, whole flakes, and retouched pieces. The artifacts are large and heavy. The length of most artifacts (63.1%) is between 100 and 200 mm, about 25.3% are 50–100 mm long, and a total of 8.5% and 3.1% of the artifacts are >200 mm and <50 mm long respectively. No artifacts less than 20 mm were collected.

The cores are classifiable as unifacial choppers ($n = 408$), bifacial choppers (52), with only 3, 2, and 2 artifacts classified as polyhedrons, discoids, and bifaces. A total of 382 whole flakes were

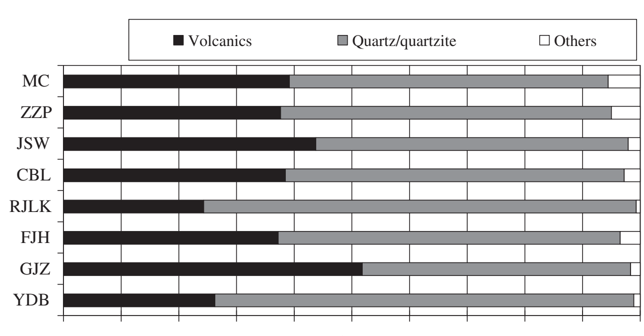

Fig. 6. Diagram showing the different raw materials exploited in different sites and modern river bed in the region. YDB, Yandunbao site; GJZ, Gaijiazhen site; FJH, Fanjiahe site; RJLK, Ranjialukou site; CBL, Chibaling site; JSW, Jingshuiwan site; ZZP, Zaoziping site; MC, Modern cobble.

excavated, representing 23.3% of the artifact assemblage. The first three flake types, those with cortical platforms (types I, II, and III), are the most abundant, representing 52.1% (n = 199), 25.9% (n = 99), and 9.7% (n = 37), while the last three flake types without cortical platforms (types IV, V, VI) represent only 5.0% (n = 19), 7.1% (n = 27), and 0.2% (n = 1). Overall, 264 retouched pieces were excavated. Most of the modified tools appear to have been retouched unifacially by direct hard hammer percussion.

3.2.5. Chibaling

Chibaling is buried at 178 m a.s.l. on the 3rd terrace of the left bank of the Yangtze River at N 29°54′53″, E 107°44′29″. It is located in the Zhenjiang town, Fengdu County. The site was discovered in 1994. An excavation conducted in 2007 exposed an area of 514 m^2. The upper fluvial deposits of sand and silt (4 m thick) covered the cobble layer (3–5 m thick). Stone artifacts were unearthed from the top of the cobble layer (Ma et al., 2009). The site was relative dated based on its position on the 3rd terrace, which is thought to date to the late Middle to early Late Pleistocene.

The excavation yielded 213 stone artifacts (Fig. 3). Quartz and quartzite (58.7%) are the major raw materials, followed by volcanics (38.5%), with only 2.8% produced on other raw materials.

Table 8 presents the Chibaling artifacts descriptive statistics. The length of most of the artifacts (60.1%) is between 100 and 200 mm,

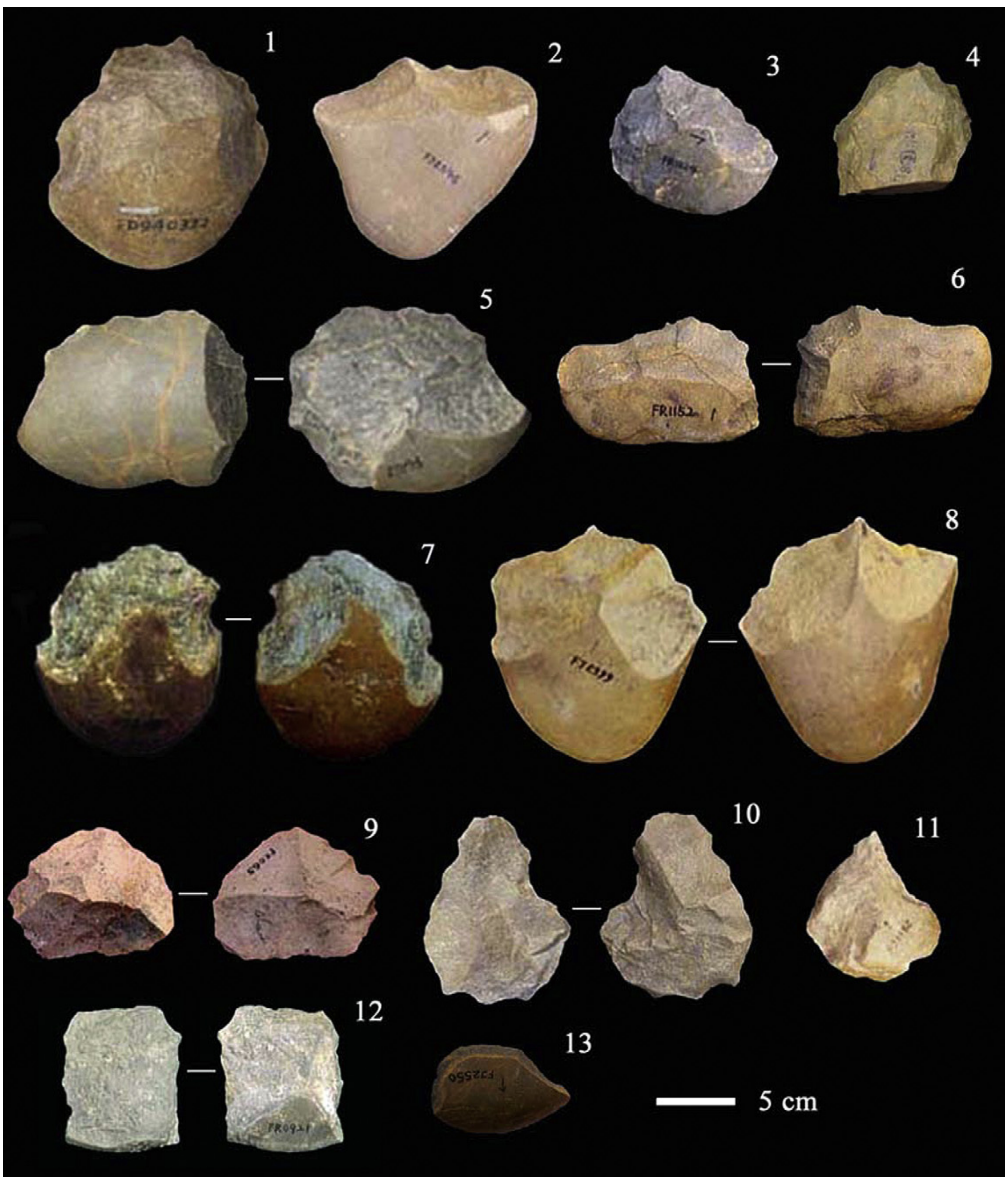

Fig. 7. Photos showing the cores and retouched pieces from the Three Gorges region. 1–4 unifacial choppers (1 and 4 from GJZ, 2 from JSW, 3 from RJLK), 5–8 bifacial choppers (5 from GJZ, 6 from RJLK, 7 and 8 from JSW), 9 discoid from ZZP, 10 and 12 bifaces from RJLK, 11 and 13 retouched pieces from JSW. YDB, Yandunbao site; GJZ, Gaijiazhen site; FJH, Fanjiahe site; RJLK, Ranjialukou site; CBL, Chibaling site; JSW, Jingshuiwan site; ZZP, Zaoziping site.

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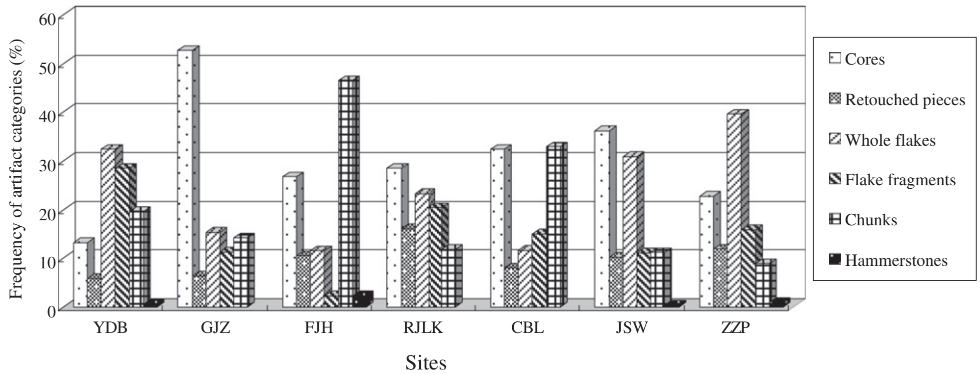

Fig. 8. Frequencies of representation of the different technological categories among different sites. YDB, Yandunbao site; GJZ, Gaijiazhen site; FJH, Fanjiahe site; RJLK, Ranjialukou site; CBL, Chibaling site; JSW, Jingshuiwan site; ZZP, Zaoziping site.

about 35.7% are 50–100 mm long, with only 4.2% of the artifacts >200 mm respectively. No artifacts less than 50 mm were found. The cores are classified as unifacial choppers ($n = 51$) and bifacial choppers (18). The flakes with cortical platforms are the most abundant, amounting to 92.0% ($n = 23$), with the flakes without cortical platforms representing only 8% ($n = 2$). Type I (15 pieces) and type II (8 pieces) are the dominant flake classes, with only 2 flakes attributed to type IV and type V. No type III or type VI flakes were identified. Seventeen retouched pieces were found.

3.2.6. *Jingshuiwan*

Jingshuiwan is situated at 168 m a.s.l. on the 2nd terrace along the right bank of the Yangtze River at N 29°52′38″, E 107°43′05″. It is located in the Sanhe town, Fengdu County. The site was discovered in 1994 and excavated from 1998 to 2002 for five successive seasons, exposing an area of about 2132 m^2. The profile is composed of fluvial deposits 16 m thick of sand and silt laminae, which can be classified into seven distinct stratigraphic layers interbedded with several lentoids of carbonate congregations (Fig. 5). Archaeological remains were mainly unearthed from the 7th layer, a layer of fine sands, 2.0 m in thickness, ~158–162 m a.s.l. Quartz grains from the fluvial sediments of layer 7 (which contained the artifacts) were dated using OSL, yielding an age of 64.5 ± 4.1–75.9 ± 3.7 ka (Pei et al., 2006b).

Fifty eight mammalian fossils and 910 stone artifacts were found at Jingshuiwan (Pei et al., 2003, 2010). The frequencies of each artifact type and utilized raw materials are summarized in Table 9. Fig. 3 presents a selection of representative stone artifacts.

The length of most of the artifacts (59.3%) is between 100 and 200 mm, and about 36% are 50–100 mm long, with 2.7% and 2.0% of the artifacts >200 mm and <50 mm long respectively. No artifact less than 20 mm was collected. Descriptive statistics for the Jingshuiwan cores, retouched pieces, and whole flakes are presented in Table 10.

A total of 304 cores are classified as unifacial choppers ($n = 216$) and bifacial choppers (113). Two hundred and eight-one whole flakes, produced by direct hard hammer percussion, were excavated, of which 192 (68.3%) had a cortical platform. Type I (87 pieces) and type II (90 pieces) flakes are the dominant flake classes, followed by type III (15 pieces). In all, 89 (or 31.7%) of the flakes can be classified as non-cortical platform flakes. Among the non-cortical platform pieces, type V (60 pieces) is the dominant flake class, followed by type IV (26 pieces), and type VI (3 pieces). The size of the flakes varies greatly. Ninety three retouched pieces were identified. Most of them appear to have been retouched by direct hard hammer percussion, with more than 60% retouched unifacially.

3.2.7. *Zaoziping*

Zaoziping is situated at 165 m a.s.l. on the 2nd terrace of the right bank of the Yangtze River at N 29°52′44″, E 107°44′09″. It is located in the Zaoziping village, Sanhe town, Fengdu County. It was discovered in 1994 and excavated in 2000 and 2002, exposing an area of 1000 m^2. The profile is composed of fluvial deposits 14 m thick of sand and silt laminae, which can be divided into four stratigraphic layers, interbedded with several lentoids of carbonate congregations. Stone artifacts were mainly unearthed from the 4th layer, scattered on the surface of the base, ~150–156 m a.s.l. (Pei et al., 2004b). The site was relative dated based on its position on the 2nd terrace, which is thought to date to the Late Pleistocene.

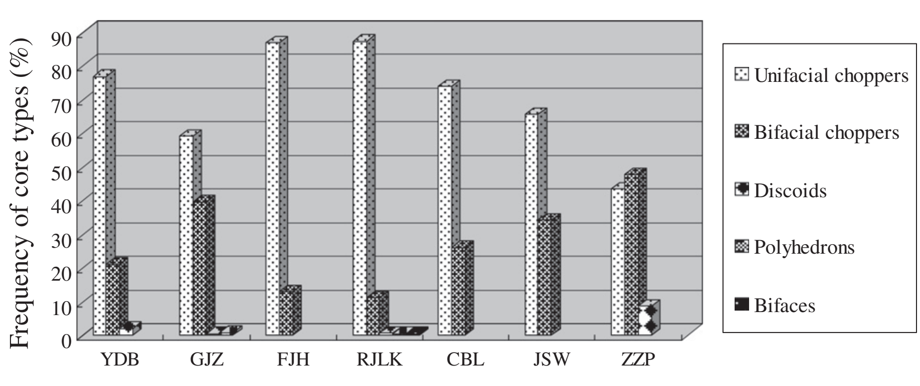

Fig. 9. Diagram showing core breakdown variation among different sites. YDB, Yandunbao site; GJZ, Gaijiazhen site; FJH, Fanjiahe site; RJLK, Ranjialukou site; CBL, Chibaling site; JSW, Jingshuiwan site; ZZP, Zaoziping site.

Table 12
Variation in the maximum dimensions of the stone artifacts among different sites.

Artifact length	Yandunbao		Gaojiazhen		Fanjiahe		Ranjialukou		Chibaling		Jingshuiwan		Zaoziping	
	N	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
<20 mm	17	1.5	1	0.1	0	0	0	0	0	0	0	0	0	0
20–50 mm	125	11.2	21	2.9	0	0	50	3.1	0	0	18	2.0	74	73.7
50–100 mm	280	25.2	109	15.2	21	24.4	415	25.3	76	35.7	328	36.0	12	11.9
100–200 mm	613	55.0	463	64.4	51	59.3	1036	63.1	128	60.1	540	59.3	15	14.8
>200 mm	79	7.1	125	17.4	14	16.3	140	8.5	9	4.2	24	2.7	0	0
Total	1114	100	719	100	86	100	1641	100	213	100	910	100	101	100

A total of 101 stone artifacts were excavated. Fig. 3 presents a selection of the artifacts. Quartz and quartzite (57.4%) are the main raw materials, followed by volcanics (37.6%), with only 5% produced on other raw materials.Table 11 presents descriptive statistics of the artifacts.

The cores are classified as unifacial choppers ($n = 10$) and bifacial choppers ($n = 11$), with only 2 artifacts assigned to discoids. Whole flakes were recovered and classified to type I ($n = 9$), type II ($n = 11$), type III ($n = 1$), type IV ($n = 8$), and type V ($n = 11$). No type VI flakes were identified. Only 12 retouched pieces were collected.

4. Inter-site technological variation

Evaluating the nature of inter-site artifact variation can provide important information to any reconstructions of hominin behavior (e.g., Gao and Norton, 2002; Stout et al., 2010). Preliminary descriptions of inter-site variability are presented using archaeological variables (e.g., raw material exploitation, artifact types, flaking technique, and retouched technology) of the seven artifact assemblages described above from the open-air sites.

4.1. Raw material exploitation

In the Three Gorges region, limestone, feldspar sandstone, siltstone and shale with vein quartz are present as bed rock of the Yangtze River. In general, these could not be exploited as raw materials for stone tools because of their hardness, isotropism and brittleness. The Yangtze River originated from the Qinghai-Tibetan Plateau, and different types of rocks were transported along the river. Large water-rounded pebbles could be obtained from the river bed and used as raw materials for manufacturing artifacts. This inference is supported by high proportions of cortical cores, flakes, and flake fragments and by our survey of raw materials in contemporary exposures and the modern channel beds. Fig. 6 shows the different raw materials exploited in the different sites. The majority of the artifacts from Yandunbao and Ranjialukou sites are made of quartz and quartzite, which amount to 72.7% and 74.9% of the total materials, while most of the artifacts from Gaojiazhen (51.7%) were made on volcanics. The raw materials exploited in other sites were similar to the materials from the modern river beds. Apart from the hammerstones which were all made of quartz and quartzite, little other obvious variation exists in the different raw materials used in the other artifact categories.

4.2. Artifact type frequencies and size

Fig. 7 presents the photos of cores and retouched pieces from the Three Gorges region. Fig. 8 shows the frequencies of the different artifact categories among different sites in the region. Cores exceed 50% of the Gaojiazhen assemblage, while debitage (whole flakes, flake fragments, and chunks) are the abundant types in all of the other assemblages from the region. Retouched pieces are scarce in all of the different assemblages. Hammerstones were common only at the Yandunbao, Fanjiahe, Jingshuiwan, and Zaoziping sites. Unifacial chopper is the dominant type of core, followed by bifacial choppers. Among the different sites, the highest percentage of unifacial choppers is 87.4% from Ranjialukou, while Zaoziping is 47.6%. The percentage of bifacial choppers from Zaoziping is 47.8%, while in Ranjialukou just 11.1%. Several discoids were collected from Yandunbao, Gaojiazhen, Ranjialukou, and Zaoziping. Three and two polyhedrons were recovered from Gaojiazhen and Ranjialukou respectively, while two bifaces were identified at Ranjialukou (Fig. 9).

In general, the stone artifacts from several different sites are large. Table 12 shows the variation in maximum dimension of the artifacts from several different sites. Apart from Zaoziping where

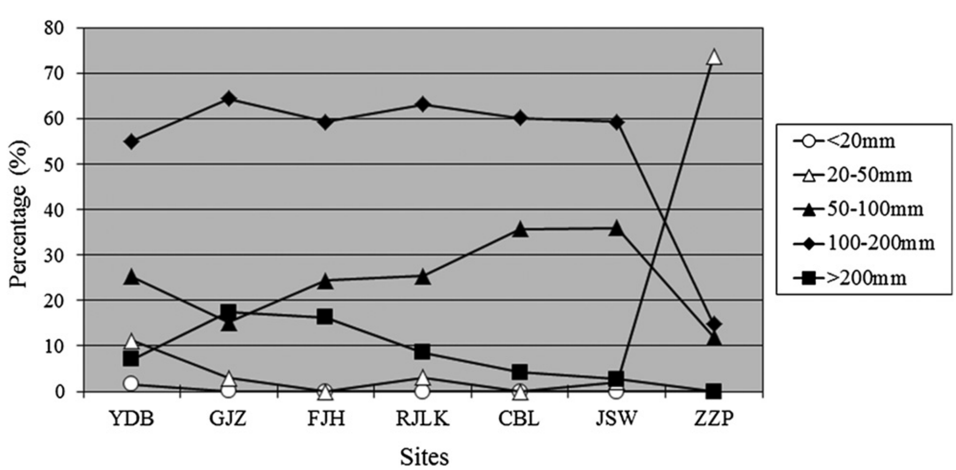

Fig. 10. Diagram showing the maximum dimension variations for stone artifacts among different sites. YDB, Yandunbao site; GJZ, Gaijiazhen site; FJH, Fanjiahe site; RJLK, Ranjialukou site; CBL, Chibaling site; JSW, Jingshuiwan site; ZZP, Zaoziping site.

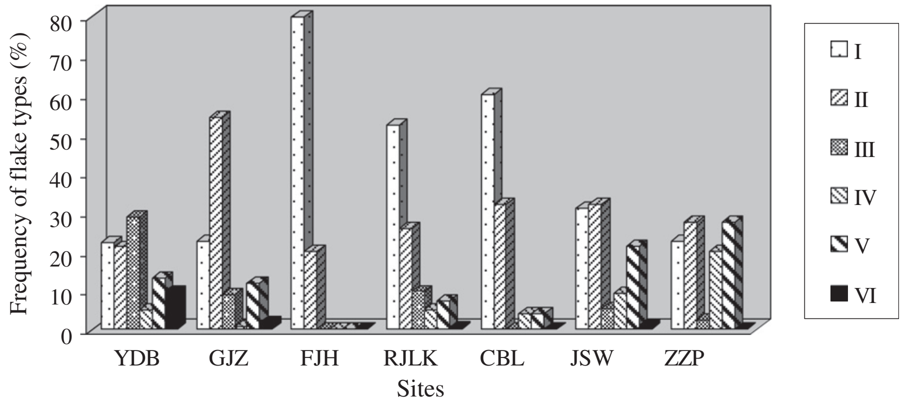

Fig. 11. Overview of whole flake breakdown for the seven sites in the region. YDB, Yandunbao site; GJZ, Gaijiazhen site; FJH, Fanjiahe site; RJLK, Ranjialukou site; CBL, Chibaling site; JSW, Jingshuiwan site; ZZP, Zaoziping site.

most of the artifacts (73.7%) are between 20 and 50 mm, the length of most of the lithics from the other sites was between 100 and 200 mm (range between 55.0% and 64.4%), followed by 50–100 mm (range from 15.2% to 36.0%), while a small percentage of artifacts (range between 2.7% and 17.4%) are larger than 200 mm. Only 17 and 1 artifacts less than 20 mm were found at Yandunbao and Gaojiazhen (Fig. 10).

4.3. Flaking technique

The existence of hammerstones, cores, flakes, flake fragments, and chunks is clear evidence that hard hammer stone knapping occurred in the region. There are some large cores which are hard to hold in one hand and which cannot be flaked by direct hard hammer percussion. As a result, some large flakes where breadth exceeds the length (and the angle of the percussive bulb exceeds 120°) were also identified in the region. It can be inferred that these cores and flakes were probably the products of the anvil flaking technique (Shen and Wang, 2000). It should be noted that some “split flakes”, which can be characterized by a pronounced area of crushing at the point of impact and a very flat release surface without a prominent bulb of percussion, were recovered from the region. These flakes were most probably produced by the throwing flaking technique (throwing one cobble against another), as experimental studies from the East African Koobi Fora site has demonstrated (Schick and Toth, 2003). The whole flake type system devised by Toth (1985) was adopted to evaluate the flake stages represented at the different sites (Toth et al., 2006). As presented in Fig. 11, a majority of the whole flakes were flake type I and II, followed by type IV and type V, while type III flakes were scarce. Very few type VI flakes were found at Yandunbao, Gaojiazhen, Ranjialukou, and Jingshuiwan, while no flake type VI was identified at Fanjiahe, Chibaling and Zaoziping. It can be inferred that these whole flakes were in the early stages of flaking.

The dominant flaking mode was recorded to examine the major pattern of core reduction at the different sites. Overall, except Zaoziping, all other samples showed a preponderance of unifacial flaking of cobbles (range between 66.0% and 91.0%), with a relatively low incidence of bifacial flaking (range between 7.7% and 27.6%). Evidence of other flaking techniques is scarce (less than 10%) (Fig. 12).

4.4. Retouched technology

Retouched pieces are a minor component of the stone assemblages, accounting for between minimally 5.8% (Yandunbao) and maximally 16.1% (Ranjialukou). The mean size dimensions of length and mass are presented in Table 13. Most of the retouched pieces were retouched on whole flakes and flake fragments [range between 64.7% (Chibaling) and 89.1% (Gaojiazhen)]. All of the retouched pieces from Zaoziping were made on whole flake and flake fragments. All of the retouched pieces from the various sites appear to

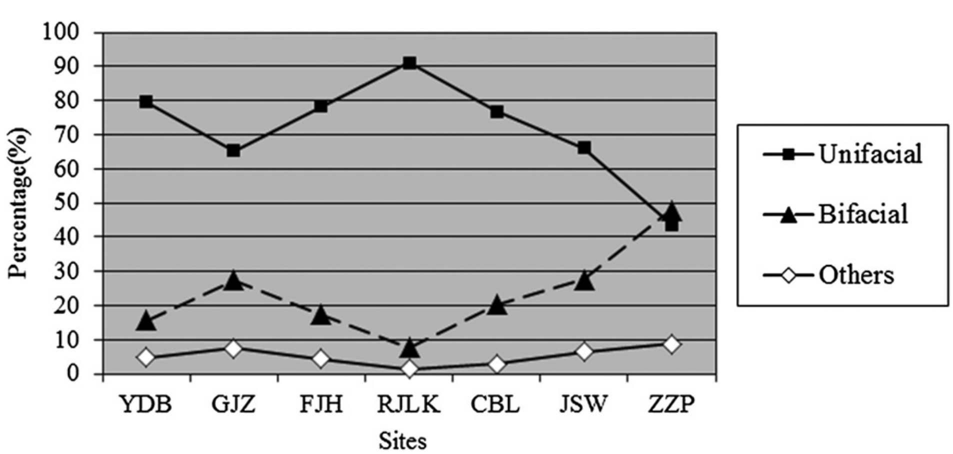

Fig. 12. Overview the flaking mode for the sites in the region. Others: Unifacial + bifacial; unifacial alternate. YDB, Yandunbao site; GJZ, Gaijiazhen site; FJH, Fanjiahe site; RJLK, Ranjialukou site; CBL, Chibaling site; JSW, Jingshuiwan site; ZZP, Zaoziping site.

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Table 13
Variation of percentage, blanks, mean size dimensions of retouched pieces among different sites.

Type of category	YDB	GJZ	FJH	RJLK	CBL	JSW	ZZP
Retouched pieces percentage (%)	5.8	6.4	10.5	16.1	8.0	10.2	11.9
Flakes and flake fragments blank percentage (%)	78.5	89.1	88.9	88.3	64.7	86.0	100
Mean size dimensions (mm)	103.1	122.4	111.2	99.2	92.7	87.3	62.6
Mean mass dimensions (g)	647.9	937.7	472.8	539.7	510.0	387.5	83.7

have been retouched by direct hard hammer percussion, with most of them unifacially retouched on the dorsal surface of the blanks.

5. Discussion and conclusions

Hominins were clearly present in the Three Gorges region from the Middle to Late Pleistocene. Analysis of the lithic assemblages from the open-air sites shows clearly that their formation was probably affected by fluvial activities. This is particularly evident due to the lack of a broader range of flaking debris (e.g., the very low percentage or lack of small debris less than 20 mm). By far the majority of artifacts, fragments, and chunks are in fresh condition with sharp edges. A few however, show some degree of weathering and abrasion (e.g., Ranjialukou), having most probably been abraded or weathered by water. It is clear that when this material was originally deposited on the river bed, it was almost immediately subjected to weathering and abrading.

Pleistocene hominin behavior in the Three Gorges region is primarily inferred from the stone tool industries. In general, the Three Gorges lithics are dominated by Mode 1 core and flake technologies. Lithic raw material exploited in the cave and open-air sites were primarily locally available river cobbles. In general, the stone artifacts are relatively large, with the length of most artifacts between 100 and 200 mm, followed by artifacts between 50 and 100 mm. All flaking is by hard hammer percussion without core preparation. Interestingly, some flakes display evidence that anvil flaking and throwing flaking techniques were also utilized. Core reduction was primarily by unifacial flaking. Unifacial flaking is also demonstrated very clearly from the cortex flakes and platforms. The flake types show that flaking occurred in the region and also demonstrate the first stages of core reduction as represented by low percentage of Types III and VI. The stone artifact assemblages from the region include cores, whole flakes, flake fragments and chunks, with a low percentage of retouched pieces. Unifacial choppers are the predominant core categories compared to the bifacial choppers, with sporadic discoids, polyhedrons and bifaces. Major blanks for retouched pieces are dominated by flakes and flake fragments. Retouched pieces appear to be retouched unifacially by direct hammer stone percussion on the dorsal surface of the blanks. It should be noted that there are two protobifaces recovered from Ranjialukou (Fig. 3-20, 21; Fig. 7-10, 12), which at least superficially resemble western Old World Mode 2 Acheulean bifaces that were produced on cobbles and large flakes. However, there has been some reluctance in classifying the Ranjialukou bifaces as typical Acheulean, because they lack the characteristic shape, symmetry and flaking that are hallmark features of the Acheulean biface. Overall, the Three Gorges region stone toolkits can be characterized by a general lack of standardization of shape and an absence of formal tool categories. The heavy reliance on locally available, generally poor quality raw materials appears to have influenced the composition and morphology of the stone toolkits in the region.

Because fossils of both archaic *H. sapiens* and modern *H. sapiens* were recovered from the region both are likely candidates for the production of the stone artifacts. A possible scenario could be where the late Middle Pleistocene/early Late Pleistocene sites are the result of archaic *H. sapiens* activity and the late Late Pleistocene the result of modern *H. sapiens* activity. However, more detailed analysis of the hominin fossils and their relationship to the archaeological evidence needs to be conducted in order to test such a model. Fortunately, such studies are currently being conducted. This study indicates that there has been a long history of hominin occupation in the Three Gorges region, likely more or less continuous during the Middle to Late Pleistocene, and possibly as far back as the early Early Pleistocene if the recent findings from Longgupo (Boëda et al., 2011; Boëda and Hou, 2011a, b) are eventually accepted by the broader scientific community.

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References

Aigner, J.S., 1981. Archaeology Remains in Pleistocene China. C. H. Beck, Munich.
An, Z., Ho, C.K., 1989. New magnetostratigraphic dates of Lantian *Homo erectus*. Quaternary Research 32, 213–221.
Antón, S.C., Swisher, C.C., 2004. Early dispersals of *Homo* from Africa. Annual Review of Anthropology 33, 271–296.
Bae, C.J., 2010. The late Middle Pleistocene hominin fossil record of eastern Asia: synthesis and review. Yearbook of Physical Anthropology 53, 75–93.
Barbour, G.B., 1935. The physiographic period of Yangtze valley. Bulletin of Geological Society of China 14, 1–15.
Bar-Yosef, O., Belfer-Cohen, A., 2001. From Africa to Eurasia—Early dispersals. Quaternary International 75, 19–28.
Boëda, E., Hou, Y.M., Huang, W.B., 2011. Introduction à l'étude du site de Longgupo. L'Anthropologie 115, 8–22.
Boëda, E., Hou, Y., 2011a. Analyse des artefacts lithiques du site de Longgupo. L'Anthropologie 115, 78–175.
Boëda, E., Hou, Y., 2011b. Étude du site de Longgupo – Synthèse. L'Anthropologie 115, 176–196.
Chia, L.P., 1957. Notes in the human and some other mammalian remains from Changyang, Hubei. Vertebrata PalAsiatica 1, 247–257 (in Chinese with English summary).
Chen, F.Y., Gao, X., Pei, S.W., Feng, X.W., Wei, Q., Zhu, S.L., Li, G.H., 2004. Preliminary study on Ranjialukou Paleolithic site, Three Gorges region, South China. Acta Anthropologica Sinica 23, 292–306 (in Chinese with English abstract).
Ciochon, R., 2009. The mystery ape of Pleistocene Asia. Nature 459, 910–911.
Clark, J.D., Schick, K.D., 1988. Context and context: impression of Paleolithic sites and assemblages in the People's Republic of China. Journal of Human Evolution 17, 439–448.
Colbert, E.H., Hooijer, D.A., 1953. Pleistocene mammals from the limestone fissures of Szechuan, China. Bulletin of American Museum of Natural History 102, 41–71.
Dennell, R., Roebroeks, W., 2005. An Asian perspective on early human dispersal from Africa. Nature 438, 1099–1104.

Dong, M.X., 1998. A preliminary report on Paleolithic remains in Sunjiadong Paleolithic site in Hubei province. Acta Anthropologica Sinica 18, 144–146 (in Chinese).

Edgar, J.H., 1933-1934. Prehistoric remains in Hsikang or Eastern Tibet. Journal of the West China Border Research Society 6, 56–61.

Etler, D.A., 1996. The fossil evidence for human evolution in Asia. Annual Review of Anthropology 25, 275–301.

Etler, D.A., 2004. *Homo erectus* in East Asia: human ancestor or evolutionary dead-end? Athena Review 4, 37–50.

Etler, D.A., Crummett, T.L., Wolpoff, M.H., 2001. Longgupo: early *Homo* colonizer or Late Pliocene Lufengpithecus survivor in South China. Human Evolution 16, 1–12.

Feng, X.W., Pei, S.W., Chen, F.Y., 2003. A study on Yandunbao site, Fengdu, Three Gorges region. Acta Anthropologica Sinica 22, 177–191.

Gao, J., 1975. Australopithecine teeth associated with Gigantopithecus. Vertebrata PalAsiatica 13 (2), 81–88 (in Chinese with English summary).

Gao, X., 2002. A study of the lithic assemblage from Zhoukoudian locality 15. Acta Anthropologica Sinica 21 (suppl), 31–52.

Gao, X., Huang, W.B., Xu, Z.Q., Ma, Z.B., Olsen, J.W., 2004. 120∼150 ka human tooth and ivory engravings from Xinglongdong Cave, Three Gorges region, South China. Chinese Science Bulletin 49 (2), 175–180.

Gao, X., Norton, C.J., 2002. Critique of the Chinese “Middle Paleolithic”. Antiquity 76, 397–412.

Gao, X., Pei, S.W., 2010. The Early Human Footprints in the Three Gorges Region. Bashu Press, Chongqing (in Chinese).

Gao, X., Wei, Q., Li, G.H., 2008. A report of the third excavation of the Ranjialukou Paleolithic site. Acta Anthropologica Sinica 27, 1–12 (in Chinese with English abstract).

Graham, D.C., 1935. Implements of prehistoric man in the west China Union University, Museum of Archaeology. Journal of the West China Border Research Society 7, 47–56.

Han, D., Xu, C., 1985. Pleistocene mammalian faunas of China. In: Wu, R., Olsen, J.W. (Eds.), Palaeoanthropology and Palaeolithic Archaeology in the People’s Republic of China. Academic Press, Orlando (FL), pp. 267–286.

Han, D.F., Xu, C.H., 1989. Quaternary mammalian faunas and environment of fossil humans in South China. In: Wu, R.K., Wu, X.Z., Zhang, S.S. (Eds.), Early Humankind in China. Science Press, Beijing, pp. 338–391 (in Chinese with English abstract).

Han, Z.Y., Li, X.S., Ren, X.M., Xu, Q.M., Yang, D.Y., 2006. Dating of river terraces in the Three Gorges Reservoir area. Acta Geographica Sinica 61 (11), 1200–1207 (in Chinese with English summary).

Hou, Y.M., Li, Y.H., Huang, W.B., Xu, Z.Q., Lu, N., 2006. New lithic materials from level 7 of Longgupo Site. Quaternary Sciences 26 (4), 555–561 (in Chinese with English abstract).

Hou, Y.M., Potts, R., Yuan, B.Y., Guo, Z.T., Deino, A., Wang, W., Clark, J., Xie, G.M., Huang, W.W., 2000. Mid-Pleistocene Acheulean-like stone technology of the Bose Basin, South China. Science 287, 1622–1626.

Hou, Y.M., Xu, Z.Q., Huang, W.B., 1999. Some new stone artifacts discovered in 1997 at Longgupo, Southern China. Longgupo Prehistoric Culture 1, 69–80 (in Chinese).

Hou, Y.M., Xu, Z.Q., Huang, W.B., 2002. Study on stone artifacts of level 8 from 1998 excavation at Longgupo, Southern China. Longgupo Prehistoric Culture 4, 1–10 (in Chinese).

Huang, W.B., Fang, Q.R., 1991. The Wushan Hominid Site. Ocean Press, Beijing (in Chinese with English abstract).

Huang, W.B., Xu, Z.Q., 2002. The Fengjie Man of 140, 000 Years Old: An Ancient Human Site Found at Tiankeng – Difeng Region. Chung Huwa Book Company Incorporation, Beijing.

Huang, W.B., Xu, Z.Q., Zheng, S.H., 2000. A preliminary report on the test excavation of Migong cave Paleolithic site, Wushan. Longgupo Prehistoric Culture, 7–63 (in Chinese with English abstract).

Huang, W.B., Ciochon, R., Gu, Y., Larick, R., Fang, Q., Schwarcz, H.P., Yonge, C., de Vos, J., Rink, W.J., 1995. Early *Homo* and associated artifacts from Asia. Nature 378, 275–278.

Huang, W.W., Hou, Y., 1997. Archaeological evidences for the first human colonisation of East Asia. In: Proceedings of the Indo-Pacific Prehistory Association, Australia National University, Canberra, 1994, vol. 3, pp. 3–12.

Jia, L.P., Gai, P., You, Y.Z., 1972. Report on the excavation at the Shiyu site in Shanxi province. Archaeologica Sinica 1, 39–58.

Leaky, M.D., 1971. Olduvai Gorge. In: Excavations in Beds I and II, 1960–1963, vol 3. Cambridge University Press, Cambridge.

Leng, J., 1998. Early Palaeolithic quartz industries in China. In: Petraglis, M.D., Korisettar, R. (Eds.), Early Human Behaviour in Global Context: The Rise and Diversity of He Lower Palaeolithic Record. Routledge, New York, pp. 418–436.

Li, C.A., 1996. The age study of Wushan Loess. In: Liu, T.S., Luo, L.D. (Eds.), Environmental Change and Quaternary Research. Southwest China Normal University Press, Chongqing, pp. 91–95 (in Chinese with English summary).

Li, C.Y., 1933. Development of the upper Yangtze. Bulletin of Geological Society of China 13, 107–117.

Li, J.J., Chen, F.F., Fang, X.M., Zou, S.Z., Pan, B.T., 1995. Uplift of Qinghai–Xizang Plateau and Global Change. Lanzhou Univ. Press, Lanzhou, China.

Li, J.J., Xie, S.Y., 1999. Uplift of the Qinghai–Tibet plateau and the geomorphologic evolution of the upper reach of the Yangtze. In: Proceedings of IAG Yangtze Fluvial Conference, Shanghai. East China Normal University Press, Shanghai, pp. 16–17.

Li, J.J., Xie, S.Y., Kuang, M.S., 2001. Geomorphic evolution of the Yangtze Gorges and the time of their formation. Geomorphology 41 (2–3), 125–135.

Liu, C., Jin, Z.X., Zhu, R.X., Yang, H., 1988. The magnetostratigraphic study of a human fossil site from Wushan, Sichuan province. Acta Petrological Sinica 5 (4), 122–123 (in Chinese with English summary).

Liu, W., 2006. Some problems on the Late Pleistocene human evolution and modern human population formation. Progress in Natural Science 16 (7), 14–21.

Liu, W., Gao, X., Pei, S.W., Wu, X.Z., Huang, W.B., 2006. Research progress of Paleoanthropology in west Hubei and Three Gorges region. Quaternary Sciences 26 (4), 514–521 (in Chinese with English abstract).

Liu, W., Wu, X.Z., Pei, S.W., Wu, X.J., 2010. A preliminary report on Huanglong Cave: a Late Pleistocene human fossil site in Hubei Province, China. Quaternary International 211, 29–41.

Lycett, S.J., Bae, C.J., 2010. The Movius line and old world Palaeolithic patterns: the state of the debate. World Archaeology 42 (4), 521–544.

Lycett, S.J., Norton, C.J., 2010. A demographic model for Palaeolithic technological evolution: the case of East Asia and the Movius Line. Quaternal International 211, 55–65.

Ma, N., Pei, S.W., Peng, F., Gao, X., Li, G.H., 2009. A preliminary report on the excavation of the Chibaling Paleolithic site in the three Gorges region. Acta Anthropologica Sinica 28 (3), 262–275 (in Chinese with English abstract).

Movius, H.L., 1944. Early man and Pleistocene stratigraphy in southern and eastern Asia. Papers of the Peabody Museum of Archaeology and Ethnology, Harvard University 19, 1–125.

Movius, H.L., 1948. The Lower Paleolithic cultures of southern and eastern Asia. Transactions of the American Philosophical Society 38, 329–420.

Nelson, N.C., 1926. Prehistoric man of central China. Natural History 26, 570–579.

Norton, C.J., Bae, K.D., 2009. Erratum to “The Movius Line sensu lato (Norton et al., 2006) further assessed and defined”J. H. Evol. 55 (2008) 1148–1150. Journal of Human Evolution 57, 331–334.

Norton, C.J., Bae, K.D., Harris, J.W.K., Lee, H.Y., 2006. Middle Pleistocene handaxes from the Korean Peninsula. Journal of Human Evolution 51, 527–536.

Norton, C.J., Braun, D.R. (Eds.), 2010. Asian Paleoanthropology: From Africa to China and Beyond. Vertebrate Paleobiology and Paleoanthropology Series. Springer Press, Dordrecht, The Netherlands.

Norton, C.J., Gao, X., Feng, X.W., 2009. The East Asian Middle Paleolithic reexamined. In: Campus, M., Chauhan, P. (Eds.), Sourcebook of Paleolithic Transitions. Springer Science and Business Media, LCC, pp. 245–253.

Norton, C.J., Jin, J., 2009. The evolution of modern humans in East Asia: behavioral perspectives. Evolutionary Anthropology 18, 247–260.

Norton, C.J., Gao, X., Liu, W., Braun, D., Wu, X.J., 2010a. Central-East China – a Plio-Pleistocene migration corridor: the current state of evidence for hominin occupations. In: Norton, C.J., Braun, D. (Eds.), Asian Paleoanthropology: From Africa to China and Beyond. Vertebrate Paleobiology and Paleoanthropology Series. Springer Press, Dordrecht, The Netherlands, pp. 159–168.

Norton, C.J., Jin, C.Z., Wang, Y., Zhang, Y.Q., 2010b. Rethinking the Palearctic-Oriental biogeographic boundary in Quaternary China. In: Norton, C.J., Braun, D. (Eds.), Asian Paleoanthropology: From Africa to China and Beyond. Vertebrate Paleobiology and Paleoanthropology Series. Springer Press, Dordrecht, The Netherlands, pp. 81–100.

Olsen, J.W., Miller-Antonio, S., 1992. The Paleolithic in southern China. Asian Perspectives 31, 129–160.

Pei, S.W., Gao, X., Feng, X.W., Chen, F.Y., Wei, Q., Zhu, S.L., Li, G.H., Wu, T.Q., 2003. Preliminary study on Jingshuiwan Paleolithic site, Three Gorges region. Acta Anthropologica Sinica 22, 261–278 (in Chinese with English abstract).

Pei, S.W., Feng, X.W., Chen, F.Y., Gao, X., Zhang, W.Q., 2004a. Natural environment of Jingshuiwan Paleolithic site in the Three Gorges region. Marine Geology & Quaternary Geology 24, 109–114 (in Chinese with English abstract).

Pei, S.W., Chen, F.Y., Feng, X.W., Gao, X., Wei, Q., Li, G.H., 2004b. Zaoziping Paleolithic site in the Three Gorges region. Acta Anthropologica Sinica 23, 200–212 (in Chinese with English abstract).

Pei, S.W., Wei, Q., Feng, X.W., Chen, F.Y., Gao, X., Zhu, S.L., Wu, T.Q., Li, G.H., 2005. The stone artifacts excavated from Gaojiazhen Paleolithic site in 1998. Acta Anthropologica Sinica 24, 104–120 (in Chinese with English abstract).

Pei, S.W., Gao, X., Feng, X.W., Chen, F.Y., 2006a. Human adaptive behavoirs during Pleistocene in the Three Gorges region. Quaternary Sciences 26, 5534–5542 (in Chinese with English abstract).

Pei, S.W., Zhang, J.F., Gao, X., Zhou, L.P., Feng, X.W., Chen, F.Y., 2006b. Optical dating of the Jingshuiwan Paleolithic site of Three Gorges. Chinese Science Bulletin 51, 1334–1342.

Pei, S.W., Gao, X., Chen, F.Y., Feng, X.W., Dennell, R., 2010. Lithic assemblage from the Jingshuiwan Paleolithic site of the early Late Pleistocene in the Three Gorges, China. Quaternary International 211, 66–74.

Pei, W.C., 1937. Paleolithic industries of China. In: George, G. (Ed.), Early Man: As Depicted by Leading Authorities at the International Symposium. The Academy of Natural Sciences, Philadelphia, pp. 221–232.

Pei, W.C., 1955. Paleolithic culture in China. Chinese Science Bulletin 1, 30–45 (in Chinese).

Peng, F., Pei, S.W., Ma, N., Gao, X., Li, G.H., 2009. A report on the 2007 excavation of the Ranjialukou Paleolithic site in the Three Gorges region, China. Anthropologica Sinica 28, 130–146 (in Chinese with English abstract).

Pope, G.G., 1995. The influence of climate and geography on the biocultural evolution of the far eastern hominids. In: Vrba, E.S., Denton, G.H., Prtridge, T.C., et al. (Eds.), Paleoclimate and Evolution, with Emphasis on Human Origins. Yale University Press, New Haven and London, pp. 493–506.

Schick, K.D., 1994. The Movius line reconsidered: perspectives on the earlier Paleolithic of eastern Asia. In: Corruccini, R.S., Ciochon, R.L. (Eds.), Integrative Paths to the Past: Paleoanthropology Advances in Honor of F. Clark Howell. Prentice Hall, Englewood Cliffs, New Jersey, pp. 569–596.
Schick, K.D., Dong, Z., 1993. Early Paleolithic of China and Eastern Asia. Evolutionary Anthropology 2, 22–35.
Schick, K.D., Toth, N., 2003. Making Silent Stones Speak: Human Evolution and the Dawn of Technology. Simon and Schuster, New York.
Schwartz, J.H., Tattersall, I., 1996. Whose teeth? Nature 381, 201–202.
Shang, H., Tong, H.W., Zhang, S.Q., Chen, F.Y., Trinkhaus, E., 2007. An early modern human from Tianyuan Cave, Zhoukoudian, China. Proceedings of the National Academy of Sciences USA 104 (16), 6573–6578.
Shen, C., Keates, S.G., 2003. Current Research in Chinese Pleistocene Archaeology. In: BAR International Series 1179. Archaeopress, Oxford.
Shen, C., Wang, S.J., 2000. A preliminary study of the anvil-chipping technique: experiments and evaluations. Lithic Technology 25, 81–100.
Shen, Y.C., 1965. The Valley Landform of the Upper Yangtze. Science Press, Beijing (in Chinese).
Stout, D., Semaw, S., Rogers, M.J., Cauche, D., 2010. Technological variation in the earliest Oldowan from Gona, Afar, Ethiopia. Journal of Human Evolution 58, 474–491.
Swartz, B.K., 1980. Continental line-making: a reexamination of basic Palaeolithic classification. In: Leakey, R.E.F., Ogot, B.A. (Eds.), Proceedings of the Eighth Congress of Prehistory and Quaternary Studies, Nairobi, 5–10th September 1977. The International Louis Leakey Memorial Institute for African Prehistory, Nairobi, pp. 33–35.
Tang, G.Z., Tao, M., 1991. The study of the neo-tectonic movement of Yangtze Gorges region and its relation to the damage of the project construction. Bulletin of Yichang Geological Institute 17, 1–70 (in Chinese with English summary).
Teilhard de Chardin, P., Young, C.C., 1935. The Cenozoic sequence in the Yangtze valley. Bulletn of Geological Society of China 14, 161–178.
Toth, N., 1985. The Oldowan reassessed: a close look at early stone artifacts. Journal of Archaeological Science 12, 101–120.
Toth, N., Sckick, K., 2009. The importance of actualistic studies in Early Stone Age research: some personal reflections. In: Sckick, K., Toth, N. (Eds.), The Cutting Edge: New Approaches to the Archaeology of Human Origins. Stone Age Institute Press, Gosport, Indiana, pp. 267–344.
Toth, N., Schick, K., Semaw, S., 2006. A comparative study of the stone tool – making skills of Pans, Australopithecus, and *Homo sapiens*. In: Toth, N., Schick, K. (Eds.), The Oldowan: Case Studies into the Earliest Stone Age. Stone Age Institute Press, Gosport, pp. 155–222.
Wang, Q., 1996. Assignment of Longgupo cave hominid incisor from Wushan. Acta Anthropologica Sinica 15, 320–323 (in Chinese with English abstract).
Wang, Y.P., 1998. Human adaptations and Pleistocene environment in South China. Anthropologie 36, 165–175.
Wang, W., Potts, R., Baoyin, Y., Huang, W., Cheng, H., Edwards, R.L., Ditchfield, P., 2007. Sequence of mammalian fossils, including hominoid teeth, from the Bubing Basin caves, South China. Journal of Human Evolution 52, 370–379.
Wei, Q., Lin, S.L., Li, Y., Chen, Y., Feng, X.W., Zhang, Z.B., Zhu, S.L., Wu, X.Z., 1997. Survey of relics of the Old Stone Age and ancient human vertebral animal. In: China Three Gorges Construction Yearbook (1997). China Three Gorges Construction Press, Yichang, pp. 100–109 (in Chinese).
Wei, Q., 2004. The Paleolithic occupation in the Three Gorges region. In: Lu, Z.E. (Ed.), The Century Retrospection of Chinese Archaeological Research – Paleolithic Volume. Science Press, Beijing, pp. 340–369 (in Chinese).
Weidenreich, F., 1943. The skull of *Sinanthropus pekinensis*: a comparative study on a primitive hominid skull. Palaeontologia Sinica, Ns D 10, 1–485.
Wu, X.H., 1989. On morphologic boundary of the southeastern Qinghai–Xizang Plateau and development of Jinsha River system. Mountain Research 7, 75–84 (in Chinese, with English summary).
Wu, X.Z., 2004. On the origin of modern humans in China. Quaternary International 117, 131–140.
Wu, X.Z., Pei, S.W., Zou, H.X., Hou, J., Wang, Y.F., 2009. Discovery and Preliminary study on the human fossils from the Three Gorges region. Archaeology 3, 49–56 (in Chinese with English abstract).
Wu, X.Z., Poirier, F.E., 1995. Human Evolution in China. Oxford University Press, Oxford.
Xie, M., 1990. New tectonic uplifted velocity and type along the Changjiang River during Quaternary. Quaternary Sciences 10, 308–315 (in Chinese with English summary).
Yang, D.Y., 1988. The genesis and evolution of Yangtze Gorges. Journal of Nanjing University, Natural Science Edition 24, 466–474 (in Chinese with English summary).
Yang, D.Y., 1990. Loess deposits in the Three Gorges region. In: Liu, D.S. (Ed.), Loess, Quaternary, and Global Environmental Changes, vol I. Science Press, Beijing, pp. 28–33 (in Chinese with English summary).
Yang, D.Y., 2006. Geomorphological Evolution of the Yangtze River. Geological Publishing House, Beijing (in Chinese).
Yang, D.Y., Chen, B.C., 1988. The study of terraces within the Yangtze Gorges. Journal of Nanjing University(Geography) 9, 32–43 (in Chinese with English summary).
Yang, D.Y., Li, X.S., Ke, X.K., Zhou, L.F., Ren, L.X., Zhang, J.X., Chen, D.J., Yang, T.M., Xue, G.F., 2001. A note on the troughs in the Three Gorges channel of the Changjiang River, China. Geomorphology 41, 137–142.
Zhang, S.S., 2002. Advances in Chinese Paleolithic archeology in the past 20 years and some comments. Quaternary Sciences 22, 11–19 (in Chinese with English abstract).
Zhang, S.S., 1999. On the important advancements of the Paleolithic archaeology in China since 1949. Acta Anthropologica Sinica 18, 193–214 (in Chinese with English abstract).
Zhang, Y.Y., 1984. The "*Australopithecus*" of west Hubei and some Early Pleistocene hominids of Indonesia. Acta Anthropologica Sinica 3, 85–92 (in Chinese with English abstract).
Zhao, C., 1996. River capture and origin of the Yangtze Gorges. Journal of Changchun University, Earth Science 26, 428–433 (in Chinese with English summary).
Zhu, R.X., An, Z.S., Potts, R., Hoffman, K.A., 2003. Magnetostratigraphic dating of early humans in China. Earth-Science Reviews 61, 341–359.

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