U-Series dating of Liujiang hominid site in Guangxi, Southern China

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It has been established that modern humans were living in the Levant and Africa ca. 100 ka ago. Hitherto, this has contrasted with the situation in China where no unequivocal specimens of this species have been securely dated to more than 30 ka. Here we present the results of stratigraphic studies and U-series dating of the Tongtianyan Cave, the discovery site of the Liujiang hominid, which represents one of the few well-preserved fossils of modern *Homo sapiens* in China. The human fossils are inferred to come from either a refilling breccia or a primarily deposited gravel-bearing sandy clay layer. In the former case, which is better supported, the fossils would date to at least ~68 ka, but more likely to ~111–139 ka. Alternatively, they would be older than ~153 ka. Both scenarios would make the Liujiang hominid one of the earliest modern humans in East Asia, possibly contemporaneous with the earliest known representatives from the Levant and Africa. Parallel studies on other Chinese localities have provided supporting evidence for the redating of Liujiang, which may have important implications for the origin of modern humans.

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Introduction

The Liujiang hominid site, or the cave of Tongtianyan, is located in a Permian limestone hill ~16 km south of Liuzhou City in southern China's Guangxi Zhuang Autonomous Region (24°10′59″N, 109°25′56″E) (Figure 1). In 1958, while digging the deposits in the cave for fertilizer, workers from the nearby Xinxin Farm found an almost complete human skull and several pieces of postcranial bones. Great care was taken by the head of the farm, who collected the fossils and immediately informed the Institute of Vertebrate Paleontology and Paleoanthropology, *Academia Sinica*, of the important discovery (Woo, 1959; Pei, 1965).

The human skeleton was identified as one of the earliest representatives of modern *Homo sapiens* in East Asia and attributed to the Late Pleistocene (Woo, 1959). Mammalian fossils recovered from the same cave include *Pongo* sp., *Ailuropoda melanoleuca fovealis, Rhinoceros sinensis, Stegodon orientalis, Megatapirus augustus, Sus* sp. etc., forming a typical Late Pleistocene *Ailuropoda–Stegodon* fauna commonly found in southern China (Pei, 1965; Huang, 1979). No trace of human cultural remains has been discovered in the cave.

For about 20 years, the origin of modern humans has been the subject of an intensive debate between exponents of two major competing hypotheses, multiregional origins (e.g., Wolpoff *et al.*, 1984; Wu, 1999; Wolpoff *et al.*, 2001) *vs.* "recent out of Africa" (e.g., Stringer, 1988, 1994, 2000). The accurate dating of relevant finds is basic to addressing this controversial topic. With new and refined dating techniques (Wintle, 1996), important changes regarding the chronology of modern *H. sapiens* have been made over the past two decades (Grün & Stringer, 1991). As an example, the antiquity of Qafzeh and Skhul in the Levant more than doubled, from the ~40 ka previously estimated based on morphological and archaeological evidence, to ~90–120 ka using thermoluminescence (TL) dating of burnt flints (Valladas *et al.*, 1988; Mercier *et al.*, 1993) and electron spin resonance (ESR) dating of tooth enamel (Schwarcz *et al.*, 1988; Stringer *et al.*, 1989).

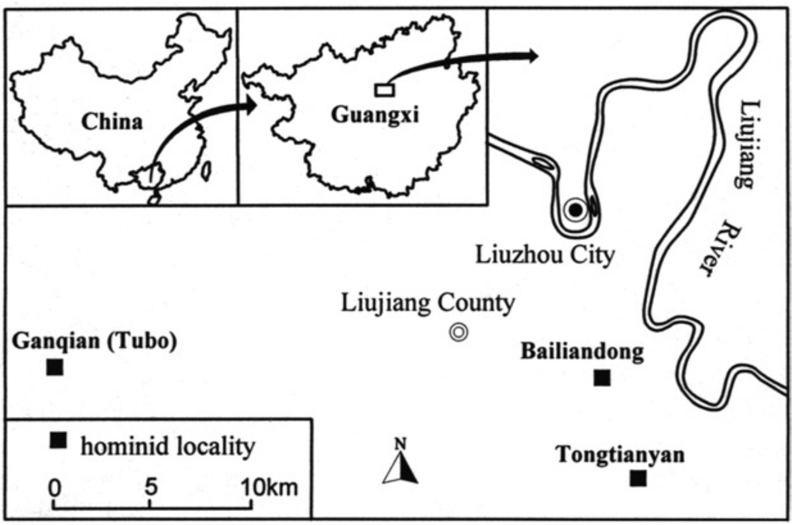

Figure 1. Map showing location of Tongtianyan Cave, the site of the Liujiang hominid, and the nearby hominid localities of Bailiandong and Ganqian Caves discussed in the text.

The redating of the Levantine hominids bolstered the out-of-Africa hypothesis, which was further supported by early dates on Border Cave (Grün *et al.*, 1990*a*) and Klasies River Mouth Cave (Grün *et al.*, 1990*b*) in South Africa.

In contrast, only a small proportion of the relevant sites in China has been numerically dated. Classical ^{14}C and U-series determinations on fossil materials remain the most utilized chronometers, but both are of limited reliability (Taylor, 1996; Rae *et al.*, 1989). It is possible that the Chinese fossil record may suffer from a compressed chronology (Shen & Wang, 2000), just as their European and Levantine counterparts did more than a decade ago (Grün & Stringer, 1991). For finds in China to be compared on equal terms, a re-study with well-established dating techniques is needed.

As one of the few well-preserved fossil representatives of modern *H. sapiens* in China, the chronology of the Liujiang hominid is important for reconstructing the history of recent human evolution. Previously, while conventional ^{14}C dating of the site gave ages of $2{\cdot}9 \pm 0{\cdot}1$ ka and >40 ka for the capping and the second flowstone layers respectively, $^{230}Th/^{234}U$ dating on the latter yielded an age of 67^{+6}_{-5} ka, possibly marking the minimum age of the hominid remains (Yuan *et al.*, 1986). Five mammalian teeth were also analyzed, giving basically concordant $^{230}Th/^{234}U$ and $^{231}Pa/^{235}U$ ages ranging from 95 to 227 ka (Yuan *et al.*, 1986). However, as the stratigraphic contexts of both the calcite and fossil samples had not been verified, and as the appearance of modern *H. sapiens* in China has generally been regarded as being younger than 40 or 50 ka (Wu, 1989), the dates obtained by Yuan and colleagues, especially those from fossil teeth, have been largely overlooked. Thus, the most frequently cited age for the Liujiang hominid is ~20 ka, inferred from the ^{14}C dating of the morphologically similar Minatogawa remains of Japan (Stringer, 1988; Wu, 1988; Brown, 1998; Rightmire, 1998; Jin & Su, 2000).

The validity of U-series dating of carefully selected, pure, compact and well-crystallized cave calcites has been well-demonstrated (Ludwig *et al.*, 1992; Schwarcz, 1992). The above-cited U-series date for the second flowstone layer may signal an early appearance of modern *H. sapiens* in southern China, if the stratigraphic relation between the flowstone layers and the hominid remains is established. However, the stratigraphic position of the Liujiang skeleton has remained unclear. In an effort to better understand the situation, we made a field investigation of the site in early 1998. Besides the previously reported ones, several more flowstone layers and other forms of speleothem formations were found intercalated in the depositional sequence. Calcite samples suitable for U-series dating were taken and analyzed. In light of the new temporal framework, careful study of the early reports relating to the stratigraphic context of the hominid skeleton and detailed field examinations of the extant depositional sequence were carried out to determine the most probable provenience of the hominid fossils. The results are presented in this paper.

Stratigraphy and sample positions

Tongtianyan is a labyrinthine cave system, in which the deposits are now preserved only in an area of ~70 m^2 near the entrance and in the North Corridor, the remaining parts having been largely removed by fertilizer miners (Figure 2). Nevertheless, from the existing cross-section (Figure 3) and the residual materials on the walls and ceiling it is possible to reconstruct the stratigraphic correlation between the removed and preserved deposits.

Overall, the stratigraphic sequence can be divided into three main depositional

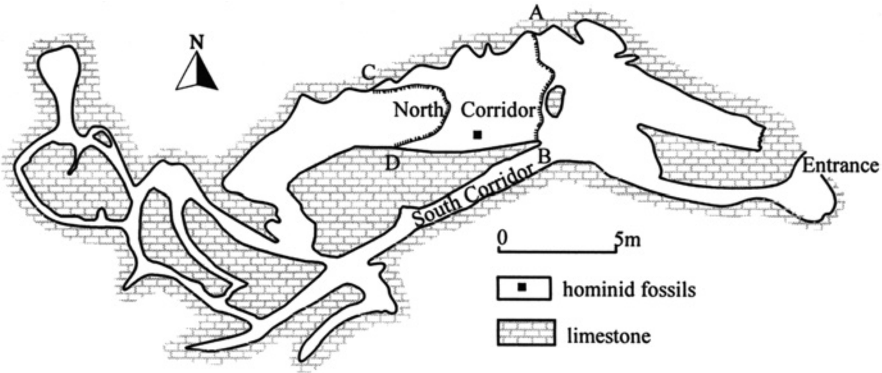

Figure 2. Plane figure of the Tongtianyan cave system. The area from the Entrance to the line AB is a zone where the deposits have been well preserved, while between AB and CD the deposits have been partly preserved, and beyond CD the deposits have been almost completely removed. The hominid skeleton probably came from a position some 2·5 m further into the cave from AB, near the southern wall and ∼1·2 m below the capping flowstone.

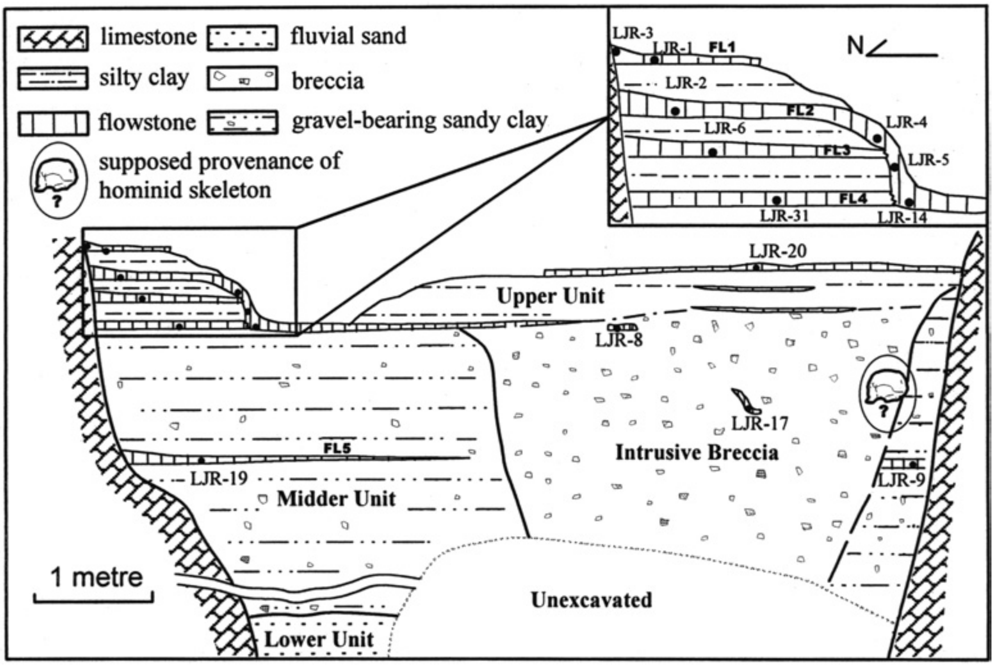

Figure 3. Sketch showing three depositional units and Refilling Breccia on the extant cross-section, which corresponds to the line AB in Figure 1. Samples for dating were collected from the five flowstone layers and other speleothem formations. Here the encircled skull denotes the probable provenience of the hominid skeleton.

units and a cone-shaped Refilling Breccia (Figure 3). The Upper Unit consists of silty clay sandwiched in flowstone layers with a total thickness of 60–90 cm. This unit may be sub-divided into three levels. Level 1 is a capping flowstone layer (FL1) up to ∼15 cm thick covering all of the deposits. This flowstone is mostly porous, friable and poorly crystallized. However, localized sub-layers of quite pure calcite can be found, from which samples suitable for U-series dating may be collected. Level 2 consists of 40–70 cm of silty clay, which is characterized by fine laminae, paucity of clasts and lack of carbonate cementation, indicating formation in stagnant water. A localized, thin and heavily contaminated flowstone layer lies in its middle. Level 3 is the second flowstone layer (FL2). Near the northern wall FL2 is quite pure, well crystallized and up to ~25 cm thick. It becomes thinner and less pure in the middle, and gradually degrades into calcrete near the southern wall. Seven samples were taken from this unit, of them LJR-1, 3 and 20 are from sub-layers of FL1, and LJR-2, 4, 5 and 14 are from different parts of FL2.

The Middle Unit is composed of a ~5 m thick fossiliferous, gravel-bearing and carbonate-cemented sandy clay. Being apparently uniform in lithologic composition, the subdivision of this unit awaits further sedimentological study. Near the northern wall, 0–15 cm below FL2, is the third flowstone layer (FL3), which is relatively pure, well crystallized and of a thickness up to ~12 cm. 20–50 cm lower still is the fourth flowstone layer (FL4). Both FL3 and FL4 come to an abrupt end ~1·5 m from the North Wall, the fractured zone being overlaid by the down-warping FL2. About 1 m below FL4 is the ~15 cm thick fifth flowstone layer (FL5). A total of four samples was taken from this unit—LJR-6 from FL3, LJR-31 from FL4, and LJR-9 and 19 from FL5.

The jagged fractures of FL3 and FL4 and a disconformity ~1·5 m further to the south provide evidence of a flood washout and re-depositional event. The Refilling Breccia, being ~3 m wide at the top and more than 1·5 m thick, cuts into the upper part of the Middle Unit (Figure 3). This loosely cemented breccia is composed mainly of flint and marl fragments, different in composition from the cave's limestone walls, but similar to nearby hills. Many of the gravels are irregular and angular, indicating their outside provenience and short-distance transportation. As no signs of bedding can be recognized, the breccia was most probably accumulated in a relatively short span of time. LJR-8 is a small piece of broken flowstone mixed with gravels near the top of the Refilling Breccia. Some 1·2 m below FL1, at about the same depth as the claimed position of the hominid skeleton (Pei, 1965), a speleothem formation in a fissure was taken as LJR-17, its nature as a secondary calcite vein being established by its natural form, its conformity with the fissure, and the direction of its laminae.

Between lines AB and CD (Figure 2), there are remnant deposits, resembling those of the Middle Unit in lithologic composition, adhering to the upper walls and ceiling. It may be inferred that this section of the corridor was entirely filled before the washout event. We recovered several mammalian fossils, including two rhinoceros tooth fragments which were sampled as LJR-33 and 34, from remnant deposits on the ceiling and along the uppermost part of the South Wall respectively.

The Lower Unit, composed of more than 2 m of fluvial sands with lenses of clay, is situated at the base of the depositional sequence.

Results and discussions

Conventional alpha spectrometry (AS) was used to measure U-Th isotopic ratios (Ivanovich & Harmon, 1992). For better precision, six key samples were analyzed by one of us (JXZ) using thermal ionization mass spectrometric (TIMS) techniques (Edwards *et al.*, 1986/87). The U-Th isotopic ratios and derived age results using AS and TIMS are presented in Tables 1 and 2 respectively. The agreement between replicates and between AS and TIMS

Table 1 Alpha spectrometric $^{230}Th/^{234}U$ analyses on speleothem samples from the Liujiang site

Sample number	Sample position	^{238}U(ppm)	$^{230}Th/^{232}Th$	$^{234}U/^{238}U$	$^{230}Th/^{234}U$	^{230}Th age (ka)	Corrected (ka) $(^{230}Th/^{232}Th)_0=1$	Corrected (ka) $(^{230}Th/^{232}Th)_0=2$
LJR-1	FL1	0·23	7·2	1·148 ± 0·017	0·154 ± 0·007	18 ± 1	16 ± 1	13 ± 3
LJR-3	FL1	0·35	12·8	1·174 ± 0·014	0·041 ± 0·003	4·5 ± 0·3	4·2 ± 0·4	3·9 ± 0·5
LJR-20	FL1	1·09	9·2	1·104 ± 0·015	0·189 ± 0·006	23 ± 1	20 ± 1	18 ± 2
LJR-2 (i)	FL2	0·18	26·6	1·121 ± 0·024	0·467 ± 0·015	68 ± 3	66 ± 4	64 ± 4
(ii)		0·18	32·3	1·090 ± 0·025	0·476 ± 0·015	70 ± 3	68 ± 4	66 ± 4
LJR-4	FL2	0·15	17·7	1·110 ± 0·020	0·506 ± 0·016	76 ± 4	73 ± 4	69 ± 5
LJR-5	FL2	0·14	15·7	1·114 ± 0·026	0·517 ± 0·016	78 ± 4	74 ± 5	71 ± 5
LJR-14	FL2	0·32	16·6	1·131 ± 0·027	0·463 ± 0·015	67 ± 3	64 ± 4	61 ± 5
LJR-8	RB	0·84	18·1	1·124 ± 0·025	0·744 ± 0·022	142 ± 11	138 ± 11	133 ± 11
LJR-17(i)	RB	4·32	28·6	1·163 ± 0·016	0·640 ± 0·016	108 ± 5	105 ± 5	103 ± 6
(ii)		3·65	22·7	1·163 ± 0·022	0·682 ± 0·019	120 ± 7	117 ± 7	113 ± 8
LJR-6	FL3	0·90	17·9	1·156 ± 0·018	0·747 ± 0·017	142 ± 7	138 ± 8	133 ± 9
LJR-31	FL4	0·91	17·4	1·130 ± 0·021	0·929 ± 0·030	250 ± 36	245 ± 36	240 ± 37
LJR-9	FL5	1·33	14·8	1·235 ± 0·018	0·984 ± 0·022	289 ± 35	283 ± 39	276 ± 50
LJR-19	FL5	2·00	21·0	1·136 ± 0·019	0·959 ± 0·027	282 ± 43	278 ± 43	273 ± 45

All isotopic ratios shown are in radioactivity. The ages are calculated using program ISOPLOT/EX of Ludwig (1999). Half-lives of ^{230}Th and ^{234}U are 75,380 and 244,600 years, respectively. All errors are $\pm 1\sigma$. Roman numerals in the first column denote replicate analyses on different splits of the same specimen. RB in the second column refers to the Refilling Breccia. Detrital Th-corrected ages are calculated assuming that the ^{238}U-^{234}U-^{230}Th systematics are in secular equilibrium and detrital $(^{230}Th/^{232}Th)_0=1{\cdot}0 \pm 0{\cdot}5$ and $2{\cdot}0 \pm 1{\cdot}0$, respectively.

Table 2 TIMS $^{230}Th/^{234}U$ analyses on speleothems from Liujiang hominid site

Sample number	Sample position	^{238}U (ppm)	$^{230}Th/^{232}Th$	$^{234}U/^{238}U$	$^{230}Th/^{234}U$	^{230}Th age (ka)	Corrected (ka) $(^{230}Th/^{232}Th)_0=1$	Corrected (ka) $(^{230}Th/^{232}Th)_0=2$
LJR-1	FL1	0·1933	7·39	1·1696 ± 0·0034	0·1535 ± 0·0020	18·0 ± 0·3	15·8 ± 1·1	13·5 ± 2·3
LJR2-1	FL2	0·3052	31·7	1·2079 ± 0·0029	0·4411 ± 0·0024	62·1 ± 0·5	60·6 ± 0·8	59·1 ± 1·4
LJR2-2		0·1195	38·6	1·1535 ± 0·0035	0·4521 ± 0·0022	64·4 ± 0·5	63·2 ± 0·7	61·9 ± 1·2
LJR2-3(i)		0·1025	23·8	1·1452 ± 0·0026	0·4805 ± 0·0022	70·0 ± 0·5	67·9 ± 1·1	65·7 ± 2·0
(ii)		0·1035	27·1	1·1399 ± 0·0028	0·4781 ± 0·0035	69·6 ± 0·7	67·7 ± 1·1	65·8 ± 1·9
LJR-6(i)	FL3	0·7303	16·6	1·1287 ± 0·0023	0·7866 ± 0·0047	160 ± 2	154 ± 3	149 ± 4
(ii)		0·7812	20·1	1·1242 ± 0·0031	0·8722 ± 0·0050	155 ± 2	151 ± 3	147 ± 4
LJR-8(i)	RB	0·6859	23·6	1·1306 ± 0·0031	0·7349 ± 0·0026	139 ± 1	135 ± 2	132 ± 3
(ii)		0·6621	24·5	1·1362 ± 0·0034	0·7527 ± 0·0045	145 ± 2	142 ± 2	139 ± 3
LJR-31	FL4	0·7247	17·5	1·1541 ± 0·0034	0·9080 ± 0·0072	228 ± 6	223 ± 7	218 ± 10

U-Th isotopic analyses were carried out on a VG Sector-54. Except that errors are 2σ, other items are the same as in Table 1.

measurements, and the conformity of the dates with the stratigraphic sequence indicate overall reliability of the measurements.

The dates on FL1 indicate that this flowstone layer was formed between 4 and 20 ka (Tables 1 and 2). Five analyses on four samples from FL2 gave consistent AS results (Table 1). The specimen of LJR-2 for TIMS was a slice from FL2, sub-samples LJR-2-1, -2-2 and -2-3 representing the upper, middle and lower parts respectively. Their TIMS U-series dates indicate that FL2 was formed between 61 ± 1 and 68 ± 1 ka (Table 2), the latter marking the minimum age of the underlying Refilling Breccia. Replicated TIMS determinations on LJR-6 from FL3 and on LJR-8 from the calcite fragment gave consistent dates with mean values at 153 ± 2 and 139 ± 4 ka (Table 2), setting the earliest limits for the washout event and for the topmost part of the Refilling Breccia respectively. The replicated AS analyses of LJR-17, from the calcite vein cross-cutting the middle part of the breccia, yield a mean age of 111 ± 4 ka, indicating that the horizon was formed no later than this date (Table 1). The Refilling Breccia is thus securely bracketed between 68 and 153 ka. If we take into account its presumably rapid formation, as shown by the lack of stratification, its best age estimate is between 111 and 139 ka.

As mentioned above, the stratigraphic position of the Liujiang skeleton has been clouded with uncertainty. There are two early reports that relate the circumstances in which the hominid skeleton was found. Youheng Li, the first geologist to arrive at the site, was told that the human and *Ailuropoda* skeletons were "embedded in the deposits of unconsolidated breccia", while other mammalian fossils were in the "consolidated yellowish deposits" (cited by Woo, 1959). Having also personally visited the cave in 1958 and 1960, Pei (1965) divided the then exposed depositional sequence under the capping flowstone into upper and lower layers separated by a flowstone layer. The upper layer consists of grayish-yellow sandy clay containing few fossils, and the lower one of reddish-yellow, fossiliferous sandy clay containing limestone and flint gravels. The human and *Ailuropoda* skeletons were retrieved from the lower part of the lower layer, ~1·2 m below the capping flowstone (Pei, 1965).

The accounts of Li and Pei were based partly on information provided by the fertilizer miners who made the discovery and partly on their own field observation. The veracity of Li's account is shown by the precise correspondence between its "unconsolidated breccia" and "consolidated yellowish deposits", on the one hand, and the Refilling Breccia and Middle Unit in the stratigraphy presented here. Similarly, Figure 8 in Pei (1965) matches quite closely to the extant cross-section. So these earlier accounts appear to be basically sound, although some imprecision might have resulted from the fact that the discovery was made by non-specialists and from the lack of stratigraphic study. The absence of any breccia formation in Pei's account is probably a misreading. To judge by its scale on the present-day cross-section, it seems hardly possible that the Refilling Breccia was entirely missing from the sequence during Pei's time, which would have been ~2·5 m further into the cave. Most probably Pei failed to distinguish the Refilling Breccia from the primarily deposited Middle Unit. Our experience tells us that without detailed studies of the stratigraphy it is possible to make such an error. Initially, we were also confused by the lateral compositional difference along the profile and tended to consider it as a facies change.

If we accept the possible discrepancy in Pei's account, the association of the hominid fossils with the Refilling Breccia seems the most plausible (Woo, 1959). This would date them to 68–153 ka, and more likely to 111–139 ka. However, the possibility that

Table 3 ^{230}Th/^{234}U and ^{227}Th/^{230}Th dating of two rhinoceros teeth fragments from the Liujiang site

Sample	^{238}U (ppm)	^{230}Th/^{232}Th	^{234}U/^{238}U	^{230}Th/^{234}U	^{230}Th age (ka)	^{227}Th/^{230}Th	^{227}Th age (ka)
LJR-33	91·6	223	1·472 ± 0·023	0·648 ± 0·022	106 ± 6	0·0454 ± 0·0023	87^{+19}_{-16}
LJR-34	240	307	1·472 ± 0·024	0·836 ± 0·023	167 ± 11	0·0417 ± 0·0009	111^{+13}_{-11}

All errors are ± 1σ.

the hominid fossils were included in the carbonate-cemented sandy clay of the Middle Unit cannot be excluded. In this case the hominid fossils would be older than 153 ka as defined by the overlying FL3. This date, though seemingly anomalous, is compatible with a recent claim that BC1, a modern hominid cranial vault from Border Cave, South Africa, may be as old as 170 ka (Grün & Beaumont, 2001).

In addition, we note that both the reports point to the association of the hominid fossils with limestone and flint gravels (Woo, 1959; Pei, 1965). Moreover, Pei (1965) pinpointed a position in the lower part of the lower layer, ~1·2 m below the capping flowstone as the provenience of the hominid skeleton. It seems highly unlikely that the human remains were buried in the silty clay of the Upper Unit, which ranges in age from 20 to 61 ka, or in the fluvial sands of the Lower Unit, which is older than 280 ka. This argument is supported by the observation that traces of calcrete are still found adhering to the orbits, external auditory meatus and endocranial cavity of the hominid cranium, and the ribs, vertebral column and medullary cavities of the femora are still heavily coated with calcrete matrix. This indicates that their provenience was the calcified Middle Unit or Refilling Breccia, rather than the carbonate-free Upper or Lower Units.

Li (Woo, 1959) and Pei (1965) agreed that most of the non-hominid mammalian fossils were derived from the consolidated sandy clay. The dates from FL3, FL4 and FL5 indicate that the Middle Unit was formed from >280 to 153 ka. Such an early and lengthy time interval explains the "aberrant" U-series dates on fossil teeth previously reported by Yuan *et al.* (1986). Using two U-series methods (Shen, 1996), we have dated the two rhinoceros teeth fragments, LJR-33 and 34. The ^{230}Th/^{234}U and ^{227}Th/^{230}Th isotopic ratios and age results are presented in Table 3. These dates, being in the range of 167 ± 11 and 87^{+19}_{-16} ka, are comparable with those of Yuan *et al.* (1986), and lend support to the observation that the residual deposits on walls and ceiling are remnants of the Middle Unit. Tongtianyan has hitherto been widely regarded as a type locality for the Late Pleistocene *Ailuropoda–Stegodon* fauna (Pei, 1965; Huang, 1979). However, the present results demonstrate that the Liujiang mammalian assemblage is in fact late Middle Pleistocene in age. An important revision of the chronology of correlated sites in southern China is required.

The above-cited dates seem surprisingly old in view of previous age estimates for the Liujiang hominid (Stringer, 1988; Wu, 1988; Brown, 1998; Rightmire, 1998; Jin & Su, 2000) and because up until now no specimens of unequivocal modern *H. sapiens* in China have been securely dated to more than 30 ka (Wu, 1989). However, supporting evidence for this older date is provided by chronological studies on two neighboring localities, Bailiandong and Ganqian (Tubo) Caves (Figure 1). Controlled excavations at the Bailiandong Cave led to the discovery of two hominid teeth, hundreds of stone artefacts, and a rich collection of mammalian fossils. The faunal composition of its lower strata is similar to that of Liujiang (Zhou, 1994). From Ganqian Cave a total of 17 hominid teeth have been found. The associated mammalian fossils, belonging to the *Ailuropoda–Stegodon* fauna, have been assigned to the Late Pleistocene (Li *et al.*, 1984; Wang *et al.*, 1999). The human teeth found at the two sites are similar to those of present-day Chinese and, hence, have been classified as modern *H. sapiens* (Li *et al.*, 1984; Zhou, 1994; Wang *et al.*, 1999). Using U-series methods, a flowstone layer overlying the hominid-bearing deposits at Bailiandong has been dated to ~160 ka (Shen *et al.*, 2001*a*), while the capping flowstone layer at Ganqian gave an age of 94 ka (Shen *et al.*, 2001*b*), both marking the minimum age for the hominid teeth. Recently, Pan *et al.* (2002) dated two fossil teeth from the Lianhua Cave in Zhenjiang, Jiangsu Province, where a human tooth attributed to late *H. sapiens* was found (Li *et al.*, 1982). The results indicate that modern humans might have been present in lower reaches of the Yangtze River in eastern China at ~100 ka.

With well-developed superciliary arches, slightly receding forehead, small mastoid processes and weak muscular markings, the Liujiang hominid represents a fundamentally "modern" individual, retaining just a few primitive features (Woo, 1959). In spite of the controversy over whether it represents an early type of Mongoloid (Woo, 1959; Brown, 1998), its classification as a modern *H. sapiens* has not been challenged. The present age estimate for the site of Liujiang, together with those for Bailiandong, Ganqian and Lianhua caves, indicate that modern humans were living in China ~100 ka ago, broadly contemporaneous with their counterparts in Africa and south-western Asia. New age determinations for the Lake Mungo 3 human skeleton from Australia are also considerably older than previously assumed (Thorne *et al.*, 1999). These results, taken together, seem too early for modern *H. sapiens* in East Asia to have arrived from Africa, even by a coastal route (Stringer, 2000). An even deeper root for African modern *H. sapiens*, or a much earlier and quicker migration into East Asia would need to be posited to conform with the out-of-Africa model.

While presenting chronological evidence for a much earlier presence of modern *H. sapiens* in southern China, this paper poses the following problems that require further study. First, the uncertain provenience of the Liujiang hominid fossils should be addressed. The U-Th dating of hominid fossils with nondestructive gamma spectrometry (Yokoyama & Nguyen, 1981) and of calcrete matrix on the fossils with TIMS (McDermott *et al.*, 1996) are likely to shed light on this problem. Second, two important representatives of archaic *H. sapiens* in China, from the sites of Maba (Wu & Peng, 1959) and Xujiayao (Jia *et al.*, 1979; Wu, 1980), have been dated to 125–139 (Yuan *et al.*, 1986) and 104–125 ka (Chen *et al.*, 1982) respectively. This means that the hominids from Liujiang, Bailiandong, Ganqian and Lianhua Caves are now inferred to be broadly contemporaneous with, or even older than, these morphologically more primitive specimens. For the moment we are not sure whether the age of the Maba and Xujiayao finds on re-dating will be pushed earlier, or whether, as in the Levant, there was temporal overlap of two morphologically different hominid populations (Valladas *et al.*, 1988; Schwarcz *et al.*, 1988; Stringer *et al.*, 1989; Mercier *et al.*, 1993). The resolution of the above-mentioned issues and further efforts to study other modern *H. sapiens* sites in China will contribute to clarifying the hotly debated issues concerning the origin, dispersal and evolution of our own species.

Conclusions

The stratigraphic sequence of the Liujiang hominid site can be divided into Upper, Middle and Lower Units together with a Refilling Breccia resulting from a washout and re-depositional event. The hominid fossils are likely to have come from the Refilling Breccia or from the primarily deposited Middle Unit. In the former case, which is more probable, they would date to not more recent than ~68 ka, but more likely to ~111–139 ka. Alternatively, they would be older than ~153 ka. In either case the Liujiang hominid is revealed as one of the earliest modern humans in East Asia, probably contemporaneous with the earliest known Levantine and African representatives.

The early presence of modern humans in China is supported by chronological studies on Bailiandong, Ganqian (Tubo) and Lianhua Caves (Shen *et al.*, 2001*a*,*b*; Pan *et al.*, 2002). Taken together, these different lines of evidence indicate that, for the out-of-Africa model to remain plausible, it would be necessary to demonstrate an even deeper root for African modern *H. sapiens*, or an earlier and quicker migration into East Asia. In the absence of evidence for either or both, a rethinking of the out-of-Africa model would be required. On the other hand, the chronology of the Maba and Xujiayao archaic *H. sapiens* hominids should be restudied to explore the issue of a possible coexistence in China of two distinct hominid populations or species in the late Middle Pleistocene or early Late Pleistocene.

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