10 Chinese Middle Pleistocene hominids and modern human origins in east Asia

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INTRODUCTION

In China the study of human origins and evolution, now known as palaeoanthropology, began with the discovery of a worn and fossilised hominid molar tooth at Zhoukoudian, 48 km southwest of Beijing, by the Austrian geologist Otto Zdansky in 1923. Subsequent work at the cave deposit between 1927 and 1937 by European, North American, and Chinese scholars, including Johan Andersson, Davidson Black, Pei Wenzhong and Franz Weidenreich, recovered a large number of hominid fossils and associated cultural remains (Wu & Wu 1997). Detailed description and comparison of the *Sinanthropus pekinensis*, now *Homo erectus*, skeletal and dental materials by Weidenreich (1935, 1936, 1937a, 1937b, 1939a, 1941, 1943), and the *Sinanthropus* artefacts by Pei & Zhang (1985), combined with faunal and palaeoenvironmental information (Jia 1978; Hu 1985; Kong 1985), and efforts to date the Locality 1 deposits (Liu et al 1977; Chen et al 1984; Liu et al 1985; Guo et al 1991; Huang et al 1991; Shen & Jin 1991) have ensured Zoukoudian's position as the most important Middle Pleistocene locality in China. However, while Weidenreich's monographs and the controversy over the loss of the original *Sinanthropus* material (Shapiro 1974) have ensured that the 'Peking Man Site' is well known, outside of China more recently discovered Middle and Late Pleistocene localities remain relatively obscure. This is particularly unfortunate given the importance of the Chinese hominid fossil record to the ongoing debate over the origins and dispersion of our own species (Wolpoff et al 1984; Stringer 1985; Bräuer & Mbua 1992; Wu 1992; Stringer & Bräuer 1994; Brown 1999).

Up until 1995, information on Middle Pleistocene China was restricted by the minimal amount of publication in languages other than Chinese, the research opportunities and interests of western palaeoanthropologists, and the limited travel opportunities available to the Chinese scientific community. This situation was dramatically changed in 1995 with the publication of Wu and Poirier's *Human evolution in China*. For the first time morphological and metrical descriptions of all of the major Chinese Pleistocene hominids were available in a single volume. A remarkable achievement given the obstacles to completing a project of this type in China. While synthesis and interpretation were not the primary goal of Wu and Poirer they make it clear that they support Franz Weidenreich's (1946) interpretation of the relationship between Middle Pleistocene *Homo erectus* and modern Chinese people (1995:234). For Weidenreich, the ancestors of modern east Asians could be identified in the *Sinanthropus* remains from Locality 1 at Zhoukoudian. Evidence for this was provided by the presence of regional patterns in skeletal morphology which persisted through time.

> . . . man has evolved in different parts of the old world. The Australian natives have some of the characteristics in common with the fossil Wadjak-Keilor man and with *Homo soloensis* . . . Some of the characteristic features of *Sinanthropus* appear in certain Mongolian groups of today.
>
> (Weidenreich 1946:138)

Weidenreich's interpretation of the significance of geographic variation, and the association between *Homo erectus* and *Homo sapiens*, has formed a central tenet within Chinese indigenous palaeoanthropology and is the foundation of the multiregional school of modern human origins (Thorne & Wolpoff 1981; Wolpoff et al 1984; Wolpoff 1989). One of the challenges to be faced by future generations of Chinese palaeoanthropologists is the limited support provided for Weidenreich's model by an expanding Pleistocene fossil record (Bräuer & Mbua 1992; Li & Etler 1992; Brown 1999), studies of regional variation in more recent human populations (Lahr 1994, 1996), and genetic data from fossil and living humans (Krings et al 1997; Underhill et al 2001).

Over the last 20 years there have been some significant additions to the Chinese Middle Pleistocene hominid fossil record. These include Hexian , Yunxian and Nanjing *Homo erectus* localities and the Jinniushan 'archaic' *Homo sapiens* skeleton. In association with the excavation of new sites there has been an intensive effort to date the Chinese sequence (Chen et al 1994, 1997) (figure 10.1). This has not been without some controversy, particularly with claims of an Early Pleistocene age for Yuanmou (Cheng et al 1977; Li et al 1979; Liu & Ding 1983; Qing 1985; Pan et al 1991; Qian et al 1991), Gongwangling (An & Ho 1989; Wu et al 1989; An et al 1990) and Longgupo Cave (Huang, W, et al 1991; Liu et al 1991; Huang et al 1995). Debate over the Early Pleistocene age of most of these localities hinges on palaeomagnetic interpretations of Matuyama or Bruhnes epoch associations. There is also some uncertainty associated with the use of uranium series and electron spin resonance (ESR) on many of the Middle Pleistocene sites. While some of the uranium series dates are on capping flowstones, for instance Hulu Cave (Zhou et al 1999), the majority are on mammal bone recovered from the hominid deposits. There is always some uncertainty about the contemporaneity of the faunal, hominid and archaeological materials, and the choice of uranium uptake model and dating procedure can have substantial implications for results. Problems of this type contribute to the range of uranium series dates from Hexian (Chen et al 1987; Grün et al 1998) and Zhoukoudian locality 1 (Zhao et al 1985; Huang et al 1991; Shen et al 1996) (Figure 10.1).

However, given the difficulties associated with dating predominantly cave and river terrace deposits the Chinese Middle Pleistocene is now as securely dated as the same time period in western Europe. With one exception, all of the sites discussed below contain *Homo erectus*, or 'archaic' *Homo sapiens*, skeletal materials with support for a Middle Pleistocene association. The exception is Longgupo Cave, also known as Wushan (Huang et al 1991; Liu et al 1991; Huang et al 1995), where there is doubt over the hominid status of some of the skeletal remains (Schwartz & Tattersal 1996; Wu 2000) and an Early Pleistocene date. There are several other Middle pleistocene localities recognised by Chinese Palaeoanthropologists but the majority of these are represented by isolated teeth, or are of less certain age and provenance.

CHINESE MIDDLE PLEISTOCENE HOMINID SITES

Longgupo Cave (Wushan)

Longgupo Cave in Wushan County, eastern Sichuan Province, was excavated by a team from the Institute of Vertebrate Paleontology and Paleoanthropology and the Chongqing National Museum between 1985 and 1988 (Gu & Fang 1991; Huang, W, et al 1991; Liu et al 1991). The excavation recovered some claimed early hominid dental remains, and stone artefacts, in association with an early Pleistocene fauna. This fauna included *Gigantopithecus* teeth and *Ailuropoda microta* (pygmy giant panda). A mandibular body fragment containing a second premolar and first molar, and an unassociated maxillary lateral incisor were assigned to early *Homo*, either *H. habilis* or *H. ergaster* (Huang et al 1995).

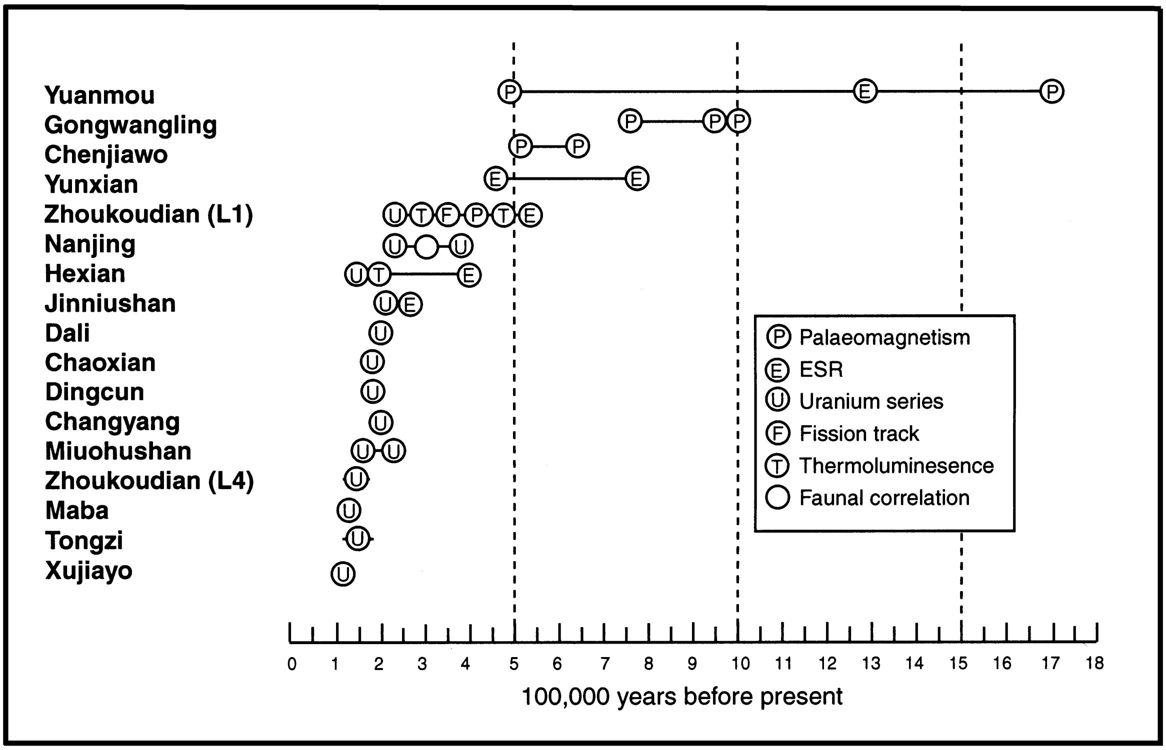

Figure 10.1 Range of dates reported for Chinese *homo erectus* and 'archaic' *Homo sapiens* localities.

Magnetostratigraphy indicated that the hominid-bearing layers of the deposit, layers 7–8, corresponded with the Olduvai event at 1.96 to 1.78 Ma (Huang, W, et al 1991; Liu et al 1991; Huang et al 1995). Electron Spin Resonance (ESR) dates on cervid tooth enamel from layer 4 ranged from 0.75±0.09 Ma using an early uptake model to 1.02±0.12 Ma using a linear uptake model. Huang et al (1995) argue that the linear uptake model generally provides ages closer to independent estimates. This would place layer 4 sediment within the Matuyama reversed epoch and support their palaeomagnetic interpretation for the age of the lower hominid-bearing layers. ESR dating of the hominid teeth, or teeth of demonstrated contemporaneity with the hominid teeth, would put this issue beyond doubt.

The Longgupo left mandibular body fragment assigned to *Homo* by Huang et al (1995) contains the second premolar, first molar and part of the alveolus for the second molar. The corpus is nearly complete below the first molar, with a corpus height of 21 mm and width of 13.5 mm, making this fragment extremely small by Asian *Homo erectus* standards (Zhoukoudian and Sangiran). Huang et al (1995) argue that the mandible more closely resembles African *Homo habilis* and *Homo ergaster*. The two mandibular teeth have moderate occlusal and interproximal wear, exposing dentine and removing details of crown morphology. The original description of the P2 emphasises the bifurcated root, thin enamel and long, wide talonid, features which are argued not to be present in the Zhoukoudian equivalents but are present in African early *Homo*. Similarly, the five cusp molar crown with thin and uncrenulated enamel is compared with *Homo habilis* and *Homo ergaster* and differentiated from *Homo erectus*. The shovel shaped and unworn maxillary lateral incisor differs from Zhoukoudian *Homo erectus* in crown height, and thickness, and by having thicker mesial and distal marginal ridges. Schwartz and Tattersal (1996), in commenting on the affinities of the Longgupo teeth, point out that five cusp molar teeth are primitive for both hominoids and hominids, and both crown morphology and wear patterns are similar to fossil Orangutan-related species from Vietnam (Tham Khuyen Cave). They also argue that second premolars with double roots and a relatively large and simple talonid are common to hominoids and not specific to hominids, or early African *Homo*. Wu Xinzhi (2000) reached the same conculsions and documents similarities with the Dryopithecine teeth from the Xiaolongtan coalmine in Kaiyuan County (Woo 1957; Zhang 1987) and also with *Lufengpithecus* (Xu & Lu 1979; Wu 1987). Schwartz and Tattersal (1996) and Wu (2000) provide a strong argument for the hominoid, rather than hominid, status of the Longgupo mandible fragment. The unassociated incisor tooth is morphologically and metrically within the range of modern east Asians (Mizoguchi 1985). It is possible that both the incisor tooth and stone artefacts could have moved to the lower Pleistocene layers at Wushan from younger sediments, after falling down cracks or some form of reworking of the deposit (bioturbation, treadage or water flow).

Yuanmou

The two Yuanmou maxillary central incisor teeth were found in 1965 on a small hill near Yuanmou city, Yunan Province. Excavations of the area by the Institute of Vertebrate Paleontology and Paleoanthropology in 1973 recovered faunal material but no artefacts or additional hominid remains. The hominid teeth were described by Hu (1973) and Zhou and Hu (1979). On the basis of their size, morphology and presumed age the teeth were assigned to *Homo erectus*. An initial reliance on palaeomagnetic dating and a complicated site stratigraphy has contributed to a prolonged debate over the age of the deposit (Cheng et al 1977; Li et al 1979; Liu & Ding 1983; Qing 1985; Pan et al 1991; Qian et al 1991). The precise location of the teeth in the deposit and their relationship to the dated horizons and faunal remains is unclear, and reworking of the deposit may also be an issue as they are of fluvial and diluvial origin. Liu and Ding (1983) noted that the faunal sequence at the site was inverted, with more extinct species in the upper levels than deeper in the deposit. They argue that the hominid teeth are associated with the Bruhnes Epoch, with a date younger than 730 ka, and probably between 500 and 600 ka. Qing (1985) disputes Liu and Deng's (1983) claims for a disturbed stratigraphy and places the hominid teeth near the Olduvai event in the Matuyama reversal at around 1.7 Ma. The application of ESR and fission track dating to the Yuanmou formation (Qian et al 1991) provided some additional support for the earlier date, with the ESR date on deer tooth enamel of around 1.3 Ma coming from higher in the deposit than the hominid teeth. Whether these dates provided meaningful information on the age of the Yuanmou incisors depends upon the stratigraphic integrity of the site. Given the distribution of dates from the more securely dated Chinese localities, a date of younger than 700 ka is more consistent with the current state of knowledge on the dispersion of hominids in east Asia.

The incisor teeth are large and robust in comparison with those in modern *Homo sapiens*. Tooth morphology and wear patterns indicate that they are from the same individual which is an unusual circumstance given the nature of the deposit. The incisors have a prominent basal tubercle on the lingual surface of the crown, with ridges extending from the tubercle to the incisive edge on the mesial and lateral sides. Between these ridges the surface appears scooped out, with fine projections extending from the tubercle into the scooped out surface. The overall effect is of a classic 'shovel shaped' incisor tooth. The labial surface of the tooth is relatively flat, apart from some fine grooves. The tooth roots are robust and somewhat flattened antero-posteriorly. Part of the root for the right incisor is not preserved. While these teeth are similar to those described for Zhoukoudian *Homo erectus* (Weidenreich 1937), this is not enough to indicate that they must be *Homo erectus* teeth. For instance, an incisor tooth of similar size and morphology is present in the Xujiayo 'archaic' *Homo sapiens* maxilla (Jia et al 1979) dated to approximately 100 ka (Yuan et al 1986), as well as Krapina Neanderthals (Wolpoff 1979).

Gongwangling

The Gongwangling cranial fragments were discovered at a small hill near Gongwang Village, east of Lantian, in 1964 by a team from the Institute of Vertebrate Paleontology and Paleoanthropology, Beijing (Wu et al 1966; Wu & Poirier 1995). The first hominid fossil to be found was an isolated maxillary molar and several months later this was followed by large cranial vault fragments. A large quantity of mammalian faunal material was also recovered from the site. A dominance of tropical and subtropical species has suggested a warmer climate than today (Gu & Jablonski 1989; Qi 1989). There are a range of palaeomagnetic dates for the hominid locality, with a choice of 750,000 to 800,000, 1 million, or 1.15 million years depending upon how the sequence is interpreted (An & Ho 1989; Wu et al 1989; An et al 1990). Liu and Ding's (1984) correlation of loess-palaeosol series with oxygen isotope records of core U28–238 placed Gongwangling at O^{18} 20–21, between 730 and 800 ka. Resolution of the dating uncertainty may come with future ESR and Uranium-series dating of the site. A small number of artefacts have been recovered from Gongwangling but their relationship to the hominid remains is uncertain (Dai 1966; Tai & Hsu 1973).

The hominid skeletal materials were first described by Woo (1965), with a detailed English language discussion of Gongwangling in Wu and Poirier (1995). The human fossils (PA 1051–6) include a complete frontal, large part of the parietals, most of the right temporal, part of the left and right nasals, and a large section of the right maxilla with associated second and third molars, and part of the left maxilla. Unfortunately, preservation of the bone fragments is extremely poor. There is some distortion through ground pressure and marked erosion of external bone surfaces. Features suggestive of *Homo erectus* are most apparent in the frontal bone which is broad, receding and has a robust supraorbital torus. There is marked postorbital constriction and no sulcus between the torus and frontal squama. Cranial vault bones are also relatively thickened, certainly compared with *Homo erectus* from Zhoukoudian; however, this may have been influenced by post-depositional taphonomic processes. The maxillary and nasal fragments, while also distorted by ground pressure, enabled Woo (1965) to reconstruct the face of Gongwangling. In his reconstruction, the mid-face is prognathic, deep and robust, and a contrast with Weidenreich and Swan's (Weidenreich 1937) reconstruction of the Zhoukoudian female *Sinanthropus*. The maxilla contains a small anterior nasal spine, prominent canine eminence and the lower margin of the zygomatic appears to have had a smooth transition to the alveolar border. The crowns of the right second and third molars are preserved, as are root fragments and alveoli of several other teeth.

Chenjiawo

Chenjiawo is the most complete of the remaining Chinese *Homo erectus* mandibles, the others being the 1959 Zhoukoudian mandible (Woo & Chao 1959) and the mandibular body fragment from Hexian (Wu & Dong 1982). The Chenjiawo mandible was found in 1963, near Yehu, ten kilometres northwest of Lantian city in Shaanxi Province. The mandible was described by Woo (1964a, 1964b) and is frequently linked with the Gongwangling cranium, also found in Lantian County, as Lantian Man. The two fossils, however, are not associated and the mandible has been argued to be from a female *Homo erectus* while the cranium appears to be male. Chenjiawo is also discussed in detail in Wu and Poirier (1995), in their standard detailed and comprehensive manner. Palaeomagnetic dating of the site suggests that the hominid remains date to around 650 ka or 500 ka (An & Ho 1989; Wu et al 1989; An et al 1990). There were 15 species of mammals recovered during the excavation of Chenjiawo and these have been discussed by Qi (1989). A few stone artefacts were also reported; however, their association with the hominid fossils is uncertain.

The Chenjiawo mandible has damage to both rami, but the mandibular body and most of the teeth are preserved. The left canine, first and second premolar and first molar were lost post mortem. Moderately heavy tooth wear is a characteristic of the remaining teeth, suggesting a middle-aged adult (30–35 years). Both third molars are congenitally absent. The mandibular body is neither particularly high or strongly reinforced. The symphysial region is receding with a small mental trigone. On the posterior surface of the symphysis there is a weak transverse torus, with a slight inferior torus below it. There is no mandibular torus, the mylohyoid line is distinct and the subalveolar fossae reasonably well developed. A slight eversion of the gonial region is suggested by what is preserved of the right ramus. The lateral prominence is poorly developed and the mandibular body not particularly thickened.

Yunxian

The two Yunxian crania (EV 9001 and EV 9002) were found in 1989 and 1990 near Mitousi Village, Yunxian County, Hubei Province. They were described by Li and Etler (1992) and Li et al (1994) who argue that their morphology is consistent with Chinese *Homo erectus* and distinct from 'archaic' *Homo sapiens*. Chen et al (1996, 1997) report a mean ESR date from mammal tooth enamel at Yunxian of 581±93 ka. The range of the 10 samples listed by the authors is from 800±164 to 455±58 ka. Faunal remains recovered from Yunxian are also considered to be of Middle Pleistocene origin (Li et al 1991). Providing the dated fauna and the Yunxian hominids are contemporaneous, this places Yunxian between Zhoukoudian and Gongwangling in the Chinese sequence. While some stone artefacts have been reported, their association with the hominid fossils remains uncertain. The recovered artefacts include a small number of bifaces (Li et al 1998).

The major difficulty in assessing the taxonomic affinity of the Yunxian crania is allowing for the comprehensive postdepositional crushing, distortion and expansion (Li & Etler 1992). Of the two crania, EV 9002 is better preserved but still extensively fractured and distorted. Few, if any, cranial dimensions can be recorded but it is clear that both crania are relatively massive. Li and Etler (1992) compare EV 9002 with *Homo erectus* and 'archaic' *Homo sapiens* crania from Africa (OH 9 and Kabwe), Indonesia (Sangiran 17, Ngandong), China (Gongwangling, Zhoukoudian, Hexian and Dali) and Europe (Petralona). They conclude that while the facial skeletons have some derived *sapiens*-like morphological features these are combined with 'plesiomorphic cranial vault and basicranial features that characterise the taxon *Homo erectus* and demonstrate that the Yunxian specimens are best placed within it' (Li & Etler 1992:406–407). However, traits which are commonly used to distinguish Asian *Homo erectus* from hominids of similar age in Africa and Europe, are poorly expressed in Yunxian. This does not preclude the Yunxian crania from being allocated to Asian *Homo erectus,* as these claimed autapomorphic traits are variably expressed in China, and are also present in African hominids (Bräuer 1990; Bräuer & Mbua 1992).

Unfortunately, many of the features which are diagnostic of *Homo erectus*, including the angulation of the occipital and nuchal planes, endocranial volume and the morphology of the supraorbital torus, are poorly preserved in both Yunxian crania. As a result of this Zhang (1995, 1998) indicates that several of the features claimed to support *Homo erectus* status by Li and Etler (1992) cannot really be assessed in the Yunxian crania and concludes that morphologically they are likely to be archaic *Homo sapiens* like Dali or Jinniushan rather than *Homo erectus*. Similarly, Wu and Poirier (1995) argue for a mixture of *Homo erectus* and *Homo sapiens* features in Yunxian. From my perspective, two factors support the *Homo erectus* status of the Yunxian crania. If the mean ESR date of 581 ka is meaningful, this falls within the middle of the Chinese *Homo erectus* sequence and is several hundred thousand years older than the earliest dated examples of archaic *Homo sapiens* (Jinniushan approximately 280 ka, Dali approximately 200 ka, Mapa approximately 132 ka). Secondly, if facial distortion is taken into account there is a remarkable similarity in both size and morphology between the facial skeletons of Sangiran 17 (Sartono 1971) and Yunxian EV 90002. Neither look anything like Jinniushan (Wu 1988; Lu 1989) or Dali (Wu 1981).

Nanjing (Tangshan)

In 1993, excavations in the branching cave of Hulu Cave on Tangshan hill, east of Nanjing in Jiangsu Province, recovered a large cranio-facial fragment from an adult *Homo erectus*. Initial uranium series dating of stalagmite on a capping flow stone layer gave a range of 417 ka to 207 ka (Chen et al 1998), with the authors not precluding the possibility of an older date. Subsequently, a date of greater than 500 ka was suggested by U-series TIMS dating of the same flow stone (Zhou et al 1999). The mammalian fauna from Hulu Cave have been described as northern Zhoukoudian type and comparable to layer 6 of Locality 1 at Zhoukoudian (Zhou et al 1999; Dong 1999; Xu 1999).

Nanjing consists of a nearly complete frontal, sections of the parietals and occipital bone, and most of the left side of the face. In lateral and facial views the frontal has similarities to Zhoukoudian *Homo erectus*. The supraorbital torus is thickened and arches over each orbit; there is marked postorbital constriction, and the frontal squama approaches Hexian in thickness. What remains of the facial skeleton indicates that Nanjing would have had a taller face than Weidenreich's (1937) of *Sinanthropus*.

Hexian

The Hexian *Homo erectus* remains were excavated by a team from the IVPP, in association with local archaeologists, from Longtandong Cave on the side of Wanjiashan Mountain in Hexian County between 1980 and 1981. Recovered *Homo erectus* fossils include a fairly complete vault (PA 830), a fragmentary left mandibular body, frontal and parietal fragments and a number of teeth. These have been described in a number of publications (Huang et al 1982; Wu & Dong 1982; Wu 1983; Dong 1989; Wu & Poirier 1995) however, as the majority of these were published in Chinese, Hexian remains comparatively unknown outside of China. Wu and Poirier (1995) provide the most extensive description in English. The initial dates for the Hexian site were surprisingly young, suggesting a possible overlap between *Homo erectus* and 'archaic' *Homo sapiens* like Dali in China. Chen et al (1987) reported a range of uranium-series dates from 150–190 ka, with a possible maximum of 270 ka. Similar results were obtained by Li and Mei (1983 cited in Wu et al 1989) with a thermo-luminesence date of 195±16 ka, and Xu and You (1984) associate the Hexian fauna with O^{18} stage 8, about 240–280 ka. However, more recently, Grün et al (1998) applied ESR and U-series to rhinoceros and bovid teeth from Hexian, obtaining a combined age estimate of 412±25. If these teeth are contemporaneous with the hominid remains, this date places Hexian towards the older part of the range reported for Locality 1 at Zhoukoudian.

A large range of vertebrate fauna were also recovered in the Hexian excavation and have been discussed by Huang et al (1982), Xu and You (1984), Xu (1984) and Han and Xu (1989). At least 47 mammal species are present, including 30 which are considered modern as well as the *Ailuropoda-Stegadon* fauna common in southern Chinese Pleistocene localities. Xu and You (1984) argue that the faunal composition, with its mixture of cold adapted northern mammals and more sub-tropical species, may be the result of the migration of northern species south during a cold climate phase. There have been no artefacts reported from Hexian.

The Hexian cranial vault is reasonably complete, with bone loss primarily restricted to the sphenoid region, roof of the orbits, zygomatic processes of the temporals, mastoid tips and baso-occipital. There is some post-depositional distortion of the anterior third of the parietals resulting in a flattened profile and some asymmetry. The vault while long and low is relatively broad for its length. Maximum cranial breadth is at the supramastoid ridge. The frontal is more receding than at Zhoukoudian, with a supraorbital torus which is both broad and thick. Rather than forming a straight bar, as in most of the Javan hominids, the supraorbital torus tends to arch over each orbit and thins as you move laterally. There is a slight bulge in the frontal squama but this is not as pronounced as in Zhoukoudian *Homo erectus*. Hexian does not have a median ridge or parasagittal depressions.

The occipital torus of Hexian forms a transverse smooth prominence, with the vault bone 17.8 mm thick at the centre of the torus. Laterally the torus extends towards asterion and there is a distinct supratoral sulcus. As is common in *Homo erectus* there is an angular transition between the nuchal and occipital planes. Cranial vault bone thickness increases as you move posteriorly and inferiorly, with thickness at the parietal eminences 14.6 mm and asterion 18 mm. This basal reinforcement is similar to *Homo erectus* from Zhoukoudian and Java. Endocranial volume for Hexian is approximately 1025 ml and the general level of robusticity suggests PA 830 was a male.

Morphological and metrical comparisons of Hexian with *Homo erectus* from Trinil, Ngandong and Zhoukoudian (Wu & Dong 1982; Dong 1989) have produced conflicting results. Wu and Dong (1982) found a general similarity in proportions and morphology indicating that all were members of the *Homo erectus* grade. In overall size Hexian was much more similar to Zhoukoudian than it was to the much smaller Trinil. However, in some proportions, and when viewed superiorly, Hexian was similar to Trinil. The great breadth of Hexian, possibly slightly influenced by post-mortem squashing, was distinct from both Zhoukoudian and Trinil. Most recently, Dong (1989) argued that the morphology of Hexian was closer to Javan *Homo erectus* than it was to Zhoukoudian.

Zhoukoudian

The Peking Man site, Zhoukoudian, is located in Beijing Municipality north-eastern China. Zhoukoudian is arguably, along with Olduvai Gorge, one of the most widely known hominid localities on the planet. Excavations at Zhoukoudian began in 1921 under the direction of Otto Zdansky, an Austrian geologist, with the first hominid remains, a molar tooth, discovered in 1923 (Wu & Wu 1997). The first *Homo erectus* (*Sinanthropus erectus*) skull cap was found by Pei Wenzhong in 1929 and up until World War II the fragmentary remains of at least 14 other individuals were recovered from Locality 1. This is by far the largest *Homo erectus* sample from a single locality in the world, with detailed descriptions of the pre-war discoveries by the German anatomist Franz Weidenreich (1935, 1936, 1937, 1937, 1941, 1943). In one of the greatest scientific tragedies of the last century, all of the Zhoukoudian hominid materials discovered before WWII were lost during an attempt to send them to the United States after the Japanese army invaded China (Shapiro 1971; Wu & Lin 1983). Fortunately, highly detailed casts had been made and in association with Weidenreich's monographs this has enabled continued study of the Zhoukoudian hominids. After WWII, excavations continued at Locality 1 and other sections of the former cave complex. Between 1949 and 1966, five teeth, a tibia and a humerus shaft fragment, a mandibular body (PA86), and frontal, parietal and occipital fragments of skull H (PA109), parts of which were found in 1934, were recovered. Descriptions of the most recent discoveries can be found in Woo and Chia (1954), Woo ans Chao (1959) and Qiu et al (1973), with an excellent English language summary in Wu and Poirier (1995) .

Chinese archaeologists have identified 13 layers in the excavated deposits at Zhoukoudian. Hominid remains and stone artefacts have been reported from layers 3 to 9, with evidence of fire claimed for layers 3, 4, 6 and 10. As well as hominid fossils the remains of more than 90 other mammal species have been recovered from Locality 1 (Hu 1985; Qi 1989). A wide range of dating procedures have been applied to Locality 1, with reasonably consistent results. These include uranium series (Zhao et al 1985), electron spin resonance (Huang, P, et al 1991), thermoluminesence (Pei 1985), paleomagnetism (Liu et al 1977; Qian 1980; Qian et al 1985) and fission track (Liu et al 1985; Guo et al 1991). While the majority of these dates suggest that the layers containing hominid fossils date to between 400,000 and 250,000 years, Shen et al's (1996) application of TIMS based U-series suggested a much greater age for the upper strata than previously thought. Skull 5, previously thought to be approximately 230 ka would be older than 400 ka. The stone artefacts recovered from Locality 1 were described and analysed by Pei Wenzhong and Zhang Senshui (1985). Long-established interpretations of the excavated materials from Locality 1, including the evidence for fire and hearths, and stone and bone artefact manufacture, were challenged by Louis Binford and coworkers in the mid-1980s (Binford & Ho 1985; Binford & Stone 1986).

The reconstruction of skull 5 (individual H) from the fragments found before and after WWII suggests that it is the largest of the Locality 1 crania and therefore probably a male. This cranial vault shares a number of features in common with the other Locality 1 crania. Maximum cranial breadth is in the auricular region, and breadth decreases steadily as you move towards the top of the vault. Overall vault shape, when viewed from the side, is long and low, with a receding forehead and marked angulation in the occipital between the nuchal and occipital planes. There is a distinct frontal bulge and the frontal squama is separated from the supraorbital torus by a well-defined sulcus. The median sagittal ridge is not as well defined, partly due to bone loss, as in some of the other Locality 1 vaults. The supraorbital ridges are projecting and connected in the glabella region forming a robust supraorbital torus. It appears that the occipital torus was well developed and separated from the occipital plane by a supratoral sulcus. The cranial vault bone is moderately thick; 10.0 mm at lambda, 16.8 mm at the external occipital protuberance and 14.5 mm at asterion. In common with most *Homo erectus* vaults the vault bone thickens laterally and basally. Given the size of the reconstructed vault the endocranial volume was probably greater than skull 10 which is estimated to be around 1225 ml.

Dali

The Dali cranium was discovered in 1978 embedded in a loess terrace near Jiefang Village, Dali County, Shaanxi Province. Initial reports of the Dali site can be found in Wang et al (1979) and Wu and You (1979), with Wu Xinzhi (1981) describing the cranium. Additional comparative information can be found in Wu Xinzhi (1988, 1989), with a detailed summary in Wu and Poirier (1995). Uranium-series dating of ox teeth from the site obtained a date of 209,000±23,000 years (Chen et al 1994) however, the nature of the association between the hominid cranium and the ox teeth remains uncertain. Given what is known about the Chinese hominid fossil record, for instance the reasonably consistent dating results for Zhoukoudian Locality 1, a date of this magnitude would not seem unreasonable. A number of small stone artefacts, primarily scrapers, were also recovered from the site.

Dali is reasonably complete and well preserved, with damage restricted to postdepositional crushing and displacement of the palate and left maxilla. A large section of the right parietal is missing, as are the maxillary teeth and left zygomatic arch. Wu (1981, 1989) found that most of the cranial dimensions and morphological features of Dali were intermediate between *Homo erectus* and *Homo sapiens*, with Dali assigned to 'archaic' *Homo sapiens*. Craniofacial anatomy and vault shape are distinct from European Neanderthals and earlier European hominids like Petralona and Atapeurca. The Dali frontal has relatively robust supraorbital development, with the torus particularly thickened mid-orbit and thinning laterally. There is a median ridge which extends into a slight pre-bregmatic eminence and very slight cruciate eminence. When viewed laterally the parietals are long and low. Unlike *Homo erectus,* maximum cranial breadth is located on the posterior-superior temporal, rather than the cranial base. From a posterior viewpoint the parietals do not have a circular profile. The remaining parietal tuberosity is distinct. Most of the vault superstructures in the temporal, occipital and frontal regions are robust. The mastoid process is small and the occipital and nuchal plane form a sharp angle similar to *Homo erectus* , with an endocranial volume of 1100–1200 ml.

While Dali's vault is relatively robust, with a mixture of *Homo erectus* and *Homo sapiens* traits, the facial skeleton is much more like those in modern *Homo sapiens*. This is particularly noticeable for the zygomatics, which apart from their thickened frontal processes, are quite delicate. Digital reconstruction of the damaged facial skeleton suggests that facial height was not great, although the alveolar region was well developed. The better preserved right orbit is quadrangular in shape, with smooth and rounded margins. The nasal bones are not particularly broad, but are flattened and the nose of Dali would have been broad and low. The inferior border of the malar region has an angular junction with the alveolar portion of the maxilla as is common in *Homo sapiens*.

Jinniushan

The Jinniushan skeleton was excavated in 1984 from a collapsed limestone cave near Sitian Village, southwest of Yinkou in Liaoning Province by students from Peking University under the direction of Professor Lu Zun'e. Original reports and preliminary descriptions of the Jinniushan skeleton were presented by Wu Rukang (1988) and Lu (1989), with Wu and Poirier (1995) providing additional information. There are a number of uranium-series dates from the cave which range from 310,000 to 200,000 years. Lu (1989) argued that layer 7 where the hominid fossils were found was dated to approximately 280,000 years. Research by Huang and You (1987) and Chen et al (1993) indicates a date of closer to 200,000 might be more appropriate.

The skeleton consists of a skull, left ulna, left innominate, 6 vertebrae, ribs and numerous bones of the hands and feet. The cranium was originally in one piece but was unfortunately damaged during excavation. Initial reconstruction of the skull was undertaken at the Institute of Vertebrate Paleontology and Paleoanthropology by Wu Rukang and his assistant Zhao Zongyi (Wu, R, 1988), with later adjustment at Peking University. Both the vault and facial skeleton are heavily reconstructed, with extensive bone loss in the frontal, parietal and occipital regions.

Similar to Dali, Jinniushan has a combination of *Homo erectus* and *Homo sapiens* anatomical features. An endocranial volume of approximately 1400 cc, combined with relatively thin cranial vault bone, some parietal expansion, rounding of the occipital region, the position of maximum cranial breadth, and overall facial morphology, have resulted in Jinniushan being allotted to archaic *Homo sapiens*. Compared with Dali, the brow ridges are less robust and not thickened mid-orbit, the supraorbital sulcus is shallower but there is greater postorbital constriction. Jinniushan has a median frontal ridge which extends on to the parietals. Like Dali, the mastoid process is small. The occipital and nuchal planes do not meet at as sharp an angle as in Dali and the occipital torus is not particularly robust. The posterior profile of the parietals is similar to Dali, as is the location of maximum cranial breadth. Derived traits, similar to *Homo sapiens*, are apparent in the relatively delicate facial skeleton. While anterior tooth wear is marked, there is relatively little wear on the molar teeth. Comparison with prehistoric Australian dentitions suggests that Jinniushan was a young adult, 16 to 20 years of age, but this would depend upon broadly similar rates of tooth wear. Lu's (1989) age estimate of around 20 years is probably closer than Wu Rukang's (1988) estimate of 30.

Maba

The Maba cranial vault fragment (PA 84) was discovered in 1958 during the collection of fertiliser at Shizishan Cave, near Maba Village, in Guandong Province. Most often allocated to 'archaic' *Homo sapiens*, Maba consists of several large fragments which can be articulated. There is a large part of the frontal and parietals, as well as most of the right orbit and nasal bones. Rodent gnawing has removed most of the left section of browridge and exposed the frontal sinus over both orbits. Maba was initially described by Wu and Pang (1959) and is further discussed in Wu Xinzhi (1988, 1989) and Wu and Poirier (1995). A uranium-series date of 135–129 ka has been reported for Maba (Yuan et al 1986) and Han and Xu (1989) describe the Late Pleistocene fauna which includes *Stegodon orientalis* and *Ailuropoda*.

Viewed laterally, the Maba frontal region is more inflated than Zhoukoudian *Homo erectus*, or Dali and Jinniushan. The browridges are prominent, with a curved outline, but without pronounced thickening medially (glabella). In some respects browridge shape is similar to European Neanderthals, for instance La Ferrassie. The reasonably complete right orbit has a circular profile. The superior orbital margin is smooth and rounded but the inferior lateral margin is sharp. The preserved orbital segment, nasal bones and fronto-maxillary pieces indicate that Maba was much longer-faced than either Dali or Jinniushan. While the nasal bones are narrow and pinched, the interorbital distance is relatively broad. There is a slight median ridge on the anterior third of the frontal, though it is more of a rounded boss. Superior temporal lines are neither particularly pronounced nor high on the side of the vault. Despite reports to the contrary the antero-lateral surface of the of the right fronto-sphenoidal process of the zygomatic does not have a particularly forward (east Asian) orientation. Viewed superiorly, there is marked postorbital constriction in combination with an inflated parietal region. Cranial vault bone thickness is similar to modern male east Asians and thinner than east Asian *Homo erectus*.

Xujiayo

The Xujiayo hominid site is located on the west bank of the Liyigou River near Xujiayo village in Shanxi Province. Between 1976 and 1979 excavations recovered a left maxillary fragment from a six-year-old child, 12 parietal fragments, two occipitals, a temporal bone and mandibular ramus, and several isolated teeth. These have been described by Jia et al (1979) and Wu Maolin (1980), who have assigned them to 'archaic' *Homo sapiens*. More detailed English language descriptions are provided by Wu and Poirier (1995). Uranium-series dating of rhinocerous teeth recovered from the fluvial deposits at the hominid site by Chen et al (1984) obtained a date of 125 ka to 104 ka. A large number of artefacts was reported from the 1976 excavation, with a predominance of scrapers and smaller sized stone tools (Jia et al 1979).

MIDDLE PLEISTOCENE HOMINIDS AND MODERN HUMAN ORIGINS IN CHINA

Over the last two decades there has been a protracted debate over the evolutionary relationship between Middle Pleistocene *Homo erectus* and anatomically modern *Homo sapiens* (Thorne & Wolpoff 1981; Stringer & Andrews 1988; Frayer et al 1994; Stringer & Bräuer 1994). This debate has its origins in Franz Weidenreich's observation that the patterns of variation amongst living human populations were paralleled by the regional variations in Pleistocene hominids, particularly *Sinanthropus* in China and *Pithecanthropus* in Java (Weidenreich 1939a, 1939, 1943). Weidenreich realised that, on average, modern humans, and their skeletons, from east Asia looked different to those from Europe and Africa. The development of these differences he traced back to regionally differentiated groups of *Homo erectus*. For Weidenreich, and the more recent members of the multiregional school (Wolpoff et al 1984; Wolpoff 1991), the ancestors of modern east Asian could be identified in the hominid remains from Locality 1 at Zhoukoudian. Others have disputed the significance of these regional features, especially their occurrence in Middle Pleistocene hominids, and see their evolution as a relatively recent phenomenon (Stringer & Andrews 1988; Groves 1989; Habgood 1989; Lahr 1994; 1996 Stringer & Bräuer 1994; Brown 1999).

In China there are some substantial obstacles to any search for modern human origins, at least if pursued through the fossil record. While there are an increasing number of Middle Pleistocene localities, with reasonably secure broad chronologies, preservation of skeletal materials remain a problem. This is particularly true for

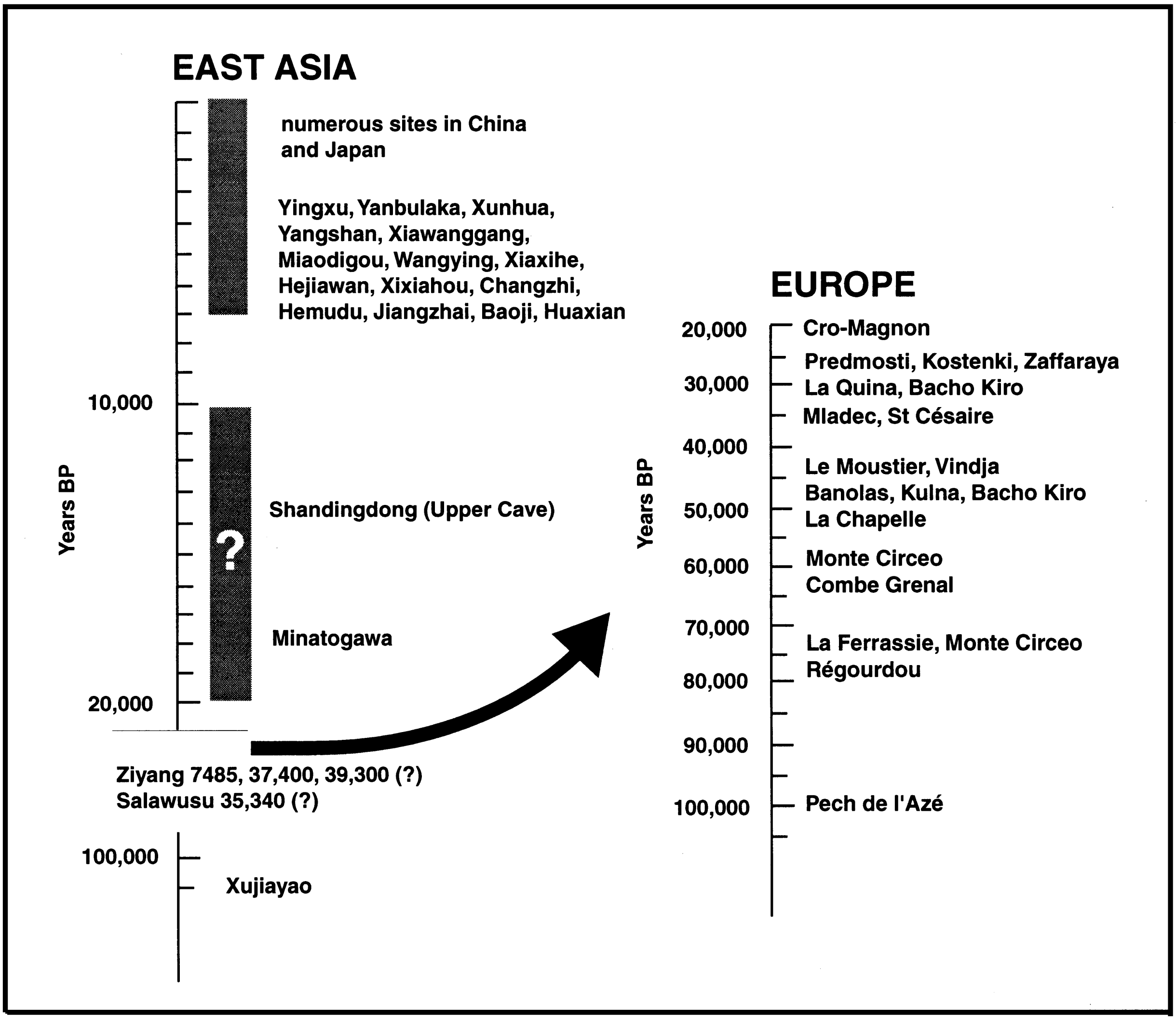

Figure 10.2 Comparison of the distribution of Late Pleistcene hominid sites in east Asia and Europe.

the facial skeleton, where the existing faces from Yunxian, Gongwangling, Nanjing, Dali and Jinniushan are either incomplete, heavily reconstructed or severely distorted. There are also substantial discontinuity's in the distribution of Chinese *Homo erectus*, 'archaic' *Homo sapiens* and *modern Homo sapiens* sites (Chen & Zhang 1991). Most importantly, during a time period in which Europe has a large number of hominid localities between 100 ka and 30 ka, east and southeast Asia is devoid of convincingly dated hominid fossils (figure 10.2). In China, between the Xujiayao fragments at 104 to 125 ka (Chen et al 1982) and the Upper Cave assemblage at either 10 ka (Wu & Wang 1985), or 24 to 29 ka (Chen et al 1989; Hedges et al 1992), there are no archaeological sites, or hominid fossils, in which both provenance and age have been securely established. Problematic localities including Salawusu on the Ordos Plateau (Woo 1958a; Dong et al 1981; Wu & Poirier 1995) and Ziyang (Woo 1958b; Wu & Poirier 1995). This is particularly unfortunate as this is presumably a time period over which modern humans may have arrived, or evolved, in east Asia. Assuming that the distribution of dates is not simply an artifice of dating technology, there would seem to be only three possible explanations. Late Pleistocene sites are present but have not been found; people were present but evidence is not preserved; or the discontinuity reflects the extinction of hominids in the Middle to Late Pleistocene and the arrival of modern humans towards the end of the Pleistocene. While the first of these is possible it seems unlikely given the extent of human activities and archaeological investigation in China. An argument for some form of preservational bias also seems unlikely given the distribution of Middle Pleistocene and Holocene archaeological sites. The final choice would depend upon large-scale environmental disruption, rapidly declining fertility, or a virulent species-specific disease, for which there is no evidence.

While a poor Late Pleistocene fossil record is an obstacle to documenting the arrival and evolution of modern east Asians, it is possible to examine the evidence for continuity over the last 25 ka (Brown 1999). In east Asia while there is considerable evidence for widespread distribution of a distinctively east Asian cranio-facial morphology by the early Neolithic (Yan et al 1960; Han & Pan 1983; Wu & Zhang 1985) there is debate over the status of the earliest modern humans from Upper Cave (Weidenreich 1939b; Wu 1960, 1961; Kaminga & Wright 1988; Brown 1999), Liujiang (Woo 1959; Yuan et al 1986; Brown 1999) and Minatogawa (Suzuki 1982; Brown 1999). Upper Cave 101 is apparently dated to between 10 and 25 ka, there is a uranium-series date of 67 kyr for a stalactite layer in the Liujiang cave but this has no demonstrated association with the skeleton (Yuan et al 1986; Chen & Zhang 1991), and Minatogawa 1 has radiocarbon dates on charcoal of 18,250±650 to 16,600±300 years BP (Kobayashi et al 1974). Morphological and statistical comparisons have repeatedly distinguished these three fossils from modern and Neolithic east Asians (Weidenreich 1939; Suzuki 1982; Kaminga & Wright 1988; Howells 1989; Wu 1992; Hanihara 1994; Brown 1999). This result is exactly what you would expect as these fossils did not come from the comparative modern and Neolithic groups. However, distinctively Asian facial proportions of mid-facial breadth, facial height, orientation of the molars, nasal morphology and prognathism were also not present (Brown 1999). If this admittedly small sample of fossils is representative it suggests that modern east Asian cranio-facial morphology has a very recent origin and does not appear to extend into the Late Pleistocene. The implication is that Middle-Pleistocene east Asians probably have little to do with modern east Asians as well.

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REFERENCES

An, Z, Gao, W, Zhu, Y, Kan, X, Wang, J, Sun, J, & Wei, M, 1990. Magnetostratigraphic dates of Lantian *Homo erectus*. *Acta Anthropologica Sinica* 9:1–7. (In Chinese with English abstract,)

An, Z, & Ho, CK, 1989. New Magnetostratigraphic dates of Lantian Homo erectus. *Quaternary Research* 32:213–221.

Binford, L, & Stone, N, 1986. Zhoukoudian: A closer look. *Current Anthropology* 27:453–475.

Binford, LR, & Ho, CK, 1985. Taphonomy at a distance: Zhoukoudian, "the cave home of Beijing man"? *Current Anthropology* 26:413–442.

Bräuer, G, 1990. The occurrence of some controversial *Homo erectus* cranial fatures in the Zhoukoudian and East African hominids. *Acta Anthropologica Sinica* 9:352–358.

Bräuer, G, & Mbua, E, 1992. Homo erectus features used in cladistics and their variability in Asian and African hominids. *Journal of Human Evolution* 22:79–108.

Brown, P, 1999. The first modern East Asians?: another look at Upper Cave 101, Liujiang and Minatogawa 1. In K. Omoto, (eds) *Interdisciplinary Perspectives on the Origins of the Japanese;* 105–131. Kyoto: International Research Center for Japanese Studies.

Chen, Q, Wang, Y, & Liu, Z, 1998. U-seies dating of stalagmite samples from Hulu cave in Nanjing, Jiangsu Province, China. *Acta Anthropologica Sinica* 17: 171–176. (In Chinese with English abstract.)

Chen, T, Yuan, S & Guo, S, 1982. Uranium series dating of Xujiayao (Hsu-chia-yao) site. *Acta Anthropologica Sinica* 1:91–95. (In Chinese with English abstract.)

Chen, T, Yuan, S, & Guo, S, 1984. The study of uranium series dating of fossil bones and an absolute age sequence for the main Paleolithic sites of north China. *Acta Anthropologica Sinica* 3:259–268.

Chen, T, Hedges, REM, & Yuan, Z, 1989. Accelerator radiocarbon dating for the Upper Cave of Zhoukoudian. *Acta Anthropologica Sinica* 8:216–221. (In Chinese with English abstract.)

Chen, T, Yang, Q, Hu, Y, & Li, T, 1996. ESR dating on the stratigraphy of Yunxian Homo erectus, Hubei, China. *Acta Anthropologica Sinica* 15:114–118. (In Chinese with English abstract.)

Chen, T, Yang, Q, & Wu, E, 1993. Electron spin resonance dating of teeth enamel samples from Jinniushan palaeoanthropological site. *Acta Anthropologica Sinica* 12:337–346. (In Chinese with English abstract.)

Chen, T, Yang, Q, & Wu, E, 1994. Antiquity of Homo sapiens in China. *Nature* 368:55–56.

Chen, T, Yuan, S, Guo, S, & Hu, Y, 1987. Uranium series dating of fossil bones from the Hexian and Chaoxian human fossil sites. *Acta Anthropologica Sinica* 6:249–254. (In Chinese with English abstract.)

Chen, T, Yang, Q, Hu, Y, Bao, W, & Li, T, 1997. ESR dating of tooth enamel from Yunxian Homo erectus site, China. *Quaternary Science Reviews* 16:455–458.

Chen, T, & Zhang, Y, 1991. Palaeolithic chronology and possible coexistance of Homo erectus and Homo sapiens in China. *World Archaeology* 23:147–154.

Cheng, G, Li, S, & Lin, J, 1977. Discussion of the age of Homo erectus yuanmouensis and the event of early Matuyama. *Scientia Geologica Sinica* 1:34–43.

Dai, E, 1966. The paleoliths found at Lantian man locality of Gongwangling and its vicinity. *Vertebrata PalAsiatica* 10:30–34. (In Chinese with English abstract).

Dong, G, Gao, S, & Li, B, 1981. New discovery of fossils of Ordos Man. *Kexue Tongbao* 26:1192–1194. (In Chinese with English abstract.)

Dong, W, 1999. The Artiodactyla from Hulu Cave, Tangshan, Nanjing and the environment of Nanjing man. *Acta Anthropologica Sinica* 18:270–281. (In Chinese with English abstract.)

Dong, X, 1989. Homo erectus in China. In Wu, R, Wu, X, and Zhang, S, (eds) *Early humankind in China;* 9–23. Beijing: Science Press.

Frayer, DW, Wolpoff, MH, Thorne, AG, Smith, FH, & Pope, GG, 1994. Getting it straight. *American Anthropologist* 96:424–438.

Groves, CP, 1989. A regional approach to the problem of the origin of modern humans in Australasia. In Mellars, P, and Stringer, C, (eds) *The human revolution;* 274–285. Princeton: Princeton University Press.

Grün, R, Huang, P, Huang, W, McDermott, F, Thorne, A, Stringer CBS, & Yan, G, 1998. ESR and U-series analyses of teeth from the palaeoanthropological site of Hexian, Anhui Province, China. *Journal of Human Evolution* 34:555–564.

Gu, Y, & Fang, Q, 1991. Human Fossils. In *Wushan Hominid Site;* 16–19. Beijing: Haiyang (Ocean) Press. (In Chinese with English abstract.)

Gu, Y, & Jablonski, N, 1989. A reassessment of Megamacaca lantianensis of Gongwangling, Shaanxi Province. *Acta Anthropologica Sinica* 8:343–346. (In Chinese with English abstract.)

Guo, S, Liu, S, Sun, S, Zhang, F, Zhou, S, Hao, X, Hu, R, Meng, W, Zhang, P, & Liu, J, 1991. Fission track dating of the 4th layer of the Peking Man site. *Acta Anthropologica Sinica* 10:73–77. (In Chinese with English abstract.)

Habgood, PJ, 1989. The origin of anatomically-modern humans in Australasia. In Mellars, P, & Stringer, S, (eds) *The Human Revolution;* 245–273. Princeton: Princeton University Press

Han, D, & Xu, C, 1989. Quaternary mammalian faunas in south China. In Wu, R, Wu, X, & Zhang, S, (eds) *Early humankind in China;* 338–391. Beijing: Science Press. (In Chinese).

Han, K, & Pan, Q, 1983. Early Neolithic human skulls from Hemudu, Yuyao, Zhejiang. *Acta Anthropologica Sinica* 2:124–131. (In Chinese with English abstract.)

Hanihara, T, 1994. Craniofacial continuity and discontinuity of Far Easterners in the Late Pleistocene and Holocene. *Journal of Human Evolution* 27:417–441.

Hedges, REM, Housley, RA, Bronk, CR, & Van Klinken, GJ, 1992. Radiocarbon dates from the Oxford AMS system: Archaeometry Datelist 14. *Archaeometry* 34:141–159.

Howells, WW, 1989. *Skull shapes and the map*. Cambridge, Mass: Peabody Museum of Archaeology and Ethnology, Hatvard University.

Hu, C, 1973. Ape-man teeth from Yuanmou, Yunnan. *Acta Geologica Sinica* 1:65–71. (In Chinese with English abstract.)

Hu, C, 1985. The history of mammalian fauna of locality 1 of Zhoukoudian and its recent advances. In IVPP, (eds) *Multi-disciplinary study of the Peking Man Site at Zhoukoudian;* 107–113. Beijing: Science Press (In Chinese).

Huang, P, Jin, S, Liang, R, Zheng, L, Yuan, Z, Cai, B & Fang, Z, 1991. Study of ESR dating for burying age of the first skull of Peking Man and chronological scale of the cave deposit in Zhoukoudian site Loc. 1. *Acta Anthropologica Sinica* 10:107–115. (In Chinese with English abstract.)

Huang, W, & You, Y, 1987. On the problem of the karst cave and the deposits of the site of Jinniushan man. *Carsologica Sinica* 6:61–67. (In Chinese with English abstract.)

Huang, W, Fang, D, & Ye, Y, 1982. Preliminary study on the fossil hominid skull and fauna of Hexian, Anhui. *Vertebrata Palasiatica* 20:248–257. (In Chinese with English abstract.)

Huang, W, Ji, H, & Yang, D, 1991. Cave and stratigraphy. In , (eds) *Wushan Hominid Site;* 10–15. Beijing: Haiyang (Ocean) Press

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

Jia, L, 1978. On the climate of the Zhoukoudian region during the time of Peking Man. *Acta Stratigraphica Sinica* 2:53–56. (In Chinese.)

Jia, L, Wei, Q, & Li, C, 1979. Report on the excavation of the Hsuchiayo Man site in 1976. *Vertebrata PalAsiatica* 17:277–293. (In Chinese with English abstract.)

Kaminga, J, & Wright, RVS, 1988. The Upper Cave at Zhoukoudian and the origins of the Mongoloids. *Journal of Human Evolution* 17:739–767.

Kobayashi, H, Hirose, Y, Sugino, M, & Watanabe, N, 1974. TK-99. *Radiocarbon* 16:384.

Kong, Z, 1985. Vegetational and climatic changes since the Paleogene at Zhoukoudian and its adjacent regions. In IVPP, (eds) *Multi-disciplinary study of the Peking Man Site at Zhoukoudian;* 119–154. Beijing: Science Press. (In Chinese.)

Krings, M, Stone, A, Schmitz, RW, Krainitzki, H, Stoneking, M, & Paabo, S, 1997. Neandertal DNA sequences and the origin of modern humans. *Cell* 90:19–30.

Lahr, MM, 1994. The multiregional model of modern human origins: a reassessment of its morphological basis. *Journal of Human Evolution* 26:23–56.

Lahr, MM, 1996. *The evolution of modern human diversity*. Cambridge: Cambridge University Press.

Li, P, Qian, F, Ma, X, Pu, Q, Xing, L, & Ju, S, 1979. A preliminary study of the age of Yuanmou Man by palaeomagnetic techniques. *Scientia Sinica* 6:579–591.

Li, T, & Etler, DA, 1992. New Middle Pleistocene hominid crania from Yunxian in China. *Nature* 357:416–419.

Li, T, Wang, Z, Li, W, Fong, X, Hu, K, & Liu, W, 1991. Geological survey and excavation of the fossil site at Quyuan River Mouth, Yunxian, Hubei Province. *Jianghan Kaogu* 1:1–14. (In Chinese.)

Li, T, Wang, Z, Li, W, Feng, X, & Wu, X, 1994. Morphological features of human skulls from Quyuan River mouth, Yunxian, Hubei and their place in human evolution. *Acta Anthropologica Sinica* 13:104–116. (In Chinese with English abstract.)

Li, Y, Ji, H, Li, T, Feng, X, & Li, W, 1998. The stone artefacts from the Yunxian man site. *Acta Anthropologica Sinica* 17:94–120. (In Chinese with English abstract.)

Liu, C, Jin, Z, Zhu, R, Yang, H, & Wu, P, 1991. Dating. In *Wushan Hominid Site;* 156–163. Beijing: Haiyang Press. (In Chinese with English abstract.)

Liu, C, Zhu, X, & Ye, S, 1977. A palaeomagnetic study on the cave-deposits of Zhoukoudian (Choukoutien), the locality of Sinanthropus. *Scientia Geologica Sinica* 1977:26–33. (In Chinese.)

Liu, S, Zhang, F, Hu, R, Liu, J, Guo, S, Zhou, S, Meng, W, Zhang, P, Sun, S, & Hao, X, 1985. Dating Peking Man Site by the fission-track method. In IVPP, (eds) *Multidisciplinary study of the Peking Man site at Zhoukoudian;* 241–245. Beijing: Science Press. (In Chinese.)

Liu, T, & Ding, M, 1983. Discussion on the age of "Yuanmou Man". *Acta Anthropologica Sinica* 2:40–48. (In Chinese with English abstract.)

Liu, T, & Ding, M, 1984. A tentative chronological correlation of early human fossil horizons in China with loess-deep sea records. *Acta Anthropologica Sinica* 3:93–101. (In Chinese with English abstract.)

Lu, Z, 1989. Date of Jinniushan man and his position in human evolution. *Liaohai Wenwu Xuekan* 1:44–55. (In Chinese.)

Mizoguchi, Y, 1985. *Shovelling: A statistical analysis of its morphology*. Tokyo: The University Museum, The University of Tokyo.

Pan, Y, Li, Q, Lin, Y, & Jiang, C, 1991. Late Pleistocene fauna discovered in Yuanmou basin, Yunnan. *Acta Anthropologica Sinica* 10:167–175. (In Chinese with English abstract.)

Pei, J, 1985. Thermoluminesence dating of the Peking Man site and other caves. In IVPP, (eds) *Multidisciplinary study of the Peking Man site at Zhoukoudian;* 256–260. Beijing: Science Press. (In Chinese.)

Pei, W, & Zhang, S, 1985. A study of the lithic artefacts of Sinanthropus. *Palaeontologica Sinica* New Series D No 12. (In Chinese with English abstract.)

Qi, G, 1989. Quaternary mammalian faunas and environment of fossil humans in north China. In Wu, R, Wu, X, & Zhang, S, (eds) *Early humankind in China;* 276–337. Beijing: Science Press. (In Chinese.)

Qian, F, 1980. Magnetostratigraphic study on the cave deposits containing fossil Peking Man at Zhoukoudian. *Kexue Tongbao* 25:359. (In Chinese.)

Qian, F, Zhang, J, & Yin, W, 1985. Magnetic stratigraphy from the sediment of the west wall and he test pit of Locality 1 at Zhoukoudian. In IVPP, (eds) *Multi-disciplinary study of the Peking Man site at Zhoukoudian;* 251–255. Beijing: Science Press. (In Chinese.)

Qian, F, Li, Q, Wu, P, Yuan, S, Xing, R, Chen, H, & Zhang, H, 1991. Lower Pleistocene, Yuanmou Formation. In IVPP, (eds) *Quaternary Geology and Paleoanthropology of Yuanmou, Yunnan, China;* 17–50. Beijing: Science Press.

Qing, F, 1985. On the age of 'Yuanmou Man'—a discussion with Liu Tungsheng et al *Acta Anthropologica Sinica* 4:324–332. (In Chinese with English abstract.)

Qiu, Z, Gu, Y, Zhang, Y & Hu, S, 1973. New discovery of the fossils and cultural remains of Sinanthropus pekinensis from Zhoukoudian. *Vertebrata PalAsiatica* 11:109–131. (In Chinese.)

Sartono, S, 1971. Observations on a new skull of Pithecanthropus erectus (Pithecanthropus VIII) from Sangiran, Central Java. *Proceedings Koninklijke Nederlandsche Akademie van Wetenschappen* ser. B 74:185–194.

Schwartz, JH, & Tattersall, I, 1996. Whose teeth? *Nature* 381:201–202.

Shapiro, H, 1971. The strange, unfinished saga of Peking Man. *Natural History* 80:74.

Shapiro, H, 1974. *Peking Man*. New York, Simon and Schuster.

Shen, G, & Jin, L, 1991. Restudy of the upper age limit of Beijing Man Cave. *Acta Anthropologica Sinica* 10:273–277. (In Chinese with English abstract.)

Shen, G, Teh-Lung, K, Bassam, G, & Yuan, Z, 1996. Preliminary results on U-series dating of Peking Man site with high-precision TIMS. *Acta Anthropologica Sinica* 15:210–217. (In Chinese with English abstract.)

Stringer, CB, 1985. Middle Pleistocene hominid variability and the origin of the Late Pleistocene humans. In Delson, E, (eds) *Ancestors: the hard evidence;* 289–295. New York: Alan R. Liss.

Stringer, C, & Andrews, P, 1988. Genetic and fossil evidence for the origin of modern humans. *Science* 239:1263–1268.

Stringer, C, & Bräuer, G, 1994. Methods, Misreading, and Bias. *American Anthropologist* 96:416–424.

Suzuki, H, 1982. Skulls of the Minatogawa Man. In Suzuki, H, & Hanihara, K, (eds) *The Minatogawa Man;* 7–49. Tokyo: University of Tokyo Press.

Tai, E, & Hsu, C, 1973. New finds of paleoliths from Lantian. *Kaogu Xuebao* 2:1–12. (In Chinese with English abstract.)

Thorne, AG, & Wolpoff, MH, 1981. Regional continuity in Australasian Pleistocene hominid evolution. *American Journal of Physical Anthropology* 55:337–349.

Underhill, PA, Rassarino, G, Lin, AA, Shen, P, Lahr, MM, Foley, RA, Oefner, PJ, & Cavalli-Sforza, LL, 2001. The phylogeography of Y chromosome binary haplotypes and the origins of modern human populations. *Annals of Human Genetics* 65:43–62.

Wang, Y, Xue, X, Jue, L, Zhao, J, & Liu, S, 1979. Discovery of Dali fossil man and its preliminary study. *Kexue Tongbao* 24:303–306. (In Chinese.)

Weidenreich, F, 1935. The Sinanthropus population of Choukoutien (Locality 1) with a preliminary report on new discoveries. *Bulletin Geological Society of China* 14:427–461.

Weidenreich, F, 1936. The mandible of Sinanthropus pekinensis. A comparative study. *Palaeontologica Sinica* D7:1–132.

Weidenreich, F, 1937a. The dentition of *Sinanthropus pekinensis*: A comparative odontography of the hominid. *Palaeontologica Sinica* New Series D No 1:1–180.

Weidenreich, F, 1937b. Reconstruction of the entire skull of an adult female individual of *Sinanthropus pekinensis*. *Nature* 140:1010–1011.

Weidenreich, F, 1939a. Six lectures on Sinanthropus and related problems. *Bulletin of the Geological Society of China* 19:1–110.

Weidenreich, F, 1939b. On the earliest representatives of modern mankind recovered on the soil of East Asia. *Bulletin of the Natural History Society of Peking* 13:161–174.

Weidenreich, F, 1941. The extremity bones of Sinanthropus pekinensis. *Palaeontologica Sinica* New Series D No 5:1–150.

Weidenreich, F, 1943. The skull of Sinanthropus pekinensis: a comparative study of a primitive hominid skull. *Palaeontologica Sinica* D10:1–485.

Weidenreich, F, 1946. *Apes, giants, and man*. Chicago: Chicago University Press.

Wolpoff, M, 1979. The Krapina dental remains. *American Journal of Physical Anthropology* 50:67–114.

Wolpoff, MH, 1989. Multiregional evolution: the fossil alternative to Eden. In Mellars, P. & Stringer, CB, (eds) *The origins of modern humans: behavioural and biological perspectives;* 62–108. Edinburgh: Edinburgh University Press.

Wolpoff, MH, 1991. Theories of modern human origins. In Bräuer, G, & Smith, FH, (eds) *Continuity or replacement? Controversies in Homo sapiens evolution;* . Rotterdam: AA Balkema.

Wolpoff, MH, Wu, X-Z, & Thorne, AG, 1984. Modern Homo sapiens origins: a general theory of hominid evolution involving the fossil evidence from east Asia. In Smith, FH, & Spencer, F, (eds) *The origins of modern humans;* 411–484. New York: Alan R Liss.

Woo, J, (Wu, R) 1957. Dryopithecus teeth from Keiyuan, Yunan Province. *Vertebrata PalAsiatica* 1: 25–32. (In Chinese with English abstract.)

Woo, J, 1958a. Fossil human parietal bone and femur from Ordos, Inner Mongolia. *Vertebrata PalAsiatica* 2: 208–212. (In Chinese with English abstract.)

Woo, J, 1958b. Tzeyang Paleolithic Man-earliest representative of modern man in China. *American Journal of Physical Anthropology* 16: 459–465.

Woo, J, 1959. Human fossils found in Liukiang, Kwangsi, China. *Gu Jizhuidongwu yu Gu Renlei* 1:97–104.

Woo, J, 1964a. Mandible of *Sinanthropus lantianensis*. *Current Anthropology* 5:98–102.

Woo, J, 1964b. Mandible of the Sinanthropus-type discovered at Lantian, Shensi. *Vertebrata PalAsiatica* 1:1–12. (In Chinese with English abstract.)

Woo, J, 1965. The hominid skull of Lantian, Shensi. *Vertebrata PalAsiatica* 10:1–22. (In Chinese with English abstract.)

Woo, J, & Chao, T, 1959. New discovery of Sinanthropus mandible from Choukoutien. *Vertebrata PalAsiatica* 3:169–172. (In Chinese with English abstract.)

Woo, J, & Chia, L, 1954. New discoveries of Sinanthropus pekinensis in Choukoutien. *Acta Paleontologica Sinica* 2:267–288. (In Chinese with English abstract.)

Wu, M. 1980. Human fossils discovered at Xujiayao site in 1977.*Vertebrata PalAsiatica* 18: 227–238. (In Chinese with English abstract.)

Wu, M, 1983. Homo erectus from Hexian, Anhui found in 1981. *Acta Anthropologica Sinica* 2:109–115. (In Chinese with English abstract.)

Wu, R, 1987. A revision of the classification of the Lufeng Great Apes. *Acta Anthropologica Sinica* 6:265–271. (In Chinese with English abstract.)

Wu, R, 1988. The reconstruction of the fossil human skull from Jinniushan, Yinkou, Liaoning Province. *Acta Anthropologica Sinica* 7:97–101. (In Chinese with English abstract.)

Wu, R, & Dong, X, 1982. Preliminary study of Homo erectus remains from Hexian, Anhui. *Acta Anthropologica Sinica* 1:2–13. (In Chinese with English abstract.)

Wu, R, & Lin, S, 1983. Peking Man. *Scientific American* 248:78–86.

Wu, R, & Pang, R, 1959. Fossil human skull of early Paleoanthropic stage found at Mapa, Shaoquan, Kwantung Province. *Vertebrata Palasiatica* 3:176–182. (In Chinese with English abstract.)

Wu, R, & Wu, X, 1997. China. In Spencer, F, (ed) *History of Physical Anthropology an Encyclopedia;* 273–282. New York: Garland

Wu, R, Wu, X, & Zhang, S, (eds) 1989. *Early humankind in China*. Beijing: Science Press.

Wu, X, 1960. On the racial type of Upper Cave man of Choukoutien. *Gu Jizhuidongwu yu Gu Renlei* 2:141–149.

Wu, X, 1961. Study of the Upper Cave Man of Choukoutien. *Vertebrata PalAsiatica* 3:181–211.

Wu, X, 1981. A well-preserved cranium of an archaic type of early *Homo sapiens* from Dali, China. *Scientia Sinica* 24:530–539.

Wu, X, 1988. Comparative study of early Homo sapiens from China and Europe. *Acta Anthropologica Sinica* 7:292–299. (In Chinese with English abstract.)

Wu, X, 1989. Early Homo sapiens in China. In Wu, X, & Shang, S, (eds) *Early humankind in China;* 24–41. Beijing: Science Press.

Wu, X, 1992. The origin and dispersal of anatomically modern humans in East Asia and Southeast Asia. In Akazawa, T, (ed) *The evolution and dispersal of modern humans in Asia;* 373–378. Tokyo: Hokusen-Sha.

Wu, X. 2000. Longgupo Hominoid mandible belongs to ape. *Acta Anthropologica Sinica* 19:1–10. (In Chinese with English abstract.)

Wu, X, & Poirier, FE, 1995. *Human evolution in China*. Oxford: Oxford University Press.

Wu, X, & You, Y, 1979. A preliminary observation of the Dali man site. *Vertebrata PalAsiatica* 17:294–303. (In Chinese with English abstract.)

Wu, X, Yuan, Z, Han, D, Qi, T, & Lu, Q, 1966. Report of the excavation at Lantian man locality of Gongwangling in 1965. *Vertebrata PalAsiatica* 10:23–30. (In Chinese with English abstract.)

Wu, X, & Wang, L, 1985. Chronology in Chinese Palaeoanthropology. In Wu, R, & Olsen, JW, (eds) *Palaeoanthropology and Palaeolithic archaeology in the People's Republic of China;* 29–68. London: Academic Press.

Wu, X, & Zhang, Z, 1985. Homo sapiens remains from Late Palaeolithic and Neolithic China. In Wu, R, &. Olsen, JW, (eds) *Palaeoanthropology and Palaeolithic archaeology in the People's Republic of China;* 107–133. London: Academic Press.

Xu, Q, 1984. Climate during the Hexian man's time. *Acta Anthropologica Sinica* 3:383–391. (In Chinese with English abstract.)

Xu, Q, 1999. The living environment of Homo erectus from Tangshan, Nanjing and other sites. *Acta Anthropologica Sinica* 18:263–269. (In Chinese with English abstract.)

Xu, Q, & Lu, Q, 1979. The mandible of *Ramapithecus* and *Sivapithecus* from Lufeng, Yunnan. *Vertebrata Palasiatica* 17:12–13. (In Chinese with English abstract.)

Xu, Q, & You, Y, 1984. Hexian fauna: correlation with deep-sea sediments. *Acta Anthropologica Sinica* 3:62–67. (In Chinese with English abstract.)

Yan, Y, Liu, C, & Gu, Y, 1960. Study of the Neolithic human skeletons from the Baoji site, Shaanxi. *Gu Jizhuidongwu yu Gu Renlei* 2:33–43.

Yuan, S, Chen, T, & Gao, S, 1986. Uranium series chronological sequence of some palaeolithic sites in South China. *Acta Anthropologica Sinica* 5:179–190. (In Chinese with English abstract.)

Zhang, X, 1987. New materials of Ramapithecus from Keiyuan, Yunnan. *Acta Anthropologica Sinica* 6:81–86. (In Chinese with English abstract.)

Zhang, Y, 1995. Fossil human crania from Yunxian: morphological comparison with *Homo erectus* crania from Zhoukoudian. *Acta Anthropologica Sinica* 14:1–7. (In Chinese with English abstract.)

Zhang, Y, 1998. Fossil human crania from Yunxian, China: Morphological comparison with Homo erectus crania from Zhoukoudian. *Human Evolution* 13:45–48.

Zhao, S, Sha, M, Zhang, C, Liu, M, Wang, S, Wu, Q, & Ma, Z, 1985. Uranium series dating of Peking Man site. In IVPP, (eds) *Multidisciplinary study of the Peking Man site at Zhoukoudian;* 246–250. Beijing: Science Press. (In Chinese.)

Zhou, C., Wang, Y, Cheng, H, & Liu, Z, 1999. Discussion of Nanjing man's age. *Acta Anthropologica Sinica* 18:255–262. (In Chinese with English abstract.)

Zhou, G, & Hu, C, 1979. Supplementary notes on the teeth of Yuanmou Man with a discussion on morphological evolution of the mesial incisors in hominoids. *Vertebrata PalAsiatica* 17:149–162. (In Chinese with English abstract.).