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Middle Pleistocene Human Cranium From Tangshan (Nanjing), Southeast China: A New Reconstruction and Comparisons With *Homo erectus* From Eurasia and Africa

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ABSTRACT The morphology and affinities of early and middle Pleistocene *Homo erectus* in East Asia have been explored since the late nineteenth century. A fragmentary hominid cranium (Nanjing no.1) recovered in Tangshan near Nanjing, China bears directly on these issues. In the present study, the morphological features of Nanjing no.1 are described and compared with *Homo erectus* from both Eurasia and Africa. Our results indicate that this middle Pleistocene hominid fossil should be referred to as *Homo erectus*. The sharing of typical *Homo erectus* features with African and European counterparts demonstrates that *Homo erectus* is a widely distributed lineage that evolved during the million years after its Pliocene origins. The differences between Nanjing no.1 and Zhoukoudian suggest certain level of regional variation in East Asian *Homo erectus*. Am J Phys Anthropol 127:253–262, 2005.

In March 1993, two fragmentary human crania and one tooth were found in a karst cave near Tangshan town, 26 km east of Nanjing, eastern China (Fig. 1). These specimens were named Nanjing no. 1, no. 2, and no. 3, respectively (Mu et al., 1993; Tangshan Archaeological Team from Nanjing Municipal Museum and Archaeology Department of Peking University, 1996). No associated stone tools have been found at the site. The date of Nanjing no. 1 was once suggested as about 0.35 Mya according to ESR and U-series (Chen et al., 1996). Several recent dating procedures by mass spectrometric U-series with TIMS and other techniques demonstrated that the age of the Nanjing hominids is older than 0.5 Mya, with the earliest age of 0.62 Mya (Chen et al., 1998; Zhou et al., 1999; Zhao et al., 2001). A recent high-precision U-series dating analysis of Locality 1 at Zhoukoudian indicated that the age of the hominid fossil-bearing layer 3 is earlier than 400 ka, possibly in the range of about 400–500 ka, and that the hominid fossils from the lower stratra are at least 600 ka (Shen et al., 2001). Thus it is possible that the Nanjing hominids and the Zhoukoudian *Homo erectus* were contemporary. The Nanjing site is 25 km south of the Yangtse River and some 1,000 km south of Zhoukoudian, China. Also, the Tangshan site is about 100 east of Hexian, where hominid fossils of another skullcap and mandibular fragments as well as a few teeth were found. A comparison of the Tangshan cranium with the fossils from these sites could help document the geographical variations of *Homo erectus* in China or East Asia (Wu and Shang, 2002). By broad comparisons with *Homo erectus* in Africa and Europe, we can further explore the relationship of the Nanjing hominids with those of the *Homo erectus* from Eurasia and Africa.

In the present study, based on its new reconstruction, the morphological features of Nanjing no.1 cranium are described, and comparisons with *Homo erectus* from Zhoukoudian and other sites in Eurasia and Africa are made.

PRESERVATION, AGE, AND SEX OF THE NANJING NO.1 CRANIUM

Among the three Nanjing hominid fossils, no.1 is the most complete. The largest of its three fragments includes the frontal, one third of the anterior part of the left parietal, the left sphenoid, the nasal, and the left maxillary and left zygomatic bones; the

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Fig. 1. General location of Tangshan site, Nanjing.

second consists of parts of the occipital and left parietal; and the third is a small piece of right parietal (Fig. 2). The Nanjing no.1 cranium preserves most of the face, from which some valuable features of facial morphology can be observed and measured.

All the preserved cranial sutures on Nanjing no.1, including the sagittal, lambdoidal suture, and coronal suture, as well as the sphenoparietal squamosal sutures, are not fully fused. The preserved parietal-sphenoid suture and sphenoid-temporal suture are also not fused. From the preserved sockets of the upper first and second premolars and first molar, we can determine that all these teeth had erupted. According to the standards of Meindl and Lovejoy (1985) and Ubelaker and Grant (1989), we estimate that Nanjing no.1 is an adult individual.

The ectocranial surface of the Nanjing no.1 cranium is gracile and not markedly muscle-marked (see below). Estimated from the preserved socket of the upper second premolar, the mesial-distal diameter of the tooth is 5.2 mm, and the root length is 13.5 mm. These measurements are within the ranges of Zhoukoudian *Homo erectus* (13.3–16.2 mm and 5.3–5.8 mm, respectively). Hence, we think that Nanjing no.1 may represent an adult female adult individual.

RECONSTRUCTION OF NANJING NO. 1

Although the Nanjing no.1 hominid fossil includes several important parts of the cranium, the fragments require a reliable and accurate reconstruction to obtain more morphological information. For this reason, a new reconstruction of Nanjing no.1 was made (Wu et al., 2002).

Both the first and second fragments of the Nanjing no. 1 cranium contain part of the left parietal, which offers great help in our reconstruction of the left parietal. Although there is a missing part between the two pieces of the left parietal, and the two pieces cannot be put together directly, judging from the existence of the middle part of the temporal border and the superior and inferior temporal lines in both parietal pieces, we are sure that the missing part is not big. The course of the superior and inferior temporal lines, the squamosal border of the left parietal bone, and the endocranial impressions of the middle meningial artery enabled Wu et al. (2002) to align the two left parietal pieces. The principle of symmetry enabled the right side of the cranium to be reconstructed (Figs. 3, 4).

DESCRIPTION AND COMPARISONS OF NANJING NO. 1 CRANIUM

Cranial vault

The cranial vault of Nanjing no. 1 is low and gently curved along the midsagittal profile. The maximum breadth is at the level of the supramastoid crest extension. An obvious and continuous supraorbital torus with a supratoral sulcus characterizes the receding frontal squama. No glabellar depression can be observed in either superior or frontal view. On both sides, the supraorbital torus exhibits a variable thickness, with maximum thickness around the inner 1/3 part and the minimum thickness in the middle 1/3 part. The cranium has strong postorbital constriction. The temporal line on the preserved left side is very weak.

The ectocranial surface of most of the frontal extending to the coronal suture is not smooth, but exhibits an undulating surface suggestive of a pathological lesion. Although composed of cortical bone, the region is depressed relative to adjacent areas, suggesting a partial thickness loss of the external cortex, which could be due to a variety of causes (e.g., partial thickness burn, or systemic or localized infection). Previous analyses attributed this lesion to periostitis (Shang et al., 2002). Whatever the cause, the result is reduced bone thickness in the area, partly obscuring bregma and what may have been a bregmatic eminence. Likewise, it is impossible to assess accurately whether sagittal keeling existed due to this pathological condition.

Judging by the prominence on the left parietal near bregma where no scar exists, there should be a bregmatic eminence on Nanjing no. 1. Accordingly, it is possible that sagittal keeling and parasagittal depressions existed on Nanjing no. 1. The parietal (left side) is probably square in shape, relatively flattened sagitally, and a little angled in coronal section at the level of the temporal lines. Based on the squamosal margin of the left parietal bone, it is reasonable to infer that the superior border of the temporal squama is relatively high and curved. On the posterior corner of both parietals, there are obvious angular tori developed. The cranial vault bones of Nanjing no. 1 are relatively thick and within the range of Zhoukoudian *Homo erectus* (Table 1). In lateral view, the most anteriorly projected part on the Nanjing no. 1 cranium is situated at the supraorbital torus, and the most posteriorly projected part is the occipital torus. The occipital is angled with an occipital angle of 106.5°, characterized by the presence of the transverse occipital torus with a shallow supratoral sulcus. The occipital torus is at the level of the Frankfurt plane, and reaches

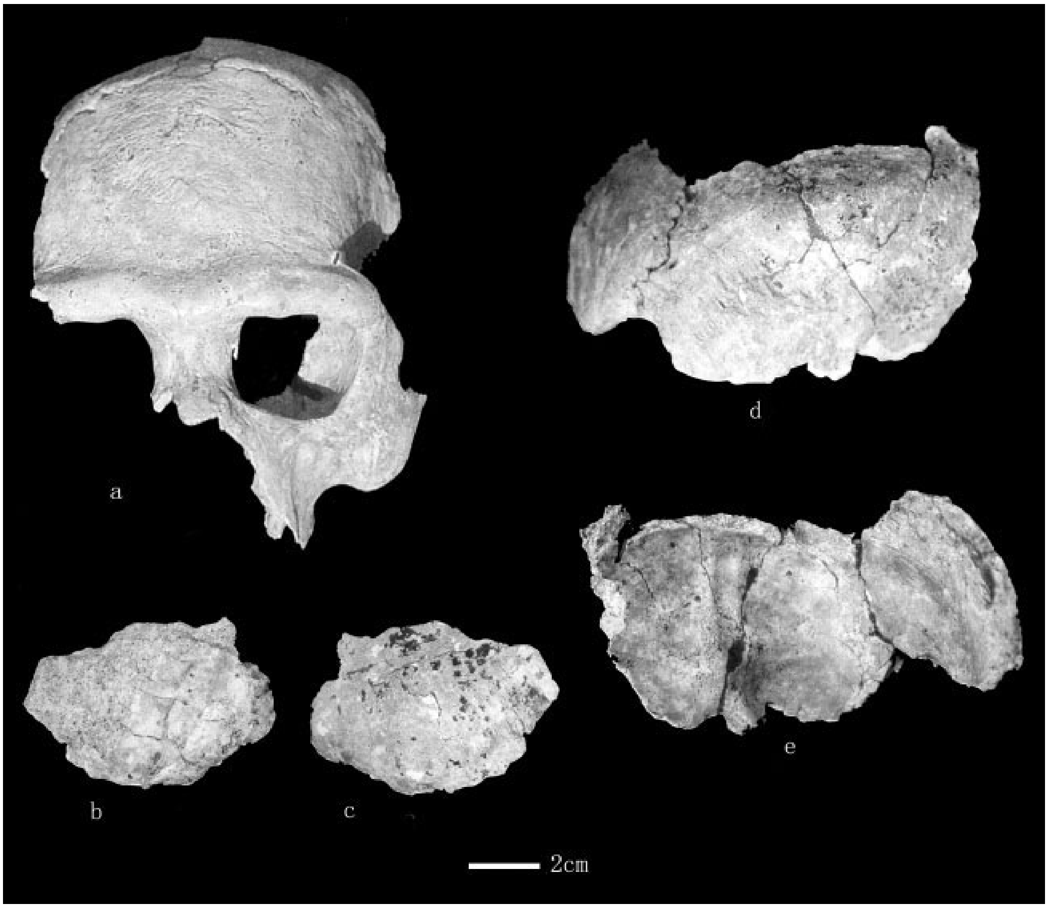

Fig. 2. Nanjing no. 1 cranial fossils. **a,** Front view of the largest fragment. **b,** External surface of the right parietal. **c,** Internal surface of the right parietal. **d,** External surface of the occipital and left parietal. **e**, Internal surface of the occipital and left parietal.

the asterionic region on both sides. The distance between inion and endinion is 37.6 mm. Based on the reconstructed Nanjing no. 1 cranium, an endocast of Nanjing no. 1 was made. By the water replacement method, the cranial capacity of Nanjing skull is about 860 cc.

Face

The Nanjing no. 1 nasal and left facial bones are well-preserved. The shape of the orbits of the Nanjing no. 1 cranium is quadrangular, with breadth exceeding height. The profile angle of the nasal roof of Nanjing no. 1 is 54°. The same angle in the Zhoukoudian skull is 69°. Thus, the nasal bone of Nanjing no. 1 is much more protruding than that of the Zhoukoudian *Homo erectus*. In the external surface of the base of the frontal process of maxillary bone, there is a bulging area in Nanjing no. 1. The frontal-nasal suture and frontal-maxillary suture are continuous, and jointly form a horizontal bone suture in both Nanjing no. 1 and the Zhoukoudian skulls. A joint suture of this pattern is more often seen in Mongoloid and African modern human populations.

On the anterior surface of the maxillary bone of Nanjing no. 1, there is a somewhat vertical alveolar jugum. On the lateral side of the alveolar jugum, there is a groove running inferiorly from the infraorbital foramen. A similar groove also occurs on the Zhoukoudian maxillary bone, the so-called sulcus maxillar.

The anterior and posterior surface of the zygomatic process of the Nanjing no. 1 maxillary bone meet each other at a blunt border. The border extends upward and laterally, and then shifts downward laterally, forming an incisura malaris, which also appears on the Zhoukoudian skulls. The zygomatic process of the Nanjing no. 1 maxillary bone meets with the maxillary body at least 8 mm above the alveolar border. The same distance for the Zhoukoudian skulls is much larger. All the Chinese *Homo erectus* fossils, except the Lantian Gongwangling *Homo erectus*, have relatively larger distance from the conjunct point of the zygomatic process of the maxillary bone with the maxillary body to the aveolar border.

Metric comparisons

To compare both the cranial size and shape, we conducted bivariate plot and principal component analysis (PCA) in our metric analyses. In bivariate plot comparisons, cranial length and breadth were used. For PCA, we chose the seven variables of cra-

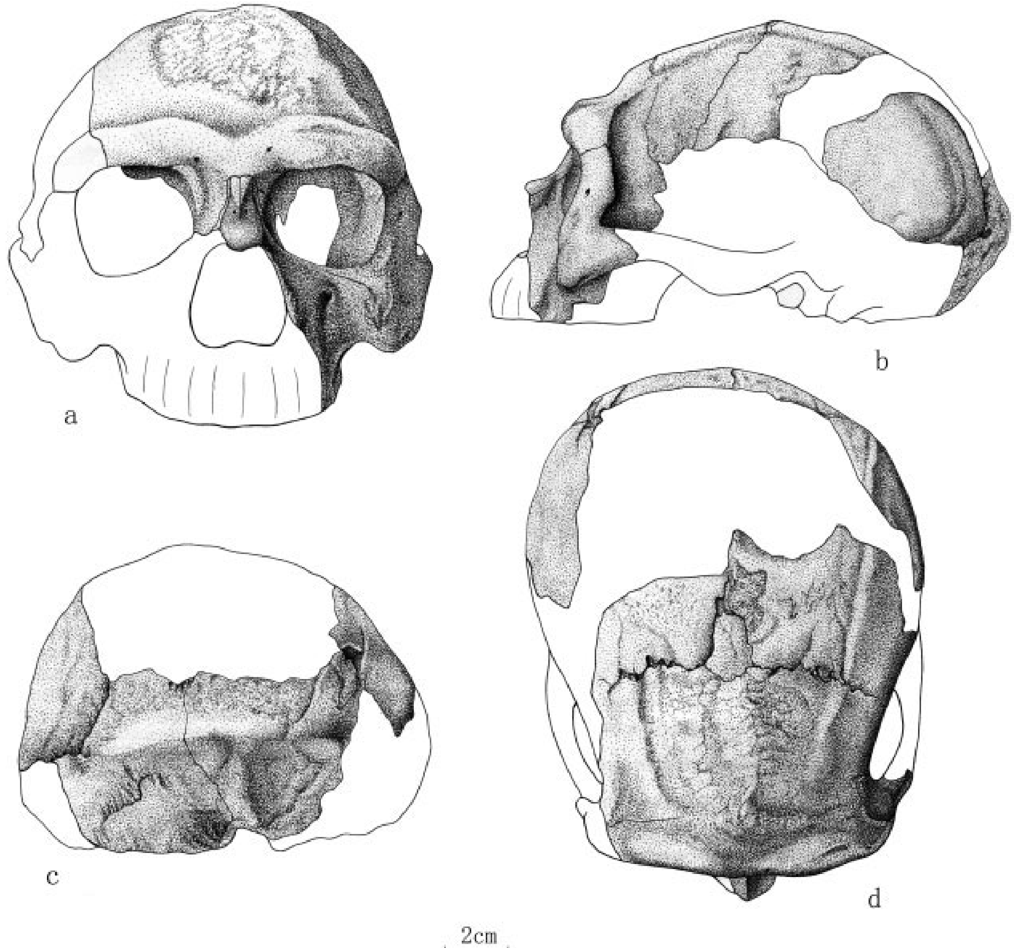

Fig. 3. Preserved and reconstructed parts of Nanjing no. 1 cranium (cited from Wu et al., 2002).

Fig. 4. New reconstruction of Nanjing no. 1 cranium in two views. **a:** Frontal. **b:** Lateral.

nial length, cranial breadth, minimum frontal breadth, biasteric breadth, biauricular breadth, cranial thickness at bregma, and cranial capacity. PCA was performed on the covariance matrices and was rotated. Because cranial capacity measures volume and all the other variables are liner measurements, we transformed the cranial capacity volumes into cube roots for our analysis. The PCA analyses were conducted based on the log-transformed data. In order to have more information and increase the

TABLE 1. Cranial measurements of Nanjing no. 1 and other Homo erectus *from Eurasia and Africa (in mm) for linear measurements, in cc for cranial capacity and in degree for angle*[1]

	Cranial length	Cranial breadth	Minimum frontal breadth	Biasterionic breadth	Biauricular breadth	Cranial thickness at bregma	Cranial capacities	Cranial length-breadth index	Cranial length-auricular height index	Occipital angle
Nanjing	185.5	143.0	83.0	111.0	139.8	8.2	860.0	72.6	51.4	106.5
ZKD II	194	127	84	103	–	9.0	1,030	65.5	–	–
ZKD III	188	131	81.5	117	141	9.6	915	69.7	51.3	106
ZKD X	199	137	89	111	147	7.5	1,225	68.8	53.3	104
ZKD XI	192	136	84	113	143	7.0	1,015	70.8	49.0	105
ZKD XII	195.5	140	91	115	151	9.7	1,030	71.6	51.9	98
Hexian	190.0	160.0	93.0	141.8	144.0	–	1,025.0	–	–	–
Sangiran 2	176.5	141	82	122	131	9	813	–	–	–
Sangiran 4	–	147	–	135	136	–	908	–	–	–
Sangiran X	195	133	86	116	124	–	845	–	–	–
Sangiran 10	–	140	83	126	129	8.8	855	–	–	–
Sangiran 12	–	146	94	125	142	10.4	1,059	–	–	–
Sangiran 17	208	161	103	142	150	–	1,004	–	–	–
Trinil	183	126?	85	92	126	8	940	–	–	–
Ngandong 1	197	–	106	127	133	10.5	1,172	–	–	–
Ngandong 6	219.5	151?	106	130	140	–	1,251	–	–	–
Ngandong 7	193	147	103	123	141	–	1,013	–	–	–
Ngandong 10	202	–	105	126	149	–	1,135	–	–	–
Ngandong 11	204.5	158	112	127	148	7.9	1,231	–	–	–
Ngandong 12	202	151	103	126	141	8.9	1,090	–	–	–
Sambungmacan 1	200	151	102	127	145	11	1,035	–	–	–
Sambungmacan 3	178.5	145.5	101	118	137	10	915	–	–	–
Sambungmacan 4	198	156	110	134	–	10	1,006	–	–	–
Dmanisi 2280	176	136	75	104	132	8.5	780	–	–	–
Dmanisi 2282	167	125	65	103	–	7.5	650	–	–	–
Dmanisi 2700	153	125	66	104	119	–	600	–	–	–
KNM-ER3733	183	142	91	124	132	–	848	–	–	–
KNM-ER3883	182	140	88	121	132	8	804	–	–	–
KNM-WT15000	175.0	141.0	73.0	106.0	–	7.9	880.0	–	–	–
OH9	206	150	100	123	140	–	1067	—	—	—
Daka	180	141.2	95	116	130	7	995	—	—	—
Ceprano	198.0	161.0	106.0	128.0	151.0	–	1057.0	—	—	—

[1] The measurements of Nanjing no. 1 were made on the original fossils by Y. Zang and X. Wu. The cranial metric data of other specimens were taken from Weidenreich (1943), Wu and Dong (1982), Vekua et al. (2002), Asfaw et al. (2002), Ascenzi et al. (2000), Delson et al. (2001), and Baba et al. (2003). Dashes indicate unavailable data.

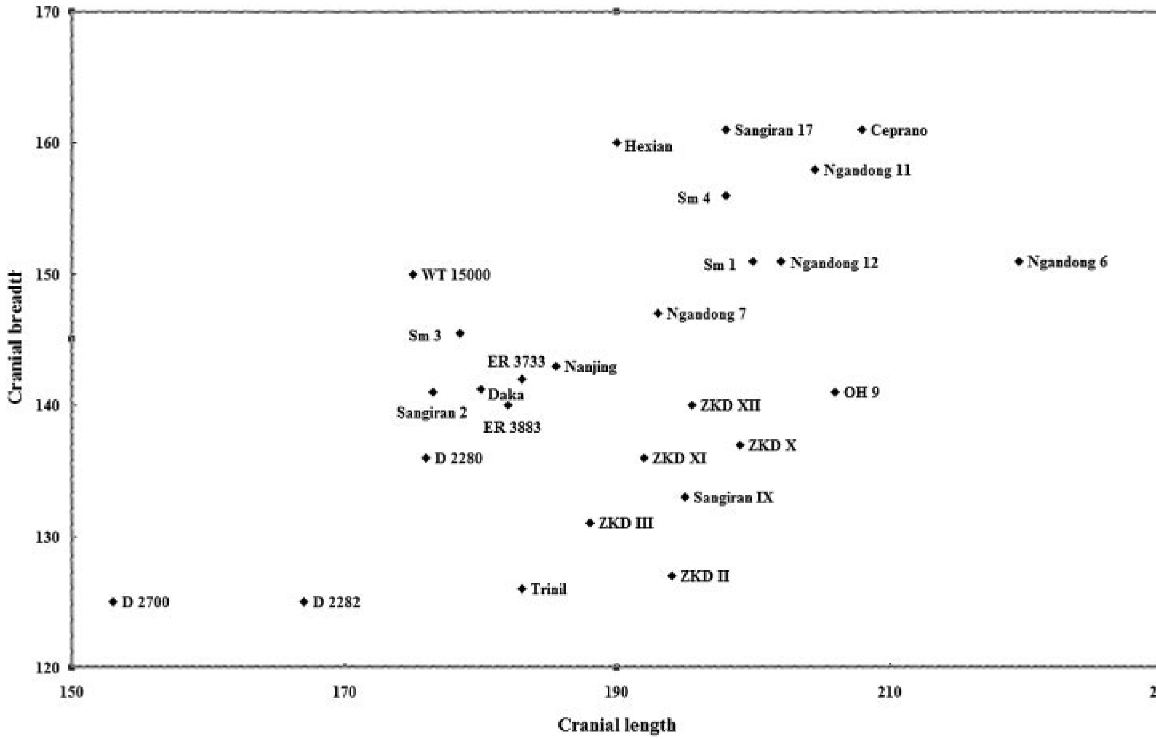

Fig. 5. Bivariate morphometric comparisons between Nanjing no. 1 and other *Homo erectus*.

number of specimens included in our analyses, we used both seven-variable and five-variable compositions. To further consider the relationship between the Nanjing no. 1 and other Asian *Homo erectus*, PCA analysis was also conducted on the Asian *Homo erectus* alone to study the intra-Asian fossil variations in a five-variable PCA. Measurement definitions mainly follow Weidenreich (1943). Here we should point out that this choice will result in some critical comments for the measurements of cranial breadth and biauricular breadth, as discussed by Antón (2002). The comparative specimens included individual *Homo erectus* from Zhoukoudian, Hexian, and Indonesia, and some from Africa (OH 9, ER 3733, ER 3883, WT 15000, and Daka) and Europe (Ceprano and Dmanisi). Table 1 lists the *Homo erectus* specimens used for metric analyses in present study.

According to Figure 5, showing bivariate plots with cranial length and cranial breadth, the position of Nanjing no. 1 is closer to most East African and some Dmanisi *Homo erectus* than to Zhoukoudian, Hexian, and most Java specimens. In its major cranial dimensions including cranial length, Nanjing no. 1 is smaller than those of Zhoukoudian and Hexian *Homo erectus*, but still within the variation ranges of *Homo erectus*. The cranial breadth of Nanjing no. 1 is greater than those of Zhoukoudian and Hexian *Homo erectus*. On the other hand, the major cranial indices of Nanjing no. 1 are very close to those of Zhoukoudian specimens, with a cranial length-breadth index of 72.6 and cranial length-auricular height index of 51.4 compared to 71.0 and 51.4 of the Zhoukoudian averages, indicating that the cranial shapes of the Nanjing and Zhoukoudian specimens are very similar.

TABLE 2. Principal components analysis loadings: seven-variable and five-variable analyses of Nanjing no. 1 and other Homo erectus

	Seven-variable		Five-variable	
Variables	PC 1	PC 2	PC 1	PC 2
Cranial length	0.064	0.080	0.124	0.379
Cranial breadth	0.109	0.080	0.133	−0.418
Minimum frontal breadth	0.402	0.397	0.544	0.649
Biasterionic breadth	0.230	0.093	0.235	−0.971
Biauricular breadth	0.071	0.042		
Cranial capacity	0.466	−0.873	0.070	0.291
Cranial thickness at Bregma	0.041	0.098		
Percent of variance	51.3%	31.0%	81.3%	11.2%

Our PCA results display similar trends. In the seven-variable PCA (Table 2 and Fig. 6), Nanjing no. 1 stays closer to the Zhoukoudian, East African, and Dmanisi specimens, and plots away from the Ngandong and Sambungmacan samples. The first PC explains 51.3% of the variances and has positive loadings on all variables. As a result, the first PC might represent mainly size and size-related shape. The second PC explains 31.0% of the variance, and cranial capacity scores strongly negatively on this axis, while the other variables score positively. The five-variable PCA analysis seems to give a clearer picture of the intersample relationship, with more specimen numbers (Table 2 and Fig. 7). The first and second PCs represent 81.3% and 11.2% of the variance, respectively, in the five-variable PCA analysis. In both Figures 6 and 7, the Chinese *Homo erectus* of

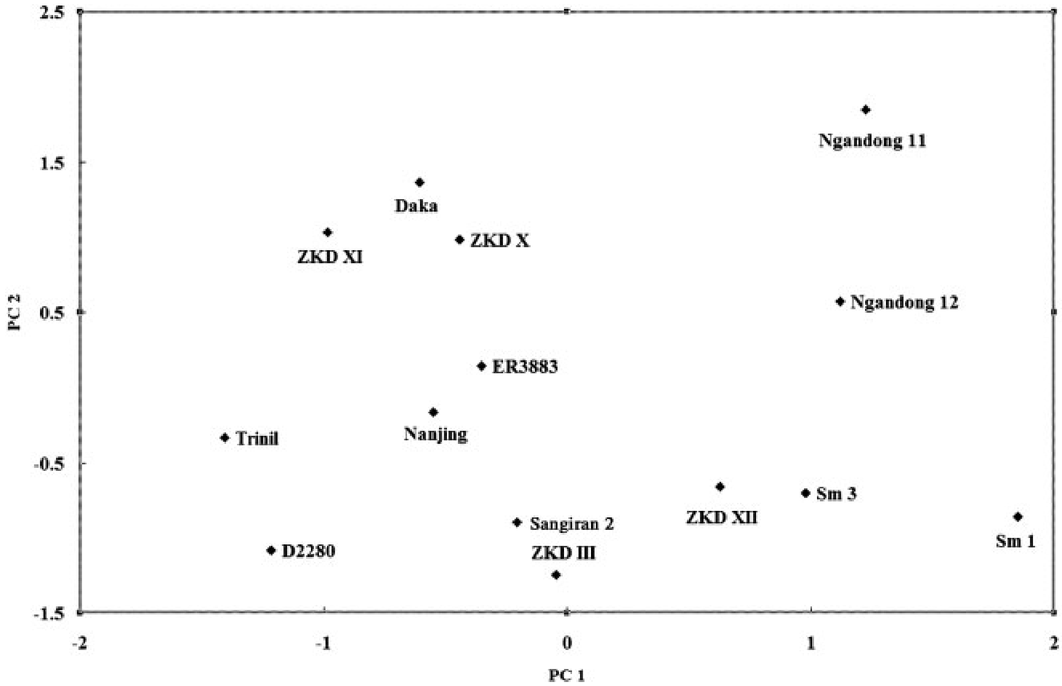

Fig. 6. Seven-variable PCA of Nanjing and other *Homo erectus*.

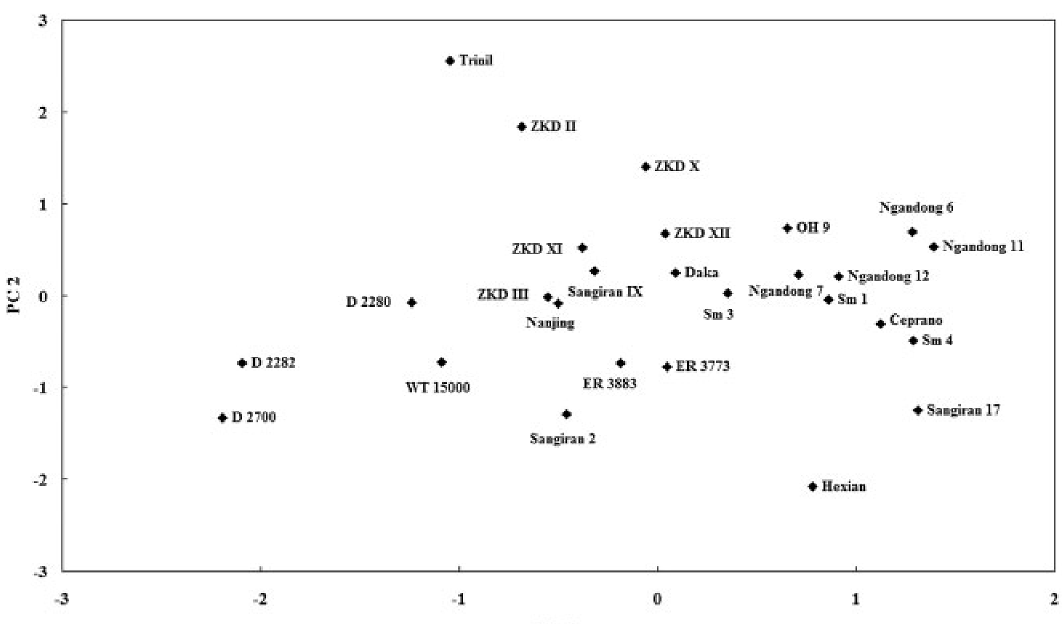

Fig. 7. Five-variable PCA of Nanjing and other *Homo erectus*.

Nanjing and Zhoukoudian are positioned centrally, with East African *Homo erectus* separating the Indonesian and Dmanisi specimens on the right and left sides, even with a few exceptions like Hexian and Trinil. In a similar PCA analysis by Antón (2002), the Hexian specimen also separates from other groups. Antón (2002) believed that the measurement error may have led to the separation. For the position of Trinil, possibly the cranial deformation caused the results (Antón, 2002).

Figure 7, drawn from the five-variable PCA analysis with more specimens included, provides a clearer picture of the relationship between Nanjing no. 1 and other *Homo erectus* from Africa and Eurasia. In Figure 7, the fossils from Africa and Eurasia plot generally following their geographic regions. Nearly all Indonesian samples, including Ngandong, plot together and separate from the Chinese and East African samples that stay centrally in the figure. The three Dmanisi crania stay on the left side, but compared with Indonesian samples, they are closer to Chinese *Homo erectus*.

To further consider the relationship within Asian *Homo erectus*, we conducted a PCA analysis of five variables with only Chinese and Indonesian samples (Table 3 and Figure 8). Our results confirmed the separation between Chinese and Indonesian *Homo erectus* geographically, as revealed in the above analysis.

TAXONOMY AFFINITY AND COMPARISONS

As described above, Nanjing no. 1 preserved many morphological features of taxonomic value. Its frontal bone is low, flat, and inclined backward with the supraorbital torus and postorbital sulcus. There is a pronounced postorbital constriction. For the occipital, the occipital surface and nuchal planum meet in an angular form, with an obvious occipital torus. There is an angular torus in the parietal bone. The bone wall of the skull is relatively thick. All these features are frequently seen in *Homo erectus* skulls from both Eurasia and Africa. Thus the Nanjing no. 1 cranium should be clearly assigned to *Homo erectus*.

Compared with Asian *Homo erectus*, Nanjing no. 1 offers both similarities and differences. The major cranial features of the Nanjing no. 1 cranium resemble those of the Zhoukoudian *Homo erectus*. Even though Nanjing no. 1 is smaller than the Zhoukoudian skulls in most metric data, its cranial indices are similar to those of Zhoukoudian *Homo erectus*, indicating that Nanjing no. 1 and Zhoukoudian *Homo erectus* share similar cranial shapes. On the other hand, Nanjing no. 1 also has some morphological features different from those of the Zhoukoudian skulls. These features include the following: the whole skull is small in size, and the cranial volume is only 860 cc; the nasal bone projects very much, and its tip is in quite a high position; there is a bulging on the surface of the lower portion of the frontal process of the maxillary bone; and the upper part of the nasal bone is much narrower than its lower part. There are also some differences in cranial feature expressions between Nanjing no. 1 and the Hexian crania, including cranial capacity, supraorbital torus shape, and others. However, we also note that there are more variations in the cranial capacity of Zhoukoudian and Indonesian hominids. Even though Nanjing no. 1 has a cranial capacity of 860 cc, some of the Zhoukoudian and Indonesian specimens also have relatively smaller cranial capacities (see Table 1). A recent cranial variation study for Asian *Homo erectus* showed that the cranial morphologies of Asian *Homo erectus* have wide ranges of variation, with early Indonesian *Homo erectus* the most variable for most nonmetric traits (Antón, 2002). All these features indicate that the East Asian *Homo erectus* had a relatively high degree of regional diversity (Antón, 2002; Wu and Shang, 2002).

For the relationship between Chinese and Indonesian *Homo erectus*, our PCA analyses indicate that

TABLE 3. Principal components analysis loadings: five-variable analyses of Nanjing no. 1 and other Asian Homo erectus

Variables	Five-variable PC 1	Five-variable PC 2
Cranial length	0.069	0.234
Cranial breadth	0.215	−0.213
Minimum frontal breadth	0.421	0.910
Biasterionic breadth	0.396	−0.967
Cranial capacity	0.032	0.201
Percent of variance	76.7%	14.6%

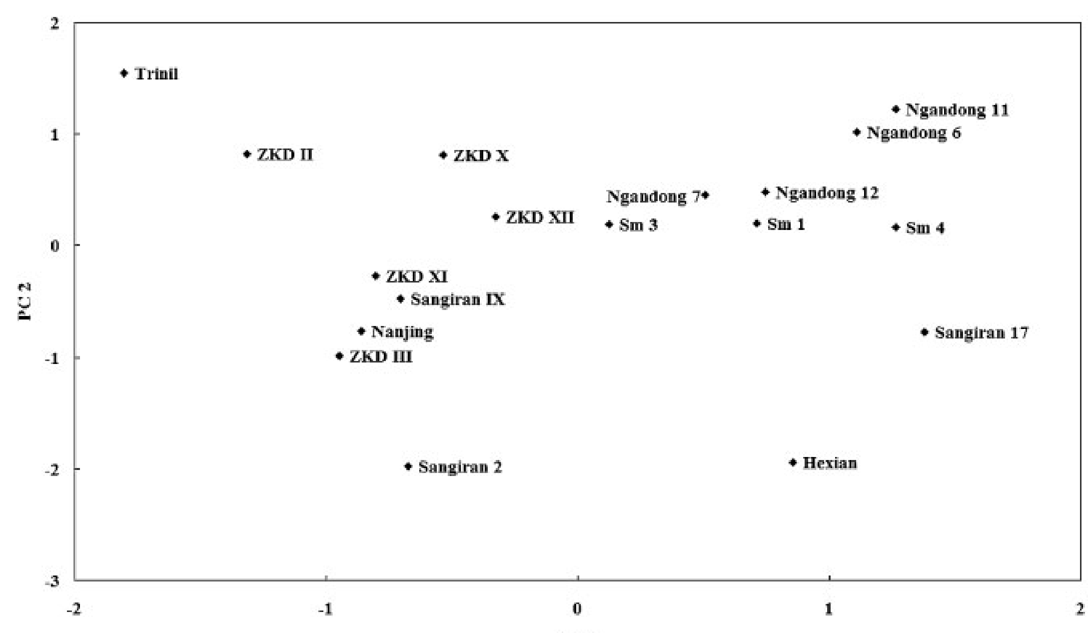

Fig. 8. Five-variable PCA of Asian *Homo erectus*.

the specimens included in our PCA analyses generally follow the geographic group distributions. Figures 6–8 (especially Fig. 8) show that Nanjing no. 1 plots with Chinese *Homo erectus* of five Zhoukoudian crania closely, with the exception of Hexian. Nearly all the Indonesian specimens get together on the right side of the PC 1 axis, with the sole exception of Trinil. According to Figure 8, within the Indonesian samples, Ngandong and Sambungmacan hominids are very closely positioned with each other. For the three Sangiran specimens included in our PCA analyses, Sangiran 2 and Sangiran IX stay in the area of Chinese *Homo erectus*, while Sangiran 17 is on the right side and seems to be closely related to Ngandong and Sambungmacan hominids. Our results partly agree with Antón (2002), that there are two geographic variants of *Homo erectus* in Asia: one from island Southeast Asia, and the other from northern mainland Asia. But from our PCA analyses, there is no evidence to support the idea that earlier and later Indonesian fossils are more similar to one another than either would be to the temporally intermediate Chinese *Homo erectus*. We think that the different cranial capacity (860 cc) we used may have caused this discrepancy.

Compared with the African and Georgian *Homo erectus*, Nanjing no. 1 also exhibits features both similar to, and different from, these fossils. Most of the key cranial features on Nanjing no. 1 can also be identified on the African early *Homo erectus* ER-3733, ER-3883, and WT-15000 (Rightmire, 1984). Usually the typical *Homo erectus* features such as sagittal keeling, supraorbital torus, and angular torus observed on Nanjing no. 1 are weakly expressed on these early African *Homo erectus* specimens, but OH-9 is more like its Asian counterparts in most typical *Homo erectus* features. The facial features of Nanjing no. 1 and Zhoukoudian *Homo erectus* show the anterior and posterior surface of the zygomatic process of the Nanjing no. 1 maxillary bone meeting at a blunt inferior border. The border extends upward and laterally, and then shifts downward laterally, forming the incisura malaris. This feature is not observed in WT-15000, the only African *Homo erectus* fossil that preserves a complete maxillary bone. The Damnisi specimens also lack an incisura malaris. The supraorbital tori were weakly developed in the Dmanisi crania, and no angular torus appears on D2700 (Gubunia et al., 2000; Vekua et al., 2002). However, Nanjing no. 1 is closer in most cranial metric data to East African and Dmanisi *Homo erectus* than to its Chinese counterparts of Zhoukoudian and Hexian. The comparisons of cranial capacities indicate that the cranial capacity of Nanjing no. 1 is smaller than that of some Asian *Homo erectus*, and close to early African *Homo erectus*. As mentioned above, PCA analyses (Figs. 6, 7) also suggest the closer positions of Chinese *Homo erectus* to East African and Dmanisi *Homo erectus*. Our analyses and comparisons of Nanjing no. 1 further indicate that *Homo erectus* is a widely distributed lineage, with a series of shared morphological features.

Although the age of Nanjing no. 1 is still debated, it is possible that Nanjing no. 1 and Zhoukoudian *Homo erectus* lived during the same period. However, the present study indicates that differences exist between Nanjing no. 1 and the Zhoukoudian specimens. This may suggest that some differences are not related to the age, but rather to the geographic diversities of the *Homo erectus* lineage. We propose that the morphological differences between Nanjing no. 1 and the Zhoukoudian specimens suggest that regional diversities of *Homo erectus* had already occurred at that time. However, the morphological differences of *Homo erectus* between Africa and Eurasia are likely due to time differences.

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