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Cranial metric, age and isotope analysis of human remains from Huoshiliang, western Gansu, China

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Introduction

The Chinese provinces of Gansu and Xinjiang are key places for understanding prehistoric exchange between West and East Eurasia. For the past 2000 years, this has been encapsulated in the term 'Silk Road' (which was, in fact, many roads), but goods and ideas have been exchanged across the region for much longer (e.g. Li et al. 2007). In this regard, the well-known existence of the Ürümqi mummies of Xinjiang, which are of Caucasian origin (e.g. Barber 1999), show that they had opportunity to interact with Mongoloid people much earlier.

Detailed examination of the hundreds of archaeological sites in the region has hardly begun and many of these are just places on a map with no further detail described. There are no regional archaeological surveys of Gansu or Xinjiang, as there are for Henan and Shandong

(e.g. Liu 2004; Underhill *et al.* 2008) and those site surveys that have been published focus on grave sites and their inclusions, and are not usually independently dated. There are few detailed material studies from non-grave sites and few independent chronologies to put the region into a wider East Asian prehistory context. Much of what has been described, such as the presence of microliths, pottery and bronze artefacts, has been dated on the basis of comparative analyses from elsewhere, most particularly from eastern China. There is no guarantee that such transported timelines necessarily apply beyond where they were established.

Western China has numerous burial sites, and hundreds of human remains and tomb contents have been analysed. For example, more than 500 human skulls have been examined from Yumen (Gansu) and Datong (Qinghai). These are between 3000 and 3600 BP in age. These are consistently Mongoloid and probably indicate there was little if any western Caucasoid incursion this far east at that time (Tan *et al.* 2005).

Bronze objects in Xinjiang have been found in a number of burial sites that span 3150 BP to 1900 BP. Those that have human remains in the Tarim Basin and northern Xinjiang sites have remains of Caucasoid people. Undecorated pottery from this region spread eastward, and painted pottery probably entered from the east since these are in Xinjiang earlier than elsewhere (Tao 2001). The Xinjiang mummies date back to about 4000 BP and a westward migration of Mongoloid people from Gansu into eastern Xinjiang is thought to have occurred from about 2000 BC (Tao 2001). The Caucasoid people are generally credited with bringing wheat agriculture, new kinds of artefacts, horsemanship, mud-brick building and new religious practices into eastern Asia (Tao 2001; references in Chengwen and Yoshinori 2002).

Here we describe, date and analyse two skulls and an associated sheep bone to provide new data on the possible co-existence of Caucasoid and Mongoloid peoples in western Gansu, and to comment on health and diet.

Huoshiliang study site

The Huoshiliang archaeological site is at 40°15.6'N and 99°18.3'E in the Black River valley of western Gansu Province (Figure 1). It occurs as a largely surface scatter of artefacts across several thousand square metres among sand dunes. The cultural sediments are about 1.6 m in depth in some places. The site has not been systematically excavated.

Evidence of material culture includes macro-fragments of plain and painted pottery, microliths, bone of *Bos* (cattle) and *Ovis* (sheep), copper ore, bronze slag and charcoal (Figure 2). Some of this material may be lag deposit from mobile dune sands and the time-depth sequence is not clear.

Fine particles at the site include small particles of charcoal, pottery, bone and cereal seeds. We have radiocarbon dates on five charcoal samples collected over a 1.6 m depth profile, and these are consistently aged between 3500 BP and 3600 BP (Dodson *et al.* 2009). In addition, we have a date from a wheat seed, of 3635 ± 45 BP. We interpret the site as a population centre where cropping, animal husbandry and bronze smelting was carried out. We believe that the majority of copper ore for smelting came from the Baishantang mine site, which is located about 100 km north of Huoshiliang (Dodson *et al.* 2009). The area is now devoid of trees, but the abundant charcoal indicates the area had significant woodland at the time of occupation.

In the course of examining the site and collecting charcoal for dating in late 2007, two complete skeletons were seen on the sand surface near the Huoshiliang site. The skeletons were eroding out of the shifting sands, and would likely be destroyed as erosion continued. The skulls (Figure 3) were examined in the Department of Archaeology at Northwest University in Xi'an. A premaxilla sheep bone was also analysed.

Figure 1. Map of northwestern China showing location of Huoshiliang.

Figure 2. View of site showing scatter of archaeological remains.

Methods

Using the standard techniques for determining Martin numbers, skull morphological features were measured and described (Martin 1928). Martin numbers are one of several systems for measuring anatomical features and this one was chosen because of its comprehensiveness. Comparative studies were made using the skull collection housed in the Department of Archaeology at North West Normal University in Xi'an and cluster analysis was used to

Figure 3. Photograph of skulls from the Huoshiliang archaeological site.

compare these with the Huoshiliang skulls.

About 10 g of bone from each skull and the sheep bone sample were transported to the Australian Nuclear Science and Technology Organisation (ANSTO) for analysis. The samples were pre-treated for radiocarbon dating in the AMS chemistry laboratories at ANSTO. Collagen was extracted to test whether they showed sufficient preservation and to identify effective removal of contamination to achieve reliable radiocarbon results.

The nitrogen percent of bone, the collagen percent of the sample, and the C:N atomic ratio of the extracted collagen were measured. ANSTO uses the ultrafiltration protocol (Brown *et al.* 1988; Bronk Ramsey *et al.* 2004; Higham *et al.* 2006) to pre-treat bone samples for radiocarbon dating. The ultrafiltration method has been shown to remove contamination more effectively than other methods (Bronk Ramsey *et al.* 2004). Ultrafiltration acts to remove material with a molecular weight below 30kD, which removes contaminants such as salts, fulvic acids and degraded collagen. The main steps in the ultrafiltration protocol used are:

- The bone sample is cleaned with a drill, washed with deionised water, dried and then crushed.
- The crushed bone samples are demineralised with 0.5M HCl.
- Humics are removed with 0.1M NaOH.
- Dissolved CO₂ is removed with 0.5M HCl.
- Samples are gelatinised with pH3 water (heated to 75°C for 20 hours).
- Samples are filtered through 100µm polyethylene eezi-filters™ to remove insoluble residues.
- Eezi-filtered gelatine is then transferred to pre-cleaned Millipore 30kD ultrafilters and centrifuged until sufficiently filtered.
- The >30kD collagen solution is then freeze dried.
- Once the collagen had been extracted, the samples were processed to graphite as described by Hua *et al.* (2001).

Some problems have been encountered with the ultrafiltration method in the past and have been fully explored in Bronk Ramsey *et al.* (2004). This contamination originates from the glycerol which is added to the ultrafilter membrane during production. The ultrafiltration

step in this method only adds carbonaceous contamination to the samples if the filters are not sufficiently cleaned. Quality assurance measures are routine in the ANSTO AMS chemistry laboratories to ensure that the use of ultrafilters does not pose a contamination risk for samples. Tests to ensure all carbonaceous contamination is removed include:

Measuring the quantity of carbon remaining on the ultrafilters after they have been cleaned. To achieve this, an ultrafilter is selected (randomly) for carbon content analysis. No measurable carbon was found, indicating that the ultrafilters had been cleaned satisfactorily.

A bone standard with a known age was run alongside the samples with unknown ages. This sample was selected was one that was a part of the VIRI international laboratory comparison study. The measured age from this bone standard matched the agreed age from the VIRI inter-comparison study, and from past measurements that the ANSTO AMS chemistry labs had attained. This further confirms that potential contamination from the use of ultrafilters was negligible.

The glycerol that coats the ultrafilters was also extracted and dated. The glycerol used on the batch of ultrafilters that was used in processing the samples resulted in a date of 1.06 pMC (with an error of ± 0.0034). This suggests no older age offsets, as might be expected if the samples were affected by contamination.

Samples OZL292-OZL294 were measured for $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ on a Elemental Analyser (EuroVector EA3000) and an Isotope Ratio Mass Spectrometer (GV Instruments IsoPrime). The reference materials used for the samples were as follows:

- $\delta^{13}\text{C}$ – IAEA C8 oxalic acid with an agreed value of -18.31‰ VPDB (used for graphite, bone and collagen) (Gonfiantini et al. 1995; Le Clercq et al. 2006).
- $\delta^{15}\text{N}$ – IAEA NO-3 with a consensus value $d^{15}\text{N AIR} = +4.7\text{‰}$ (Bohlke and Coplen 1995) and IAEA N-2 with a consensus value of $d^{15}\text{N AIR} = +20.3\text{‰}$ (bone and collagen) (Bohlke and Coplen 1995).
- 3:1 atomic ratio standard – Internal standard of 2-isopropylimidazole (bone and collagen).
- Collagen standard employed: Internal material check standard – un-denatured bovine achilles tendon collagen.

The ^{14}C content was measured on the STAR Accelerator at ANSTO and AMS ages were calculated after estimating fractionation effects from the $\delta^{13}\text{C}$ values determined on the same samples used for dating.

In addition, cereal seeds were collected from the site by sieving surface sands, and we counted a number of these to obtain a snapshot of the types and relative amounts of cereals grown at Huoshiliang.

Results

Table 1 gives measurements on the two skulls found at Huoshiliang.

Morphological characteristics

Skull No. 1. The skull is from a middle-aged female, probably between 40 and 45 years of age. Its morphology is oval and the cranial index is 75.64, meaning it is mesocrany in size. The length-height index of the skull is 74.79, putting it in the taller metriocrany range. The skull is acrocrany type as the breadth-height index is 98.86. The middle supracalar arch has a range below 1/2. The forehead is even and straight with a frontal index of 69.7. This places it as eurymetor type, with no suture in the middle forehead. The bregmatic and vertex part in the

coronal suture are microwave type, and both top and back of the coronal suture are of indented type. The mastoid process is small and the external occipital protuberance is slightly prominent. The orbital cavity is oval (index 73.56), belonging to the lower range in orbital cavity size. The upper part of the Apertura piriformis is heart-shaped, and below this it has a nest type form. The nasal base is superficially hollow, no nasal spine is apparent and the nasal index is 52.38, showing it to be of a broad nasal type. The nasal bridge is hollow type and the nasal bone is Type II. The Canine fossa show moderate growth, the Zygomatic bone is slender (i.e. there is no zygomatic-jaw node) and the jaw angle is clearly evident. Both sides of the skull have Parietal apertures, the sigittal crest is evident and the Palate form is 'V' type. The Upper facial index is 51.92, showing it to be meseny type, while the gnathic index is 92.31, showing it to be orthognath type.

Skull No. 2 The skull is from a female, probably with an age of about 35–40 years. Its morphology is oval and the cranial index is 74.73, meaning it is a shorter dolichocrany skull type. The middle supracalar arch has a range below 1/2. The forehead is moderate and the frontal index is 66.33, indicating it is metriometor type. No suture was apparent in the middle forehead. The bregmatic part of the coronal suture is deep wave type. Both the top and back part of the coronal suture are of indented type, while the vertex aperture part is microwave type. The Mastoid process is large and the external occipital protuberance is moderate. The orbital cavity is oval, with an index of 78.65, suggesting it is medium type. The supraorbital foramen is heart-shaped and its lower edge is obtuse. The nasal base is superficially hollow and the nasal spine is degree II in type. The nasal index is 54.36 and her nose is chamaerrhiny type. The nasal bridge is hollow type and the nasal bone is I type. The Canine fossa is middle range in degree. The zygomatic bone is middle range in height and breadth and no zygomatic-jaw node was apparent. The jaw angle is apparent. Both sides of the skull have Parietal apertures, a sigittal crest is evident, and the Palate form is 'V' type.

Interpretation

The morphology characters of the two skulls are very similar, in being both mesocrany and dolichocrany type. The skulls have simple coronal suture, an oval orbital cavity, medium-narrow

Table 1. Comparative measurements from the Huoshiliang skulls and nine ancient skull groups (female) (mm, degree, %). The numbers in brackets refer to the sample size for comparative measurements.

Martin #	Items	HSL	XC	QC	PP	SLY	HD	LW	SSJZ (H)	SSJ (K)	LJS
1	Cranial length (g-op)	174.49 (2)	174.74 (5)	173.97 (16)	177.5 (3)	180.50 (2)	183.9 (5)	178.58 (12)	174.1 (21)	175.1 (102)	177.30 (8)
8	Cranial breadth (eu-eu)	134.8 (2)	133.26 (5)	134.20 (16)	140.6 (3)	137.25 (2)	136.1 (5)	132.27 (10)	135.8 (21)	135.1 (103)	136.40 (8)
17	Cranial height (ba-b)	130.5 (1)	137.98 (5)	135.95 (15)	130.6 (3)	138.50 (1)	149.1 (1)	131.63 (16)	129.1 (18)	131.3 (99)	130.60 (8)
9	Minimum frontal breadth	91.6 (2)	86.26 (5)	89.89 (17)	90.7 (3)	90.47 (3)	91.1 (5)	87.42 (12)	89.0 (22)	88.9 (102)	89.20 (8)
45	Zygomatic breadth (zy-zy)	125.0 (1)	127.55 (2)	127.50 (12)	134.0 (3)	127.75 (2)	134.1 (3)	129.04 (16)	129.6 (17)	126.3 (93)	125.30 (7)
48	Upper facial height (sd)	67.8 (2)	69.88 (2)	67.70 (17)	67.5 (2)	70.70 (2)	70.6 (4)	70.73 (16)	71.0 (19)	71.7 (84)	72.10 (8)

Table 1. *Continued*

Martin #	Items	HSL	XC	QC	PP	SLY	HD	LW	SSJZ (H)	SSJ (K)	LJS
52	Orbital height right	33.5 (2)	32.38 (4)	32.71 (17)	33.1 (3)	31.90 (2)	33.4 (4)	33.13 (16)	34.6 (22)	34.1 (102)	34.60 (8)
51	Orbital breadth right	44.0 (2)	39.45 (4)	42.31 (17)	43.2 (3)	40.20 (2)	42.2 (4)	41.80 (16)	40.5 (21)	41.0 (103)	40.90 (8)
54	Nasal breadth	28.1 (2)	25.23 (4)	26.03 (17)	26.5 (3)	27.90 (2)	27.8 (4)	25.76 (17)	26.2 (20)	25.9 (99)	26.80 (8)
55	Nasal height (n-ns)	52.7 (2)	50.32 (5)	48.75 (17)	50.0 (3)	52.50 (2)	50.6 (4)	51.03 (16)	52.1 (21)	52.6 (98)	52.40 (8)
72	Facial angle	90.5 (2)	81.40 (4)	83.27 (15)	85.7 (3)	82.00 (1)	85.7 (3)	87.00 (12)	85.4 (18)	84.9 (76)	86.90 (8)

orbital type, an obtuse low edge of the supraorbital foramen, a shallow hollow of the nasal bases and obvious chamaerrhiny. The angle of jaws is down in gradient. They are of moderate range in their Canine fossa, and have hollow-type nasal bridges, evident sigittal crests, meseny and relatively flat degree faces. The two skulls therefore belong to the Mongoloid race.

To further examine their possible origin, an analysis of mean categories for the two cases against mean values for nine ancient groups was carried out. Ten measured items and eight indices and angles from nine ancient groups were selected for the comparison and these are shown in Table 1. In the analysis below, all measurements are based on female skulls, and the nine ancient people groups chosen for comparison are as follows:

- (a) Zhou Dynasty people at Xicun in the south of Fengxiang, Shaanxi Province. These skulls are close to South and East Asia types of the Mongolian race.
- (b) West Zhou skulls from Wotianma-Qucun in Shanxi Province. The skulls of the group are similar to the East Asia type, but include some factors close to North and South Asia Mongoloid types.
- (c) Pengpu Bronze Age people in Guyuan County, Ningxia Province. This skull group belongs to the North Asia Mongoloid type.
- (d) A group from the Zhou Dynasty in Shaolingyuan in Xi'an, Shaanxi Province. The skulls of the group are close to South Asia and East Asia types of the Mongolian race, and hence similar to the Xicun group.
- (e) The skull group of Neolithic Hedang people in Foushan City, Guangdong Province. The skulls of the group are of South Asia type.
- (f) The skull groups of Liuwan, Machang and Qijia cultures in Ledu, Qinghai Province. The skulls of these people are East Asia type.
- (g) The skull group from the Han Dynasty in Shangsunjiashai in Datong, Qinghai Province.
- (h) The skull group from the Kayue culture group in Shangsunjiashai (Datong), Qinghai Province.

- (i) Skull group sample from the of Kayue Culture in Lijiashan, Xunhua, Qinghai Province.

The latter three skull groups are close to the East Asia type of the Mongoloid race and similar to modern Tibetan people.

The comparative data used for analysis are shown in Table 2. The D_{ij} value between the two skulls from Huoshiliang and nine ancient groups was calculated using the following formula:

Where i, j indicating skull groups, k indicating measured items, m indicating the sample number for measured items. The smaller of D_{ij} value, the closer the morphological set of

$$D_{ij} = \sqrt{\frac{\sum_{k=1}^m (x_{ik} - x_{jk})^2}{m}}$$

relationships of the skull groups. The results are shown in Table 3. The D_{ij} values show that the skulls of Huoshiliang are most similar to the group of skulls from Liuwan, but differ from the Hedang group and are quite different from the Xicun group of the Zhou Dynasty.

A cluster analysis based on squared Euclidian distances was used to show the distribution of D_{ij} values between the Huoshiliang group and other groups. The results are shown in Figure 4. This suggests that the Hedang group (6) has greater differences from all other groups, and Pengpu (4) is also relatively different from the other groups. The other eight groups are divided into two categories; with groups 8, 9, 10, 7, 1 as a category, and group 2, 3, 5 as the other. Morphological character is relatively similar in the group containing 8, 9 and 10. Group 1 belongs to this category and indicates that the Huoshiliang people group are members of the East Asia race. They thus have a close relationship with modern residents in North China. Group 2, 3, 5 is a mixture of South and East Asia Mongoloid people. So the values of D_{ij} and CA analysis all show that the morphology of female skulls in Huoshiliang group is close to the East Asia type of the Mongoloid race.

Table 4 shows the bone protein yield, $\delta^{13}\text{C}$, $\delta^{15}\text{N}$, C:N ratio and radiocarbon results. The chemical indicators from the pre-treatments confirmed that the collagen that was extracted

Table 2. The key measurement data of skulls No. 1 and No. 2 from Huoshiliang site.

Martin No.	Measured Items	Skull 1(♀)	Skull 2(♀)	Average	Examples	Standard error
1	Cranial length (g-op)	174.5	184.0	179.25	2	6.72
8	Cranial breadth (eu-eu)	132.0	137.5	134.75	2	3.89
17	Cranial height (b-ba)	130.5	—	130.5	1	—
21	uricular height (po-po)	110.8	—	110.8	1	—
9	Frontal breadth (ft-ft)	92.0	91.2	91.6	2	0.57
7	Foramen magnum length (ba-o)	31.0	—	31.0	1	—
16	Foramen meanum breadth (FOR. MA. B)	24.5	—	24.5	1	—
25	Cranial sagittal arc (n-o)	367.0	365.0	366.0	2	1.41
26	Nasion-bregma chord (n-b)	122.0	107.0	114.5	2	10.61
27	Bregma-lambda chord (b-l)	132.0	142.0	137.0	2	7.07
28	Lambda -opisthion chord (l-o)	113.0	116.0	114.5	2	2.12
29	Nasion-bregma chord (n-b)	105.5	97.5	101.5	2	5.66
30	Bregma-lambda chord (b-l)	118.0	129.8	123.9	2	8.34

Table 2. Continued

Martin No.	Measured Items	Skull 1(♀)	Skull 2(♀)	Average	Examples	Standard error
31	Lambda -opisthion chord (l-o)	91.0	99.6	95.3	2	6.08
23	Cranial horizontal circumference (g,op)	500.0	—	500.0	1	—
24	Cranial transverse arc (po-b-po)	307.0	—	307.0	1	—
5	Basion-nasion length (n-enba)	97.4	—	97.4	1	—
40	prosthion to Endobasion length (pr-enba)	90.0	—	90.0	1	—
48	Upper facial height (n-pr)	65.7	65.0	65.4	2	0.49
48	Upper facial height (n-sd)	67.8	67.7	67.8	2	0.07
45	Bijugal breadth (Facial breadth) (zy-zy)	125.0	—	125.0	1	—
46	Bimaxillary breadth (zm-zm)	98.0	—	98.0	1	—
	sub zm-ss-zm	25.0	—	25.0	1	—
	Bimaxillary breadth (zm-zm)	97.2	—	97.2	1	—
	sub zm ₁ -ss-zm ₁	23.0	—	23.0	1	—
43(1)	Bifrontal breadth (fmt-fmt)	103.2	105.0	104.1	2	1.27
50	Vordere Interorbital breite (mf-mf)	17.6	19.0	18.3	2	0.99
MH L	Zygomatic height left (fmo-zm)	42.0	—	42.0	1	—
MH R	Zygomatic height right	41.8	42.3	42.1	2	0.35
MB L	Zygomatic breadth left (zm-rim)	20.8	—	20.8	1	—
MB R	Zygomatic breadth right	22.6	25.0	23.8	2	1.70
54	Nasal breadth	27.5	28.7	28.1	2	0.85
55	Nasal height (n-ns)	52.5	52.8	52.7	2	0.21
SC	Simotic chord	11.0	8.0	9.5	2	2.12
SS	Simotic subtense	2.2	2.6	2.4	2	0.28
51 L	Orbital breadth left (mf-ek)	43.5	—	43.5	1	—
51 R	Orbital breadth right	43.5	44.5	44.0	2	0.71
51a L	Orbital breadth left (d-ek)	40.6	—	40.6	1	—
51a R	Orbital breadth right	40.5	42.4	41.5	2	1.34
52 L	Orbital breadth height left	34.2	—	34.2	1	—
52 R	Orbital breadth height right	32.0	35.0	33.5	2	2.12
03	Interorbital breadth	55.0	—	55.0	1	—
SR	Rhinion height	12.2	—	12.2	1	—
60	Maxillo-alveolar length (pr-alv)	50.0	43.0	46.5	2	4.95
61	Maxillo-alveolar breadth (ekm-ekm)	61.8	54.0	57.9	2	5.52
62	Palatal length (ol-sta)	44.9	42.6	43.8	2	1.63
63	Palatal breadth (enm-enm)	36.3	38.6	37.5	2	1.63
12	Maximum Biasterionic breadth (ast-ast)	103.8	115.2	109.5	2	8.06
	(po-po)	112.6	—	112.6	1	—
11	Biauricular breadth (au-au)	116.0	—	116.0	1	—
44	Biorbital breadth (ek-ek)	100.0	—	100.0	1	—
FC	Innere Biorbitalbreite (fmo-fmo)	95.7	100.0	97.9	2	3.04
FS	Nasal orbital internal breadth and height	11.2	17.5	14.4	2	4.45
DC	Interorbital breadth (d-d)	20.8	21.5	21.2	2	0.49
DN	Dacryon-nasion salient	3.5	5.8	4.7	2	1.63
DS	Dacryal subtense	6.5	7.3	6.9	2	0.57
NLD	Nasal bone length (n-rhi)	25.8	29.0	27.4	2	2.26
RP	Rhinion- Alveolar length (rhi-pr)	40.4	37.0	38.7	2	2.40

Table 2. *Continued*

Martin No.	Measured Items	Skull 1(♀)	Skull 2(♀)	Average	Examples	Standard error
32	Profile angle of the frontal bone from nasion ($\angle n-m$ FH)	86.0	82.0	84.0	2	2.83
	Profile angle of the frontal bone from glabella ($\angle g-m$ FH)	81.0	77.0	79.0	2	2.83
	Bregmatic angle ($\angle g-b$ FH)	46.0	47.0	46.5	2	0.71
72	Total facial angle ($\angle n-pr$ FH)	89.0	92.0	90.5	2	2.12
73	Nasal prognathism ($\angle n-ns$ FH)	91.0	94.0	92.5	2	2.12
74	Alveolar Prognathism ($\angle ns-pr$ FH)	76.0	80.0	78.0	2	2.83
75	profilwinkel des Nasendaches ($\angle n-rhi$ FH)	70.0	75.0	72.5	2	3.54
77	Naso-malar angle ($\angle fmo-n-fmo$)	154.0	143.0	148.5	2	7.78
SSA	Zygo-maxillary angle ($\angle zm-ss-zm$)	125.0	—	125.0	1	—
SSA	$\angle zm1-ss-zm1$	129.0	—	129.0	1	—
	Winkel des gesichts-dreiecks I ($\angle n-pr-ba$)	76.0	—	76.0	1	—
	Winkel des gesichts-dreiecks II ($\angle pr-n-ba$)	64.0	—	64.0	1	—
	Winkel des gesichts-dreiecks III ($\angle n-ba-pr$)	40.0	—	40.0	1	—
	Nasal bridge angle	19.0	17.0	18.0	2	1.41
8:1	Cranial index	75.64	74.73	75.19	2	0.64
17:1	Cranial length–height index	74.79	—	74.79	1	—
17:8	Cranial height–breadth index	98.86	—	98.86	1	—
9:8	Forehead breadth index	69.7	66.33	68.02	2	2.38
16:7	Index of occipital foramen	79.03	—	79.03	1	—
40:5	Gnathic index	92.31	—	92.31	1	—
48:17 pr	Vertical cranial index	50.34	—	50.34	1	—
48:17 sd		51.95	—	51.95	1	—
48:45 pr	Upper facial index (K)	50.34	—	50.34	1	—
48:45 sd		51.92	—	51.92	1	—
48:46 pr	Middle facial index (V)	67.04	—	67.04	1	—
48:46 sd		69.18	—	69.18	1	—
54:55	Nasal index	52.38	54.36	53.37	2	1.40
52:51 L	Orbital index	78.62	—	78.62	1	78.62
52:51 R		73.56	78.65	76.11	2	3.60
52:51a L	Orbital index	84.24	—	84.24	1	—
52:51a R		79.01	82.55	80.78	2	2.50
54:51 L	Nasal orbital index	63.22	—	63.22	1	—
54:51 R		63.22	64.49	63.86	2	0.90
54:51a L	Nasal orbital index	67.9	—	67.9	1	—
54:51a R		67.73	67.69	67.71	2	0.03
SS:SC	Nasal base index	20.0	—	20.0	1	—
61:60	Alveolar index	123.6	125.58	124.59	2	1.40
63:62	palatal index	80.85	90.61	85.73	2	6.90
45: (1+8)/2	Transverse cranial index	81.57	—	81.57	1	—

Table 2. *Continued*

Martin No.	Measured Items	Skull 1(♀)	Skull 2(♀)	Average	Examples	Standard error
17: (1+8)/2	High level index	85.15	—	85.15	1	—

Table 3. The Dij values used for comparison of the Huoshiliang group to nine ancient groups (female).

	Xicun	Qucun	Pengpu	Shaolingyuan	Hedang	Liuwan unite	Shangsunjiazhai (Han)	Shangsunjiazhai (Kayue)	Lijiashan
HSL	18.23	13.06	14.89	15.15	27.43	10.31	15.31	13.78	14.06

Figure 4. Hierarchical analysis map between the Huoshiliang skulls and other groups. Where 1 = Huoshiliang; 2 = Xicun; 3 = Qucun; 4 = Pengpu; 5 = Shaolingyuan; 6 = Hedang; 7 = United Liuwan group; 8 = Shangsunjiazhai (Han); 9 = Shangsunjiazhai (Kayue); and 10 = Lijiashan.

from the bone samples was sufficiently preserved for reliable dating. The samples also exhibited an acceptable level of nitrogen in the whole bone sample. Measuring the percentage of nitrogen of the whole bone allows us to estimate the quantity of collagen present before chemical treatment commences. For nitrogen, this usually ranges from approximately 4% in a fresh bone to below 0.2% in a poorly preserved bone (Tisnérat-Laborde et al. 2003). The nitrogen levels of the bones (ca. 4%) was acceptable, although the yield for OZL292 was surprisingly low. The small amount of collagen extracted from that bone appears not to be the result of poor preservation, as the percentage of nitrogen of the whole bone was of an acceptable value (4.1%) and the C:N ratio (3.23) of the collagen was satisfactory. This unusual result is most likely explained by a loss of collagen during the pre-treatment steps. In general, the C:N ratios of the collagen were within the acceptable range (ca. 3%), indicating that the collagen preservation was acceptable for dating (see Deniro 1985) and contaminants had been effectively removed.

The skull ages and the sheep bone overlap in age in the $\pm 2\sigma$ range (Table 4 shows the $\pm 1\sigma$ values and $\pm 2\sigma$ calibrated range values), which probably puts them all within an age range of 1700–2017 cal BC. The calibrated ages are based on Reimer et al. (2004). Other radiocarbon dates from the site have yet to be published and these are based on charcoal (five samples) and a charred wheat seed (one sample). These all have calibrated ages within the range 1733 to 2135

cal BC and the dates are therefore consistent within the site and the bone ages are consistent with these. The sheep bone sample has an indistinguishable radiocarbon age from the human skulls, suggesting they were contemporaneous.

The $\delta^{13}\text{C}$ values of the human skulls are about the same, but they are low negative values (ca. -8 to -9‰). The sheep bone had a value of ca. -18‰.

The seed analysis was based on 13,472 identified seeds (Table 5). The relative ease of finding cereal seeds suggests that crops were a staple part of the diet and people at the site were farmers. The seeds were dominated by broomcorn and foxtail millet types, with the latter declining in proportion above about 60 cm depth, when wheat and oat make an increasing contribution. Broomcorn millet is the dominant seed type in the upper layers, suggesting this was by far the dominant local crop, but an increase in crop diversity in the upper layers is suggested by the seed numbers.

Discussion

Table 4. Bone protein, $\delta^{13}\text{C}$, $\delta^{15}\text{N}$ and radiocarbon results. Calibrated ages are from Reimer *et al.* (2004).

Sample name	Bone protein yield (%)	Whole bone N (%)	$\delta^{13}\text{C}$ (‰) graphite collagen	$\delta^{15}\text{N}$ (‰)	Collagen C:N ratio	AMS date number	Age BP	Calibrated age (BC) $\pm 2\sigma$
HSG-01	0.5	4.22	-8.2 $\pm$ 0.1 -8.71	6.1	3.19	OZL 292	3515 $\pm$ 45	1955-1737
HSG-02	4.1	4.1	-9.0 $\pm$ 0.1 -8.86	9.8	3.23	OZL 293	3590 $\pm$ 45	2124-1995
HSG-03	6.5	3.93	-17.5 $\pm$ 0.1 -18.51	11.8	3.20	OZL 294	3515 $\pm$ 40	1946-1776

Table 5. Distribution of seed types with depth at Huoshiliang.

Sample depth (cm)	<i>Panicum miliaceum</i> Broomcorn millet	<i>Setaria italica</i> Foxtail millet	<i>Triticum</i> Wheat	<i>Avena sativa</i> Oat	<i>Hordeum vulgare</i> Barley	Other	Total seeds
0-20	95.74	2.13	1.49	0.11	0	0.54	900
20-40	90.03	9.47	0.41	0.01	0	0.09	10973
40-60	92.08	5.87	1.76	0.07	0	1.72	1256
60-80	76.21	18.97	2.41	0	0.69	0	221
80-100	73.24	26.76	0	0	0	0	52
100-120	77.61	22.39	0	0	0	0	52
120-140	72.22	27.08	0	0	0	0	13
140-160	100.00	0	0	0	0	0	5

The correspondence of the radiocarbon ages of the skulls, sheep bone and other materials from the site indicate that Huoshiliang was occupied by East Asian people between about 1860 BC and 2020 BC. The skull dates are the first definitive early ages of Mongoloid people in this part of Central Asia. Earlier people from the region were possibly Caucasoid (e.g. Barber 1999), but since the remains analysed in this study are from a sample of two, it remains to be demonstrated whether the site was wholly occupied by Mongoloid people, whether there was mixed occupation, or whether there was merely the opportunity for exchange.

Elsewhere, we have published evidence of bronze technology (Dodson *et al.* 2009) and we have also noted that wheat, barley and oats at Huoshiliang are among the oldest in China

(Li et al. 2007). It is probable that this mix arose from western Asia and is thus indicative of at least strong east-west interaction by around 2000 BC. The seed evidence shows that millets, the quintessentially north China and Yellow River valley crops, dominated agriculture at Huoshiliang.

Stable isotope analyses on bone can reveal much about diet and living conditions of individuals (Larsen 1998). In this case, the human bones had low negative $\delta^{13}\text{C}$ values, which indicates that C4 plants, and possibly protein from animals which fed on C4 plants, were the mainstay of the diet. There has been no systematic study of the abundant animal bone at the site, although sheep bone fragments are relatively common. However, the human ^{15}N values (6–10‰) are low and suggest that very little animal protein was consumed. The sheep value may be inflated due to fertilising pastures or manuring. Millet agriculture originated in the Yellow River valley of China from about 8000 BP; these are C4 plants, while wheat, oats and barley are C3 plants. We surmise that millet was the underpinning mainstay of the human food chain at Huoshiliang around 2000 BC. The sheep bone had a more negative $\delta^{13}\text{C}$ value, suggesting part of its diet included C3 plants.

Several other studies in the Yellow and Wei river systems of northern and northeastern China, where millet agriculture originated, have measured similar $\delta^{13}\text{C}$ values in human bone samples and concluded that millets must have been the mainstay of the food chain to humans (Pechenkina et al. 2005; Hu et al. 2008). Barton et al. (2009) recently argued that the domestication of dogs and pigs in northern China was accompanied by a shift to less negative $\delta^{13}\text{C}$ values, which were associated with broomcorn and foxtail millet forming part of their diet.

The sheep bone from Huoshiliang has a more negative $\delta^{13}\text{C}$ value, but one that is less negative than C3 plants in general, suggesting its diet was a mix of C3 and C4 plant foods. Perhaps sheep protein was not a large part of the Huoshiliang women's diet.

Skull No. 1 showed periodontitis. More than 50% of the tooth roots were exposed. For the left top jaw, P1, P2, M1 show abscess, and some corroded holes in the cheek side had diameters of 3.8 mm, 4.5 mm and 4.0 mm respectively. In Skull No. 2, all teeth had fallen out in the upper jaw. The alveolar had atrophied and closed completely. Both skulls thus show severe mouth disease and poor teeth health. This may be evidence of a narrow diet based on millet. Larsen argued some time ago (Larsen 1998) that the agricultural transition from hunter-gather society was probably associated with greater sedentism, narrower diet and a proneness to poor dental health and even earlier death.

Conclusion

The morphological characteristics of the two skulls from Huoshiliang show they are female and are representatives of the East Asia type of the Mongoloid race. The cluster analysis shows that the skull morphologies are similar to those of groups that were in China from the Neolithic to Han Dynasty times. The individuals and the archaeological site in which they were found have an age between 1860 BC and 2020 BC, and evidence of pottery, bronze and agriculture suggests they were part of a complex society with strong technological links to both western and eastern Asia. While the range of crops became more complex with the introduction of wheat, oats and barley, millets remain the dominant food plant, and this is reflected in the stable-isotope data obtained from the bones. The two individuals may have lived before a diversification of additional crops appeared at the site. The lack of animal protein and reliance on millet consumption may have contributed to poor oral health.

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