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Neurocranial abnormalities of the Gongwangling *Homo erectus* from Lantian, China

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ABSTRACT

The *Homo erectus* cranium found at Gongwangling, near Lantian, China, and dated to ≈1.2 ma BP has been analyzed with respect to its evolutionary position. However, the remains, and especially the internal and external surfaces of the neurocranium, present a series of marked abnormalities. These irregularities consist principally of a pronounced cresting and scalloping of the external surface of the frontal bone and anterior parietal bone and a similar alteration of the internal surface of a mid transverse section of parietal bone that connects with the fossilization break across the anterior parietal bone. There is no obvious exposure of diploë on the surfaces. Woo (*Vertebrata PalAsiatica* 10:1–16, 1966) briefly ascribed these abnormalities to postmortem erosion, and Caspari (*Am. J. Phys. Anthropol.* 102:565–568, 1997) has attributed the irregularities of the right supraorbital torus to antemortem trauma. It has been suggested that the pervasive neurocranial alterations might be pathological. Computerized tomography (CT) analysis of the frontal and parietal bones revealed complete radiopacity of the anterior half of the fossil; it is possible to distinguish large frontal sinuses but other details, including in the area of the purported traumatic lesion, are invisible. However, in the posterior frontal bone and preserved portions of the parietal bone the diploë and tables are discernible. Externally on the frontoparietal section and internally on the transverse parietal piece, there are clear erosional lacunae in the associated table, combined with a thin layer of matrix which obscures the eroded diploë externally. The superficial irregularities are therefore due to postmortem taphonomic alterations of the bone and not pathological processes. In addition, it is apparent that the two pieces were embedded in the matrix at different angles, resulting in their differential erosion.

1. Introduction

In 1964 a partial human cranium, Gongwangling cranium (Institute of Vertebrate Paleontology and Paleoanthropology (IVPP) PA105), was discovered in the Early Pleistocene deposits of a small hill, Gongwangling (Gongwang Hill) close to the village of Gongwang, near Lantian in the north-western part of China (Fig. 1; Jia, 1965; Woo, 1965; Wu et al., 1966). Since it may be the oldest human fossil currently known from more northern mainland eastern Asia, the incomplete and significantly altered Gongwangling cranium (Fig. 2) has been described extensively from a comparative morphological perspective (e.g., Woo, 1966a,b; Wu and Poirier, 1995; Wolpoff, 1999; Wu et al., 1989). However, the abundant alterations of the neurocranial bone on the specimen have received only limited attention.

Woo (1966a: p. 14), in his original description of the remains, noted slight "distortion by compression," a "markedly rugged appearance" of the external frontal bone, and "depressions (with) rather sharp edges," all of which he attributed to "the corrosive process during fossilization." Subsequently, Caspari (1997) interpreted the depression in the right supraorbital torus and the associated upward displacement of bone to a healed antemortem trauma. In the meantime, Zhang Z. (pers. comm.) has commented to one of us that the abnormal condition of the Gongwangling cranium must be pathological, with a variety of more systemic conditions (as opposed to localized lesions as from trauma) suggested as being responsible for the condition of the fossil.

In light of the condition of the Gongwangling cranium and uncertainties regarding the origin of its abnormal condition, we scanned it using computerized tomography to determine whether the unusual condition of this early Chinese fossil could be due to a pathological condition, thereby joining a host of other abnormal Pleistocene *Homo* fossils, or only reflects, as stated by Woo (1966a), postmortem fossilization processes. In this reassessment the null hypothesis,

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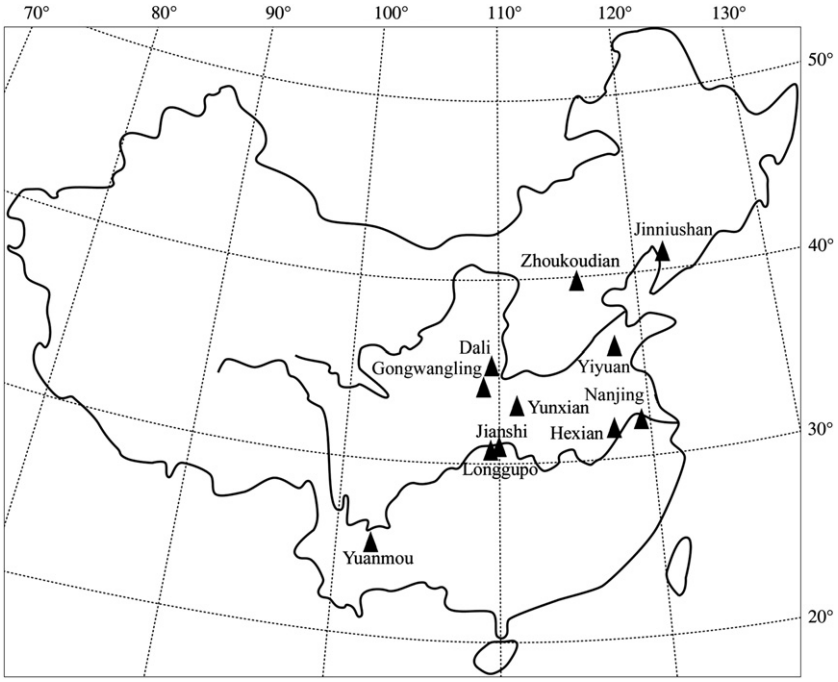

Fig. 1. Map of China showing the locations of the principal Early and Middle Pleistocene *Homo* fossil localities.

following Woo, should be that the abnormalities of Gongwangling cranium are taphonomic, and not pathological, in nature.

2. The Gongwangling site and the cranium discovery

The Gongwangling site (34°11′N, 109°29′E) (Fig. 1) consists of a series of 12 exposed paleosols, loess, and clay levels. Layer 6, from the middle of the sequence, consisted of a 2.6 m thick loess-like silty clay level containing *in situ* an abundance of concretions of varying size, with the human remains and macrovertebrates being found within or attached to the concretions. An isolated maxillary human molar was discovered *in situ* on May 1964, and the remainder of the human remains were extracted from one of the Layer 6 hard matrix concretions at the IVPP subsequently during 1964.

The human fossil containing layer yielded an abundance of mammalian remains (Chow et al., 1965; Gu and Jablonski, 1989; Qi, 1989; Wu and Poirier, 1995), indicating a relatively warm climatic phase during the Early Pleistocene. This paleoclimatic inference has been supported by paleosol stable isotope analysis (Wang et al., 1997). The Gongwangling site has also yielded a small number of Paleolithic artifacts *in situ* (Dai, 1966; Tai and Hsu, 1973). Subsequent attempts to date the levels by paleomagnetism have yielded a progressively older series of dates of 750–800 ka BP (Ma et al., 1978), 1.0 ma BP (Cheng et al., 1978) and 1.15 ma BP (An and Ho, 1989; An et al., 1990). The last value, which is based on secure identification of both the Bruhnes/Matuyama boundary and the Jaramillo event through the stratigraphic sequence, combined with sedimentological extrapolation, provides an age range of 1.07–1.20 ma BP with a most likely age $\approx$1.15 ma BP. As such, the Gongwangling cranium is likely to represent the old human fossil from mainland east Asia, considerably older than the Chenjiawo (IVPP PA102) *H. erectus* mandible from nearby Chenjiawo (An and Ho, 1989; Wu and Poirier, 1995) (only the Yuanmou incisors (Hu, 1973) might be older (Wu and Poirier, 1995)).

3. The Gongwangling cranium human remains

Gongwangling cranium consists principally of a frontoparietal piece, with most of the frontal bone and an anterior transverse section of the right and left parietal bones (Figs. 2 and 3). Separate from it is a transverse piece of the mid-parietal bones, which originally joined to the anterior parietal piece with the frontal bone, but damage to the edges has made the contact between them approximate. There are separate, incomplete and eroded portions of the nasal bones, the midline and right inferior maxillae with a separate piece of the superior left maxilla, and the petrous portion of the right temporal bone.

The neurocranium of Gongwangling is most notable, aside from its overall *H. erectus* cranial morphology, for the massively altered external surface of the frontal bone and the anterior parietal bone, plus pronounced internal and minimal external alteration of the mid-parietal piece. The external surface changes consist of a series of irregular grooves on the bone, hollowed out depressions, raised sharp edges between the depressions, and variably smooth and rough portions of the bony surface (Figs. 2–4). There are randomly scattered small (1–2 mm) holes in the external surface, and there are what appear as small nubbins of bone protruding in various places on the surface. There is no indication of exposed diploë, giving the impression that the external surface consists of cortical bone. These irregularities of the external surface extend to the broken edges of the preserved bone.

The raised and altered contour of the bone is most evident along the right supraorbital torus and temporal line, around the left temporal line and coronal suture, and across the posterior break of the piece through the anterior parietal bones. In addition, the lateral portion of the right supraorbital torus extending over to the right frontozygomatic suture has been displaced anteriorly and laterally, with a matrix filled crack between it and the more medial and posterior adjacent portions of the frontal bone.

In contrast, the endocranial surface of the frontal bone and adjacent anterior parietal bones appear normal, with a gentle and regular concavity, interrupted only by the coronal suture, small expansion cracks in the anterolateral left parietal bone, and minor general erosion of the sub-meningeal cortical bone. The frontal crest is preserved most of the distance from the nasal root to bregma, and the anterior portion of the sagittal sinus sulcus is evident from near bregma to the posterior break of the bone, along the internally fused sagittal suture.

Fig. 2. Superior (left) and inferior (right) views of the Gongwangling neurocranium, with the mid-parietal piece articulated with the frontoparietal portion. Scale in centimeters.

The mid-parietal transverse piece consists of a least four pieces of bones which are held together by matrix and/or glue (more pieces if smaller fragments along the breaks are considered). It fits reasonably well with the more anterior section along the medial right break and the mid-parietal left break, even though edges of both pieces are eroded and have lost bone. This piece, however, is relatively smooth on its exocranial surface, close to that seen on the anterior neurocranial piece endocranially, but its endocranial surface is heavily altered, similar to the pattern on the external frontal bone and anterior parietal bones.

The temporal and facial pieces sustained surface erosion, but they lack the extensive changes seen on the more anterior exocranial and further posterior endocranial vault pieces.

As noted above, these alterations were originally attributed by Woo (1966a) to postmortem fossilization, but it has been questioned whether they, like the right supraorbital changes interpreted as the result of trauma by Caspari (1997), might be pathological. Prior to any paleopathological diagnosis, however, it is necessary to eliminate postmortem changes as the cause of the irregularities.

4. Methods

To evaluate the Gongwangling neurocranium, we scanned the frontal and parietal bones at the People's Hospital of Peking University. Two hundred sixty-five sagittal CT slices were made with a Lightspeed QX/i Medical scanner from GE Medical Systems with an exposure of 350 mAs at 140 kV tube voltage and a slice thickness of 0.63 mm. The resultant slices were viewed using Image-J 1.4.3.67 (2006) (Bethesda: NIH & Broken Symmetry Software), Plug N View 3D (Edinburgh, Voxar), and Mimics 11.0 (Leuven: Materialise NV).

It was assumed that, if the neurocranial bone surface was largely intact through fossilization, the cranial vault bone would reveal relatively continuous internal and external tables with variable thickness of the intervening diploë. As such, it would require a paleopathological differential diagnosis. If the bone, alternatively, presented a normal table and adjacent diploë on only one side (endocranially on the frontal bone and exocranially on the mid-parietal piece) but a discontinuous table on the other side with diploë at or immediately adjacent to the surface, then there would be two alternative interpretations. It could have been eroded postmortem, or it could have been subjected to a pathological process which resorbed one of the tables but had little effect on the diploë or the other table.

Fig. 3. Anterior view of the Gongwangling frontal bone, showing the irregularity (possible healed trauma) of the right supraorbital torus and the irregular contour of the frontal squamous portion. Scale in centimeters.

Fig. 4. Detail of the alterations of the mid-frontal external squamous portion. Anterior is above and the postorbital constriction is evident, especially on the right side. Scale in millimeters.

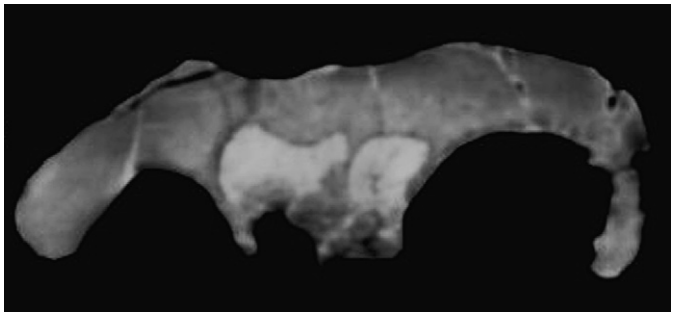

Fig. 5. Reconstructed CT transverse section through the supraorbital torus of Gongwangling cranium, showing the interorbital distribution of the frontal sinuses and the distortion of the right supraorbital torus.

5. Results

The CT scanning of the Gongwangling frontal bone provided little information in its anterior half (Figs. 5–7). The bone is heavily mineralized in that region, and it was not possible to discern more than the external contours for most the supraorbital region and the anterior squamous portion. We attempted to verify Caspari's interpretation of the right supraorbital torus irregularity as a healed traumatic lesion, and the complete radiopacity in that region permitted neither confirmation nor refutation of her interpretation (Figs. 5 and 7A). The postmortem cracks and displacement of the right anterolateral frontal bone evident externally (Fig. 2) is also apparent radiographically. However, the anterior frontal bone otherwise has a generally homogeneous appearance, reflecting mineral uptake rather than internal skeletal anatomy. The only novel anterior aspect of note was the documentation of two substantial frontal sinuses (Figs. 5 and 6A) extending across the interorbital area and through the inferior half of the supraorbital torus (Woo (1966a) was unable to see them in his radiograph and concluded that they were absent).

It is therefore not possible to confirm on the anterior or mid-frontal squamous whether the depressions on the external surface are due to removal or remodeling of the external table. However, just posterior of the deformed left supraorbital torus and toward the middle of the frontal squamous a thin layer of heavily mineralized matrix is evident in the CT slices (Fig. 7B). This appears to represent a very thin coating of dense matrix that smoothes over the surface, covers any diploic bone that might have been exposed, and produced the largely continuous external surface on the fossil (Fig. 4). The thin matrix is not evident on the right side (Fig. 7A), and the CT slices there appear to reflect only mineralization and external surface irregularities.

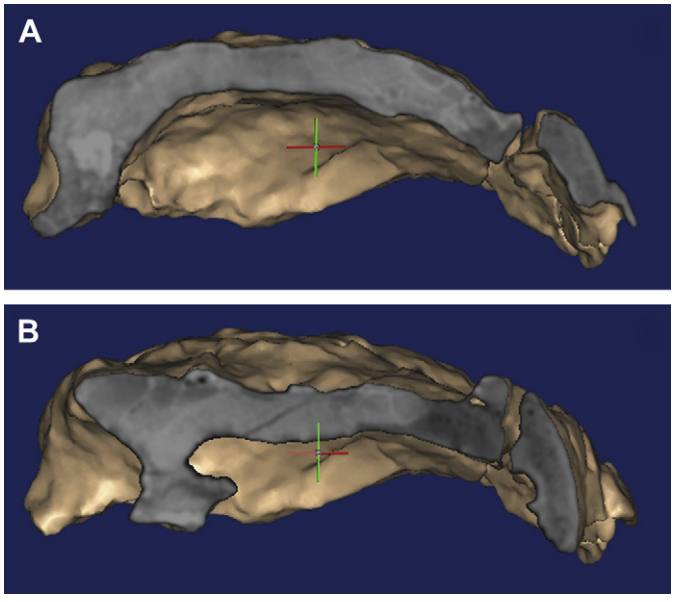

Fig. 6. Reconstructed sagittal CT sections of the Gongwangling neurocranium. (A) approximately on the midline. (B) through the approximate mid left orbit. The position of the mid-parietal piece is approximate and not in articulation with the more anterior neurocranial piece.

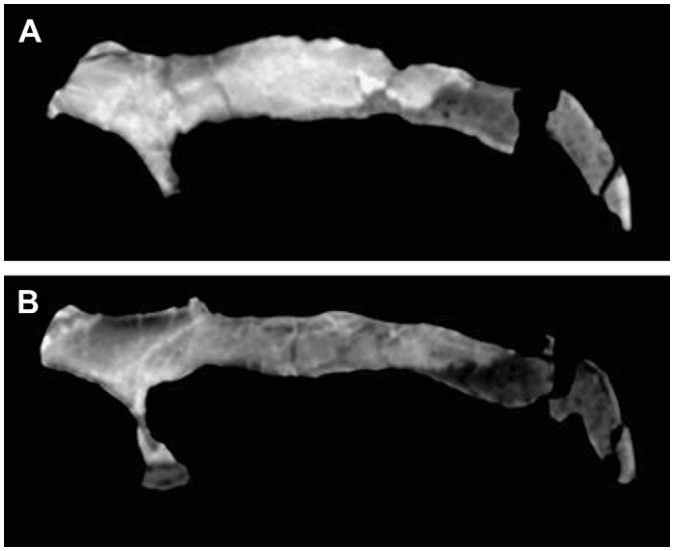

Fig. 7. Parasagittal CT sections of the Gongwangling neurocranium. (A) through the approximate mid right orbit. (B) through the approximate mid left orbit. The position of the mid-parietal piece is approximate and not in articulation with the more anterior neurocranial piece.

More posteriorly on the frontal bone and especially on the two sections of the parietal bones, it is possible to discern higher density tabular cortical bone and the lower density diploë (Figs. 6 and 7). Near the midline (Fig. 6A), the middle parietal bone evinces both tables, although a relatively thin one endocranially, and diploic bone between them. On the left side (Figs. 6B and 7B), the more anterior parietal bone exhibits a clear internal table, a wide diploic space, but complete or almost complete loss of the external table, such that the less dense diploic bone is at or very close to the external surface. More posteriorly on the left parietal bone, on the separate piece of mid-parietal bone, the external table is present and has an even convex curvature, and the diploë appears normal. However, there appears to be internal table present, but it is deformed with a depression and crests of bones protruding endocranially. The right side parietal bone (Fig. 7A) exhibits normal diploë. The more anterior section has a clear internal table but no evidence of the external table. The more posterior portion has a clear, if thin, external table but little or no evidence of an internal table.

6. Discussion

From these CT images, it is apparent that at least the more posterior preserved portions of the Gongwangling neurocranium experienced irregular loss of the external table more anteriorly and loss or deformation of the internal table more posteriorly. The extensive mineralization of the bone on most of the frontal bone prevents such observations more anteriorly, although it is apparent that portions of the external surfaces retain a paper-thin layer of highly dense matrix, which has smoothed over much of the external neurocranium. The question remains whether the loss of tabular bone could have been the product of an antemortem pathological process or must have been postmortem.

Several pathological conditions will produce loss of the external table. Mycobacterial and treponemal diseases (i.e., tuberculosis and syphilis) can produce neurocranial lesions that are lytic, but they tend to be either localized areas of bone loss and/or larger irregular areas with extensive remodeling of the external table (Steinbock, 1976; Aufderheide and Rodríquez-Martin, 1998). Neither one fits the pattern of Gongwangling cranium. Porotic hyperostosis can produce the expansion of the diploic honeycomb through the external table in extreme cases through enlargement of the hematopoetic tissues in the diploic spaces (Stuart-Macadam, 1992). However, it does not produce the marked irregularities present on Gongwangling cranium, does not expand into the supraorbital region, and should affect primarily the external table of the frontal and parietal bones, whereas it is the internal table of the mid-parietal bones of Gongwangling cranium that have cortical bone loss.

A variety of forms of trauma to the neurocranium, including localized impacts, tensile trauma to the scalp (hair-pulling injuries), scalping, and burns (Hamperl and Laughlin, 1959; Ortner and Putschar, 1981; Cooling and Viccellio, 1991; Smith, 2003; Gümüş et al., 2006; Seifert and Püschel, 2006; Yeong et al., 2006; see Shang and Trinkaus, 2008), can produce localized or widespread alteration and even necrosis of the external table. However, none of them is likely to affect the internal table of the mid-parietal bones and affect all of the exposed external surfaces of the frontal and anterior parietal bones but leave the adjacent external mid-parietal bones essentially unscathed.

Given these considerations, it is likely that the extensive alterations of the Gongwangling neurocranium are due, as originally suggested by Woo (1966a), to postmortem erosion and breakage. It cannot be eliminated that they are the product of one of the antemortem pathological conditions mentioned, especially one of the traumatic forms (including the possible supraorbital trauma proposed by Caspari), combined with extensive postmortem breakage and erosion. However, the localization of the defects on the larger frontoparietal piece to the external surface and on the mid-parietal piece largely to the internal table makes such a combination unlikely.

In addition, the more anterior external damage and the more posterior internal alterations suggest that the two pieces became separated and differently positioned in the deposits prior to the erosion of the surfaces.

7. Conclusion

A consideration of the surface condition of the Gongwangling human cranium in combination with CT scans of the frontoparietal bones makes postmortem erosion and fossilization damage the most likely cause of the readily apparent abnormalities of the specimen. It remains possible that some form of traumatic lesion, in addition to the possible right supraorbital one, contributed to the unusual texture of the bone. But the data are insufficient to reject the null hypothesis of Woo that Gongwangling cranium is merely one of the more eroded earlier *H. erectus* fossils known.

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