International Journal of Osteoarchaeology
Int. J. Osteoarchaeol. (2012)
Published online in Wiley Online Library
(wileyonlinelibrary.com) **DOI**: 10.1002/oa.2283

SHORT REPORT

Neurocranial Trauma in the Late Archaic Human Remains from Xujiayao, Northern China

X. J. WU[a]* AND **E. TRINKAUS**[b]

[a] *Key Laboratory of Evolutionary Systematics of Vertebrates, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing, China*
[b] *Department of Anthropology, Washington University, Saint Louis MO, USA*

ABSTRACT The early Late Pleistocene late archaic human remains from Xujiayao, northern China, reveal several abnormalities of the neurocranial vault. The Xujiayao site is located on the northwestern boundary of the Nihewan Basin, and on the basis of various indicators, it dates to the early Late Pleistocene. Among the 15 human neurocranial elements found at Xujiayao in the 1970s, three elements show minor traumatic lesions of the external table: the largely complete Xujiayao 5a immature parietal bone, the Xujiayao 8 small piece of anterior right parietal bone and the Xujiayao 12 partial occipital bone. The lesions are all superior to the temporal or nuchal lines and hence were subcutaneous, covered only by the pericranium, the galea aponeurotica and the overlying skin. The external tables are variably concave with irregular bone within the bony depressions, and the diploë show varying degrees of involvement. The Xujiayao abnormalities join a series of minor neurocranial healed lesions among Pleistocene humans, as well as more pronounced healed neurocranial and facial trauma. Copyright © 2012 John Wiley & Sons, Ltd.

Key words: Asia; crania; Pleistocene; paleopathology; trauma

Introduction

Assessments of the risk of injury and of posttraumatic survival among Pleistocene humans are dependent on the documentation and differential diagnosis of lesions on the available human fossil remains. A recent tabulation of traumatic (or probably traumatic) lesions among Pleistocene *Homo* (Wu *et al.*, 2011: Table S2) has indicated that minor lesions of the neurocranium, generally indicated by small exocranial depressions with irregular remodelled bone, are relatively common among Middle and Late Pleistocene humans, both archaic and early modern humans. A few of these specimens exhibit more pronounced neurocranial lesions [especially Dolní V stonice 11/12, Krapina 34.7, Maba 1 and Qafzeh 11 (Tillier, 1999; Mann & Monge, 2006; Trinkaus *et al.*, 2006; Wu *et al.*, 2011)], and several specimens exhibit marked facial trauma [especially Atapuerca-SH Cr.1, Dolní V stonice 3 and Shanidar 1 (Pérez *et al.*, 1997; Trinkaus, 1983; Trinkaus *et al.*, 2006)]. It is in this context that we present several neurocranial lesions evident on the fragmentary and disassociated human remains from the site of Xujiayao, China.

The Xujiayao site

The site complex of Xujiayao (Hsuchiayao), on the northwestern boundary of the Nihewan Basin in northern China, consists of a long series of fluviatile and lacustrine deposits. The human remains, and associated artefacts and faunal remains, derive from fluviatile sediments, at Locality 74093 (40° 06′ 02″ N, 113° 58′ 39″ E) (Chia & Wei, 1976; Chia *et al.*, 1979; Wu & Poirier, 1995; Norton & Gao, 2008; Ma *et al.*, 2011).

The assemblage contains a diverse colder climate vertebrate faunal assemblage that is dominated by late Middle and Late Pleistocene species (Chia *et al.*, 1979;

* Correspondence to: Xiu-Jie Wu, Key Laboratory of Evolutionary Systematics of Vertebrates, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing 100044, China.
e-mail: wuxiujie@ivpp.ac.cn

Wu & Poirier, 1995). The age of the paleoanthropological remains has proven difficult to determine precisely (see discussions in Norton & Gao, 2008; Wang *et al*., 2008; Bae, 2010). U-series dates on six *Equus* sp. and *Coelodonta antiquitatis* teeth yielded mean ages between ~104 and ~125 ka BP (Chen *et al*., 1982; Wu & Wang, 1985), and a preliminary optically stimulated luminescence date for the fossil horizon yielded an age of 69 ± 8 ka BP (Nagatomo *et al*., 2009). The Xujiayao human remains therefore likely derive from early Late Pleistocene [Marine isotopic stage (MIS) 4 or 5] deposits, although they could be late Middle Pleistocene in age if the paleomagnetically reversed deposits represent one of the later Middle Pleistocene excursions (cf., Lund *et al*., 2006). As such, they are broadly coeval with other late archaic humans from East Asia, such as the ones from Changyang, Chaoxian and Maba (Chia, 1957; Woo & Peng, 1959; Xu & Zhang, 1986). Morphologically, they represent late archaic humans and are distinct from earlier *Homo erectus* remains from eastern Asia (Chia *et al*., 1979; Wu, 1980, 1986; Wu & Poirier, 1995).

The Xujiayao human remains consist of 15 partial neurocranial elements (some of which are parietal antimeres), a partial maxilla with six teeth, a mandibular ramus and three isolated molars. They were discovered during excavations in 1976, 1977 and 1979 (Chia *et al*., 1979; Wu, 1980, 1986; cf., Wu & Poirier, 1995). The maxilla (Xujiayao 1) and three associated right and left parietal elements (Xujiayao 5) are immature; the remainder of the elements are mature, and many appear to be older adults on the basis of expanded diploë and thin tables (cf., Skrzat *et al*., 2004; Hatipoglu *et al*., 2008). The majority of the pieces are free of pathological lesions. However, a largely complete left immature parietal bone (Xujiayao 5a), a right anterosuperior parietal bone (Xujiayao 8) and an occipital bone (Xujiayao 12) show neurocranial abnormalities.

Materials and methods

The materials consist of the original human fossils of Xujiayao 5a (PA 1485), 8 (PA 1489) and 12 (PA 1495) in the Institute of Vertebrate Paleontology and Paleoanthropology (IVPP), Chinese Academy of Sciences, Beijing.

Xujiayao 5a and 12 were scanned using a high-resolution industrial computer tomography (CT) scanner (type: 450 kV) in the IVPP. CT scan parameters were X-ray tube voltage 400 kV and X-ray tube current 1.5 mA; slice distance is 0.3 mm, and pixel size is 0.2 mm. Xujiayao 8 was μCT scanned using a 3D cone bunch of X-ray scans (type: 225 kV micro-CT) in the IVPP. CT scan parameters were the following: X-ray tube voltage is 180 kV; X-ray tube current is 80 mA; and pixel size is 38.6 μm. The 3D reconstructions were created by postprocessing the CT data and running Mimics 14.0 (Materialise NV) to extract the maximum information concerning internal cranial features, osseous distribution and the lesions. Scanning electron microscopy was used to exam the postmortem damage on the Xujiayao 5a specimen.

The differentiation of neurocranial traumatic lesions (all of the trauma of concern here) from other pathologies follows the criteria of Lovell (1997), in which an inference of an antemortem external force on the living tissue with a resultant depression and remodelling of the bone can be made. Given the incomplete paleontological nature of these bones, some degree of remodelling following the alteration of the external neurocranium is necessary to infer antemortem trauma, as opposed to postmortem fossilisation damage.

Results

The Xujiayao 5a parietal bone lesion

The largely complete Xujiayao 5a left parietal bone [Figure 1(A)] derives from a juvenile, on the basis of its completely open sutural interdigitations, its overall thinness relative to the adult remains from Xujiayao, and the small portion of the cross-section that consists of diploë. The bone exhibits two exocranial areas of altered bone. One set of marks is just above the parietomastoid suture and posterior to the temporal line, and it consists of three small elongated grooves. On close (scanning electron microscope) inspection [Figure 1(B)], they are evident as the products of postmortem localised crushing of the external table from a rounded object or objects, either small rocks during sediment compaction or possibly small carnivore canines. There is no other carnivore damage to Xujiayao 5a, and the marginal breaks are postmortem dry bone breaks.

The other alternation is a slightly elongated depressed posterosuperior area, just below where the sagittal suture turns onto what was probably the suture for a large lambdoidal sutural ossicle. The depression is ~15 mm long (anterosuperior to posteroinferior) and ~8 mm wide. When the lesion is enlarged [Figure 1(C)], the bone within it is irregular with rounding of what may be diploic trabeculae exposed through the erosion of the external table. The surface of it is clearly remodelled, and hence, it represents an antemortem lesion. There is no evidence of endocranial alteration in the vicinity of the lesion. Depending on the position and orientation of the CT slice [Figure 1(D)], the external table of the

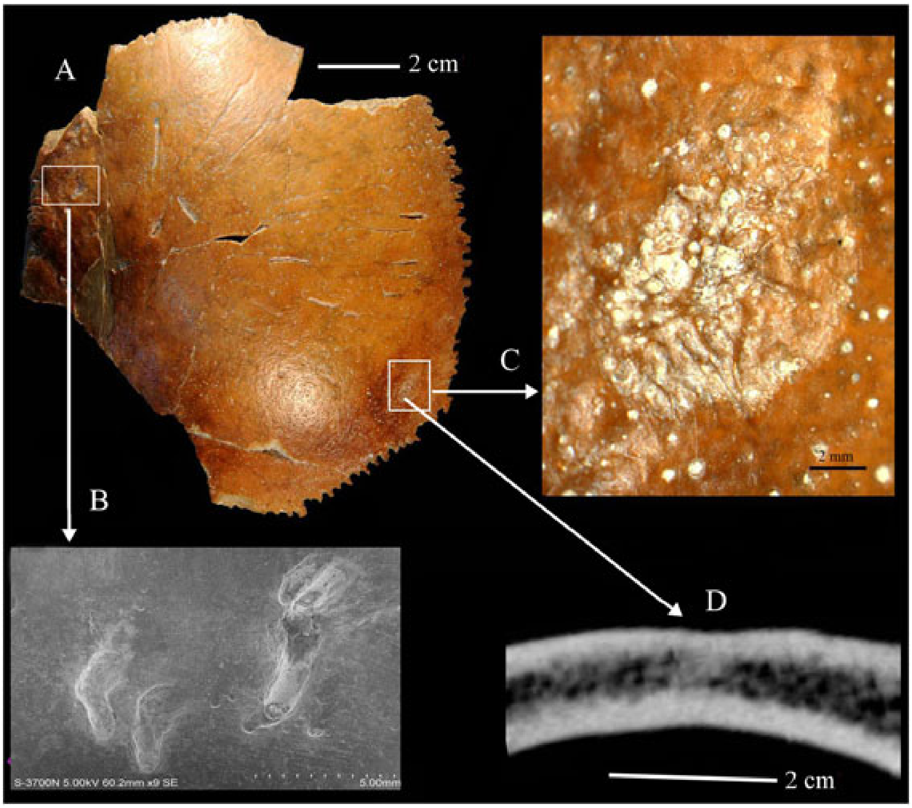

Figure 1. The Xujiayao 5a left parietal bone. (A) superolateral view of the exocranial surface; (B) scanning electron microscopy micrograph of the postmortem damage to the posteroinferior corner; (C) detail of the posterosuperior lesion; (D) coronal views of the computer tomography slice of the lesion. This figure is available in colour online at wileyonlinelibrary.com/journal/oa.

lesion appears as a distinct depression and slightly thinned. The adjacent diploic trabeculae at the point of the maximum depression became denser. The depression has nonetheless changed the contour of the border between the external table and the underlying diploë.

The Xujiayao 8 parietal bone lesion

Xujiayao 8 is a small piece of anterior right parietal bone, with a section of the coronal suture preserved endocranially, no evidence of the temporal line, and the superior end of the anterior meningeal groove [Figure 2(A)]. It should be close to bregma. On the basis of its marked thickness, thin external and internal tables and fine intervening diploic trabeculae, it derives from an older adult. It may be associated with one of the other Xujiayao neurocranial pieces with similar cross-sectional morphology, but that cannot be confirmed by contacts or antimeric symmetry. It is ~54 mm anteroposterior.

On its exocranial surface, and centred ~25 mm from the coronal suture, there is a broad and shallow depressed area with minor pitting of the surface [Figure 2(A)]. It has a slightly raised lip superiorly, a depressed area in the middle and a shallower depressed area along its inferior margin. It extended across the anterior postmortem break of the bone, probably close to the coronal suture. It is 20 mm high and (rounding out the anterior margin) was probably ~35 mm long. The anterior break indicates that the thin external table retained its thickness through the lesion, because it retains the same thickness (~2.5 mm) across the depression at the break. When the lesion is enlarged [Figure 2(B)], the surface of the external table is rough and irregular, and it was clearly remodelled before death. The 3D reconstruction [Figure 2(C)] from the μCT highlights the depressed area on the exocranial surface. A cross-sectional μCT image [Figure 2(D)] shows that the outer table is depressed inward, and that the diploë of the lesion region was remodelled antemortem.

The Xujiayao 12 occipital bone lesions

Xujiayao 12 is a partial occipital bone from the left asterion to the middle of the right nuchal plane [Figure 3(A)]. The left nuchal plane is intact to the posterior margin of the foramen magnum, as is the

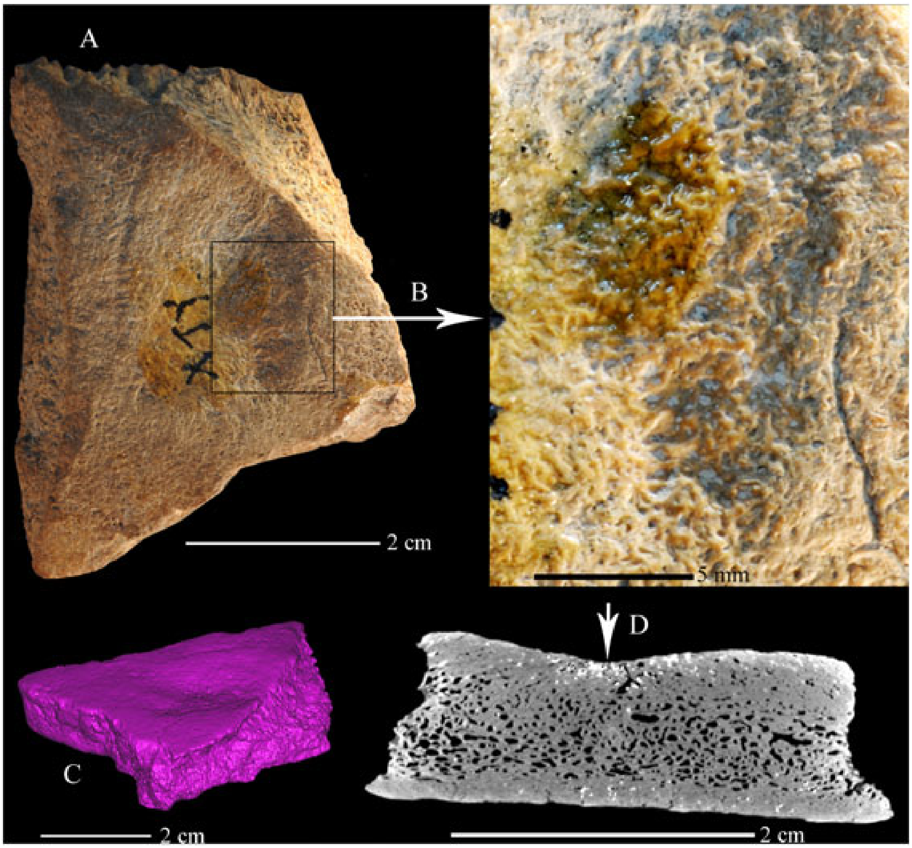

Figure 2. The Xujiayao 8 right parietal bone. (A) external view of the exocranial surface (the coronal suture is above); (B) detail of the lesion; (C) 3D reconstruction showing the depressed lesion; (D) coronal μCT slice through the depression, showing the remodelling of the bone. This figure is available in colour online at wileyonlinelibrary.com/journal/oa.

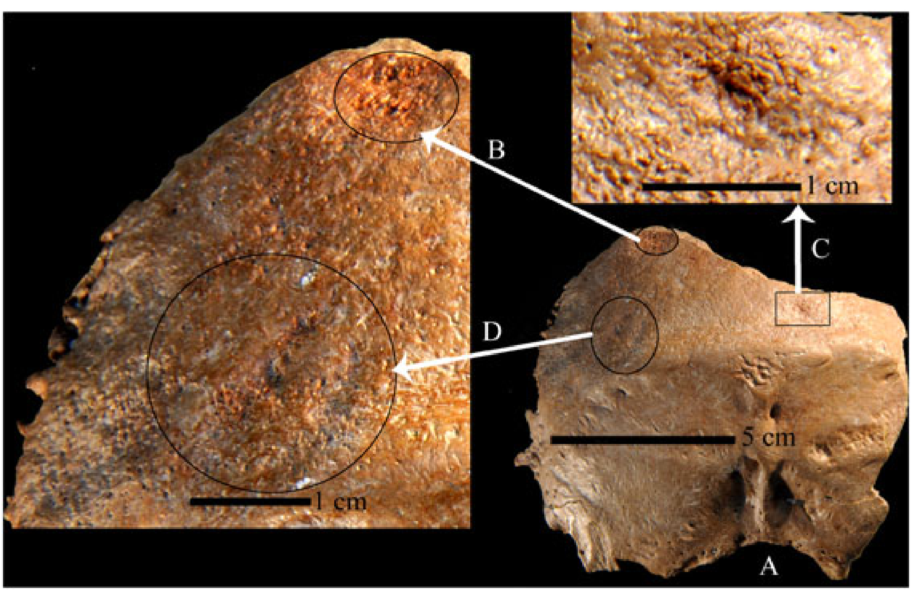

Figure 3. The Xujiayao 12 occipital bone. (A) external views of the exocranial surface, showing the three small exocranial irregularities; (B) the detail of the lesion to the lambdoid suture; (C) the detail of the lesion to the right of the midline; (D) the detail of the lesion above the left lateral nuchal torus. This figure is available in colour online at wileyonlinelibrary.com/journal/oa.

medial half of the right nuchal plane. The right squamous portion retains only 13–15 mm of the bone along the medial half of the nuchal torus. The left one is more complete and forms a triangle that is bounded by the nuchal torus, most of the left lambdoid suture, and an oblique break from the suprainiac area to the lambdoid suture. On the basis of diploic expansion and table thinning, it appears to be an older adult, although the preserved lambdoid suture and the retained occipitomastoid suture show little evidence of fusion; there are only a few lambdoid interdigitations that appear to have fused prior to death.

The bone presents three small exocranial irregularities [Figure 3(A)]; there are no endocranial antemortem changes. The largest exocranial alteration is an irregular, circular depressed area, ~12 mm wide, adjacent to the lambdoid suture and extending across the postmortem break [Figure 3(B)]. The floor of the depression has rounded irregular bone and slight porousness. The second lesion [Figure 3(C)] is located 12 mm to the right of the midline and 7 mm from the middle of the nuchal torus. It is a shallow depression with irregular surface bone, ~15 mm wide and ~9 mm high; it is not related to a suprainiac fossa, because no such depression exists on the bone above inion. The third irregularity is a raised area from the left lateral nuchal torus, ~6 mm wide and extending from the torus superiorly and then laterally to the lambdoid suture [Figure 3(D)]. It may represent an alteration of the muscle insertion in the area, or it may be a non-pathological anatomical variant.

Figure 4 shows 3D reconstructions through the irregular areas of Xujiayao 12 and 2D reconstructions of its internal skeletal anatomy. From the CT slices, it is evident that the internal structures of all three lesion areas were remodelled. A coronal section through the superior left irregularity [Figure 4(A1) and 4(A2)] reveals a depression of the outer table, no change in the

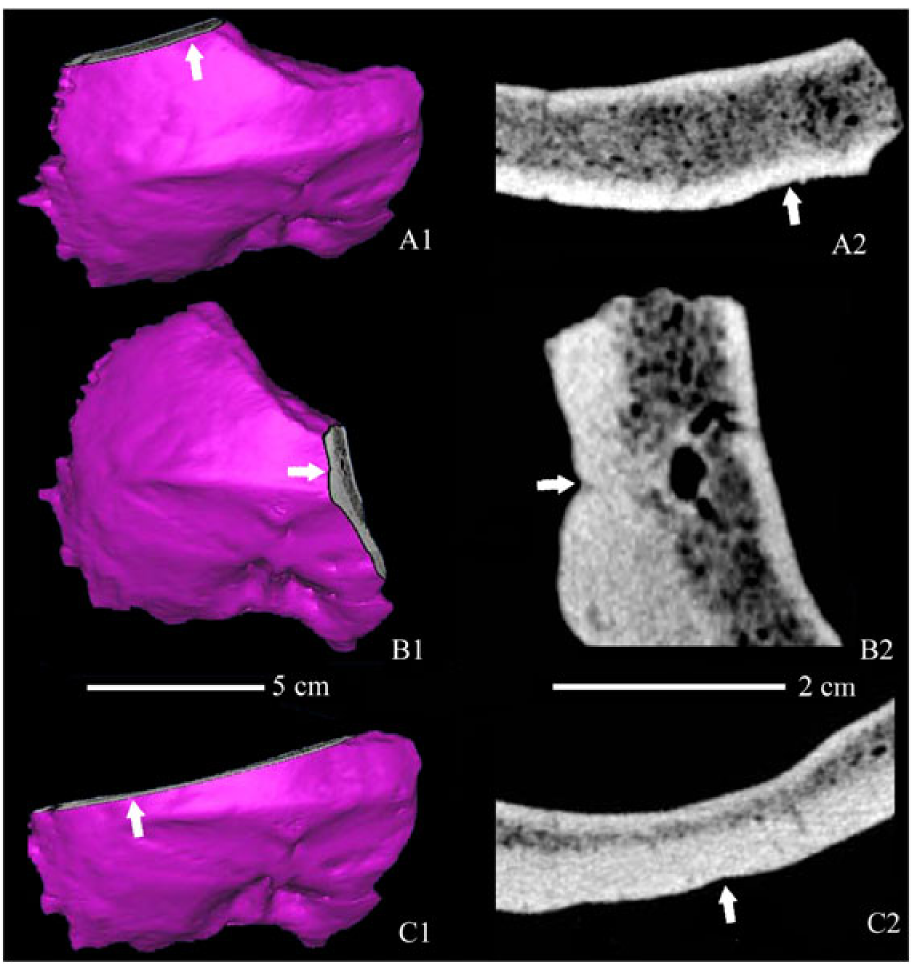

Figure 4. 3D reconstruction images and 2D slices through the areas of the three exocranial irregularities on the Xujiayao 12 occipital bone. (A1, A2) Coronal slices through the lesion adjacent to the lambdoid suture; (B1, B2) sagittal slices through the lesion to the right of the midline; (C1, C2) coronal slices through the lesion above the left lateral nuchal torus. This figure is available in colour online at wileyonlinelibrary.com/journal/oa.

thickness of the table, but a narrowing of the diploic space and/or a slightly raised adjacent area to the depression. A sagittal sectional [Figure 4(B1) and 4(B2)] through the right suprainiac depression shows a localised depression, well superior to the nuchal torus, with diploic irregularities. The horizontal section through the left lateral nuchal torus [Figure 4(C1) and 4(C2)] shows little change of the external table, but there is a thinning of the diploë in the region.

Diagnoses

The depressions on the neurocranium of Xujiayao 5a, 8 and 12, with irregular and altered bone within them, appear to be the results of minor antemortem trauma. None of them occurs in areas that would have been covered by masticatory or nuchal musculature, and therefore, they would have been covered only by the pericranium, the galea aponeurotica and the overlying skin. The surficial and CT sectional appearances of the lesions suggest blunt impacts, resulting in the minor depression of the external table and/or disruption of the overlying tissue with secondary remodelling of the external table and diploë. None of them shows signs of porosity outside of the depressions, and the slight porosity within the Xujiayao 8 and 12 lesions could result from diploic involvement through their altered external tables. It does not appear necessary to invoke other pathological processes [e.g. neoplasms, infectious diseases and/or dietary deficiencies (Aufderheide & Rodríguez-Martin, 1998; Ortner, 2003; see discussions in Shang & Trinkaus, 2008; Wu *et al*., 2011)] to account for these minor lesions. It is unlikely that any of them would have incurred more than temporary localised discomfort and minor bleeding.

Discussion

The exocranial lesions on the Xujiayao 5a, 8 and 12 neurocranial pieces therefore appear most likely to have been the results of minor localised trauma, caused by accidental or intentional wounding. They join a growing list of similar irregularities and depressions of the external table from minor cranial trauma among Pleistocene humans (cf., Wu *et al*., 2011; Trinkaus, 2012). Currently, for Early and Middle Pleistocene humans, they have been documented on 21 individuals from across Eurasia and Africa, and for Late Pleistocene archaic and modern humans are known for 13 individuals (Wu *et al*., 2011).

Neurocranial abnormalities had been identified in several East Asian human fossils; however, when reevaluated, secure evidence for marked trauma is only found in the Maba 1 late archaic human cranium (Wu *et al*., 2011) and the Middle Pleistocene partial cranium from Hulu Cave, Nanjing (Shang & Trinkaus, 2008). Only two of the Zhoukoudian *H. erectus* crania originally identified as having experienced trauma (Weidenreich, 1943; Boaz & Ciochon, 2004) appear to have had antemortem neurocranial trauma (cf., Weidenreich, 1943). The distortion of the supraorbital torus of the Lantian (Gongwangling) calvarium may be posttraumatic (Caspari, 1997), but that cannot be radiographically verified (Shang *et al*., 2008). The Dali cranium has a small posterior neurocranial depression similar to the Xujiayao ones (Wu and Athreya, n.d.). Other East Asian human fossils, such as those from Jinniushan, Hexian, Liujiang, Minatogawa, Niah, Tianyuan and Zhoukoudian-Upper Cave (Brothwell, 1960; Wu, 1981; Suzuki, 1982; Wu & Dong, 1982; Wu, 1988; Wu & Poirier, 1995; Shang & Trinkaus, 2010), do not appear to have evidence of healed antemortem trauma.

Although craniofacial trauma is relatively well documented for adult Pleistocene humans, it is relatively rare among immature specimens, previously noted only for the Atapuerca-SH 3, 6 and 7 crania and Qafzeh 11 (Pérez *et al*., 1997; Tillier, 1999). Xujiayao 5 joins these immature specimens in this aspect. It is, of course, not known whether the mature fossils with lesions sustained them prior to or after full maturity. Similar lesions appear to be evenly distributed around neurocranium in Pleistocene humans; the distribution of the Xujiayao lesions (one right, one left and the rest posterior) follow this pattern.

It is difficult to ascertain the ultimate behavioural contexts of the trauma for these minor lesions. They could be from personal accidents, induced by prey species or other predators, or from interhuman violence (cf., Trinkaus & Buzhilova, 2010; Trinkaus, 2012). If the last, they could be from accidents, minor altercations or serious aggression.

Conclusion

The neurocranial lesions of the Xujiayao late archaic human remains, from the early Late Pleistocene of northern China, add to our sample of minor abnormalities among these foraging populations. The exocranial lesions of the Xujiayao 5, 8 and 12 elements add modestly to the incidence of minor exocranial trauma among these people, reinforcing the frequent incidences of these insults, which are most likely to leave a skeletal stigma on the neurocranial vault above the temporal and nuchal lines.

Acknowledgments

We thank Prof. Wu Maolin and Prof. Wei Qi for their support of the study of the Xujiayao human fossils. This work has been supported by the Chinese Academy of Sciences (KZZD-EW-03, XDA05130101) and the National Natural Science Foundation of China (41272034).

References

Aufderheide AC, Rodríguez-Martin C. 1998. *The Cambridge Encyclopedia of Human Paleopathology*. Cambridge University Press: Cambridge UK.

Bae CJ. 2010. The late Middle Pleistocene hominin fossil record of eastern Asia: Synthesis and review. *Yearbook of Physical Anthropology* **53**: 75–93.

Boaz NT, Ciochon RL. 2004. *Dragon Bone Hill: An Ice-Age Saga of Homo Erectus*. Oxford University Press: New York.

Brothwell DR. 1960. Upper Pleistocene human skull from Niah Caves, Sarawak. *Sarawak Museum Journal* **9**: 323–349.

Caspari R. 1997. Evidence of pathology on the frontal bone from Gongwangling. *American Journal of Physical Anthropology* **102**: 565–568.

Chen T, Yuan S, Gao S, Wang L, Zhao G. 1982. Uranium-series dating of Xujiayao (Hsu-Chia-Yao) site. *Acta Anthropologica Sinica* **1**: 91–95.

Chia LP. 1957. Notes on the human and some other mammalian remains from Changyang, Hupei. *Vertebrata PalAsiatica* **1**: 247–255.

Chia LP, Wei C. 1976. A Palaeolithic site at Hsü-Chia-Yao in Yangkao County, Shansi Province. *Acta Archaeologica Sinica* **2**: 97–114.

Chia LP, Wei Q, Li CR. 1979. Report on the excavation of Hsuchiayao man site in 1976. *Vertebrata PalAsiatica* **17**: 277–293.

Hatipoglu HG, Ozcan HN, Hatipoglu US, Yuksel E. 2008. Age, sex and body mass index in relation to calvarial diploe thickness and craniometric data on MRI. *Forensic Science International* **182**: 46–51.

Lovell NC. 1997. Trauma analysis in paleopathology. *Year book of physical anthropolology* **40**: 139.

Lund S, Stoner JS, Channell JET, Acton G. 2006. A summary of Bruhnes paleomagnetic field variability recorded in Ocean Drilling Program cores. *Physics Earth Planetary Interiors* **156**: 194–204.

Ma N, Pei SW, Gao X. 2011. A preliminary study on the stone artifacts excavated from Locality 74093 of the Xujiayao site in 1977. *Acta Anthropologica Sinica* **30**: 275–288.

Mann A, Monge J. 2006. A Neandertal parietal fragment from Krapina (Croatia) with a serious cranial trauma. *Periodicum Biologorum* **108**: 495–502.

Nagatomo T, Shitaoka Y, Namioka H, Sagawa M, Wei Q. 2009. OSL dating of the strata at Paleolithic sites in the Nihewan Basin, China. *Acta Anthropologica Sinica* **28**: 276–284.

Norton CJ, Gao X. 2008. Hominin–carnivore interactions during the Chinese Early Paleolithic: Taphonomic perspectives from Xujiayao. *Journal of Human Evolution* **55**: 164–178.

Ortner DJ. 2003. *The Identification of Pathological Conditions in Human Skeletal Remains*, 2nd edn. Academic Press: New York.

Pérez PJ, Gracia A, Martínez I, Arsuaga JL. 1997. Paleopathological evidence of the cranial remains from the Sima de los Huesos Middle Pleistocene site (Sierra de Atapuerca, Spain). Description and preliminary inferences. *Journal of Human Evolution* **33**: 409–421.

Shang H, Trinkaus E. 2008. An ectocranial lesion on the Middle Pleistocene human cranium from Hulu Cave, Nanjing, China. *American Journal of Physical Anthropology* **135**:431–437.

Shang H, Trinkaus E. 2010. *The Early Modern Human from Tianyuan Cave, China*. Texas A&M University Press: College Station.

Shang H, Trinkaus E, Liu W, Wu X, Zhu Q. 2008. Neurocranial abnormalities of the Gongwangling *Homo erectus* from Lantian, China. *Journal of Archaeological Science* **35**: 2589–2593.

Skrzat J, Brzegowy P, Walocha J, Wojciechowsji W. 2004. Age dependent changes in the diploe in the human skull. *Folia Morphologica* **63**: 67–70.

Suzuki H. 1982. Skulls of the Minatogawa man. In Bulletin of the University Museum, University of Tokyo, Suzuki H, Hanihara K (eds). *The Minatogawa Man. The Upper Pleistocene Man from the Island of Okinawa*. **19**: 7–49.

Tillier AM. 1999. *Les Enfants Moustériens de Qafzeh. Interprétation Phylogénétique et Paléoauxologique*. CNRS Éditions: Paris.

Trinkaus E. 1983. *The Shanidar Neandertals*. Academic Press: New York.

Trinkaus E. 2012. Neandertals, early modern humans, and rodeo riders. *Journal of Archaeological Science* DOI: 10.1016/j.jas.2012.05.039.

Trinkaus E, Buzhilova AP. 2010. The death and burial of Sunghir 1. *International Journal of Osteoarchaeology*. DOI: 10.1002/oa.1227.

Trinkaus E, Hillson SW, Franciscus RG, Holliday TW. 2006. Skeletal and dental paleopathology. In *Early Modern Human Evolution in Central Europe: The People of Dolní V stonice and Pavlov*, Trinkaus E, Svoboda JA (eds). Oxford University Press: New York; 419–458.

Wang X, Løvlie R, Su P, Fan XZ. 2008. Magnetic signature of environmental change reflected by Pleistocene lacustrine sediments from the Nihewan Basin, North China. *Palaeogeography, Palaeoclimatology, Palaeoecology* **260**: 452–462.

Weidenreich F. 1943. The skull of *Sinanthropus pekinensis*; A comparative study on a primitive hominid skull. *Palaeontologia Sinica* **10D**: 1–485.

Woo RK, Peng RC. 1959. Fossil human skull of early Paleoanthropic stage found at Mapa, Shaoguan, Kwantung Province. *Vertebrata PalAsiatica* **3**: 176–182.

Wu M. 1980. Human fossils discovered at Xujiayao site in 1977. *Vertebrata PalAsiatica* **18**: 227–238.

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

Wu M. 1986. Study of temporal bone of Xujiayao Man. *Acta Anthropologica Sinica* **5**: 220–226.

Wu RK. 1988. The reconstruction of the fossil human skull from Jinniushan, Yinkou, Liaoning Province and its main features. *Acta Anthropologica Sinica* **7**: 97–101.

Wu RK, Dong XR. 1982. Preliminary study of *Homo erectus* remains from Hexian, Anhui. *Acta Anthropologica Sinica* **1**: 2–13.

Wu XZ, Poirier FE. 1995. *Human Evolution in China*. Oxford University Press: New York.

Wu XZ, Wang LH. 1985. Chronology in Chinese palaeoanthropology. In *Paleoanthropology and Palaeolithic Archaeology in the People's Republic of China*, Wu RK, Olsen JW (eds). Academic Press: Orlando; 29–51.

Wu XJ, Schepartz LA, Liu W, Trinkaus E. 2011. Antemortem trauma and survival in the Late Middle Pleistocene human cranium from Maba, South China. *Proceedings of the National Academy of Sciences USA* **108**: 19558–19562.

Xu C, Zhang Y. 1986. Human fossil newly discovered at Chaoxian, Anhui. *Acta Anthropologica Sinica* **5**: 305–310.