Engraved bones from the archaic hominin site of Lingjing, Henan Province

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The production of abstract engravings is considered an indicator of modern human cognition and a means for the long-term recording and transmission of information. This article reports the discovery of two engraved bones from the Lingjing site in Henan Province, China, dated to 105–125 kya. The carefully engraved nature of the incisions, made on weathered rib fragments, precludes the possibility of unintentional or utilitarian origins. Residue analysis demonstrates the presence of ochre within the incised lines on one specimen. This research provides the first evidence for the deliberate use of ochred engravings for symbolic purposes by East Asian Late Pleistocene hominins.

Keywords: East Asia, China, Late Pleistocene, symbolism, art, ochre

Introduction

Opinions differ between those who consider archaic hominin cognition to be comparable to that of anatomically modern humans (e.g. Hovers & Belfer-Cohen 2006; Nowell 2010;

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d'Errico & Stringer 2011; Zilhão 2011; Villa & Roebroeks 2014), and those who consider morphological, physiological, ontogenetic and behavioural differences to suggest different cognitive frameworks (e.g. Spoor *et al.* 2003; Lieberman 2007; Gunz *et al.* 2010; Junker 2010; Mellars 2010; Benazzi *et al.* 2011; de Boer 2012; Pearce *et al.* 2013; Bruner 2014; Neubauer 2015). The first viewpoint is supported by the fact that the emergence of our species in Africa, *c.* 300 kya (Grün *et al.* 1996; Stringer 2016; Hublin *et al.* 2017), was not accompanied by the immediate development of behaviours characteristic of historically documented populations. For tens of thousands of years after their emergence, anatomically modern human populations in Africa continued to use technologies that differed little from those of the non-modern populations preceding them, or from those contemporaneous populations inhabiting other regions, both inside and outside the African continent. It is also supported by the discovery of cultural innovations generally considered to be hallmarks of modern cognition among archaic populations of Eurasia. Burials, the collection of fossils and other rare objects, the production of personal ornaments and engraved patterns, pigment use, cave painting and the extraction of bird feathers and claws are all interpreted as proof that Neanderthals in Europe and the Near East engaged in symbolically mediated behaviour (e.g. Pettitt 2002; Zilhão *et al.* 2010; Peresani *et al.* 2011; Finlayson *et al.* 2012; Rodríguez-Vidal *et al.* 2014; Romandini *et al.* 2014; Radovčić *et al.* 2015; Hoffmann *et al.* 2018). Most of these innovative cultural adaptations, however, are virtually unknown in vast regions inhabited by archaic hominins prior to the arrival of modern human populations—particularly in East Asia. A putative engraving on a bone flake from the Shiyu site, Shanxi Province, dated to 32–28 kya (You 1984), has been interpreted as resulting from post-depositional surface modifications (Bednarick 1994).

Abstract engravings are reported from almost 40 African and Eurasian sites dated prior to 40 kya (see online supplementary material (OSM) 1). The earliest examples are the engraved patterns on a freshwater shell from Trinil, Indonesia, dating to 540 kya; a bone from Bilzingsleben in Germany (370 kya; see, however, Müller & Pasda 2011), ochre fragments from the South African sites of Klasies River, Pinnacle Point and Blombos Cave (110–73 kya); and an antler from Vaufrey in France, dating to 120 kya (Vincent 1988; Henshilwood *et al.* 2009; Watts 2010; d'Errico *et al.* 2012). In China, engraved objects from Pleistocene contexts are rare. The earliest possible example is a *Stegodon* ivory tusk found in a layer dated to 150–120 kya at Xinglongdong Cave, south China. The piece displays a few longitudinal incisions close to the tip of the tusk. Both the site's chronology and the anthropogenic nature of the incisions have been questioned, as elephants use their tusks for a variety of activities that could result in their breakage or the development of ground facets and incisions (Haynes 1991; Villa & d'Errico 2001; Norton & Jin 2009). Elsewhere, a pebble from a context dated to *c.* 40 kya from the lower cultural unit of Shuidonggou locality 1 exhibits a set of sub-parallel and intersecting lines (Peng *et al.* 2012). Pei (1934) describes an engraved antler from Zhoukoudian Upper Cave, now dated to 34–29 kya (Chen *et al.* 1992). A putative engraved bone flake recovered from the Shiyu site, Shanxi Province, dated to 32–28 kya (You 1984) has been questioned on the basis of post-depositional surface modifications (Bednarik 1994). Finally, an antler fragment with an engraved pattern comprising sinuous parallel lines is reported from Longgu Cave, Hebei Province, dated to 13 kya (Bednarik & You 1991).

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Here, we report the discovery of weathered bone fragments exhibiting deliberately engraved lines, one of which is filled with ochre, found at the 125–105 kya site of Lingjing in China. The fragments were found in the same stratigraphic layer that yielded hominin remains attributed to an archaic population exhibiting a mosaic of anatomical features suggestive of complex population dynamics between Eastern and Western Eurasia (Li *et al.* 2017). Recently, it has been suggested that the Lingjing hominins were Denisovans (Martinón-Torres *et al.* 2017: 444), although there is currently insufficient palaeogenetic evidence to corroborate this hypothesis.

Archaeological context

Lingjing (34° 04' 08.6" north, 113° 40' 47.5" east; 117m asl) is an open-air site located in Henan Province, northern China, approximately 120km south of the Yellow River (Figure 1). The site was discovered in 1965. Since 2005, excavations under the supervision of the first author have uncovered 551m^2 of the site. The 9m-deep, water-lain sedimentary sequence comprises 11 geological layers (for details, see OSM 2). Three main archaeological horizons attest to human occupation of the site during the Holocene (layers 1–4), the Late Glacial Maximum to the Younger Dryas (layer 5), and the early Late Pleistocene (layers 10–11). Optically stimulated luminescence (OSL) dates from layer 11 indicate that deposition took place *c.* 125–105 kya (Nian *et al.* 2009), during the early phases of Marine Isotope Stage 5. The faunal assemblage from layer 11 is dominated by horse (*Equus caballus*), onager (*Equus hemionus*) and auroch (*Bos primigenius*). Skeletal elements from late Middle and early Late Pleistocene fauna were also identified in this layer (Li & Dong 2007). The high proportion of limb elements (>60 per cent) and high frequency of cut marks observed on midshafts (approximately 34 per cent) suggest that Lingjing layer 11 was a kill-butchery site (Zhang *et al.* 2012).

The lithic assemblage from layer 11 comprises mostly quartz and quartzite artefacts. The presence of cores, flakes, formal tools and debris, plus the identification of use wear on some artefacts (Li 2007; Li *et al.* 2019), of bone retouchers, organic soft hammer and pressure flakers (Doyon *et al.* 2018, 2019), suggest that knapping activities, including tool manufacture and use, occurred at the site. The two engraved bone fragments described in this study also derive from layer 11. Discovered in 2009, their engravings were later identified during analysis of the faunal assemblage conducted in 2016.

Methods

Excavation methods at Lingjing involved the careful removal of sediments using curved-tipped trowels to avoid damaging finds, the 3D plotting of bone remains and lithic artefacts, and sediment sieving through 2mm mesh. Lithic and faunal remains are cleaned using soft brushes under running water. When present, sediment concretions are not removed from the faunal remains.

The artefacts described in this study are curated at the Henan Provincial Institute for Cultural Relics and Archaeology, Zhengzhou, China. Permission was granted to analyse one object (9L0141) at the Raman and Scanning Electron Microscopy Facilities of the

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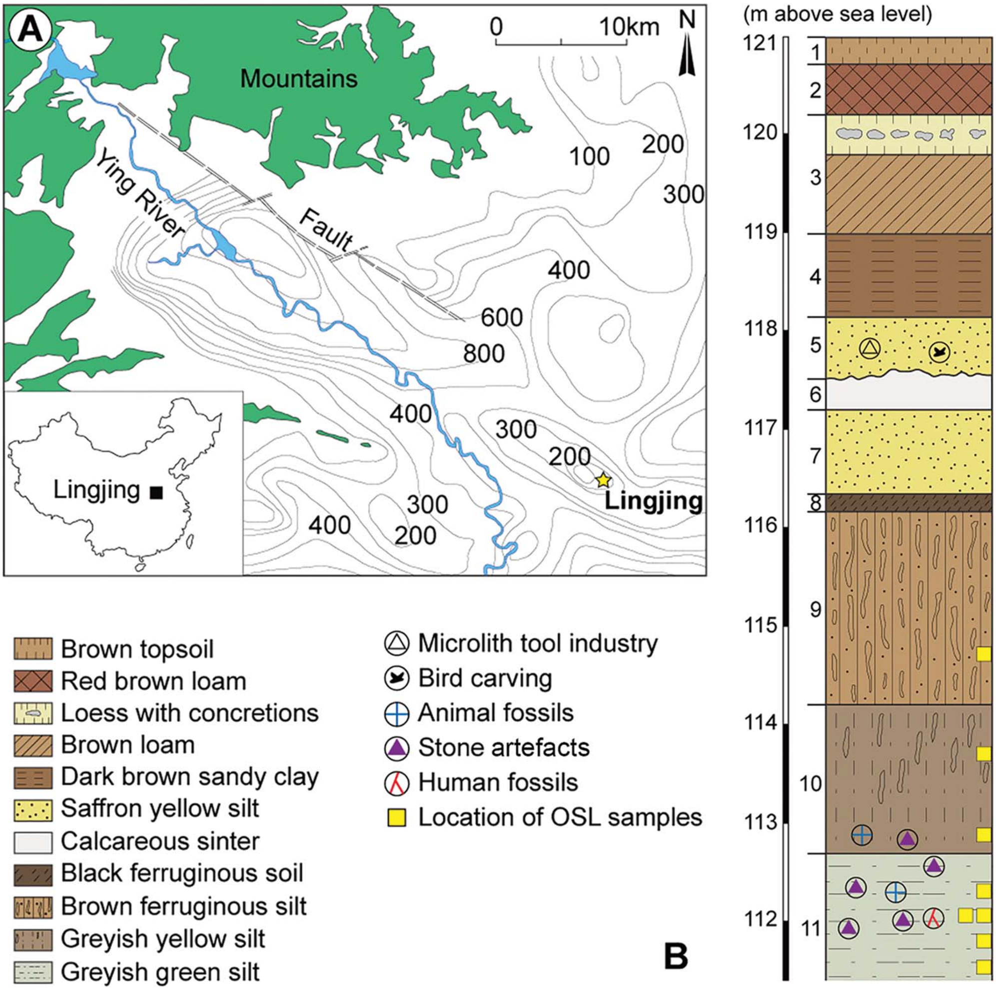

Figure 1. A) Location of Lingjing (Henan Province, China); B) stratigraphy indicating the geological and cultural layers (after Doyon et al. *2018).*

Shandong University's Institute of Measurement and Testing. The specimens were examined visually, and then photographed with Canon PowerShot 100 and Nikon D300 AF Micro Nikkor 60 mm f/2.8D cameras. Microscopic analysis was conducted using a Leica Wild M3C stereomicroscope equipped with a Nikon CoolPix 900 digital camera at magnifications ranging from 4–40×. Data on the morphology and features of the engraved lines were recorded, along with the presence of a red residue. Identification of the cause of the modifications on the bone's surface is based on criteria inferred from the experimental reproduction and subsequent microscopic analysis of sequential marks produced on bone using different tools and motions (d'Errico 1995; Fritz 1999).

A total of 227 bone fragments from the 2005–2015 excavations exhibiting few or no concretions were examined microscopically. The following variables were recorded for those

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specimens that exhibit indisputable cut marks (Noe-Nygaard 1987; Lyman 1994; Fisher 1995; Fernández-Jalvo & Andrews 2016): number, arrangement (divergent, overlapping, parallel or sub-parallel), morphology (curved, sinuous or straight), edge morphology (clean or fringed), and the occurrence of side striations, conspicuous changes in direction, surface micro-breaks and the presence of red residue.

A selected area of the engraved part of specimen 9L0141 was replicated using Coltene President regular body dental elastomer (Coltène, Switzerland). The negative replica was analysed with a Sensofar S-Neox confocal microscope driven by the SensoScan 6 software (Sensofar, Barcelona). The data was processed with SensoMap 7.3 software. Specimen 9L0141 and a sample of sediment from the cancellous bone were analysed with SEM-EDS and Raman spectroscopy. Sediment from layer 11 was analysed with ED-XRF (for details, see OSM 3).

Results

Taphonomic analysis

The surfaces of the analysed faunal remains are, when not affected by taphonomic processes or coated by concretions, exceptionally well preserved. Cut marks are the main anthropogenic modification observed on the faunal assemblage (23.79 per cent; Figure 2; OSM 4). They are present on all skeletal elements, including ribs (12.96 per cent). They show morphological traits typical of cut marks on fresh bone (Fisher 1995) and very rare changes in direction (OSM 4). Root etching affects 22.03 per cent of the analysed sample, while gnawing and etching resulting from consumption by carnivores affect 3.96 and 2.20 per cent of the sample, respectively. Other modifications include percussion marks possibly associated with marrow extraction (3.52 per cent), traces of use as retouchers (3.08 per cent) and staining produced by heat (1.32 per cent). Other than on specimen 9L0141, no red residues were detected on the 227 sampled faunal bone fragments.

Microscopic analysis

Although specimen 9L0141 is too fragmentary to propose a firm taxonomic attribution based on morphology (Figure 3), the thickness and flatness of the cortical bone and the morphology of the cancellous bone suggest that 9L0141 is the distal portion of an adult, large-sized mammal rib. The periosteal surface is pronounced and fibrous, comprising natural, alternating sub-parallel grooves and ridges (OSM 6). The four broken edges are ancient, as indicated by their colour and the slight smoothing of their surfaces under the microscope. The morphology of the broken edges and orientation indicate that they occurred on weathered bone (Villa & Mahieu 1991; Lyman 1994). Seven sub-parallel lines cross the periosteal surface (Figure 4A). The abrupt terminations of L1 and L2, and the lower terminations of L3–5 indicate that they were interrupted by the adjacent fractures (Figure 5A; OSM 6). The upper terminations of L3–5 were engraved after the piece had already fragmented (OSM 6). L6 and L7 are complete and uninterrupted. The grainy appearance of the surface of all of the lines (Figure 6), their micro-fringed outlines, and the step micro-fractures produced when incising

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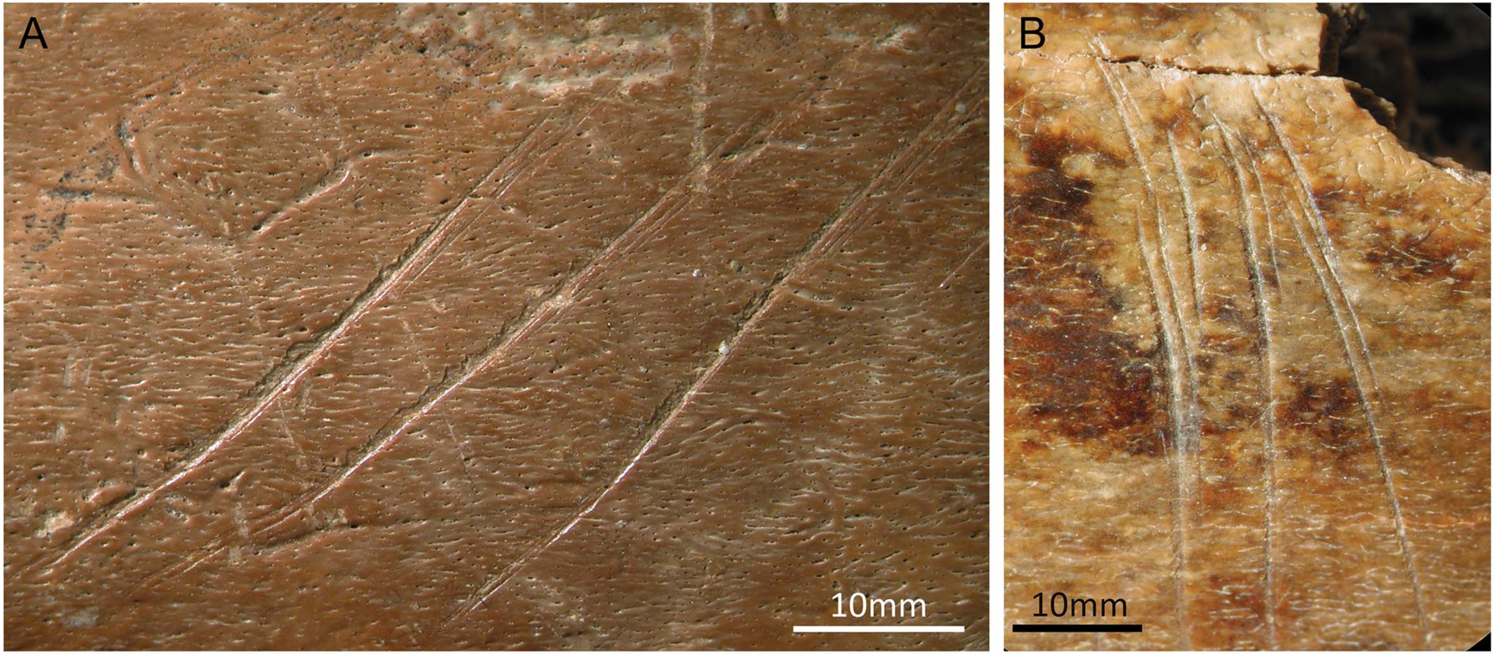

Figure 2. Well-preserved sets of cut marks on faunal remains from Lingjing, layer 11 (photographs by F. d'Errico & L. Doyon).

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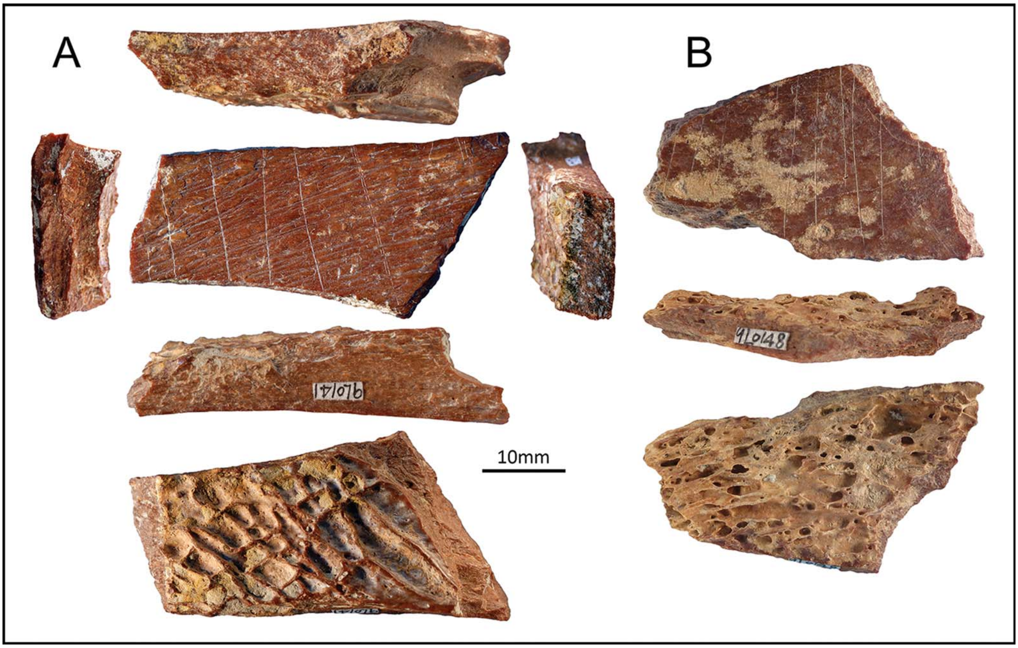

Figure 3. Photographs of the engraved specimens: A) 9L0141; B) 9L0148 (photographs by F. d'Errico & L. Doyon).

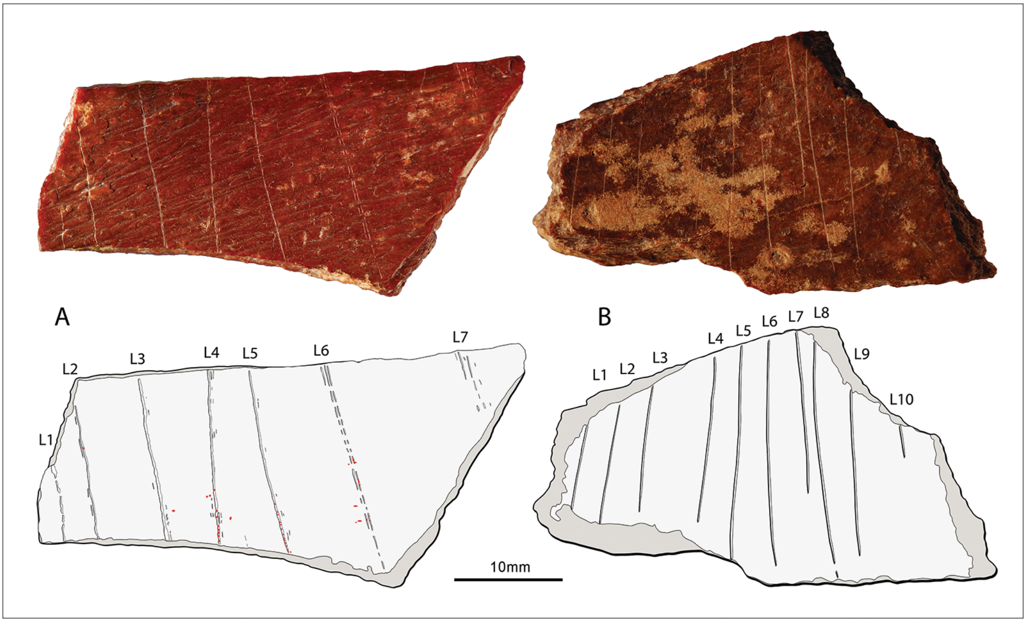

Figure 4. Photographs and tracing of the engraving on specimens: A) 9L0141 (red dots indicate the location of red residues); B) 9L0148 (photographs by F. d'Errico & L. Doyon).

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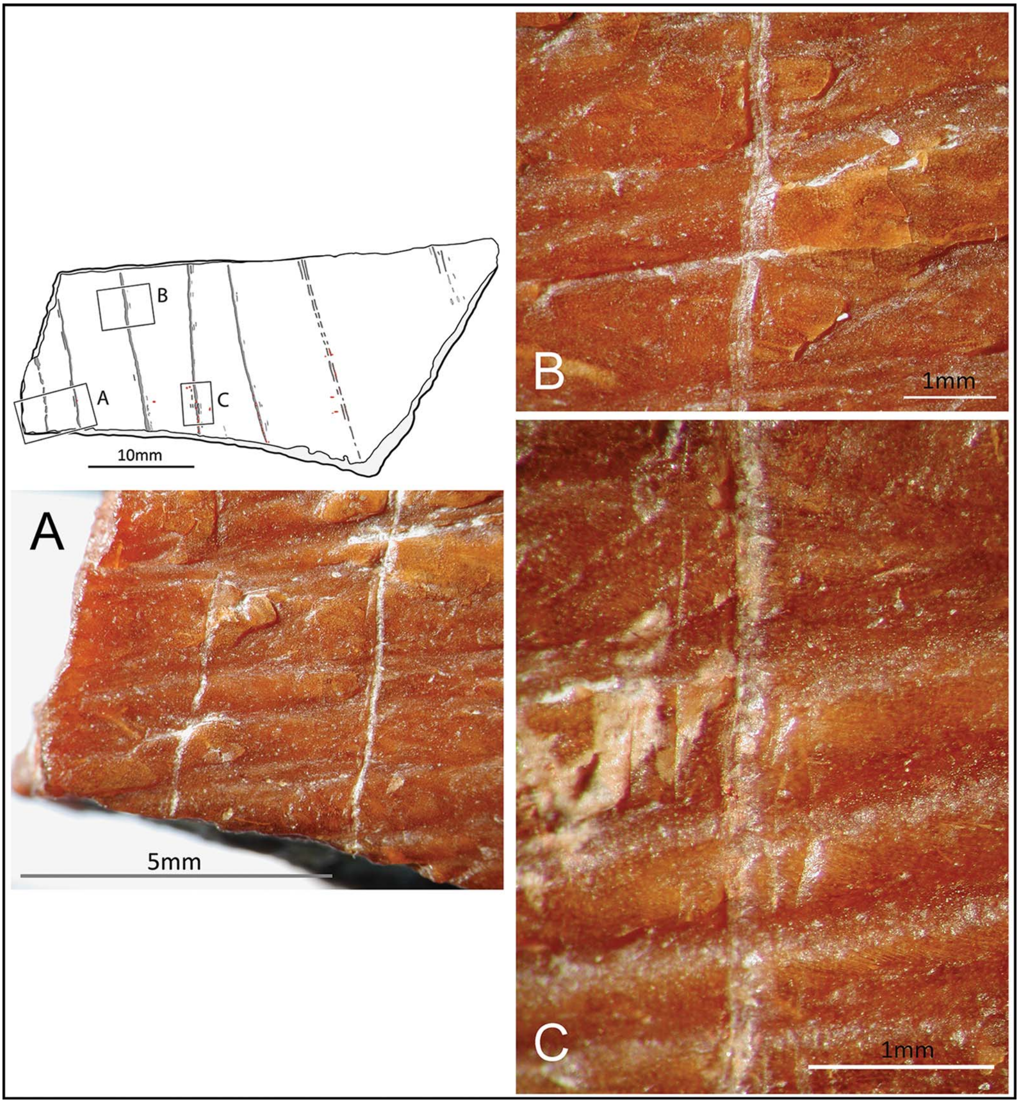

Figure 5. Microscopic photographs of engraved lines on specimen 9L0141. Changes in direction of lines crossing the fibrous structure of the bone indicate the use of a sharp point (A–B). Red residues are present inside the engraved lines (C) (photographs by F. d'Errico & L. Doyon).

through the natural ridges of the bone surface (see OSM 6), all suggest that they were engraved on weathered rather than fresh bone (OSM 5).

The depths of L1–5 remain constant when crossing the micro-grooves and ridges of the fibrous periosteal surface (Figure 5A–B), analysis of which shows that the grooves vary between 50 and 100µm in depth and between 100 and 600µm in width (OSM 6). Evidently, the tool tip was extremely sharp and no more than 50–100µm in width. The frequent, sudden changes in direction of L1–6 (Figure 5B–C) suggest instances of the momentary loss of control in the engraver's motion, due to tool speed changes when crossing the natural

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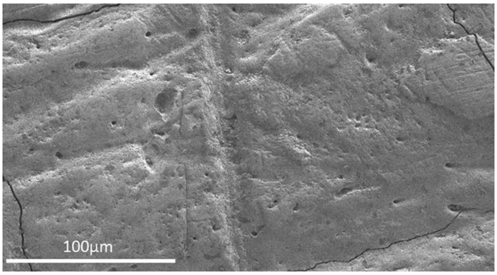

Figure 6. SEM photograph of specimen 9L0141 showing the grainy, slightly eroded appearance of L4 (photographs by H. Li, Q. Wang & Z. Zhang).

undulations of the bone's surface (d'Errico 1994, 1995). L1–5 were each engraved by a single passage of the tool. L6–7 comprise, respectively, three and five close, parallel and discontinuous striations each produced by a single passage of the point (OSM 6).

Similarities in section and width indicate that L1–2 were engraved by the same point, which created a narrow groove with a flat bottom (Figure 5A). L3–5 were also produced by the same point, which generated a wider and shallower groove with internal striations similar to each other, and side-striations on both sides of the main line. The multiple striations that comprise L6–7 were probably made by the same tool that was used to engrave L3–5, although the former is more superficial (OSM 6). The morphological differences between L1–2 and L3–7 can either be attributed to a tool change, or to the wear or breakage of the point used to engrave L1–2. The location of the micro-fractures on the periosteal ridges indicates that the lines were engraved from the longer to the shorter edge of the bone (Figure 5A; OSM 7). The sections of well-defined lines are asymmetrical to the right (see OSM 5), which, considering the motion of direction, indicates a right-handed engraver (Bosinski *et al.* 2002; d'Errico *et al.* 2018). Right-handed engravers generally create sequences of parallel lines by juxtaposing them from left to right (d'Errico 1992). This would favour the interpretation that the morphological differences between L1–2 and L3–7 are the result of wear or breakage of the engraving tool.

Specimen 9L0148 is a rib fragment from an adult, large-sized mammal (Figure 3B). The flat periosteal surface displays areas of chemical etching (whitening) (Figure 7A), removal of primary bone lamellae and parallel sets of thin striations, which are attributable to trampling. The top, bottom and left broken edges are eroded and fringed; those on the right side are fresher, suggesting that the fragment experienced at least two distinct breakage events. Ten sub-parallel lines (L1–10), produced before breakage of the rib (see OSM 5), cross the periosteal surface (Figure 4B). Their narrowness, similar internal morphology and the absence of side striations demonstrate that they were engraved using the same sharp lithic point, in a single session (Figure 7B). Slight changes in direction when crossing natural micro-fractures and taphonomically damaged areas, along with their irregular outline, suggest that the lines were engraved on weathered bone. They were cut using a quick motion towards the wider edge of the object, as indicated by the narrow terminations of L6–10.

Residue analysis

Abundant red residues were observed microscopically on specimen 9L0141 within lines L2 and L4–6, and adjacent to lines L3–6 (Figure 4A; OSM 7). The whitish sediment from layer 11, which was trapped in the specimen's cancellous bone, showed no such evidence of residue (see OSM 7). Raman analysis of the red residues from within the lines produced a composite spectrum with seven peaks at 225, 293, 411, 497, 612, 1242 and 1271cm^{-1} (see OSM 7).

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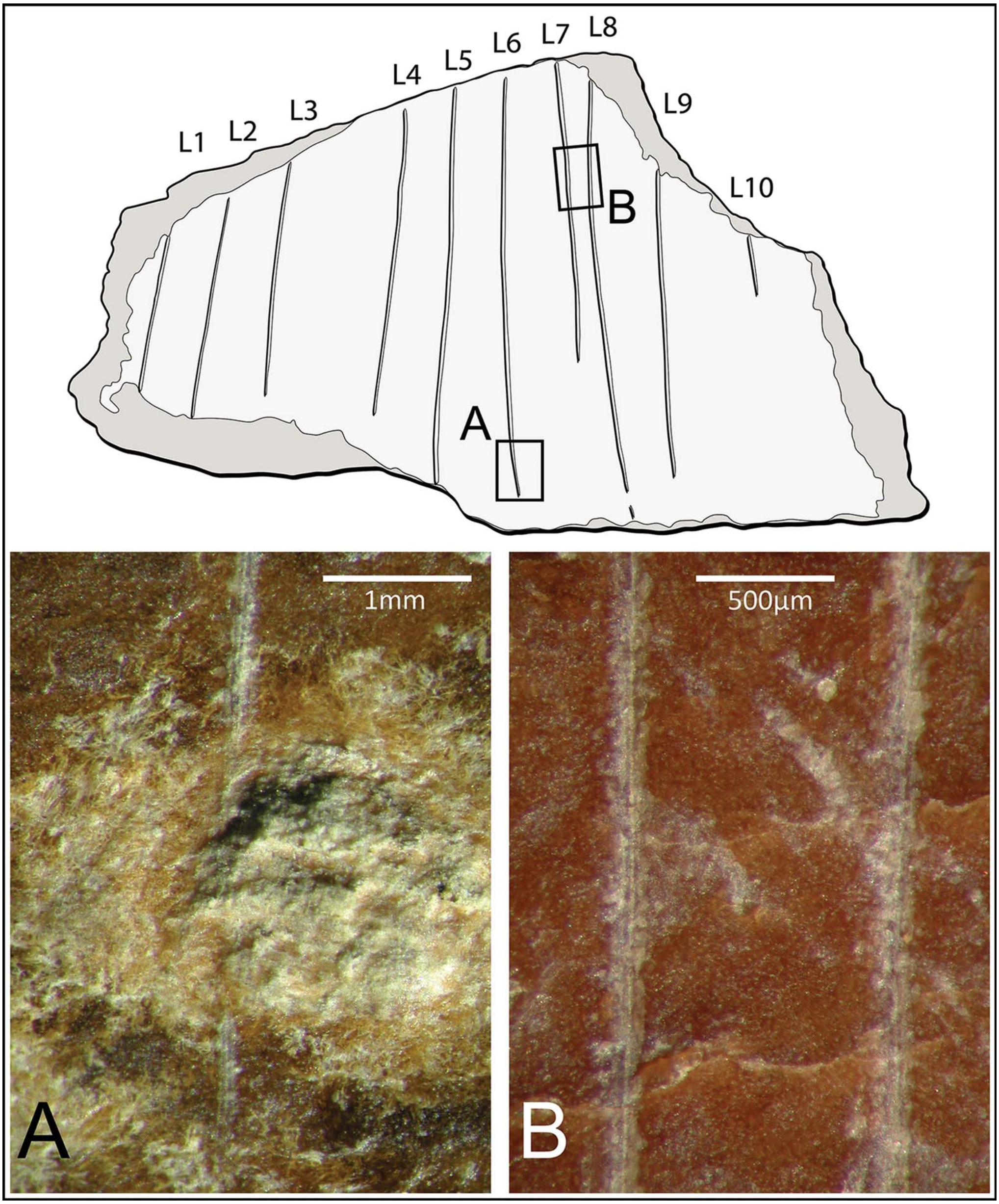

Figure 7. Close-up views of L6, L7 and L8 on specimen 9L0148: A) chemical etching affecting the bone's surface subsequent to the engraving; B) similar internal morphology indicating the use of the same tool (photographs by F. d'Errico & L. Doyon).

The five peak values in the low frequencies identify the residue as haematite (de Faria *et al.* 1997). Raman analysis of the sediment from the cancellous bone identified only quartz and a single instance of a particle containing haematite (see OSM 7). SEM-EDS analysis reveals that the sediment comprises particles ranging from 20–200µm in size, and is mainly composed of mica—either muscovite or biotite—embedded in a clay matrix, which also contains

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small quantities of iron (Fe), magnesium (Mg) and calcium (Ca). Single instances of quartz grain, zircon, bone fragment and an iron-rich particle are also detected (see OSM 7). ED-XRF analysis of sediment from layer 11 confirms that silicon (Si) is the predominant chemical element, followed by aluminium (Al) and potassium (K); iron (Fe) accounts only for 2.4–2.6 per cent (see OSM 7).

Discussion and conclusion

The lines on bone specimens 9L0141 and 9L0148 cannot result from excavation, cleaning or curation of the faunal assemblage. They differ in a number of respects from the lines exhibited on cut-marked bones from within layer 11. Cut marks on the latter generally display microscopic features consistent with cuts made on fresh bone. Generally, sets of close cut marks made in rapid succession on fresh bone by the same cutting edge rarely exceed four cuts, and they usually slightly diverge from a focal point, keeping a similar outline. In contrast, the lines on the two specimens—particularly on 9L0141—were made on partially weathered fragments; several lines on this specimen were engraved when the bone was already fragmented. The lines on 9L0141 were produced by an extremely sharp point, and the prehistoric individual was particularly careful when engraving the first five lines, given the rugged topography of the periosteal surface. To increase the visibility of the subsequent lines (L6–7), the engraver marked them using multiple strokes. Combined, this evidence does not support an interpretation of the lines as evidence of butchery activity on 9L0141, but rather, deliberate engraving of the bone. Although less striking, the lines on 9L0148 still differ from fresh cut marks on faunal remains from the same layer in their number, morphology and in the tool used to produce them. Furthermore, damage to some of the lines by chemical alteration of the periosteal surface indicates that they are of ancient origin, attributable to neither excavation nor curation.

The numerous haematite-rich residues identified within four lines on 9L0141 and the virtual absence of iron-rich particles in the clay sediment of layer 11 is puzzling. Considering the chemical composition of layer 11, one would have expected to find white residue composed of clay and micas at the bottom of the engraved lines. The absence of white sediment and the presence instead of haematite-rich deposits in the lines and nearby recessed areas could be explained by the smearing of ochre powder on the bone surface to highlight the engraved pattern and increase its visibility—a common practice in Upper Palaeolithic mobiliary art (Buisson *et al.* 1989; García *et al.* 2016). The use of ochre to modify the appearance of personal ornaments is attested at 80 ka BP from Middle Stone Age Moroccan sites, such as Taforalt, Rhafas and Ifri n'Ammar (d'Errico *et al.* 2009). The earliest evidence for the use of ochre in China comes from Zhoukoudian Upper Cave and Shuidonggou localities 2 and 8, in the form of modified ochre lumps and ornaments coloured with ochre (Pitarch Martí *et al.* 2017).

A growing body of evidence from Europe and Southeast Asia (Table 1; OSM 1) supports the hypothesis that the cultural adaptations of archaic hominins involved symbolically mediated behaviour, thereby challenging the notion that modern cognitive abilities are restricted to *Homo sapiens*. While many scholars now agree on this hypothesis with regard to Neanderthals, the present article offers the first evidence to suggest that the same may

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also apply to Denisovans—the probable creators of the engravings described here. The Lingjing engravings represent the first possible example of such behaviour in Eastern Asia to predate 40 kya. Results were obtained by combining contextual and taphonomic data, with detailed analyses of the objects. The deliberate nature of the markings on 9L0141—and probably on 9L0148—as well as the application of ochre on the former appear to confirm the intentional character of these practices, and is fully consistent with the hypothesis that meaning may have been attributed to the patterns, to the moment in which the action took place, or to the action itself.

We are still far from understanding the meaning of these engravings for the archaic human groups living in China during the early Late Pleistocene. Doyon *et al.*'s (2018, 2019) recent identification of bone and antler fragments from layer 11 at Lingjing that were used to retouch lithics demonstrates that the Lingjing hominins were familiar with the mechanical properties of weathered bone and considered it to be a suitable raw material for producing artefacts. The Lingjing engravings suggest that these populations also saw bone as a medium on which they could permanently record sequential markings and use ochre as a substance to help highlight them. Future research may identify spatiotemporal consistencies that could offer clues to help in fully evaluating the significance of these behaviours.

Supplementary material

To view supplementary material for this article, please visit https://doi.org/10.15184/aqy.2019.81

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References

Bednarik, R.G. 1994. The Pleistocene art of Asia. *Journal of World Prehistory* 8: 351–75. https://doi.org/10.1007/BF02221090

Bednarik, R.G. & Y. You. 1991. Palaeolithic art from China. *Rock Art Research* 8: 119–23.

Benazzi, S., K. Douka, C. Fornai, C.C. Bauer, O. Kullmer, J. Svoboda, I. Pap, F. Mallegni, P. Bayle, M. Coquerelle, S. Condemi, A. Ronchitelli, K. Harvati & G.W. Weber. 2011. Early dispersal of modern humans in Europe and implications for Neanderthal behaviour. *Nature* 479: 525–28. https://doi.org/10.1038/nature10617

Bosinski, G., F. d'Errico & P. Schiller. 2002. *Die gravierten Frauendarstellungen von Gönnersdorf*. Stuttgart: Franz Steiner.

Bruner, E. 2014. Functional craniology, human evolution, and anatomical constraints in the

Neanderthal braincase, in T. Akazawa, N. Ogihara, H.C. Tanabe & H. Terashima (ed.) *Dynamics of learning in Neanderthals and modern humans, volume 2*: 121–29. Tokyo: Springer. https://doi.org/10.1007/978-4-431-54553-8_13

Buisson, D., M. Menu, G. Pinçon & P. Walter. 1989. Les objets colorés du Paléolithique supérieur: cas de la grotte de La Vache (Ariège). *Bulletin de la Société préhistorique française* 86: 183–91.

Chen, T., R.E.M. Hedges & Z. Yuan. 1992. New AMS ^{14}C dating on Upper Cave and relative issues. *Acta Anthropologica Sinica* 11: 112–15.

d'Errico, F. 1992. Technology, motion, and the meaning of Epipaleolithic art. *Current Anthropology* 33: 94–109. https://doi.org/10.1086/204039

– 1994. *L'art gravé azilien: de la technique à la signification*. Paris: CNRS Éditions.

– 1995. Image analysis and 3-D optical surface profiling of Upper Palaeolithic mobiliary art. *Microscopy and analysis* 51: 27–29.

d'Errico, F. & C.B. Stringer. 2011. Evolution, revolution or saltation scenario for the emergence of modern cultures? *Philosophical Transactions of the Royal Society B: Biological Sciences* 366: 1060–69. https://doi.org/10.1098/rstb.2010.0340

d'Errico, F., M. Vanhaeren, N. Barton, A. Bouzouggar, H. Mienis, D. Richter, J.-J. Hublin, S.P. McPherron & P. Lozouet. 2009. Additional evidence on the use of personal ornaments in the Middle Paleolithic of North Africa. *Proceedings of the National Academy of Sciences of the USA* 106: 16051–56. https://doi.org/10.1073/pnas.0903532106

d'Errico, F., R.G. Moreno & R.F. Rifkin. 2012. Technological, elemental and colorimetric analysis of an engraved ochre fragment from the Middle Stone Age levels of Klasies River Cave 1, South Africa. *Journal of Archaeological Science* 39: 942–52. https://doi.org/10.1016/j.jas.2011.10.032

d'Errico, F., L. Doyon, I. Colagé, A. Queffelec, E. Le Vraux, G. Giacobini, B. Vandermeersch & B. Maureille. 2018. From number sense to number symbols: an archaeological perspective. *Philosophical Transactions of the Royal Society B: Biological Sciences* 373: 20160518. https://doi.org/10.1098/rstb.2016.0518

de Boer, B. 2012. Loss of air sacs improved hominin speech abilities. *Journal of Human Evolution* 62: 1–6. https://doi.org/10.1016/j.jhevol.2011.07.007

de Faria, D.L.A., S. Venâncio Silva & M.T. de Oliveira. 1997. Raman microspectroscopy of some iron oxides and oxyhydroxides. *Journal of Raman Spectroscopy* 28: 873–78. https://doi.org/10.1002/(SICI)1097-4555(199711)28:11<873::AID-JRS177>3.0.CO;2-B

Doyon, L., Z. Li, H. Li & F. d'Errico. 2018. Discovery of *circa* 115 000-year-old bone retouchers at Lingjing, Henan, China. *PLoS ONE* 13: e0194318. https://doi.org/10.1371/journal.pone.0194318

Doyon, L., H. Li, Z. Li, H. Wang & Q. Zhao. 2019. Further evidence of organic soft hammer percussion and pressure retouch from Lingjing (Xuchang, Henan, China). *Lithic Technology* 44: 100–17. https://doi.org/10.1080/01977261.2019.1589926

Fernández-Jalvo, Y. & P. Andrews. 2016. *Atlas of taphonomic identifications*. New York: Springer. https://doi.org/10.1007/978-94-017-7432-1

Finlayson, C., K. Brown, R. Blasco, J. Rosell, J.J. Negro, G.R. Bortolotti, G. Finlayson, A. Sánchez Marco, F. Giles Pacheco, J. Rodríguez Vidal, J.S. Carrión, D.A. Fa & J.M. Rodríguez Llanes. 2012. Birds of a feather: Neanderthal exploitation of raptors and corvids. *PLoS ONE* 7: e45927. https://doi.org/10.1371/journal.pone.0045927

Fisher, J.W. 1995. Bone surface modifications in zooarchaeology. *Journal of Archaeological Method and Theory* 2: 7–68. https://doi.org/10.1007/BF02228434

Fritz, C. 1999. Towards the reconstruction of Magdalenian artistic techniques: the contribution of microscopic analysis of mobiliary art. *Cambridge Archaeological Journal* 9: 189–208. https://doi.org/10.1017/S0959774300015377

García, C.R., V.V. Bonilla, I.R. Marín & S.M. Mascarós. 2016. A unique collection of Palaeolithic painted portable art: characterization of red and yellow pigments from the Parpalló Cave (Spain). *PLoS ONE* 11: e0163565. https://doi.org/10.1371/journal.pone.0163565

Grün, R., J.S. Brink, N.A. Spooner, L. Taylor, C.B. Stringer, R.G. Franciscus & A.S. Murray. 1996. Direct dating of Florisbad hominid. *Nature* 382: 500–501. https://doi.org/10.1038/382500a0

Gunz, P., S. Neubauer, B. Maureille & J.-J. Hublin. 2010. Brain development after

https://doi.org/10.15184/aqy.2019.81 Published online by Cambridge University Press

birth differs between Neanderthals and modern humans. *Current Biology* 20: 921–22. https://doi.org/10.1016/j.cub.2010.10.018

Haynes, G. 1991. *Mammoths, mastodonts, and elephants: biology, behavior and the fossil record*. Cambridge: Cambridge University Press.

Henshilwood, C.S., F. d'Errico & I. Watts. 2009. Engraved ochres from the Middle Stone Age levels at Blombos Cave, South Africa. *Journal of Human Evolution* 57: 27–47. https://doi.org/10.1016/j.jhevol.2009.01.005

Hoffmann, D.L., C.D. Standish, M. García-Diez, P.B. Pettitt, J.A. Milton, J. Zilhão, J.J. Alcolea-González, P. Cantalejo-Duarte, H. Collado, R. de Balbín, M. Lorblanchet, J. Ramos-Muñoz, G.-C. Weniger & A.W.G. Pike. 2018. U-Th dating of carbonate crusts reveals Neandertal origin of Iberian cave art. *Science* 359: 912–15. https://doi.org/10.1126/science.aap7778

Hovers, E. & A. Belfer-Cohen. 2006. 'Now you see it, now you don't': modern human behavior in the Middle Paleolithic, in E. Hovers & S.L. Kuhn (ed.) *Transitions before the transition*: 295–304. Boston (MA): Springer.

Hublin, J.-J., A. Ben-Ncer, S.E. Bailey, S.E. Freidline, S. Neubauer, M.M. Skinner, I. Bergmann, A. Le Cabec, S. Benazzi, K. Harvati & P. Gunz. 2017. New fossils from Jebel Irhoud, Morocco and the pan-African origin of *Homo sapiens*. *Nature* 546: 289–92. https://doi.org/10.1038/nature22336

Junker, T. 2010. Art as a biological adaptation, or: why modern humans replaced the Neanderthals. *Quartär* 57: 171–78.

Li, H., Z. Li, X. Gao, K. Kuman & A. Sumner. 2019. Technological behavior of the early Late Pleistocene archaic humans at Lingjing (Xuchang, China). *Archaeological and Anthropological Science*. https://doi.org/10.1007/s12520-018-0759-7

Li, Z. 2007. A primary study on the stone artifacts of Lingjing site excavated in 2005. *Acta Anthropologica Sinica* 26: 138–54.

Li, Z. & W. Dong. 2007. Mammalian fauna from the Lingjing Paleolithic site in Xuchang, Henan Province. *Acta Anthropologica Sinica* 26: 345–60.

Li, Z., X. Wu, L. Zhou, W. Liu, X. Gao, X. Nian & E. Trinkaus. 2017. Late Pleistocene archaic human crania from Xuchang, China. *Science* 355: 969–72. https://doi.org/10.1126/science.aal2482

Lieberman, P. 2007. The evolution of human speech: its anatomical and neural bases. *Current Anthropology* 48: 39–66. https://doi.org/10.1086/509092

Lyman, R.L. 1994. *Vertebrate taphonomy*. New York: Cambridge University Press. https://doi.org/10.1017/CBO9781139878302

Martinón-Torres, M., X. Wu, J.M. Bermúdez de Castro, S. Xing & W. Liu. 2017. *Homo sapiens* in the Eastern Asian Late Pleistocene. *Current Anthropology* 58(S17): 434–48. https://doi.org/10.1086/694449

Mellars, P. 2010. Neanderthal symbolism and ornament manufacture: the bursting of a bubble? *Proceedings of the National Academy of Sciences of the USA* 107: 20147–48. https://doi.org/10.1073/pnas.1014588107

Müller, W. & C. Pasda. 2011. Site formation and faunal remains of the Middle Pleistocene site Bilzingsleben. *Quartär* 58: 25–49.

Neubauer, S. 2015. Human brain evolution: ontogeny and phylogeny, in E. Bruner (ed.) *Human paleoneurology*: 95–120. Cham: Springer.

Nian, X.M., L.P. Zhou & J.T. Qin. 2009. Comparisons of equivalent dose values obtained with different protocols using a lacustrine sediment sample from Xuchang, China. *Radiation Measurements* 44: 512–16. https://doi.org/10.1016/j.radmeas.2009.06.002

Noe-Nygaard, N. 1987. Taphonomy in archaeology with special emphasis on man as a biasing factor. *Journal of Danish Archaeology* 6: 7–62. https://doi.org/10.1080/0108464X.1987.10589975

Norton, C.J. & J.J.H. Jin. 2009. The evolution of modern human behavior in East Asia: current perspectives. *Evolutionary Anthropology* 18: 247–60. https://doi.org/10.1002/evan.20235

Nowell, A. 2010. Defining behavioral modernity in the context of Neandertal and anatomically modern human populations. *Annual Review of Anthropology* 39: 437–52. https://doi.org/10.1146/annurev.anthro.012809.105113

Pearce, E., C. Stringer & R.I.M. Dunbar. 2013. New insights into differences in brain organization between Neanderthals and anatomically modern humans. *Proceedings of the Royal Society of London B: Biological Sciences* 280: 20130168. https://doi.org/10.1098/rspb.2013.0168

Pei, W.C. 1934. A preliminary report on the Late Palaeolithic cave of Choukoutien. *Acta Geologica Sinica* 13: 327–58.

Peng, F., X. Gao, H. Wang, F. Chen, D. Liu & S. Pei. 2012. An engraved artifact from Shuidonggou, an early Late Paleolithic site in northwest China. *Chinese Science Bulletin* 57: 4594–99. https://doi.org/10.1007/s11434-012-5317-6

Peresani, M., I. Fiore, M. Gala, M. Romandini & A. Tagliacozzo. 2011. Late Neandertals and the intentional removal of feathers as evidenced from bird bone taphonomy at Fumane Cave 44 ky B.P., Italy. *Proceedings of the National Academy of Sciences of the USA* 108: 3888–93. https://doi.org/10.1073/pnas.1016212108

Pettitt, P. 2002. The Neanderthal dead: exploring mortuary variability in Middle Palaeolithic Eurasia. *Before Farming* 2002(4): 1–26. https://doi.org/10.3828/bfarm.2002.1.4

Pitarch Martí, A., Y. Wei, X. Gao, F. Chen & F. d'Errico. 2017. The earliest evidence of coloured ornaments in China: the ochred ostrich eggshell beads from Shuidonggou Locality 2. *Journal of Anthropological Archaeology* 48: 102–13. https://doi.org/10.1016/j.jaa.2017.07.002

Radovčić, D., A.O. Sršen, J. Radovčić & D.W. Frayer. 2015. Evidence for Neandertal jewellery: modified white-tailed eagle claws at Krapina. *PLoS ONE* 10: e0119802. https://doi.org/10.1371/journal.pone.0119802

Rodríguez-Vidal, J. *et al.* 2014. A rock engraving made by Neanderthals in Gibraltar. *Proceedings of the National Academy of Sciences of the USA* 111: 13301–306. https://doi.org/10.1073/pnas.1411529111

Romandini, M., M. Peresani, V. Laroulandie, L. Metz, A. Pastoors, M. Vaquero & L. Slimak. 2014. Convergent evidence of eagle talons used by late Neanderthals in Europe: a further assessment on symbolism. *PLoS ONE* 9: e101278. https://doi.org/10.1371/journal.pone.0101278

Spoor, F., J.-J. Hublin, M. Braun & F. Zonneveld. 2003. The bony labyrinth of Neanderthals. *Journal of Human Evolution* 44: 141–65. https://doi.org/10.1016/S0047-2484(02)00166-5

Stringer, C. 2016. The origin and evolution of *Homo sapiens*. *Philosophical Transactions of the Royal Society B: Biological Sciences* 371: 20150237. https://doi.org/10.1098/rstb.2015.0237

Villa, P. & F. d'Errico. 2001. Bone and ivory points in the Lower and Middle Paleolithic of Europe. *Journal of Human Evolution* 41: 69–112. https://doi.org/10.1006/jhev.2001.0479

Villa, P. & E. Mahieu. 1991. Breakage patterns of human long bones. *Journal of Human Evolution* 21: 27–48. https://doi.org/10.1016/0047-2484(91)90034-S

Villa, P. & W. Roebroeks. 2014. Neandertal demise: an archaeological analysis of the modern human superiority complex. *PLoS ONE* 9: e96424. https://doi.org/10.1371/journal.pone.0096424

Vincent, A. 1988. L'os comme artefact au Paléolithique moyen: principes d'étude et premiers résultats, in M. Otte, L. Binford & J.P. Rigaud (ed.) *L'homme de Néandertal 4, la technique*: 185–96. Liège: ERAUL.

Watts, I. 2010. The pigments from Pinnacle Point Cave 13B, Western Cape, South Africa. *Journal of Human Evolution* 59: 392–411. https://doi.org/10.1016/j.jhevol.2010.07.006

You, Y.Z. 1984. Preliminary study of a Palaeolithic bone engraving. *Kexue Tongbao* 29: 80–82.

Zhang, S., Z. Li, Y. Zhang & X. Gao. 2012. Skeletal element distributions of the large herbivores from the Lingjing site, Henan Province, China. *Science China: Earth Sciences* 55: 246–53. https://doi.org/10.1007/s11430-011-4279-x

Zilhão, J. 2011. Aliens from outer time? Why the 'human revolution' is wrong, and where do we go from here?, in S. Condemi & G.-C. Weniger (ed.) *Continuity and discontinuity in the peopling of Europe*: 331–66. Dordrecht: Springer.

Zilhão, J. *et al.* 2010. Symbolic use of marine shells and mineral pigments by Iberian Neandertals. *Proceedings of the National Academy of Sciences of the USA* 107: 1023–28. https://doi.org/10.1073/pnas.0914088107

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