A Paleolithic bird figurine from the Lingjing site, Henan, China

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Abstract

The recent identification of cave paintings dated to 42–40 ka BP in Borneo and Sulawesi highlights the antiquity of painted representations in this region. However, no instances of three-dimensional portable art, well attested in Europe since at least 40 ka BP, were documented thus far in East Asia prior to the Neolithic. Here, we report the discovery of an exceptionally well-preserved miniature carving of a standing bird from the site of Lingjing, Henan, China. Microscopic and microtomographic analyses of the figurine and the study of bone fragments from the same context reveal the object was made of bone blackened by heating and carefully carved with four techniques that left diagnostic traces on the entire surface of the object. Critical analysis of the site’s research history and stratigraphy, the cultural remains associated with the figurine and those recovered from the other archaeological layers, as well as twenty-eight radiometric ages obtained on associated archeological items, including one provided by a bone fragment worked with the same technique recorded on the object, suggest a Late Paleolithic origin for the carving, with a probable age estimated to 13,500 years old. The carving, which predates previously known comparable instances from this region by 8,500 years, demonstrates that three-dimensional avian representations were part of East Asian Late Pleistocene cultural repertoires and identifies technological and stylistic peculiarities distinguishing this newly discovered art tradition from previous and contemporary examples found in Western Europe and Siberia.

Introduction

Our knowledge about the origins of symbolically mediated behaviors has substantially increased over the last twenty years. The idea of a symbolic explosion occurring in Europe 40,000 years ago [1–3], associated with the arrival of anatomically modern human populations...
in the region, has given way to a complex gradualist scenario [4–7]. Multiple evidence now demonstrates that behaviors generally associated with symbolic thought, such as producing abstract drawings and engravings, using pigments, wearing personal ornaments and performing complex mortuary practices, are three to ten times older than what was acknowledged two decades ago. It is also becoming clear that these practices emerged gradually among both African Middle Stone Age populations and the so-called archaic populations living in Europe and Asia [8–16]. Figurative representations were considered until recently the only symbolic manifestation for which Europe could claim precedence. This view was challenged in the last few years by the dating of 42,000-year-old calcite deposits covering animal, human, and hand stencils depictions at sites from Southeast Asia [17–19]. Furthermore, the modern human authorship of all Paleolithic paintings has likewise been questioned with the dating of calcite deposits covering hand stencils and painted signs from three Iberian caves, suggesting that these representations were made some 63,000 years ago, a time at which only Neanderthal populations were living in Europe [20]. Although repeatedly disputed [21–24], these dates were produced with the same methods applied to establish the age of the earliest Southeast Asian cave paintings [25] and were obtained following strict protocols, which apparently duly considered possible sources of error [26–28]. The carving of small figurines is, for the time being, the only artistic practice that may have originated in Europe and that could represent an innovation created by anatomically modern populations colonizing this region. The earliest known carvings consist of animal and human figurines sculpted in mammoth ivory, and were found at sites from the Swabian Jura, Germany, in layers containing Early Aurignacian artifacts and dated to circa 40–38 ka [29,30]. For vast regions of the world, however, it remains unclear when the production of three-dimensional representations became a part of the cultural repertoire of prehistoric groups, and whether this happened independently or through diffusion from a point of origin.

Here we report the discovery of a diminutive carving, depicting a standing bird, found at the Paleolithic site of Lingjing, Henan, China. Careful consideration of the site’s research history and stratigraphy, of the cultural remains it yielded in association with the figurine and from other archeological layers, as well as of the numerous radiometric ages obtained from the associated archeological items argues in favor of a Late Paleolithic origin for the carving, with a probable age of 13,500 years. The exceptional state of preservation of the figurine, unmatched by comparable Paleolithic carvings, and the application of state-of-the-art methodology to its study allowed us to reconstruct in detail the technology and evaluate the skills that led to its manufacture. Our results highlight peculiar features that make this carving the first known instance of an original artistic tradition, i.e., a body of technical, thematic, and stylistic traits applied to the production of symbolic artifacts shared by a society and transmitted to new generations of artists [31].

Archeological context and dating

Lingjing is an open-air site located in Henan, 120 km south of the Yellow River (Fig 1a). This water-lain deposit was discovered in 1965 [32,33] and excavated yearly from 2005 to 2018 under the direction of one of us (LZ). The excavation, extending over a surface of 551 m², identified eleven layers, numbered from 1 at the top to 11 at the bottom, within a 9 m deep sedimentary sequence (Fig 1b). Seven layers contain archeological remains. The uppermost layers 1–4 are Holocene in age; they were identified over the entire excavated surface but were associated with archeological material only along the northern edge of the site, i.e., >50 meters north of the area where layer 5 was identified in the stratigraphy. Layers 1–4 yielded a few dozen isolated, fine pottery sherds that could not be refitted with one another. Their outer
surface bears decor that allow their cultural attribution to periods spanning from the Yangshao Neolithic (~6.5–5 ka BP) to the Shang-Zhou Bronze Age (~4–2.5 ka BP). Neither stone tools nor faunal remains were recovered from these layers. Layer 5 and sediments originating from it (see below) included artifacts reflecting an occupation spanning from the LGM to the Younger Dryas. Layers 6 to 9 are sterile. Layers 10 and 11, attributed to the early Late Pleistocene, were dated by OSL between 99 ka and 118 ka [34]. Both layers yielded lithic artifacts and faunal remains [35]. Two incomplete human skulls were also found in layer 11. They bear a mosaic of morphological features interpreted as indicating both regional continuity and inter-regional population dynamics [33,36]. Analysis of faunal remains from layer 11 identified the earliest known evidence for pressure flaking [37], the first bone retouchers from East Asia [38], and the use of metapodials as organic soft hammer for marrow extraction [39]. Two weathered bone fragments bearing parallel engraved lines and traces of ocher were also found in this layer [15].

When one of us (LZ) excavated the site in 2005, he found that most of layer 5 had been removed by well diggers in 1958 and that only a small portion of this layer was still present in the stratigraphic profile near the southern limit of trench T1. The layers overlaying the remnants of layer 5 were completely sterile in this area. The excavation of the intact portion of layer 5 yielded a small amount of quartz tools, high quality black chert microliths, and pottery sherds. During the 2008 and 2013 excavation campaigns, the spoil heap left by the well diggers in 1958 was identified less than 10 m away from the water cistern built over the spring opening, which is located near the southern edge of the excavated area. Water sieving of these sediments produced a rich microcore and microblade industry made of high-quality black chert, a raw material only found in layer 5, few pottery sherds, burnt and unburnt faunal remains, charcoal, ostrich egg shell fragments, a perforated ostrich egg shell pendant (Figs 2 and 3), and the bird figurine described in the present study. The pottery sherds found in the intact
Fig 2. Archaeological remains associated with the bird carving. (A) Selection of microblade cores. (B) Retouched tools including scrapers, burins and points. (C) End-scrapers. (D) Ostrich egg shell pendant. (E) High quality black chert flake from layer 5. Scales = 1 cm.

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Fig 3. Burnt bone fragments associated with the bird carving. (A) Fragment dated by $^{14}$C bearing traces of gouging (close up at the right) comparable to those recorded on the carving. (B-T) Other fragments, some of which bearing traces of modification (see Table 2 for details). Scale = 1 cm.

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remnants of layer 5 and in the spoil heap differ greatly from those recovered from Holocene contexts i.e., layers 1–4. They are thick, crude, simple in shape, with plain surfaces, very fragile, and fired at low temperatures [40,41]. The lithic assemblage from layer 5 is dominated by pyramidal type microblade cores, followed by boat-shaped and wedge-shaped cores [41–43]. Retouched tools include in decreasing order short end-scrapers, scrapers, and burins. Analysis of this assemblage identified consistencies in raw material use (Fig 2e), technology and typology supporting the syndepositional nature of the assemblage and striking similarities with Late Glacial industries from Northern China [40–43]. Aside from the few ostrich eggshell fragments, the faunal assemblage found in association with the figurine contains 215 remains consisting of 80 unidentifiable, blackened bone fragments, a quarter of which was radiocarbon dated (see below), as well as 135 fragmentary equids and bovids molars.

Burnt bones, charcoals and charred residues from the pottery sherds recovered in the spoil heap in which the bird carving was found were radiocarbon dated (Fig 1c, Table 1) at three dating laboratories: the Institute of Accelerator Analysis Ltd., Kawasaki City, Kanagawa, Japan (IAAA), the University of Tokyo Radiocarbon Laboratory (TKa), and the Beijing University Radiocarbon Laboratory (MTC), China [40–43]. The thirty-six available ages, three of which obtained in the framework of this study (see below), were calibrated with the OxCal 4.3.2 online software [44] using the IntCal13 atmospheric calibration curve [45]. With the exception of a single old age obtained from a charcoal sample (IAAA-100080: 28,690 ± 120 14C years), not included in Fig 1c, two distinct sets of ages are identified by the dated material. The first set, which includes all ages obtained on burnt bone and charcoal, ranges between ~13.8 and ~13.0 ka cal BP. Considering the age of Northern Chinese sites with comparable microblade assemblages, this set covers the time span for the occupation of the site by Late Glacial hunter-gatherers bearing microlithic technologies. The ages of the second set, all obtained from charred residues present on pottery sherds, range from ~12.1 to ~8.6 ka cal BP. This last set probably reflects two successive occupations by ceramics users, centered around 10.3 ka cal BP and 9.2 ka cal BP [40].

In order to estimate the age of the bird figurine, three new burnt bone samples, one of which bearing evidence of gouging, an anthropogenic modification observed on the bird carving (see below), were sent to the Beta Analytic Testing Laboratory, Miami (FL, USA). All of them were analyzed following the ISO/IEC 17025:2005 Testing Accreditation PJLA #59423 protocols. Charred bone pretreatment with alkali allowed for the extraction of collagen. All work was done at Beta facilities in four in-house NEC accelerator mass spectrometers and four Termo IRMSs. The “Conventional Radiocarbon Age”, calculated using the Libby half-life i.e., 5,568 years, was corrected for total isotopic fraction, and was used for calendar calibration. Conventional Radiocarbon Ages and sigma were rounded to the nearest 10 years and are reported as radiocarbon years before present, i.e., before 1950. When counting statistics produced sigma lower than 30 years, a conservative ±30 BP was cited for the results. δ13C values were obtained on the material itself, not on the AMS δ13C.

The three burnt bone samples selected for radiocarbon dating yielded sufficient amount of collagen within the expected value required for passing the quality assurance tests. All three ages fall within the first cluster previously identified and range between 13.4 and 13.1 ka cal BP (Fig 1c, Table 1). The age of the bone bearing a deep notch produced by gouging is 11,520 ± 40 (Beta-515953), which corresponds to an age of 13,448–13,279 cal BP (95.4%). It is noteworthy that twenty-one of the twenty-eight (75%) 14C ages from the first set statistically overlap (95%) the age obtained on the modified bone (Fig 1c). The coherent results obtained for the ages of bone and charcoal samples indicate that both the faunal remains and the fire fuel, i.e., the charcoals, are of the same age, which rules out the possibility that the craftsman would have selected a sub-fossil fragment to burn and to carve the figurine [46].
| Lab ID   | Material | 14C age | Error | Calibrated date (1σ) | Calibrated date (2σ) | References |
|---------|----------|---------|-------|----------------------|----------------------|------------|
|         |          |         |       | From | To | Probability | From | To | Probability |
| Beta-515951 BB 11290 30 13165 13090 68.2% 13211 13070 95.4% | This study |
| Beta-515952 BB 11470 30 13353 13275 68.2% 13412 13251 95.4% | This study |
| Beta-515953 BB 11520 40 13410 13315 68.2% 13448 13279 95.4% | This study |
| IAAA-92123 BB 11530 50 13424 13317 68.2% 13463 13276 95.4% | 40–43 |
| IAAA-92124 BB 11590 50 13473 13364 68.2% 13500 13300 90.7% | 40–43 |
| IAAA-92125 BB 11940 40 13820 13719 68.2% 13967 13701 87.9% | 40–43 |
| IAAA-100080 CH 28690 120 33050 32593 68.2% 33310 32313 95.4% | 40–43 |
| IAAA-100082 BB 11760 40 13611 13480 64.7% 13719 13470 95.4% | 40–43 |
| IAAA-102634 BB 11480 50 13390 13276 68.2% 13443 13214 95.4% | 40–43 |
| IAAA-102635 BB 11720 50 13571 13472 68.2% 13641 13440 89.9% | 40–43 |
| IAAA-102636 CM 8570 40 9553 9517 68.2% 9600 9483 95.4% | 40–43 |
| IAAA-102538 CH 10270 40 12123 11959 68.2% 12169 11821 93.8% | 40–43 |
| IAAA-102639 CH 11760 50 13618 13481 59.6% 13726 13466 95.4% | 40–43 |
| IAAA-102640 CH 11930 50 13825 13705 59.1% 13864 13574 86.8% | 40–43 |
| IAAA-102641 BB 11520 50 13416 13310 68.2% 13460 13270 95.4% | 40–43 |
| IAAA-102642 CH 11120 50 13071 12935 68.2% 13089 12830 95.4% | 40–43 |
| IAAA-102643 BB 11370 50 13268 13155 68.2% 13307 13099 95.4% | 40–43 |
| IAAA-102644 CH 11610 50 13490 13374 68.2% 13559 13322 95.4% | 40–43 |
| IAAA-102645 BB 11610 50 13490 13374 68.2% 13559 13322 95.4% | 40–43 |
| IAAA-102647 CH 11300 50 13198 13094 68.2% 13263 13070 95.4% | 40–43 |
| IAAA-102648 CH 11600 50 13480 13370 68.2% 13550 13314 95.4% | 40–43 |
| IAAA-102649 BB 11930 50 13825 13705 59.1% 13864 13574 86.8% | 40–43 |
| IAAA-102650 CH 11920 50 13800 13702 51.8% 13856 13566 90.7% | 40–43 |
| IAAA-150572 BB 11710 40 13558 13479 68.2% 13599 13441 95.4% | 40 |
| IAAA-150573 BB 11660 40 13498 13449 39.1% 13574 13421 95.4% | 40 |
| IAAA-150574 BB 11430 40 13316 13216 68.2% 13377 13155 95.4% | 40 |
| IAAA-150575 BB 11639 40 13495 13427 53.3% 13570 13395 95.4% | 40 |
| TKa-15555 CM 9330 60 10603 10486 50.1% 10703 10372 92.4% | 40 |
| TKa-15556 CM 9530 70 10869 10711 37.5% 11133 10652 93.8% | 40 |

(Continued)
Although the bird figurine was found in a spoil heap, a number of contextual observations argue in favor of its Paleolithic origin. First, the spoil heap did not contain Neolithic or Bronze Age cultural remains. Likewise, no archeological remains attributed to Paleolithic ages were found in layers 1–4; these latter layers were archeologically sterile in the area where remnants of layer 5 and the associated spoil heap were identified. The distance separating the areas containing Neolithic/Bronze Age and LGM/Younger Dryas archeological material is too important, i.e., \( >50 \) m, to suggest the carving percolated into layer 5 from overlying more recent layers. The absence of evidence suggesting the mixing of both assemblages, i.e., from layer 5, on the one hand, and from layers 1–4 on the other, is further supported by the differences in the manufacture, decoration, and ages of the ceramic remains. While the sherds from layer 5 are crude, without decoration, and fired at low temperature, those from layers 1–4 are fine and bear stylistic features that allow their cultural attribution to the Yangshao Neolithic and Shang-Zhou Bronze Age. It is well-known that crude pottery appears in the Chinese archeological record at the end of the Upper Paleolithic and in Epipaleolithic contexts. The oldest known occurrences appear \( \text{circa} \ 20 \) ka BP in South China \([47–49]\) and \( \text{circa} \ 12 \) ka BP in North China \([40,50]\). Should the pottery sherds from layer 5 have had a Neolithic/Bronze Age origin, their expected ages would have ranged between \( 7 \) and \( 5 \) ka BP, not \( 12 \) to \( 9 \) ka BP. Finally, although the figurine could date to any of the three episodes of the human occupation identified by the \( \text{^{14}C} \) ages, none of the numerous dated faunal remains falls into the timeframe of the two most recent proposed human occupations, i.e., between \( 11 \) and \( 10 \) ka BP or between \( 9.6 \) and \( 8.7 \) ka BP; their radiocarbon ages are exclusively comprised between \( 13.8 \) and \( 13 \) ka BP regardless of the testing laboratory to which they were submitted for dating. Moreover, the figurine and associated faunal remains feature a similar color range and patina, which argues in favor of their syndeposition. These results and contextual information indicate that the most probable age of the figurine corresponds to that of the directly dated faunal remain bearing evidence of gouging, i.e., within the \( \sim 13.4–13.2 \) ka cal BP time interval.

**Materials and methods**

The Lingjing bird carving and the associated archeological material analyzed in this study are curated at the Henan Provincial Institute of Cultural Relics and Archaeology, Zhengzhou, Henan Province, China (Repository ID: 09L5鸟-01). No permits were required for the
described research, which complied with all relevant regulations. The Lingjing bird carving was 3D scanned using a General Electrics (GE) Vtome x|s microtomography housed at the PLACAMAT facilities, Bordeaux University. The figurine was scanned with the beak facing downward to minimize artifacts produced when X-rays are tangential to the surface. The acquisition was done with a 180 kV X-ray nanofocus tube and the following beam parameters: 100 kV and 200 μA. The scan was performed at a cubic voxel size of 11.5 μm. A copper filter of 0.1 mm was used and 1875 projections were taken at 360˚. The reconstruction of the volume was performed with the Datos | Rec software of GE. 3D visualizations were then performed within the Avizo 9.1 (FEI) workspace. A simplified 3D surface was also generated (S1 Data) with the MiKTeX Console 2.9.7076.

The object was photographed with a Sony E 30 mm with a macro-lens, and examined and photographed with a motorized Leica Z6 APOA equipped with a DFC420 digital camera linked to LAS Montage and Leica Map DCM 3D computer software. Images showing various aspects of the figurine were imported into Adobe Illustrator and used to make a tracing of the areas bearing traces of manufacture identified under the microscope. This tracing was compared to the original specimen under a microscope and corrected as required. High-resolution surface topography of selected areas was obtained with a Sensofar S neox confocal microscope driven by SensoScan 6 software (Sensofar) in order to better visualize and characterize traces of manufacture and use wear. Data acquired from the various imaging methods were compared to establish the technique of manufacture used and the orientation of the motion on each identified area. Distinction between traces of manufacture and alterations resulting from use was based on diagnostic features identified on ethnographic, experimental and archeological bone items [51–62]. When two or more techniques were identified on the same area, partial obliteration of the original anthropogenic modifications by traces generated through the subsequent application of another technique clarified their chronological ordering.

Results

The figurine depicts a small standing bird (length 19.2 mm, width 5.1 mm, height 12.5 mm). The subject’s morphology and proportions, i.e., short head and neck, robust, rounded bill and long tail, are reminiscent of Passeriformes. Passeriformes is an order that encompasses more than half of all known extant bird species. Unfortunately, the lack of minute details on the figurine prevents a more precise identification. Aside from the ostrich eggshell fragments found in the spoil heap, no avian remains were identified in the faunal assemblages of any archeological layers at Lingjing, i.e., layers 1–4, 5, 10, and 11. Nonetheless, our identification of the carving as representing a passerine is fully compatible with the paleoecology of the species comprised in this order as they were, and are, found on virtually all continents and climatic settings, including present-day and Late Pleistocene China [63,64]. In lieu of the passerine short legs, a large, rectangular pedestal allows the figurine to stand in the upright position (Fig 3, S1 Data). The oversized tail prevents the object from tilting forward. The lateral aspects of the body are flat and the wings are not represented.

Openings left on the surface by capillaries and vascular canals demonstrate the use of cortical bone for the manufacture of the figurine (Fig 4a–4d, S1 Video). Microtomography reveals a densely vascularized fibrolamellar complex without evidence of remodeling. The orientation of the bone structure corresponds to the bill-tail axis of the carving (S1 Video). The lack of lamellated layers and the presence of the same pattern of vascularization throughout the figurine suggest that the bone outermost and innermost cortex were removed when carving the object. The presence of transverse layers of demineralized bone is consistent with the action of osteolytic bacteria [65–67] (Fig 4e). Increased bone density at the surface of the object indicates
the infilling of mineral deposits following physicochemical and biochemical alterations [65,68,69] after the action of microorganisms. Reticular fibrolamellar bone tissue is found in birds, large dinosaurs and in long bones of fast-growing juvenile mammals such as herbivores [70–75]. Considering the orientation of the bone structure and the figurine dimensions, the bird was likely carved from a diaphyseal fragment of a medium-size mammal limb bone.

The bone figurine as well as other worked and unworked osseous fragments found in the spoil heap are completely blackened (Fig 3, Table 2). Recent and heat fractures present on some specimens illustrate the extent of the process in cross-section. The color gradient ranges from a dark brown, almost black, outer layer measuring between 0.2 mm to 0.8 mm in thickness to dark black at the center. None of the original bone coloration remains visible on the specimens. Although the staining of bones could result from a variety of processes [76], the
observed color gradient and the density of the bone fragments suggest they might have been subjected to a controlled heat treatment. Exposure to open flame, and contact with calcitic ash, may cause the bone to crack, shrink and deform. However, the recognition of histological structure remains achievable when bone is burnt at less than 600˚C [77–85]. Experimental data highlights that the temperature of cremation, the duration of heat exposure, and the availability of oxygen and organic compounds in the environment play key roles in modifying the aspect and structure of osseous remains [86]. Based on the color gradient visible in cross-section, and considering that microtomography reveals an intact histological structure, the faunal fragments were most likely heated from 1 to 3 hours in an anaerobic environment at a temperature ranging between 300 and 500˚C. Controlled experiments are required, however, to reproduce this treatment accurately and assess its effects on easing the carving of osseous raw material.

To study the manufacturing process of this exceptional object, we applied a novel approach consisting in surveying diagnostic traces of manufacture and post-depositional modifications by multifocus and confocal microscopy, while using high-resolution microtomography to detect edges between worked areas. We recorded sixty-eight areas distributed over the entire surface of the object, each corresponding to distinct carving episodes leading to the shaping of the figurine (Fig 5, Table 3). For each area, we documented the manufacturing technique applied and, when possible, the orientation of the gesture. In thirteen cases, we were able to identify the superimposition of techniques. Gouging was applied with the robust edge of a stone tool, such as a burin spall, producing flat facets covered by chatter marks, i.e., undulations perpendicular to the direction of the tool motion generated by pressure changes (Fig 6a). Prolonged use of a burin in a gouging activity may result in the microchipping of its flat edge.

Table 2. Technological and morphometric data on burnt bone fragments associated with the bird carving.

| Figure | Maximum Length | Maximum Width | Maximum Thickness | Cortical Thickness | Human modification | Modification type | Burnt | Fracture Type |
|--------|----------------|---------------|-------------------|-------------------|-------------------|------------------|-------|--------------|
| Fig 3a | 43.39          | 14.65         | 9.67              | 6.04              | Yes               | Fl, Go, Po       | y     |              |
| Fig 3b | 29.01          | 7.82          | 5.28              |                   | Yes               | Po, St           | y     | Recent       |
| Fig 3c | 21.21          | 7.56          | 6.67              |                   | No                |                  | y     |              |
| Fig 3d | 13.31          | 7.61          | 3.64              |                   | Yes               | Ab               | y     |              |
| Fig 3e | 24.53          | 11.98         | 4.04              |                   | No                |                  | y     |              |
| Fig 3f | 15.3           | 12.61         | 5.52              | 5.17              | Maybe             | Fl, Go(?)        | St    | y            |
| Fig 3g | 17.92          | 10.45         | 6.81              |                   | No                |                  | y     |              |
| Fig 3h | 10.99          | 3.7           | 3.21              |                   | Yes               | Cm, No, St       | y     |              |
| Fig 3i | 14.43          | 11.61         | 6.64              |                   | Yes               | No, St           | y     |              |
| Fig 3j | 15.23          | 6.21          | 4.75              |                   | No                |                  | y     |              |
| Fig 3k | 24.1           | 9.46          | 3.17              |                   | Yes               | Ab, Po           | y     |              |
| Fig 3l | 16.84          | 2.87          | 2.79              |                   | Yes               | Po, Sa(?)        | y     | Old          |
| Fig 3m | 10.25          | 4.8           | 3.23              |                   | No                |                  | y     |              |
| Fig 3n | 10.46          | 8.77          | 3.07              | 2.13              | No                |                  | y     |              |
| Fig 3o | 19.03          | 5.09          | 4.2               |                   | Yes               | Pf, Re           | y     |              |
| Fig 3p | 14.81          | 7.24          | 4.78              |                   | No                |                  | y     |              |
| Fig 3q | 14.3           | 6.81          | 3.81              |                   | No                |                  | y     |              |
| Fig 3r | 21.81          | 11.79         | 6.56              | 6.3               | Yes               | Fl, Po           | y     | Heat         |
| Fig 3s | 12.04          | 6.91          | 3.38              |                   | Maybe             | Fl               | y     |              |
| Fig 3t | 18.74          | 5.75          | 2.93              |                   | No                |                  | y     | Recent       |

Ab: Abrading; Cm: Cut mark; Fl: Flaking; Go: Gouging; No: Notching; Pf: Pressure flaking; Po: Polishing; Re: Retouching; Sa: Sawing; St: Striations

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Fig 5. Microtomography of the Lingjing bird carving. (A) Location of the three sections. (B-D) Transverse sections showing that inner cortical bone was used to carve the object and that the bill-tail axis was oriented along the bone structure. (E) Longitudinal section showing diagenetic alterations. Increase density near the surface (arrows) indicate probable infilling of mineral deposits following physicochemical and biochemical alteration. Transversal layers of demineralized bone (arrow heads) suggesting the action of osteolytic bacteria. Scales = 2 mm.
which can then produce uninterrupted superficial striations running parallel to the gouging motion and keeping a constant depth on the undulations of the chatter marks. Abrading was performed by displacing the object on an abrasive grindstone which resulted in broad, spindle-like grooves of variable depths (Fig 6b). Scraping was achieved with retouched and unretouched lithic cutting edges resulting in groups of shallow grooves featuring internal parallel striations (Fig 6c). Incisions were done either by deeply engraving the surface with the dihedral-shaped tip of a stone tool, or by superficially marking the bone with a sharp point (Fig 6d).

| Area N° | Techniques | Visible on aspect: | Area N° | Techniques | Visible on aspect: |
|---------|------------|--------------------|---------|------------|--------------------|
|         | 1st 2nd    | Right Left Top Bottom Front Rear |         | 1st 2nd    | Right Left Top Bottom Front Rear |
| 1       | Go         | • • •              | 35      | Go         | Sc • •             |
| 2       | Go         | • • •              | 36      | Sc         | • • •              |
| 3       | Go         | • • • •            | 37      | Ab         | • • • • •          |
| 4       | Go         | • • •              | 38      | Ab         | • • •              |
| 5       | Go         | • • • •            | 39      | Go         | • • •              |
| 6       | Go         | • • • •            | 40      | Go         | • • •              |
| 7       | Go         | • • • •            | 41      | Go         | Sc, Po • • • •     |
| 8       | Go Sc      | • • • •            | 42      | Sc         | • • • •            |
| 9       | Go         | • • • •            | 43      | Ab         | • • • • •          |
| 10      | Go Sc      | • • • • •          | 44      | Ab         | Po • • • • •       |
| 11      | Go         | • • • • •          | 45      | Go         | • • • • • •        |
| 12      | Go         | • • • • • •        | 46      | Go         | • • • • • • •      |
| 13      | Go Sc      | • • • • • • • • • | 47      | Go         | • • • • • • • • • |
| 14      | Go Sc      | • • • • • • • • • | 48      | Ab         | • • • • • • • • • |
| 15      | Go         | • • • • • • • • • | 49      | Go         | • • • • • • • • • |
| 16      | Go Sc      | • • • • • • • • • | 50      | Go         | • • • • • • • • • |
| 17      | Go Sc      | • • • • • • • • • | 51      | Ab         | • • • • • • • • • |
| 18      | Go         | • • • • • • • • • | 52      | Go         | • • • • • • • • • |
| 19      | Ib         | • • • • • • • • • | 53      | Go         | • • • • • • • • • |
| 20      | Ib         | • • • • • • • • • | 54      | Go         | • • • • • • • • • |
| 21      | In         | • • • • • • • • • | 55      | Go         | • • • • • • • • • |
| 22      | In         | • • • • • • • • • | 56      | Go Sc      | • • • • • • • • • |
| 23      | In         | • • • • • • • • • | 57      | Go         | • • • • • • • • • |
| 24      | In         | • • • • • • • • • | 58      | Go         | • • • • • • • • • |
| 25      | In         | • • • • • • • • • | 59      | Go         | • • • • • • • • • |
| 26      | In         | • • • • • • • • • | 60      | Go Sc      | • • • • • • • • • |
| 27      | Go         | • • • • • • • • • | 61      | Go Sc      | • • • • • • • • • |
| 28      | Go         | • • • • • • • • • | 62      | Ab         | • • • • • • • • • |
| 29      | Go         | • • • • • • • • • | 63      | Go         | • • • • • • • • • |
| 30      | Ab         | • • • • • • • • • | 64      | Go Sc      | • • • • • • • • • |
| 31      | Go         | • • • • • • • • • | 65      | Ab         | • • • • • • • • • |
| 32      | Sc         | • • • • • • • • • | 66      | Go         | • • • • • • • • • |
| 33      | Sc         | • • • • • • • • • | 67      | Go         | • • • • • • • • • |
| 34      | Sc         | • • • • • • • • • | 68      | Go         | • • • • • • • • • |

Ab: Abrading; Go: Gouging; Ib: Incising with burin; In: Incising; Po: Polishing; Sc: Scraping

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Although the initial stage of manufacture cannot be identified, it is possible that the first step entailed abrading the bone fragment. A large area on the right side of the figurine, covered by traces of abrasion on a coarse grindstone may represent the remnant of this first shaping event (Fig 6b). Gouging was used to rough out the figurine. This technique was vigorously applied to shape concave surfaces such as the throat and breast (Figs 6a and 8a, S1 Data), the back (Fig 7b, S1 Data), the undertail coverts and, in particular, the pedestal (Fig 7c, S1 Data). It was used more gently to carve the head (Fig 7d, S1 Data) and flat sides of the figurine (Fig 7e, S1 Data). Scraping was used on both sides of the throat (Fig 8a, S1 Data), the back (Figs 7b and 9a, S1 Data) and the vent (Fig 8b, S1 Data), to smooth out the chatter marks, and refine the final shape of the carving. The edges of the pedestal were carefully shaped by juxtaposing tiny facets of abrasion (S1 Data). The base of the pedestal was first carved by gouging and subsequently even out by two episodes of scraping (Figs 7c and 8c, S1 Data). The purpose of the second episode, carried out with a retouched cutting edge, may have been to slightly change the orientation of the base to ensure the bird could stand upright. On the right aspect of the head, two groups of incisions may have served to identify the bird’s eye and bill (Fig 7d). The first group is composed of two deep incisions made with the same burin. The second includes six subparallel, superficial incisions made with the same sharp point.

At the microscopic scale, prominent features left by the manufacture are smoothed at varying degrees by an abrasion that has produced randomly oriented striations (Fig 9). The
absence of such smoothing associated with randomly oriented striations of different widths on the other small blackened bone fragments from the same assemblage rules out the possibility that this wear may result from natural mechanical abrasion. The presence of sediment in some striations indicates they are ancient in origin. Based on experimental criteria, these traces differ markedly from those produced by manipulation or intentional polishing with skins or furs. They are, however, entirely consistent with use wear pattern resulting from the experimental transportation of an osseous object in a leather bag [60]. Other striations cutting into sediment deposits developed following the deposition of the object. Finally, we also recorded traces of gouging, abrading, scraping and incising on small fragments of burnt bone recovered from the same context (Fig 10, Table 2). Aside from the specimen, bearing a deep notch produced by gouging (Fig 10a, Table 2) and directly dated to 13,448–13,279 cal BP (Beta-515953: 11,520±40 BP), the assemblage also contains fragments of bone rods shaped by scraping displaying incisions perpendicular and oblique to the main axis (Fig 10, Table 2).
Discussion

A representation is generally defined as the use of signs that stand in for, and take the place of, something else [87,88]. In the domain of artistic expressions, a representation is a type of recording in which the sensory information about a physical object, or being, is recorded in a medium. The degree to which an artistic representation resembles the object, or the being, it represents is a function of resolution. Our contention for the Lingjing figurine representing a bird is based on four lines of evidence. First, its outline, with the exception of the pedestal, almost perfectly matches that of a bird and identifies several avian anatomical features, e.g., the tail, head, bill, throat, breast, and belly. Second, the edges of the outline are modified on both aspects to enhance the anatomical features of most birds, i.e., rounded volume of the body, conical morphology of the bill, etc. Third, marks were added on the head at the location of the eye and bill. Finally, the technological analysis of the modifications present on the carving demonstrates they were deliberately produced, and the carving techniques were coherently chosen in order to highlight the anatomical features of a bird. The fact that the wings are not carved does not represent an obstacle to identifying the carving as a representation of a bird since an artistic representation is by definition an operation of subtraction, addition, and/or modification of the real world, which depends on the chosen medium, the artist’s know-how.
Fig 9. Manufacturing techniques applied to Lingjing bird. (A) Traced of scraping on the left side of the bird throat. (B) Traces of scraping on the left side of the bird tail. (C) Base of the pedestal with traces of scraping superimposed to those of gouging. (A-C) Black and white micrographs. Scales = 1 mm.

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Fig 10. **Microscopic wear.** (A) Area on the back of the figurine showing traces of scraping smoothed by wear associated with randomly oriented striations. (B-C) Areas on the left side of the head (B) and the body (C) on which traces of manufacture are removed by wear associated with randomly oriented striations. (A-C) 3D renderings obtained with a confocal microscope.

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and skills, and cultural rules he/she wishes to comply to, or to transgress. Thus, the absence of wings may be explained by limitations inherent to the thickness of the bone fragment chosen to produce the carving, the diminutive size of the figurine itself, the difficulties to carve these features with the techniques and/or tools available to the artist, the stylistic canons the craftsman was conforming to, or a combination of these reasons.

Although the definition of an artistic tradition would ideally require the identification of shared technical, thematic, and stylistic traits on a number of asynchronous artistic productions, we argue that, in the case of single items, striking concomitant differences in different characterizing domains, i.e., technological, thematic, and stylistic, may reasonably be used to infer original artistic traditions. Our analysis reveals that the Lingjing artist has chosen the appropriate techniques and applied them skillfully to faithfully reproduce the distinct anatomical features of a passerine. The style of this diminutive representation is original and remarkably different from all other known Paleolithic avian figurines. Avian representations, and passerine in particular, constitute a recurring theme in Chinese Neolithic art, the oldest example being a passerine made of jade dating back to \textit{circa} 5 ka BP \cite{89,90}. The Lingjing bird carving predates previously known instances from this region by almost 8,500 years. The sophistication reflected by the object manufacturing process suggests this three-dimensional representation is several conceptual stages removed from the origin of a long-standing artistic tradition, extending well into the Paleolithic, that may be better characterized by future discoveries.

Even though carving and painting are generally seen as activities demonstrating the acquisition of symbolic thought, the ways in which they reify meaning in matter differ markedly. Each activity involves different spatial conceptualizations, sensorimotor experiences, analogical reasonings, and skill-learning processes \cite{91–93}. Pigment preparation and application obviously play a key role in painting. At times, particular morphological features of the canvas, e.g., natural protuberances or concavities of a cave wall, might have been exploited to enhance the perspective of a representation. Carving a figurine, on the other hand, requires the combination of different techniques, e.g., scraping, grinding, polishing, gouging, incising, and notching, their adaptation to the selected raw material, and the alternating application of different tools and motions. It also requires the ability to mentally visualize a volume in matter and create symmetries in a three-dimensional space. Unlike paintings, anchored to sites charged with symbolic meaning, Paleolithic carvings are representations made to be transported, curated, manipulated, and often hung on clothing \cite{30}. In view of the above, the cognitive requirements and technical skills needed to produce and perpetuate painted, engraved and drawn representations, on the one hand, and sculptures, on the other hand, may vary considerably and justifies approaching the emergence of these practices independently. The bird figurine from Lingjing constitutes the first carving found at an East Asian Paleolithic site and it differs technologically and stylistically from previous and contemporaneous representations of avifauna found in Europe and Siberia. The earliest known statuettes, made of mammoth ivory and including a flying waterfowl, are found in the Aurignacian of the Swabian Jura \cite{29,30}. They are dated to c. 40–38 ka BP. Few other three-dimensional carvings representing birds, made of teeth and antler, come from West European late Upper Paleolithic sites \cite{94–97}. The only Paleolithic bird carvings from Asia are those found at Mal’ta and Buret’, two neighboring Siberian sites located west of Lake Baikal \cite{98}. They mainly consist of pendants made of ivory and antler representing flying waterfowls. The Lingjing figurine is the only Paleolithic three-dimensional object carved in burnt bone and representing a bird standing on a pedestal. It is also the only Paleolithic carving for which, thanks to its exceptional state of preservation, the final stages of manufacture could be documented in detail.
Supporting information

S1 Data. Interactive 3D.pdf model of the Lingjing bird carving obtained by microtomography.
(PDF)

S1 Video. 3D model of the Lingjing bird with longitudinal and transverse sections showing the reticular fibrolamellar bone structure and vascularization pattern.
(MP4)

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