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1 **Innovation in bone technology and artefact types in the Late Upper Palaeolithic of China:**  
2 **insights from Shuidonggou Locality 12**

3

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23 **Abstract**

24 Information on Palaeolithic bone technology from China is sparse. Here we present the  
25 results of a techno-functional analysis of a bone tool assemblage recovered from Shuidonggou  
26 Locality 12 (SDG12), layer 11, Northern China, dated to c. 12-11 cal ka BP. Five bone tool  
27 artefact types are identified: wedges, awls, spear points, a knife handle, a possible sewing  
28 implement, and a notched carpal. Two other artefacts could not be attributed to a specific type.  
29 The artefacts are made of *Procapra przewalskii*, *Lepus* sp., *Sus* sp., *Equus przewalskii*, and  
30 unidentifiable bone fragments from medium/large size mammals. At least three methods are used  
31 to extract blanks: percussion of altered limb bones, longitudinal splitting of *Sus* sp. canine and  
32 large rib, and probably, the groove-and-splinter technique. Grinding and scraping are the  
33 dominant shaping techniques together with grooving, notching, polishing, drilling, flaking, and  
34 retouching. Tool type variability and function fit the hypothesis according to which the SDG12  
35 and similar sites would be residential camps in which hunter-gatherers produced artefacts  
36 enabling them to cope with cold environmental conditions. Our results, however, indicate that not  
37 all bone tools match the expectations associated with a serial specialist production. Expedient  
38 wedges and awls may have been produced by any member of the group, and whenever the need  
39 arose. The SDG12 bone tool assemblage provides a significant contribution to our knowledge  
40 about hunter-gatherer adaptations to the Tardiglacial environments of Northern China.

41

42 **Keywords:** Bone Tools; Specialized tool-kit; Sewing Equipment; Knife handle; Tardiglacial;

43 Northern China

44

## 45 **Highlights**

46 ● We analyze the most abundant Tardiglacial bone tool assemblage from Northern China

47 ● Five artefact types and three methods to extract blanks are identified

48 ● Blanks were shaped into tools with eight different techniques

49 ● Typological and functional variability fits the specialized tool-kit hypothesis

50 ● Artefacts are interpreted as part of a cultural adaptation to cold conditions

51

## 52 **1. Introduction**

53 Formal bone tools are defined as objects that were cut, carved, polished, or otherwise  
54 modified to produce fully shaped implements such as points, awls, harpoons, and wedges (Klein,  
55 1999). Prior to 45 ka BP, only a handful of African and Australian sites have yielded formal bone  
56 tools (Brooks et al., 1995; Yellen et al., 1995; McBrearty and Brooks, 2000; Henshilwood et al.,  
57 2001; Jacobs et al., 2006; d'Errico and Henshilwood, 2007; Backwell et al., 2008; d'Errico et al.,  
58 2012a,b; Campmas et al., 2015; Backwell and d'Errico, 2016; Langley et al., 2016). After 45 ka  
59 BP, formal bone tools are found in Eurasia and are particularly abundant in European Upper  
60 Palaeolithic toolkits (e.g., Conard and Bolus, 2003; d'Errico et al., 2003, 2012c). Instances of  
61 complex bone technologies in other regions of Eurasia, such as China, are rare (Zhang et al.,  
62 2016a). Clear evidence for the production of formal bone tools in Northern China comes from  
63 Zhoukoudian Upper Cave (Pei, 1939), Xiaogushan (Zhang et al., 1985; Huang et al., 1986;

64 Zhang et al., 2010), Shizitan (Song et al., 2016), and Shuidonggou (Guan et al., 2012; Pei et al.,  
65 2012; Yi et al., 2013). Sites that yielded formal bone tools in Southern China include Chuandong  
66 (Zhang, 1995; Mao and Cao, 2012), Maomaodong (Cao, 1982), Zhadong (Chen et al., 2004), and  
67 Ma'anshan Cave (Zhang et al., 2016a), etc. The technology of these early bone artefacts is often  
68 insufficiently documented and their function remains hypothetical (Mao and Cao, 2012 and  
69 references therein). In China, the newly published analysis of the bone tools from Ma'anshan  
70 Cave, Guizhou province, represents one of the first attempts to describe in detail this category of  
71 Palaeolithic material culture (Zhang, et al., 2016a). It identifies evolutionary trends in bone  
72 technology from 35 to 18 ka BP, and records the earliest known barbed points outside Africa.

73 In this paper, we analyze another key bone tool assemblage from China, recovered from  
74 Shuidonggou Locality 12 (SDG12). Dated to between 12.2 and 11.1 ka BP, this assemblage is  
75 exceptional for its excellent state of preservation and the variety of tool types it comprises.  
76 Photographs of selected artefacts from this assemblage appeared in the literature (Yi et al., 2013,  
77 2014; Zhang et al., 2016b). However, no detailed technological analysis of key artefact types has  
78 been published except for some needles (Zhang et al., 2016b). Our analysis highlights  
79 technological features peculiar to the Ordos Plateau and artefact types previously unrecorded at  
80 Palaeolithic sites from Asia. It also represents a unique opportunity to document formal bone tool  
81 types found in association with microlithic technologies (*cf.*, Wang, 2005).

82 It has been proposed that microblade technologies, grindstones, and specific bone tools  
83 found at this and other sites represent an adaptation to the cold environments of the LGM and the  
84 Younger Dryas in the loessic landscapes of Northeast Asia (Chen, 1983; Yi et al., 2013). Slotted

85 bone handles fitted with microblades, bone needles, awls, and technologies devoted to the  
86 manufacture of hunting nets would have been used to procure rabbit skins and produce  
87 sophisticated winter clothing (Yi et al., 2013). As far as bone technology is concerned, this  
88 interpretation is only based on a preliminary description of a few bone tools without documenting  
89 the technologies and know-how involved in the production of the bone artefacts found at the site.  
90 The aim of the present paper is to reconstruct these aspects of human behaviour and identify the  
91 function for key categories of bone artefacts recovered at SDG12. This will allow us to test, on a  
92 category of material culture other than lithics, the pertinence of the “serial specialist” hypothesis  
93 (Binford, 1980, p. 17), i.e., the idea that the SDG12 hunter-gatherers subsistence strategy would  
94 have relied on standardized tool production to face seasonal challenges in the Tardiglacial  
95 environments of Northern China (Yi et al., 2013).

## 96 **2. Archaeological context**

### 97 **2.1 Site location, stratigraphy, and chronology**

98 Located on the second terrace of the Biangou River floodplain (Ningxia Hui Autonomous  
99 Region, Northern China), 3 km south-east from the well known Shuidonggou Locality 1 (Licent  
100 and Teilhard de Chardin, 1925; Boule, 1928; Pei et al., 2012), SDG12 is an open-air site  
101 discovered in 2005 during an archaeological survey of the exposed river bank (Liu et al., 2008;  
102 Gao et al., 2009; Pei, et al., 2012; Yi et al., 2013). In 2007, salvage excavation was carried out  
103 over a 12-m<sup>2</sup> area and a depth greater than 9 m. A total of twelve geological layers were  
104 identified based on granulometry and sediment colour (Fig. 1). Archaeological material was only

105 recovered from the c. 50-centimetre-thick ashy layer 11, all other layers being sterile. Sediments  
106 from this layer were sieved with a 2-millimetre mesh. The layer was further subdivided into five  
107 sub-levels, level 1 (youngest) to 5 (oldest). Lithics from these sub-levels are typologically and  
108 technologically similar, and are considered as a single assemblage (Yi et al., 2013). The dating of  
109 a charcoal from the middle part of layer 11 provided a  $^{14}\text{C}$  age of  $9,797 \pm 91$  BP (11,164 – 11,378  
110 cal BP). OSL ages from layers 10 and 12 are consistent with the  $^{14}\text{C}$  determination when the  
111 standard error is taken into account (Liu et al., 2008). These ages suggest that the site was  
112 occupied toward the end of, or immediately after, the Younger Dryas Cold Event (c. 12,900 –  
113 11,700 cal BP; Rasmussen et al., 2014).

## 114 **2.2 Lithic Technology**

115 The SDG12 lithic assemblage, comprising more than 9,000 pieces, is typical of the Late  
116 Pleistocene microlithic industries found in China (Gao et al., 2009; Pei et al., 2012; Yi et al.,  
117 2013, 2016) and in adjacent regions from Central Asia to Alaska (Goebel, 2002; Brunet, 2012;  
118 Gómez Coutouly, 2012; Tabarev, 2012; Takakura, 2012; Kato, 2014). It is dominated by  
119 microblade cores and highly standardized microblades, which were likely obtained by pressure  
120 flaking (Pelegriin, 2012), but also includes end-scrapers, notches, points, borers, and burins (Gao  
121 et al., 2013; Yi et al., 2013). A variety of grinding tools are represented (Yi et al., 2013). A  
122 fragment of an axe and small discs, shaped by grinding, were also found as well as a large  
123 number (>13,000) of burnt stone fragments (Gao et al., 2013). The lithic assemblage composition  
124 indicates that stone knapping, osseous tool shaping, plant processing, and woodworking were

125 carried out at the site (Yi et al., 2013, 2014).

### 126 **2.3 Faunal Assemblage and Taphonomy**

127 The faunal assemblage comprises more than 10,000 remains, 1,821 of which were identified to  
128 species, or to order for microfauna. *Lepus* sp. (57.4%) dominates the faunal spectrum followed  
129 by *Procapra przewalskii* (22.2%), *Bubalus* sp. (6.8%), *Meles meles* (5.7%), *Equus przewalskii*  
130 (2.9%), and birds (2.9%). The remaining 2.1% of the NISP is composed of Cervidae, *Sus* sp.,  
131 *Felis microtus*, rodents and a single remain of a reptile (Zhang et al., 2013). Cut-marks are  
132 present on 5.1% of the NISP, a proportion similar to that observed at other Chinese Late  
133 Pleistocene sites analyzed with comparable methods, e.g., Ma'anshan Cave (Zhang et al., 2010).  
134 Carnivore and rodent modifications were only detected on four pieces. This combined evidence  
135 suggests that the faunal assemblage is mainly the result of anthropogenic activities. Root etching  
136 is the main post-depositional alteration. Although fluvial action is considered a key factor in the  
137 formation of this site (Liu et al., 2008) no obvious modification produced by this process were  
138 detected on the faunal remains.

### 139 **3. Materials and methods**

140 The osseous industry from SDG12 is curated at the Institute of Vertebrate Palaeontology  
141 and Palaeoanthropology of China, Beijing.

142 Each bone artefact was studied with a Nikon SMZ1500 stereomicroscope at magnifications  
143 ranging from 7.5x and 112.5x. Anthropogenic modifications were distinguished from natural

144 ones on the basis of criteria known in the literature (Shipman and Rose, 1983; Behrensmeier et  
145 al., 1986; Lyman, 1994; Fisher, 1995). Identification of manufacturing techniques and use-wear  
146 traces was based on observation of ethnographic, experimental, and archaeological bone tools  
147 (LeMoine, 1994; Malerba and Giacobini, 2002; d'Errico et al., 2003; Karavanić and Šokec, 2003;  
148 Backwell and d'Errico, 2004; Christidou and Legrand, 2005; Griffiths, 2006; d'Errico and  
149 Henshilwood, 2007; Legrand and Sidéra, 2007; Gates Saint-Pierre and Walker, 2007; Legrand  
150 and Radi, 2008; Mozota Holgueras, 2008, 2009, 2012; Bradfield and Lombard, 2011; Buc, 2011;  
151 Byrd, 2011; Bradfield, 2012; Jéquier et al., 2012; Mallye et al., 2012; Blasco et al., 2013;  
152 Bradfield and Brand, 2013; Daujeard et al., 2014; Hardy et al., 2014; Jéquier, 2014; Moigne et  
153 al., 2016; Tejero et al., 2016; Yeshurun et al., 2017). When identifiable, the species and  
154 anatomical elements selected as blanks were recorded. Otherwise, an animal size class was  
155 estimated from the cortical thickness. Techniques of manufacture, the area where they were  
156 applied, and the location and type of use-wear were documented. Morphometric data were  
157 collected using digital callipers, and included the maximum length, width, and thickness of the  
158 artefact. Identification of tool types has taken into account archaeological and ethnographic data  
159 from Europe, Africa, and America, with tentative attributions based on the morphology, size,  
160 traces of utilisation, and hafting (LeMoine, 1994; Henshilwood, et al., 2001; d'Errico and  
161 Henshilwood, 2007; Gates Saint-Pierre and Walker, 2007; Backwell, et al., 2008; Bradfield,  
162 2010).

#### 163 **4. Results**

164 The specimens analyzed in this paper comprise 16 of the 35 bone artefacts recovered at  
165 SDG12 (Table 1). Needles (Zhang et al., 2016b) are excluded from the present study, as they will  
166 be the focus of a global comparative study. This number differs from a previous publication (Gao  
167 et al., 2013) as it also takes into account fragmentary artefacts identified by two of us (ZS, ZY)  
168 during the archaeozoological analysis of the sieved material. Five bone tool types were  
169 identified: wedges (4), one of which was also used as a retoucher, awls (4), spear points (3), knife  
170 handle (1), possible sewing implement (1), notched carpal (1). Two artefacts could not be  
171 attributed to a specific tool type. In the following description, we indicate for each object the  
172 figure in which it is illustrated followed by the catalogue number as it appears in Table 1.

#### 173 **4.1 State of preservation**

174 Three objects are complete, seven are represented by mesial fragments, six by distal  
175 fragments, and one by a proximal fragment. One of the objects (Figure 2, n. 8, cat. 2859) consists  
176 of two non-joining fragments attributed to the same tool based on their morphology, technology,  
177 traces of heating, and shade. Although most artefacts (> 76%) bear traces of root etching, the  
178 surfaces not affected by this natural modification are exceptionally well preserved and allow a  
179 precise identification of anthropogenic modifications. No traces produced by other non-human  
180 taphonomic agents were detected.

#### 181 **4.2 Osseous Technology**

##### 182 4.2.1 Wedges and a retoucher

183 Four different artefacts are attributed to this tool category. The first, almost complete, shows

184 recent marginal breaks affecting its proximal and mesial edges (Figure 2 n. 1, cat. 132). The  
185 second, also almost complete, displays an ancient proximal break (Fig. 2 n. 2, cat. 4008). The  
186 third is incomplete and made of compact bone (Fig. 2, n. 3, cat. 3091). It has a triangular section  
187 and tapers to the distal end creating a convex bevel. The fourth is a small distal fragment,  
188 bearing recent longitudinal and proximal fractures, but retaining a portion of its original bevel  
189 (Figure 2 n. 4, cat. 2857). The blank to produce the first artefact comes from a *Procapra*  
190 *przewalskii* long bone, possibly the posterior aspect of a radius. The other three wedges were  
191 manufactured out of an undetermined long bone from a small/medium size mammal.

192 The blank used to manufacture the wedges were likely obtained by fracturing a weathered  
193 bone, as indicated by their longitudinal outline and morphology of the fractures (Lyman, 1994:  
194 315-353). Both scraping and grinding were applied to shape the first tool (Fig. 3a, cat. 132).  
195 Scraping was used to regularize the lateral edges (Fig. 3b, cat. 132). The periosteal surface of the  
196 bevel was ground following different directions. The endosteal surface was ground obliquely.  
197 After utilisation, grinding was applied again, this time parallel to the tool main axis, to resharpen  
198 the bevel. Obvious traces of utilisation are detected on the bevel. They take the form of a polish  
199 covered by a palimpsest of microstriations perpendicular or slightly oblique to the edge, which is  
200 characteristic of an action against sorted abrasive particles (Fig. 3c, cat. 132). A more discrete  
201 polish, observed on the lateral edge of the tool, may result from handling or hafting. A group of  
202 aligned impact scars, present on the endosteal face close to the proximal fracture, suggests that  
203 the tool may have also been used, in a single instance, as a retoucher (Karavanić and Šokec,  
204 2003; Mozota Holgueras, 2008, 2009, 2012; Mallye et al., 2012).

205           The blank used to manufacture the second wedge was only slightly modified by removing a  
206 series of adjacent microflakes on its right edge (Fig. 2, n. 2, cat. 4008) and by marginally  
207 scraping the left edge. The bevel displays a highly polished convex facet on the periosteal surface  
208 (Fig. 3d, cat. 4008) and imbricated stepped tangential scars with highly polished ridges on the  
209 endosteal surface (Fig. 3e, cat. 4008). The bevel edge features a crenulated outline with tightly  
210 closed incipient fractures. The above features likely result from the use of the tool as a wedge  
211 exerting either pressure or percussion on hard material. The proximal fracture may have resulted  
212 from the break of the tool during its use.

213           The third wedge was entirely shaped by grinding, including a small facet blunting the  
214 proximal end (Fig. 4a, cat. 3091). The presence of tangential flake scars originating from this end,  
215 partially removed by this facet, suggests that the facet was ground to avoid further breakage  
216 owing to percussion exerted during use (Fig. 4b, cat. 3091).

217           The bevel of the fourth wedge was shaped by vigorously grinding the blank end with an  
218 oblique motion (Fig. 3f, cat. 2857). Contrary to the traces of grinding on piece SDG12-132,  
219 consisting of individual spindle-like striations resulting from grindstone releasing abrasive  
220 particles during the work, those on piece SDG12-2857 are coarser and reminiscent of an abrasion  
221 against a harder rock such as quartzite. Polish resulting from utilisation covers the bevel edge and  
222 the ridges of the grinding striations. The edge displays, as with SDG12-4008, a crenulated  
223 outline, probably resulting from a similar utilisation (Fig. 3f, cat. 2857).

#### 224 4.2.2 Awls

225           Two objects attributed to this bone tool type are almost complete (figure 2 n. 5 and 6, cat.

226 130 and 2850) although the mesial portion of SDG-130 is heavily eroded; they were respectively  
227 manufactured from the proximal epiphysis (Figure 2, n. 6, cat. 2850) and the diaphysis (Figure 2,  
228 n. 5, cat. 130) of *Procapra przewalskii* metatarsals. The third artefact comes from a diaphysal  
229 fragment of a *Lepus* sp. long bone (Figure 2, n. 7, cat. 1208). Its proximal portion is missing. A  
230 fourth object, shaped on a shaft fragment of a juvenile medium size herbivore, comprises two  
231 non-joining mesial-distal fragments (Fig. 2 n. 8, cat. 2859).

232 The orientation and morphology of the fractures on SDG12-130 suggest that the blank was  
233 extracted from a weathered bone in order to obtain an elongated, thin splinter. The resulting  
234 blank was slightly shaped at one end by flaking. The other end was scraped and subsequently  
235 ground obliquely to the tool axis (Fig. 5a, cat. 130). Its prolonged use as an awl developed on the  
236 tip a use wear consisting of a heavy polish, which partially removed the striations produced by  
237 grinding (fig 5b, cat. 130). The blank of SDG-2859 comes from a weathered bone, as indicated  
238 by the morphology and orientation of the fracture visible on the endosteal face. The tool was  
239 manufactured by longitudinal scraping, confined to its distal portion, followed by grinding  
240 applied to the edges and all over the object surface near the tip (Fig. 5c, cat. 2859). Transversal  
241 white streaks, resulting from exposure to heat, cover the left half of the periosteal surface (Fig.  
242 5d, cat. 2859). White, isolated spots caused by the same process are also visible on both  
243 fragments. The blank of SDG-1208 was probably also extracted by percussion, before  
244 regularising the edges and the tip of the bone flake by perpendicular grinding (Fig. 5e-f, cat.  
245 1280). The tip may have been deliberately heated to harden it. Subsequent use as an awl has  
246 smoothed the traces of grinding. Longitudinal striations on the smoothed ground surfaces may be

247 due to a gentle resharpening of the tip by scraping or utilisation. The manufacture of  
248 SDG12-2850 entailed production of the blank by percussion and, subsequently, grinding the  
249 edges and a portion of the periosteal surface. The grinding was exerted perpendicularly and  
250 obliquely to the object axis (Fig. 5g, cat. 2850). The constricted morphology of the tip was  
251 obtained with the same technique.

#### 252 4.2.3 Projectile points

253 The three specimens interpreted as projectile points comprise a mesial-distal (Fig. 2, n. 9,  
254 cat. 1211), a mesial (Fig. 2, n. 10, cat. 2854), and a proximal (fig; 2, n.11, cat. 2858) fragment.  
255 Long bone diaphyses of medium size herbivores were selected for the manufacture of the first  
256 two objects. A rib from a similar size class mammal, likely juvenile, was used for the third.  
257 SDG12-1211 was manufactured by obliquely grinding the blank with the exception of the  
258 medullary canal. Traces of grinding were partially obliterated, close to the tip, by longitudinal  
259 scraping resulting in elongated facets (Fig. 6a, cat. 1211). SDG12-2854 was instead shaped by  
260 longitudinally scraping the whole surface (Fig. 6b, cat. 2854) and slightly modifying an area  
261 close to the proximal fracture by grinding (Fig. 6c, cat. 2854). The shaft of SDG12-2858 was  
262 exclusively manufactured by longitudinal scraping (Fig. 6e, cat. 2858). Diagnostic traces of  
263 manufacture are absent on the flat base (Fig. 6d, cat. 2858). However, its morphology and outline  
264 suggest that this area of the object was manufactured by grinding. At the opposite end, the step  
265 fracture is typical of damage resulting from use as projectile point (Pétillon, 2006; Bradfield,  
266 Lombard, 2011; Bradfield and Brand, 2013; Doyon and Knecht, 2014).

#### 267 4.2.4 Possible sewing implement

268 This artefact presents one pointed and one curved end, partially removed by an ancient scar  
269 (Fig. 2, n. 12, cat. 1213). Its thickness indicates that the blank was extracted from the limb bone  
270 of a medium/large size mammal. Four techniques were used to manufacture the tool. The  
271 preform was given a spindle shape by longitudinal scraping (Fig. 7a, cat. 1213). A perforation  
272 was then made close to one end by drilling both sides of the object. The section of the hole and  
273 the concentric striations covering its surface indicate that the perforation was likely made with a  
274 hafted lithic point (Fig. 7b, cat. 1213). A deep longitudinal groove was subsequently incised,  
275 starting from the hole, and enlarged on both faces until an elongated eye was produced. On both  
276 faces, the groove terminations diverge toward the right. The resulting rods were given a circular  
277 section by scraping. The eye's maximum dimensions are 28.2 mm (length), 4.9 mm (width), and  
278 5.7 mm (thickness). Finally, the end close to the hole was ground in order to reduce its length and  
279 create a squeezed cone (Fig. 7c-e, cat. 1213). The handling of the object may explain the slight  
280 polish that covers the whole surface. The function of the tool is difficult to establish. However,  
281 its shape is reminiscent of ethnographic implements used in sewing activities (see discussion).

#### 282 4.2.5. Handle

283 Reconstructed from six fragments, this elongated artefact is almost complete apart from  
284 recent fractures affecting one end and, to a lesser extent, both lateral edges (Fig. 2, n.13, cat.  
285 141). It was manufactured from a rib of a large mammal, split longitudinally. The artefact bears  
286 traces of intense polishing that have obliterated marks left by the shaping of the blank. By  
287 comparison with fragments of modified ribs from the same assemblage to produce needles, the  
288 object was likely modified by grinding the trabecular tissue and scraping the compact bone

289 before regularizing the surface by polishing. One edge was carefully grooved, probably to insert  
290 straight bladelets (Yi et al., 2013). The groove is 80.9 mm long, 2 mm wide, and 3.5 mm deep. A  
291 well-defined longitudinal incision was engraved on each side of the object, a millimetre apart  
292 from the opposite edge (Fig. 8a, cat. 141). Two sets of fifty and forty-six equidistant notches  
293 were cut between these incisions, creating a ladder-like motif (Fig. 8b, cat. 141). The size and  
294 outline of the notches suggest that both sets were made in a single session with the same cutting  
295 edge. They are heavily worn by the handling of the tool. Their cross-section is too superficial to  
296 be documented.

#### 297 4.2.6. Notched carpal

298 This artefact is a horse (*Equus przewalskii*) left third carpal with a recent break removing a  
299 fragment on its posterior aspect (Fig. 2, n. 14, cat. 2855). Root etching has heavily altered its  
300 surfaces. However, traces of intentional grinding are visible on the distal articular face of the  
301 object and at least seven parallel notches were cut on its anterior proximal margin (Fig. 9a, cat.  
302 2855). Due to its state of preservation and the loose structure of the bone, it is problematic to  
303 establish whether the notches were made by a single or by multiple cutting edges. A difference in  
304 patina is observed between the outer bone surface and that of the notches suggesting the latter  
305 were made when the bone was already partially fossilized.

#### 306 4.2.7 Undetermined

307 Piece SDG12-1215 is a refitted mesial fragment of a rod bearing recent proximal, distal, and  
308 longitudinal fractures (Fig. 2, n15. cat. 1215). It was manufactured on the diaphysis of a medium  
309 size mammal. The object is triangular in section. It bears traces of longitudinal scraping, partially

310 erased by polishing (Fig. 9b, cat. 1215). Intense grinding has gently tapered one end of the piece  
311 (Fig. 9c, cat. 1215).

312 Piece SDG12-3266 (Fig. 2, n16, cat. 3266) is a mesial fragment of a wild boar (*Sus* sp.)  
313 canine with recent fractures on both ends. It is triangular in section with a face retaining the  
314 enamel, the second displaying the occlusal wear facet, and the third showing a deliberate  
315 modification by intense grinding exerted perpendicularly to the object main axis (Fig. 9d, cat.  
316 3266).

### 317 **Discussion and conclusion**

318 Upper Palaeolithic sites from Northern China have only yielded few bone tools and a limited  
319 number of artefact types, e.g., Shizitan Locality 29 (Song et al., 2016), Shuidonggou Locality 2  
320 (Guan et al., 2012), and Xiaogushan (Huang et al., 1986). The paucity of large and  
321 well-preserved bone tool assemblages and the loss of the abundant collection from Zhoukoudian  
322 Upper Cave (Pei, 1939) offered limited opportunities to conduct technological and functional  
323 analyses of this category of prehistoric material culture in this region. The rich assemblage from  
324 SDG12 now makes this endeavour possible.

325 The SDG12 bone tools were manufactured with a wide array of techniques. The few cases in  
326 which the species could be identified testify to the selection of skeletal elements from the two  
327 predominant taxa in the faunal assemblage, i.e., *Procapra przewalskii* and *Lepus* sp. The cortical  
328 thickness and morphology of most of the other bone artefacts indicate that *Procapra przewalskii*

329 long bones may have been used for their manufacture. Four artefacts were produced from  
330 skeletal elements of larger mammals, which are marginally represented in the faunal assemblage;  
331 this is the case for the ground *Sus* sp. canine, the notched *Equus przewalskii* carpal, the possible  
332 sewing implement made out of a robust limb bone, and the handle manufactured from a large rib.

333 At least three methods were used to extract blanks at SDG12. Most of them resulted from the  
334 percussion of slightly altered limb bones, which produced elongated blanks. Judging from the  
335 morphology of the fractures, this may also be the case for the awl shaped on a proximal fragment  
336 of a *Procapra przewalskii* metatarsal (Fig. 2, n. 6). The second technique entails the longitudinal  
337 splitting of a large rib. This technique was used to extract the blank employed to manufacture the  
338 handle (Fig. 2 n. 13). A similar technique may have been used to reduce the wild boar canine.  
339 The canines of suids can be easily split longitudinally by percussion and, when weathered, often  
340 already present longitudinal cracks that facilitate this task (d'Errico et al., 2012 c). Finally, few  
341 blanks were probably obtained by applying the groove-and-splinter technique (Fig. 2, n. 9, 10, &  
342 12). The production of the slot on the handle and the eye on the possible sewing implement  
343 indicate that longitudinal grooving, essential for the production of blanks with this technique,  
344 was well-mastered at SDG12.

345 Grinding and scraping are the dominant shaping techniques. When it was possible to  
346 establish the order in which both were applied, scraping precedes grinding. The only exception is  
347 a projectile point (Fig. 2 n. 9) on which marginal scraping applied to the tool tip may be due to its  
348 resharpening. The systematic use of grinding documented at SDG12 is consistent with what has

349 been observed at other Asian sites (Rabett and Piper, 2012; O'Connor et al., 2014; Aplin et al.,  
350 2016; Perera et al., 2016; Zhang et al., 2016a). In contrast, this technique is virtually absent in the  
351 Upper Palaeolithic of Western Europe (Camps-Fabrer, 1976; Langley, 2016), with the possible  
352 exception of a single Uluzzian awl from Grotta del Cavallo, layer E III (d'Errico et al., 2012b).  
353 Although it has been proposed that grinding was applied to osseous material in the Gravettian of  
354 Eastern Europe (Goutas 2004, 2013), supporting evidence is limited. In Africa, grinding is  
355 relatively rare in the Middle Stone Age (d'Errico and Henshilwood, 2007; Backwell and  
356 d'Errico, 2016; d'Errico et al., 2012a). It becomes common in the Later Stone Age (Yellen, 1998;  
357 Bradfield, 2016).

358         Six other shaping techniques are less frequently applied at SDG12: grooving, notching,  
359 polishing, drilling, flaking, and retouching. It is worth noticing that the first two techniques are  
360 used for very different purposes. Grooving is used both for blank extraction and for shaping  
361 specialized tools, i.e., the possible sewing implement and the handle. Notching was applied to  
362 produce dozens regularly spaced sets of short incisions on the handle or a short sequence of  
363 notches on the edge of a horse carpal. Five artefacts bear evidence for heating. Establishing  
364 whether these objects were intentionally treated with heat is problematic. However, for the awl  
365 made of rabbit long bone (Fig. 2 n. 7), the heating is limited to its tip, which strengthened this  
366 hypothesis.

367         The probable function of some artefact types, such as wedges, awls, and spear points, can be  
368 reasonably inferred from their morphology, use wear (see below), and similarity with prehistoric

369 and ethnographic specimens. The fragmentary state of others (Fig. 2 n. 15 & 16) prevents a  
370 functional interpretation. The artefact interpreted as a handle does not show microblades in its  
371 groove. However, its strong technological and morphological similarity with known complete,  
372 more recent knife handles from Xiliang, dated to c. 8.5 ka BP (Liu, 2007), Shangzhai, dated to  
373 7.9-6.6 ka BP (Cui et al., 2010), and Dadiwan, dated to 7.9-6.0 ka BP (Yi et al., 2013; Bettinger  
374 et al., 2015), clearly indicates that we are dealing with the same tool type, which apparently was  
375 used almost unchanged for at least 4,000 years in Northern China. If highly standardized  
376 microblades are taken as an archaeological proxy for a technological system that includes the  
377 production of composite knives, the SDG12 object (Fig. 2 n. 13) may represent a rare instance of  
378 a long-term tradition going back to the very appearance of microblades in China. In such  
379 technological system, standardized microblades obtained by pressure flaking would facilitate the  
380 repair of the knife cutting edge. The minute, careful decoration visible on this object may signal  
381 group affiliation or personal ownership (Wiessner, 1983; Barton, 1997; Bar-Yosef, 2002), which,  
382 if one accepts the association handle-microblades hypothesis, may have been at work in China as  
383 early as 30 ka BP.

384       We have found no obvious ethnographic comparisons for the possible sewing implement.  
385 Shuttles used for net making either bear two opposite deep indentations, or one pointed and one  
386 concave end associated with an eye longitudinally crossed by a prong (Keddie, 2010; Bless et al.,  
387 2015). Although none of these features are visible on our object, its round shape and the careful  
388 application of two manufacturing techniques fit the interpretation of a tool used in domestic

389 activities, perhaps in combination with needles to produce tight seams, or for net making (Yi et  
390 al., 2013). No such tool have been reported from Upper Palaeolithic contexts in Eurasia, where  
391 weaving and net making would have used bone tools of different morphology (Soffer, 2004).

392 Our analysis has revealed that many bone artefacts bear indubitable traces of utilisation. A  
393 polish on the active area is the main trace of use recorded on wedges, awls, and the possible  
394 sewing implement. A polish possibly due to hafting and handling was recorded on a wedge (Fig.  
395 2, n. 2) and the knife handle respectively (Fig. 2, n. 13). In the case of the possible sewing  
396 implement eye, the use wear slightly deformed its original outline (Fig. 2, n. 12). Other traces of  
397 use include crenulation of the wedges' active edge (Fig. 2, n. 2 & 4) and tangential flake scars  
398 due to percussion (Fig. 2 n. 3). The projectile point made out of a rib (Fig. 2 n. 11) displays a step  
399 fracture typical of hafted armature broken on impact. Finally, one wedge was also used as a  
400 retoucher in a single occasion (Fig. 2 n. 1). The differences in the types of use-wear recorded on  
401 the wedges suggest that a functional distinction must be made for at least one specimen (Fig. 2 n.  
402 1). The polish characteristic of an action against sorted abrasive particles observed on  
403 SDG12-132 (Fig. 3d) could indicate it was used as an end-scraper in activities such as hide  
404 working (Christidou and Legrand, 2005), while the others (Fig. 2 n. 2-4) were likely used as  
405 cleaver as attested by the crenulations and flake scars present on their bevel.

406 In summary, SDG12 bone assemblage demonstrates a remarkable mastery of the techniques  
407 known in prehistory to modify osseous materials and, in a number of respects, a know-how of a  
408 complexity comparable to that known in the European Upper Palaeolithic. The technological and

409 morphological variability observed in typologically analogous tools (e.g., wedges, awls, points)  
410 suggests that these artefacts represent instances of a much broader variability. This diversity in  
411 tool types and forms gives the impression that we have an incomplete view of the bone artefacts  
412 brought to, manufactured, used, and lost or disposed at the site. Some wedges, for example, fall  
413 in the category of fully modified formal tools (e.g., end-scraper) while others are better described  
414 as expedient tools (e.g., cleavers). Some awls have very sharp active areas while others are  
415 sturdier. Very specialized artefacts such as the possible sewing implement, the knife handle, the  
416 notched carpal, and the ground *Sus* sp. canine correspond to single instances of clearly distinct  
417 artefact types.

418       These observations are only partially consistent with the recently proposed hypothesis  
419 according to which the SDG12 toolkit would reflect a cultural adaptation to the cold  
420 environments of the Tardiglacial. According to this hypothesis, SDG12 is interpreted as a  
421 residential camp site in which hunter-gatherers would have prepared themselves for winter by  
422 carrying out a variety of activities (e.g., hunting, carcass processing, sewing clothes, net making,  
423 processing plants, etc.). The production of specialized highly effective cultural items would have  
424 been guaranteed by “serial specialists” i.e., members of the group detaining the know-how  
425 allowing them to produce highly standardized artefacts such as microblades (Yi et al., 2013). The  
426 technology used to manufacture a number of tools involved shaping by grinding, which may  
427 have been performed on the numerous grinding tools found at the site. The functions for which  
428 the SDG12 bone tools were likely used (e.g., hunting, skin cutting and processing, sewing

429 clothes, net knitting, etc.) fit the residential hypothesis and the idea that the osseous toolkit was  
430 an effective adaptation to the cold environment (Goebel, 2002). However, not all bone tools  
431 match the expectations associated with a serial specialist production, i.e., highly standardized tool  
432 produced, possessed, and transported by a specialist. While the knife handle and the possible  
433 sewing implement could fit this interpretation, any member of the group could have produced the  
434 expedient wedges and awls whenever the need for such tools arose. This distinction can be  
435 explained by the fact that high quality lithic raw material for the manufacture of microblades  
436 were transported to the site and processed by specialized knappers, while many bone tools were  
437 likely manufactured from readily available carcasses, then used and discarded at the site. We are  
438 clearly witnessing a complex technical system in which different know-hows are required to  
439 accomplish a wide variety of tasks. In order to better understand the behavioural complexity  
440 necessary for the production and use of bone tools in these tasks, we would need a richer bone  
441 assemblage including a greater number of specimens for each tool type and, ideally, by-products  
442 of their manufacture. The SDG12 bone tool assemblage nevertheless provides a significant  
443 contribution to our knowledge on hunter-gatherer adaptation to the Tardiglacial environments of the  
444 Ordos Plateau of China.

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741 **Legends of figures and table**

742 Figure 1: a: location of Shuidonggou Locality 12; b: photo of the stratigraphy indicating the  
743 geological layers and their limits (b, modified after Pei et al. 2012)

744 Figure 2: Osseous artefacts from SDG12 layer 11 analysed in this study. Scales = 1 cm. See table  
745 1 for additional information

746 Figure 3: Traces of manufacture and use on SDG12 wedges; a-c: 132; d-e: 4008; f: 2857. Scales:  
747 a, b = 1mm; c = 200  $\mu$ m; d~f = 500  $\mu$ m

748 Figure 4: Traces of manufacture on wedge SDG12-3091. Scales: a = 1000  $\mu$ m; b = 500  $\mu$ m.

749 Figure 5: Traces of manufacture and use on SDG12 awls; a-b: 130; c-d: 2859; e-f: 1208; g: 2850.  
750 Scales: a, d g = 1 mm; b, c = 500  $\mu$ m; e, f = 250  $\mu$ m

751 Figure 6: Traces of manufacture and use on SDG12 projectile points; a: 1211; b-c: 2854;  
752 d-e: 2858. Scales: a, c = 1 mm; b = 500  $\mu$ m; d, e = 250  $\mu$ m

753 Figure 7: Traces of manufacture and use on possible sewing implement SDG12-1213. Scales: a, c,  
754 d, e = 1 mm; b = 20  $\mu$ m

755 Figure 8: Traces of manufacture on the knife handle SDG12-141. Scales: a = 1 cm; b = 1 mm

756 Figure 9: Traces of manufacture on SDG12 artefacts; a: 2855; b-c: 1215; d: 3266. Scales: a =  
757 500  $\mu$ m; b~c = 1mm; d = 500  $\mu$ m. The oblique bar in *a* indicates the area enlarged at the  
758 bottom of the figure

759 Table 1: Descriptive, technological, and morphometric data on SDG12 (layer 11) bone artefacts.

