



HAL
open science

Tracing the Past: Butchering a Bison with Middle Palaeolithic Stone Tools

Marie-Cécile Soulier, Sandrine Costamagno, Émilie Claud, Marianne Deschamps

► **To cite this version:**

Marie-Cécile Soulier, Sandrine Costamagno, Émilie Claud, Marianne Deschamps. Tracing the Past: Butchering a Bison with Middle Palaeolithic Stone Tools. Mărgărit, M., Boroneanț, A (eds.). Recreating artefacts and ancient skills: from experiment to interpretation, Cetatea de Scaun Publishing, pp.13-31, 2022, 978-606-537-565-9. hal-03761715

HAL Id: hal-03761715

<https://hal.science/hal-03761715v1>

Submitted on 26 Aug 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

1 **Tracing the past: butchering a bison with Middle Palaeolithic stone tools**

2 Marie-Cécile Soulier^a, Sandrine Costamagno^a, Emilie Claud^b, Marianne Deschamps^{a,c}

3

4

5 **Affiliations**

6 Corresponding author: Marie-Cécile Soulier marie-cecile.soulier@cnr.fr

7 ^a CNRS UMR 5608-TRACES, Université de Toulouse Jean Jaurès, Maison de la Recherche, 5
8 allées A. Machado, FR-31058 Toulouse cedex 9

9 ^b INRAP, Centre Archéologique de Poitiers, 122 rue de la Bugellerie, FR-86000 Poitiers

10 ^c UNIARQ, Faculdade de Letras da Universidade de Lisboa, Alameda da Universidade, 1600-214
11 Lisboa, Portugal

12

13

14

15

16

17

18 **Abstract**

19 In order to better document food practices of past societies, we butchered a female adult American
20 bison (*Bison bison*) using replicas of Middle Palaeolithic stone tools. This experiment, carried out
21 as part of the collective research project “Des Traces et des Hommes”, was designed to test
22 whether specific stone tools or raw materials were more efficient for certain activities, build a new
23 dataset for activity specific use-wear patterns, and identify cut-marks characteristic (i.e. location
24 and orientation) of each stage of the butchery process. The carcass was skinned, defleshed, and
25 disarticulated, with the tendons also removed. Each butchery stage left cut-marks on the bison
26 bones. Comparisons with available data for medium-sized ungulates shows comparable patterns in
27 the interpretation of cut-marks, although some differences were observed, suggesting caution
28 when interpreting cut-mark data on larger species such as bison. Moreover, our experiment
29 revealed certain tools to be more efficient than others for butchery, and that the choice of tool type
30 and/or raw material can influence the generation of cut-marks.

31

32

33 **Keywords** experimentation; butchery; Middle Palaeolithic stone tools; bison; cut-marks

34

35

36 **1. Introduction**

37 Cut-marks on bones and use-wear on stone tools are amongst the most reliable means
38 for identifying carcass processing by past societies. Combined with our current understanding of
39 taphonomic processes, several different forms of experimental and ethnographic evidence are
40 available to reconstruct past butchery practices. There is now sufficient comparative data linking
41 patterns in cut-mark distribution and frequency with butchery activities to allow these processes to
42 be identified on various species, including reindeer, deer, African bovids, birds or rabbits (e.g.
43 Binford 1981; Bez 1995; Nilssen 2000; Laroulandie 2001; Lloveras *et al.* 2009; Val and Mallye
44 2011; Soulier and Costamagno 2017; Costamagno *et al.* 2019; Soulier 2021). In order to add
45 another reference collection to this growing body of evidence, we butchered an adult female
46 American bison (*Bison bison*) using replicas of Middle Palaeolithic stone tools. This experiment
47 was carried out as part of the collective research project “Des Traces et des Hommes” (coord. C.
48 Thiébaud: Thiébaud *et al.* 2019). Our goal was to test potential correlations between stone tool
49 types or particular raw materials and specific activities, characterize use-wear generated on stone
50 tools for each activity, and build an interpretative framework for cut-marks that allow traces on large
51 ungulate bones to be linked to a specific stage of the butchery process. This is of particular
52 importance for bison, as this species is frequently encountered on archaeological sites (e.g. Speth
53 1983; Todd and Frison 1992; Farizy *et al.* 1994; Gaudzinski 1996; Frison 2004; Johnson and
54 Bement 2009; Rodríguez-Hidalgo *et al.* 2017) and no reference collection is currently available for
55 this large ungulate. Here we present the results of our butchery experiment, paying particular
56 attention to the cut-mark data, and explore whether the coding system for medium-sized ungulates
57 is equally applicable to bison. To this end, we mobilized data from butchery experiments involving
58 red deer carried out within the framework of the same collective research project (Soulier and
59 Costamagno 2017; Costamagno *et al.* 2019).

60

61 **2. Material and methods**

62 The bison (*Bison bison*) carcass was butchered in April 2011, 48h after its death. This 300
63 kg, twenty-year old adult female was raised at the ‘Randals Bison’ park (Lanuéjols, France) and
64 transported in a refrigerated truck. In order to reliably recognize and interpret traces left on both
65 stone tools and bones, the experiment was designed to avoid as much as possible carrying out
66 more than one activity on the same area of a bone, and only one tool was used in a given activity.
67 For example, the circular incision in the skin was made at mid-diaphysis on the metacarpals such
68 that the tendons could be cut at the proximal and the distal end of the bone. This ensured that cut-
69 marks potentially generated by these activities, could be reliably recorded. As control, the entire
70 experiment was videotaped¹, photos were taken, and all contacts between the tool and bone as

¹A short film (in French) for also been made available under a free Creative Commons-BY-SA-3.0 license and can be viewed at <http://traces-et-hommes.revolublog.com/decoupe-de-bison-c17394045>. This video footage can be freely

71 well as tool motions were recorded for each activity on a dedicated data sheet. The butchery
72 experiment involved several types of stone tools, including hafted examples, made of various raw
73 materials (Table 1). All butchery activities were carried out by several archaeologists familiar with
74 bison anatomy and experimental carcass processing, with two professional butchers present to
75 provide advice on how to best process the carcass.

76

77 A total of 35 stone tools were used during the butchery experiments. Surgical plasticine
78 molds were made of the edges of the stone tools before and after butchery in order to identify
79 macro- and micro-traces. Related lithic use-wear data have already been partially published (Claud
80 and Thiébaud 2011; Claud *et al.* 2015, 2019). The leg bones were soaked in water with enzymes
81 and the axial skeleton buried for a year in order to be cleaned and prepared for the cut-mark
82 analysis. Bones were observed by two zooarchaeologists (M.-C. S and S. C) under low-angled
83 light using a 30x magnifying hand-lens. All cut-marks were recorded on Adobe Illustrator© bone
84 templates and, for ease of presentation, cut-mark distributions on left and right bone elements and
85 each group of vertebrae and ribs were combined on the same anatomical drawing. The action that
86 created them was then deduced from the contact sheets filled out during the butchery experiment.
87 Cut-mark orientations on the meat-bearing long bones were assessed and quantified using QGIS
88 (version 3.4.11 Madeira). In order to better visualize the data, a 6-part division is shown on figures
89 depicting cut-marks on meat-bearing long bones (1 proximal and 6 distal portions).

90

91

92 **3. Carcass Processing Protocol**

93

94 The carcass was entirely processed on the ground. For health reasons, the bison was
95 already eviscerated via an opening cut in the abdomen. The first stage of the butchery process,
96 skinning (blue and gray areas in Fig. 1), was begun from this incision, with a cut made along the
97 throat and a circular incision around the neck. Circular incisions were then made mid-diaphysis on
98 both metacarpals of the front legs. For the right front leg, a longitudinal incision was made on the
99 inner side, along the limb to the ventral incision for evisceration. For the left leg, this longitudinal
100 incision started on the inner side from the metacarpal to the radio-ulna, and continued on the
101 anterior face on the humerus. As the proximal diaphyses of the metatarsals had been broken at the
102 slaughterhouse, a circular incision was unnecessary on the hind legs. On both sides on the hind
103 legs, this longitudinal incision was made on the inner face of the legs from the metatarsals up to
104 the ventral cut made for evisceration. For the axial skeleton, the skin was removed longitudinally,
105 pulled from the ventral incision to the spine. The skin was subsequently removed from the lower
106 legs, starting from the circular incision on the metacarpals and the broken area of the metatarsals.

107 A longitudinal incision was then made on the inner face of both rear legs, on the anterior face of the
108 right hind-leg and on the lateral face on the left one. The remnant skin was removed via a circular
109 incision made as close as possible to the hooves, which on a bison is at the level of the second
110 phalanx. For the head, the skin was first removed from the mandible, beginning with an incision
111 along the lower teeth, and then removing the skin from the body of the mandible with a motion from
112 the teeth to the ventral face of the mandible. The skull was skinned by first making an incision
113 along the teeth, and then moving upward.

114 As much meat as possible (cf *infra*) was recovered from all anatomical elements,
115 including the head. The carcass was disarticulated (red area in Fig. 1) after defleshing in a manner
116 consistent with the storage of bones for later use. The head was removed with three direct blows
117 with a hafted quartzite cleaver at the junction with the atlas vertebra. Once defleshed, the mandible
118 was detached by cutting and twisting. The sternum was separated from the ribs using hafted
119 quartzite cleavers, with the surface scraped beforehand to facilitate breakage. The right side ribs
120 were separated from the vertebrae, with ribs 2, 3 and 4 forcibly detached once the sternum was
121 opened, while ribs 5 to 13 were broken using a cleaver at the proximal end of the rib. The pelvis
122 was separated from the trunk by percussion at the 4-5th lumbar vertebrae junction. The limb bones
123 were disarticulated using cutting motions involving different tools and raw material according to the
124 leg (see Table 1). Extensor and flexor tendons were removed from the lower legs, and we
125 attempted to extract the horny outer covering of the hooves.

126

127

128 **4. Results**

129

130 A total of 2203 cut-marks were recorded on the butchered bones (Table 2). Despite paying
131 particular attention to avoid performing multiple activities at a same location, this was not always
132 possible. For example, tool/bone contacts on the pelvis were signaled by the experimenter during
133 both disarticulation and defleshing; however, due to the mass of flesh, it was difficult to precisely
134 identify the location of these contacts. Consequently, reliably interpreting cut-marks in certain areas
135 of the carcass is complicated. Moreover, cut-marks were identified in certain areas despite no
136 contact being reported during butchery, making it difficult to assign them to a particular activity. Cut-
137 marks impossible to reliably assign to a specific butchery activity are shown in gray in the figures.

138

139 **4.1 Skinning**

140 Removing the skin from the bison's head produced cut-marks on the maxilla, just above
141 the cheek teeth, as well as on the vestibular surface of the teeth, around the orbital zone, and on
142 the nasal and frontal bones (Fig 2a). The circular incision around the nose left multiple transverse
143 cut-marks both on the nasal bones and premaxilla. Cut-marks on the tympanic bulla are connected
144 to the removal of the ears during the skinning process. Skinning the jaw (Fig. 2b) generated cut-

145 marks on teeth, both on cheek teeth and the third incisor, at the periphery of the mental foramen
146 and the corpus of the mandible up to the mandibular angle. Transverse cut-marks were recorded
147 on the palmar edge of the mandible, slightly extending to the lingual side.

148 On the legs, the circular incisions made at mid-diaphysis on the metacarpals are clearly
149 visible, with transverse and clustered cut-marks evident on the medial face of both metacarpals
150 (Fig. 3a). No circular incision was made on the metatarsals (see above). The second circular
151 incision made as close as possible to the hooves generated transverse and clustered cut-marks on
152 the mesial phalanges of the rear legs (Fig 3e). Scattered, oblique or sub-transverse cut-marks
153 were left on the metacarpals and the metatarsals as well as the phalanges when stone tools were
154 used in an oblique motion to detach the skin. Whether on the metacarpals, the metatarsals or the
155 associated short bones, no longitudinal cut-marks were produced by the longitudinal incision in the
156 skin, even when made on the lateral or medial faces where the skin is in direct contact with the
157 bone.

158

159 **4.2 Defleshing**

160 The carcass was nearly completely defleshed, with very little meat remaining on the
161 bones after the experiment (Fig. 4). Just over 140kg of meat was recovered, with the axial skeleton
162 producing 53kg and the two femurs an identical amount. Considering the mass of meat recovered,
163 the front legs appear to be substantially less interesting. The proportions of meat recovered from
164 the legs are very similar to what was observed by Emerson (1990:432) for a 16-year-old female
165 *Bison bison*, where the femur accounted for 58% of the meat retrieved from the appendicular
166 skeleton.

167

168 All the meaty long bones bear cut-marks produced during defleshing, comprising 87 %
169 (N=741) of all cut-marks observed on the long bones. Cut-marks are evident across the entire
170 diaphysis (Fig. 5). Cut-marks linked to defleshing are also present on or around several articular
171 extremities, such as the tibia plateau. Defleshing cut-marks are mostly transverse or oblique, and
172 longitudinal cut-marks produced by defleshing represent less than 3% of all marks on long bones
173 (Table 3).

174

175

176 Significant numbers of cut-marks connected to defleshing were also recorded on the
177 scapular and pelvic girdles (cf Fig. 2c&d), most of which are longitudinal and elongated. On the
178 axial skeleton, most cut-marks are also longitudinal (i.e. aligned with the cranio-caudal axis).
179 Defleshing related cut-marks on vertebrae (Fig. 6) primarily occur on the spinous process (axis;
180 thoracic 1 to 5 and 7 to 10; lumbar 3 to 5) and on the transverse processes (cervical 5 and 6;
181 thoracic 1, 4 to 11, 13, 14; lumbar 1, 3 to 5). Cut-marks are less frequently positioned close to the
182 cranial or caudal articular process (axis, cervical 4 and lumbar 2), near the *fovea costalis* inferior

183 (thoracic 3) or near the inferior articular process (cervical 4 and thoracic 4). On the axis, defleshing
184 cut-marks are also evident on the vertebral body as well as on the lamina and on both the ventral
185 and dorsal faces of the atlas.

186 Cutmarks are mostly located at the neck and on the head of the ribs and occur both on the ventral
187 and the dorsal faces (Fig. 7). They occur less frequently on the shaft and the sternal extremity, and
188 only one is evident on the articular facets.

189

190 Flesh was also removed from the head, especially the cheeks, leaving cut-marks on the
191 maxilla and the ascending ramus when the masseter muscle was removed (Fig. 2a). The removal
192 of the tongue (Fig. 2b) produced oblique cut-marks on the lingual side of the mandible, with more
193 transverse examples occurring just below the jugal teeth on the lingual face. Long longitudinal cut-
194 marks are also present near the symphysis (lingual side).

195

196

197 **4.3 Disarticulation**

198 After being defleshed, the entire carcass was disarticulated. The head was removed by percussion
199 with a hafted cleaver, splitting one of the occipital condyles (Fig. 8a). Some tearing is observable
200 on the atlas vertebrae (Fig. 8b), probably resulting from the twisting of the head, and is associated
201 with cut-marks on the cranial articulation (Fig. 2). The separation of the skull from the jaw left cut-
202 marks on the zygomatic, the ascending ramus and on the distal face of the upper third molar. The
203 rib cage was dislocated by percussion with a hafted flake cleaver, producing several fractures. The
204 right transverse process is entirely or partially broken on 6 of the final thoracic vertebrae (thoracic 9
205 to 11 and thoracic 13 to 15), as well as the caudal articular facet of the 14th thoracic vertebrae.
206 Tearing is evident on the *fovea costalis* of the second thoracic, linked to the removal of the 3rd rib
207 by flexion. All but the first and last right ribs were broken when removed from the spinal column
208 (Fig. 8e). Although the left ribs were left attached to the vertebrae, three (rib 3, 8, 13) were
209 nevertheless fractured by a blow brought to the other side of the rib cage. The opening of the
210 sternum by percussion did not leave any marks on the ribs. The anterior and posterior portions of
211 the carcass were separated by percussion at the 4-5th lumbar junction, which broke the 4th lumbar
212 in 3 pieces. The mamillary process of the 5th lumbar was broken and chopmarks are evident on the
213 body of this vertebra and on the spinous process of the sacrum (Fig. 8c).

214

215

216 Of the 850 cut-marks identified on the long bones, only 11 % (n=94) were produced during
217 disarticulation (Table 4). Interestingly, 30% of these marks are orientated longitudinally. The
218 detachment of the entire leg from the body and the disarticulation of the humerus produced no cut-
219 marks on the scapula. No cut-marks were produced on the humerus when it was separated from
220 the scapula. The disarticulation of the humerus and radio-ulna (Fig. 5), on the other hand,

221 generated several cut-marks on the distal part of the humerus of both legs as well as on the
222 olecranon, close to the trochlear incision of the radius. A small crushed area can be observed on
223 the anconeal process (Fig. 8d), probably resulting from twisting during disarticulation. The
224 disarticulation of the forelimb was followed by separating the radius from the first row of carpals.
225 Cut-marks are observable on the right pyramidal and on both legs on and around the ulnar styloid
226 process as well as on the semi-lunars and the scaphoids.

227

228 Due to the very large muscle mass around the pelvic girdle, which requires both defleshing and
229 disarticulation at the exact same place, only cut-marks located on the femoral head (Fig. 5c) can
230 be confidently attributed to disarticulation, as their location and orientation match those reported by
231 the butcher. Separating the femur from the tibia generated cut-marks on both of the femoral medial
232 condyles as well as on the tibial plateau (Fig. 5). Numerous cut-marks were produced when
233 disarticulating the tibia and tarsal bones, especially on the medial face of the talus, but also on the
234 calcaneum and the cuboid (Fig. 3). Several cut-marks are also observable on the distal part of the
235 tibia and on the malleolus. The dislocation of the metacarpophalangeal joint left cut-marks on the
236 distal condyles of the metacarpal, close to the proximal articulation of the first phalanges and on
237 the sesamoids. Cut-marks on the hind legs are uniquely observable near the proximal articulation
238 of the second phalanx. Finally, cut-marks are evident on the abaxial side of a second phalanx,
239 produced when the axial and abaxial phalanges were separated from each other.

240

241 **4.4 Tendon removal**

242 Cutting the flexor and extensor tendons (Fig. 3) on the front leg with an upward motion left cut-
243 marks on the distal half of the pyramidal, the upper part of the hamate bone and on the capitate-
244 trapezoid, and on the upper portion of the posterior face of the first phalanges. On the hind leg, this
245 cutting motion created cut-marks on the proximal portion of the anterior face, the condyles of the
246 metatarsal, and on the first phalanx. Oblique and longitudinal cut-marks were also produced on the
247 diaphyses of the metapodials, on the sesamoids and phalanges when tools were used in a
248 longitudinal motion between the bone and the tendon.

249

250

251 **5. Discussion**

252 Butchery experiments are a necessary first step towards a better understanding of cut-marks on
253 bison as well as large ungulates in general. Although the cut-mark dataset produced during our
254 experiment is relatively limited due to the processing of a unique carcass, several interesting
255 patterns can nevertheless be observed

256

257 Correspondence with cut-mark patterns on medium-sized ungulates

258 The cut-mark data presented here are almost entirely in agreement with previously published data
259 for medium-sized artiodactyles (Soulier and Costamagno 2017; Costamagno *et al.* 2019). Of the
260 135 cut-mark codes documented here², 127 perfectly match the medium-sized artiodactyls dataset
261 (detailed table available here: <https://figshare.com/s/336e50835696f3d0aff8>). Some discrepancies
262 are however evident with cut-marks produced by activities differing from those previously docu-
263 mented for medium-sized ungulates. The least consistent codes come mostly from the vertebrae (4
264 of the 8 non-concordant codes), where several cut-marks that would normally be interpreted as
265 linked to disarticulation based on medium-sized ungulates data (Nilssen 2000; Costamagno *et al.*
266 2019) were produced by defleshing.

267

268 Our data further highlights the need for caution when interpreting cut-marks near articular
269 extremities, as 63% of the cut-marks located in these areas (portions 1 & 6) in our experiment
270 result from defleshing instead of dismemberment.

271

272 No codes existed for several locations and/or orientations, meaning that new ones were created for
273 the butchery of the bison (N=83; Fig. 9). As was done for red deer (Soulier and Costamagno 2017),
274 these codes incorporate data collected by Nilssen (2000) for the butchery of large ungulates in
275 South Africa³.

276

277

278 *Cut-mark incidence: the influence of stone tools, raw material, experimenter and carcass size*

279 Cut-mark orientations are roughly similar to those documented for red deer as part of the same
280 collective research project and hence butchered by same people. Upon closer examination,
281 several differences are however evident (Table 5). Fewer longitudinal cut-marks were generated on
282 the bison bones during defleshing (5.7% on the red deer vs 2.8% on the bison), while more
283 longitudinal cut-marks were produced during disarticulation on the bison (31%) compared to the
284 red deer (11%). However, this does not necessarily demonstrate the disarticulation of a bison to
285 produce more longitudinal cut-marks compared to medium-sized ungulates as 1) longitudinal cut-
286 marks produced during disarticulation mostly occur on the right femoral head and right humeral
287 trochlea (although different butchers were involved) and no cut-marks were produced in these
288 areas for the left limbs, and 2) longitudinal disarticulation marks were also generated in these
289 areas during the disarticulation of the red deer (see fig 5 in Soulier and Costamagno 2017).

290

291 The participation of multiple experimenters, raw materials and tools makes it difficult to explain
292 these differences. The two participants (Butcher V. & Butcher M.) who butchered the red deer with
293 a quartzite cleaver produced cut-marks distributed in comparable proportions in terms of

2 Codes already identified as ubiquitous (means that can be created by several activities) excluded

3 Note that Nilssen's "Large bovid" class includes a large weight range (~from 80kgs to 600kgs) comprising 1 Blesbok, 3 Black Wildebeest and 3 Eland.

294 orientation (Table 6). In contrast, Butcher M. produced significantly different proportions of cut-mark
295 orientations on the bison, notably transverse cut-marks. Carcass size therefore might influence the
296 orientation of cut-marks produced during defleshing, perhaps connected to the likelihood that a
297 heavier and therefore less manageable carcass constrains butchering movements. More focused
298 experiments are necessary to shed additional light on the relationship between cut-mark
299 orientation and carcass size.

300

301 Carcass size has been suggested to influence, positively or negatively, the frequency of cut-marks
302 produced on bones (Egeland 2003; Dominguez-Rodrigo and Barba 2005; Pobiner and Braun
303 2005). Our dataset shows that despite using the same type of tool/raw material (i.e. a quartzite
304 cleaver), a greater number of cut-marks were produced on the bison compared to the red deer
305 (Table 6). However, this difference is based on the total *number* of cut-marks counted on *complete*
306 bones. In archaeological assemblages bones are *fragmented*, and it is often the *percentage* of
307 fragments bearing at least one cut-mark that is used for analysis. How differences in the total
308 number of cut-marks (as observed in our experiments) are related to cut-mark percentages (as
309 reported in most zooarchaeological studies) is still poorly understood and requires further research.

310

311

312 Cutmarks and cleaning treatment

313 Several of the cut-marks observed on the bison bones are superficial and may not be preserved on
314 archaeological material as a result of post-depositional alterations. These superficial traces were
315 primarily observed on the leg bones compared to the axial skeleton and, interestingly, these two
316 sections were cleaned in different ways. Prolonged immersion in water with enzymes appears to
317 slightly attack the bone surface and is therefore an unsuitable cleaning process for experiments
318 focused on the analysis of cut-marks.

319

320

321 Tool efficiency

322 In addition to exploring cut-mark distribution and frequency, our bison butchery experiment equally
323 aimed to investigate the function and efficiency of different typical Middle Palaeolithic tools. As
324 detailed use-wear data for these tools has been published elsewhere (Claud and Thiébaud 2011;
325 Claud *et al.* 2015, 2019), here we focus uniquely on tool efficiency. During our experiments,
326 quartzite tools proved more difficult to handle during butchery, as the grease quickly settled in the
327 pores of the quartzite, making it necessary to constantly clean them. On the other hand, the
328 quartzite cleavers proved to be extremely efficient for disarticulating the bison carcass by
329 percussion. Moreover, hafting the cleavers both increased the force of the blow and avoided
330 fatiguing the user by absorbing part of the shock. The hafting of two small quartzite pseudo-
331 Levallois points equally increased their ease of use, as these pieces were very uncomfortable to

332 use when held in the bare hands. Moreover, the thin handles on to which the points were fixed did
333 not hinder the tool penetrating the flesh and were very quick to fashion (partially split wooden stick).

334

335

336 **6. Conclusion**

337

338 Several reference collections resulting from controlled butchery experiments are currently available
339 for the interpretation of cut-marks on small and medium-sized species. The analysis of cut-marks
340 sheds light on the activity that produced them, which, in turn, permits a more accurate reconstruc-
341 tion and understanding of the butchery *chaîne opératoire* of past human groups. In particular, ex-
342 periments butchering red deer have linked cut-mark orientation and distribution with specific butch-
343 ering activities (Soulier and Costamagno 2017; Costamagno *et al.* 2019). The applicability of this
344 approach to larger mammals has, however, remained difficult to assess. Our experiment further
345 strengthens the interpretive potential of this analytical tool, providing a new dataset for large bovids,
346 a family that was frequently exploited throughout the Palaeolithic and into later periods. Our results
347 confirm the applicability of the red deer butchery data for the interpretation of cut-marks on large
348 ungulates, such as bison albeit with some adjustments to the analysis, especially elements of the
349 spinal column. Differences observed in cut-mark orientations on the bison long bones compared to
350 what was documented for medium-sized ungulates needs to be explored more thoroughly, includ-
351 ing additional experiments and a better appreciation of the impact of tools and butchers.

352

353

354 **Acknowledgments**

355 Our warmest thanks go to the Regional Archaeology Service of the Midi-Pyrénées region
356 for financial assistance to this multi-year collective project. This project has been very stimulating in
357 terms of research questions and has deeply enriched our capacity to visualize the lifeways of
358 prehistoric societies. We are very grateful to our colleagues who participated in the experiment,
359 especially Michel Brenet, Stéphane Brenet, Aude Coudenneau, David Colonge, Marie-Pierre
360 Coumont, Jean-George Ferrié, Jessica Lacarrière, Vincent Mourre, Célimène Mussini, and Aurore
361 Val. A special mention goes to Céline Thiébaud, who coordinated the collective research project
362 over the last 10 years. We would also like to acknowledge the French National Institute of Rescue
363 Archaeology (INRAP) for allowing several of its members to participate in this project. Thanks also
364 go to the Natural History Museum of Toulouse for cleaning the limb bones. Finally, we would like to
365 thank Emmanuel Discamps for his comments on the manuscript, Brad Gravina for the language
366 editing, and the SMP3C research team of the CNRS-UMR5608 for their continued support and
367 financing of the language editing.

368

369 **Bibliography**

- 370 Bez, J.-F. 1995. Une expérience de découpe bouchère pratiquée au silex : aspects anatomiques.
371 *Préhistoire Anthropologie Méditerranéennes* 4: 41–50.
- 372 Binford, L.R. 1981. *Bones: Ancient Men and Modern Myths*. Academic Press. New York.
- 373 Emerson, A. 1990. *Archaeological Implications of variability in the economic anatomy of Bison*
374 *bison*. PhD. Washington State University. Washington.
- 375 Nilssen, P. J. 2000. *An actualistic butchery study in South Africa and its implications for*
376 *reconstructing hominid strategies of carcass acquisition and butchery in the upper Pleistocene and*
377 *Plio-Pleistocene*. Ph. D. University of Cape Town. Cape Town.
- 378 Claud, E., Deschamps, M., Colonge, D., Mourre, V., Thiébaud, C. 2015. Experimental and
379 functional analysis of late Middle Paleolithic flake cleavers from southwestern Europe (France and
380 Spain). *Journal of Archaeological Science* 62: 105–127.
- 381 Claud, E., Thiébaud, C., Coudenneau, A., Deschamps, M., Mourre, V., Brenet, M., Chacón-
382 Navarro, M.G., Colonge, D., Lemorini, C., Maury, S., Servelle, C., Venditti, F. 2019. Le référentiel
383 des outils lithiques. In Thiébaud, C., Claud, E., Costamagno S. (eds), *L'acquisition et le traitement*
384 *des matières végétales et animales par les néandertaliens : quelles modalités et quelles*
385 *stratégies ?* Palethnologie, Toulouse: 56–194.
- 386 Claud, E., Thiébaud, C. 2011. Analyse du matériel lithique. In Thiébaud, C., Claud, E., Costamagno,
387 S. (eds.), *“Des Traces et des Hommes” : Projet de recherche interdisciplinaire sur l’identification des*
388 *modalités d’acquisition et de traitement des matières végétales et animales au Paléolithique*
389 *moyen en Europe occidentale*. Rapport annuel déposé au SRA Midi-Pyrénées: 230–259.
- 390 Costamagno, S., Soulier, M.-C., Val, A., Chong, S. 2019. Le référentiel de stries de boucherie. In
391 Thiébaud, C., Claud, E., Costamagno S. (eds), *L'acquisition et le traitement des matières végétales*
392 *et animales par les néandertaliens : quelles modalités et quelles stratégies ?* Palethnologie,
393 Toulouse: 195–291.
- 394 Domínguez-Rodrigo, M., Barba, R. 2005. A study of cut marks on small-sized carcasses and its
395 application to the study of cut-marked bones from small mammals at the FLK Zinj site. *Journal of*
396 *Taphonomy* 3: 121–134.
- 397 Egeland, C.P. 2003. Carcass Processing Intensity and Cutmark Creation: An Experimental
398 Approach. *Plains Anthropologist*: 48, 39–51.
- 399 Farizy, C., David, F., Jaubert, J., 1994. *Hommes et Bisons du Paléolithique Moyen à Mauran*
400 *(Haute-Garonne)*, XXX° Suppl. ed. Éd. du CNRS, Paris.
- 401 Frison, G.C. 2004. *Survival by Hunting: Prehistoric Human Predators and Animal Prey*. University
402 of California Press, Berkeley.

- 403 Gaudzinski, S. 1996. On Bovid Assemblages and their Consequences for the Knowledge of
404 Subsistence Patterns in the Middle Palaeolithic. *Proceedings of the Prehistoric Society* 62: 19–39.
- 405 Johnson, E., Bement, L. 2009. Bison butchery at Cooper, a Folsom site on the Southern Plains.
406 *Journal of Archaeological Science* 36: 1430–1446.
- 407 Laroulandie, V. 2001. Les traces liées à la boucherie, à la cuisson et à la consommation d’oiseaux.
408 Apport de l’expérimentation. In Bourguignon, L., Ortega, I., Frère-Sautot, M.-C. (eds.), *Préhistoire*
409 *et Approche Expérimentale*. Editions Monique Mergoïl, Montagnac: 97–108.
- 410 Lloveras, L., Moreno García, M., Nadal, J. 2009. Butchery, Cooking and Human Consumption
411 Marks on Rabbit (*Oryctolagus cuniculus*) Bones: An experimental Study. *Journal of Taphonomy* 7:
412 179–201.
- 413 Pobiner, B., Braun, D. 2005. Strengthening the Inferential Link Between Cutmark Frequency Data
414 and Oldowan Hominid Behavior: Results From Modern Butchery Experiments. *Journal of*
415 *Taphonomy* 3: 107–120.
- 416 Rodríguez-Hidalgo, A., Saladié, P., Ollé, A., Arsuaga, J.L., Bermúdez de Castro, J.M., Carbonell,
417 E. 2017. Human predatory behavior and the social implications of communal hunting based on
418 evidence from the TD10.2 bison bone bed at Gran Dolina (Atapuerca, Spain). *Journal of Human*
419 *Evolution* 105: 89–122.
- 420 Soulier, M.-C. 2021. Exploring meat processing in the past: Insights from the Nunamiut people.
421 *Plos One* 16: e0245213.
- 422 Soulier, M.-C., Costamagno, S. 2017. Let the cutmarks speak! Experimental butchery to
423 reconstruct carcass processing. *Journal of Archaeological Science: Reports* 11: 782–802.
- 424 Speth, J.D. 1983. *Bison Kills and Bone Counts: Decision Making by Ancient Hunters*. University of
425 Chicago Press. Chicago.
- 426 Todd, L., Frison, G.C. 1992. Reassembly of bison skeletons from the Horner Site: a study in
427 anatomical refitting. In Hofman, J.L., Enloe, J.G. (eds.), *Piecing Together the Past: Applications of*
428 *Refitting Studies to Archaeology*. BAR International Series 578, Oxford: 63–82.
- 429 Val, A., Mallye, J.-B. 2011. Small Carnivore Skinning by Professionals: Skeletal Modifications and
430 Implications for the European Upper Palaeolithic. *Journal of Taphonomy* 9: 221–243.

431 **Captions**

432 Fig 1 Schematic depiction of the butchery activities carried out during the bison experiment. The
433 locations of the circular incisions in the skin are indicated in blue (in grey: incisions made at the
434 slaughterhouse) and the disarticulation spots are in red (lines = cutting motions; circles = disarticu-
435 lation by percussion).

436

437 Fig 2 Cut-marks produced on the (a) skull, (b) mandible, (c) scapula, and (d) pelvis by activity:
438 black = defleshing; green = dismemberment; blue = skinning. In grey, cut-marks impossible to link
439 to a specific activity.

440

441 Fig 3 Cut-marks produced on the (a) metacarpal, (b) metatarsal, (c) sesamoids, (d) malleolus, (e)
442 phalanges, (f) carpals, (g) tarsals per activity: green = dismemberment; red = tendon removal; blue
443 = skinning. In grey, cut-marks impossible to link to a specific activity. * abaxial side of the medial
444 phalanx.

445

446 Fig 4 Meat remaining on a defleshed bison limb and weight of meat (kg) recovered per skeletal
447 element. Photo © “Des Traces et des Hommes”.

448

449 Fig 5 Cut-marks on the (a) humerus, (b) radio-ulna, (c) femur, and (d) tibia per activity: black =
450 defleshing; green = dismemberment. In grey, cut-marks impossible to link to a specific activity.

451

452 Fig 6 Cut-marks on the a) atlas, b) axis, c) cervical, d) thoracic, e) lumbar and f) sacrum vertebrae
453 per activity: black = defleshing; green = dismemberment (atlas); purple lines = chopmarks. Grey
454 cut-marks on the sacrum cannot be linked to a specific activity.

455

456 Fig 7 Cut-marks (in black) produced on the ribs during defleshing.

457

458 Fig 8 Splitting of a) the occipital condyles, b) the atlas, c) chopmarks on the sacrum, d) crushing on
459 the anconeal process of the ulna and e) breakage on the ribs (in red) produced during disarticula-
460 tion.

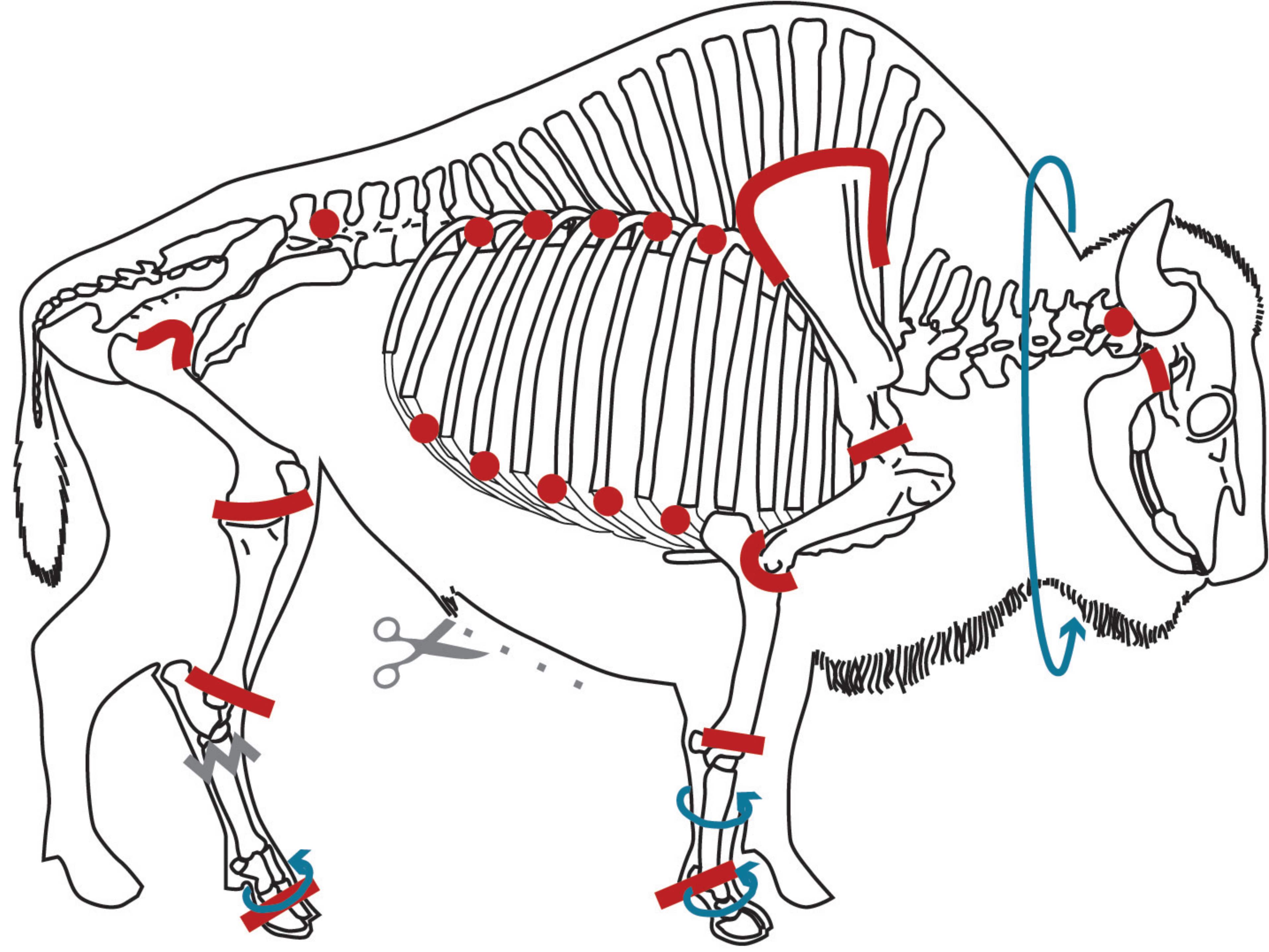
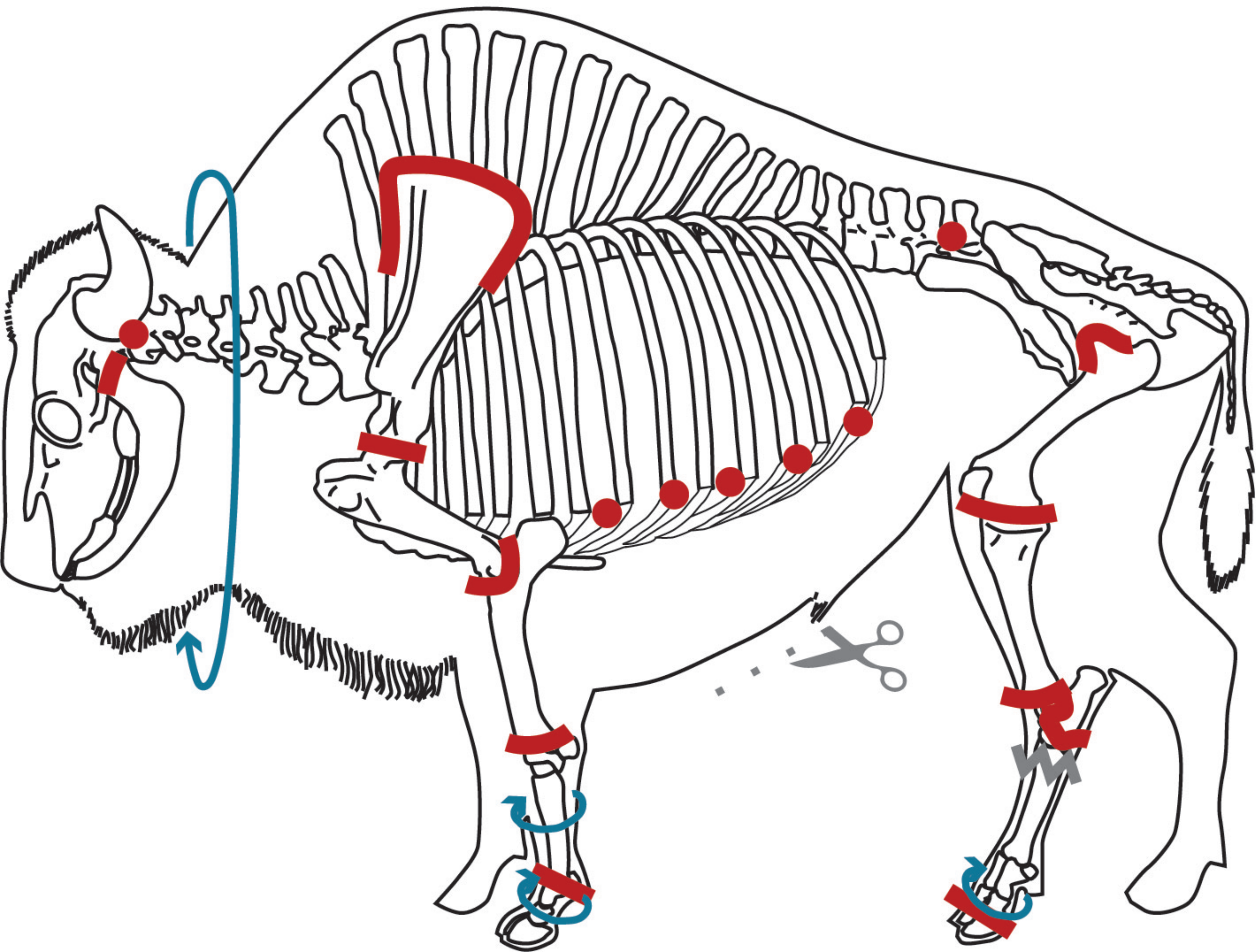
461

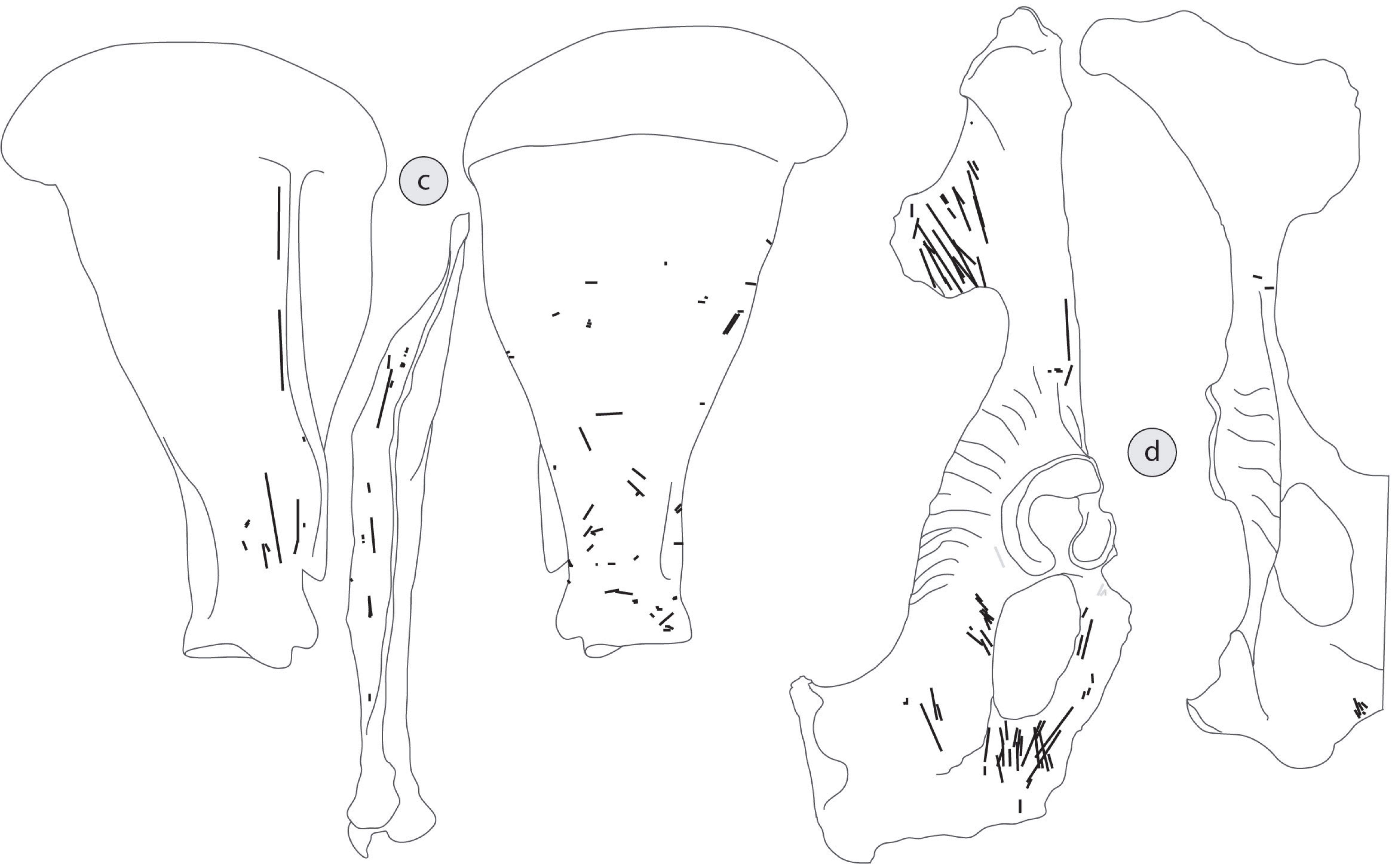
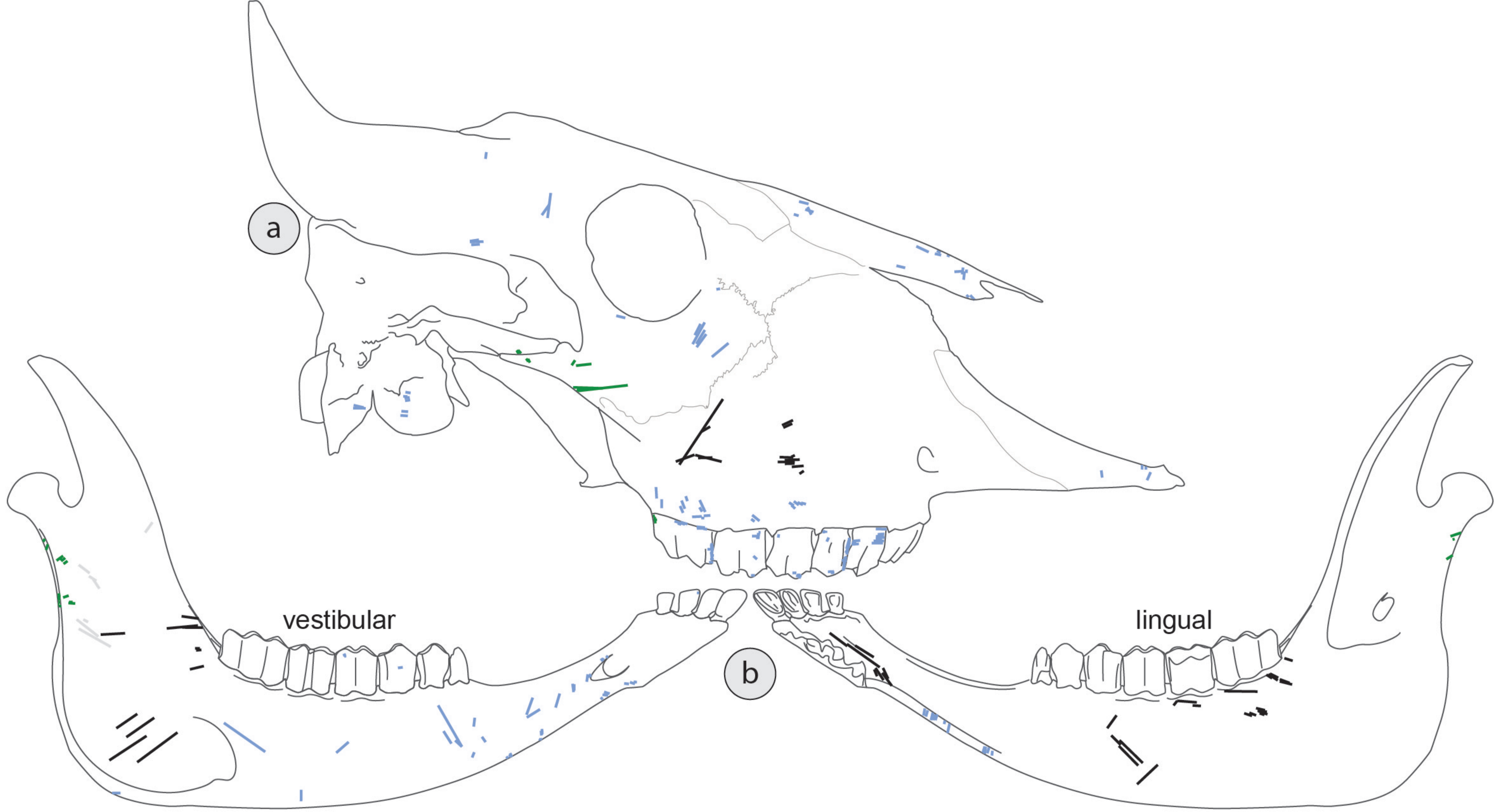
462 Fig. 9 New coded areas for undocumented elements (a) skull, e) ribs, j) pelvis), and new areas
463 created on previously coded elements (b) mandible lingual side, c) sacrum, d) atlas, f) radius distal,
464 g) metatarsal distal, h) lunate, i) calcaneum, k) first phalanx and l) second phalanx. Bluish tints are
465 for defleshing, reddish for disarticulation, greenish for skinning and yellowish for tendon extraction.
466 See <https://figshare.com/s/336e50835696f3d0aff8> for a descriptive table.

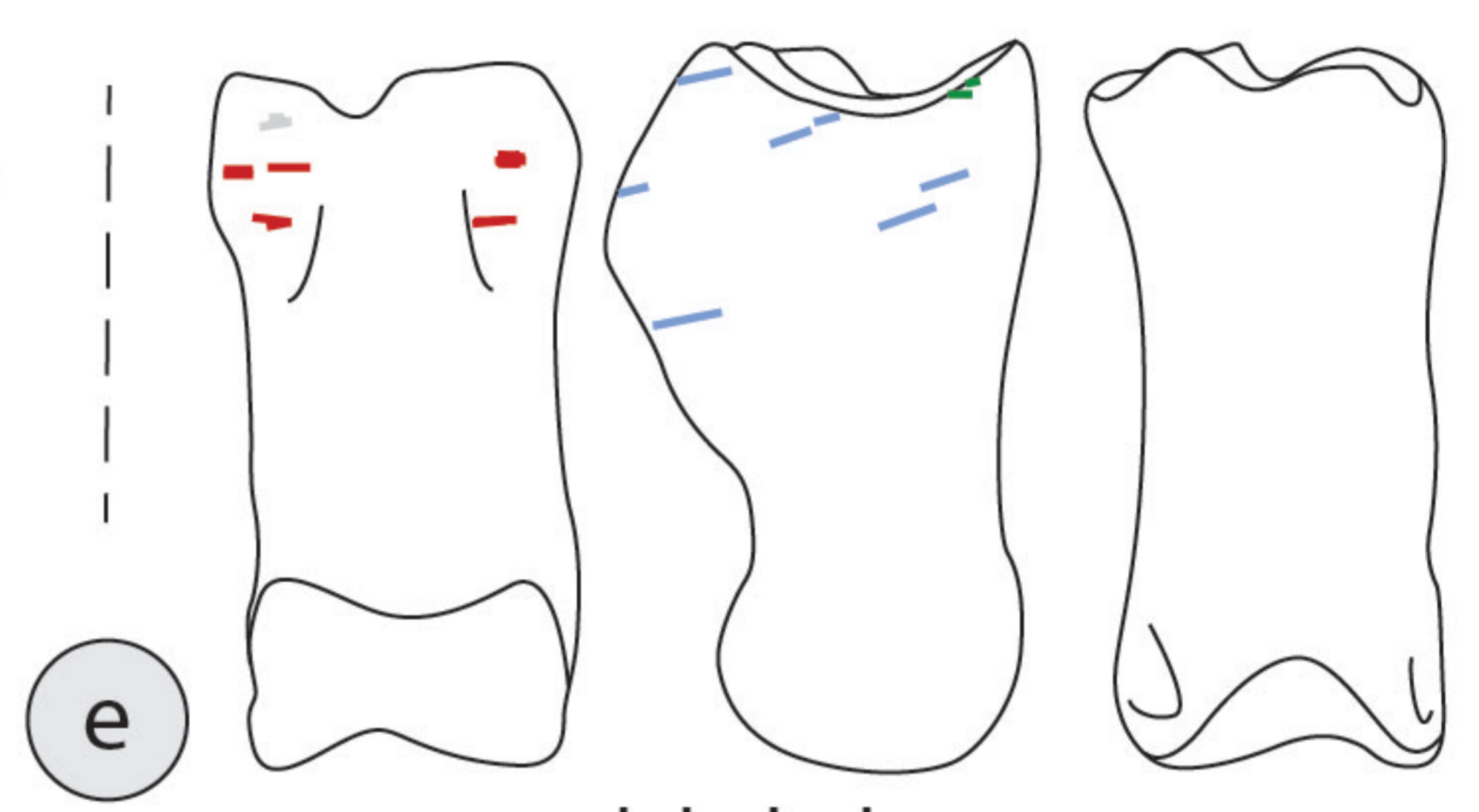
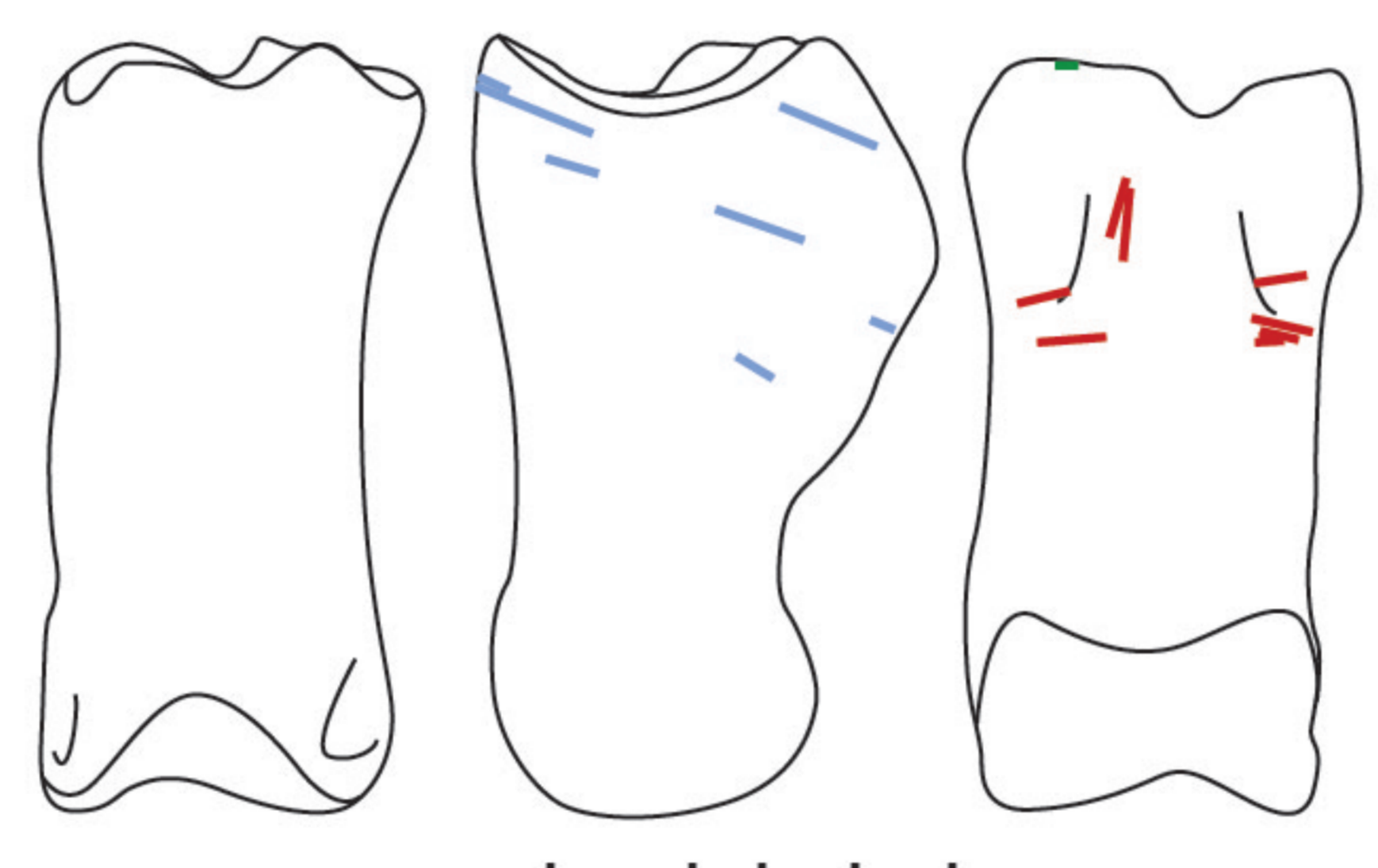
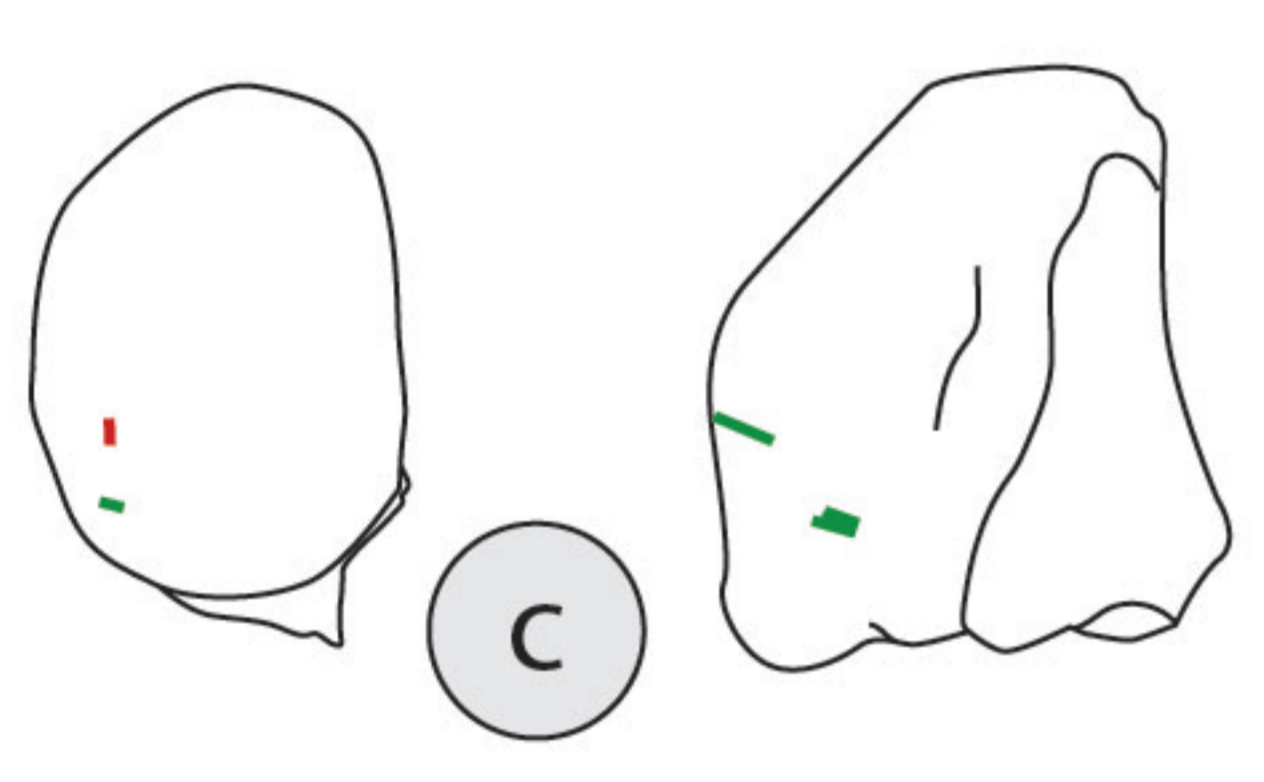
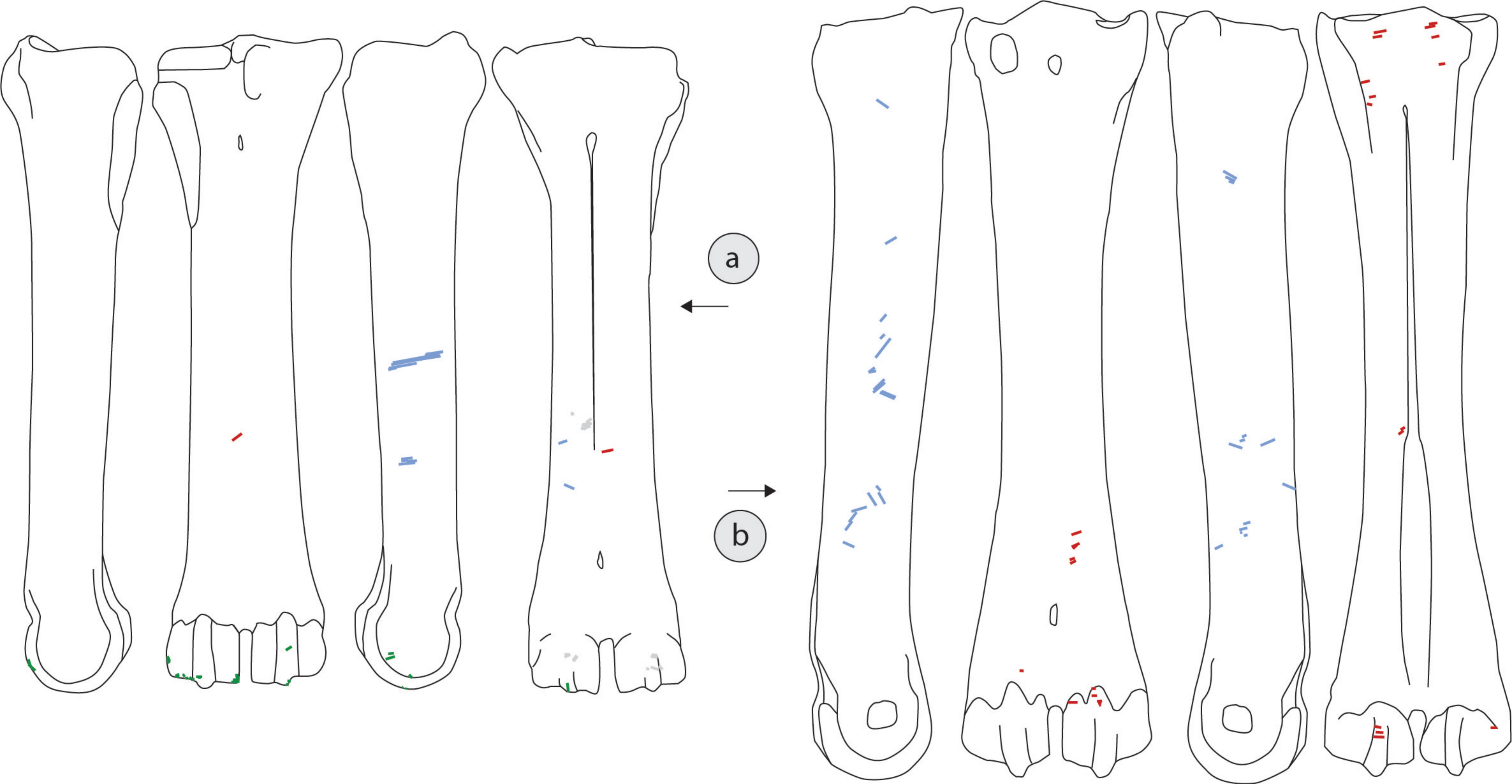
467

468

469 Table 1 Tools and raw materials (F=flint; Qzte=quartzite) used by activity.
470
471 Table 2 Total number of cut-marks produced on the bison by skeletal part.
472
473 Table 3 Orientation of the defleshing cut-marks on the meaty long bones. R = Right; L = Left
474
475 Table 4 Orientation of cut-marks produced by disarticulation. R = Right; L = Left
476
477 Table 5 Comparison of cut-mark orientation between bison and red deer. Red deer data derived
478 from drawings in Soulier and Costamagno 2017.
479
480 Table 6 Comparison of cut-marks made with the same tool/raw material (quartzite cleaver) on a
481 red deer and bison by two different experimenters.

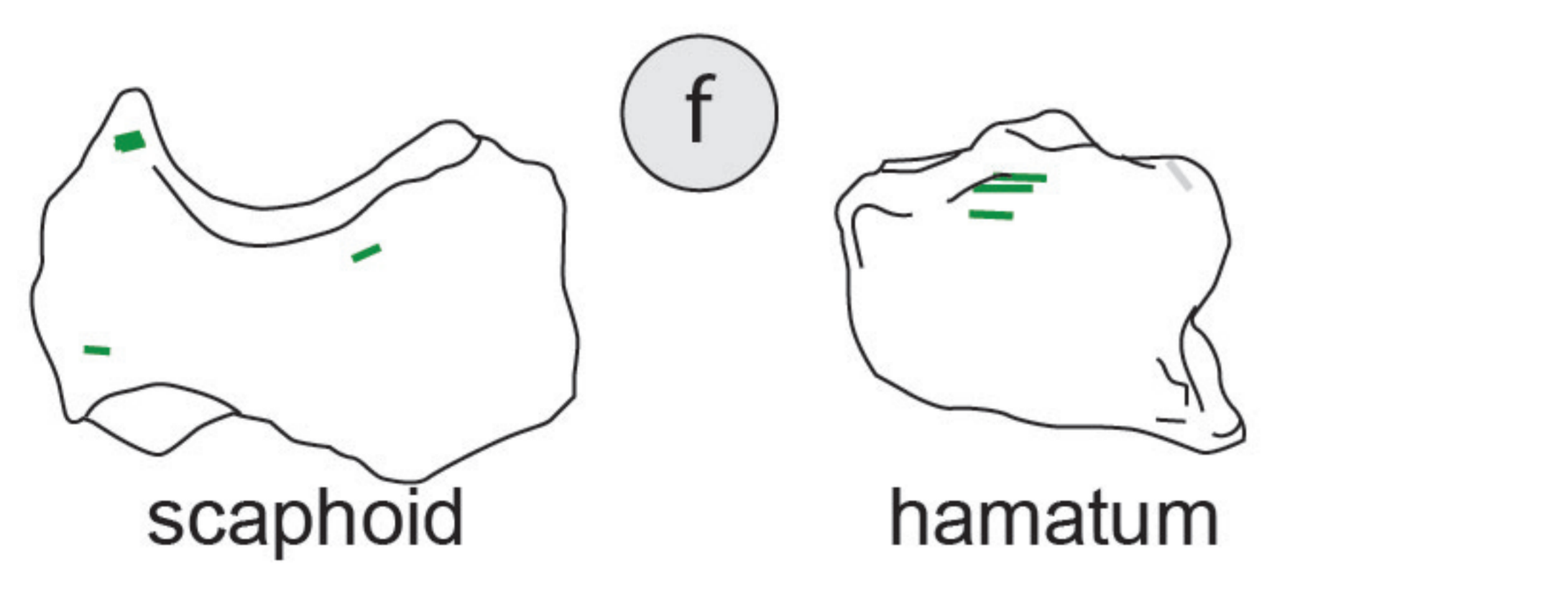
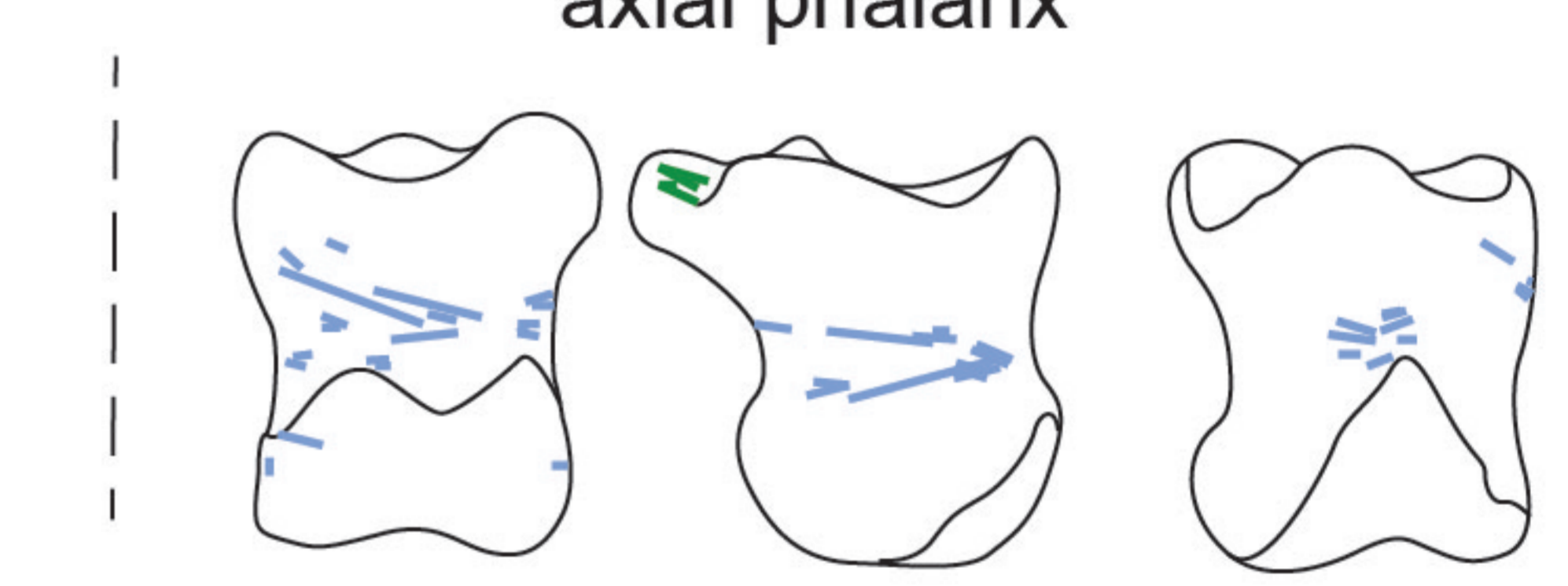
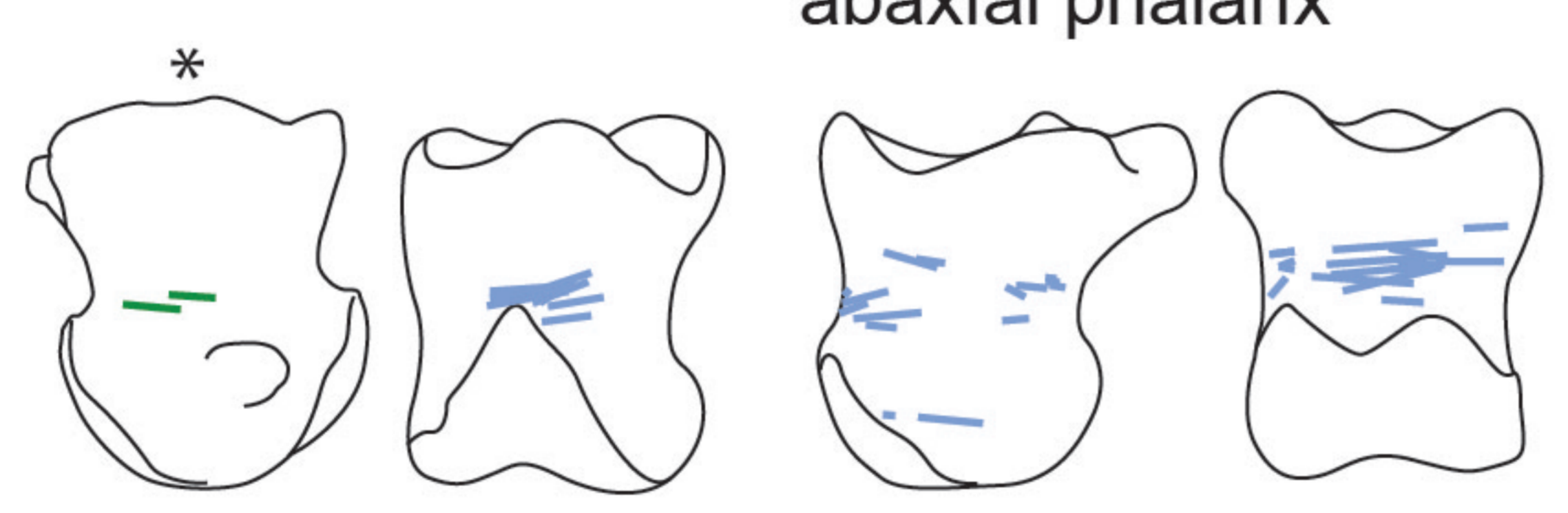
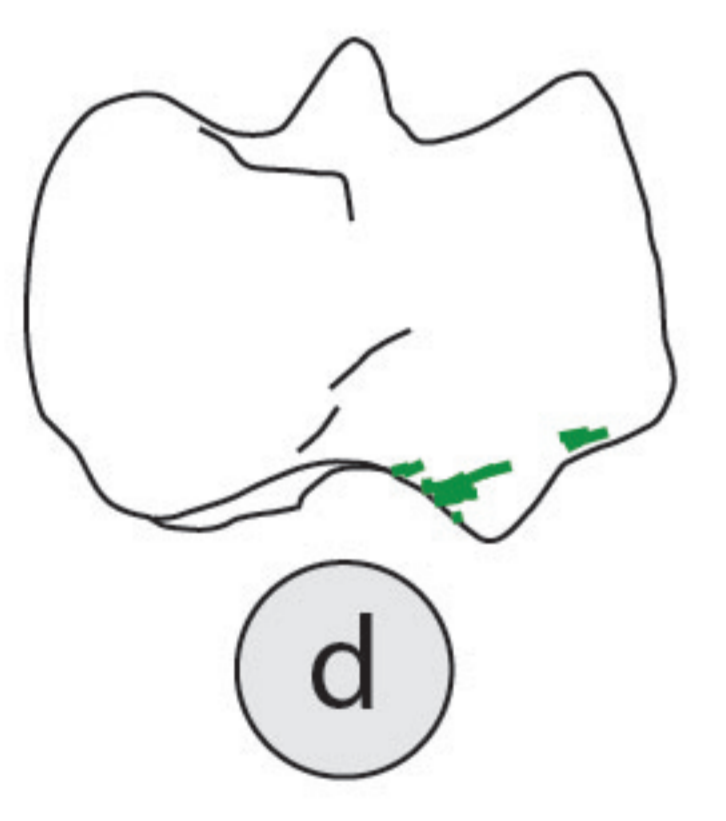






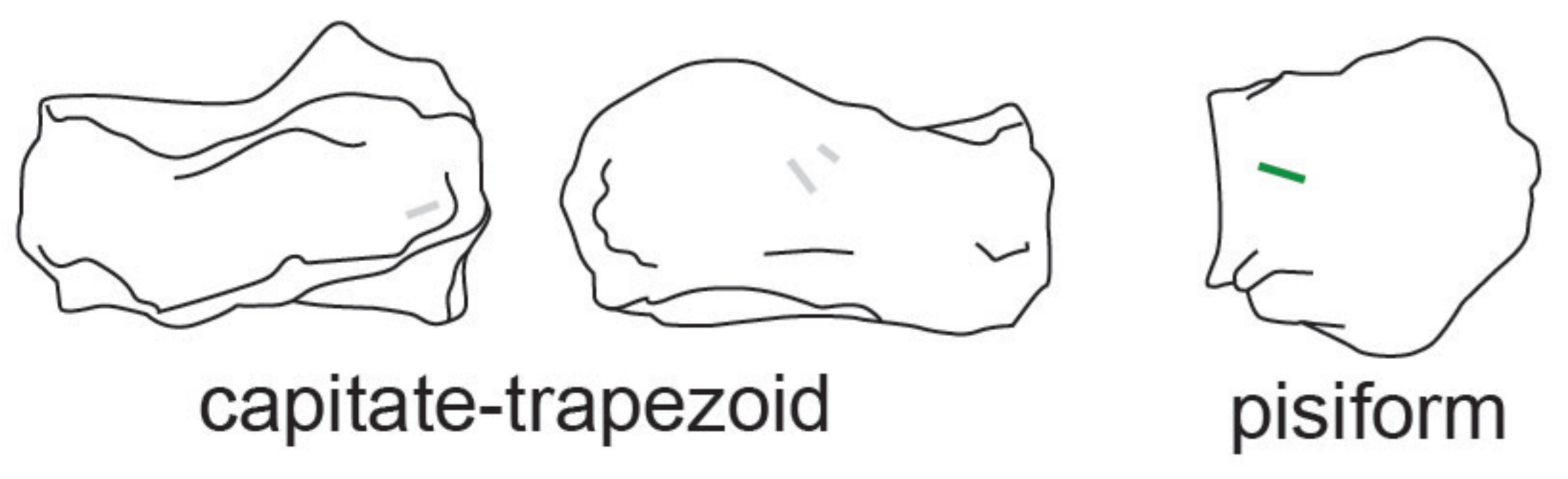
abaxial phalanx

axial phalanx



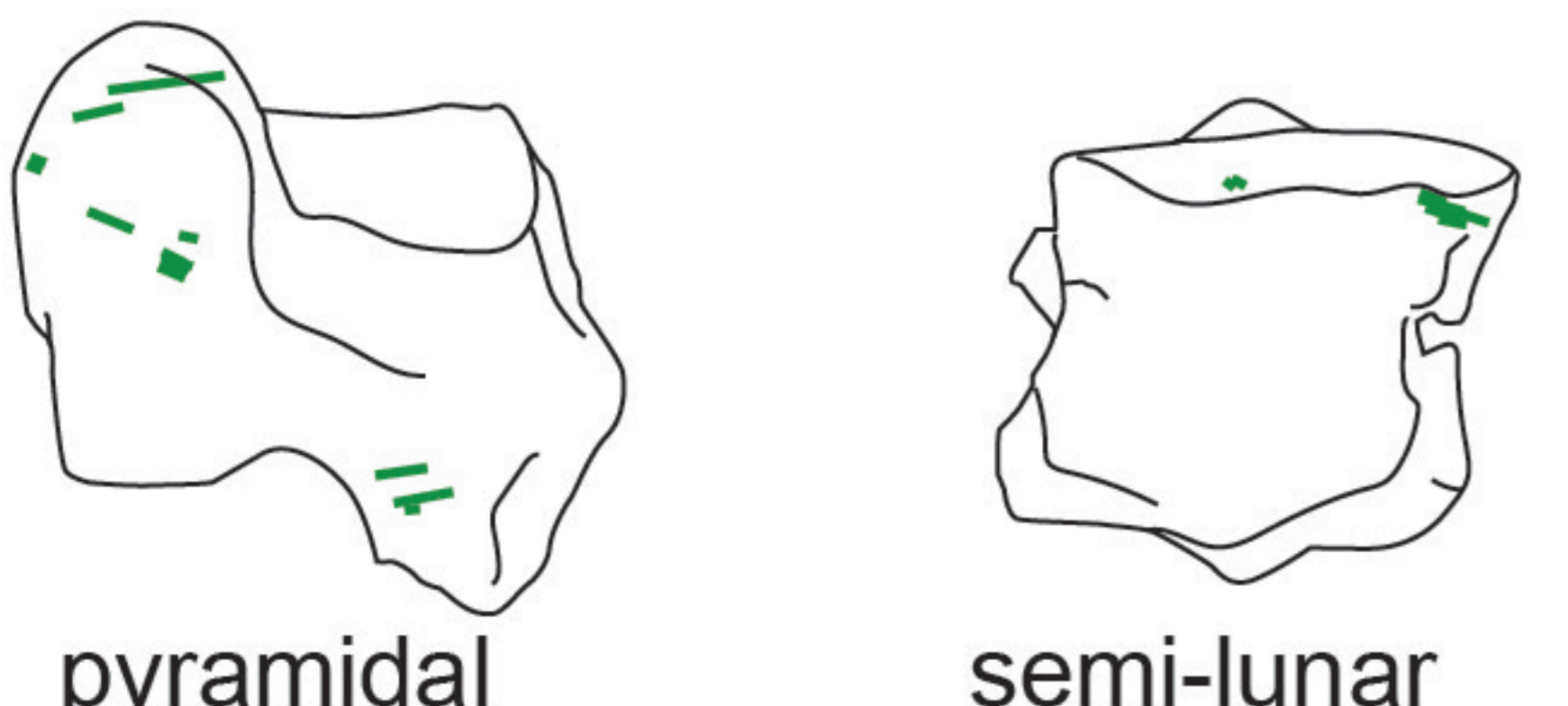
scaphoid

hamatum



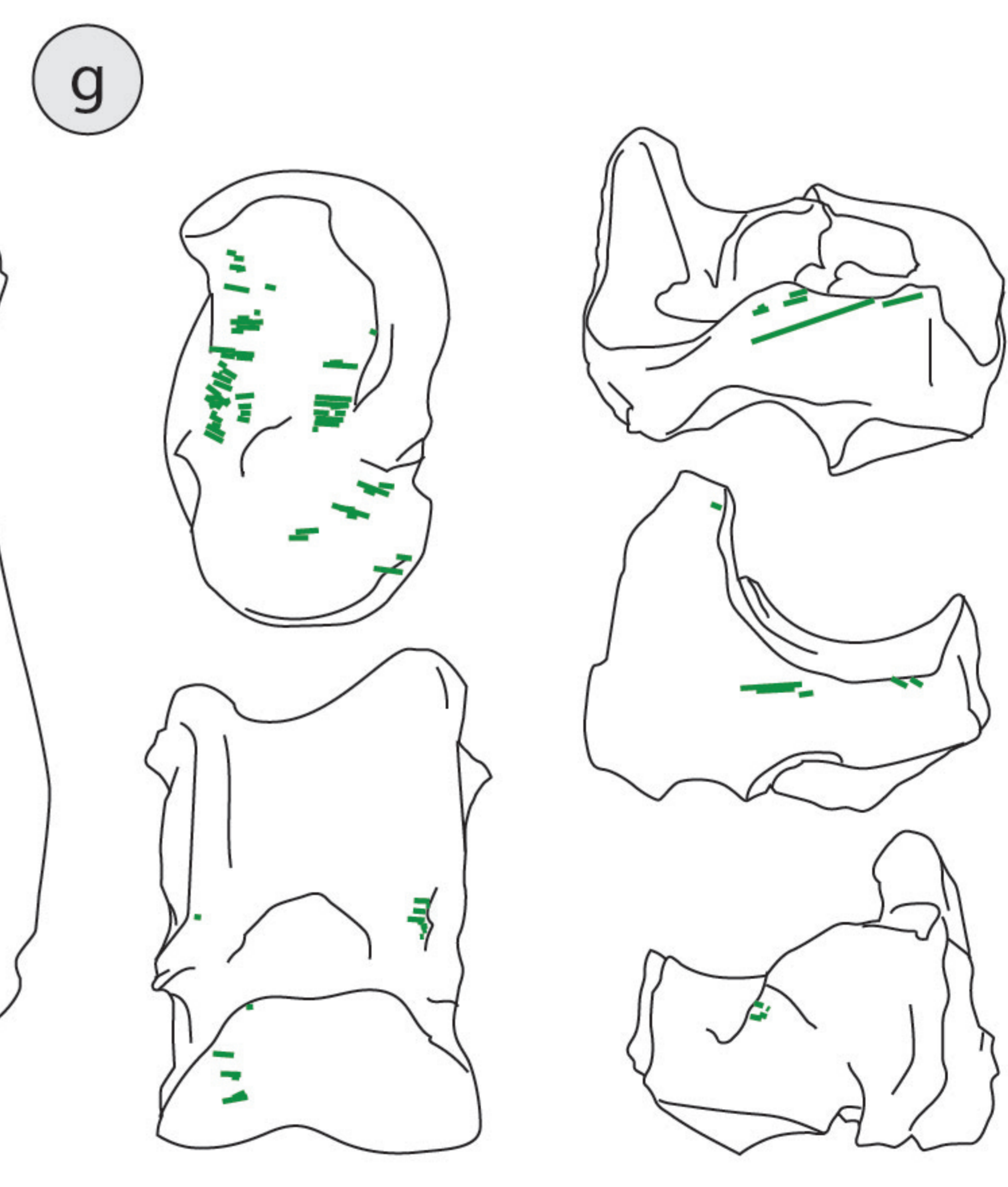
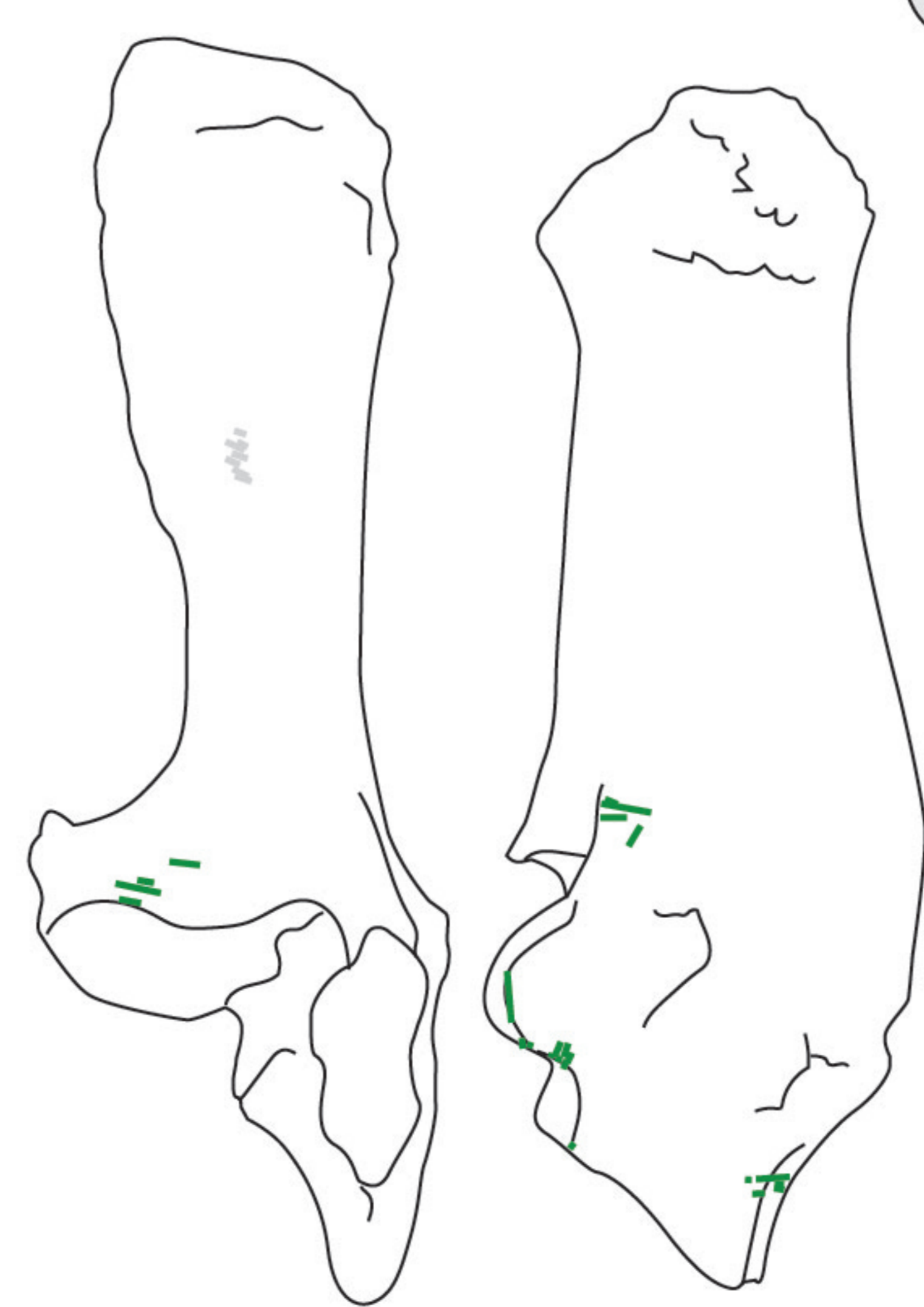
capitate-trapezoid

pisiform



pyramidal

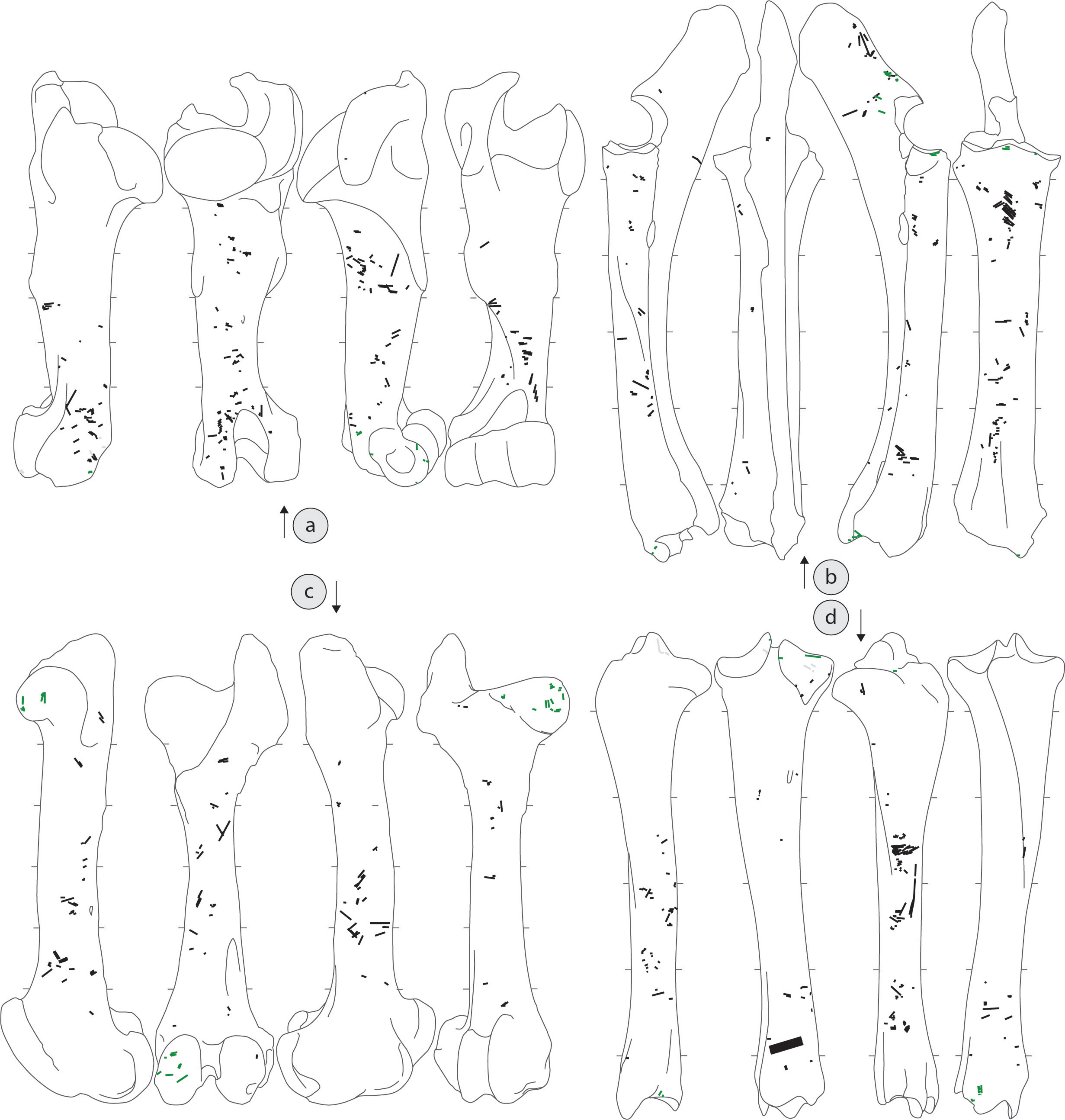
semi-lunar

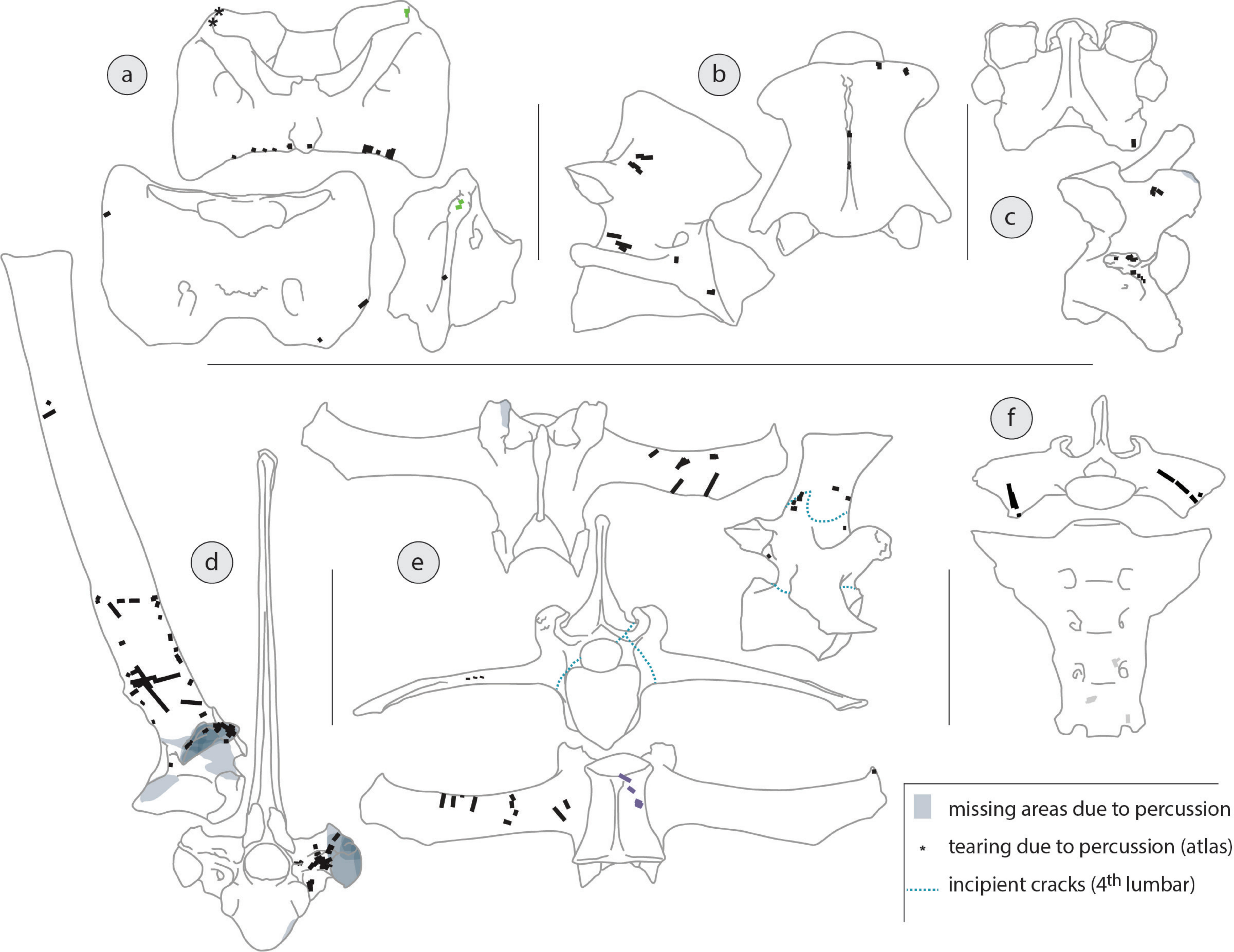


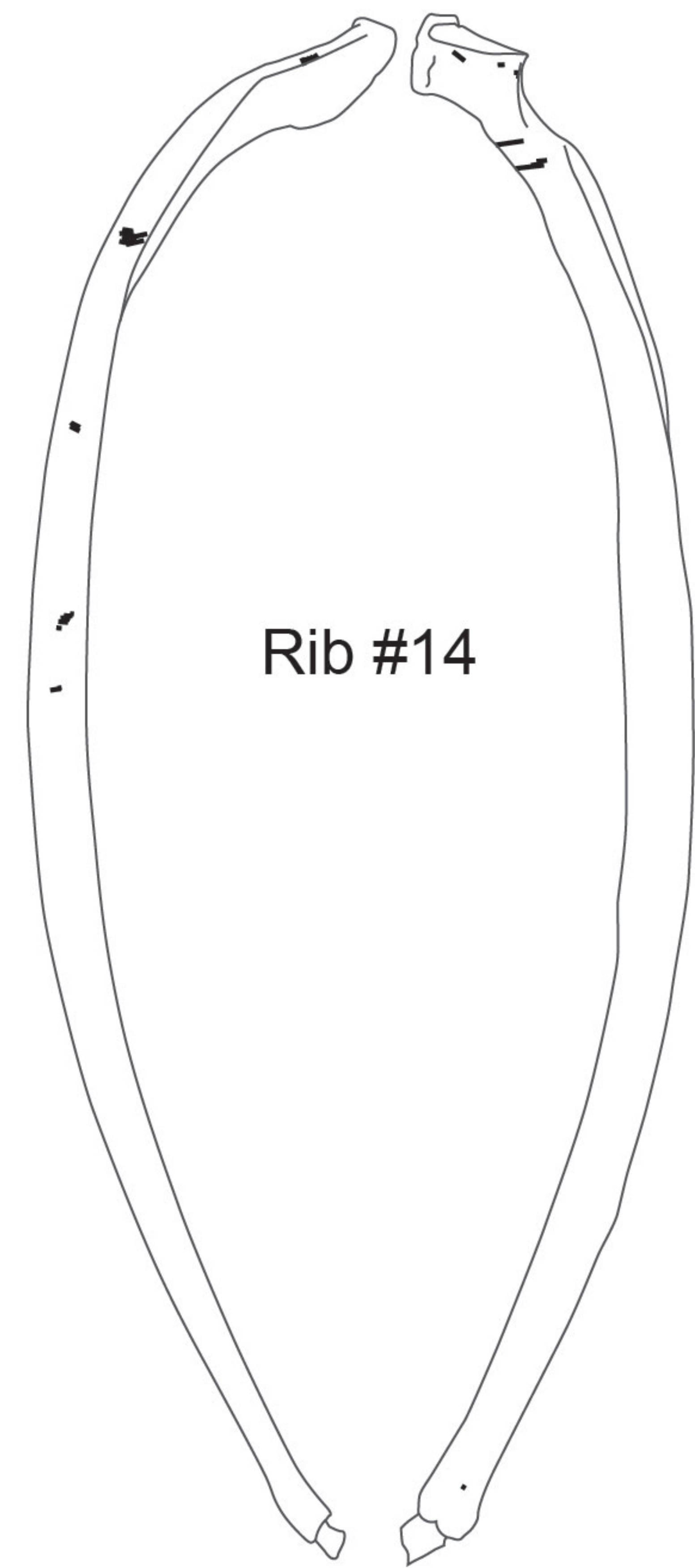
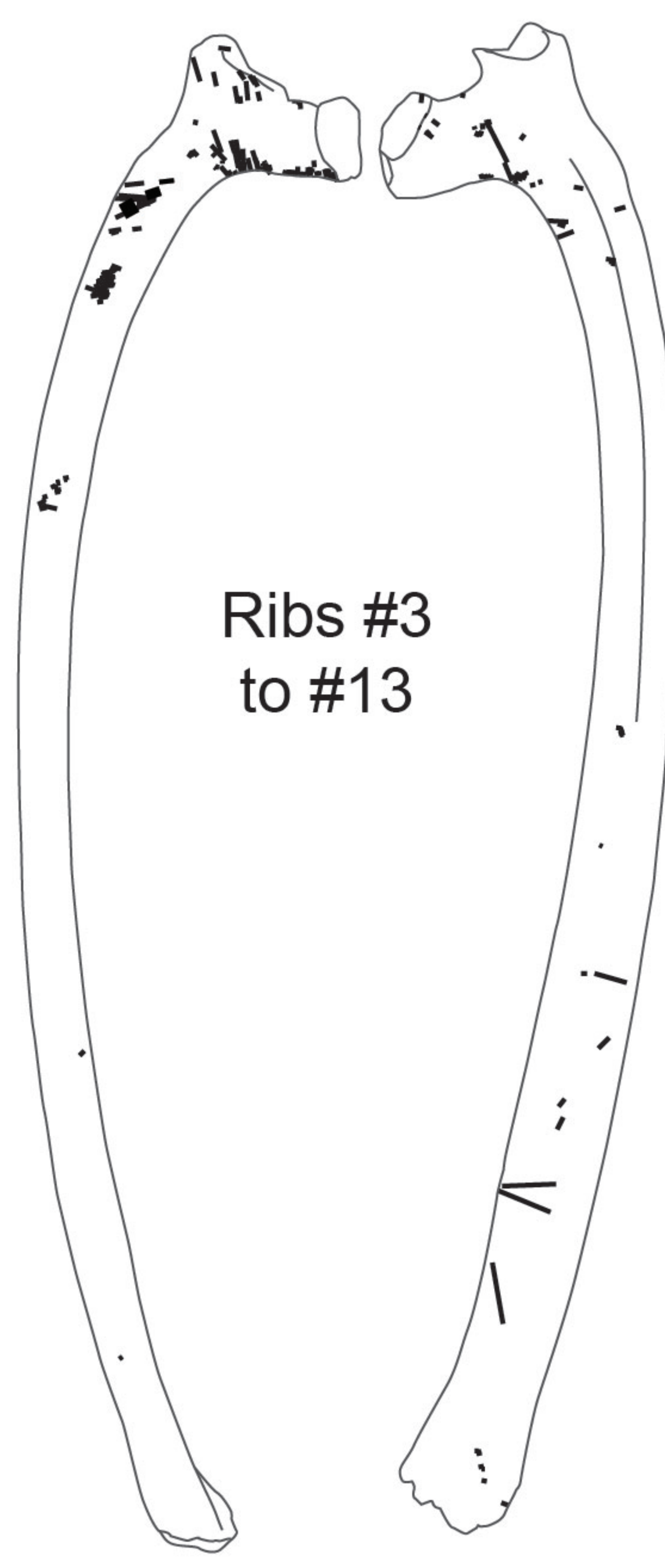
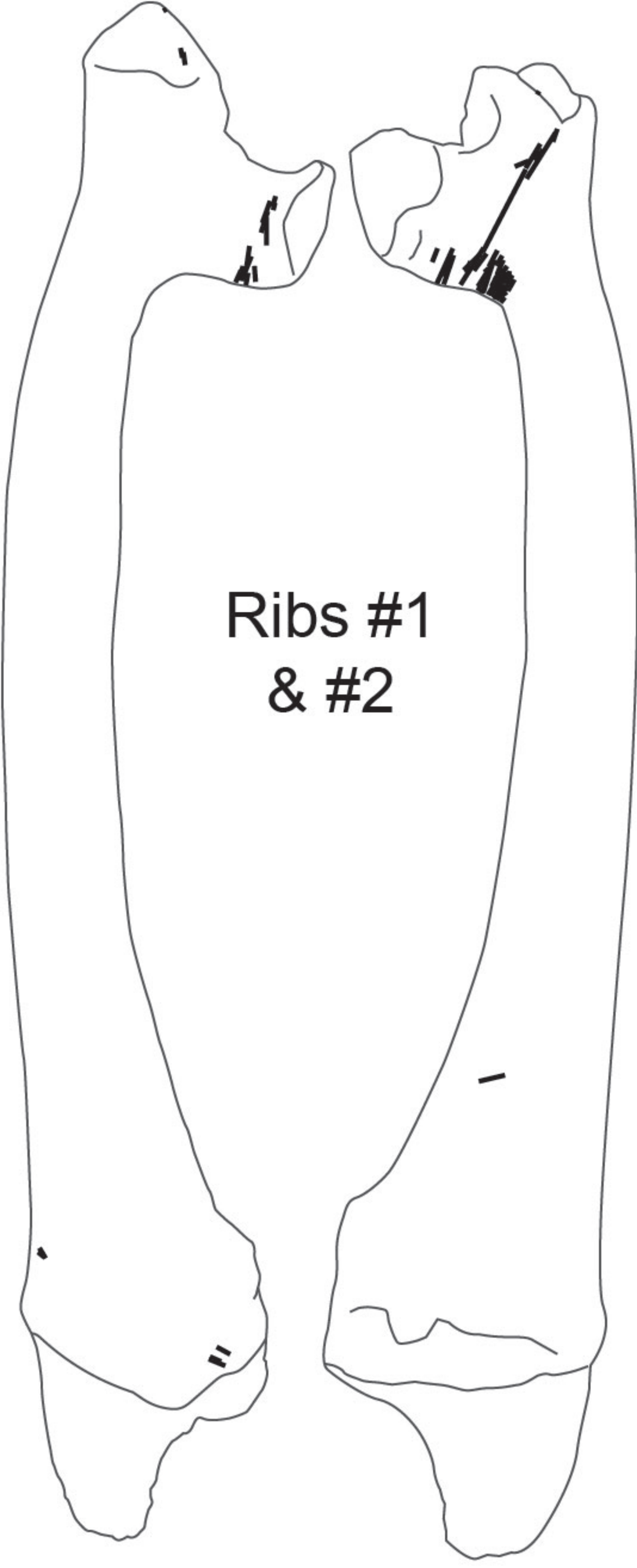
g

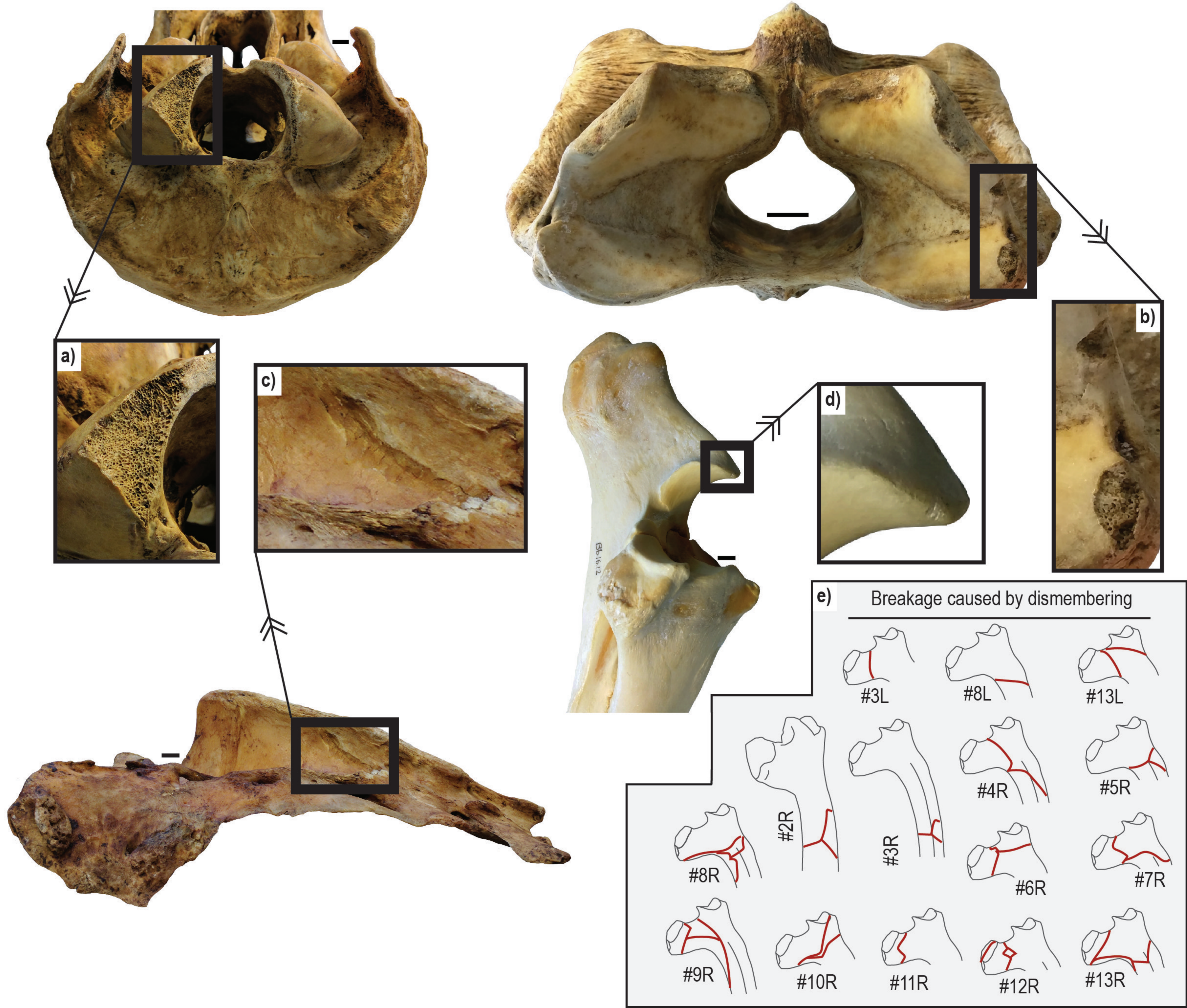


<i>weight of meat</i>	left	right
axial	53	
scapula	7	9
humerus	6	6
radioulna	0.5	1
femur	26	27
tibia	4.3	4









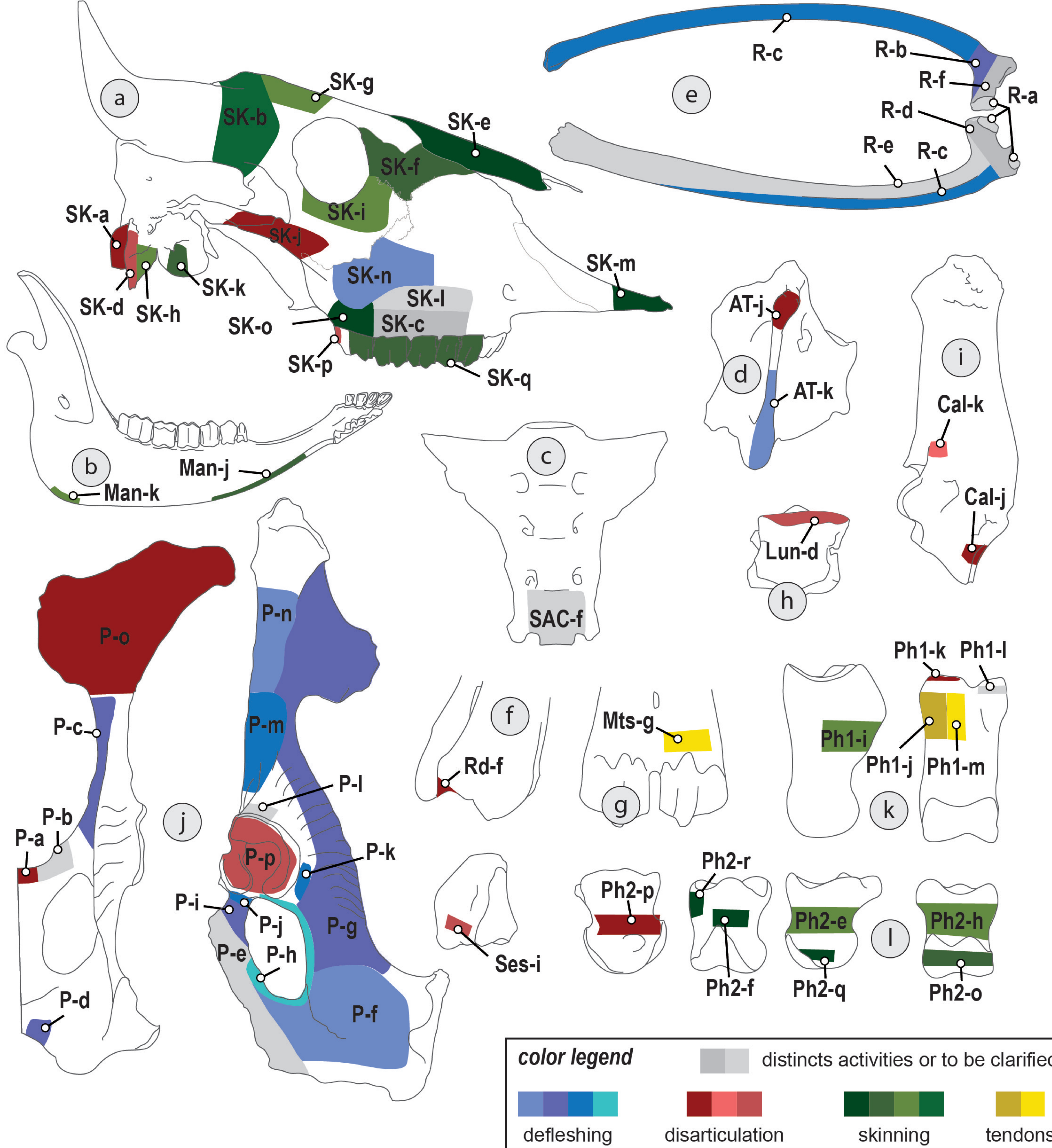


table 1

activity	location	Tool & raw material
skinning	head	unretouched flake [F]
	forelimbs	pseudo-Levallois point [Qzte]
	hindlimbs	pseudo-Levallois point [F]
	body	cortical backed flake [Qzte]
defleshing	head	pseudo-Levallois point [F] ; unretouched flake [F]
	R forelimb	bifaces [Qzte]
	L forelimb	cleavers [Qzte]
	R hindlimb	pseudo-Levallois point [Qzte]
	L hindlimb	pseudo-Levallois point [F]
	loin & ribs	mousterian point [F]
dismembering	R forelimb	biface [F]
	L forelimb	cleaver [Qzte]
	R hindlimb	denticulate [Qzte]
	L hindlimb	pseudo-Levallois point [F]
	head/atlas	hafted cleaver [Qzte]
	spine/ribs/sternum	hafted cleaver [Qzte]
	pelvis/spine	hafted cleaver [Qzte]
tendons	lower legs	flake [Qzte]

table 2

	N cuts
Skull	97
Mandible	119
Vertebrae	217
Ribs	303
Scapula	85
Humerus	225
Radioulna	228
Carpals	33
Metacarpal	69
Pelvis	86
Femur	175
Tibia	223
Malleolus	15
Tarsals	118
Metatarsal	63
Phalanges	141
Sesamoids	6
Tot.	2203

table 3

	Defleshing only : all portions								Defles			
	Humerus		Radioulna		Femur		Tibia		<i>Tot.</i>	Humerus		Radic
	R	L	R	L	R	L	R	L		R	L	R
longitudinal	9	1	2		3	1		5	21	5		1
oblique	67	31	68	51	37	55	43	47	399	37	20	49
transverse	43	57	32	49	6	31	53	50	321	24	42	27
Tot.	119	89	102	100	46	87	96	102	741	66	62	77

table 3

Fishing only : portions 2 to 5					
Ulna	Femur		Tibia		Tot.
L	R	L	R	L	
	2	1		3	12
39	33	51	28	40	297
44	5	28	51	49	270
83	40	80	79	92	579

table 4

Disarticulation	Humerus		Radius		Femur		Tibia		<i>Tot.</i>
	R	L	R	L	R	L	R	L	
longitudinal	2					18	9		29
oblique	5		1	8		14	2		30
transverse		4	10	7	5	5	4		35
Tot.	7	4	11	15	5	37	15	0	94

table 5

	Disarticulation & defleshing				Defleshing				Disarticulation			
	Bison		Red deer		Bison		Red deer		Bison		Red deer	
	N	%	N	%	N	%	N	%	N	%	N	%
longitudinal	52	6.1	200	6	21	2.8	172	5.7	29	30.9	23	11.1
oblique	441	51.8	2141	64.1	399	53.9	1956	64.7	30	31.9	113	54.3
transverse	358	42.1	999	29.9	321	43.3	893	29.6	35	37.2	72	34.6
Tot.	850		3340		741		3021		94		208	

table 6

	Red deer				Bison	
	Butcher V.		Butcher M.		Butcher M.	
	N	%	N	%	N	%
longitudinal	9	16.98	19	13.01	2	0.93
oblique	42	79.25	119	81.51	94	43.93
transverse	2	3.77	8	5.48	118	55.14
Tot.	53		146		214	

^a Abbreviations: T = transversal; ST = sub-transversal; O = oblique; L = longitudinal ; SL = sub-longitudinal.

^b Abbreviations: dist. = distal; prox. = proximal; art. = articulation; L = lateral; M = medial; P = posterior; A = Anterior; Cran. = cranial

^c Location according to a division of the bone in 6 portions.

^d XX + XX indicates that both activities are documented; XX(+ XX?) indicates that the first activity mentioned is attested but the activity has been modified from the initial attribution (see text). Abbreviations: DC = defleshing; DS = disarticulation; DP = skinning; TAR1 = tarsals first row; TAR2 = tarsals second row; RAD = radius; TIB = tibia; MET = metapodial.

^e Abbreviation: nl. = not labeled (when the cutmarks are illustrated but not coded).

Numbers in italics and green indicate the number of code repetitions

bone	code	orientation ^a	location ^a	portion ^c
Skull	SK-a	T	occipital condyles	
	SK-b	L/O/T	base of the horns	
	SK-c	L/O	maxilla, just above tooth row	
	SK-d	O/T	caudal part of the jugular process	
	SK-e	L/O/T	nasal	
	SK-f	O/T	lacrima bone	
	SK-g		frontal	
	SK-h	L	cranial part of the jugular process	
	SK-i	L/O	zygomatic bone, around orbital cavity	
	SK-j	L/O	zygomatic arc	
	SK-k	L	tympanic bulla	
	SK-l	L/O	maxilla	
	SK-m	T/ST	premaxilla	
	SK-n	L/O	maxilla	
	SK-o	L/O/T	maxilla, above third molar	
	SK-p	L	distal face of the distal lobe of the upper third molar	
SK-q	L/O	cheek teeth		
Mandible	Man-a	T/O	incisors and alveolar arch	
	Man-b	T/O	jugal teeth	
	Man-c	T/O	horizontal branch, below jugal teeth	
	Man-d	T/O	ascending ramus, below condyle	
	Man-e	T/O	condyle and coronoid process	
	Man-f	T/O	ascending ramus	
	Man-g''	T	horizontal branch, below jugal teeth	
	Man-g'	L	horizontal branch, below jugal teeth	
	Man-j''	T	palmar edge	
	Man-k'	L	angle, horizontal branch	
	Atlas	AT-c	T/O	caudal part of the body
AT-c'		L	caudal part of the body	
AT-d		O	cranial part of the body	
AT-g		T/O	caudal part of the body	
AT-h			articular cavities for condyles of the occipital bone	
AT-j			Lateral edge, cranial-most portion	
AT-k			lateral edge, caudal-most half	
Axis	AX-b'	L	body, cranial part	
	AX-c'	L	spinous process, middle part	
	AX-g'	L	base of the spinous process	
	Ax-j	O	cranial part of the body	
	AX-j'	L	cranial part of the body	
	AX-k''	T	middle part of the body	
Cervical vertebrae	CV-b	T/O	superior articular process	
	CV-b'	L	superior articular process	
	CV-c	O	middle part of the body	
	CV-c'	L	middle part of the body	

Thoracic vertebrae	TV-a	O	spinous process
	TV-a'	L	spinous process
	TV-c	O	on the superior articular process
	TV-c'	L	on the superior articular process
	TV-d'	L	below the superior articular process, and body
	TV-i	T/O	below the transverse apophysis
	TV-j	T/O	body
	TV-l	O	transverse apophysis
	TV-l'	L	transverse apophysis
	Lumbar vertebrae	LV-a'	L
LV-f		O	base of the inferior articular process

Lumbar verte	LV-h	O	transverse process
	LV-h'	L	transverse process
	LV-m	O	transverse process
	LV-m'	L	transverse process
	LV-m''	T	transverse process
Sacrum	SAC-d	O	sacral ala
	SAC-d'	L	sacral ala
	SAC-e	O	body
	SAC-f	O	body
	SAC-f'	L	body
Ribs	R-a		articulation
	R-b		neck
	R-c		shaft
	R-d		head
	R-e		shaft
	R-f		head
Scapula	Sc-b	O	neck
	Sc-b'	L	neck
	Sc-c	T/O	neck
	Sc-d'	T	neck
	Sc-d	O	neck
	Sc-e	T/O	body
	Sc-e'	L	body

Humerus	Hp-b	T/ST	humeral neck	1
	Hp-m'	L	greater tubercle: below the tricripital line	1
	Hp-m''	T	greater tubercle: below the tricripital line	1
	Hs-a	T/O	shaft	2 to 5
	Hs-a'	L	shaft	2 to 5
	Hd-c	T/O	at the coronoid fossa	6
	Hd-d	T/O	edge of the trochlea to th insertion of the M. pronator teres	6
	Hd-d'	L	edge of the trochlea to th insertion of the M. pronator teres	6
	Hd-e	T/O	epitrochlea to the insertion of the M. pronator teres	6
	Hd-f'	O	dist. portion except epicondylar crest é edge of the coronoid	6
	Hd-g	T/O	edges of the olecranon fossa	6
	Hd-g'	L/SL	edges of the olecranon fossa	6
	Hd-h	T/O	capitulum	6
	Hd-h'	L	capitulum	6
	Rp-a	T/ST	close to the prox. art. (lateralmost)	1

Radius	Rp-b	T	close to the prox. art. (medialmost)	1
	Rp-c	O	prox. portion	1
	Rp-f	O	prox. portion	1
	Rp-g	T/O	prox. portion	1
	Rs-a	T/O	shaft: upper half	2 + 3
	Rs-a'	L	shaft: upper half	2 + 3
	Rs-b	O	shaft: lower half	4 + 5
	Rs-b''	T	shaft: lower half	4 + 5
	Rs-c	O	shaft: lower half	4 + 5
	Rs-c'	L	shaft: lower half	4 + 5
	Rs-c''	T	shaft: lower half	4 + 5
	Rd-b	T	close to the dist. art.	6
	Rd-c	T/O	upper half of portion 6	6
	Rd-d'	L	dist. portion	6
	Rd-d	O	dist. portion	6
	Rd-e	T/O	radial styloid process	6
	Rd-f	O	dist. portion	6
Ulna	Up-b	T/O	olecranon: dist. half of the post. part	1
	Up-c	O	olecranon: dist. half, near the semilunar notch	1
	Up-d	T/O	olecranon: anteriormost part	1
	Up-i	T	posterior aspect of the ulna	1
	Us-a	T/O	shaft	2 to 4
	Us-b	O	shaft	5
	Ud-a	T/O	ulnar styloid process [short cut]	6

Carpals	Pis-c	T	pisiform	
	Pyr-a	T/O	pyramidal: close to the prox. art.	
	Pyr-b	T/O	pyramidal: close to the dist. art.	
	Pyr-c	T/O	pyramidal: mid-bone	
	Lun-a	T/O	lunatum: close to the prox. art.	
	Lun-d	O	proximal articulation	
	Sca-a	T/O	scaphoid: close to the prox. art.	
	Sca-b	T/O	scaphoid: close to the dist. art.	
	Unc-a	T/O	unciform: close to the prox. art.	
	Unc-b	T/O	unciform: close to the dist. art.	
	Ctt-a	T/O	capitato-trapezoid: close to the prox. art.	
	Ctt-b	T/O	capitato-trapezoid: close to the dist. art.	
Metacarpal	Mcs-a'	T	condyles	2 to 5
	Mcs-d	T/O	shaft	4
	Mcs-e	O	shaft	5
	Mcs-f	T/O	groove: edge or inside	2 to 5
	Mcd-a	O	condyles	6
	Mcd-b	T/O	condyles	6
	Mcd-c	T/O	condyles	6
	Mcd-c'	L	condyles	6
Pelvis	P-a		pubic symphysis	
	P-b		pecten ossis	
	P-c		ischial spine	
	P-d		ischial arch	
	P-e		inferior ramus of pubis	
	P-f		tabula of ischium	
	P-g		ischium body to iliaque spine	
	P-h		edge of the obturator foramen	
	P-i		superior ramus of pubis	
	P-j		superior ramus of pubis	
	P-k		edge outside acetabulum	
	P-l		edge outside acetabulum	
	P-m		body of ilium	
	P-n		ilium	
P-o		iliac tuberosity		
P-p		inside acetabulum		
Fp-a	T/O	femoral head	1	
Fp-a'	L	femoral head	1	

Femur	Fp-b		femoral head: edge [encircling]	1
	Fp-g	T/O	greater trochanter: below	1
	Fp-h	T/O	greater trochanter: below	1
	Fs-a	T/O	shaft	2 to 5
	Fs-a'	L	shaft	2 to 5
	Fd-a	T/O	above trochlea & condyles	6
	Fd-c	T/O	condyles: on or adjacent to	6
	Fd-c'	L	condyles	6
	Fd-f	T/O	epicondyle	6
Tibia	Tp-a	T/O	intercondyloid eminence [encircling]	1
	Tp-b	T/O	tibial plateau	1
	Tp-b'	L	tibial plateau	1
	Tp-e'	O	tibial plateau: edge	1
	Ts-a	T/O	shaft	2
	Ts-b	T/O	shaft	3 + 4
	Ts-c	T/O	shaft	3 + 4
	Ts-c'	L	shaft	3 + 4
	Ts-d	O	shaft	5
	Ts-d''	T	shaft	5
	Ts-e	O	shaft	5
	Ts-e''	T	shaft	5
	Td-a	O	tibia: dist. part	6
	Td-a''	T	tibia: dist. part	6
	Td-b	O	tibia: dist. part	6
	Td-b''	T	tibia: dist. part	6
	Td-b'	L	tibia: dist. part	6
Td-c	O	tibia: dist. part	6	
Td-d	T/O	groove of the M. extensor carpi radialis	6	
Malleolus	Ml-a	O	edge of the articulation for the calcaneus	
Tarsals	Tal-a	T/O	talus: prox. articulation	
	Tal-b	T	talus: dist. articulation	
	Tal-c	O	talus: mesial part	
	Tal-c''	T	talus: mesial part	
	Tal-d	T/O	talus: dist. part	
	Cbn-a''	T	cubonavicular bone	
	Cbn-a	O	cubonavicular bone	
	Cal-a	T/O	calcaneus: middle part	
	Cal-e'	L	calcaneus: close to the malleolar articulation	
	Cal-j''	T	calcaneus: close to the articulation	
Cal-k	O/T	calcaneus: above CAL-E		
Metatarsal	Mtp-c	T	groove: edge	1
	Mtp-d	O	prox. shaft	1
	Mts-a	O	shaft [shallow]	2 to 5
	Mts-b	O	shaft [shallow]	2 to 5
	Mts-c	T/O	groove: inside	2 to 4
	Mts-f	T/O	groove: edge	2 to 4
	Mts-g''	T	distal shaft	5
	Mtd-b''	T	condyles	6
Mtd-c	T/O	condyles	6	
Sesamoid _s	Ses-f	T/O	external abaxial sesamoid: contact with post. edge	
	Ses-h	T	sesamoid	
	Ses-h'	L	sesamoid	
	Ses-i	O	sesamoid	
Ph1	Ph1-b	T/O	contact with the proximal articulation	
	Ph1-c''	T/ST	proximal shaft	
	Ph1-c	O	proximal shaft	
	Ph1-d	T	contact with the proximal articulation	

Phalanges

Ph1-i	O	Mid-shaft
Ph1-j''	T/ST	tubercle axial
Ph1-k''	T	contact with articulation
Ph1-l'	L	above Ph1-d
Ph1-m	T	between the two tubercles
Ph2-b	O	contact with the proximal articulation
Ph2-h	O/T	shaft
Ph2-e	O/T	shaft
Ph2-f	O/T	shaft
Ph2-o''	T/ST	distal articulation
Ph2-p''	T	shaft
Ph2-q''	T	distal
Ph2-r	O	proximal shaft, extending Ph2-c

Description of the coding system

anial; Palm. = palmar; Ext. = external.

at the second, in parentheses, is uncertain; XX?/XX? indicates that the protocol used does not allow discrimination between the activities; * indicating; TN = tendon-removal; exten. = extension; flex. = flexion; SP = suspension; ANT = anterior; POST = posterior; CAR1 = carpals first row; CA

Conditions for vertebrae and phalanges. Codes in bold are the new codes created from this bison study

face ^d	Nilssen ^b	T & H cerf ^{b,d}	Bison	
			Right	Left
	DS		DS arrach	DS
	DP		DP	DP
	DS		DP	
	DS			
	DP		DP	DP
	DP			
	DP			
			DP	DP
			DS	DS
				DP
	DS		DC	
			DP	DP
			DC	DC
			DP	
Vest.			DS	DS
Vest.			DP	DP
Vest.		DP		DP
Vest.		DP	DP	
Vest.		DP	DP	DP
Vest., Ling.		DS	DS	
Vest.		DS+DC	DS	
Ling.		DC	DC	DC
Ling.		DC	DC	DC
Palm.			DP	DP
Palm.	DP		DP	
Vent.	DC+EV	DS (ATL/AXI)		DC
Vent.	DC+EV			DC
Dors.	DC			DC
Dors.	DC	incidental DS marks		DC
Cra.	DS	DS (CRA/ATL)		DS
Lat				DS
Lat				DC
Lat.	DC			DC
Lat.	DC			DC
Lat., Dors.	DC			DC
Vent.	DC+EV	DS (ATL/AXI)		DC
Vent.	DC+EV			DC
Vent.	DC+EV	incidental DS marks		DC
Lat.	DS+DC	DS (AXI/CER3)	DC	1
Lat.	DC		DC	1
Lat.	DC	incidental DS marks	DC	1
Lat.	DC		DC	1

Lat.	DC	DC	DC	7
Lat.	DC	DC	DC	7
Lat.		DS	DC	3
Lat.	DC		DC	4
Lat.	DS RIB	?	DC	1
Cra.		DS	DC	1
Cau.	DS RIB		DS (tearing)	1
Cra.	DC		DC	4
Cra., Dors.	DC		DC	7
Lat.	DC	DC	DC	3
Lat.		DS	DC	1

Dors.	DC	DC	DC	2
Cra., Dors.	DC	DC	DC	1
Vent.		DC	DC	2
Vent.		DC	DC	1
Vent.			DC	1
Cra., Vent.	DC	DC	DC	
Cra., Vent.	DC		DC	
Vent.	EV		?	
Vent.			?	
Vent.			?	
all	DS		DC	
Dors.	DC		DC	
Dors.	DC		DC	
Vent.	DS (+EV ? DC ?)		DC	
Vent.	EV + DC		DC ? EV ?	
Dors.	DS + DC		DC	
Lat., Post.	DC	DC	DC	
Lat., Post.	DC	DC	DC	DC
Med., Ant.	DC	DC	DC	DC
Med.	DC*			DC
Med.			DC	DC
all	DC	DC	DC	DC
all	DC	DC	DC	DC

Post.	DC	DS+DC		DC
Lat.		DC	DC	
Lat.			DC	
all	DC	DC	DC	DC
all	DC	DC	DC	
Med.	DC	DC	DC	DC
Med.	DS	DS (exten.)	DC	DS
Med.	DC	DS (flex.)		?
Med.	DC	DS+DC	DC	?
Lat., Ant			DC	
Post., Lat.	DC (+DS?)	DS+DC	DC+DS	DC
Post.	DC	DC	DC	DC
Lat.	DS	DS	DS	DS
Lat.		DS	DS	
Ant.	DS	DS	DS	

Ant.	DC (+DS?)		DS	
Ant.		DC	DC	
Med.	DC	DC	DC	DC
Lat.	DC	DC		DC
all	DC	DC	DC	DC
all	DC	DC	DC	
Med., Lat., Post.	DC	DC	DC	DC
Med., Lat., Post.	DP?/DC?	DC	DC	DC
Ant.	DC	DC	DC	DC
Ant.		DC	DC	
Ant.	DP?/DC?	DC	DC	DC
Ant.				DS
Lat.		DC	DC	
Post.	DC		DC	
Post.			DC	
Med.		DS		DS
Lat				DS
Med., Lat.	DC	DC	DC	DC
Med., Lat.		DS		DS
Med., Lat.	DC	DC	DC	DS+DC
Post.	DC	DC	DC	
Med., Lat., Post.	DC	DC		DC
Lat., Post.		DC		DC
Palm., Lat., Post.	DS	DS	DS	

Lat., Med.	DS		DS	
Ant., Lat., Post.		DS (RAD/CAR1)		DS
Ant., Lat., Palm.		DS (CAR1/CAR2)	DS	
Lat., Ant.		incidental DS marks		DS
Ant., Post.	DS	DS (RAD/CAR1)		DS
Cra.			DS	
Ant., Med., Post.	DS	DS (RAD/CAR1)	DS	DS
Ant., Med., Post.	DS	DS (CAR1/CAR2)		DS
Ant., Lat., Post.	DS	DS (CAR1/CAR2)		?
Ant., Lat., Post.	DS			?
Ant., Med., Post.	DS	DS (CAR1/CAR2)		?
Ant., Med., Post.	DS		?	
Med.		DP	DP	DP
Ant.		DP + TN ANT	TN+DP (+ ?)	DP
Ant.			DP	
Post.		TN POST		TN
Med., Lat.		DS	DS	DS
Post.			DS	DS
Ant.		DP		?
Ant.		DS		DS
	DS (splitting pelvis)			
Dors.	DS + DC			
	DC		DC	
Dors.	DC			DC
	DS (splitting pelvis)			
	DC		DC	DC
	DC		DC	DC
	DC		DC	DC
	DC		DC	?
	DC			?
	DC (+ DS ?)			
	DC		DC	DC
	UC (+US pel/sacrum?)			
Dors.	DS pel/sacrum			
	DS			
	DS	DS		DS
				DS

all	DC (+DS?)	DS		DS
Med.	DC		DC	
Ant., Lat.	DC			DC
all	DC	DC	DC	DC
all	DC	DC		DC
Ant., Post.	DC	DC	DC	DC
Post.	DC (+DS?)	DS+DC	DS	DS
Post.	DC	DS+DC	DC	
Med.		DC		DC
Cran.	DS	DC	DS	?
Cran.		DC	DS(+ ?)	DC
Cran.		DC		DC
Lat.				DC
all	DC	DC		DC
Med.	DC	DC	DC	DC
Ant., Lat., Post.	DC	DC	DC	DC
Ant., Lat., Post.	DC	DC		DC
Med.		DC		DC
Med.	DP	DC		DC
Ant., Lat., Post.	DC	DC	DC	DC
Ant., Lat., Post.	DP	DC	DC	DC
Med.			DS	
Med.	DP		DC	
Ant.		DC		DC
Ant.	DP	DC	DC	DC
Ant.			DS	
Lat., Post.			DC	
Post.		DC	DC	
Lat.		DS	DS	DS
Ant.	DS	DS TIB/TAR (flex.)	DS	DS
Ant.	DS	DS TIB/TAR	DS	DS
Med.		DS TIB/TAR (flex.)	DS	
Med.	DS	DS TIB/TAR (exten.)	DS	DS
Med.	DS	DS	DS	DS
all	DS	DS TAR1/TAR2 + TAR/MTM (depending on location)		DS
all				DS
Ant.	DC/susp.	DS (TIB/TAR flex.)	DS	?
Lat.		DS (TIB/TAR flex.)	DS	DS
Lat				DS
Lat			DS	
Ant.		TN ANT		TN
Med., Lat.		DP	DP	
Med.		DP	DP	DP
Lat.		DP	DP	
Ant.		TN ANT		TN
Post.		TN POST	TN	
Post.				TN
Post.		DP+DS		TN
Ant.	DS	DS+TN POST	TN	
Lat		DS (MET/PH1)		DS
Post.		DS (MET/PH1)		DS
Post.				TN
Lat				DS
Ant., Ext.		DS	DP	1
Ant., Ext.		DS+DP	DS	1
Ext.			DP	4
Post.		DS (between Ph1)	TN	4

Ext.		DP	2
Post.		TN	2
Post.		DS	1
Post.		TN	1
Post.		IND	1
Ext.	DS	DS	1
Post.		DP	4
Ext.		DP	4
Ant.		DP	4
Post.		DP	1
		US between	
Int.		phal.	1
Ext.		DP	1
Ant.		DP	1

states that the interpretation of
AR2 = carpals second row;