Supplementary Information (SI):

Not so unusual Neanderthal bone tools: New examples from Abri Lartet, France

Archaeological and Anthropological Sciences

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SI - 1. Archaeological context

The Abri Lartet is a locus about 120 square meters of the Grotte de Montgaudier located on the west side of the cave, above the Grand Porche (Fig. 2a). Unlike the main parts of the cave complex, Abri Lartet had not been excavated or even looted prior to Duport's excavation (1966–1986). Three stratigraphic profiles are available for this locus. Debénath (1974) discerned six layers in the west part of the Abri, over a total depth of about 2m (see cut 1; Fig. 2b, 2c). Three additional layers (see L.7–9; Fig. 2d) were later excavated in a smaller test pit. The stratigraphy is as follows:

- L.1, topsoil, modified upper part of layer 2
- L.2, red brecciated layer containing some limestone blocks
- L.2bis, red slightly brecciated layer with stalagmite fragments
- L.3, brown sandy-clay layer
- L.4, yellow brecciated layer with stalagmite fragments and limestone blocks
- L.5, yellow sandy-clay layer containing numerous small limestones and fallen rocks
- L.6, very hard breccia containing abundant faunal remains
- L.7, sandy layer
- L.8, layer with abundant limestone gravel embedded in sandy matrix, with concretions in its lower part
- L.9, layer composed of a sandy-clay-silt sediment containing some small and medium sized limestone gravel (Debénath 2010).

Two stratigraphic profiles, recorded in the eastern part of the Abri, were drawn by Duport and Leuvrey for an unpublished 1996 site report (see cut 2 and cut 3; Fig. 2b, 2d). Although layer 1 and Layer 2 are present throughout the Abri, the underlying layers appear to be discontinuous (Fig. 2d), and the stratigraphic assignments in the eastern part are not the same as in the western part. The reason for the lack of correspondence can be partially attributed to an east-west slope in the deposits below layer 2 (Duport and Leuvrey's 1996 report), but is also due to the fact that much of the middle portion of the cave was not excavated in order to keep the "paved stone floor", discovered there in 1971, intact (Duport 1972; Fig. 2b).

SI - 2. Debénath and Duport's bone tools identification

In 1971, A. Debénath and L. Duport published several worked and used bones belonging to the layer 2 and 2bis from the Abri Montgaudier. The 'worked bones' ('os travaillés') consist of two rib fragments from large mammals described as follows: the first (not illustrated) shows scraping traces on at least one of its sides, while the second (Fig. 3b) has use traces on almost its entire surface and its distal end has been intensively used. Unfortunately, we could not locate either of these rib fragments. The 'used bones' ('os utilisés') include four more specimens. The first one is a bone flake from a *Rangifer tarandus* long bone (Fig. 3a) with a rounded distal end that has been highly used. The use has produced a blunting of the cortical and medullar sides and the edges over a length of several centimeters. The second piece (Fig. 3c) is a vestigial *Equus sp*. metapodial showing a blunted tip with shiny surfaces and scraping striations over 15mm on its concave side. The third specimen is a long bone fragment from a large ungulate with scraping traces and impact scars on its cortical side (Fig. 3d). The last one (not illustrated) is a small fragment of a *Rangifer tarandus* long-bone with impact scars on its cortical side (Debénath and Duport 1971). We were able to locate the first two pieces and included them in our study.

SI - 3. Microtomography

µCT imaging was performed on six blunted-end tools from layer 2 and 2bis of the Abri Lartet (Files 1–6) with a microtomodensitometer—a General Electric dual source V|tome|xS scanner—in the PACEA laboratory at the University of Bordeaux. The aim was to generate 3D models to illustrate the global shape of the tools (notably, to compare with 3D models provided by Soressi et al. 2013) and to obtained clear sections of the active parts, i.e., clear views of the localization and the extent of modifications due to the manufacture and use. The dimensions of the microtomodensitometer chamber, 260 mm in diameter and 420 mm long, allowed complete acquisition of each specimen at voxel sizes between 77 µm and 25 µm (minimum values determined by the size of the object). More detailed scans of regions of interest were obtained at resolutions between 55 µm and 7 µm (minimum values determined by the volume to be covered; Table 2). The microtomodensitometer operated at a voltage of 110 to 120 kV and an intensity of 110 to 200 µA. The X-ray beam was filtered by a 0.1 mm thick copper plate. Four projections with a 500 ms exposure were acquired at each rotation step, the first one being discarded and the last three ones averaged to reduce noise while scanning with a reasonable time.

SI - 4. Frame of references

The methodological framework mobilised is that of traceology, as defined by S.A. Semenov, taking into account both the traces of manufacture and use, at all scales of analyses, with the naked eye and from low to high magnification (Semenov 1957, 1964). Bone tool micro-wear analyses are usually performed on material from particularly favourable preservation environments, often Holocene (see in particular 1989; Stordeur Campana and Anderson-Gerfaud 1985; Lemoine 1991; Christidou 1999; Maigrot 1997, 2003; Legrand 2005; Van Gijn 2005; Buc 2010; Clemente Conte et al. 2010; Bertoni and Hohenstein 2017). Due to a poorer state of preservation, bone tools from Pleistocene assemblages can often not be characterised in this way. Only macroscopic markers are considered (e.g., Stordeur 1979; Vincent 1993; Goutas 2015; Pétillon 2006; Rigaud 2001, 2007; Averbouh and Buisson 2003; Aguirre 2005; Tartar 2012; Mozota 2012; Baumann 2014; Romandini et al. 2014; Huston et al. 2018). As with any archaeological discipline, use wear analysis is based on actualist frames of reference (Plisson 1991). Through the regularities observed in the causal relationship between effectors and effects, reading rules can be proposed for deciphering features resulting from shaping, use, curation and alteration. The macro-traces of use (striation, removal, blunt, deformation), can, depending on their location, their extent, their orientation, the transition with the contiguous surface and their association, provide information on the gesture, the force applied, the relative duration of use and the position of the tool with respect to the worked material (Semenov 1964; Sidéra 1993; Maigrot 2003). For the interpretation of the archaeological material, we have supplemented published references—which are still few for the material considered—with an experimental frame of reference specifically dedicated to Mousterian tools. This work is carried out by a working group involving French (PACEA, UMR 5199, University of Bordeaux), Russian (Institute of Archaeology and Ethnography, Siberian Branch of the Russian Academy of Sciences; ZooSCAn IRL 2013) and Belgian (Tracéolab, University of Liege) researchers (Baumann et al. 2020; Shalagina et al. 2020; Kolobova et al. 2022).

Our experiments cover the entire *chaîne opératoire*: blank production, shaping processes, tool use on different materials, in activities chosen according to the archaeological context. The *débitage* was performed by percussion on 45 long bones (Femurs, Tibias, Humeri, Radio-Ulna), 8 flat bones (ribs) and 5 short bones (vestigial metapodial) of medium (Deer, Sheep) and large mammals (Equidae, Bovines). The blank shaping (sizing, design of the active part) was mainly made by percussion and, to a lesser extent, scraping and abrasion. The comparative experimental collection includes about 100 bone tools used in flint knapping (e.g., shaping scrapers), woodworking (e.g., handle making), plant working

(e.g., herb harvesting), skin working (e.g., proto-tanning), ice working (e.g., drilling hole for fishing), butchery (e.g., cutting up bovid lower limbs), and soil (e.g., root digging) activities (Fig. 5).

SI - 5. Contamination issues

Although excavations were conducted at the Abri Lartet as recently as 1986, they did not meet modern standards: for instance, finds were generally not piece-plotted, and the depth of excavation cuts was not recorded. Earlier storage conditions of the assemblage also resulted in the loss or misplacement of some materials (e.g., we were unable to locate some of the tools described by Debénath and Duport), and some materials from other sites may have been erroneously attributed to the Abri (see below). The excavated Middle Paleolithic sample from level 2 at the Abri Lartet is homogenous, although a few indicators suggest that some contamination or mixing is present in the current level 2 material. These include: (1) superficial medieval deposits and (2) a handful of Upper Paleolithic lithic pieces. However, none of the post-Mousterian diagnostic materials we identified are compatible with the dates obtained by our radiocarbon dating program.

Medieval deposits

In 1971, Duport uncovered a "sol empierré" (paved stone floor), with several anatomically connected animal skeletons, in the upper part of level 2. Although initially interpreted as evidence of a "Neanderthal reindeer cult" (Duport 1972), these deposits were later revealed to be a medieval Suidea deposit (Debénath and Duport 1986; Debénath 2014). Our analysis suggests that these deposits represent only a tiny fraction of the faunal remains excavated from level 2, and are probably mostly limited to the upper parts of layer 2. We excluded material from the highest stratigraphic layer at the site (layer 1, also labelled as "terre végétale" or "terre noire," indicating organic soil) from our study because we found that it contained significant recent material (metal, ceramics, Suidae). As noted in the text, more than 96% of the faunal remains we identified in level 2 were attributed to *Rangifer tarandus*, which clearly could not have been deposited in the medieval period.

Upper Paleolithic elements

The probable Upper Palaeolithic lithic pieces found in the Abri Lartet consist of two *fléchettes* and one burin spall. These were found with the faunal material from level 2, unit Z3. Two additional possible backed blades, presumably Magdalenian (M. Langlais, personal communication), were found in a bag marked "Abri Lartet" but without further information on their provenance. The radiocarbon dates obtained for the material dated here are clearly incompatible with a Magdalenian origin.

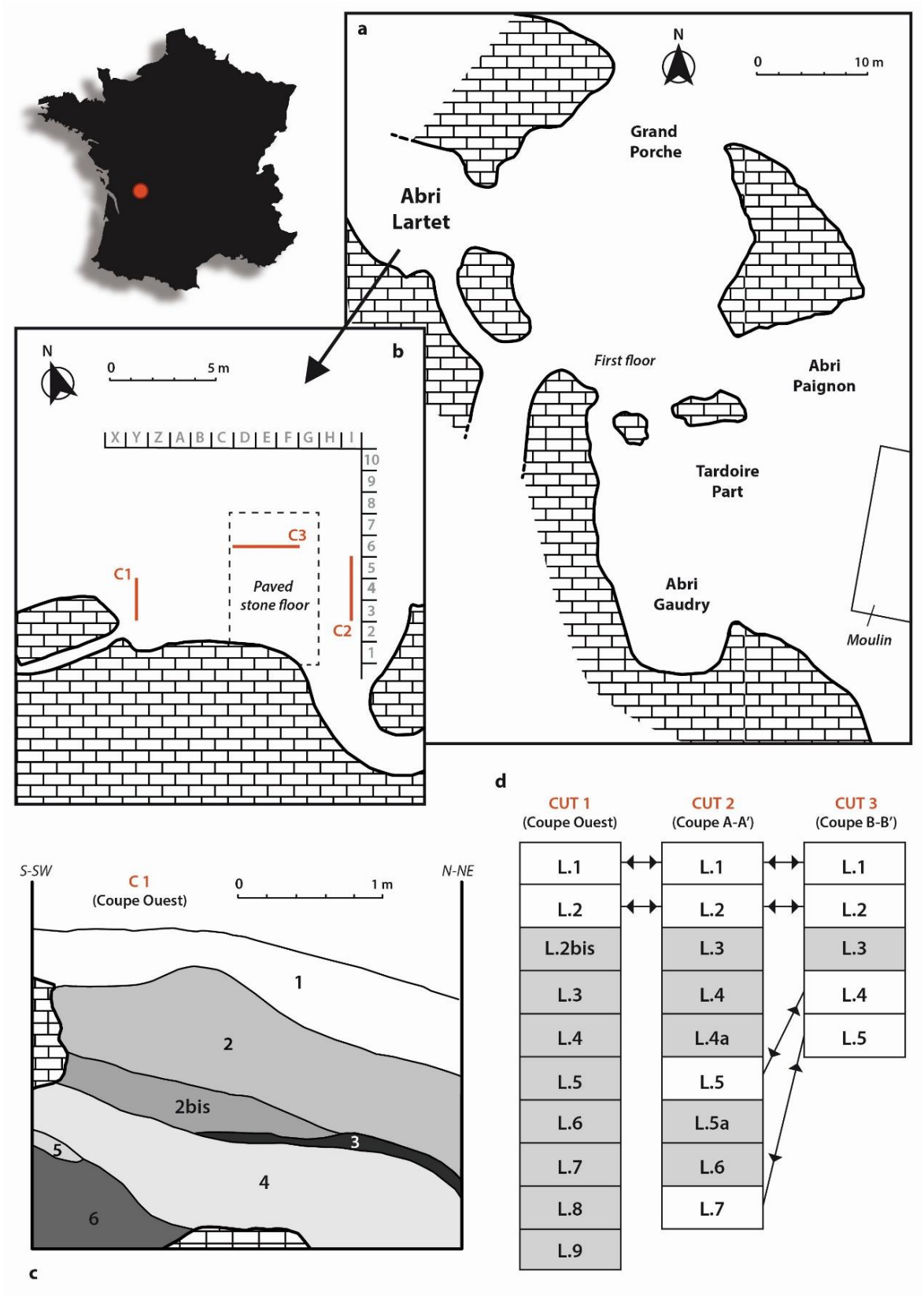
During our faunal analysis we also identified two worked antler objects. One, from level 2, unit B2, has a proximal end cut by a superficial notch and detached using flexion. At the distal end of this object, the section is slightly flattened and the cancellous tissue is apparent, but surface preservation problems make it unclear whether this reflects intentional shaping or natural wear (Fig. 6a). It is not possible to assign this piece to a particular industry or period.

The other worked antler piece was sectioned by sharp percussion on the proximal part. This technique, as well as the location and orientation of the grooved sections on the lateral edges of the piece, are consistent with configurations found on characteristic Middle/Upper Magdalenian pieces (Fig. 6b; Averbouh 2000; Bräem 2008) again, much later than our dated pieces. Furthermore, this piece was found in a single bag labelled "Sac 540 MG AL "entre les blocs Foyer C. 2.3?" [between the blocks hearth C

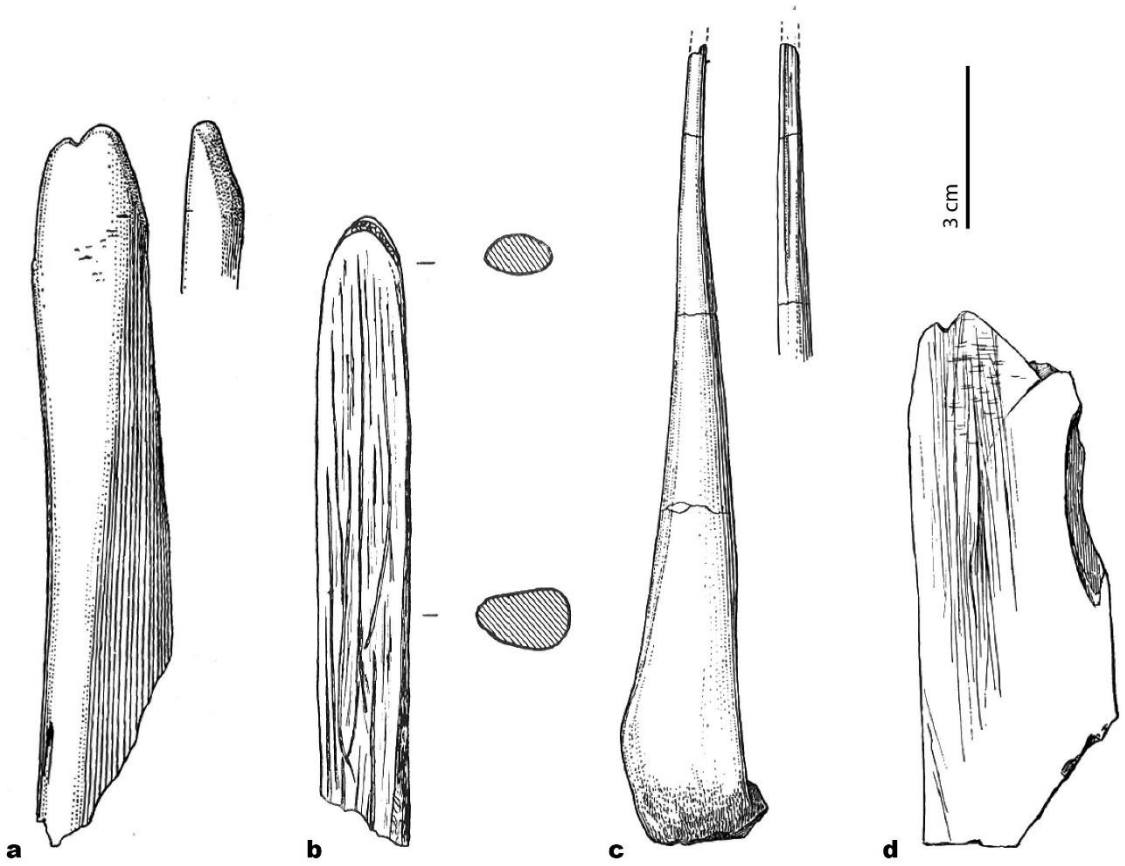
2.3]". The material in this bag was very different in appearance from the other Abri Lartet material, and we found no other mention of a hearth (foyer) or "blocks" in the site reports or materials. Therefore, we suspect that this material has been erroneously attributed to the Abri Lartet and probably originated elsewhere in the Grotte de Montgaudier.

In summary, the only pieces found in level 2 of the Abri Lartet that seem to provide a reliable indication of Upper Paleolithic use of the site are the three lithic pieces from unit Z3 and one worked antler piece. The presence of these materials, combined with the lack of detailed information on the spatial provenance of the remains, led us to view the attribution of the bone tools to the Middle Paleolithic with caution. Therefore, we sought to confirm their age by direct radiocarbon dating.

SI Fig. 1 Examples of ribs with smoothed ends discovered in other Middle Paleolithic contexts. a, c–d) Abri Peyrony; b) Pech de l'Azé (after Soressi et al. 2013); e) Zaskalnaya VI (after Stepanchuk et al. 2017); f) Chagyrskaya Cave (after Baumann et al. 2020); g) Abri des Canalettes (after Patou-Mathis 1993); h) Axlor (after Mozota Holgueras 2012); i–k) La Quina (after Henri-Martin 1907–1910); l–m) Grotte du Noisetier (after Oulad El kaïd 2016)



SI Fig. 2 Abri Lartet, Charente, France. a) layout of the Grotte Mautgaudier; b) layout of Abri Lartet showing the excavation units; c) stratigraphy of cut 1 showing layers 2 and 2bis where bone tools have been found (after Debénath 1974); d) stratigraphic cuts showing correspondences established by Duport and Leuvey (after Ready and Morin 2019)

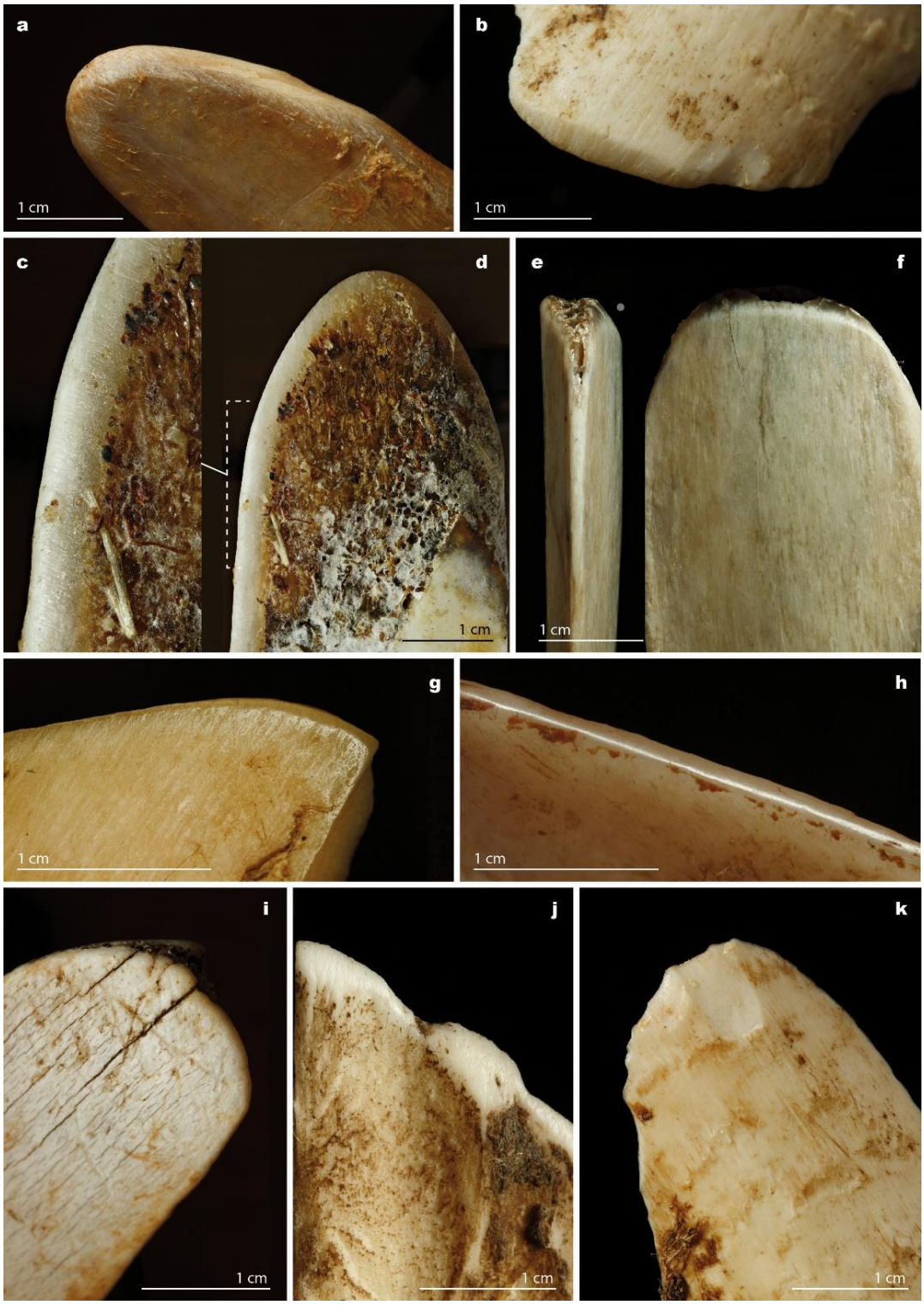


SI Fig. 3 Bone tools from Abri Lartet Level 2 and 2bis, reported by Debénath and Duport (1971). a) *Rangifer tarandus* tibia fragment with polished distal end; b) rib fragment with polished and rounded end; c) *Equus ferus* vestigial metapodial with polished distal end and fine striations; d) large mammal diaphysis fragment with retouchers and scrape marks (after Debénath and Duport 1971)

SI Fig. 4 Bone tools found in the Abri Lartet assemblage, level 2 and 2-bis. a, b) awls; c) bevelled tool; d) blunt-ended tool on diaphysis; e–h) blunt-ended tool on ribs (photos: M. Baumann)

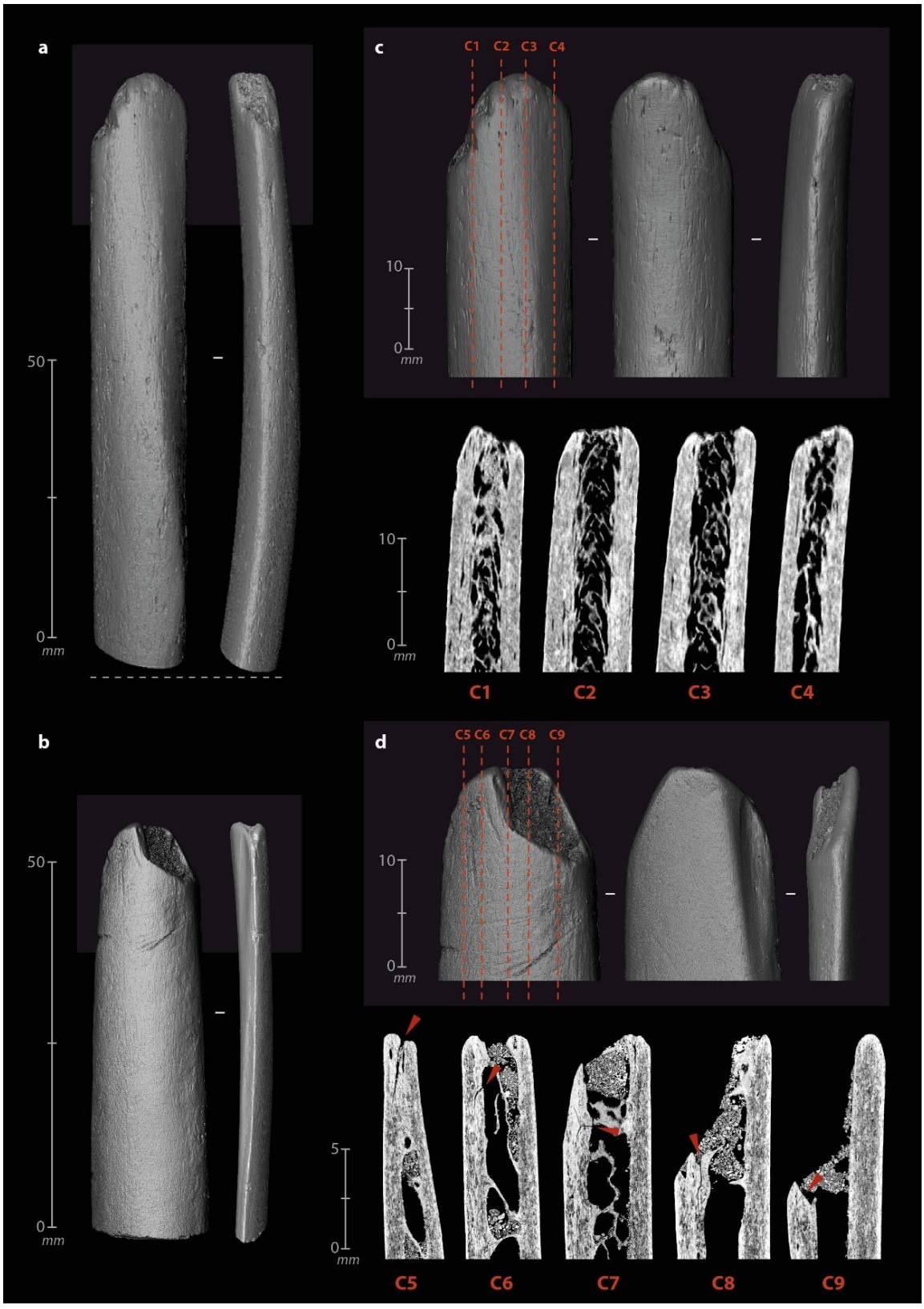
SI Fig. 5 Experiments with replicas of Mousterian type bone tools. a) flakes from bone shaping; b) fresh Bovinae long bones; c) bone blanks made by percussion; d) Mousterian side scrapers shaped with bone retouchers; e) bark peeling; f) abrasion shaping of a bone blank; g) shaping a wooden handle with a bone chisel; h) fresh hide fleshing with a sharp bone flake; i) meat cutting with a sharp bone flake (photos: H. Plisson)

SI Fig. 6 Industry on *Rangifer tarandus* antler, Abri Lartet. a) section of frontal tine; b) antler beam fragment showing traces of double grooving and notching; c) detail of flexion fracture and percussion marks at the proximal end; d) a grooved section (photos: M. Baumann)

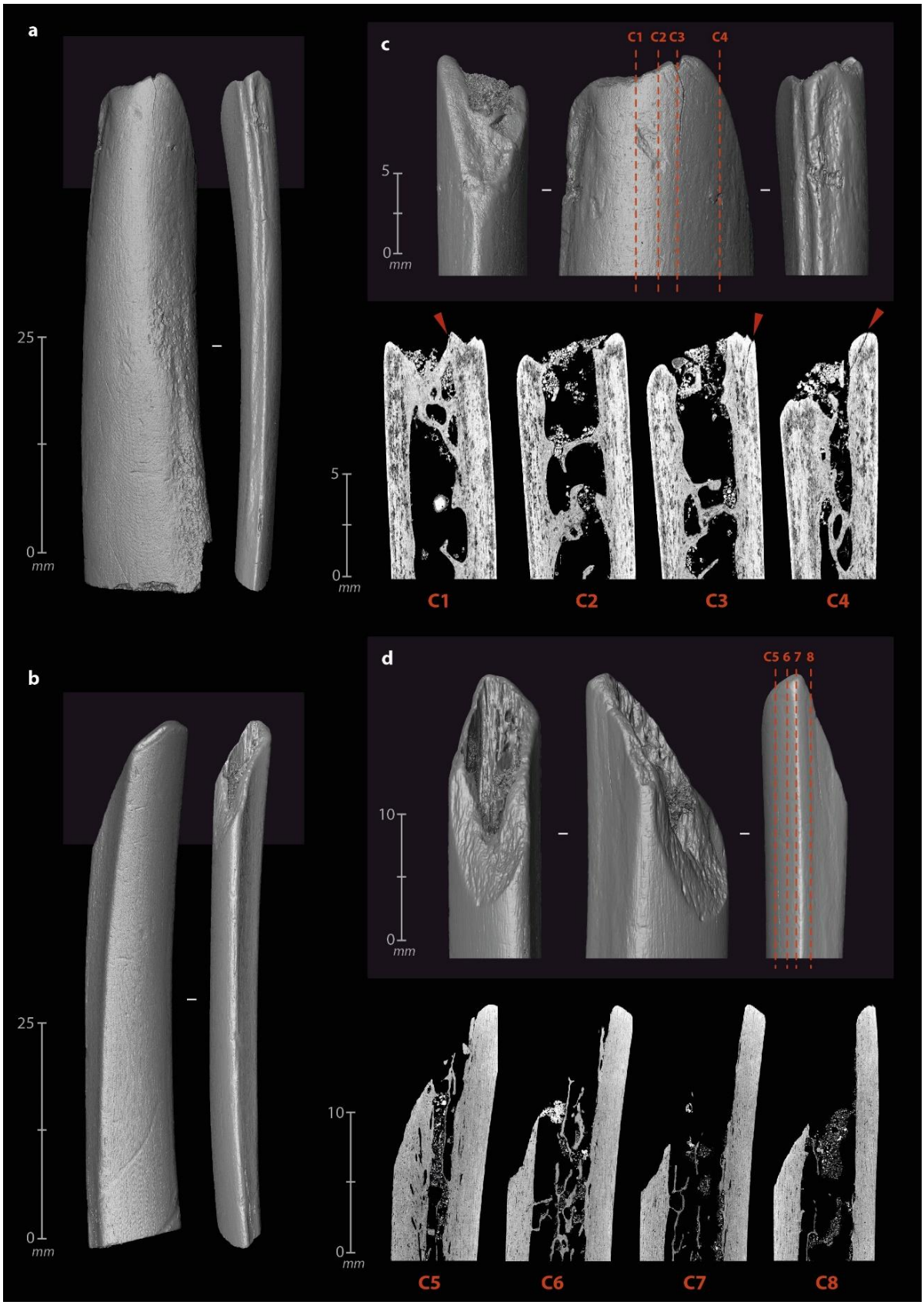


SI Fig. 7 Active ends of experimental bone tools. a) unused pressure flakers shaped by abrasion on coarse-grained sandstone; b) bevel from soft sandstone carving; c) short striations from abrasion shaping with fine-grained sandstone; d) spatulated flake used to spread fresh brain on a raw *Cervus elaphus* skin; e–f) lissoir used to rub grease into a *Capreolus capreolus* dry skin with fat; g) bone flake used for fleshing fresh Cervus elaphus skin; h) bone flake used for debarking fresh wood (*Salix alba L.*); i) unshaped rib of a *Cervus elaphus* used for digging humus; j) bone flake used for dehairing dry *Cervus elaphus* skin; k) edge damage of a bone flake used for carving fresh wood (*Salix alba L.*) (photos: H. Plisson)

SI Fig. 8 Microtomographic imaging of diaphysis fragments with smoothed ends. a) 3D reconstruction of the tool on the *Rangifer tarandus* tibia; b) 3D reconstruction of the tool on the *Rangifer tarandus* metatarsal; c–d) location of the sagittal sections on the active parts; C1–C4) sagittal sections showing the active part of the tool on *Rangifer tarandus* tibia; C5–C8) sagittal sections showing the profile of the active part of the tool on the *Rangifer tarandus* metatarsal (µCT image processing and computer-aided design: M. Baumann)



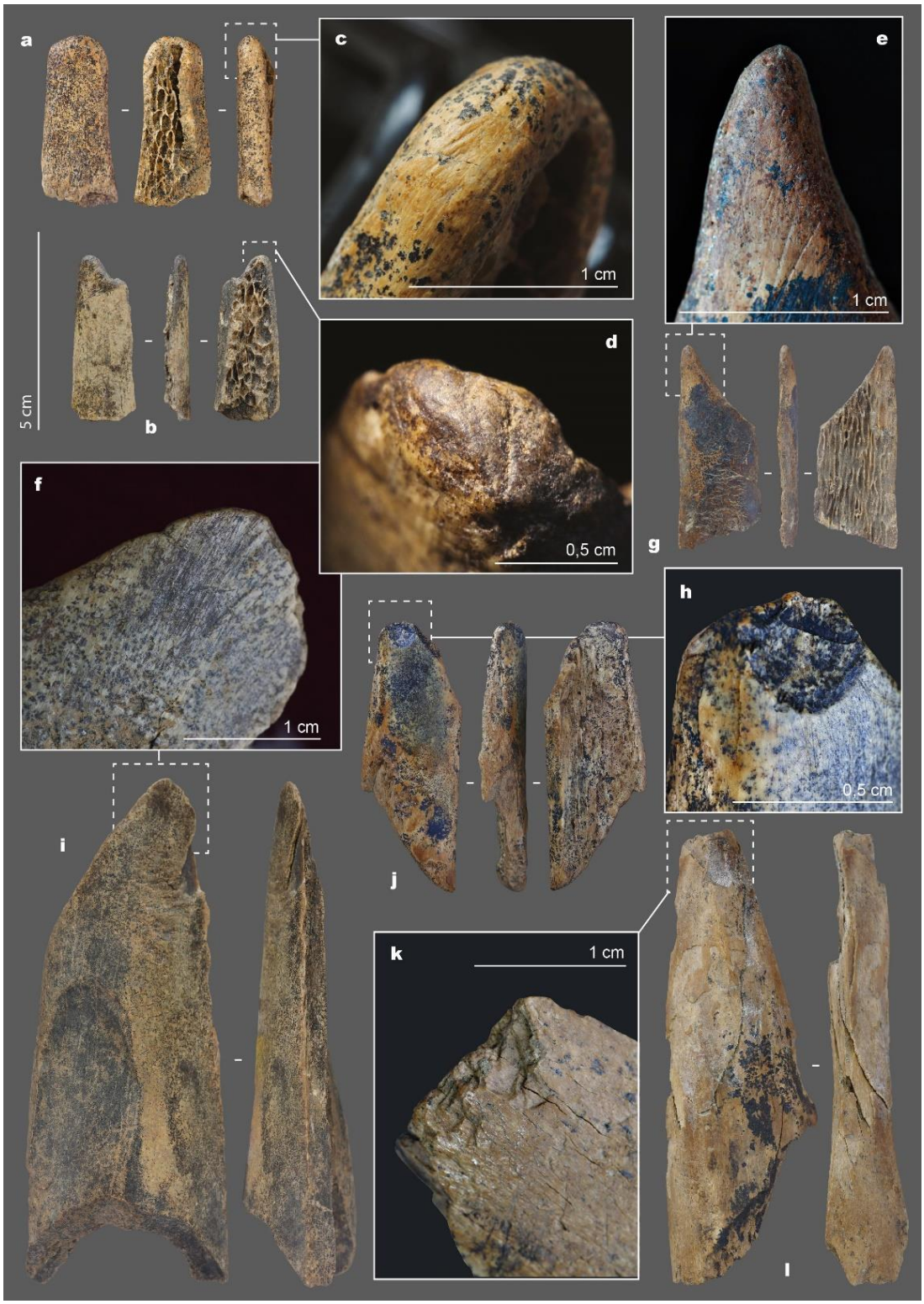
SI Fig. 9 Microtomographic imaging of diaphysis fragments with smoothed ends. a) 3D reconstruction of the tool on the rib of a *Equus ferus*; b) 3D reconstruction of a tool on the rib of a medium-sized ungulate; c–d) location of the sagittal cuts on the active parts; C1–C4) sagittal sections showing the active part of the tool on *Equus ferus* rib; C5–C8) sagittal sections showing the active part of the tool on ungulate rib (µCT image processing and computer-aided design: M. Baumann)



SI Fig. 10 Microtomographic imaging of medium-sized ungulate ribs with smoothed ends. a–b) 3D reconstructions; c–d) location of the sagittal sections on the active parts; C1–C8) sagittal sections showing the active part of the tool (µCT image processing and computer-aided design: M. Baumann)

SI Fig. 11 Lartet bone tools used as retouchers. a) specimen on a tibia of *Rangifer tarandus*; c) specimen on a metatarsal of a *Rangifer tarandus*; e) specimen on a rib of *Equus ferus*; g) specimen on a medium-sized rib of an undetermined ungulate; b, d, f, h) impact scars of utilization as retoucher (photos: M. Baumann)

SI Fig. 12 Awls, Abri Lartet, level 2. a) *Equus ferus* vestigial metapodial; b) bending fracture and smoothing on the active distal end; c) conical end with scraping traces; d) *Rangifer tarandus* metapodial (photos: M. Baumann)



SI Fig. 13 Examples of tools made from axial skeletal elements from the Neanderthal deposit of Chagyrskaya (Russia). a, b, g) blunt-end tools on ribs; i) retouched tool; j, l) intermediate tools; c) remnants of abrasion shaping; d) nicks and striations resulting from use as a compressor; e) regular and localized rounding of the edges of the fracture sections forming the point ; f) rounding, micro-flaking and group of striations related to the use of the cutting edge shaped by retouching; h) flaking intersecting with use grooves on a beveled tool; k) scarring and compaction of the active edge of an intermediate tool (all photos except c, e: M. Baumann; c, e: H. Plisson)

SI Table 1

Smoothed-end ribs in the Mousterian context identified in the literature

Country	Site	Number	Industry	Dates	References
France	Abri Peyrony	3	MTA	MIS 3(43–37 ka)	Soressi et al. (2013)
	Noisetier	2	Discoid	MIS 3(42 ka)	Oulad El Kaïd (2016)
	La Quina	3	MTA/Denticulate	MIS 3(48–40 ka)	Henri-Martin (1907–1910); Debénath et al. (1998)
	Pech de l'Azé	1	MTA	MIS 3(51 ka)	Soressi et al. (2013)
	Pradayrol	1	Discoid Levallois	MIS 3	Villeneuve et al. (2019)
	Jonzac	1	Quina	MIS 4(72 ka)	Rendu et al. (2020); Richter et al. (2013)
	Canalettes	1	Levallois	MIS 5–4(73 ka)	Patou-Mathis (1993); Valladas et al. (1987)
Spain	Cueva Mórin	1	MTA(Vasconian)	MIS 3(>43 ka)	Freeman (1971); Maíllo-Fernández et al. (2014)
	Axlor	1	Quina	MIS 3(>47 ka)	Mozota Holgueras (2012); Gómez-Olivencia et al. (2018)
Germany	Salzgitter-Lebenstedt	8	Levallois	MIS 3(55–48 ka BP)	Gaudzinski (1999); Pastoors 2009
Russia	Zaskalnaya VI	1	Levallois (Ak-Kaya)	MIS 3(39–30 ka)	Сапожникова (2008); Stepanchuk et al. (2017)
	Chagyrskaya	2	Micoquian (Sibiryachika)	MIS 4–3(60–50 ka)	Baumann et al. (2020)

Abbreviation: MTA = Mousterian of Acheulean tradition

SI Table 2

Microtomographic recording parameters of the bone tools from the Abri Lartet

Number	Raw material	Tool category	Region of Interest	Voxel size (µm)	Slice Number	Corr. Val.	kV	µA
0000-P16000-C22-Po455 n°311	*Rangifer tarandus* tibia		Complete	77	876	6.7	120	200
			Active part	15	2550	26.9	120	200
Sac 709	*Rangifer tarandus* Metatarsal	Blunt end retoucher	Complete	25	1275	15.1	120	200
			Active part	10	2250	34.4	120	200
0000_P16000_C34_Po875	*Equus ferus* rib	Blunt end retoucher	Active part	55	2000	9	120	110
			Medial part	55	2000	9	120	110
			Proximal part	55	2000	9	120	110
0000_P16000_C34_Po882 n°207	Rib med-sized	Blunt end	Complete	37	1500	11.5	120	120
			Active part	15	2550	27	120	120
			Detail active part	7	2550	51.6	110	140
Sac 710	Rib med-sized	Blunt end	Complete	37	1500	11.5	120	120
			Active part	15	2550	27	120	120
			Detail active part	7	2550	51.6	110	140
Sac 194	Rib med-sized	Blunt end	Complete	37	1500	11.5	120	120
			Active part	15	2550	27	120	120
			Detail active part	7	2550	51.6	110	140

Abbreviation: Corr. Val. = Correction value

SI Table 3

Bone tools recovered from Abri Lartet and radiocarbon dates

Photo	Lab. number	Unit-layer	Description	Species	Part	Uncalibrated 14C date[a]
Fig S4a	OxA-40377	A4-2	Awl	*Equus ferus*	Vestigial metapodial	36000 ± 1300
Fig S4b	(Not dated)	A4-2	Awl	*Rangifer tarandus*	Metapodial	
Fig S4c	OxA-40233	B4-2bis	Retoucher Smoothed-end	*Rangifer tarandus*	Metatarsal?	>43800
Fig S4d	OxA-39508	C3-2	Retoucher Smoothed-end	*Rangifer tarandus*	Tibia	34950 ± 720
Fig S4e	OxA-40234	B4-2	Smoothed-end	*Equus ferus*	Rib	36450 ± 910
Fig S4f	OxA-39507	Unknown	Smoothed-end	Ungulata size 2-3	Rib	40600 ± 1500
Fig S4g	OxA-40235	A5-2	Smoothed-end	Ungulata size 2-3	Rib	48000 ± 4000
Fig S4h	(Not dated)	Z4-2	Smoothed-end	Ungulata size 2-3	Rib	

a. Due to the small size of some of the samples and low collagen yields, none of the samples were ultrafiltered

SI Table 4

Additional provenience and radiocarbon sample information for Abri Lartet tools

Photo	Lab number	Collection number	Inventory number	% yield	% C	$\delta^{13}C$	$\delta^{15}N$	CN ratio
Fig S4a	OxA-40377	0000_P16000_C34_Po875	Sac 154, no. 164	2.9	41.8	-20.2	6.9	3.4
Fig S4b	(Not dated)		Sac 154					
Fig S4c	OxA-40233		Sac 709	5.5	41.6	-19.5	6.5	3.3
Fig S4d	OxA-39508	0000_P16000_C22_Po455	no. 311	3.8	43.5	-19.7	7.0	3.3
Fig S4e	OxA-40234	0000_P16000_C34_Po875		5.4	42.3	-20.9	6.7	3.3
Fig S4f	OxA-35507	0000_P16000_C34_Po882	no. 207?	3.9	43.0	-19.8	6.3	3.2
Fig S4g	OxA-40235		Sac 710	4.4	41.8	-19.1	6.8	3.3
Fig S4h	(Not dated)		Sac 194					

SI File 1 3D model of the smoothed-end tool on *Rangifer tarandus* tibia, n°311, 0000-P16000-C22-Po455, Unit C3, Layer 2, Abri Lartet. Provided as a separate interactive .pdf file

SI File 2 3D model of the smoothed-end tool on *Rangifer tarandus* metatarsal, sac 709, Unit B4, Layer 2bis, Abri Lartet. Provided as a separate interactive .pdf file

SI File 3 3D model of the smoothed-end tool on *Equus ferus* rib, n°32, 0000-P16000-C34, Unit B4, Layer 2, Abri Lartet. Provided as a separate interactive .pdf file

SI File 4 3D model of the smoothed-end tool on middle-sized ungulate rib, n°207?, 0000-P16000-C34-Po882, Unknown provenance, Abri Lartet. Provided as a separate interactive .pdf file

SI File 5 3D model of the smoothed-end tool on middle-sized ungulate rib, Sac 710, Unit A5, Layer 2, Abri Lartet. Provided as a separate interactive .pdf file

SI File 6 3D model of the smoothed-end tool on middle-sized ungulate rib, Sac 194, Unit Z4, Layer 2, Abri Lartet. Provided as a separate interactive .pdf file

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