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Rhinoceros (*Stephanorhinus hemitoechus*) exploitation in Level F at the Caune de l'Arago (Tautavel, Pyrénéés-Orientales, France) during MIS 12

Xi Chen[1,2,3] | Anne-Marie Moigne[4]

[1] Key Laboratory of Vertebrate Evolution and Human Origins, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing, China

[2] CAS Center for Excellence in Life and Paleoenvironment, Beijing, China

[3] University of Chinese Academy of Sciences, Beijing, China

[4] Histoire Naturelle de l'Homme Préhistorique (HNHP, UMR 7194 CNRS), Tautavel, France

Correspondence
Xi Chen, Key Laboratory of Vertebrate Evolution and Human Origins, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, 142 Xizhimenwai Street, Beijing 100044, China.
Email: chenyy1158@163.com

Anne-Marie Moigne, Département Hommes Environnements MNHN (HNHP, UMR 7194 CNRS), Tautavel, France.
Email: anne-marie.moigne@mnhn.fr

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Abstract

Caune de l'Arago is a Middle Pleistocene site in Southern France, where Acheulean artefacts and hominin fossils were excavated. Rhinoceros (*Stephanorhinus hemitoechus*) remains from Level F (MIS 12) were studied from a zooarchaeological and taphonomic perspective to investigate the potential human exploitation of this large taxon. The well-represented butchering marks, as well as scarce carnivore marks, indicate primary access to rhinoceros carcasses by hominins. The juvenile-dominated mortality profile further suggests aggressive scavenging or occasional opportunistic hunting. Furthermore, differential skeletal representation shows that humans selectively transported the nutrient-rich body sections. In addition, thorough processing of the carcasses for consumption inside the cave is highlighted by the frequent cut marks, intensive fragmentation, and regular spatial distribution. The analyses of the Arago Level F rhinoceros confirm the rhinoceros exploitation by humans during the Lower Palaeolithic; however, the rhinoceros mortality profile differs from that of large mammals such as equids, argali, and all other game species of this archaeological layer. Caune de l'Arago is the earliest hominin site where the systematic exploitation of rhinoceros has been documented.

KEYWORDS

aggressive scavenging, butchering marks, megaherbivore, Middle Pleistocene, mortality profile

1 | INTRODUCTION

Meat consumption plays an important role in the history of hominid evolution, as part of a larger complex scene in Western European archaeological contexts. The analyses of Middle Palaeolithic sites support the hypothesis that Neanderthals were heavily dependent on meat for their diets (Richards & Trinkaus, 2009; Salazar-García et al., 2013) and were likely efficient hunters (Discamps, Jaubert, & Bachellerie, 2011; Gaudzinski-Windheuser & Kindler, 2012; Niven et al., 2012; Patou-Mathis, 2000). Diversified scenarios of animal exploitation were exhibited in the Lower Palaeolithic age. Competition between hominids and carnivores was reported in the Lower Pleistocene sites of Vallonnet Cave (Echassoux, 2004), Barranc de la Boella (Pineda et al., 2017), and Gran Dolina TD 6.3 (Saladié et al., 2017). Primary access to carcasses was demonstrated at Gran Dolina TD 6.2 in MIS 21–20 (Saladié et al., 2014), Boxgrove in MIS 13 (Roberts & Parfitt, 1999), and Gran Dolina TD 10.1 in MIS 11–9 (Rodriguez-Hidalgo, Saladié, Ollé, & Carbonell, 2015). Hunting behaviours were also proposed in several sites during MIS 11–6, such as Gran Dolina TD 10.2 (Rodríguez-Hidalgo et al., 2017), Schöningen (Van Kolfschoten, Buhrs, & Verheijen, 2015; Voormolen, 2008), Orgnac 3, Terra-Amata, and Lazaret (Valensi, 2000; Valensi, Michel, El Guennouni, & Liouville, 2013).

The rhinoceros is a common giant mammal in Pleistocene human sites (Tong, 2000), yet few fossil populations have been reported, because they usually lack quantity in sample size. In Europe, the earliest *Stephanorhinus hundsheimensis* assemblage was reported at 1.2–1.1 Ma in the Vallonnet Cave (France; Michel et al., 2017), where abundant carnivore marks, relative complete limb bones, and few human cut marks indicate strong carnivore activities rather than human utilization (Echassoux, 2004). Isernia La Pineta (Italy), an Early Middle Pleistocene open-air site dating to 600 ka, yielded a large number of *S. hundsheimensis* fossils (Coltorti et al., 2005; Sala & Fortelius, 1993). During the Middle Palaeolithic, evident human exploitation of rhinoceros was documented at the open-air site of Biache-Saint-Vaast (France) in MIS 7 (Auguste, 1995; Bahain et al., 2015; Louguet, 2002), the travertine site of Taubach (Germany) in MIS 5 (Bratlund, 1999), and the cave site of La Cotte de St Brelade in MIS 6/7 (Scott, 1986; Smith, 2015).

Several rhinoceros assemblages were also reported in East Asia, which were associated with artefacts and/or human fossils. At the 1.2-Ma Shanshenmiaozui site, the bones of nine individuals of *Coelodonta nihowanensis* were unearthed from a fluvial layer, which received intense carnivore modifications before burial, but these remains lack traces of human activities (Liu et al., 2016; Tong, Hu, & Han, 2011). At the Middle Pleistocene Nanjing Man Cave site, a juvenile-dominant *Stephanorhinus kirchbergensis* population was reported (Tong, 2001), but no artefacts or cut marks were detected. At the Dadong cave site, dated to MIS 6/7, 285 *Rhinoceros sinensis* specimens are associated with human teeth, artefacts, and teeth/bone flakes (Miller-Antonio, Schepartz, & Bakken, 1999; Schepartz & Miller-Antonio, 2010).

In addition to rhinoceros, many other Early/Middle Pleistocene megaherbivore exploitations were documented in Africa and Europe. In the Early Pleistocene, most sites showed only the coexistence between megaherbivores and artefacts, such as the elephant remains from Barogali (Djibouti; Berthelet & Chavaillon, 2001) and Fuente Nueva 3 (Spain; Espigares et al., 2013) and the hippopotamus remains from Olduvai WK Hippo Cliff (Tanzania; Leakey & Roe, 1994) and Gombore II-2 (Ethiopia; Chavaillon & Berthelet, 2004). In the Middle Pleistocene, the presence of cut marks provided straightforward evidence of elephant butchery, such as Ambrona (Spain; Villa et al., 2005), Gesher Benot Ya'aqov (Israel; Goren-Inbar, Lister, Werker, & Chech, 1994), La Cotte de St Brelade (France; Scott, 1986; Smith, 2015), and Áridos 2 (Spain; Yravedra et al., 2010). A marginal foraging strategy in hominin subsistence was inferred for early megaherbivore processing (Rabinovich et al., 2012; Yravedra et al., 2010).

Caune de l'Arago long has been an important site for the construction of hominid behaviour of European Acheulean culture during MIS 14–12 (de Lumley, de Lumley, Merle des Iles, Moigne, & Perrenoud, 2014). Throughout the stratigraphy, eight large mammals were exploited and, in particular, horses (Bellai, 1995), argali (*Ovis ammon antiqua*; Moigne et al., 2006; Rivals, Testu, Moigne, & de Lumley, 2006), and beavers (*Castor fiber*; Lebreton, Moigne, Filoux, & Perrenoud, 2017) reveal clear evidence of hominid butchering of a variety of taxa. Hunting was demonstrated clearly for cervids, bovids, and equids (Moigne, 1983). This paper will present the zooarchaeological analysis of rhinoceros (*Stephanorhinus hemitoechus*) remains from Level F of Caune de l'Arago (Arago F) to evaluate whether humans utilized this giant mammal during MIS 12.

1.1 | *Stephanorhinus hemitoechus*

Four species of genus *Stephanorhinus* were found in Western Europe during the Pleistocene period: *Stephanorhinus etruscus*, *S. hundsheimensis*, *S. kirchbergensis*, and *S. hemitoechus* (Fortelius, Mazza, & Sala, 1993). *S. hemitoechus* is one of the most widespread rhinoceros in Western Europe, existing from ca. 0.5 Ma to the end of the last glaciation period. *S. hemitoechus* has relatively short limbs, a low-slung cranium, hypsodont molars, and a reduced premolar series, indicating a landscape mostly comprising grasslands (Fortelius et al., 1993; van Asperen & Kahlke, 2015). *S. hemitoechus*, of which the morphology was studied in detail in the Caune de l'Arago (Lacombat, 2005), has a relatively large size index in MIS 12 (Lacombat, 2009).

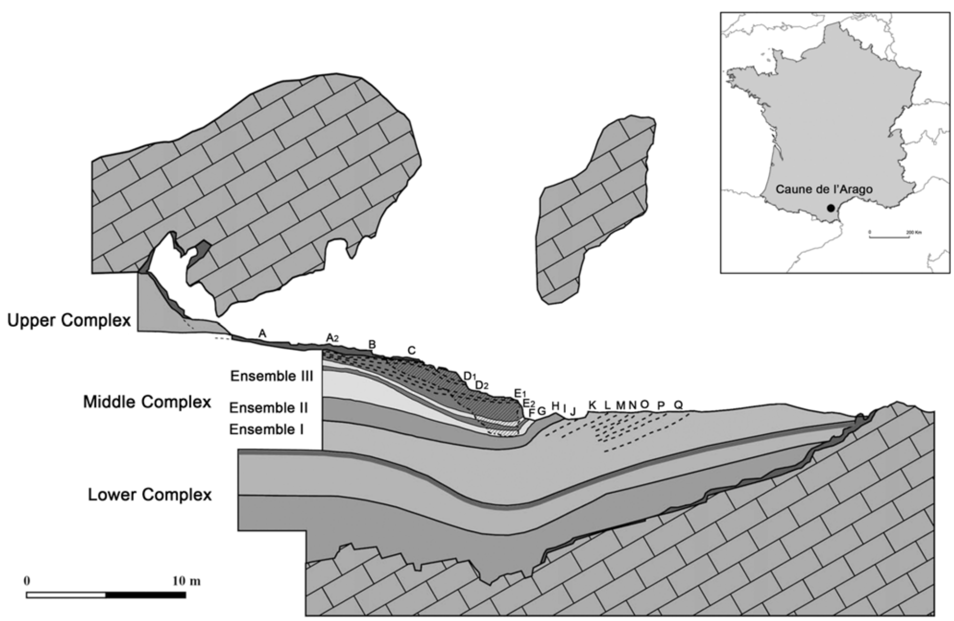

FIGURE 1 Location map and stratigraphical sequence of Caune de l'Arago (from de Lumley, Fournier, Park, Yokoyama, & Demouy, 1984, modified by Falguères et al., 2004)

2 | SITE CONTEXT

2.1 | Stratigraphical background

The Caune de l'Arago is a limestone cave in Tautavel, near Perpignan, Southern France (Figure 1). The 15-m stratigraphy is divided into four complexes. The middle stratigraphical complex is the main part, consisting of three distinct "ensembles" from bottom to top. Ensemble I (Levels Q to K) comprises stratified sands linked to cold and dry conditions (correlated with MIS 14). Ensemble II (Levels J to H) comprises claylike sandy silt formed during a relatively humid and temperate period (MIS 13). Ensemble III (Levels G to D) comprises stratified sands accumulated during a dry and cold period (MIS 12; de Lumley et al., 2014; Falguères et al., 2015). The dates of Level F, divided into three archaeostratigraphical layers (de Lumley et al., 2015), are 392 ± 43 ka according to ESR/U-series dating of herbivorous teeth (Falguères et al., 2015).

2.2 | Arago fauna

Arago fauna is a typical Galerian fauna, consisting of more than 120 species. The fauna of the Middle complex reflect a cold period, consisting of the following taxa: *Canis mosbachensis*, *Cuon priscus*, *Vulpes vulpes*, *Panthera leo spelaea*, *Felis silvestris*, *Lynx spelaea*, *Ursus arctos*, *Ursus deningeri*, *Cervus elaphus*, *Rangifer tarandus*, *Praeovibos priscus*, *Hemitragus bonali*, *Rupicapra* aff. *pyrenaica*, *O. ammon antiqua*, *Bison priscus*, *Equus ferus mosbachensis*, *S. hemitoechus*, and *Palaeoloxodon antiquus* (Moigne et al., 2006).

2.3 | Level F

Level F is the second most major level of the cave for the quantity of lithic artefacts and bones. The currently excavated section covers an area of 49 m^2 (de Lumley et al., 2015). Both the pollen and microfauna composition indicate that the area around the cave mostly was an open landscape with rare woodlands and a dry and cool climate. Herbivores are dominant with 64% argali, 16% horse, 2.5–3.5% muskox, thar, bison, reindeer, deer, and rhinoceros, whereas carnivores (1.8%) are much rarer than those in the other levels. A total of 423 rhinoceros specimens were identified, according to the diagnoses proposed by Lacombat (2005). Hominin occupation of Level F was recurrent and seasonal, indicated by the continuous proportion of faunal species and lithics in the three sublevels (Rivals et al., 2006). Hominin remains correspond to at least one child and one young adult based on the naturally shed deciduous teeth. The industry is typical of the Acheulean culture with handaxes, tools, flakes, and debris from mainly local raw material (Grégoire, Moigne, Barsky, & de Lumley, 2007).

3 | METHODS

3.1 | Ageing

Age structure is important to recognize scavenging from natural dead animals, unselective hunting, or selective hunting. Here, the ageing criterion is based on the cheek teeth eruption sequence and wearing stage of recent black rhinoceros (*Diceros bicornis*; Goddard, 1970), which was modified and introduced to *S. hemitoechus* by Moigne (1983) and Louguet (2002). Six stages of isolated teeth are described, starting from eruption stages until complete abrasion of the crown, using occlusal morphology, crown height, and root development. The teeth then were categorized into eight age groups corresponding to the calendar age of the black rhinoceros (Table 1) by using the cheek teeth wearing stage. In Arago F, most dental materials are fragments of isolated teeth and only a few are associated with maxillae or mandibles. Some teeth fragments were refitted to reconstruct the age profile of the population. The black rhinoceros population from Tsavo National Park was used for comparison, because it was one of the few stable rhinoceros populations in record (Goddard, 1970). Although the similar wear stage of black rhinoceros and *S. hemitoechus* may not

TABLE 1 Age groups of *Stephanorhinus hemitoechus*, based on the wear stages of cheek teeth

Milk dentition				Permanent dentition						Age group	Age (Goddard, 1970)
D1	D2	D3	D4	P2	P3	P4	M1	M2	M3		
4	5	4/5	4				1			I	0–1 year
5/6	5/6	5/6	5			1	2	1		II	2–3 years
(6)	(6)	(6)	6	4	3	(3)	2/3	2	1	III	4–5 years
+				4/5	3/4	3	3/4	3/4	2	IV	6–7 years
+				4/5	4/5	3/4	4/5	4/5	3	V	8–9 years
				5/6	5/6	4/5	5/6	4/6	4	VI	10–12 years
				(6)	(6)	5/6	6	5/6	5	VII	13–21 years
				(6)	(6)	6	(6)	6	6	VIII	22–40 years

TABLE 2 Age distribution of rhinoceros from Arago F, comparing with Biache-Saint-Vaast (Louguet, 2002)

Age group (year)	0–1	2–3	4–5	6–7	8–9	10–12	13–21	22–40	Sum
Arago F	5	2	1	0	0	3	1	1	13
Biache-Saint-Vaast	4	7	2	8	9	3	0	0	33

precisely represent the same absolute age, a general comparison based on the relative ontogenetic stages could be reasonable.

3.2 | Skeletal element representation

The number of identifiable skeletal parts (NISP) was used to evaluate the skeletal element representation (Lyman, 2008). Minimum numbers of elements (MNE) were adopted to calculate the numbers of each bone (Binford, 1984; Marean, Abe, Nilssen, & Stone, 2001). Minimum number of individuals was derived based on the MNE (Badgley, 1986). The relative abundance of each skeletal unit was estimated by the minimum animal unit (MAU) and the MAU%, which could eliminate disturbances from the different numbers of each bone (Binford, 1984).

3.3 | Surface modification

Bone surfaces were examined with a Stereomicroscope (Leica MZ8); some bones were also observed with an environmental scanning electron microscope (Philips XL 30) in the European Centre of Prehistoric Research, Tautavel.

Taphonomic modifications were examined from the aspects of weathering, oxide coating, carnivore tooth marks, cut marks, and bone breakage. Weathering stages were determined following Behrensmeyer (1978); carnivore tooth marks were identified according to Blumenschine (1995); oxide coating was recorded in terms of presence or absence; butchery activity and bone breakage were also considered an important agent in site formation.

We analysed the cut marks and bone breakages to evaluate the human modifications. Cut marks were identified according to Shipman (1981) and Domínguez-Rodrigo et al. (2009) and then correlated with concrete butchery activities following Binford (1981) and Nilssen (2000). Cut marks normally are elongated striations, parallel to each other, V-shaped in profile, with microstriations on the wall. They are also diverse in morphology and anatomical location, due to different actions such as skinning, dismembering, defleshing, and scraping (Binford, 1981; Domínguez-Rodrigo et al., 2009). Cut marks were also illustrated on the template of girdle and limb bones, to show their anatomical distribution. Breakage type (green/dry) was identified on the basis of the criteria outlined by Haynes (1983) and Villa and Mahieu (1991). Green broken specimens are characterized by smooth fracture surfaces, oblique breakage planes, and acute or obtuse breakage plane angles, while contrasting with the uneven, sometimes microstep fractures, longitudinal/transverse breakage planes, and nearly vertical breakage plane angles of dry breaks.

3.4 | Spatial distribution

Three-dimensional coordinates and measurements (length/width/thickness) of each specimen were input into to the GIS software, which was developed by the European Centre of Prehistoric Research.

TABLE 3 Skeletal statistics of rhinoceros remains from Arago F

	NISP	MNE	MAU%
Cranium (upper teeth)	115 (108)	13	100%
Mandible (lower teeth)	74 (65)	13	100%
Teeth fragment	28	-	—
Cervical vertebra	5	5	5%
Thoracic vertebra	4	3	1%
Lumbar vertebra	3	3	6%
Sacrum vertebra	1	1	8%
Caudal vertebra	0	0	0%
Rib	21	16	4%
Scapula	4	2	8%
Humerus	9	7	27%
Ulna	3	2	8%
Radius	6	3	12%
Carpal	6	6	3%
Metacarpal	3	3	3%
Phalanx anterior	21	18	8%
Pelvis	5	2	15%
Femur	12	6	23%
Patella	1	1	4%
Tibia	6	3	12%
Fibula	3	2	8%
Tarsal	16	16	9%
Metatarsal	4	4	4%
Phalanx posterior	27	27	12%
Foot bones fragments	9	8	—
Sesamoid	37	37	12%
Total	423	195	—

Note. NISP: number of identifiable skeletal parts; MNE: minimum numbers of elements; MAU: minimum animal unit.

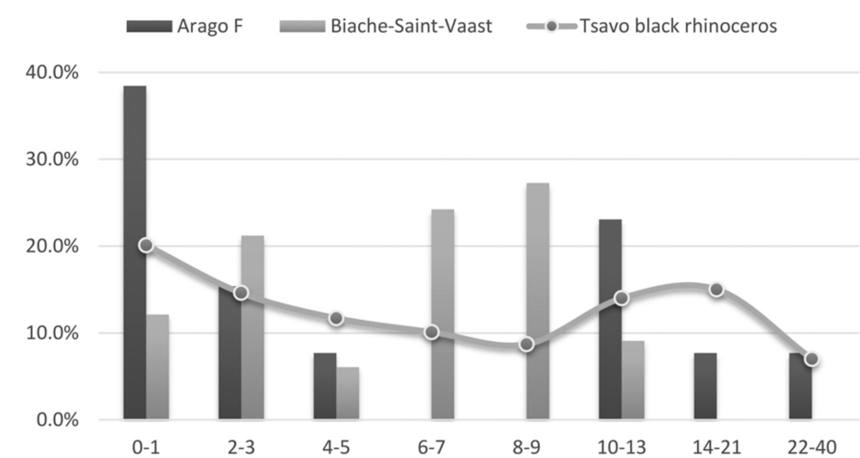

FIGURE 2 Mortality rate of each age stage of *Stephanorhinus hemitoechus* from Arago F, Biache-Saint-Vaast (Louguet, 2002), and comparing with black rhinoceros from Tsavo National Park, Kenya (Goddard, 1970, table 8)

Each skeletal proportion was displayed in a unique colour. Point density analysis was also conducted.

4 | RESULTS

4.1 | Mortality profile

The age distribution of *S. hemitoechus* in Arago Level F yields 13 individuals, based on 115 upper teeth/maxillae and 74 lower teeth/mandibles (Table 2; Figure 2). Young animals between 0 and 5 years old (61.5%) are the most highly represented. Rhinoceroses at this age normally are not yet sexually mature and are nursed by their mothers (Goddard, 1970; Schenkel & Schenkel-Hulliger, 1969). In addition, there are three adults between 10 and 12 years old and two senior adults between 14 and 40 years old. The young adult class between 6 and 9 years old is absent. In brief, the rhinoceros mortality profile is defined by the dominance of juveniles and the absence of young adults. For the postcranial bones, at least two juveniles are recognized based on the unfused epiphyses, but most of them are too fragmented to get the age information.

4.2 | Skeletal element representation

Except for caudal vertebrae, all skeletal parts are represented for the Arago F rhinoceros. In total, 423 rhinoceros specimens (NISP) represent 195 skeletal elements (MNE; Table 3). NISP is best represented by isolated teeth, which are 40.9% of the total NISP, whereas MNE are more represented by foot bones. Remarkable differences exist between NISP and MNE, especially with heavily fragmented elements, for example, cranium, mandible, and limb bones. NISP distribution of rhinoceros in Arago F is similar to that of Biache-Saint-Vaast Level IIa, where isolated teeth are 40% of NISP and foot bones are also highly represented (Auguste, 1995: Figure 6a).

Relative skeletal abundance is displayed by MAU% and compared with the carnivore-modified Shanshenmiaozui site (Tong et al., 2011; Figure 3). At Arago F, the cranial section is represented much better than the postcranial section, because the highest MAU% of postcranial bones is only 27% (humerus). The axial parts (vertebrate and rib) are the most poorly represented and are only 3.4% of that which is expected. For the legs, meaty elements are more abundant than the meatless elements. The proximal limb bones (humerus/femur) are represented better than the distal ones (radius/ulna/tibia/fibula). In addition, the phalanges are more abundant than the metapodial and carpal/tarsal elements because the foot sole of the rhinoceros is rich in fat. Bone density and marrow content were considered to be the main factors of skeletal survival of bovid, cervid, and equid taxa in the hominin sites (Lam, Chen, & Pearson, 1999); in contrast, rhinoceros long bones are characterized by very thick compact bones and undeveloped marrow cavities. Therefore, the nutrition distribution across the skeletal parts determined part retrieval and carcass processing during the formation of the Arago F rhinoceros assemblage.

4.3 | Bone surface modification

4.3.1 | Nonhuman modification

All the bones maintain intact cortical surfaces and are at the 0–1 weathering stage, according to Behrensmeyer (1978). The major natural modifications on the surface are the manganese coatings (40%).

Carnivore marks affected only two bones, a humerus and a fibula, which is 0.5% of NISP. The lateral epicondyle of the humerus presents

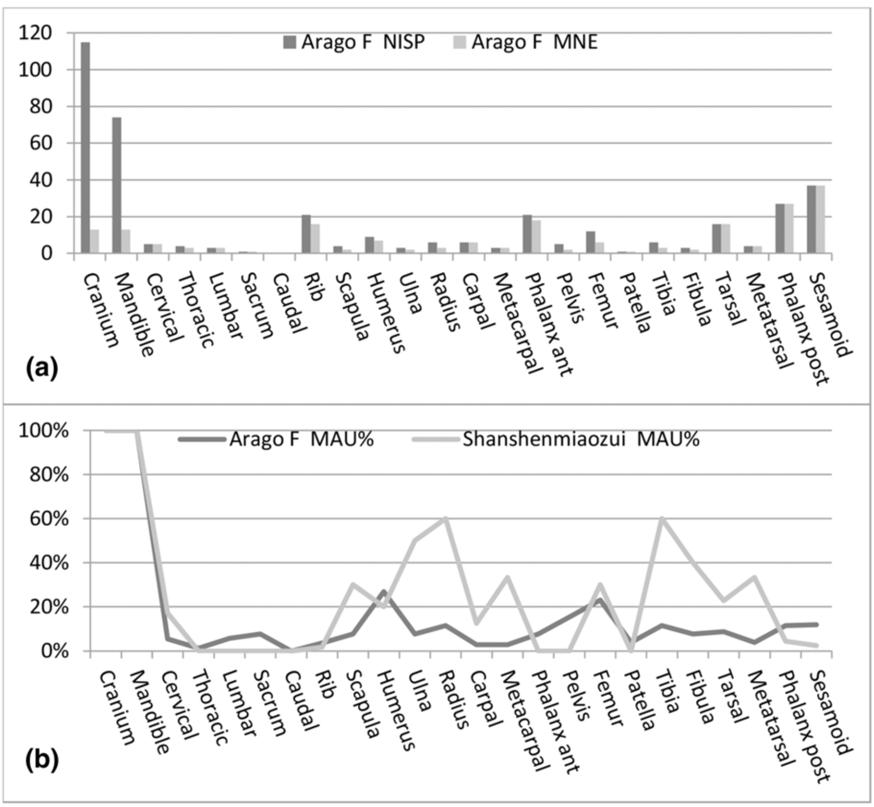

FIGURE 3 (a) Number of identifiable skeletal parts (NISP) and minimum numbers of elements (MNE) distribution of Arago F rhinoceros. (b) Relative skeletal abundance (MAU%), comparison between Arago F and Shanshenmiaozui rhinoceros

a semirounded pit; the fibula shows some chewing scores on the distal end. On the argali remains from Arago F, carnivore marks account for 1% of NISP, but 17.6% in Levels M, N, and O, when bears and canids are the main accumulators in this cave (Rivals et al., 2006). In sum, nonhuman modification is limited during the formation of the Arago F bone assemblage.

4.3.2 | Cut marks

In total, 153 specimens bear cut marks, which comprise 36.2% of the NISP. On axial parts, girdle bones, limb bones, and foot bones, the proportion of cut marks is 70.6%, 66.7%, 64.1%, 71.8%, respectively. These cut marks are related to skin removal from carcasses (skinning), separation of articulated bones (disarticulation), detachment of meat, or periosteum adhering to bones (defleshing/scraping).

Skinning marks are present on the dorsal and lateral sides of metapodials. The lateral shaft of a right metatarsal IV (Figure 4a) presents a set of short, straight, parallel, and oblique cut marks. These marks are broad and V-shaped in profile, with distinct microstriations. Disarticulation marks are found around the articular surface (Figure 4 b,c). Two main types are recognized. One type is a set of short, V-shaped marks on the ligament attachment. The second, deep at the beginning, then quickly shrinking to the end of the epiphysis, can be left by the cutting of cartilage. Defleshing marks are distributed on the meaty areas of mandibles, vertebrae, ribs, scapulae, pelvis, and limb bones (Figure 4d,e). The morphology of defleshing marks is varied. Some marks are long, curving, and deep at the beginning on scapulae, pelvis, and limb bones; some of these cut marks are short, straight, and deep in the midsection, such as on the ribs; others are fork-shaped, which could be formed by retouched flakes or even a handaxe (De Juana, Galán, & Domínguez-Rodrigo, 2010). Scraping marks, characterized by sets of shallow, parallel striations, are only encountered on the scapula and metatarsal (Figure 4f). In brief, the high proportion of cut marks reveals the heavy consumption of the rhinoceros carcass. The complete butchering process is exhibited on the bones, and the morphology of cut marks is quite diverse.

4.3.3 | Bone breakage

The rhinoceros remains are heavily fragmented (81.6%). The complete specimens belong to short bones, mainly foot bones, including 77% of carpals, tarsals, phalanges, and sesamoids. Size range of specimens is between 12 and 220 mm, with a mean of 47.7 mm. All the skull or mandible bones were broken into small pieces, with a mean of 68.9 mm, ranging from 28 to 120 mm. Limb bones present only

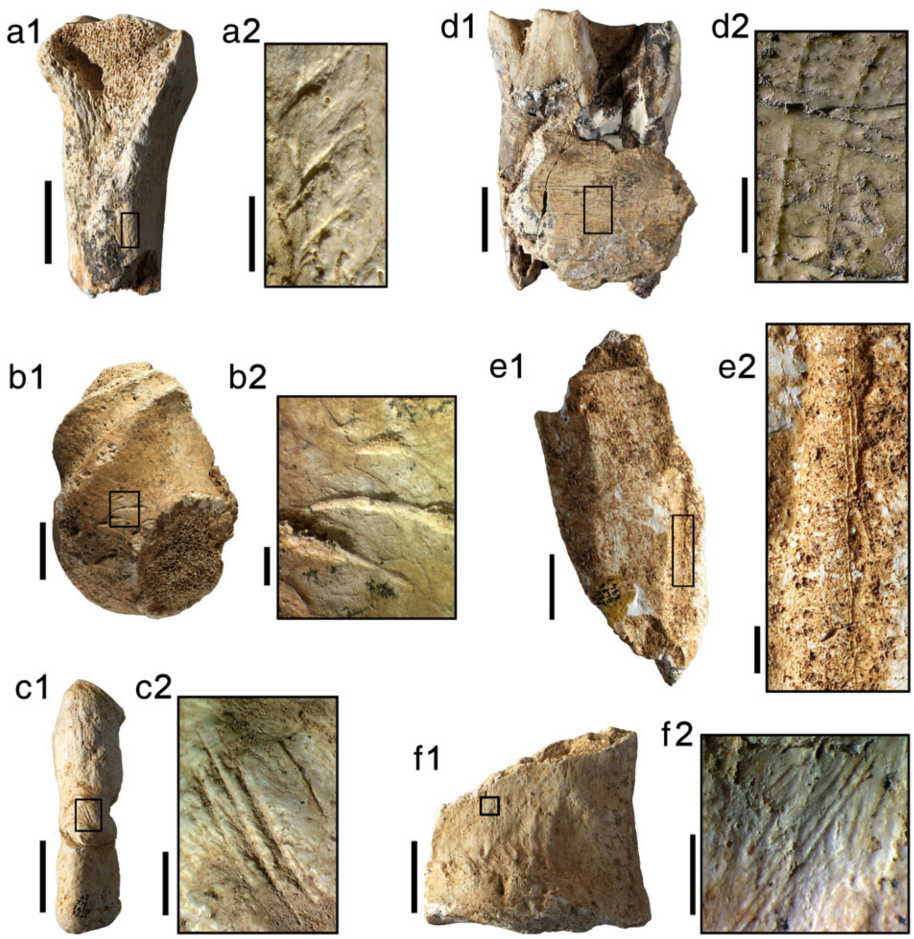

FIGURE 4 Human cut marks. (a) Skinning marks on the lateral plantar side of metatarsal IV; (b) disarticulation marks on the lateral posterior side of humerus; (c) disarticulation marks on the posterior side of pisiform; (d) defleshing marks on the lingual side of mandible; (e) defleshing marks on the dorsal side of ilium; (f) scraping marks on the lateral side of scapula. Scale bars for a1–f1 equal 2 cm, for a2–f2 equal 2 mm [Colour figure can be viewed at wileyonlinelibrary.com]

broken epiphyses or extreme parts of shafts (Figure 5), which are 84.2 mm on average, ranging from 18 to 152 mm.

Most of the bones (88.1%) were broken while fresh, with smooth fracture surfaces. The majority of the teeth (71.2%) were broken in a vertical direction, normally stricken from the crown. The postcranial bones mainly present oblique fractures (49%), with a few longitudinal (26%), transversal (19.2%), or spiral (5.8%) fractures. Limb bones often show continuous percussion cones along the shaft, rather than spiral fractures. On the scapulae and pelvis, typical spiral fractures appear on the necks and long fractures exist on the flat area, along the prior cutting marks (Figure 6d). On the metapodials and phalanges, fractures often are longitudinal or transverse and the percussion cone is located on the posterior shaft.

4.3.4 | Spatial distribution

For the spatial distribution of rhinoceros remains in Level F (Figure 7), most of the rhinoceros bones are scattered in the north-east area; two smaller groups appear in the north-west and south-east areas, and few bones are present in the south-west area. The squares C16–18 and D16–18 are in a geochemically altered area, and bones are lacking.

The girdle bones (scapula/pelvic) and the large long bone fragments are present near the east wall of cave. Isolated teeth and small bones are distributed all over the site. The fragments of skull bones (cranium/mandible) appear around the isolated teeth. In addition, the sesamoids seem to be in pairs. These distinctive distributions are possibly a result of butchering activities. The area with the most percussion activity seems to be in the centre of the cave, and the large fragments are scattered towards the walls of the cave. Generally, the distribution of rhinoceros and the distribution of argali remains are superposed in the same level (Rivals et al., 2006).

Although articulation among different bones is not certain, several fragments of the same bone can be refitted. There are eight associated groups (19 specimens) in the teeth, scapula, humerus, pelvis, or phalanx. The farthest association is between two fragments of scapula, with a distance of 661.7 cm on the plane; the other associations are 0.5–2 m in distance. These associations revealed expressive contemporary hominin activity in the cave. Considering the carnivore modification is scarce in Level F, the distribution of rhinoceros remains is formed logically by the human management of the space.

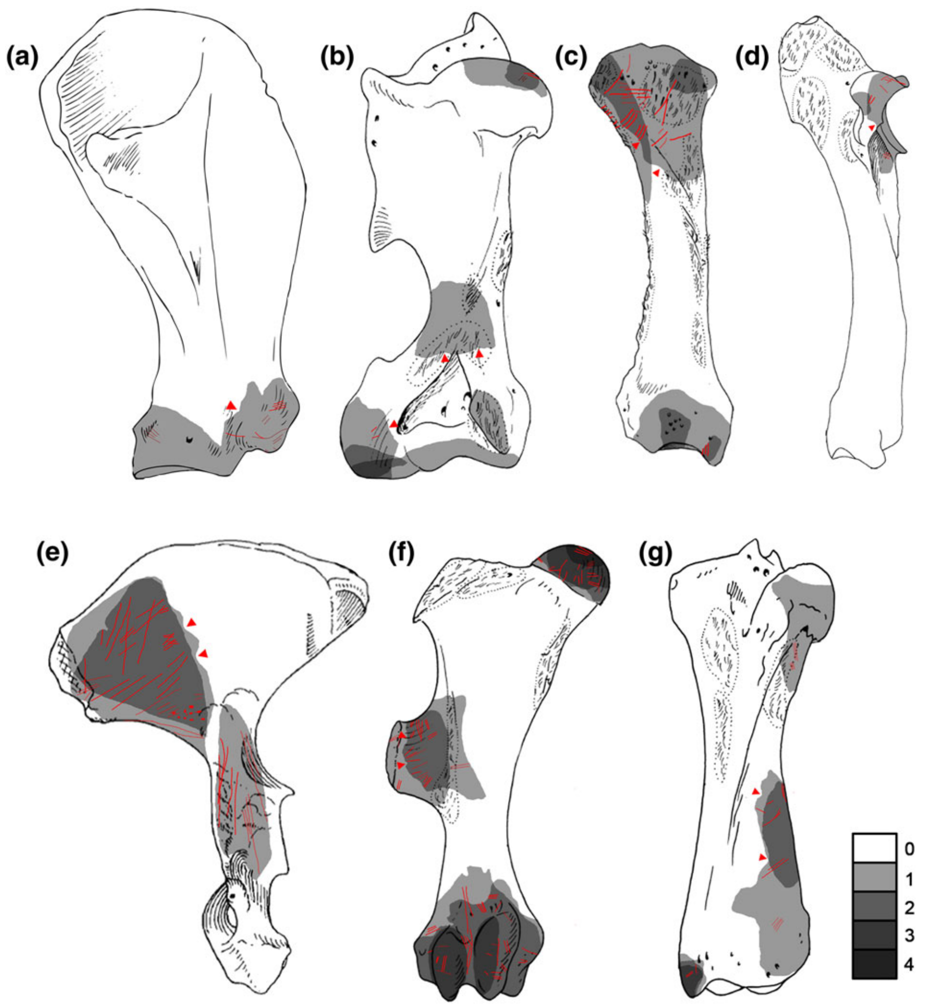

FIGURE 5 Preservation and surface modification of (a) scapula, (b) humerus, (c) radius, (d) ulna, (e) pelvis, (f) femur, and (g) tibia. Red trigons show percussions, red lines show cut marks, and greyscale show the number of fragments [Colour figure can be viewed at wileyonlinelibrary.com]

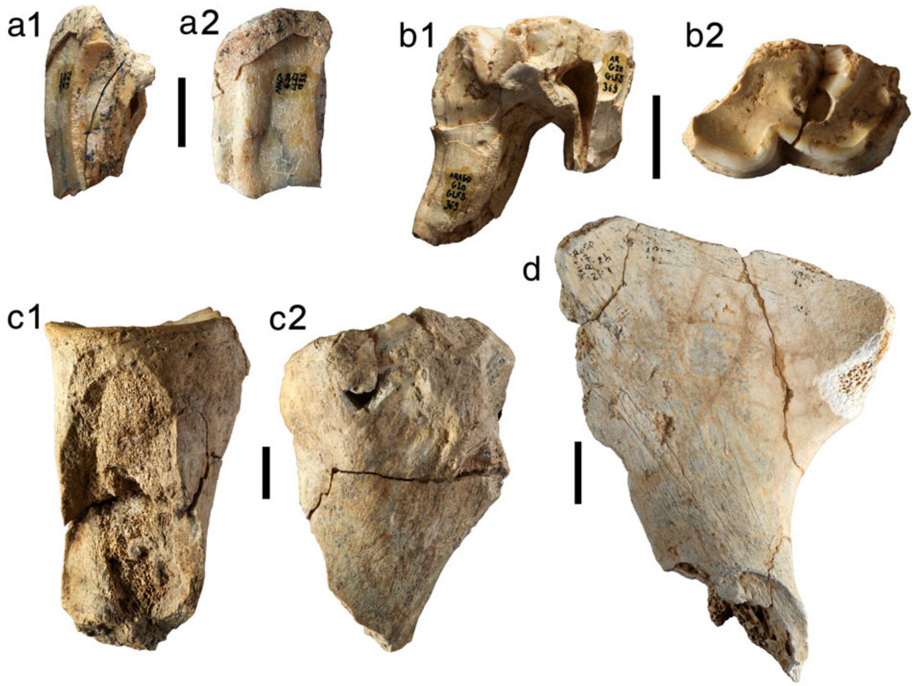

FIGURE 6 Anthropic fragmentations. (a1, a2) Distal and buccal views of lower third molar, showing vertical fracture surface; (b1, b2) lingual and occlusal views of lower third molar, showing vertical fracture surface; (c1, c2) lateral and anterior views of radius, with continuous percussions on the shaft; (d) ventral view of ilium, showing straight fracture along the cut marks (top) and typical spiral fracture (bottom). Scale bars = 2 cm [Colour figure can be viewed at wileyonlinelibrary.com]

5 | DISCUSSION

5.1 | Exploitation of the rhinoceros

Generally, the mortality profile of Arago F rhinoceros resembles that of the black rhinoceros from Tsavo Natural Park in Kenya (Goddard, 1970), despite that the 0- to 1-year-old calves are over-represented at Arago F (Figure 2). Rhinoceros assemblages are represented by the dominance of juveniles and are poor in older animals at Vallonnet Cave, Nanjing Man Cave, and Taubach (Bratlund, 1999; Echassoux, 2004; Tong, 2001). This outcome is consistent with the natural mortality profile; however, the rough division of the age stages prevents further comparison. In contrast, for the anthropic Level IIa of Biache-Saint-Vaast, the animals between 6 and 9 years old account for 51.5% of the total, without older individuals (Louguet, 2002). This pattern was explained as a hunting behaviour that specially targeted the young adults that had just left their mothers.

Several models can be proposed, including passive scavenging, active scavenging, opportunistic hunting, and selective hunting. In Arago F, hominins likely had the first access to the rhinoceros carcasses, based on the high proportion of butchering marks and scarce carnivore marks. Thus, scavenging after carnivores should be eliminated from the possibilities, due to the very faint carnivore activities. Selective hunting also seems to be unlikely even though there is a high proportion of juveniles because rhinoceros calves are usually protected seriously by their mothers (Sillero-Zubiri & Gottelli, 1991). The most likely rhinoceros from selective hunting probably are the inexperienced subadults, such as what happened at Biache-Saint-Vaast (Louguet, 2002). Furthermore, the age structure of Arago F rhinoceros generally is consistent with a natural mortality profile, which is characterized by many juveniles, few seniors, and nearly absence of young adults. This point supports the active scavenging of carcasses of animals that died naturally. Nevertheless, the occasional opportunistic hunting could not be ruled out completely, when it was proposed to explain the Argali population (Rivals et al., 2006) and horse population from the same level (Bellai, 1995).

5.2 | Transportation of carcasses

Although all the skeletal parts were encountered on-site, the differential preservation across them is significant. Skeletal patterning indicates that hominins transported predominantly nutrition-yielding skeletal elements of the rhinoceros carcasses. Skulls and mandibles were selected, perhaps for the processing of head nutrition (brain, tongue, facial muscles, etc.) in the cave, as suggested by the elephant exploitation pattern (Agam & Barkai, 2016; Reshef & Ran, 2015). Furthermore, the upper part of the rhinoceros leg has more meat than the lower part, and the feet bear abundant fat in the sole; they also thus are chosen for transport. By contrast, these meaty elements are less represented in the Shanshenmiaozui site because of carnivore consumption in situ (Tong et al., 2011; Tong & Wang, 2014). We can also speculate that some less nutritious elements could be abandoned in the field, when hominins confronted the competition of carnivores. In consideration of the weight of rhinoceros, it is also possible that sometimes hominins cut the meat to take it back without bones.

In African ethnographic research, the heads of big mammals, such as elephants, are usually not carried back to camp sites (Haynes & Klimowicz, 2015; O'Connell, Hawkes, & Blurton Jones, 1988). However, in our opinion, it perhaps depends on the carcass size, distance, and carrying value. Caune de l'Arago is in a small intermountain basin,

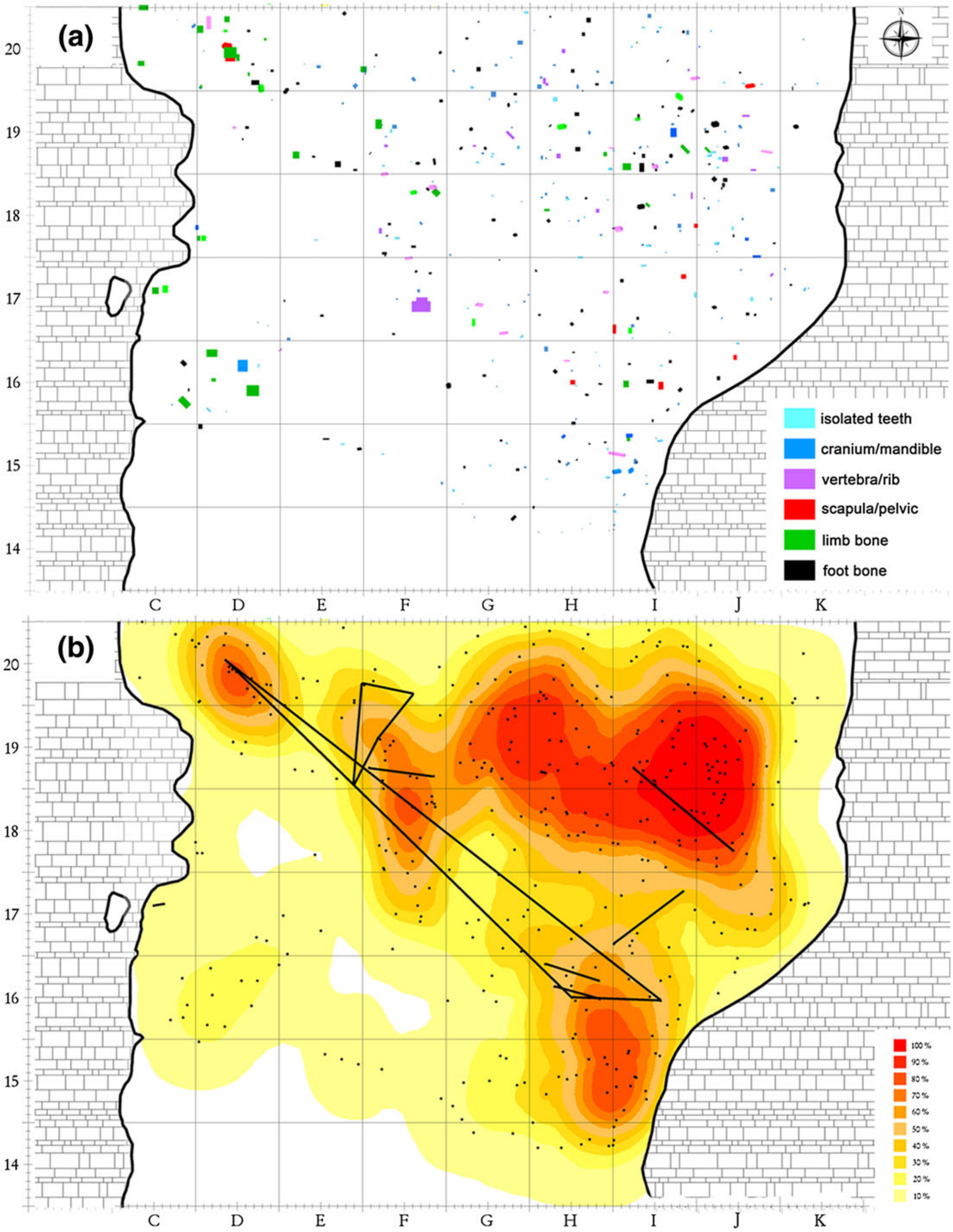

FIGURE 7 (a) Spatial analysis on plan: Distribution of different skeletal parts. (b) Density analysis and association of refitting bones [Colour figure can be viewed at wileyonlinelibrary.com]

so it is easier to transport the heavy body elements than in the African savanna, especially when most of the rhinoceros are juveniles. In addition, the meat and fat certainly would keep fresh longer in cold climates than in tropical climates. Considering the great physical effort for transportation, group cooperation strongly was implied (Agam & Barkai, 2016).

5.3 | Rhinoceros consumption in cave

Meat consumption of hominins is supported clearly by the high density of bone fragments and extraordinarily frequent cut marks in Arago F. The scattering of bones and refitting between specimens show that hominins intentionally may manage the living space in caves. There is no evident trace of carnivorous disturbance during the period of the hominin occupation. All the body parts of rhinoceros were utilized thoroughly, based on the severely fragmented specimens. This use was not limited to only the cranium and mandible, as the teeth were also fragmented intentionally (Figure 6), perhaps due to the removal of the meat between the gums or for secondary utilization of cheek teeth fragments. Although the medullary cavity is not developed in rhinoceros long bones, hominins still may attempt to attract the grease from inside through fragmentation. In comparison, rhinoceros bones are much more complete in carnivore-modified sites such as the Vallonnet Cave and Shanshenmiaozui site, where the teeth were still attached to maxillae or mandibles, and at least half of the bones or shaft cylinders of limb bones were preserved (Echassoux, 2004). In brief, Arago F hominins performed the utmost utilization of the carcasses.

The cut marks normally are scarce in the ethnographic records of both hippopotamus (Crader, 1983) and elephant carcasses (Haynes, 1991; Haynes & Klimowicz, 2015). In contrast, the percentage of cut marks of Arago F rhinoceros is 36.2%, and this percentage also exceeds 20% in the Neanderthal site Biache-Saint-Vaast (Auguste, 1995). Diverse consumption behaviours could be responsible for this contradiction despite the differences regarding the tools and butchering skills. Until now, more evidence has been needed to understand the diversity of megaherbivore carcass utilization in hominin evolution.

6 | CONCLUSION

Previously studied rhinoceros assemblages from Lower Palaeolithic Period sites such as the Vallonnet Cave and Nanjing Man Cave were formed by carnivorous activity or hominin scavenging (Echassoux, 2004; Tong, 2001). Caune de l'Arago provided the first case of the systematic exploitation of rhinoceros in the Lower Palaeolithic Period. More rhinoceros exploitation cases were documented later in the Middle Palaeolithic, such as at the sites of Biache-Saint-Vaast, Taubach, Dadong, and La Cotte de St Brelade (Auguste, 1995; Bratlund, 1999; Schepartz & Miller-Antonio, 2010; Smith, 2015). Among them, Biache-Saint-Vaast showed valid evidence of selective hunting of young adults, as often documented in herbivores of the Middle Palaeolithic. Based on prior analyses, the Arago F rhinoceros assemblage provides unique evidence of active rhinoceros procurement by Lower Palaeolithic hominin populations. Furthermore, it also sheds new light on the origin of the effective acquisition and processing on megaherbivores, which often was considered as marginal foraging behaviour during the Lower Palaeolithic Age.

At Caune de l'Arago, hominins have shown the ability to exploit large mammals and mesofauna, as well as rhinoceros. Although the rhinoceros individuals account for only 3.5% of Arago F, their huge body mass provided a large quantity of meat for hominin occupants. In the anthropic level of Caune de l'Arago, the high density and taphonomic signatures of the bone fragments show that meat and marrow extraction was an important aspect of hominin activity at the site. Finally, we infer that the relative cold and dry environment during this time drove hominins to explore a wide variety of meat resources.

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ORCID

Xi Chen http://orcid.org/0000-0001-7343-3825

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