



## A taphonomic and zooarchaeological study of the early Middle Pleistocene 3 colluvio level from Isernia La Pineta (Molise, Italy)

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### ABSTRACT

The early Middle Pleistocene site of Isernia La Pineta (MIS 15), discovered in the 1970s, is one of the oldest archaeological sites excavated in Western Europe. Since its discovery, this Lower Palaeolithic open-air site has provided an interesting opportunity for the study of human behaviour during this early period of human evolution. Taphonomic studies conducted at the site, mostly of archaeosurface 3a in sector I, the level containing the most artefacts, have indicated that there was strong anthropogenic influence on the formation of the deposit, which is supported by the rich technological record. In this paper, we present a taphonomic study of the 3 colluvio level, in which bison is the most abundant taxon, and on which preliminary studies have highlighted the anthropogenic component. Our aim is to identify the involvement of hominins and carnivores in the accumulation, modification, and destruction of animal carcasses. The coexistence of hominins and carnivores is well-documented at the site, although co-occurrence of both predators over the same remains is rare. The almost total absence of modification on bone surfaces produced by hominins (cut marks) and carnivores (tooth marks) could be the result of taphonomic processes of alteration of bone surfaces, as hominins and carnivores seem to have acted as modificatory agents. Our study reveals that these groups probably acted independently, in different events, as part of the foraging and resources acquisition activities that these predators carried out in this environments.

### 1. Introduction

The frequencies and distributions of carnivorous and anthropogenic modifications or signals on bone surfaces are used as proxies for reconstructing the interactions or relationships among large predators, hominins included, and their role in the formation of the archaeological record (Domínguez-Rodrigo, 1997; Capaldo, 1998; Lupo and O'Connell, 2002; Domínguez-Rodrigo and Piqueras, 2003; Egeland et al., 2004; Saladié et al., 2014). However, the use of these proxies is limited or even impossible at sites where bone surfaces are not well preserved.

At open-air sites, the absence of bone surface modifications made during the nutritional phase of the carcasses (according the taphonomic

phase descriptions of Capaldo (1998)), such as cut marks or carnivore tooth marks, is usually documented (Diez Fernández-Lomana et al., 1997; Egeland, 2007, 2008; Egeland and Domínguez-Rodrigo, 2008; Malerba et al., 2000; Espigares et al., 2013; Pineda et al., 2014, 2019; Mosquera et al., 2015; Pineda and Saladié, 2019). Processes such as weathering (Behrensmeier, 1978), hydric abrasion (Behrensmeier, 1975; Petraglia and Potts, 1994), or lixiviation (Pineda et al., 2014) can affect the osteological sample and alter or obliterate pre-existing modifications. Reconstructing taphonomic histories related to hominin and carnivore behaviours on such sites is difficult and occasionally unreliable (Domínguez-Rodrigo et al., 2010).

In Western Europe, the Early and Middle Pleistocene archaeological

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record shows an increasing number of open-air sites in which evidence of hominin and/or carnivore activity is documented. This scenario is described in Pirro Nord (Arzarello et al., 2007), Fuente Nueva 3 (Espigares et al., 2013) and Barranc de la Boella (Mosquera et al., 2015; Pineda et al., 2017) during the Early Pleistocene, and in a wider number of sites from Middle Pleistocene, such as Notarchirico (Moncel et al., 2019), Fontana Rannuccio (Segre Naldini, et al., 2009), Castel di Guido (Boschian y Saccà, 2010), La Polledrara di Ceganibbio (Santucci et al., 2016), Boxgrove (Roberts and Parfitt, 1999), Cuesta de la Bajada (Domínguez-Rodrigo et al., 2015) or Torralba and Ambrona (Villa et al., 2005; Pineda and Saladie, 2019).

Taphonomic and zooarchaeological study of faunal assemblages in which bone surfaces are bad preserved cannot be based, almost exclusively, in the analysis of bone surface modifications. In order to solve this phenomenon, different methods based on actualistic observations have been proposed. These methods are based on the anatomical representations of bones and bone portions (p.e. epiphysis-to-shaft or axial-to-limb ratios) and its application to archaeological contexts in order to identify grades of ravaging of carcasses and to infer level of competition among predators (Domínguez-Rodrigo and Organista, 2007; Faith et al., 2007; Egeland, 2008; Saladié et al., 2014; Pineda et al., 2015, 2017).

These methods have been demonstrated to be valid proxies for studying the impact of hominins and carnivores on osteological remains. Faith and Behrensmeyer (2006) described a drastic reduction in axial elements abandoned by carnivores in Amboseli Park (Kenya) between 1975 and 2004. The considerable increase in carnivore density (particularly *Crocuta crocuta*) was considered the main factor influencing the increase in ravaging, which itself is usually associated with an increase in competition. However, competition is not the only factor influencing ravaging, since other circumstances, such as the degree of nutritional stress in carnivores, can also lead to high degrees of ravaging.

Isernia La Pineta is a Lower Paleolithic, open-air site dated in early Middle Pleistocene chronologies (Peretto et al., 2015). Some taphonomic and zooarchaeological studies have been conducted, mainly focused on patterns of bone breakage and strategies of exploitation and transport of remains of bison, the most abundant taxon at the site (Anconetani and Peretto, 1996a; Thun-Hohenstein et al., 2005, 2009; Peretto et al., 2004b). However, problems related to the poor preservation of bone surfaces and bone surface modifications have made some taphonomic analyses and interpretations more difficult (Anconetani et al., 1996; Díez Fernández-Lomana et al., 1997; Malerba et al., 2000; Thun-Hohenstein et al., 2004a, 2009). In this paper we complete a taphonomic reconstruction of the 3 colluvio level of the Isernia La Pineta site, assessing bone modifications and skeletal profiles from a holistic point of view. The aim is to infer the role of hominins in the formation of the assemblage, considering problems derived from the poor preservation of bone surfaces and taphonomic signals related to the processing of carcasses by hominin groups.

## 2. Isernia La Pineta

Isernia La Pineta is an open-air site situated in the southern Italian Peninsula, close to the town of Isernia (Molise, Italy). It is located in the middle upper part of the Volturno River basin, at an altitude of 457 m asl (Peretto et al., 2015). The complete stratigraphy of Isernia La Pineta has recently been updated by Peretto et al. (2015). The sedimentary filling of the Volturno River basin is characterised by four major unconformity-bounded stratigraphic units (UBSU 1–4) (Coltorti et al., 1982, 2005; Thun-Hohenstein et al., 2009; Peretto et al., 2015). The earliest USBU has been dated around the Lower-Middle Pleistocene boundary, while the later USBU 3 contains deposits dated to the Middle Pleistocene. This USBU comprises sands, gravels, and silts containing a number of coarse-grained (pumice) pyroclasts. Four archaeosurfaces have been identified and excavated in two different sectors: 3c, 3a, and

3 s10 in sector I; and 3a in sector II (Peretto et al., 2015).

UBSU 2 contains Units 2 and 3. This latter includes the 3 coll level, with a total extension of 100 m<sup>2</sup>; it is formed of sand levels and thin layers of gravels deposited by ephemeral rivers, and is subdivided into three sub-units: U3A, U3E, and U3F (Peretto et al., 2015) containing two archaeosurfaces: 3a and 3 s10.

On top of archaeosurface 3a, level 3 coll was found. It comprises calcareous loam, containing numerous crystals of volcanic origin (Marrocchino and Vaccaro, 2006). The first dating (<sup>40</sup>Ar/<sup>39</sup>Ar) of crystals from level 3 coll gave a time of 610 ± 10 ka (Coltorti et al., 2005). However, new <sup>40</sup>Ar/<sup>39</sup>Ar measurements suggest a more recent chronology, of around 583–561 ka, for the formation of these deposits (Peretto et al., 2015).

Numerous macromammals have been identified throughout the sequence of Isernia La Pineta, consisting mainly of the following taxa: *Elephas (Palaeoloxodon) antiquus*, *Hippopotamus cf. antiquus*, *Stephanorhinus hundsheimensis*, *Bison schoetensacki*, *Praemegaceros solihacus*, *Cervus elaphus cf. acoronatus*, *Dama cf. roberti*, *Capreolus sp.*, *Sus scrofa*, and *Hemitragus cf. bonali*. Among the carnivores, the most abundant remains are from *Ursus deningeri*, although only one tooth of *Panthera leo fossilis* has also been identified (Sala, 1996; Thun-Hohenstein et al., 2002, 2004c, 2009; Ballatore and Breda, 2013; Breda et al., 2015; Peretto et al., 2015). Recently, have been found a mandible of *Panthera pardus* in the archaeosurface 3a (Thun-Hohenstein et al., 2009) and a human deciduous incisor (possibly di<sup>2</sup>) in the 3 coll level. The latter has been assigned to the genus *Homo* but without specific attribution (*Homo sp. cf. heidelbergensis*) (Peretto et al., 2015).

Zooarchaeological studies (Anconetani and Peretto, 1996a; Thun-Hohenstein et al., 2005, 2009; Peretto et al., 2004a) have suggested some homogeneity in the patterns of taxonomic representation throughout the sequence, characterised by: a) a predominance of bison (*Bison schoetensacki*) and, to a lesser extent, rhinoceros (*Stephanorhinus hundsheimensis*) and bear (*Ursus deningeri*), a fact that according to Thun-Hohenstein et al. (2009) is attributed to anthropogenic selection; b) a predominance of cranial elements and forelimbs, attributed to selective transport, although in the specific case of bison, Thun-Hohenstein et al. (2009) suggested the presence of all skeletal elements could be the result of the transport of some complete carcasses; c) a predominance of adult and sub-adult individuals among bison remains, explained by a higher economic profitability in obtaining these individuals (Thun-Hohenstein et al., 2009); d) poorly preserved bone surfaces with few cut marks identified (Díez Fernández-Lomana et al., 1997; Malerba et al., 2000); e) a well-documented pattern of anthropogenic breakage, mainly in skulls, mandibles, and long bones; and finally f) specialised hunting as the main strategy for acquiring bison meat and marrow, although opportunistic scavenging has not been ruled out (Thun-Hohenstein et al., 2009).

Preliminary descriptions of the lithic industry from the 3 coll level, contributed by Peretto et al. (2015), highlight the exploitation of local raw materials (flint and limestone), with short *chaîne opératoire*, flakes without a standardised morphology and with worked edges for obtaining denticulate tools and sidescrapers. The cores indicate unipolar, multidirectional and centripetal (cf. discoid) exploitation. Bipolar percussion on an anvil has been proposed for the reduction of flint tablets (Peretto et al., 2015).

Among the small mammals, the most representative species are *Arvicola mosbachensis*, *Sorex aff. runtonensis*, *Pliomys episcopolis* and *Microtus (Terricola) arvalidensis* (Sala, 1983, 1996). Pollen studies have shown that herbaceous plants are dominant, especially palustrine species such as *Cyperaceae* and *Typha*. Arboreal plants are represented by *Alnus*, *Salix*, cf. *Populus*, *Platanus*, *Quercus*, *Pinus* and *Cedrus*, but are infrequent (Arobba et al., 2004). Combination of these studies have let us to infer an arboreal steppe landscape, with presence of water pounds and deciduous forests in the surrounding area (Accorsi et al., 1996).

**Table 1**  
Weight-size categories established for non-identified specimens and taxa included in each.

Weight-size categories	Taxa
Very large sized (> 1000 kg)	<i>Elephas (Palaeoloxodon) antiquus</i> <i>Hippopotamus cf. antiquus</i> <i>Stephanorhinus hundsheimensis</i>
Large sized (300–1000 kg)	<i>Bison schoetensacki</i> <i>Praemegaceros solihacus</i> <i>Ursus deningeri</i>
Medium sized (100–300 kg)	<i>Cervus elaphus cf. acoronatus</i> <i>Panthera pardus</i>
Small sized (10–100 kg)	<i>Dama cf. roberti</i> <i>Sus scrofa</i> <i>Hemitragus cf. bonali</i> <i>Capreolus sp.</i> <i>Canis cf. mosbachensis</i>
Very small sized (< 10 kg)	Aves cf. <i>Oryctolagus</i>

### 3. Material and methods

A total of 5700 remains was analysed, including all the remains recovered larger than 20 mm in size that were recovered during the excavation. The remains were identified both anatomically and taxonomically. Where this was not possible, they were grouped according to bone morphology (long, flat, and articular/compact bones), as well as animal groups by weight (Table 1). The age profiles of the individuals were estimated from the level of eruption of teeth and tooth wear (Stiner, 1990). The sample was quantified using the following indices: Number of Identified Specimens (NISP); Minimum Number of Elements (MNE), and Minimum Number of Individuals (MNI) (Binford, 1984; Grayson, 1984). NISP was estimated based in the anatomical and taxonomical identification. The Minimal Animal Unit (MAU) was calculated and standardized (%MAU) to characterise the skeletal representation (Binford, 1984). Bone mineral density was correlated with %MAU to evaluate the integrity of the sample (Lyman, 1994, Lam et al., 1999) by applying Spearman's rho for non-parametric variables.

To estimate the disappearance of limb bone ends in the assemblage, we calculated the epiphysis:shaft ratio of the fresh-broken bones (using NISP) (Blumenschine and Marean, 1993; Domínguez-Rodrigo et al., 2002), and the percentage of change (Marean and Spencer, 1991), as modified by Domínguez-Rodrigo et al. (2002) to gain insight into the epiphysis destruction process for application to archaeological assemblages:  $(MNE \text{ before ravaging} - MNE \text{ after ravaging}) / (MNE \text{ before ravaging}) * 100$ . Domínguez-Rodrigo et al. (2002) consider each limb element originally had a diaphysis and two epiphyses. As Saladié and colleagues (2014: 49) summarized, “the total number of epiphyseal fragments in an archaeological assemblage may be greater than the assumed number, but working with complete epiphyses according to the MNE can yield a minimum estimate of the percentage of change”.

The %MAU of the limb bone ends was correlated with their mineral density according to Faith and Behrensmeyer (2006) and Faith et al. (2007). The theoretical method established by Egeland (2008) was applied to discover the competition levels at the site, based on the correlation of the epiphysis:shaft ratio and the axial:appendicular ratio.

Abrasion is defined as the modification of the bone surface or edged caused by water currents. Exfoliation is defined as the loss of the cortical surface. Both modifications were described as diffuse, slight or strong, also indicating the percentage of surface that presented the alteration (0%, 0–25%, 25–50%, 50–75%, 75–100%). “Slight” refers to smooth and located evidences; “diffuse” is defined as smooth evidences over different areas of the bone; finally, “strong” implies heavy modifications, reaching to modify the original morphology and proprieties of the surfaces. Weathering was described according to the stages described by Behrensmeyer (1978). Other taphonomic modifications

identified (Iron and manganese coating, root etching, trampling, and chemical corrosion) were documented by presence/absence.

To analyse the fragmentation and breakage of long limb bones, analyses of both length and cross section fragmentation (Bunn, 1983; Villa and Mahieu, 1991), and fracture edges (Villa and Mahieu, 1991) were conducted on a representative selection of the studied sample ( $n = 533$  limb bones; 30% NISP of limb bones). The dimensions of the skeletal remains (in mm) were divided into four categories: < 21–30; 31–40; 41–50; greater than 51 mm.

The surfaces of all remains were inspected using a stereomicroscope (OPTHEC 120 Hz, between 7x and 40x). Because of the high levels of abrasion documented on bone surfaces at different levels of Isernia, Malerba et al. (2000) established three categories (cut marks, natural abrasion striations, and badly preserved striae with a possible anthropic origin), integrating the documented striations into these, based on the observable macro- and micromorphological characteristics, which have also been employed in this work. The identification of cut marks was limited to well-preserved bone surfaces, in which the most commonly identified diagnostic features of cut marks were present (Domínguez-Rodrigo et al., 2009), reducing as far as possible the degree of analytical subjectivity (Domínguez-Rodrigo et al., 2017, 2019). According to the conclusions of previous works, only clearly identified cut marks have been considered in order to avoid any erroneous inferences or misinterpretations (Domínguez-Rodrigo et al., 2010; Pineda et al., 2014; Pineda et al., 2019). The analysis of the distribution of the frequencies of the cut-marked limb bones has been described (Domínguez-Rodrigo, 1997). The identification of anthropogenic breakage was carried out following the patterns described experimentally by Anconetani and Peretto (1996b) and Peretto et al. (1996), previously applied in zooarchaeological studies of Isernia (Anconetani and Peretto, 1996a; Thun-Hohenstein et al., 2002, 2004a, b, 2005, 2009, 2019), based on identification of diagnostic criteria such as percussion notches.

The carnivore-induced bone surface modifications identified involved scores and pits (Maguire et al., 1980; Binford, 1981). Tooth marks were measured following the criteria established by Selvaggio and Wilder (2001) and Andrés et al. (2012). The dimensions of the depressions were compared with results previously provided by other researchers (Selvaggio, 1994; Delaney-Rivera et al., 2009; Andrés et al., 2012; Rodríguez-Hidalgo et al., 2013; Saladié et al., 2013; Sala et al., 2014) to distinguish the size of the carnivores that acted during the formation of the assemblage.

### 4. Results

#### 4.1. Bone assemblage preservation

A total of 1,025 remains (18%) were anatomically and/or taxonomically identified from the 3 coll level (Table 2), while the remaining 4675 (82%) rest as indeterminate. *Bison schoetensacki* was the most well-represented taxa in the assemblage and included 41.3% of the NISP ( $n = 423$ ) and 45.3% of the counted elements (MNE = 125). Counting by MNE, ribs and articular bones are the most documented, followed by cranial elements and vertebrae (Table SOM 1). *Stephanorhinus hundsheimensis* and *Elephas (Palaeoloxodon) antiquus* were the two other species of herbivores extensively represented. *Stephanorhinus hundsheimensis* accounted for 16.2% of NISP ( $n = 166$ ) and 19.9% of the counted elements (MNE = 55). *Elephas (Palaeoloxodon) antiquus*, on the other hand, comprised 10.7% of the NISP ( $n = 110$ ) but only 2.9% of the MNE ( $n = 8$ ), basically due to the high number of tusk fragments recovered ( $n = 95$ ). Among the carnivores, the most common remains belonged to *Ursus deningeri* (NISP = 114). The other carnivores identified were *Panthera pardus* and *Canis cf. mosbachensis*, through a single tooth in each case. Grouped by weight sizes (Table 3), most of the remains identified belonged to large-sized animals, accounting for 88% of the NISP.

The MNI identified is 28, being bison (MNI = 8) and bear

**Table 2**  
Quantification of the remains recovered from the Isernia 3 coll level. Both absolute and percentage data are presented as NISP / MNE / MNI.

Taxa	NISP		MNE		MNI	
	Abs.	%	Abs.	%	Abs.	%
<i>Elephas (Palaeoloxodon) antiquus</i>	110	10.7	8	2.9	2	7.1
<i>Hippopotamus cf. antiquus</i>	8	0.8	2	0.7	1	3.6
<i>Stephanorhinus hundsheimensis</i>	166	16.2	55	19.9	2	7.1
<i>Bison schoetensacki</i>	423	41.3	125	45.3	8	28.6
Bison/rhino	48	4.7	11	4	0	0
<i>Praemegaceros solihacus</i>	8	0.8	6	2.2	2	7.1
<i>Cervus elaphus cf. acoronatus</i>	4	0.4	3	1.1	1	3.6
<i>Dama cf. roberti</i>	1	0.1	1	0.4	1	3.6
Cervidae	50	4.9	6	2.2	0	0
<i>Sus scrofa</i>	5	0.5	4	1.4	2	7.1
<i>Hemitragus cf. bonali</i>	5	0.5	4	1.4	1	3.6
<i>Capreolus</i> sp.	1	0.1	1	0.4	1	3.6
Artiodactyla	15	1.5	0	0	0	0
Herbivorous indet.	51	5	0	0	0	0
<i>Ursus deningeri</i>	114	11.1	42	15.2	3	10.7
<i>Panthera pardus</i>	1	0.1	1	0.4	1	3.6
<i>Canis cf. mosbachensis</i>	1	0.1	1	0.4	1	3.6
Carnivora indet.	8	0.8	1	0.4	0	0
Aves	1	0.1	1	0.4	1	3.6
<i>cf. Oryctolagus</i>	5	0.5	4	1.4	1	3.6
Indet.	4675	–	–	–	–	–
Total NISP (carnivore)	124	2.2	45	16.4	5	17.9
Total NISP (herbivorous)	900	15.8	230	83.3	22	78.6
Total NISP	1025	18	–	–	–	–
Total	5700	100.0	276	100	28	100

**Table 3**  
Quantification of the remains recovered from the Isernia 3 coll level, grouped by weight categories. Both absolute and percentage data are presented as NISP/MNE/MNI.

	NISP		MNE		MNI	
	Abs.	%	Abs.	%	Abs.	%
Very large size	102	7.3	8	2.2	1	3.7
Large size	1236	88	316	86.1	15	55.6
Medium size	47	3.3	26	7.1	6	22.2
Small size	15	1.1	13	3.5	4	14.8
Very small size	5	0.4	4	1.1	1	3.7
Total	1405	100	367	100	27	100

**Table 4**  
Age profiles identified at Isernia La Pineta 3 coll.

	Juvenile	Adult	Old	NMI
<i>Elephas (Palaeoloxodon) antiquus</i>	1	1		2
<i>Hippopotamus cf. antiquus</i>		1		1
<i>Stephanorhinus hundsheimensis</i>		2		2
<i>Bison schoetensacki</i>		8		8
<i>Praemegaceros solihacus</i>		1		2
<i>Cervus elaphus cf. acoronatus</i>		1		1
<i>Dama cf. roberti</i>		1		1
<i>Sus scrofa</i>	1	1		2
<i>Hemitragus cf. Bonali</i>		1		1
<i>Capreolus</i> sp.		1		1
<i>Ursus deningeri</i>	1	1	1	3
<i>Panthera pardus</i>		1		1
<i>Canis cf. mosbachensis</i>		1		1
Aves		1		1
<i>cf. Oryctolagus</i>		1		1
Total	3	24	1	28

(MNI = 3) the taxa with a major number of individuals identified. Grouped by age of death (Table 4), the individuals identified are mainly adults, although three juvenile individuals (elephant, wild boar and bear) and one senile bear were also identified.

The appendicular skeleton represented 52.9% of the NISP, the cranial one 29.9%, and the axial one (represented predominantly by rib fragments) 15.4%. The correlation of the mineral density with %MAU was positive and significant for medium sized carcasses ( $\rho = 0.24$ ;  $p = < 0.05$ ), for large sized carcasses ( $\rho = 0.26$ ;  $p = < 0.05$ ) and for bison remains ( $r = 0.26$ ;  $p = < 0.05$ ). These data indicate the existence of a light destruction of different bone portions according to its mineral density.

Around half of the remains (54.2%) showed signs of water abrasion on bone surfaces, mostly in light or diffuse grades (40.2%). Similar results were found in the weathering analysis (Channarayapatna et al., 2017, 2018), with 59.4% of the sample presenting evidence of weathering. Weathering is mainly documented in stages 1 (40%) and 2 (14.4%), according to Behrensmeyer (1978) categories. Natural abrasion striations produced by trampling were observed on 30.9% of the remains. Signs of exfoliation were observed in 19.3% of the sample, generally light and affecting < 50% of the surface area. Fe- and Mn-oxide coating was very evident in the assemblage, affecting 82.9% and 95.7% of the remains, respectively. In contrast, chemical dissolution of the surfaces and root-etching was observed in a low proportion of the sample: 8.6% and 7.9%, respectively. In summary, the post-depositional modification data evidenced bad preservation of the faunal materials from the 3 coll level (Table 5).

#### 4.2. Faunal spectrum and palaeoenvironments

At palaeoecological level, the predominant taxa support the presence of an open (bison and rhinoceros) or semi-open (deer) habitats. However, the presence of aquatic species indicates large bodies of water nearby, particularly considering the remains of *Hippopotamus cf. antiquus*, for which several researchers have described an exclusively aquatic activity (Palmqvist et al., 2003; Madurell-Malapeira, 2012). The presence of some riparian taxa, such as *Sus scrofa*, also suggests closed habitats in the inferred palaeoecosystem.

#### 4.3. Bone breakage

The sample studied from Isernia 3 coll is characterised by a high degree of fragmentation of the remains: there are 111 complete bones, although these correspond mainly to articular bones, phalanges and one vertebra. Among the limb bones, only four bear metapodials and one from a bison were recovered complete. Analysing shaft breakage (Fig. 1A) allowed us to identify 45.2% of shaft lengths as being less than  $\frac{1}{4}$  of the bone, as well as one section smaller than  $\frac{1}{3}$ . The remains with a complete diaphysis represented only 0.4% of the shafts analysed.

A total of 782 fracture edges belonging to 290 limb bones were analysed (Fig. 1B). Curved, oblique, and smooth edges represent 64.5% of the fracture edges analysed, indicative of a high degree of green breakage. On the other hand, fracture edges associated with dry fracture (transverse delineation and right angles) represent only 2.1% of the sample. The identification of medullar and cortical flakes in 103 remains (1.8%), in addition to 34 conchoidal flakes (0.6%) supports the identification of green breakage.

The remains which were smaller than 30 mm were 6% of the selected sample. Conversely, 65% of the recovered remains are larger than 50 mm, indicating a high degree of representation of large fragments in the 3 coll assemblage (Fig. 1C).

#### 4.4. Anthropogenic bone surface modifications

Because of this elevated evidence of abrasion, identifying clear cut marks was, at this moment, only possible on 18 remains (0.3% of the NR) from the 3 coll level, although this can be added to the cut marks described in previous researches (Anconetani, 1996; Anconetani and Peretto, 1996a; Thun-Hohenstein et al., 2002, 2009, 2019), which supports hominin processing of at least a portion of the carcasses. In the

**Table 5**

Taphonomic modifications of samples from the Isernia 3 coll level. \*Weathering stages after Behrensmeier (1978). Percentages over total number of remains (NR = 5700) in all cases.

Erosion							
Grades	Eroded Surface (in %)						Total
	Indet.	0	0–25%	25–50%	50–75%	75–100%	
Absent	0	45,6	0,2	0,0	0,0	0	45,8
Diffuse	7,8	0	0,7	1,0	1,0	1,9	12,4
Slight	4,6	0	7,0	5,8	3,5	6,9	27,8
Strong	3,5	0	2,7	3,2	1,9	2,6	13,9
<b>Total</b>	<b>15,9</b>	<b>45,6</b>	<b>10,6</b>	<b>10,1</b>	<b>6,4</b>	<b>11,5</b>	<b>100</b>
Exfoliation							
Grades	Exfoliated Surface (in %)						Total
	Indet.	0	0-25%	25-50%	50-75%	75-100%	
Absent	0	80,7	0	0	0	0	80,7
Diffuse	1,4	0	0,4	0,7	0,8	0,8	4,1
Slight	4,0	0	3,5	0,8	0,2	0,2	8,6
Strong	3,1	0	2,2	0,7	0,3	0,3	6,6
<b>Total</b>	<b>8,5</b>	<b>80,7</b>	<b>6,1</b>	<b>2,2</b>	<b>1,3</b>	<b>1,3</b>	<b>100</b>
Weathering stages*	%	Category	Mn painting	Fe painting	Root-etching	Chemical dissolution	Trampling
Stage 0	40,6	<b>Present</b>	95,7	82,9	7,9	8,6	30,9
Stage 1	40,0	<b>Absent</b>	4,3	17,1	92,1	91,4	69,1
Stage 2	14,4	<b>Total</b>	100	100	100	100	100
Stage 3	4,1						
Stage 4	0,8						
<b>Total</b>	<b>100</b>						

3 coll level, cut marks were identified on seven identified remains: on a bison's jaw and on bison's humerus and tibia shafts (Fig. 2), the trochanter of the femora and a cranial fragment of a rhino, on an undetermined bear metapodial and on an elephas shaft fragment. The other cut marks were located on non-identified specimens: six shaft fragments, one cranial fragment, on the spiny process a large sized vertebra and on three unidentified remains. All cut mark located on limb bones were identified on the mid-shaft (Table 6). The analysis of the distribution of the frequencies of the cut-marked limb bones indicated that cut-marked humerus of bison represent the 6.7% of the total, while in the case of the tibia, it represents the 5.3%. In the case of the rhino's femur, the only specimen recovered show cut marks (Table SOM 2). On the other hand, were identified possible cut marks on 81 bones (1.2%). These marks are heavily altered and could not be safely ascribed as cut marks, reason why remain as possible.

In addition to the cut marks, evidence of anthropogenic bone breakage was also identified, confirming hominin access to some of the carcasses, as occurs throughout the Isernia sequence (Anconetani and Peretto, 1996a; Peretto et al., 2004b; Thun Hohenstein et al., 2009). In the 3 coll, percussion notches were identified in 211 remains (3.7%). Most of the anthropic breakage is documented on limb bone fragments (n = 153), being femora and humerus the most identified elements which anthropic breakage. Eleven flat bones also present signs of anthropic breakage, mainly in bison's jaws (n = 8). By taxonomical groups, anthropic breakage is mainly concentrated on bison and large-sized remains, including one bear jaw.

#### 4.5. Carnivore bone surface modifications

Carnivore damage on the osteological sample was identified through the presence of tooth-marks on 44 remains (0.8% of the sample) (Table 7). These are located mainly on long bones (a tibia, a radius-ulna, and two femorae of bison, and an indeterminate ulna), although tooth-marks were also found on a rib belonging to a large-sized animal, a herbivore mandible, an indeterminate cranial fragment,

a bison scapula, and some articular bones (including a bear sesamoid) (Fig. 3). Focusing on portions of the limb bones (n = 15), 80% of the tooth marks were located on the shaft, while the rest were observed on epiphyseal fragments, including the femur head from a bison. Only one remain presents evidence of co-occurrence between hominins and carnivores: the proximal fragment of a bison tibia, including the epiphysis, with both cut marks and pits on the shaft.

Thirteen pits were measured. The analysis of the pits reflected a high metrical variability, with a wide confidence interval (Table 8). Comparing the dimensions of these pits with actualistic data (Selvaggio, 1994; Delaney-Rivera et al., 2009; Andrés et al., 2012; Rodríguez-Hidalgo et al., 2013; Saladié et al., 2013; Sala et al., 2014) shows the activity of at least one large carnivore on the assemblage (Fig. 4). There were < 30 pits, so this comparison lacks statistical significance (Andrés et al., 2012) and is only used as a guideline.

#### 4.6. Ravaging and competition among predators

The axial:appendicular ratio was 0.76. Comparing with most archaeofaunal assemblages and, especially, many actualistic assemblages, this could be considered as a fairly high value, indicating high survival of elements from the axial skeleton. The results of this ratio were similar when only the remains of bison (0.69), the most represented taxa, were considered. The calculation of the epiphysis:shaft ratio indicated a high disappearance rate (0.12) based on the identified elements (NISP). The result was high when considering just bison remains (0.7), indicating that considerably more epiphysis fragments were preserved from this taxonomic group. When evaluating the disappearance of epiphyses based on the percentage of change of the MNE, we see that the values were close to 50% for all sizes, including bison remains, signifying a moderate preservation of epiphyses, around half in all cases. In general, there was a notably high presence of epiphyses of metapodials, compared with a high absence in the case of radii (Table 9), in addition to a relatively high presence of axial skeleton remains.

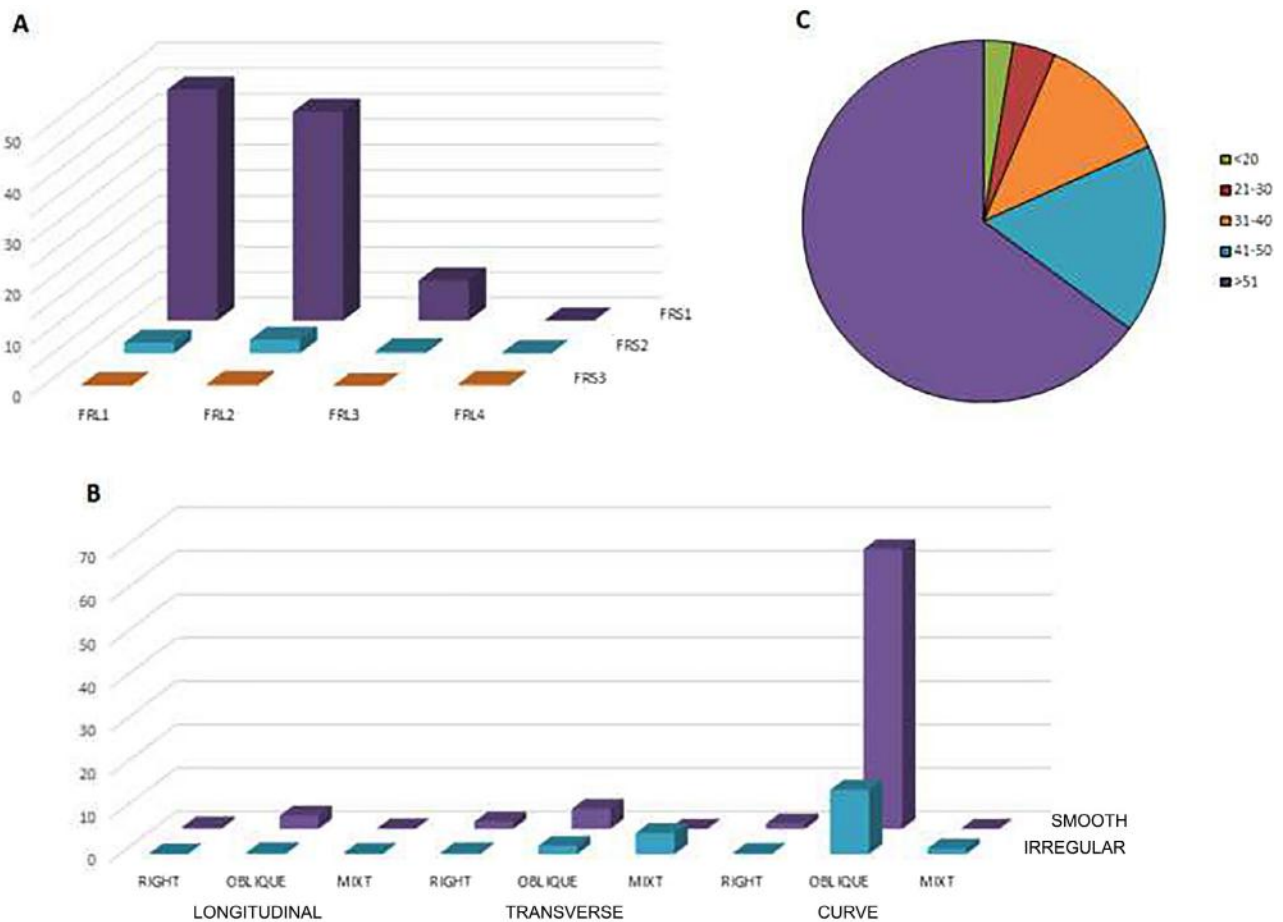


Fig. 1. A) Analysis of fracture angle, outline, and edge for Isernia La Pineta levels based on the criteria of Villa and Mahieu (1991). B) Analysis of the fragmentation of bone shaft circumference (FRS) and length (FRL) based on Bunn (1983) and Villa and Mahieu (1991). C) Percentage of bones grouped by size-category (data in mm).

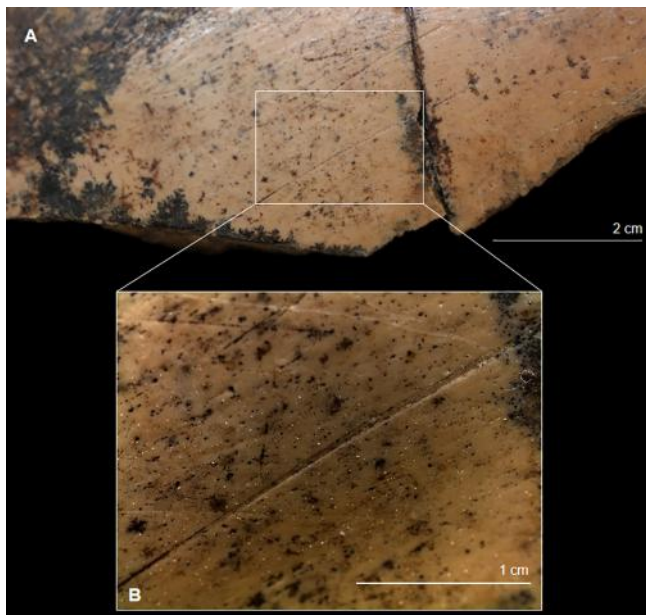


Fig. 2. Bison's left humerus with cut marks. A) Macroscopic view of the cut-marked shaft; B) Detailed view of the cut mark. Reference: I-3coll-148-168 (hosted at UNIFE).

Correlating the %MAU of the limb bone ends with the mineral density gave different results when considering large carcasses or just bison remains. Low number specimens belonging to small- and medium-sized weight categories prevent its application for these groups. Spearman's rho reflects positive and significant results for large sized ( $\rho = 0.51$ ;  $p = < 0.05$ ) and positive but non-significant for bison remains ( $\rho = 0.33$ ;  $p = > 0.05$ ). According to Faith and colleagues (2007), strength, positive and statistically significant correlation between %MAU and mineral density on limb bones ends, as occurs when analysing all large sized carcasses, is expected under low competitive scenarios, because of the destruction of the less dense and richest body parts. On the other hand, the absence of significant correlation, as occurs on bison remains, is expected under conditions of high competition because, according to them, carnivores will consume any and all parts they can get a hold of regardless of their density and grease or marrow content.

Applying the theoretical model developed by Egeland (2008) (Fig. 5) did not enable us to infer the competition context for the entire Isernia 3 coll assemblage, which is beyond the scope of the model. Analysing by weight categories, the medium-sized animals were situated in what Egeland (2008) considers a highly competitive environment, with low epiphysis:shaft and axial:appendicular ratios. However, it should be remembered that this category involves just 3.3% of the remains from Isernia. The large carcasses, which include most of the identified remains, are still beyond the established model. A more interesting result was found when we applied the model to *Bison schoetensacki*, the most well-represented species in the assemblage. The high epiphysis:shaft (0.7) and axial:appendicular (0.69) ratios placed it in an environment of low inferred competition, where ravagers only

**Table 6**  
Cut-marked specimens at Isernia 3 coll level, by skeletal elements and taxa.

	<i>Elephas (Palaeoloxodon) antiquus</i>	<i>Stephanorhinus hundsheimensis</i>	<i>Bison shoetensaki</i>	Bison/Rino	<i>Ursus deningeri</i>	Indet.	Total
Cranium		1 (5.5%)				1 (5.5%)	2 (11%)
Mandible			1 (5.5%)				1 (5.5%)
Vertebra				1 (5.5%)			1 (5.5%)
Hummer			1 (5.5%)				1 (5.5%)
Femur		1 (5.5%)					1 (5.5%)
Tibia			1 (5.5%)				1 (5.5%)
Shaft indet.	1 (5.5%)					6 (33%)	7 (38.5%)
Metapodial indet.					1 (5.5%)		1 (5.5%)
Indet.						3 (16.5%)	3 (16.5%)
Total	1 (5.5%)	2 (11%)	3 (16.5%)	1 (5.5%)	1 (5.5%)	10 (55%)	18 (100%)

consume the least dense elements and portions of bison rich in fat content (Egeland, 2008).

## 5. Discussion

The open-air site of Isernia La Pineta is important for studying the dynamics of human groups during the early Middle Pleistocene. Prehistoric literature suggests that there was a gap in hominin presence in Europe during this period (e.g., Dennell et al. (2011), Manzi et al. (2011), Bermúdez de Castro et al. (2013, 2016), Mosquera et al. (2013), and so some aspects of early Middle Pleistocene (700–500 ka) European hominin populations remain unknown. Isernia La Pineta, dated to MIS 15 (Peretto et al., 2015), therefore can play an important role in our understanding of hominin behaviour during this period. Stratigraphic studies at the site have allowed for the identification of a total of four archaeosurfaces (3c, 3a, and 3s10 in sector I; and 3a in sector II). Level 3 coll, placed on the top of archaeosurface 3a, containing one of the widest faunal and lithic assemblages of the site (Peretto et al., 2015).

Evidence of bone surface abrasion affecting almost half of the remains indicates that the faunal accumulation of Isernia 3 coll has been affected by water flows. Actualistic studies suggest that one of water flows' main influences on archaeological assemblages is the separation of elements by weight, density, and size (Behrensmeier, 1975; Petraglia

and Potts, 1994). In archaeological assemblages it can be difficult to assess the original density and weight of bones; however, it is possible to take into consideration other direct characteristics like their dimensions. At 3 coll, the most abundant bones are those larger than 6 cm, which could support a lagged model. In fact, level 3 coll is placed in a stratigraphic unit comprising levels of sand and thin layers of gravel deposited by ephemeral rivers. Level 3 coll has been described as colluvial, a debris flow deposited on archaeosurface 3a (Peretto et al., 2010, 2015) containing resedimented materials.

Earlier microscopic studies on the bone surfaces of the Isernia (Anconetani et al., 1996; Malerba et al., 2000; Thun Hohenstein et al., 2004a) remains emphasised the high level of alteration of these surfaces, which show many striations due to the volcanic origin of the sedimentary particles comprising the deposit. The result is a sequence with faunal assemblages with abundant evidences of abrasion caused by trampling and/or water flows, where it has been difficult to identify anthropogenic modification of bone surfaces (Anconetani et al., 1996; Díez Fernández-Lomana et al., 1997; Malerba et al., 2000; Thun-Hohenstein et al., 2004, 2009).

Hominid-produced bone surface modifications are rare in the 3 coll assemblage. This phenomenon is common throughout the sequence at Isernia La Pineta: previous studies have shown cut marks on a second phalange and some shaft fragments of a bison in the archaeosurface 3a

**Table 7**  
Distribution of the 44 remains with carnivore-induced modifications, by skeletal elements and taxa.

	<i>B. shoetensacki</i>	<i>Bison/rhino</i>	Herbivorous	<i>U. deningeri</i>	Medium sized	Large sized	Indet.	Total tooth-marked
Cranium	–	–	–	–	–	–	1 (2.3%)	1 (2.3%)
Mandible	–	–	1 (2.3%)	–	–	–	–	1 (2.3%)
Rib	–	–	–	–	–	1 (2.3%)	1 (2.3%)	2 (4.5%)
Scapula	–	–	–	–	–	–	1 (2.3%)	1 (2.3%)
Radii/ulnae	1 (2.3%)	–	–	–	–	–	–	1 (2.3%)
Ulnae	–	–	–	–	–	–	1 (2.3%)	1 (2.3%)
Femorae	2 (4.5%)	–	–	–	–	–	–	2 (4.5%)
Tibiae	1 (2.3%)	–	–	–	–	–	–	1 (2.3%)
Calcaneus	–	1 (2.3%)	–	–	–	–	–	1 (2.3%)
Carpal/Tarsal	–	–	–	1 (2.3%)	–	–	–	1 (2.3%)
Shaft	–	–	–	–	1 (2.3%)	13 (29.5%)	8 (18.2%)	22 (50%)
Epiphyses	–	–	–	–	–	–	2 (4.5%)	2 (4.5%)
Indet.	–	–	–	–	–	2 (4.5%)	6 (13.6%)	8 (18.2%)
Total tooth-marked	4 (9.1%)	1 (2.3%)	1 (2.3%)	1 (2.3%)	1 (2.3%)	16 (36.4%)	20 (45.5%)	44 (100%)



**Fig. 3.** Carnivore-damaged bones recovered from 3 coll. A) Rib belonging to a large animal with two scores; B) shaft fragment of a large animal with visible scores.

**Table 8**

Basic statistical data on the dimensions of pits (length and width) identified on samples from the Isernia 3 coll level. N = number, CI = confidence interval; Min = minimum; Max = maximum; SD = standard deviation.

	N	Mean	95 CI-	95 CI+	Min.	Max.	SD
Pit's Length	13	2,4	1,6	3,2	0,6	5,6	1,5
Pit's Width	13	1,56	0,99	2,14	0,4	3,5	1,1

(Diez Lomana et al., 1997; Malerba et al., 2000; Thun Hohenstein et al., 2009), on a cranium and radius of bison in the 3 coll level (Thun Hohenstein et al., 2009) and on some bear remains (Thun Hohenstein et al., 2005). At 3 coll level, two taphonomic factors should be taken into account: first, ca. 50% of the bones present poorly-preserved cortical tissue; second, natural abrasion striations are one of the most common taphonomic signals, documented in more than 30% of bone surfaces (more than 50% of the bones when considering only well-preserved bone surfaces). These factors could have masked possible signs of hominin activity at Isernia (Diez Fernández-Lomana et al., 1997; Malerba et al., 2000). In fact, in this assemblage, a total of 81 bones (1.2%) present possible cut marks on bone surfaces, but problems derived from the alteration of bone surfaces or bone surface modifications prevent us from confirming their anthropic origin. We cannot rule out the possibility that cut marks are currently underrepresented because some of them could not be correctly identified, since mark interpretation must be limited to those documented from well-preserved bone surfaces or portions of those assemblages where bone preservation maintains the original properties of the cortical surface (Domínguez-Rodrigo et al., 2010).

In a general view, among the modifications documented on bone surfaces produced during the nutritive phase of the carcasses (Capaldo, 1997) carnivore tooth marks and anthropic breakage are the most common. Based on these, an explanation for the lack of cut marks is

that we are in front of events of scavenging of carcasses abandoned by other predators (Blumenschine, 1988; Capaldo, 1995, 1997). The analysis and comparison of tooth marks size has shown the intervention of at least one large carnivore in the assemblage. The modifications produced by large carnivores probably masked other modifications produced by small carnivores, which probably acted over the carcasses, since that the different carnivores accessing the same carcasses is common in open landscapes (Kruuk, 1972; Schaller, 1972; Brain, 1981; Blumenschine, 1986; Domínguez-Rodrigo, 1999).

The 80% of tooth marks on limb bones were identified on mid-shafts and tooth marks on ribs were also documented. These patterns support the idea that carnivores had primary access to the carcasses (Blumenschine, 1987). However, cut marks on mid-shafts can also reflect primary access by hominin groups (Selvaggio, 1994; Capaldo, 1997, 1998; Domínguez-Rodrigo, 1997). For this reason and considering that just 5% of bones have taphonomic signals, we should consider alternative hypotheses, such as that the assemblages may be the result of the accumulation of successive and independent events by hominins and carnivores. Signals of the activity of both actors are mainly documented on mid-shafts of limb bones, which supports this hypothesis (Capaldo, 1997; Domínguez-Rodrigo, 1997).

The absence of the co-occurrence of activities of these agents could support the idea that hominins and carnivores acted independently, in different events (Egeland et al., 2004). Absence of evidence of co-occurrence can also occur in situations in which both agents acted on the same carcasses, because these groups act on different portions (e.g., epiphyses and shafts of limb bones) of skeletal remains (Saladié et al., 2014). However, at 3 coll tooth marks and cut marks mainly occur in the same areas of bone, the mid-shafts of limb bones, supporting that there were independent interventions by hominins and carnivores on the faunal remains. Cinegetic activities have been recognized in Europe since the Early Pleistocene. At TD6.2 of the Gran Dolina site (Sierra de Atapuerca, Spain), the acquisition, processing and consumption of several animals by hominin groups has been identified (Saladié et al., 2011). At this site, primary access to animals of different weights has been demonstrated. In level TD6.2, the distribution and frequency of cut marks is in keeping with the processing of large pieces of meat and other soft tissues. Hominins also accessed bone marrow and viscera (Saladié et al., 2011), and use of the cave as a refuge to reduce competition with other predators has been documented (Saladié et al., 2014). Carnivores had secondary access to remains, centered on the consumption of intramuscular fat from bone portions with more spongy tissue (Saladié et al., 2014). It is likely that later hominin populations had similar hunting capabilities, although we should not dismiss the possibility that they may have also scavenged, since that behaviour has been documented at some sites from the Middle Pleistocene (p.e. Huguet et al. (2001), Lumley et al. (2004), Voormolen (2008), Stiner et al. (2009), Smith (2012), Domínguez-Rodrigo et al. (2015), Van Kolfschofen et al. (2015)). In fact, Thun-Hohenstein and colleagues (2009) suggested that the possibility that at least part of the carcasses were scavenged by hominins should not be discarded in the Isernia La Pineta assemblage. Actualistic studies have shown that in environments with large herbivorous guilds, such as the Isernia paleoenvironment, there may have been many opportunities for scavenging (Blumenschine, 1986; Cavallo and Blumenschine, 1989).

In spite of these findings, that carnivore- and hominin-induced modifications are almost absent could be the result of a previously overlooked scenario: the absence of activities of both actors. However, the documentation of high breakage supports that hominins and/or carnivores could have played an important role in the formation of the assemblage. The almost total absence of anthropic modification on bone surfaces may not necessarily indicate that there was no anthropic processing of carcasses. Instead, taphonomic processes may have altered bone surfaces, obliterating or masking pre-existing modifications (Diez Fernández-Lomana et al., 1997; Malerba et al., 2000). Obliteration or masking of the pre-existing modifications could be the result of



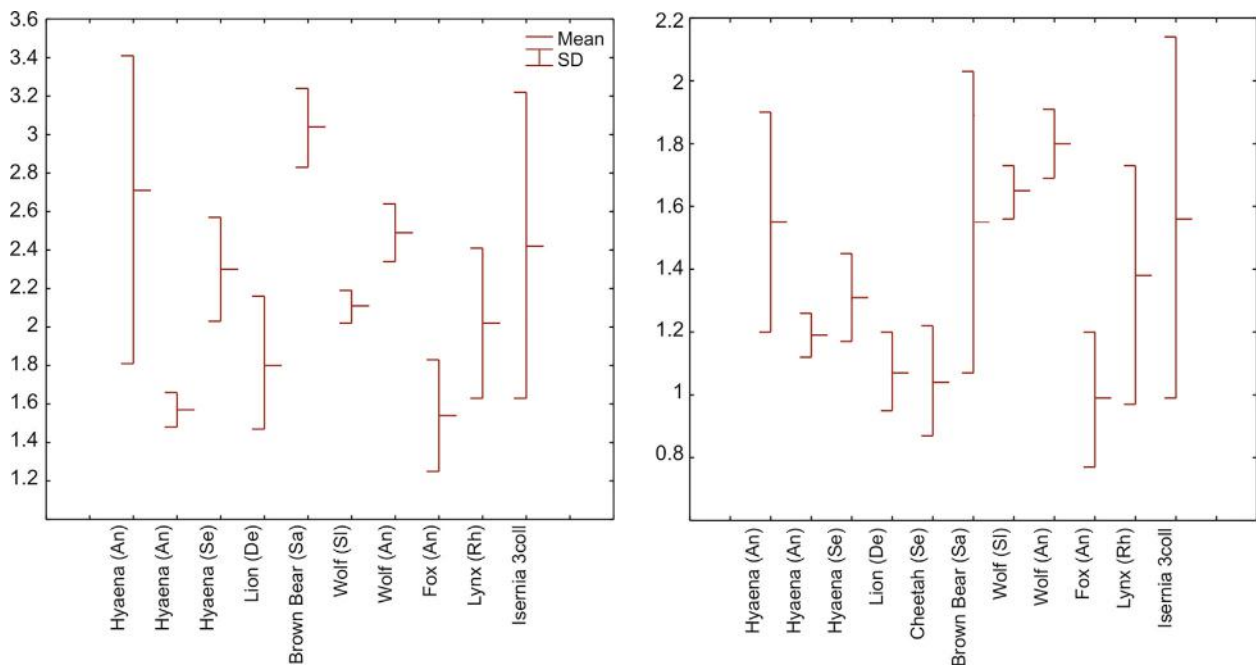


Fig. 4. Comparisons of the length (left) and width (right) of the pits identified in 3 coll level, with data from actualistic research (Selvaggio, 1994 (Se); Delaney-Rivera et al., 2009 (De); Andrés et al., 2012 (An); Rodríguez-Hidalgo et al., 2013 (Rh); Saladié et al., 2013 (Sa); Sala et al., 2014 (Sl)).

Table 9

Percentage of change of the various limb bones recovered from the 3 coll level. The data is presented by the different weight categories, the whole sample, and exclusively for the *Bison schoetensacki* remains. Data obtained represent the percentage of epiphyses preserved in relation to the number of epiphyses assumed (according to MNE).

	Small size	Medium size	Large size	Total (all sizes)	Bison
Hummeri	50	50	50,0	50,0	50
Radii-ulnae	-	100	62,5	81,3	50
Femora	-	50	64,3	57,1	62,5
Tibiae	-	50	45	47,5	42,8
Metapodials	50	0	16,7	22,2	31,25
Total	50	50	44	48,1	45,4

these processes (Shipman and y Rose, 1983; Domínguez-Rodrigo et al., 2010).

6. Conclusions

The open-air site of Isernia La Pineta provides an interesting opportunity to study human groups during the early Middle Pleistocene in southern Europe. A common phenomenon throughout the sequence at Isernia La Pineta is the poor preservation of bone surfaces and bone surface modifications, which makes it difficult to reconstruct hominin behaviour. This phenomenon also affects level 3 coll, which is the focus of this taphonomic study. Hominin presence at the site is documented through the large stone tool sample recovered at 3 coll. However, evidence of processing of carcasses is rare, mainly documented through anthropic breakage and, to a lesser extent, in the form of cut marks on bone surfaces. Carnivore tooth marks have also been documented. The data seem to suggest that hominins and carnivores had primary access to processing the carcasses, which reflects independent intervention by both agents in different carcasses. Evidence of hominin activity is underrepresented because some of it may have been altered or obliterated as a result of alteration processes that affected bone surfaces, since our interpretations are limited to well-preserved bones and bone modifications.

CRediT authorship contribution statement

Antonio Pineda: Conceptualization, Formal analysis, Writing - original draft, Writing - review & editing. Sharada Channarayapatna: Formal analysis. Giuseppe Lembo: Resources. Carlo Peretto: Resources, Supervision, Funding acquisition. Palmira Saladié: Conceptualization, Writing - original draft. Ursula Thun-Hohenstein: Conceptualization, Formal analysis, Supervision.

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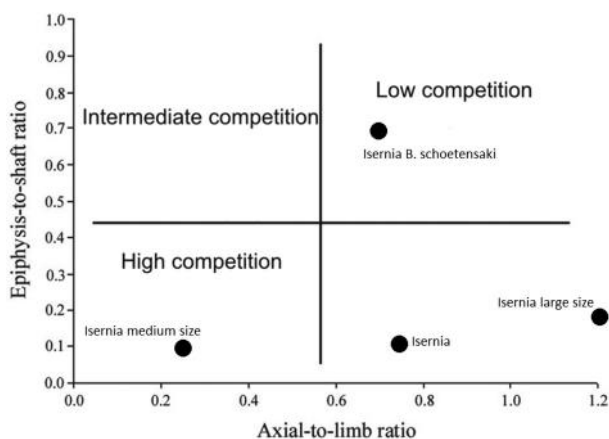


Fig. 5. Location of the Isernia 3 coll in the theoretical model developed by Egeland (2008). Data for both medium and large weight categories, remains of *Bison schoetensacki*, and the entire sample from the 3 coll level are presented.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jasrep.2020.102469>.

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