Università degli Studi di Ferrara

DOTTORATO DI RICERCA
in
Scienze Umane

IDQP
Erasmus Mundus Joint Doctorate in Quaternary and Prehistory

CICLO XXX

COORDINATORE Prof. Carlo Peretto

Archaeozoological and Taphonomical Analyses of Faunal Remains from Lower Palaeolithic site of Isernia La Pineta, Italy

Settore Scientifico Disciplinare L-ANT/10

Dottorando
Dott. Sharada V. Channarayapatna

C.V. Sharada
____
(firma)

Tutore
Prof.ssa Ursula Thun Hohenstein

____
(firma)

Tutore
Prof.ssa Clare Gaillard

____
(firma)

Tutore
Prof.ssa Anne Marie Moigne

____
(firma)

Anni 2015/2017

Acknowledgements…

At the very outset, I am extremely grateful to the Erasmus Mundus Consortium, for conducting the International Doctorate in Quaternary and Prehistory (IDQP) and for selecting me to experience this remarkable academic opportunity. The scholarship was a blessing in disguise and came at a time in my life when I most needed it. I am thankful to my host institute, Università degli Studi di Ferrara (Ferrara, Italy), and mobility institute- Muséum National d'histoire Naturelle de Paris (MNHN, Paris, France); and partner institutes- Universitat Rovira i Virgili (Tarragona, Spain), Instituto Politecnico de Tomar (Macao, Portugal) - Universidade de Tras-os-montes e Alto Douro(Portugal), and University of the Philippines Diliman (Philippines) for their cooperation, support and taking care of every student's academic and personal well-being.

I would like to thank the Board of Examiners and other esteemed members of the Erasmus Mundus Doctorate Thesis Committee for their valuable suggestions, comments and for their time and cooperation.

My supervisors, Prof. Ursula Thun Hohenstein (Università degli Studi di Ferrara, Italy), Dr. Claire Gaillard (Muséum National d'histoire Naturelle, Paris, France) and Dr. Anne Marie Moigne (Centre Européen de Recherches Préhistoriques, Tautavel and Muséum National d'histoire Naturelle, Paris, France) are women of substance and intellect and justifiably scholars in their own right in the field of Archaeology. Their drive and passion in their work is admirable and influential. I find myself fortunate to have been guided and mentored by them. I thank them for giving me invaluable 'research freedom' and for creating an inspiring 'free dialogue/discussion' ambience wherein I could unhesitatingly converse with them on any subject, academic or otherwise. I sincerely thank them.

At Ferrara, I would like to express my deepest gratitude to Prof. Carlo Peretto and Dr Marta Arzarello and at Paris, Chafika Falguères (Programme Co-ordinators). Marta epitomises efficiency, competence and multi-tasking in the truest sense of the word. I appreciate her for her prompt response to my distress emails and calls at all odd hours pertaining to myriad topics, for patiently explaining to me the layout and format of the programme and answering the same questions repeatedly. I especially thank Giuseppe Lembo for the GIS maps.

The officials working in various capacities at the International Student's Office (IUSS) and Ufficio Mobilità e Didattica Internazionale (Office for Mobility and International Education), and Centre for Linguistics, rendered assistance in the last three years and I thank them. I thank Rita Accorsi (secretary for administration and accounting) and the staff at SEM laboratory, Unife, for their help and cooperation.

The 'Erasmus Mundus' experience would have been incomplete without the numerous people I met during my journeys and short stays in many different countries, cities and towns. They have influenced me, taught me, enriched my existence and contributed to a treasure trove of memories in varied ways. From locals at a restaurant or museums to fellow travellers in flights, trains, metro, buses, and boats, casual acquaintances, friends, batch-mates, lab-mates and flatmates. At different points in time they were selflessly there by my side to provide a patient ear to my words, strength to counter my weaknesses, confidence to boost my morale, humour to overwhelm melancholy and reason and logic to remove ambiguity. Through this acknowledgement I wish to express my earnest love, best wishes and gratitude to all of them.

My family in Ferrara and back home in India, I am grateful to all of you for your support, encouragement, love and kind wishes.

Lastly, I also take this opportunity to thank the printers and binders at Ferrara… unsung heroes and often forgotten… who helped to bring this academic task to fruition.

Contents

List of Tables

List of Figures

Fig 2.1 A: Location of the site (modified after Shao et al., 2011) in Italy; B: Location of the site in the Volturno Basin (modified after Coltorti et al., 2005, cited in Gallotti and Peretto, 2014, p. 3); C: Arial view of the site demarcated by a yellow line boundary in which are visible (A)- Sector II of the excavation, (B) Sector I of the excavation and (C)- the museum building (Google Earth image) (Lembo, 2014, p. 70); D: Left column refers to the stratigraphy of the site characterized by 5 main units (from U1 to U5) and 2 buried paleosoles (S1 and S2). E: Excavation in progress in Sector I (image: www.archeologicamolise.beniculturali.it); F: IS42- Human deciduous tooth recovered from 3 coll layer (image: www. archeologicamolise.beniculturali.it); G: 1-6 Flint tablets from the unworked assemblage of t.3c (Gallotti and Peretto, 2014, p. 7).

Fig 2.2: Isernia La Pineta. A: Pollen diagram (Accorsi, 1985); B: Pollen diagram of the most important taxa from the survey at the site (Lebreton, 2001).

Fig 2.3: Caune de l'Arago. A: Location of the site in France (Lebreton, 2015, p. 2); B, C and D: Synthetic stratigraphic section of the site with corresponding MIS and dates (B: after de Lumley et al., 1984, cited in Falguères et al., 2004, p. 942; B: Perrenoud, 2016; C: personal communication Anne Marie Moigne).

Fig 2.4: Caune de l'Arago. A: Level G handaxes made on sandstone-quartzite at the top and level P handaxes made on quartzite (Barsky, 2013, p. 310); B: Level P handaxes made on quartzite (Barsky, 2013, p. 311); C: Excavation floor with exposed faunal remains and lithic industry (personal communication Anne Marie Moigne).

Fig 2.5: Caune de l'Arago: Appearance and disappearance of large mammal fauna in the context of stratigraphy and geochronology of the Middle Pleistocene infilling (Moigne et al., 2006, p. 793).

Fig 3.1: Isernia La Pineta: Distribution map of the provenance and number of faunal remains from excavated squares of Archaeosurface 3a (Sector I) – the subject of this study.

Fig 3.2: Isernia La Pineta: Distribution map of the provenance and number of faunal remains from excavated squares of 3 colluvium layer (Sector I) – the subject of this study, A- before fusion; B- after fusion.

Fig 3.3: Isernia La Pineta: Distribution map of the provenance and number of faunal remains from excavated squares of 3s6-9 layer (Sector I) – the subject of this study.

Fig 3.4: Isernia La Pineta: MS Access data collection sheet for faunal remains updated in 2014.

Fig 3.5: Codification for long bone fracture morphologies and shaft fragmentation indices (modified after Outram (2002; 2001; 1998), Villa and Mahieu (1991, cited in Valensi, 2000), Bunn (1983; 1982).

Fig 3.6: An example of diaphyseal fragments displaying oblique (A and B), longitudinal (A and B) and transverse (B) fracture outlines.

Fig 3.7: Fracture outlines (modified after Grunwald, 2016, p. 357; Marshall, 1989, p. 14).

Fig 3.8: Style wear codification (not to scale).

Fig 4.1: Isernia La Pineta 3a: Representation of faunal remains (NRDt/NISp-16).

Fig 4.2: Isernia La Pineta 3a: Distribution of anatomical elements of determined taxa.

Fig 7.2: Isernia La Pineta 3s6-9 layer mandibular dental remains: A- Subadult right i_1 (4.121.006) lingual (left) and distal (right) view; B- Adult 1 right I_1 (1.147.138) lingual (left) and distal (right) view; C- Adult 2 M_2 (1.157.176); D- M_3 (1.168.099) buccal (left) and occlusal (right) view (not to scale).

Fig 7.3: Isernia La Pineta 3s6-9 layer maxillary dental remains: Adult 1- P^2 (1.167.101), P^3 (1.168.134), M^2 (1.147.124); Adult 2- P^3 (1.177.035), M^2 (1.178.047) and M^3 (4.110.052); Adult 3- P^4 (1.157.071), M^2 (1.147.071) and M^3 (4.111.046). a- occlusal view, b- lingual/buccal view, c- mesial/distal view (not to scale).

Fig 7.4: Caune de l'Arago: Lower levels (H-Q) dental remains: A- occlusal view and B-lingual view of left maxilla (B12.64); C- occlusal view and D- buccal view of left mandible (B12.496 (P_3), B12.540 (P_4) and B12.491 (M_1)); E-occlusal view and F- lingual view of left mandible (H9.673); G-occlusal view and H- buccal view of left mandible (E8.304) (not to scale).

Fig 7.5: Caune de l'Arago: Level G mandibular dental remains: A- occluso-buccal view of right mandible (F19.2610) from sub level G1; B- occluso-buccal view of right mandible (D18.851) from sub level G1; C-occlusal view of left mandible (D17.1422) from sub level G2; D-occluso-ligual view of left mandible (C19.372) from sub level G3; E- occlusal view of right mandible (F15.1638) from sub level G4 (not to scale).

Fig 7.6: Caune de l'Arago: Level G maxillary dental remains: A- occlusal view of right maxilla (E16.2580) from sub level G3; B- occlusal view of left maxilla (D20.4626) from sub level G2; C- occluso-buccal view of left maxilla (G16.5591+5729) from sub level G3; D-occluso-ligual view of left maxilla (D19.5783) from sub level G3 (not to scale).

Fig 7.7: Caune de l'Arago: level F dental remains: A- occlusal view of left maxilla (J20.1934) from sub level F1; B- occlusal view of right mandible (F20.1306) from sub level F3 and C-occlusal view of right maxilla (J19.4508) from sub level F2 (not to scale).

Fig 7.8: Isernia La Pineta: Archaeosurfaces 3c, 3a, 3S10; layers 3 colluvium and 3s6-9; mortality curve for Bison schoetensacki from previous study-" (Di Nucci et al., 2006) and present study-*.

Fig 7.9: Caune de l'Arago: Lower levels H-Q; mortality curve for Bison sp.

Fig 7.10: Caune de l'Arago: Upper level G; mortality curve for Bison priscus.

Fig 7.11: Caune de l'Arago: Upper level F; mortality curve for Bison priscus.

Fig 7.12: Caune de l'Arago: Mortality profile for Bison schoetensacki from Isernia La Pineta (3c, 3a, 3S10, 3 colluvium and 3s6-9); Bison sp. from lower levels (H-Q) and Bison priscus from upper levels (F and G) of Caune de l'Arago.

Chapter 1

Research theme and questions

1.1 Introduction

A phenomenon dating back to 1.5 million years ago as demonstrated through archaeological evidence (Arzarello and Peretto, 2010), the first peopling of the European continent by prehistoric man began, a journey originating in Africa. Several important Palaeolithic sites, home to rich and reliable evidence of a Lower Pleistocene occupation of the European continent, especially the western part, are found in Italy. These sites provide valuable testimony to show that human groups migrated to Europe towards the end of the Lower Pleistocene spreading in the southern regions and progressively occupying the temperate regions (Broglio, 1998). In this scenario, the Paleolithic site of Isernia La Pineta (henceforth Isernia), in south central Italy (Molise region), is perceived as one such significant site, rather a 'milestone', in the European context for it has delivered abundant archaeological evidence. Coming from thick stratified deposits, composed of very rich and large-sized occupation layers, the prehistoric record at Isernia contains faunal remains, lithic industry and now also human skeletal remains. It thus provides immense scope for multidisciplinary studies at the site to reconstruct the paleogeographic, paleoclimatic and the socio-techno-cultural context in which the site was actively occupied in the past. Since the site is under excavation even after 40 years, with every passing year, the excavation campaign in the summer at Isernia brings forth new and fresh evidence, especially a consistently large number of faunal remains. In particular, simultaneously with the geomorphological and sedimentological investigations, a detailed analysis of both the environmental aspects and the human-animal interactions at the site in the past becomes imperative to consistently upkeep the available information and interpretations. It is in this setting that the sub-discipline of archaeozoology has contributed in a fundamental way not only to the reconstruction of the ancient natural environment in which the prehistoric man was located but also to the reconstruction of the subsistence strategies adopted by them and the type of fauna that was exploited.

Faunal remains have, for a long time, been a ubiquitous part of the archaeological record. Archaeozoology refers to the study of animal remains excavated from archaeological sites. The primary goal and use of zooarchaeological research is to understand the interactions of humans and animals and the results of this relationship for both humans and their environments, especially between Humans and other animal populations (Reitz and Wing, 2008). In the same way, taphonomic studies complete the picture painted by archaeozoologists, through the detailed description of the events that led to the formation and modification of the site. The most primal relationship between Humans and other animals is that of ‘predator’ and ‘prey’. The necessity to eat and avoid being eaten portrays the character of the quest for the existence in which both Humans and other animals have been engaged throughout the course of evolution. In the beginning, the animal flesh was most likely procured by scavenging on the remains of creatures, which had either been killed by other predators or had died a natural death. The killed animals were not only consumed as food, but their skin was also used for warmth and their bones as a raw material for tools. To date, the hunting way of life has been the most successful and persistent adaptation man has ever achieved (Lee and DeVore, 1968, p. 3). It should be acknowledged that animal bones do not relate simply to the “economic” aspects of a culture, but also to all areas of the living world. One traditional area of archaeozoology is the reconstruction of past ecology/environment and populations of animal species. This diversity, associated with the application of many physical, biological, ecological and anthropological concepts and methods of studying animal remains throughout the world by scholars with a wide range of theoretical interests and training, characterizes the scope and significance of archaeozoology. A majority of the animal remains are the consequences of complex human and non-human behaviours with regard to resources in the environment, cultural perceptions of those resources, and the technological repertoire used to exploit them.

The kind and degree of faunal evidence available, directly and indirectly, varies over different time periods. In the cultural contexts successive to Lower Palaeolithic, availability of supporting evidence in the form of the cave and rock art, bone tools, bone ornaments etc provide better scope to reconstruct human-animal interactions in the past. On the contrary, notably in the Lower Palaeolithic context, the study material is primarily osseous remains of animals. Evidence-based archaeozoology, in this context, hence poses immense challenges. Another important scope of archaeozoological studies is that it continuously incorporates and applies new and robust analytical methods from other disciplines and fields in combination with the traditional methods to explore varied ways of providing better, relevant and meaningful interpretations of the faunal record. The prehistoric site of Isernia provided excellent scope to implement some recent methodological advances in archaeozoology along with traditional methodologies. Besides taxonomical and anatomical determination and taphonomical studies, recent analytical methods such as diaphysis freshness fracture analyses, bison dental mesowear analyses and Geographic Information System (henceforth GIS) for spatial analysis were conducted for a sample of the Isernia faunal material.

With regard to skeletal part representation, the analysis of body-part representation of the faunal spectrum in a faunal assemblage gives an indication of which part of the carcass appears to be more represented on site. The underlying principle behind this approach is to look at an assemblage that is the result of butchery at some stage or other of its formation process and therefore can be best analysed in terms of portions (Corrado et al. 2004, p. 50). Invariably, long bone diaphyses and teeth, by virtue of their composition and survival rate, frequently dominate archaeofaunal assemblages and they do so in Isernia too as revealed from previous faunal studies of the site. Diaphyses freshness fracture index is an important method to resolve one of the basic questions plaguing prehistoric faunal assemblages- if they were created/accumulated by anthropic, carnivore or natural agents? This index provides an mportant, all-inclusive analytical tool to be able to distinguish between these agents and has been applied in the context of Isernia, where this question is all the more pertinent.

Similarly, to take advantage of the abundance and good preservation of dental remains in a faunal assemblage, several methodological advances termed mesowear and microwear analyses, came into existence which allowed to reconstruct the age classes, mortality profiles and palaeodiets of the species identified at an archaeological site. These methods are chiefly based on a comprehensive examination of the stage of eruption/substitution of teeth, degree and intensity of occlusal surface use, abrasion and reduction of crown height, length and form of roots and measurements of dental remains. At Isernia, previous faunal studies consistently gave ample evidence of the major presence of the dental remains of one particular species- the bison. Dental use-wear studies have been conducted at Isernia previously, a review of which is provided in chapter 2. Hence, a sub-study was designed and implemented to take the study of the bison dental remains from Isernia forward. To broaden the scope of this study and in order to test the veracity of results obtained from the dental material of bison from Isernia, two prerequisites had to be fulfilled by another site chosen for comparison. This site had to be more or less contemporaneous or contiguous in cultural and temporal context with Isernia as well as have a sample size of bison dental remains large enough for their comparison. The prehistoric site of Caune de l'Arago (henceforth Arago), situated near Tautavel in France fulfilled these requirements. Moigne et al. (2006), in their biochronological study of large mammals from Arago with Middle Pleistocene sites of Italy, found that the faunal assemblages from the Middle Complex (Ensemble Stratigraphic I) of Arago were correlatable to the Isernia Faunal Unit attributed to the middle Galerian. The two sites were positively associated not only in terms of faunal lists, based on the totality of the species documented in the two sites, but also because the accumulation of faunal assemblages at the two sites were primarily because of anthropic contribution.

Yet another scope provided by the extensively well-documented and inter-disciplinarily researched excavated site of Isernia in the last few years for the application of a powerful and appropriate computer-based tool for the simultaneous treatment of all information concerning its finds, especially faunal remains, was recognized. Specifically, because of the recording of the spatial coordinates (x, y, z) referring to the positioning of the excavated excavations, it was considered appropriate to work with spatial analysis to try to better understand the characteristics of the archaeological levels (Lembo, 2014). At Isernia, it was facilitated by the setting-up of a pavilion covering the excavation site, completed in 1999, which rendered it possible to set up a permanent, computerised theodolite for recording the coordinates of the archaeological remains, with the organisation of a computer-based workstation. This equipment has directed research work towards a fresh approach in the utilisation of computers for archaeological excavation: i.e. the processing of information does not represent the final phase, but instead follows the work throughout its various stages, from excavation to the final interpretation. The aim is to obtain a more immediate management and utilisation of the data at our disposal, in order to assess the informative and analytical qualities of an information system applied directly onsite. This has involved a reorganisation of documentation methods, attempting above all to speed up data collection, as the times involved in excavations of complex, abundant archaeosurfaces tend to be extremely long (Arzarello et al., 2003) (Peretto et al., 2010). As observed by Peretto et al. (2004, p. 1), "*Such spatial studies moreover will contribute in resolving interpretative aspects regarding the significance of accumulations and concentrations of materials highlighted during excavations. Besides methodological reasons, the use of a GIS as an integrated system was directed toward the processing of various types of intra-site analyses. The aim was to analyse and tentatively interpret the distribution patterns of the archaeological remains, from both two-dimensional and three-dimensional viewpoints. Distribution phenomena were identified by thematic mapping, while trends of concentration/dispersion of materials were obtained through multi-dimensional analyses and stratigraphic relationships, and by visualising longitudinal and transverse profiles: preliminary 'guidelines' thus emerged for drawing up models of material deposition and of human presence in the deposit in relation to all the evidence considered*". More than 50,000 finds from the four archaeological surfaces have been examined and plotted.

At Isernia, the artefacts were found to be distributed planimetrically and stratigraphically over a large area at different levels. To make better sense of this huge data-set, the database created for the documentation of finds from this site contained comprehensive information on numerous variables with respect to each find such as material, size, orientation, inclination, taxonomy, taphonomy, type, technology, use-wear etc. In the context of faunal assemblage, certain interesting patterns were observed and published subsequently. Till present, GIS-enabled analyses, visualisation (2D frequency, density and distribution maps) and tentative interpretation of intra-site spatial distribution trends in the faunal context were designed and developed for all osseous remains (3a, 3 coll, 3s6-9 and 3s1-5), species (3c and 3a), anatomical parts of all species (3c and 3a), and in particular, of bison, elephant and rhinoceros (3a) (Lembo, 2015; Gallotti et al., 2012;

Lembo and Peretto, 2012). However, taphonomic variables had not been incorporated yet. In other words, they are yet to address further spatial queries on other variables such as distribution and patterning of different taphonomic marks (natural and anthropic) for each species and each skeletal part. The research problem is therefore also centered on the application of the GIS, as was done previously, but with refreshed spatial queries and objectives with a focus on taphonomical history of the faunal remains. The research problem here is to delve deeper into spatial studies with regard to distribution and intra-site patterning of localised and general post-depositional phenomena across different stratigraphic layers. The research problem also focuses on combining previous data with fresh emerging data from recent studies in order to update our understanding of the depositional histories of the site and go beyond preliminary spatial analyses of taxonomic and anatomic distribution.

For all the above analyses, the scope was provided by the layers 3 colluvium (henceforth 3 coll) and 3s6-9 faunal assemblages from Sector I of Isernia. It contributed towards the implementation these methodologies and to take the archaeozoological studies of not only these layers but also the at the site of Isernia, forward. These two layers were selected for certain reasons. Recently, the layer 3 coll came into prominence for the site's first human remain discovery, a deciduous incisor, dated to 583-561ka by 40Ar/39Ar (MIS 15/MIS 14) (Peretto et al., 2015). Moreover, both layers have yielded large quantities of faunal remains including dental remains from well-defined stratigraphic provenances with coordinates essential for GIS applications.

1.2 Aims and objectives

With the above background on the research theme, the scope of this research is presented through the following objectives:

- The principle aim of this research is to conduct a systematic analysis and interpretation of the faunal record of selected layers 3 coll and 3s6-9 from Isernia to gain a better understanding of the function and role of the site, its palaeoenvironment, the human-animal interaction and the formation history of these layers during and after their period of occupation.
- The next aim is to analyse the faunal assemblage from Isernia, not analysed yet and recovered till the 2016 excavation campaign, using internationally standardized protocols with regard to archaeozoological and taphonomical analyses. In addition, to reanalyse a part of the faunal material already examined. To synthesize previous database with fresh emerging data from recent studies in order to keep them updated. Furthermore, to

effectuate uniformity in the updated database and compatibility with GIS by modifying the format of data registered, where required.

- To apply some select archaeozoological methods to estimate the relative richness/abundance of taxon and anatomical elements. With reference to the taxonomical and anatomical composition of the faunal assemblage, this research aims to propose questions such as: what does the proportional representation of each taxon suggest regarding the past environment of the settlement, its role and function in the subsistence strategy of humans and the degree and nature of human involvement in the creation of these assemblages? This data allows to understand and make finer distinctions between anthropic and carnivore generated or accumulated assemblages. In the light of this kind of information, the archaeofaunal remains from Isernia will be studied with a new perspective.
- In addition, the nature and effect of anthropic practices such as butchering, processing of animal carcass, bone marrow extraction on/from animal skeletal elements is explored. This objective also addresses the impact of post-depositional processes in Isernia's site formation history. This will aid in finding answers to questions like- what is the nature of meat processing procedure at Isernia? How did the occupants of Isernia obtain meat? How was meat consumed at Isernia? How much of the original evidence of anthropic activity and its integrity has been obliterated due to other natural and biological factors of modification?
- A smaller study within the realm of this research is to attempt to make a comparative analyses of age-classes and degree of use wear of bison dentition from Isernia and the contemporaneous prehistoric site of Arago in France to understand the composition of the population structure of this animal and their palaeodiet.
- To attempt to reconstruct the pre- and depositional history of the select layers based on the spatial distribution of some chosen variables through the application of GIS. This entails creation of two dimensional thematic maps to locate and visualize the results of the spatial queries, delineate intra-site patterns if present, and interpret them accordingly.

The thesis, therefore, comprises an introductory part, composed of the second and third chapters. Chapter 2 provides an introduction to the two sites, Isernia and Arago. It elaborately reviews and accurately reports on the literature available on researches conducted on the various aspects of these sites. It traces the history of the discovery of the site from the time of discovery to today, with reference to topography, geology, stratigraphy, dating, and the natural palaeoenvironment, the composition and characteristics of the fauna and flora. Moreover, there is a brief description of the lithic industry that concerns the site with a look at the main knapping techniques and the human remains discovered in each site.

Chapter 3 begins with the description of the precise origin of the faunal remains that are the subject of this thesis. The chapter also contains a summary of the main stages of the archaeozoological analysis. It contains a description of the methodological aspects related to taphonomy, diaphysis fracture analyses, and bison dental analyses.

Chapter 4, 5 and 6 present the results of archaeozoological and taphonomical analyses of faunal remains from archaeosurface 3a; layers 3 coll and 3s6-9 of Isernia. The composition and salient characteristics of the faunal assemblages are elucidated. This is followed by the data which emerged from the taphonomical analysis made by macroscopic and microscopic observation of all the bone surfaces of all the faunal remains. In particular, the results reported include the micromorphological examination conducted by means of stereomicroscopes at high magnifications of the Laboratory of Archaeozoology and Taphonomy of hard animal materials (L. A. T.) of the University of Ferrara, under the direction of Dr. Ursula Thun Hohenstein. In addition, electronic scanning analyzes were performed at the University's electronic microscopy center (S.E.M.).

Chapter 7 elaborates on the results obtained from the study of bison teeth from Isernia and Arago. A qualitative and quantitative description of associations and refittings between dental remains, minimum number of individuals, age class compositions, use wear and mortality curve is provided.

In chapter 8, the final considerations are discussed encompassing the results procured from chapters 4 to 6 with a conclusive understanding of this research.

The chapters are followed by the photographic plates, containing a series of photos of some faunal remains, which were chosen with the aim of presenting some glimpses of the species that compose the fauna and some examples of taphonomic agents. Finally, the references which are mentioned in the chapters are listed alphabetically and chronologically in the bibliography to aid the readers with further cross-reference.

Chapter 2

Background to Research

(Literature Review)

2.1 Introduction to Isernia La Pineta

Isernia La Pineta is an important Lower Palaeolithic site, located in central-southern Italy, on the southern side of the present-day town of Isernia, near the town of Santo Spirito in Molise (Fig 2.1A). Isernia La Pineta is part of the continental Pleistocene deposits forming the Pleistocene sediments of the Isernia-Venafro infra-Apennine basin, situated in the Upper Volturno valley (Fig 2.1B). It is situated 457 m above sea level. On August 19th, 1978, the site was discovered by Alberto Solinas, who first noticed archaeological artefacts and collected some samples from the southern periphery of the site during the construction work of the Naples-Vasto road highway (Peretto, 1999; 1996; 1994; Peretto et al., 1983). The collected samples were brought under the inspection of Professors Carlo Peretto, Benedetto Sala and Mauro Cremaschi of the University of Ferrara. Upon confirming the antiquity of the site and importance of the finds, systematic scientific excavations at the site were initiated in May 1979, continued till 1993, resumed in 2000 and continue till today. The excavations are authorized by the *Direzione Regionale per i Beni Culturali del Molise* and of the Italian Ministry of Culture as part of a collaboration between the Archaeological Superintendency of Molise and the University of Ferrara, under the direction of Prof. Carlo Peretto, to unravel the stratigraphic series, to verify the extension of the deposit and the distribution of lithic and faunal finds. With the support of local institutions at the Province, Region and Municipality level, research, enhancement, and dissemination activities continue. This has contributed to the development of wide-ranging initiatives that have favored the internationalization of the activities and the possibility of creating a local research center which today finds its valid support in the Center for European Research in Prehistory (CERP) (www.archeologicamolise.beniculturali.it).

The initial investigations were carried out in two distinct sectors situated on either side of the railway line. Excavations began in the Sector I in the NE and in Sector II in the SW (Fig 2.1 C and E). The first sector, divided into four quadrants is positioned in relation to a landmark with georeferenced coordinates and partitioned into a grid 1 x 1 m squares. Being rich in archaeological artefacts, it was covered since 1979 by a prefabricated building, further extended in 1999 towards the west for about 200 m^2 (Peretto, 1994). This sector covers an area of about 250-300 m^2. This stretch between Sector I and the adjacent building which serves as the museum is covered by a canopy. The museum has a viewing gallery for the public. The covering over Sector I serves the purpose of protecting the excavated area from bad weather, possible vandalism, ensuring greater regularity and safety during the excavation of the site (Peretto, 1994) (Fig 2.1 C).

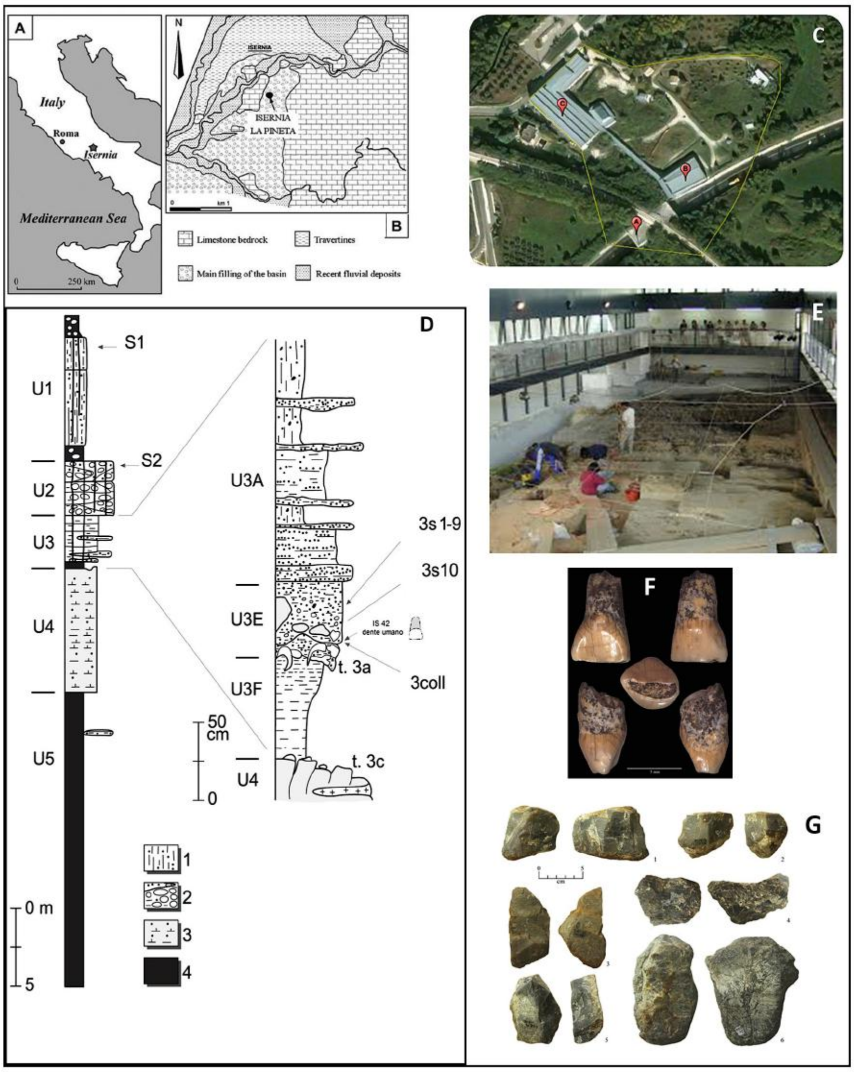


Fig 2.1: Isernia La Pineta. A: Location of the site (modified after Shao et al., 2011) in Italy; B: Location of the site in the Volturno Basin (modified after Coltorti et al., 2005, cited in Gallotti and Peretto, 2014, p. 3); C: Aerial view of the site demarcated by a yellow line boundary in which are visible (A)- Sector II of the excavation, (B) Sector I of the excavation and (C)- the museum building (Google Earth image) (Lembo, 2014, p. 70); D: Left column refers to the stratigraphy of the site characterized by 5 main units (from U1 to U5) and 2 buried paleosoils (S1 and S2). The right column refers to Unit 3 which contains various sedimentological layers (U3A, U3E, U3F) and two important archaeological layers (t.3a and t.3c). 1, colluvial deposits including a pyroclastic fall layer; 2, sands and gravels; 3, travertine; 4, silts and clays (modified from Coltorti et al., 2005, cited in Lembo, 2014, p. 74); E: Excavation in progress in Sector I (image: www.archeologicamolise.beniculturali.it); F: IS42- Human deciduous tooth recovered from layer 3 coll (image: www. archeologicamolise.beniculturali.it); G: 1-6 Flint tablets from the unworked assemblage of t.3c (Gallotti and Peretto, 2014, p. 7).

Sector II, on the other hand, located about 50 m east of Sector I, occupied an area of 90 m^2 (Peretto et al., 1983). It was archaeologically not as rich as Sector I and underwent excavations in the 1980's mainly to salvage artefacts from it prior to irreparable damage (Anconetani et al., 1992; Peretto, 1992). Besides excavations, exposure of stratigraphic sections and regular drilling surveys helped to estimate the extent of the archaeological deposit on a surface area of thousands of square meters. However, the finds are not uniformly distributed, and their frequency varies from area to area.

2.1.1 Geology, geography and stratigraphy

The site is located along the left bank of the river Carpino, which together with river Sordo, joins the Cavaliere stream, a tributary in the middle upper part of river Volturno, which in turn drains into the Adriatic Sea. More precisely, it can be found inside the main filling of the basin within the valley dug by the complex hydrographic network formed by the two rivers Cavaliere-Sordo and represents the oldest and morphostratigraphically the highest sedimentological unit described in the basin (Brancaccio et al., 1997; Coltorti, 1983; Van Otterloo and Sevink, 1983; Coltorti et al., 1982). This unit was cut by a subsequent deepening of the valley. The downcutting process was interrupted and small fluvial terraces of limited extent were progressively deposited at gradual heights with respect to the river valley bed. These deposits are biochronologically associated with Middle Galerian. Two sedimentary cycles comprise this deposit which is nearly 20 m thick. The first one occurred in the Lower Pleistocene. It commenced with the transgression of lacustrine sediments above the weathered surface cut in limestone bedrock and ended with emersion faulting and weathering of travertine. The second one represented by fluviatile sediments may have been due to the aggradation of the alluvial fan. Since the beginning, the fluviatile sediments are connected with volcanic activity.

Located in a tectonic depression that began during the Lower Pleistocene, the Volturno river basin is bordered by a series of faults oriented in the NE-SW and NW-SE directions, with major fault escarpments arranged in a succession of steps. Formed since the Mesozoic, in marine basins, the geological units found here were characterized by different types of sedimentation, evolutionary processes and tectonic movements oriented to the East during the Messinian-Pliocene Inferior. However, the normal faults not only displaced these units but also the remains of a planation surface which levelled all the previous structural units as well as previous topographic contrasts created during the contractional phase (Coltorti, 1983; Coltorti and Cremaschi, 1982). The onset of the extensional tectonics in the basin also is poorly constrained due to the limited information on the age of the sediments which fill the deeper part of the Upper Volturno basin. They have been attributed mostly to the Middle Pleistocene and only for a limited thickness to the Lower Pleistocene (Brancaccio et al., 1997; Coltorti et al., 1982). Sedimentary changes were mainly controlled by neotectonic development in the Isernia basin. These tectonic movements modified stratigraphic sequences and ancient human occupation surfaces. The tectonic activity that generated the Isernia depression is still active and controls the intense seismicity of the area (Chiarabba et al., 2005; Di Bucci et al., 2002). Various volcanic eruptions occurred concurrently with the deposition of the fluvio-lacustrine successions. The volcanic components of fluvio-lacustrine sedimentary series in Southern Apennines are mainly associated with the plinian and ultraplinian eruptions of Roccamonfina and Vulture volcanoes (Peretto et al., 2015, p. 3).

Four major unconformity-bounded stratigraphic units (UBSUs) define the Volturno river basin filling. They are arranged in three terraced fluvial deposits at successive altitudes from the base of the valley. They underwent deposition during the Pleistocene and Holocene (Coltorti et al., 2005; Brancaccio et al., 2000; 1997; Coltorti et al., 1982). Unlike the Isernia town, the calcareous tufa in the area where the site is located is covered by sands and gravels. The top depositional surface of the tufa and that of the alluvial deposits (UBSU 1 and 2) are located almost at an equal elevation and were named "main filling" (Coltorti et al., 2005; Coltorti et al., 1982), or "main unit" (Brancaccio et al., 2000; 1997, cited in Peretto et al., 2015, p. 3). The youngest UBSU correlates to a terrace enclosed between the Holocene floodplain and the older UBSU and is attributed to the Late Pleistocene (Brancaccio et al., 2000; 1997; Coltorti and Pieruccini, 2014, cited in Peretto et al., 2015, p. 3). Alluvial fans coming from the lateral valleys locally covered the oldest UBSU and laterally correlate with the Late Pleistocene terrace (Peretto et al., 2015, p. 3).

Hence, the closeness to a stream, which regularly flooded, and the occurrence of volcanic events contributed to the good preservation of the site, which was covered by flood deposits (silt and clay) alternating with volcanic materials (tuff) (www.whc.unesco.org/en/tentativelists/5020). The archaeological layers at Isernia La Pineta were discovered at around 4 m below the surface inside the older UBSU buried under sediments belonging to the Middle Pleistocene (Shao et al., 2011; Longo et al., 1997; Coltorti et al., 1982, cited in Peretto et al., 2015, p. 3). Five sedimentary or lithological units were recognized from bottom to top and are described as follows (Gallotti and Peretto, 2015; Peretto et al., 2015, p. 3-6; Minelli et al., 2006) (Fig 2.1D).

Unit 5: located south of the La Pineta locality, the sequence highlighted by the river Cavaliere illustrates this Unit. It belongs to the upper part of the oldest UBSU. It is composed of non-compact lacustrine clays with thin layers of gravel and debris.

Unit 4: It belongs to the upper part of the oldest UBSU. It is majorly a phytoclastic and to a lesser extent phytostromatic and phytohermal calcareous tufa deposited by a freshwater river. It is eroded and altered tufa intermittently present with clayey and silty thin beds and some slope deposits. In the NW part of the studied section near the limit of the basin, they are interlayered and modified by neotectonics. This unit is covered by a thin volcanic layer. At the uppermost part of Unit 4, below the oldest occupation layer (t.3c), a primary pyroclastic fall, labelled as U4T, including white weathered pumice (up to 1 cm in diameter) containing transparent sanidines, clinopyroxenes (Cpx) and biotites is found. A common feature found at the lowermost part of both sectors- I and II was the basal unit and the travertinous unit. The other stratigraphic units, however, showed variation between different areas of the site.

Unit 3: It belongs to the second UBSU. It's rich palustrine, pyroclastic fraction, remodelled. It contains deposit with sands and fine and thin layers of gravels which were deposited by low-energy ephemeral rivers.

Unit 2: It belongs to the second UBSU. It is made up of sands and gravels deposited by ephemeral rivers (braided facies).

Unit 1: It is composed of gravels and sands with intercalated/superposed tuffs. It is a colluvial sequence, including a pyroclastic fall.

All archaeological horizons are present in Unit 3. The important features of the archaeological horizons and the findings from each of them is discussed in detail further on in this chapter in subsections 2.1.4, 2.1.5 and 2.1.6. The level represents the deepest part of a series of fluvial and pyroclastic deposits divided into different facies. It is a complex association of fluviatile facies including overbank deposits (sub-unit 3F and 3A), channel deposits (sub-units 3B and 3C) and pyroclastic sediments due to mass transport (sub-unit 3G and 3E) described below.

Sub-unit 3G: It is made of coarse sands with a characteristic dark green color for the presence of eudal augite crystals and biotites. The sediment also consists of fragments of pumice, sanidine and rare fragments of flint (Cremaschi, 1983).

Sub-unit 3F: Formed by sedimentary structures, it has a thickness of 1 m. It is a massive layer formed at the base by light yellow-brown clays and at the top by silts. This sub-unit is further divided into three layers (Cremaschi, 1983):

t.3c: The oldest archaeosurface is 3c. It contains archaeological and paleontological remains lying on the phytoclastic travertine (Unit 4) passing laterally to a phytohermal travertine. It lies at the top of calcareous tufa and is buried under a thin layer of mixed phytostromatic tufa and clay sediments. It is about 20 cm thick and is characterized by reddish sands with concreted and sometimes cemented sections, with thick carbonate-travertine crusts which locally tend to fade into banks of lithoid travertine, more or less altered by probable pedogenic phenomena (Cremaschi, 1983).

t.3b: It is an archaeologically sterile layer of sand and silt in a lacustrine environment deposited inside travertine pools. Apart from unidentified vegetal entities, this deposit is completely devoid of remains. The silt is grey, sometimes light yellowish in colour. In the lower horizon, it tends to

increase in the clay content and fracture polyhedrally, if dry, with frequent lacquering of iron and manganese oxides and numerous carbonate concretions (Cremaschi, 1983).
t.3a: archaeosurface lying on top of t.3b as well as on the travertine. It is composed of a high concentration of lithic artefacts, faunal remains and reworked natural elements of travertine (Cremaschi, 1983).

Sub-unit 3E: Also referred to as 3 coll, this layer is a pyroclastic debris-flow of about 30–100 cm thick and covers the inhabited soil in the Sector I. It is composed of reworked and well-sorted elements such as silts, sandy silts, sands, large blocks of travertine, both natural and anthropogenic. It is rich in archaeological remains and crystals of sanidine and pyroxene, which are the basis of dating this layer, and in turn, the site as a whole (Cremaschi, 1983).

Sub-unit 3D: This is a 150 cm thick layer of gravel, coarse sands, finer sediments and travertine boulders (Cremaschi, 1983). It is divided into three artificial cuts- 3s1-5, 3s6-9 and, 3s11. It overlies the archaeological horizon 3S10. Archaeological remains are dispersed within its thickness and it is present only in Sector I (Anconetani et al., 1992).

3s11 cut: It has a thickness of about 30 cm and is characterized by sands of dark gray-green, coarse, compact, sometimes cemented, which include a siliceous fraction and numerous pebbles. Rich in femic minerals, the layer also incorporates osteological findings and lithic artefacts. It can be interpreted as a debris flow put in place by a deposition mechanism similar to that already known for the excavation sector.

Archaeosurface 3S10: It has a thickness of 5-10 cm. It is characterized by yellowish or yellowish-green sands, locally coarse, also concreted, with an important lime component. There is limestone, travertine, flint pebbles and faunal fragments in it. It can be interpreted as a new layer that is added to the three already identified. In this layer, there is a substantially homogenous distribution of finds, with a quantitative increase where the thickness of sediments increases. This layer interacted with natural factors such as water transport which resulted in its burial since some of the larger artifacts show particular distribution and some of the bones and few lithics show weathering caused by water.

3s6-9 cut: This layer is made of yellowish sands, compact, interspersed with layers of coarser sands with frequent lacquering of iron and manganese oxides. Minerals, also coarse, of volcanic origin of greenish and black color are present. Moreover, in these cuts, with a total thickness of about 50 cm, there are lithic artefacts and osteological finds in a secondary position.

3s1-5 cut: This layer is composed of yellowish sands with a lentiform shape, compact, interspersed with layers of coarser sands, with frequent lacquering of iron and manganese oxides and concentrations of $CaCO_3$. In the lower horizons, it is characterized by the presence of rare lithic artefacts and osteological fragments, evidently in a secondary position. The overall thickness is about 40-50 cm.

Sub-unit 3C: It is composed of gravels. A gravel-lenticular layer formed by limestone gravels and siliceous elements and to a lesser extent by travertine elements alternating with coarse and medium sands rich in pyroxenes and amphiboles deposited by a stream coming from S-E. The facies only surfaces in the sector I (Cremaschi, 1983).

Sub-unit 3B: It is composed of sands and gravels. It is also a layer composed of medium and coarse stratified cross-sands interspersed towards the flat and elongated pebble roofs, extending westwards to the base of the facies (Cremaschi, 1983).

Sub-unit 3A: It is composed of gravels with heterometric and polygenic pebbles, mainly siliceous, in silty-clayey and sandy silty matrix, brown in color, with large blackish-iron-magenta patches. The stratification is flat-parallel with alternation of sand and silt. It is compact, sometimes concretized and sterile (Cremaschi, 1983).

The upper part of Unit 2 corresponds to a deeply weathered palaeosol (S2). Unit 1 is weathered at the top by a palaeosol (S1) (Fig 2.1D). Associated with long-term interglacials, they represent short sedimentary breaks. Van Otterloo and Sevink (1983) state that in all probability, the uppermost unit, with the palaeosol, evolved during the Holocene because it has been observed above more recent geomorphological units (i.e. terraces) and sometimes it contains pottery fragments and other archaeological remains.

2.1.2 Dating

Several dating techniques including physical and chemical methods have been applied by various laboratories over the years to assign an absolute chronology to this site. Chronostratigraphy (stratigraphy, pedology, small and large vertebrate biostratigraphy, palynological analyses) and techno-typological characteristics of lithic finds attribute the site to an early phase of Middle Pleistocene (Galerian Mammal Age). Dating methods such as radiometric analysis (Coltorti et al., 1982; Sevink et al., 1981), palaeomagnetism (Gagnepain, 1996; Coltorti et al., 1982) and biostratigraphy (Peretto, 1996; Peretto et al., 1983; Sala, 1983) were used.

In terms of oxygen isotope, the site corresponds to stage 15. The radiometric analysis of ^{40}K/^{40}Ar was applied to the three uppermost tephras (not impacted by post-depositonal phenomena). Biotite crystals were sampled from a layer above the archaeosurface 3a as well as from the same layer as archaeosurface 3a. The former revealed an age of 680 ± 660 ka, the other 730 ± 700 ka (Sevink et al., 1981). K/Ar method was also performed on reworked sanidine crystals separated from tuffaceous beds which came from sub-unit 3E, laying directly above the archaeological finds (archaeosurface 3a). They were determined to be 610 ± 10 ka and 606 ± 2 ka (Coltorti et al., 2005). This places the site firmly in the first part of the Middle Pleistocene. This date concords well with the composition of the fauna: for example, the presence of the rodent *Arvicola cantiana* and its association with *Bison schoetensacki*, *Stephanorhinus hundsheimensis* and *Elephas antiquus* (Lembo, 2014, p. 78). Recently, archaeosurface 3S10; layers 3 coll and 3s6-9 from U3E were dated using the ^{40}Ar/^{39}Ar method, following the discovery of the human tooth from layer 3 coll. The ages of 583 ± 2 ka, 583 ± 3 ka and 587 ± 2 ka obtained for the youngest sanidine populations for archaeosurface 3S10; layers 3 coll and 3s6-9 respectively can be accepted into account (Peretto et al., 2015). It is therefore very probable that the age of Unit 3 which contains the most important archaeological layers corresponds to the transition between the Interglacial 15 and the Glacial 14 phases, as is also shown by the sedimentological analyses of the Isernia basin area (Coltorti and Pieruccini, 2014, cited in Lembo, 2014, p. 79).

The bones and enamel of the elephant's teeth, rhinoceros and bear were subjected to another method i.e. racemization of amino acids from which the ages of 550 ± 140 ka and 650 ka were obtained (Belluomini et al., 1997; Belluomini, 1985). ESR/U-series (Bahain et al., 1992; Falguères et al., 2007) on tooth enamel of two elephant teeth, two rhino teeth and a bison tooth yielded underestimated results with an error-weighted mean age of 435 ± 24 ka, approximately 200 ka younger than the ^{39}Ar/^{40}Ar dates obtained from four bison teeth belonging to the archaeosurface 3a (Shao et al., 2011). Both types of analysis provide very young ages that do not concord with other ages obtained by other methods, perhaps due to residual Uranium infiltrations in different dental tissues, or due to erroneous estimates. The tuffaceous beds from Unit 1 exhibit no signatures of post-depositional transport. These Unit 1 pyroclastic layers are dated at 470 ± 50 and 550 ± 50 ka (Delitalia et al., 1983). Another set of dates show it to be 499 ± 13 ka (Coltorti et al., 2005).

The palaeomagnetic investigations at Isernia revealed that the magnetic polarity was negative below the occupation layers and subsequently reversed to positive in the layers overlying the occupation layer. In other words, palaeomagnetic dating conducted at Isernia indicates that the human activities took place around the same time of the Matuyama-Brunhes shift from reversed to normal earth magnetic polarity. This shift has been located in many places of the world, and securely dated (by means of potassium Argon dating) to about 0.73 million years ago (McPherron et al., 1983, p. 67).

2.1.3 Excavation Methods

An archaeological excavation is a vital and basic investigative tool that allows the recovery of buried archaeological remains, the identification and documentation of the relationships between the different layers of the stratigraphic series and their relationship with the different remains. At the Palaeolithic site of Isernia, the excavation follows the principles of the stratigraphic method (Minelli and Peretto, 2003). In this method, the archaeological artefacts are recovered, studied and restored in respect to their spatial position and the relationship that associates them with the sediment deposit which forms their provenance. To fulfil this goal, the recovery of these artefacts is done in a systematic manner to retain as much important information as possible about them and their spatial distribution. With these goals, the archaeological excavations at Isernia, from the initial stages till date, implemented and followed a method that relied on documentation on both paper and computer. The broad extension of the paleosurface required a subdivision of the excavation area of Sector I into a matrix of four quadrants, each of them divided into sub-quadrants or squares of one meter of area each (Peretto, 1994; Giusberti et al., 1991).

At the site of Isernia, of fundamental importance is the use of the total station, an optical system with laser pointer able to record on a computer the coordinates, the distances of an object within the site etc. The total station is positioned at the point of origin from which the main axes of the excavation grid are determined. The latter is divided into 4 quadrants, in turn divided into squares of 1x1 m each to which a number has been assigned (Minelli, 2003). The excavation takes place on different archaeological layers in various squares, the stratigraphic sections are documented 1:10 scale. The remains are drawn on a 1:5 scale. The excavation proceeds as per quadrants and when a remain is discovered, it proceeds with the recording of all information pertaining to it. Since the excavation is primarily a destructive process, it is important that the data-collection form collects maximum information about the find. This form consists of numerous fields such as: excavation date, quadrant, subquadrant/square, stratigraphic unit-series; category of remains (bone, flint, limestone, travertine); coordinates (x, y, z) acquired using Total Station (Model GTS-605); the orientation of the remain with respect to the North, the dimension of the remains and all the fundamental information necessary for identification, description and location of the remain. The data sheets are also supported by planimetric and photographic recording.

The large quantity of remains found on archaeosurfaces and the large amount of data related to them, has necessitated the requirement of using methods of study leading to an interdisciplinary analysis based on the use of innovative technologies (Minelli and Peretto, 2003). Traditional methods of recording and management of large quantities of data were not useful and hence the use of technology in the archaeological excavation was introduced. The computerized data management follows all phases of research, starting from the activity of excavation, the recovery of archaeological finds, collecting data about them and until their restoration. The use of GIS, the photorestitution and 3D survey, allows to accurately detect objects in terms of orientation, direction and inclination on the archaeosurface, and to speed up the acquisition and processing of the information and to manage them directly in digital format limiting the possibility of error (Gallotti and Lembo, 2007; Gallotti et al., 2004; Arzarello et al., 2003).

The first step of *in situ* recovery is the removal of coarse sediment: the excavation in each square is conducted on uniform horizontal planes to avoid creation of holes, in order to follow the profile of the find and to facilitate its removal. Different tools are used depending on the type of sediment present. Tools such as trowel, awls or scalpels are preferably used on sediments such as silt, clay, sand and gravel. Chisel and hammer with rubber striker are used on harder sediments in order to remove portions of earth. The sediment removed is collected with a brush and a scoop and placed in a bucket (Corti, 2003). Once the find has been completely released from the surrounding sediment, the phase of consolidation is initiated. When the finding, completely free from sediment, is free of fractures or evident cracks it can be lifted and placed in a white paper bag with all the identifying information of the find written on it. In the event that the object is large or in an evident state of bad preservation, a medical gauze with a glue is placed on its surface. Once dried the gauze will acquire the consistency of a plaster. Remains not recovered *in situ* and those that have passed into the sediments in the bucket can be recovered through the washing and sieving activities. The washing of sediment contained in the buckets occurs with the use of two overlapping sieves, one with a 5 mm mesh and the other with a 1 mm mesh. The coarse sediment coming from the excavation is placed on the first sieve and washed abundantly with water in order to isolate the material larger than 5 mm. The second, narrower mesh sieve is then washed, isolating the material larger than 1 mm. The operation ends with the drying of the sieves. Each sieve contains inside a ticket with all the information needed to indicate the stratigraphic origin of the washed materials written on it. The screening consists in the recovery operation of all those materials (fragments of flint, fragments of bones and teeth of micromammals, complete bones and teeth of micromammals, etc.) that are mixed inside the sediment. The sorting is done by analyzing small portions of materials arranged on a white tray using pincers. In order to consolidate the most deteriorated remain it is necessary to use a consolidator (dilution of Paraloid B72 with acetone). Once the phases of consolidation and securing of the remain are over, they are transported to the restoration laboratory, waiting for subsequent operations related to the study, display and storage of the remains (Minelli, 2003).

2.1.4 Human remains

A single well-preserved human remain was discovered from the layer 3 coll of the site in 2014 (Peretto et al., 2015). This fossil tooth is a deciduous left maxillary lateral incisor attributed to a child of 5-7 years of age (Fig 2.1F). The tooth has been labelled with the number IS42. New ^{40}Ar/^{39}Ar measurements of sanidine crystals forming the surrounding matrix of the tooth is dated to about 583–561 ka, corresponding to the end of Marine Isotope Stage (MIS) 15. Taxonomic determination of this tooth is at the current stage not possible due to inadequate comparative contemporary hominin skeletal record. Peretto et al. (2015, p 1-19) observe that "*Given the emerging variegated pattern of hominin evolution during the Middle Pleistocene in Europe, the most conservative option is attributing the tooth to an undetermined species of the genus Homo, i.e. to Homo* sp. (cf. *heidelbergensis). Thus, the tooth is currently the oldest human fossil specimen in Italy and it is an important addition to the scanty European fossil record of the Middle Pleistocene*".

2.1.5 Lithic industry

The provenance of the lithic industry in Isernia is primarily Unit 3 comprising archaeosurfaces 3c, 3a, 3S10 and layers 3s1-11 from Sector I and archaeosurface 3a of Sector II. Rich in quantity in Sector I when compared to Sector II, they are the tangible evidences of human occupation of this site. Sector I lithic assemblage has both limestone and flint whereas Sector II has yielded mostly artefacts of flint but almost negligible limestone. The lithic industry has been investigated for archaeosurfaces 3c, 3a (Gallotti and Peretto 2015; Minelli et al. 2004; Peretto et al., 2004; Longo et al., 1997; Peretto, 1994); layers 3 coll (Rivera Pérez, 2016) and 3s6-9 (Srinivas, 2016). Studies have also been specially conducted on the artefacts manufactured from limestone (Gallotti and Peretto, 2015; Rufo et al., 2009).

The representation of a wide range in the assemblage is characterised by a dominance of flakes which were struck off slabs and tablets for flint whereas cobbles and pebbles for limestone. Flint, of alluvial origin, was procured from a secondary context. However, limestone was sourced from travertine bedrock, *in situ* at the locality as well as from the secondary context. Additionally, debris has also been recovered. Short reduction sequences resulting in small to medium-sized flakes with cutting edges was the objective, hence the knappers predominantly employed opportunistic methods. Centripetal and discoid methods were also observed which led to lengthening of the reduction sequences. The lithic assemblage also had a few cases of Kombewa flakes. Direct percussion by hard hammerstone, followed by the bipolar-on anvil, was the most often used technique of debitage. The selection of these methods is reflective of the type of raw material available to the knappers. Flint and limestone are the two main raw materials exploited for this industry, but they were not of superior quality. Flint, in particular, was plagued by tectonic fractures.

Archaeosurface 3c: Lithic finds, mostly small and medium-sized flakes, are mainly of flint and very few of limestone locally available in primary and secondary context (Fig 2.1G). They present a good state of conservation as they have still retained sharp edges and not been impacted majorly by any type of post-depositional transport. The debitage methods employed here were mostly unifacial unidirectional, discoid and direct hand-held percussion by hard hammer. Cores were not reworked or reused as tools and were discarded as waste products (Gallotti and Peretto, 2015). The depositional conditions were influenced by displacement phenomena of the travertine which had altered the original location of artifacts.

Archaeosurface 3a of Sector I: The lithic assemblage from this archaeologically rich layer includes small flint (denticulate), limestone, some choppers and roughly chipped pebbles (Peretto, 1994; Giusberti et al., 1983). Despite limestone artefacts comprising a small fraction of the lithic assemblage, the number of cores struck on limestone are equivalent to the number of cores on flint. Regarding the state of preservation, flint-based artefacts appear fresher with sharp cutting edges than limestone artefacts which have undergone superficial weathering and surface alteration (Rufo et al., 2009; Minelli et al., 2004, Crovetto, 1994). Two techniques of flake production – direct hand-held percussion by hard hammerstone and bipolar-on-anvil are demonstrated on flint cores (Minelli et al., 2004; Crovetto, 1994; Longo et al., 1997). They clearly show evidence of unidirectional, bidirectional, orthogonal, multidirectional and centripetal removals (Crovetto, 1994). Moreover, cases of cores-on-flake and, pyramidal and subpyramidal cores are detected (Minelli et al., 2004; Crovetto, 1994). The assemblage in general consists of a very large number of flakes, flake fragments and debris, and pieces which are classified as denticulates, notches, beaks and end-scrapers (Gallotti and Peretto, 2015, p. 274). Functional analysis employing a stereomicroscope, metallographic microscope and a scanning electron microscope was conducted on the flint artefacts of this archaeosurface (Minelli et al., 2004; Longo, 1994). The analyses recognised that the artefacts were most probably used for butchery processes, and cutting operations of both soft material, like muscular masses, and more resistant material, like skin and tendons (Longo, 1994; Minelli et al. 2004, p. 64). The analyses further helped to show that artefacts categorised as denticulates, beaks, notches and end-scrapers had no microscopic elements to imply use (Longo, 1994; Minelli et al., 2004, p. 64), supporting the hypothesis of the ‘retouched tools’ being flaking products, based on the experimental work (Crovetto et al., 1994b). Regarding the travertine and fragments, these lie in high concentration in a southerly direction along the edge of the motorway embankment. However, the natural limestone lies in a different area than the worked ones. The frequency of flakes was found to the south east. This area probably represents a flint workshop placed in direct contact with travertine below.

Archaeosurface 3a of Sector II: The salient features that set apart the lithic assemblage of Sector II from that of Sector I are the total absence of limestone artefacts, the high proportion of flakes and flake 'tools' and the presence of refitting elements in the former (Peretto et al., 2004; Crovetto et al., 1994a). The cores are marked by a wide range of variation such as unidirectional, bidirectional unifacial bipolar, unifacial orthogonal, bifacial orthogonal, bipolar, multidirectional, globular, prismatic, subpyramidal, pyramidal and irregular. The cores were frequently on slabs and tablets. Nonetheless, even pebbles and cobbles were utilised. They were exploited using both the direct hand-held hard hammer percussion and bipolar-on- anvil percussion techniques. The identified methods of debitage are opportunistic, centripetal and discoid (Crovetto, 1994).

Layer 3 colluvium: Rufo et al. (2009) conducted investigations on the limestone artefactual component from this layer's lithic assemblage. They are available in the form of pebbles and cobbles, both in a primary and a secondary context near the site (Gallotti & Peretto, 2015). Further, the limestone artefacts present traces of surface alteration and hydraulic abrasion (Rufo et al., 2009, p. 83). Recent studies on the techno-economic aspects of the lithic assemblage of layer 3 coll brings to the forefront that from plates or plaques of reduced size flint, the débitage was managed with relatively short *chaines opératoires*, that resulted because of the size and inferior quality of the raw material. Simple, non-hierarchical, and not involving any core preparation, all stages of the reduction sequence can be traced in the assemblage. The method of debitage is opportunistic, with a unipolar and orthogonal arrangement. Core forms are mostly irregular, although some other forms are present such as subquadrangular, subpyramidal and pyramidal cores. Hammerstones and anvils (blocks with percussion marks) are observed and identified as pebbles with utilisation traces. Flake removals are few, and superficial, thus resulting in many flakes preserving their cortical cover (Rufo et al., 2009). Radinović (2015) conducted functional analysis on a limited sample of flint flakes, produced with the bipolar technique. He identified use-wear imputable to their use in working with soft animal material, animal tissues and butchering activities. Rivera Pérez (2016), in a recent study of 3 coll lithic industry of Isernia, found that simple flakes, retouched flakes and cores and a small proportion of debris composed the assemblage. Flint was the predominant raw material used for tool manufacturing. The possible alterations resulting from the natural processes such as water abrasion that eventually affected the artifacts were observed at a macroscopic level on the 3 coll lithic industry. The archaeological material in flint did not present significant alterations. Similarly, the few examples of water abrasion show the limited wear of archaeological material as a result of water transport (Lembo, 2014; Peretto et al., 2004, 1994; Gallotti, 2004). These pieces usually show a polished outer surface with its positive reliefs worn and even erased. Flakes were mainly produced through discoid, opportunistic, centripetal and Kombewa method. In the lithic set of the layer 3 coll, the production of flakes/instruments was managed through the debitage. The different identified methods of knapping give an account of a conceptual scheme that sought to obtain different types of artifacts by means of the organization of the gestures used during the production of tools (Arzarello et al., 2011).

Archaeosurface 3S10: The lithic assemblage is fragmented and presents a partially fresh and partially rolled state of preservation (Peretto et al., 2004; Anconetani et al., 1992). Flint artefacts and flint debris contribute in majority to this assemblage. Limestone, in lesser fraction, was primarily used for the manufacture of heavy duty tools such as choppers, chopping tools and rabots. Flint was used for making flakes.

Layer 3s6-9: The lithic assemblage from this layer yielded evidence of cores, flakes, debris, and tools on flint from which the stages of reduction sequence could be reconstructed. The cores display two techniques of percussion – the direct hand-held hard hammer percussion technique and the bipolar-on-anvil percussion technique. They were exploited using different reduction schemes – the unidirectional unifacial, the bidirectional, the orthogonal, the bipolar, the multidirectional, and the unifacial centripetal. Flakes were further actively exploited as core-blanks. These flakes are uniform in their dimensions which suggests that the knappers probably had a fixed mental template for flakes and flake-tools or a strong influence of the raw materials block dimensions and morphology. Such an observation is also made on the retouch on the flakes which demonstrate continuity and standardisation. The standardised tool-kit consists of a variety of tool types, including denticulate morpho-forms, classical 'tools' and backed tools. Srinivas (2015, p. 150) observes, "*The reduction sequence at Isernia La Pineta is geared towards the production of small and medium-sized flakes. This, the paucity of secondary working of flakes, and the lack of LCTs had previously characterised the assemblage of Isernia La Pineta as a Mode I techno-complex. But the identification of façonnage and an assemblage rich in retouched flakes, now forces a reconsideration of this assemblage as a Mode II techno-complex. This evidences the underlying technological variability in the lithic assemblages of Isernia La Pineta, in particular, and that of the Western European Mode II, in general*".

2.1.6 Faunal record

The extensive study of Isernia La Pineta faunal assemblage involving identification, classification, osteometry, taphonomy, experimental studies and spatial distribution investigations over the last 30 odd years have helped to understand the role, function and exploitation patterns of different animals from an anthropogenic causative perspective. Carnivore presence is limited at Isernia with presence of bear, and single remain of hyaena, lion and leopard positively confirmed. The scarcity of their remains aids in attributing the assemblage accumulation to anthropogenic origin. The faunal assemblages are dominated by bison, rhinoceros, deer, elephant and hippopotamus. These hunted animals are represented by nutrition rich anatomical parts such as long bones and mandibles which the hominins altered using lithic tools to access the marrow and meat. Repeated high frequency of marks, fractures and notches in certain places on the remains points to a systematic and intentional carcass utilisation process. Other marks caused by natural agents include trampling, erosion, exfoliation corrosion, evidences of different stages of weathering and deposition of concretions were part of the post-depositional history.

Experimental studies on bone breakage dynamics

The aim to better comprehend the *chaîne opératoire* employed by the ancient occupants of Isernia to exploit the carcasses of animals optimally was the central theme of the experimental programme. These well-designed experiments focused on decoding the breakage dynamics resulting from different techniques put into force and to define, with greater precision, diagnostic characteristics of intentional breakage as a result of these techniques. Long bones and mandible of cattle (*Bos taurus*) were the raw material chosen for these experiments. The following aspects and their outcomes were evaluated (Peretto et al., 1996, p. 302-307).

1. Parameters involved in the experiment- the physical strength of the experimenter was not as important as the force with which the blow was struck on the bone. Stronger blows broke the bone quickly with minimal bone debris to contaminate the marrow inside. Bones exposed to sunlight for some hours were ideal for breakage. Fresh green bones were highly elastic and dry bones, exposed to sunlight for long, were inconsistent and brittle. The thickness of the bone, a factor age-dependent, helps in quicker breakage but comes with greater flake-production, risk of shattering and lesser quantity of marrow content.
2. Fragments produced experimentally with respect to both their position on the entire bone and to their absolute dimensions. The experiments revealed that the number of bone fragments representes a clear selection of certain areas on the bone to receive the blows. This choice of suitable areas was also determined by the good support provided by an anvil or an easy grip in thrown percussion. Direct percussion impacted a larger area, realised by greater number of blows resulting in smaller-sized flakes. On the contrary, thrown percussion method needed greater energy and was influenced by the physical strength of the experimenter, the dimensions and weight of the bone. The bones break more easily, with an impact area of limited dimensions and few number of flakes are produced. Percussion cones are smaller while the size of the fragments is larger.
3. Identification of diagnostic characteristics of intentional breakage in relation to the different techniques used and the skeletal part could be more or less narrowed down to certain variables. Dimension of the impact area, age of the individual, nature of percussor, the nature and dimensions of percussion notch, the edge of impact in a notch, cortical and medullary detachments, diaphyseal flakes; thickness, curvature and porosity of the bones are the variables.

The observations and patterns made on bone breakge dynamics through experimental studies were tested on the taphonomic study of intentionally broken bones from Isernia's faunal assemblages (Anconetani and Peretto, 1996b, p. 488-490). Bison bones displayed higher frequency and diagnostic features of intentional bone breakage. This was followed by rhinoceros. Evidence of intentional breakage was rare on bear bones. The skeletal parts which displayed the diagnostic features of intentional bone breakage were mostly the long bones and mandibles fo the species mentioned above. Humerus, radius-ulna, tibia, mandible, metacarpal and diaphyses fragments demonstrated these features in descending order of intensity. Mandibles were generally broken along the horizontal ramus just below the teeth to extract marrow. Long bones were broken along the longitudinal plane. However, transversal breakage of long bones was also noticed in the archaeofaunal assemblage of Isernia. Percussion notches, percussion cones, medullar and cortical detachments were identified in the faunal assemblage. All these variables helped to create particular breakage morphotypes and although modelled on the experiments and the archaeofaunal assemblage of Isernia, they can be applied to other similar contexts.

Archaeosurface 3c (Di Nucci and Thun Hohenstein, 2006a; Anconetani, 1996a)

The archaeosurfaces 3c (Sector I) yielded 684 faunal remains primarily fragmentary in nature from an excavated surface area of 70 m^2. A homogenous spatial distribution of faunal remains was observed in this archaeosurface. Among the 684 remains, 385 remains were unidentified, 172 remains determined anatomically and 155 remains taxonomically. The rate of determination taking into account the addition of anatomically and taxonomically determined remains (327) came to 47.8%. If only NISp is considered the rate equalled 22.7%. Among determined remains, red deer elements were the highest with 37 elements (23.8%) attributed to them, followed by elephant (16.1%), bison (13.5%), bear (9.7%) and rhinoceros (8.4%). Animals with lesser representation were hippopotamus (2.6%), giant deer and fallow deer with one each (0.6%). Ungulates of large size were 28 and ungulates in general were 10 in number. The number of identified specimens accounted for four bison, two bears, two cervids, one rhinoceros, one elephant and one hippopotamus. The state of conservation of remains from this archaeosurfaces was less well preserved in comparison to those from archaeosurfaces 3a. Small fragments contributed majorly to the composition of this assemblage apart from some occasional occurrences of incomplete remains either of small or large size. In most of the remains, a high incidence of dissolution of bone surfaces and rounding of fracture edges was noted. Postcranial remains were prevalent in the assemblage, with 72 diaphyses and a substantial number of fragmented ribs and vertebrae. These remains were attributable to large animals such as bison and elephant. The important presence of elephant tusk fragments, otherwise only partially balance the element count attributable to the cephalic component of the animal's skeleton. In this assemblage, analysis of relative species abundance revealed the dominance of cervids and an increase in the abundance of a bear when collated with the archaeosurfaces overlying it, 3a. Hippopotamus was mainly represented by dental elements, a few of large dimension and one complete jugal tooth. Bison, on the other hand, was characterised by an almost complete absence of cranial remains but teeth were definitely present. Skeletal part abundance revealed the prevalence of dental elements because of their constitution. Cervid vertebrae were better represented than bear and rhinoceros vertebrae. However, in case of front limbs, bison were better represented than cervids.

Potts index (1983) was applied to confront the aspect of the mode of acquisition of carcasses. High fragmentation of remains and absence of external comparisons rendered this analysis difficult. The values obtained were in agreement with documented situations where hunting activities were carried out. Intentional fractures were documented on eight remains. Anthropic activities were evidenced in the fracture planes, their morphology similar to fresh bone fractures as corroborated and observed on experimentally fractured modern bones. The evidence was observed on medial fragments of humeri, on a diaphysis fragment, on the distal portion of an ulna and on the olecranon of an ulna. Also observed were three localized impact points on the medial portion of a hollow semicircular section of the humerus. They were in the medial position with respect to the bone and to the fragment, with one impact point associated with a detachment in the medullary face, while the remaining two impact points were not associated with ay detachments. In a medial-distal fragment of another humerus fragment, an impact point was documented on its proximal-medial part, on the lateral face, associated with a detachment on the cortical face and another detachment on the medullary face.

Archaeosurface 3a (Thun Hohenstein et al., 2009; Di Nucci and Thun Hohenstein, 2006a and 2006b; Anconetani, 1996).

Between the decades of the 80s and 90s, archaeosurface 3a was exposed on a surface area of around 140 m^2. To the south-west of the first sector lies the second sector where archaeosurfaces 3a was recognized and excavated. Most of the archaeological material was removed to allow its restoration and subsequent exhibition at the museum of S. Maria of Monache. In the later years between 2000-2005, excavation of this archaeosurface expanded to a surface area of another 46 m^2, the total area is more than 200 m^2 and yielded a rich repertoire of over 20,000 artefacts, both lithic and faunal included. Unlike the earlier excavations, the remains found on the floor were not removed. They were left partially still embedded in the floor which made their comprehensive analysis difficult. The spatial arrangement of faunal remains is particular as the large bones are overlapped and so numerous that they covered the underlying silt in an almost uniform way (Giusberti et al., 1983). A total of 7420 faunal remains were analysed prior to this study, of which 3743 (50.5%) were unidentified and 3677 (49.5%) were identified. Faunal remains were not only abundant but also of large size. Among the determined faunal remains, 1361 (18.3%) were determined only anatomically while 2316 (31.2%) were determined at the taxonomic level. The remains determined solely at the anatomic level consisted of long bone diaphyses, cranial, mandible, ribs, vertebrae and dental fragments. The faunal composition was dominated by bison (43.7%), followed by elephant (18%), rhinoceros (17.8%), bear (5%), deer (2%), giant deer (1%), fallow deer (0.2%), hippopotamus (0.2%), wild boar (0.1%) and lion (0.04%). Due to the lack of distinct morphological features, 108 remains were classified as bison/rhinoceros or ungulates of large size category and 170 remains were attributed to the large herbivore category. The calculation of minimum number of individuals indicated the presence of at least 75 bison, 36 rhinoceroses, 15 bears, 12 elephants, five giant deer, a hippopotamus, a boar, a deer and a lion. The indeterminate faunal remains were particularly frequent (Anconetani, 1996).

Some salient features regarding bison, subject of further intensive study (Thun Hohenstein et al., 2009) and the most predominant species in this assemblage, was that the cranial remains were mostly constituted by posterior regions of the skull, horn cores, mandibles which were often represented by the premolar or molar portion with the teeth in anatomical connection, then the angular or articular portions of the ascending ramus showing marked preference over other anatomic parts. Isolated teeth comprised mostly upper and lower molars and premolars, while the incisors were rare. For the axial skeleton, the vertebrae were very often fragmented. Vertebrae were also numerous although in a fragmented state. Scapulae were essentially represented by the proximo-mesial part, with the glenoidal articulation. The pelvis was represented by fragments of the acetabulum or iliac. In the appendicular skeleton, a number of remains of the forelimb with respect to the hind limb favoured the former containing undeniable characteristics of intentional anthropic fractures in order to recover meat and marrow from them. Metacarpals were the most abundant followed by metatarsals, other tarsal and carpal bones as they were found whole or incomplete because of their small size, their conservation being average. Phalanges were relatively more complete, some of them intentionally fractured to open the medullary canal. The rhinoceros was well represented by front limb and pelvic bones, which were endowed with muscle mass. However, there was the prevalence of other anatomic parts such as cranial and mandibular fragments along with tarsals, carpals and phalanges. The remains of this species were characterized by a high degree of fragmentation, hence reducing the possibility of documenting intentional fractures of anthropic origin. The elephant was represented mostly by pelvic fragments, long bone diaphyses and incomplete vertebrae while cranial fragments were scarce. The abundance of cephalic components of bear revealed a particular mode of exploitation of this species. The hippopotamus was represented by dental remains. Deer, especially giant deer, were represented by teeth and antler remains.

The imbalance in the representation of body parts reflects the difference in the frequency of the anatomical elements, which does not depend on the differential conservation of the bones, but on the fruit of an obvious selection of the portions of carcasses transported on the site by the prehistoric occupants (Anconetani, 1999; 1996a). The marginally scarce presence of faunal remains that could belong to young individuals excludes the possibility of their selective hunting. Some young individuals of elephant are present in the assemblage and even fewer numbers for some other species. Advanced mature adults of rhinoceros are present. Naturally, shed whole antlers of cervids and giant deer contributed to the assemblage. Some prominent examples of anthropic marks on faunal remains included a radius diaphysis fragment which on its posterior face exhibited a long cut mark. Similarly, cut-marks were also found on the acetabulum of the pelvis, a thoracic vertebra and a second phalanx (Thun Hohenstein et al., 2004; Malerba et al., 2000; Diez Lomana et al., 1997). Intentional fractures were recorded on 64 remains such as radius (6), mandible (14), humerus (14), tibia (8), metacarpal (8), diaphysis (2), femur (1), ulna (1). The state of preservation of remains from this archaeosurface was fairly good. The remains near the faults, a place with greater disturbance, exhibited disarticulations.

Archaeosurface 3S10 **(**Di Nucci and Thun Hohenstein, 2006a; Thun Hohenstein et al., 2002)

The provenance of faunal remains from this layer is an area of around 20 m^2 explored in a stratigraphical excavation in 1992 and 2001 (Minelli and Peretto, 2003; Anconetani et al., 1992). The remains from this layer came from a sedimentary context mainly sandy in nature, accumulated in the N-E area of the excavation floor. Totally, 514 faunal remains were recovered from the archaeosurface 3S10 excavated between the years 1979-93 and 2000-2005. Anatomically, they were composed chiefly of fragments of the diaphysis of long bones, ribs, crania, teeth and vertebrae. They were in many instances not determinable at the genus or species level. Of the 514 remains, 38.4% were determined taxonomically. The rate of determination, when both NRDa and NISp are taken into consideration, gave a rate of 57.2%. When remains determined only taxonomically are considered, the calculation amounts to 21.9%. The remains were found to be highly fragmented having small dimensions with a state of conservation both fresh and rounded.

The species with higher representation were bison (23.9%), elephant (22.1%), rhinoceros (10.6%) and bear (8%). With lesser representation were, giant deer (2.7%), and roe deer (1.8%). Some elements lacked diagnostic morphological features and/or were highly fragmented for specific identification, hence they were placed under umbrella categories such as cervids (3.5%) and ungulates (27.4%). The minimum number of individuals for these species amounted to two for bear, one each for elephant, rhinoceros, giant deer, roe deer and three for bison. Among the remains identified, teeth were the most represented. A total of 44 teeth were present in which 15 were identified at the species level. A molar and two canines of bear, four molars and two premolars of rhinoceros, a canine of a hippopotamus, a molar of fallow deer, a molar, two premolars and an incisor of bison were present. Trampling marks observed on the remains were characterised by a chaotic state, often superficial and with the quadrangular background. The faunal material from this layer was heavily modified by post-depositional alterations such as erosion, exfoliation and fractures. They made the analyses of anthropic marks on bones difficult. However, on two fragments of the humerus, one of radius-ulna and one of the tibia, fracture borders attributable to anthropic breakage of fresh bone was apparent (Anconetani, 1996a). The remains demonstrated the rare occurrence of rounding of fracture edges, a phenomenon well documented in archaeosurfaces 3c and 3a.

Layer 3s1-5 (Di Nucci and Thun Hohenstein., 2007; Thun Hohenstein et al., 2005; Di Nucci, 2003) A total of 1024 remains were recovered from this layer of which 45.4% were unidentified remains and 54.6% were identified remains. Among the identified remains, 36.5% of the remains were identified at an anatomic level but were fragmented enough with no distinguishing morphological features to classify them into genus and species. The remaining 18.2% were determined anatomically and taxonomically. On the basis of the number of determined remains, the faunal composition was majorly represented by bison (34%), followed by rhinoceros (19%), bear (18%) and elephant (11%). With numbers much lesser were other species such as fallow deer (2.7%), giant deer (1.1%), red deer (0.5%) and hyaena (0.5%). The minimum number of individuals calculation showed that there were at least three bison, two bears and two rhinoceros, and one of hyaena and elephant each.

Regarding the state of conservation of faunal remains from 3s1-5, there is the definite presence of various phenomena which caused alterations in the remains. For instance, the presence of erosion, exfoliation and weathering at different degrees of intensity and diffusion were noted. These alterations contributed to the difficulty in identification of cut-marks associated with the use of lithic tools and distinguishing these anthropic marks from those generated by abrasion or trampling. Totally, 61.4% of the 1024 remains exhibited well-preserved surfaces and facilitated deeper study of cut-marks. A total of six cut-marks were recognised on the following bones: an indeterminate fragment, the proximal radius of rhinoceros, a mandibular fragment of bison, a metatarsal, a metapodium and a phalanx of the bear. These marks are insufficient in number to provide a complete picture for the reconstruction of stages of carcass exploitation, however, they do indicate some action. The numerous cut-marks on right mandible fragment of bison, especially near areas of muscular attachments could be correlated with the action of skinning/disarticulation. The cut-marks on rhinoceros' proximal radio fragment depicted deep repeated actions similar to detachment of muscle mass. On the metatarsal and metapodium of bear, butchering marks have been found imputable to skinning action, which in the case of the metapodial, appear as scrapings that run along the longitudinal axis of the diaphysis (Thun Hohenstein et al., 2005, p. 27); striations imputable to a disarticulation action were, instead, found on a phalanx. Evidence of slaughter found on anatomic segments of bear is particularly relevant. These traces, in scarce numbers, register one of the initial stages of slaughter and could still be indicative of the occasional character of this activity towards the bear and confirm primary access to some carcasses (Thun Hohenstein et al,. 2005). A study of fracture planes led to the identification of a good number of intentionally fractured remains which at times also bore characteristic percussion notches and/or detachments in the cortical or medullary faces of bones. They were documented on 333 remains, out of which 32 were identifiable taxonomically as well. Most of such evidence was found on bison remains (14), followed by rhinoceros (5), bear (4), ungulates (4), cervids (2), elephant (1) and fallow deer (1).

Anatomically, they were mainly found in long bones, crania and mandibles (Di Nucci and Thun Hohenstein., 2007).

The faunal remains recovered from layer 3s1-5 come from a matrix consisting mainly of yellowish sands interspersed with coarser sands of fluvial origin. On the floor of the excavation, they do not have preferential distribution axes but are distributed randomly. The distribution map of the studied area shows a homogeneous distribution, with the exception of some areas where there is a lower concentration of finds. This phenomenon can also be observed in the underlying layers until archeosurface 3S10 is arrived at in correspondence with the holes, circular sinking of clays due to the settling of the underlying travertine, where osteological remains and artefacts in flint have been found.

2.1.7 Palaeoclimate and palaeoenvironment

An inter-disciplinary approach combining sedimentological (Coltorti and Pieruccini, 2014), palynological (Peretto, 2013; 2010; Lebreton 2001), malacofaunal (Esu, 1983) and palaeontological (Breda et al., 2015; Peretto, 2013; 2010; 1996; Thun Hohenstein et al., 2009; Sala, 2006; 1996; 1990; 1983; Alhaique et al., 2004; Abbazzi and Masini, 1996; Fortelius et al., 1993; Sala and Fortelius, 1993;) researches conducted so far at Isernia has provided abundant data to comment on and reconstruct the palaeoenvironment of the locality. The following paragraphs briefly summarize the results and their interpretations procured from various studies carried out at Isernia.

Palaeoclimate through stable isotope analysis

Zanazzi et al. (2015) analyzed the enamel of 17 rhinoceros teeth sampled from four different stratigraphic layers (from lowermost to uppermost: 3 coll, 3S10, 3s6-9, and 3s1-5) of Isernia. The the carbon and oxygen stable isotope composition of the carbonate component of enamel was investigated to see the proportion of C3 vs C4 plants in the palaeoenvironment which in turn can be used as a proxy for mean annual precipitation, vegetation structure, composition of meteoric precipitation and temperature. Carbon isotope values did not differ much for layers 3 coll and 3s1-5. On the contrary, archaeosurface 3S10 and layer 3s6-9 values of carbon isotope suggested higher mean annual precipitation during the deposition of these layers. Similar results were obtained for oxygen isotopes. Layers 3 coll and 3s1-5 values were close whereas the values for 3S10 and 3s6-9 suggested slightly warmer conditions during their deposition. The mean annual temperature was calculated to be lower than the present day. The authors suggest that an overall temperate and seasonally equable climate was a crucial deciding factor for the human occupation of this part of Europe during the Middle Pleistocene.

Palaeobotanical analysis

Studies on macro and micro floral remains were carried out by Lebreton (2001) and Accorsi et al. (1996) (Fig 2.2A and B). A complete sampling of the series was made on the section of Isernia - Fiume Cavaliere (IFC), about 5 km west of the archaeological site and included three layers related to the anthropic horizons. Approximately, 6000 pollen were collected and the survey was conducted on 5000 pollens and spores at the same time as sedimentary deposits at various levels. Nearly 120 taxa have been identified. Both pollen analyzes delineated a two-phase alternation.

Prior to human occupation of the locality, in the oldest phase (pollen area IFC1, the transient floral landscape passed from that of a dense forest with dominance of conifers and especially pines to an open landscape characterized by more or less steppe grasslands, sometimes arboreous. However, the ecological conditions were conducive enough for the survival of not only certain mesophilous broad-leaved trees (hornbeam, oak, ash, birches, chestnuts and beech) in a sparse forest but also for the maintenance of wet/humid environments around the locality, as can be confirmed from the presence of pollens of botanicals species such as *Alnus*, *Salix* and aquatic plants (floating grasses) such as *Potamogeton*, *Sparganium, Alisma* and *Cyperaceae*. The broad-leaved trees thrived on the conditions guaranteed by a seasonal rainfall and presence of lacustral and marshy areas. Evergreen trees were few. Certain pollens of different species, such as *Poaceae*, *Cichorideae*, *Helianthenum*, *Leguminoseae*, attested to the existence of a prairie. The entire first phase seems to be distinguished by cold temperate climatic conditions with increasing aridity and decreasing temperature.

The second phase (IFC2 pollen zone), was marked by the widespread occurrence of broad-leaved trees. This indicated a resurgence of forested areas, to which the archaeological levels can be associated, followed by a steppe period. A deciduous forest was established in the proximity in concomitance with a warmer climatic phase when compared to the previous one as there was now availability of water. A forest made of wide range of species, though not very dense, came into existence. The various trees, shrubs and lianas (*Carpinus betulus*, *Pterocarya*, *Tilia*, *Castanea*, *Hedera*, *Vitis*, *Humulus*). Also frequent in this landscape were sclerophyllous evergreens such as *Quercus ilex* type, *Olea*, *Myrtus*, *Pistacia*) have a certain frequency. A succession of vegetational bands at increasing altitudes can be reconstructed. For instance, there was a band with evergreen sclerophylls, a deciduous hill and higher altitudes with different formations (*Fagus*, *Abies*, *Cedrus*). In this phase the pollen diagram also reveals the highest frequencies of humid environment plants (*Alnus*, *Salix*, *Populus, Platanus*) and it is connected to the archaeological horizons. At this moment there follows a period that appears markedly arid, with the extreme rarefaction of the forest cover and the spread of steppe formations (Accorsi et al., 1996) (Fig 2.2A).

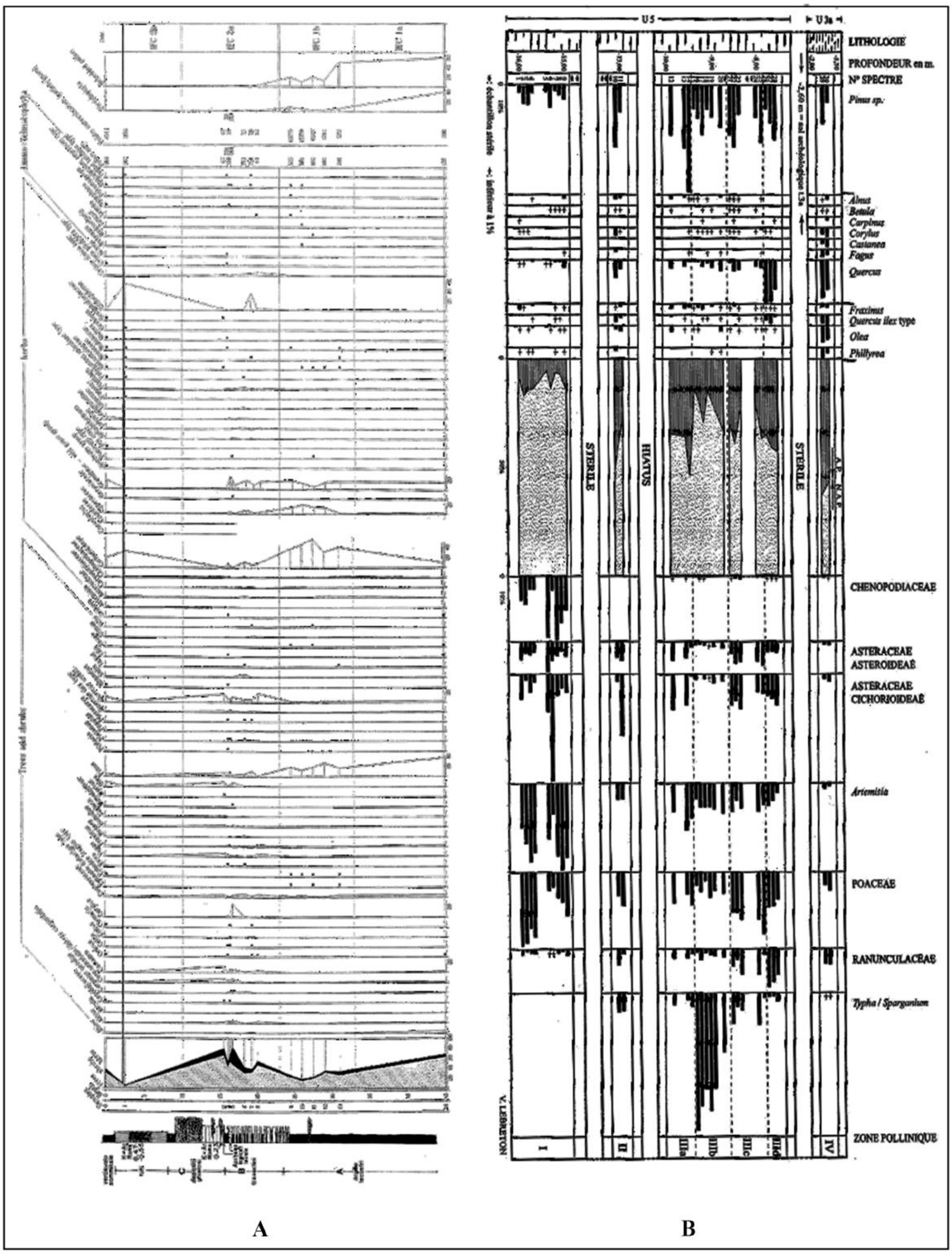


Fig 2.2: Isernia La Pineta. A: Pollen diagram (Accorsi, 1985); B: Pollen diagram of the most important taxa from the survey at the site (Lebreton, 2001).

Lebreton (2001) in his recent analysis took into consideration two distinct deposits, lake clays of Unit 5 which precedes the site's occupation as well as the fluvial clays after the archaeological levels of the lakes for documenting the contemporary paleoenvironmental and paleoclimatic settings. Four pollen zones were demarcated. In the first pollen zone, which is located at the base of the sequence, the presence of a steppe landscape rich in xerophilous and heliophilous taxa is attested to. It was formed in a period with a rather arid climate with low temperatures. The extension of the lake relative to the basin of the high Volturno was minimal in the sequence examined. The rare tree taxa characterized the wetlands located on the banks. A deciduous mesophilous forest covered the hills surrounding the lake basin. This episode corresponds to the most rigorous climatic conditions recorded in the sequence and is attributable both to intestadial episodes and to interglacial periods of the Bavelian "complex" or to the beginning of the Cromerian "complex". The second and third pollen zones, subsequent to the first one bear witness to the progressive filling of a lake as shown by the presence of aquatic flora. Consequently, a semi-open vegetation was installed and developed according to an altitude gradient in cool and temperate climatic conditions, less arid than the previous ones. Humidity returned only at the top of the sequence, the fourth pollen zone, which was associated with the Middle Pleistocene. It provided evidence of the presence of *Fagus* which translates to the passage of the landscape from a lacustrine sedimentation to a river (Fig 2.2B).

Palaeontological analysis

The faunal association of Isernia is considered a reliable chronological indicator to calibrate other archaeological or palaeontological sites in Italy (Gliozzi et al., 1999; Sala, 1996; 1983). In the Italian biochronological scale, it is termed as the Isernia Faunal Unit (Gliozzi et al.,1997) (Table 2.1). The assemblage is dominated by remains of large herbivores, which suggests a woodland environment with open areas/steppe grasslands (Peretto, 2013; 2010; Coltorti et al., 2005).

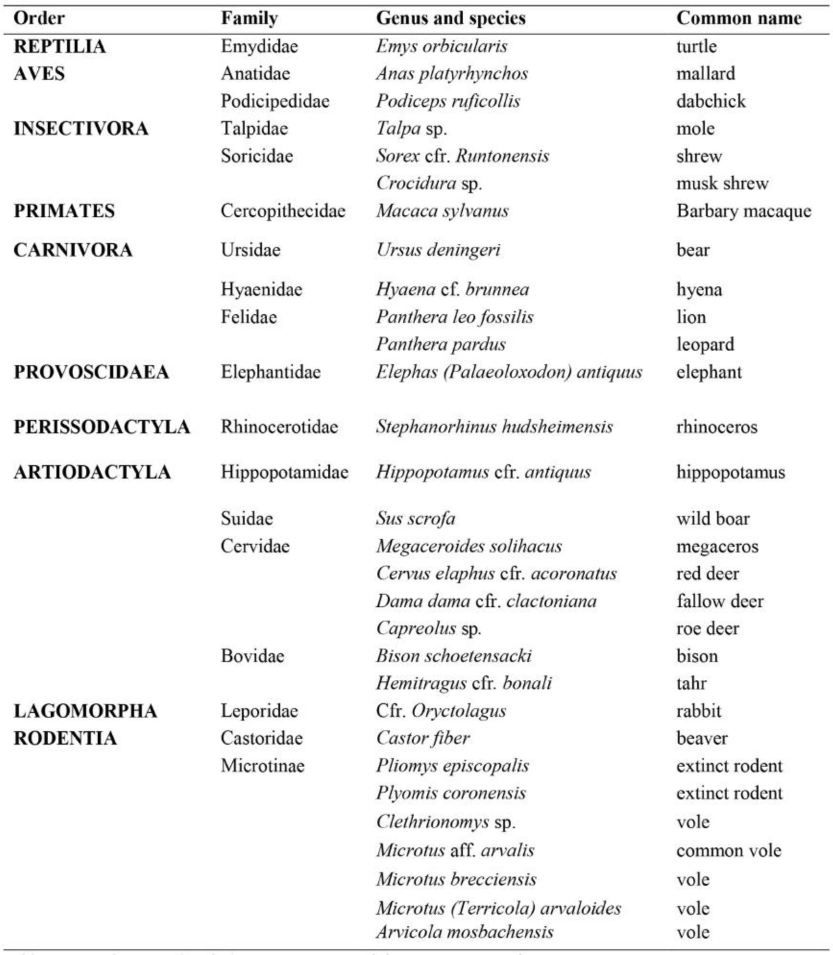
The presence of turtles and aquatic birds, the malacofaunal remains, and the palynological evidences of *Typha*, *Artemisia* and *Plantago*, indicate a marshland environment in the immediate vicinity of the site. While the macro fauna is associated with the Middle Galerian, the microfauna is associated with Lower Toringian. Together, they point to an environmental setting, more arid than the present, yet cooler (Peretto, 2013, p. 43). The faunal record is well-supported by the palynological record. There were were two distinct seasons. The first was a long and dry one while the other was a short and humid one with precipitation. From the information on flora described in previosu sub-section, it is clear that the surrounding flora provided habitats to a rich wildlife spectrum. The flora and fauna, in conjunction, provided favourable conditions at the disposal of prehistoric occupants for their exploitation and survival. The large and open spaces of steppe or grassland vegetation helped herbaceous plants to thrive and dominate whereas sporadic broad-leaved woodlands were found at the valley floor, along the water courses. Herds of bison and elephants were conspicuous in this rich landscape of pastures. In the more restricted and protected areas, characterized by a more developed arboreal vegetation, wild boar and cervids survived (Sala, 1996). Hippopotamus could survive well in this environment as during the day it rested in the water or sheltered areas and grazed pastures in the open environments at night. The thar inhabited the browsing zones characterised by discontinuous herbaceous vegetation on mountains in the vicinity.

The assemblage is represented by *Bison schoetensacki* Freudenberg 1910, *Stephanorhinus hundsheimensis* (Toula 1902), *Palaeoloxodon antiquus* Falconer and Cautley 1847, *Ursus deningeri* von Reichenau 1906, *Hippopotamus* cf. *antiquus* Desmarest 1822, *Sus scrofa* L. 1758, *Hemitragus* cf. *bonali* Harle and Stehlin 1913, *Praemegaceroides solilhacus* Robert 1829, *Cervus elaphus* cf. *acoronatus* Beninde 1937, *Dama* cf. *D. roberti* Breda and Lister 2013, *Capreolus* sp., *Panthera pardus* Linnaeus, *Panthera leo fossilis* von Reichenau 1906, and cf. *Hyaena* sp. Some remains were attributable to the mallard (*Anas platyrhynchos*), plum (*Tachybaptus ruficollis*) and a passeriform (Tonon, 1989). In particular, some animal species provide more precise information about the chronology and palaeoenvironment. For instance the *Bison schoetensacki* species had spread in the Lower and Middle Galerian in the Middle Pleistocene (Gliozzi et al., 1997; Sala et al., 1992). In the first part of the Middle Pleistocene this species was found widespread throughout Western Europe to disappear later. *Ursus deningeri* followed the same evolutionary process as that of bison, thus restricting the age of the Isernia deposit to the first part of the Middle Pleistocene. *Praemegaceros solilhacus* is also chronologically indicative because it was widespread throughout the Middle Pleistocene (Abbazzi and Masini, 1997). The Middle Galerian faunas not so frequently found and and hence in this scenario, Isernia serves as a reference site, with the earliest evidence of the dispersal of the lion as well as *Ursus deningeri* in Italy. The discovery of the primate *Macaca sylvanus* and *Castor fiber* in the layers of 3s1-9 is noted, implying a climate tending towards warmer and more interglacial conditions (Sala, 2006). This hypothesis is also confirmed by the presence of the beaver that is linked to more forested sheltered areas. It is therefore a little dry and cold environment (Sala, 2006).

Small mammals

Sediments recovered during the excavation process were screened thus allowing the collection of a number of small insectivorous and rodent mammals, also useful for palaeoenvironmental reconstruction. Animals of small size such as vertebrae of fish, bones of amphibians, fragments of marsh turtle carapace, waterfowl, such as the grebe and the mallard. The rodent faunal assemblage is composed of Clethrionomys sp., *Pliomys episcopalis* Mehely 1914, *Pliomys lenki* Heller 1930, *Microtus* aff. *arvalis* Pallas 1778, *Microtus brecciensis* Gieber 1847, and *Microtus* (*Terricola*) gr. *multiplex-subterraneus*, *Arvicola cantiana* Hinton 1926. The geological epochs and their respective deposits can be strongly associated with presence and absence of certain micro-mammals. For example, at Isernia, the *Arvicola cantiana* Hinton is indicative of the attribution of the deposit to the first part of the Middle Pleistocene, as it represents a very primitive population with characters of transition between *Mimomys* and *Arvicola*, associated with reason to *Pliomys episcopalis* and the rare *Pliomys lenki*, to primitive forms of the genus *Microtus* (Sala, 1996). The insectivores are *Talpa* sp., *Sorex* cf. *runtonensis* Hinton and *Crocidura* sp. The microfaunal assemblage represents a wooded environment at least on the valley floor encircled by relatively more open areas. They also point to a less temperate climate than the present.

Table 2.1: Isernia La Pineta: List of faunal taxa identified (Peretto, 2013, p. 46; Alhaique et al., 2004).



Order	Family	Genus and species	Common name
REPTILIA	Emydidae	*Emys orbicularis*	turtle
AVES	Anatidae	*Anas platyrhynchos*	mallard
	Podicipedidae	*Podiceps ruficollis*	dabchick
INSECTIVORA	Talpidae	*Talpa* sp.	mole
	Soricidae	*Sorex* cfr. *Runtonensis*	shrew
		Crocidura sp.	musk shrew
PRIMATES	Cercopithecidae	*Macaca sylvanus*	Barbary macaque
CARNIVORA	Ursidae	*Ursus deningeri*	bear
	Hyaenidae	*Hyaena* cf. *brunnea*	hyena
	Felidae	*Panthera leo fossilis*	lion
		Panthera pardus	leopard
PROVOSCIDAEA	Elephantidae	*Elephas (Palaeoloxodon) antiquus*	elephant
PERISSODACTYLA	Rhinocerotidae	*Stephanorhinus hudsheimensis*	rhinoceros
ARTIODACTYLA	Hippopotamidae	*Hippopotamus* cfr. *antiquus*	hippopotamus
	Suidae	*Sus scrofa*	wild boar
	Cervidae	*Megaceroides solihacus*	megaceros
		Cervus elaphus cfr. *acoronatus*	red deer
		Dama dama cfr. *clactoniana*	fallow deer
		Capreolus sp.	roe deer
	Bovidae	*Bison schoetensacki*	bison
		Hemitragus cfr. *bonali*	tahr
LAGOMORPHA	Leporidae	Cfr. *Oryctolagus*	rabbit
RODENTIA	Castoridae	*Castor fiber*	beaver
	Microtinae	*Pliomys episcopalis*	extinct rodent
		Plyomis coronensis	extinct rodent
		Clethrionomys sp.	vole
		Microtus aff. *arvalis*	common vole
		Microtus brecciensis	vole
		Microtus (Terricola) arvaloides	vole
		Arvicola mosbachensis	vole

Malacofaunal analysis

Remains of polmonate snails (continental malacofauna) were discovered within the silty and clayey matrices below the travertine of Unit 5 (Esu, 1983). They are represented by *Lymnaea truncatula* (Muller), *Vertigo pygmaea* (Draparnaud), *Vertigo moulinsiana* (Dupuy), *Pupilla muscorum* (Linnaeus), *Vallonia pulchella* (Muller) and *Succinea oblonga* (Drapanaud). These species are not extinct and are commonly associated with the cold phases of the Lower and Middle Pleistocene deposits of Europe (Coltorti et al., 2005, p. 13). The species mentioned above are equally representative of an open environment devoid of trees, in the vicinity of a marshy area that proved conducive for the establishment of a fresh and humid climate. The malacological association is referred to the Lower Pleistocene-Middle pleistocene boundary. The travertine base has also yielded the *Bytinia leachi operculum* and the imprints of small gastropods of the genus *Bitynia* and *Planorbis*, as well as freshwater ostracods. These changes in the composition of the malacofauna, between clays and travertines, show the establishment of typically lacustrine conditions.

Thus, taking into consideration the available evidences from studies above, the reconstruction of the immediate palaeoenvironment around Isernia La Pineta can be attempted. It helps to establish the context within which hominin action took place, more so in the background of a dynamic

Quaternary environment characterised by its climatic instability and alternating warm and cold periods (Peretto, 2013). It is postulated that in the times preceding hominin occupation, there existed a relatively large lake in the Isernia plain as evidenced by the lacustrine levels underlying the anthropic deposit, which preserved terrestrial, hygrophilous, marsh and lake remains of cold climates (Esu, 1983). Subsequently, the lake gradually filled up. During temperate times, travertinous areas formed on its surface. The Paleolithic site of Isernia arose on these travertines (Peretto, 1996; Cremaschi, 1983). The Isernia travertines are not associated with hot water springs and indicate that the area was frequented at the end of an Interglacial period. This event was succeeded by progressive drying up of the ancient lake's plain, as a result of which the expanse of the plain increased traversed by a meandering river. This river flooded periodically.

The two archaeological horizons of Sector I are correlated with a major change in the environmental settings. During an interglacial period, when the surrounding slopes were vegetated by thick woods, along the banks of the river, last phases of travertine deposition occurred and this is the same period which coincides with human occupation. Travertine floors were exposed in certain spots where hominins frequently and repeatedly found a resting place. Both lacustrine clays and phytohermal travertine have yielded flint tools. The richest archaeosurface 3a was deposited over the travertine layers. This archaeosurface was covered by alluvial sediments in a cold and arid environment. The alluvial sediments are associated with a high surcharge of solid load in the riverbed. The fluvial facies is also correlated with a high seasonality of precipitation. Hence, human occupation probably occurred at the beginning of a Glacial stage (Sala, 1996). One point of view regarding the temporal context of these archaeosurfaces puts forth the hypothesis that they are different facies of a single settlement phase, which the sequence of events surrounding their burial lead to be erroneously attributed to separate archaeological layers, from a chronological point of view. A humid environment in the locality, as can be conjured from the partly emerged travertine formations was a common feature between the three archaeosurfaces. The gradual extension of these formations, horizontally and vertically, brought about by flowing water is evidenced in the exposed sections and excavation reliefs testifying typical structures linked to this phenomenon. The travertine deposits sometimes carved out inter-connecting pools and ponds.

Here, the hominins were protected by the bends of the meander so they continued to occupy it for continuous periods of time despite the seasonal overflowing of the river that covered the muddy silt travertine. The evidence for prolonged occupation of these long and narrow outcropping surfaces for a certain period of time is evidenced by a variety of lithic artefacts is demonstrated by some refittings. Faunal remains, on the other hand, are fewer on the travertinous ground and more on the shores of these ancient acqueous bodies. This open environment was advantageous for hominins, as it provided them necessary protection against danger. The Palaeolithic occupants during their cyclical wanderings in search of food, explored this area and came across highly visibile and accessible herds of large ungulates, followed them to capture them or retrieve their carcasses which they translocated to the outcropped areas. This was done because the travertinous small islands provided more safety than open prairie zones (Peretto et al., 2004; Sala, 1996). The animal carcasses were further processed, to strip the bones off their meat, muscle before getting intentionally fractured, so as to obtain the extremely nutritious marrow. It is hypothesized from the distribution of faunal remains in a spatial context that at the end of that process, the bones were discarded in water, either to hide them from the attention of carnivores and other scavengers nearby who could get attracted to these carcasses and revisit the site or in order to overcome the problem of an overflowing river, the occupants probably consolidated the travertinous resting places with refuse of bone fragments of animals that they consumed (Sala, 1996). In these areas, flint artefacts are scarce with the ones present having transcluscent surfaces to indicate their submersion in water. The bone/flint ratio thus changes in relation to the area, i.e. reliefs or the lower humid zones. After vacating the locality, the encampments underwent quick covering by blankets of alluvial sediments, originating from a rapid erosion of the surrounding reliefs. The site was moreover impacted by the Quaternary tectonic events which on the one hand led to the rise of the heights or rejuvenation of the slopes in the proximity of the human settlements, sweeping them up in a more rapid way, and on the other provoked volcanic eruptions with the subsequent deposition of volcanic sediments. Volcanic deposits (cinerites) filled in the sunken areas, separating the archaeosurfaces and tended to level out the whole area, and rise up – like the living floors themselves – along the sloping edge of the travertine bar towards the lake area. Cumulatively, all these brought about a rapid burial of the vestiges left by Palaeolithic occupants of Isernia.

To sum up, the Isernia basin and locality was chiefly a spring/marshland or a small lake basin (wetland environment), characterised by a small river which flooded the surrounding areas during more or less intense seasonal rainfall, encompassed by an open woodland – steppe vegetation of conifers and deciduous tree cover. The seasonal nature of the climate must have ensured the frequent visits of the animals to the available spring waters at the locality, creating a natural food store for carnivores and hominins (even though no actual evidence of hunting are identified, cut-marks, butchery marks and percussion flakes imply that hominins exploited the faunal resource present at the site) (Srinivas, 2016).

2.2 Introduction to Caune de l'Arago

The Caune de l'Arago (Pyrénées-Orientales, southern France), first discovered in 1829, is one of the most important European sites with a rich archaeological record (faunal and human remains and lithic industry) enabling the reconstruction of past human behaviour, faunal renewals, habitats and climate dynamics and their inter-relationships. It is a Middle Pleistocene prehistoric site located around 20 km from the city of Perpignan in the valley of Tautavel (Fig 2.3A). Located close to the mouth of the Gouleyrous gorge, it is carved into the Urgo-Aptian limestone formation inside the Corbières Massif occupied by the Verdouble River, at a height of 88 m from the river, the karstic gallery is 35 m long and 7–10 m wide (Falguères et al., 2015; 2004; Rivals et al., 2006; de Lumley et al., 1984; Yokoyama and Nguyen, 1981).

2.2.1 Stratigraphy

A series of eight cores were drilled through the entire cave-filling in order to determine the thickness and sequence of the Quaternary deposits in the 1980's (Barsky, 2013; Falguères et al., 2004; de Lumley et al., 1984). Excavations in the cave began in 1964 and continue till today to unearth fossils and stone tools from the Quaternary deposits dated from 690,000 to 90,000 years. On the basis of mammalian faunal associations, the sedimentary deposits were assigned to the Middle Pleistocene which witnessed climatic variations between MIS 14 and MIS 5. Three major sedimentary complexes were compartmentalised and termed 'Lower', 'Middle' and 'Upper' (Falguères et al., 2015; de Lumley et al., 2004 (Fig 2.3 B, C, and D)).

The Lower Stratigraphical Complex is known through the analysis of 5 cores. It is composed of silty sandy clays deposited by dripping water, on top of a stalagmitic floor at the bottom, it becomes more than 7 m thick towards the cave's rear end. The Middle and Upper Stratigraphical Complexes have been further divided into around 17 archaeological levels termed alphabetically from level Q to level A (bottom to top).

A major part of the deposit is attributed to the Middle Stratigraphical Complex (690,000 to 400,000 years ago) with a minimum of fifteen successive and spatially distinct archeostratigraphical units (clay and sand), each correlating to distinct prehistoric occupations. Excavation of the Middle Stratigraphic complex (*Complex Moyen*) individualized three levels termed as-

- Ensemble I (CM1, 570,000-330,000 years ago) at the lower level made of homogeneous stratified sands, correlated with MIS 14 containing levels K, L, M, N, O, P and Q. It underwent deposition during dry and cold conditions.
- Ensemble II (CM2, 530,000-480,000 years ago) in the middle composed of sandy-clayey sediments, correlated to MIS 13 containing levels H, I and J. It underwent deposition during temperate, humid and wet conditions.
- Ensemble III (CM3, 480,000-400,000 years ago) at the top with stratified coarse sands accumulated by wind, attributed to isotopic stage 12 comprising levels D, E, F and G. It was deposited during a dry and cold period These levels are separated from each other by sterile levels. The unit is homogeneous over its entire thickness of up to 4 m in the central part of the cave.

The Upper Stratigraphical Complex begins with Unit IV and constitutes a series of alternating stalagmitic floors and silty-clayey sands. It was formed during the temperate climatic periods of the second half of the Middle Pleistocene, representing climatic variations, and is 1 m thick. The filling then underwent a period of dismantling and clogging of the breccia corresponding to the last sedimentation episode of the cave, the summit complex (de Lumley et al., 2000).

2.2.2 Dating

After considering relative dates through faunal associations, several dating techniques to assign absolute dates to the archaeological levels at Arago have been carried out since 1981 (Table 2.2). The material used for dating were bones, teeth, quartz, calcite and the oft-repeated techniques were ESR and U-series- using alpha and gamma spectrometry. The lower stalagmitic floor lay directly on the Urgonian bedrock. ESR analyses performed on three calcite samples (YC62, 9UL8, YCP17) yielded ages of 630 ± 100 ka, 760 ± 80 ka and 690 ± 70 ka, respectively (Falguères et al., 2015; 2004). The speleothem from the Lower Stratigraphical Complex was dated by ESR method at about 700, 000 years (Falguères et al., 2015; 2004; Yokoyama et al., 1982). Dating of level Q gave a date of 550, 000 years at the base and 400, 000 years for level C at the top (OIS 14 to 10). The stalagmitic floor at the base of Upper Complex was dated by U-series, yielding a minimum age of 350,000 to 400,000 years for the underlying levels containing human remains, corroborating the results of Yokoyama and Nguyen (1981), while the most recent deposits are probably contemporaneous with the MIS 5 (Falguères et al., 2004). Recently, herbivorous teeth were analysed through ESR/U-series models by Falguères et al. (2015) from levels F to P/Q of the Middle Stratigraphical Complex to provide a more structured chronological scheme for the archaeological sequence at Arago. For level G, 438 ± 31 ka and for level F, 392 ± 43 ka was calculated, corresponding to MIS 12 (424-478 ka). Level P yielded an age range of 300 – 530 ka.

2.2.3 Human remains

Humans repeatedly occupied the Arago cave over thousands of years. They were the primary agent of accumulation of the lithic industry and faunal remains. Their occupation of the cave and exploitation of their natural surroundings is in one way evidenced by their own skeletal remains at the site. Classified as *Homo erectus tautavelensis* (de Lumley, 2015), from 1964 to 2014, 148 of their remains have been discovered in excavations. During the history of the cave's occupation, humans experienced two cold and dry periods of climatic fluctuations (Stratigraphic Complexes I and III). They also survived through a humid-temperate period (Stratigraphic Complex II). Levels F and G (Stratigraphic Complex III) corresponding to a cold and windy steppe environment have yielded most of the human remains. Along with human remains, stone tools and faunal remains have also been recovered from these levels. The population structure as represented by the 148 remains was composed of 30 individuals, of which 18 were adults and 12 children. Anatomically, the assemblage consists of five mandibles, 123 teeth (isolated or still on the alveolar arch), nine upper limb elements and 19 lower limb elements. De Lumley (2015, p. 303) observes that the inventory mainly comprises cranial elements, the most important of which is the anterior portion of a skull, Arago XXI, discovered on 22 July 1971, which revealed the physical aspect of the first Europeans for the first time. In terms of common characteristics, they come close to Asian and African forms of *Homo erectus* but are distinct from the *Homo heidelbergensis* of Mauer. From 0.55 Ma, the set of 148 human remains, and in particular, the skull Arago XXI (Table 2.2), point to the presence of a new, well-documented form. The morphofunctional and cultural characteristics of Homo erectus tautavelensis represent the stock of a long European lineage, leading to the emergence of Neanderthals.

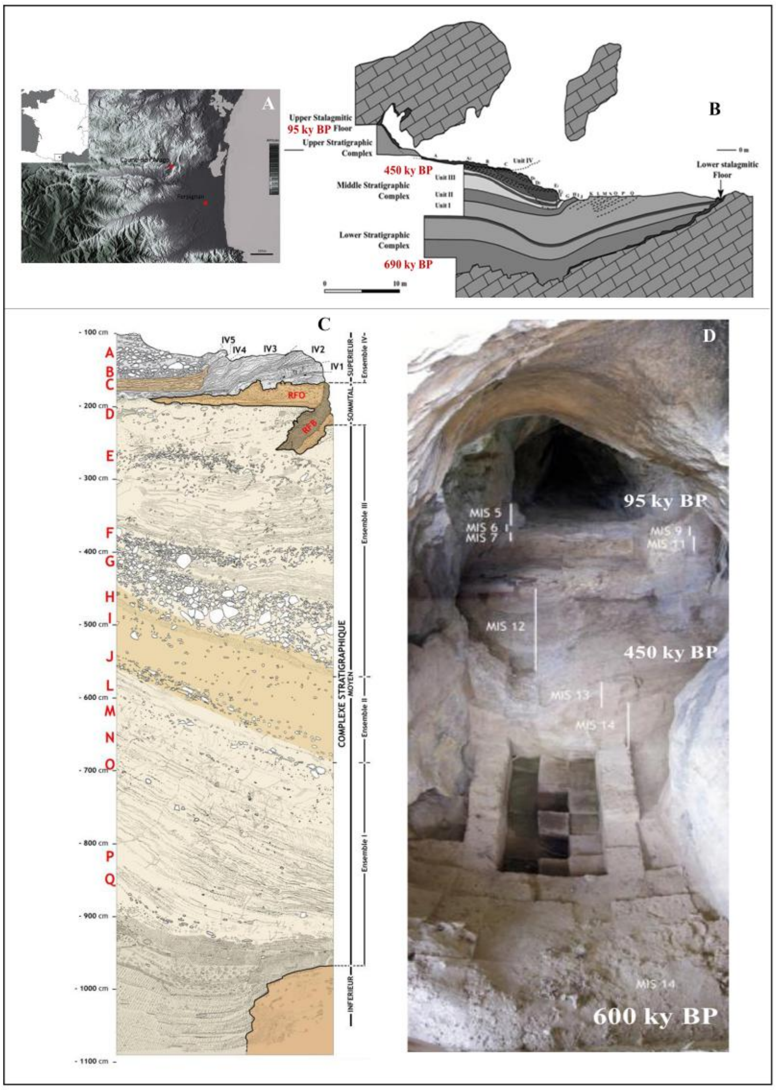


Fig 2.3: Caune de l'Arago. A: Location of the site in France (Lebreton, 2015, p. 2); B, C and D: Synthetic stratigraphic section of the site with corresponding MIS and dates (B: after de Lumley et al., 1984, cited in Falguères et al., 2004, p. 942; B: Perrenoud, 2016; C: personal communication Anne Marie Moigne).

Table 2.2: Summary of radiometric dates, stratigraphic units, sedimentology, climate, dominant species and habitat type (Barsky and de Lumley, 2010, p. 72).

Radiometric dating	Units	Levels	Sedimentology	Climate	Dominant species	Habitat type
OSI 5	Stratigraphic Unit V	A and	Stalagmitic floors between archeological levels	Alternate temperate humid and cool phases	Horse, red deer, argali	Shorts stays, bivouacs
104–151 Ka 215–229 Ka 273–>350 Ka Stalagmitique floor by ESR, U/Th >350 Ka	Stratigraphic Unit IV	C	Stalagmitic floors between archeological levels	Alternate temperate, humid with cool, dry phases	Horse, red deer, argali	Shorts stays, bivouacs
Quartz dated by ESR 430 ± 85 Ka	Stratigraphic Unit III	D	Coarse, layered sands	Cold and dry	Cervids dominant, argali, horse, fallow deer	Seasonal habitat with species-specific hunting
		E	Coarse, layered sands	Cold and dry	Argali dominant, horse, red deer, thar, bison, musk ox	Seasonal habitat with species-specific hunting
		F	Coarse, layered sands	Very cold and dry with strong winds	Argali dominant, thar, red deer, horse, reindeer, chamois	Seasonal habitat with species-specific hunting
ARAGO XXI Hominid skull directly dated by spectrometry gamma 455+ indet./-210 Ka		FG	Coarse, layered sands	Cold and dry	Musk-ox, argali, horse	Shorts stays, bivouacs with species-specific hunting
		G	Gravel with silty-sand matrix	Fresh to cold and dry	Horse, bison, rhinoceros, reindeer, red deer, argali, thar, musk-ox	Long term stays with non-species-specific hunting
>350 < 690 Ka	Stratigraphic Unit II	H1, 2,3	Clay with silty-sand	Temperate and humid	Red deer, fallow deer	Seasonal habitat
		I1, 2			Fallow deer, red deer	Seasonal habitat
		J			Red deer, fallow deer, argali	Seasonal habitat
	Stratigraphic Unit I	K	Layered sands	Cold and dry with strong winds	Reindeer	Selective hunting halt
		L				Selective hunting halt
		M to O			Horse, reindeer, bison	Shorts stays, bivouacs
		P			Horse, reindeer, bison, argali, bear, panther	Shorts stays, bivouacs
		Lower stratigraphic complex (not yet excavated)				
Stalagmitic floor dated by ESR to 690 Ka			Y			

2.2.4 Lithic remains

The lithic industry, with the presence of handaxes, is considered Acheulean (Barsky and de Lumley, 2010) (Fig 2.4A and B). Some of the human occupations can be attributed to the earliest mode 2 (Barsky, 2013). A specialised study of the variability and provenance of raw material chosen, typology and technology utilised in each stratigraphical unit has aided in understanding their production methods. Similarities, differences and evolving patterns in the lithic assemblage depict adaptation to different uses of the cave in the context of a contrasting palaeoenvironment. The industries from the base of Unit I are amongst the earliest western European handaxe assemblages; the Unit II industries demonstrate that Mode 2 assemblages may not include handaxes and the Unit III assemblages show a regional progression towards a more standardized, Mode 3 type ensemble while conserving remnant Mode 2 features (Barsky, 2013, p. 322).

In Unit 1 (OIS 14), which forms the base of the sequence, lies level P containing the earliest Mode 2 assemblage with well-shaped standardised handaxes, retouched tools (notched tools and points) and a cleaver. However, there is a paucity of limestone-based tools at this level. The local raw material was preferred and shaping was achieved with a soft percussion instrument. The bifacial-discoidal technique was used for the manufacture of handaxes. In levels K and L, side scrapers dominated the industry with fewer retouched tools. The Unit lying above this ensemble, Unit II (OIS 13) is characterised by the absence of handaxes and cleavers, more retouched tools with diversification, selective use of quality raw material, few cores, centripetal flaking methods for knapping and use of quartz, vein quartz and sandstone. In level H, initial stages of reduction were not carried out in the cave as cortical flakes are few. However, pebble tools were shaped inside the cave (Barsky, 2013, p. 318). The Unit III, situated above Unit II, has yielded a rich assemblage of lithic industry and faunal remains in association with human remains. Unit II archaeological levels (H, I and J) are rich in stone industries knapped principally from poor quality vein quartz whereas a small proportion of the lithics were knapped from better quality materials collected from 15-30 km away (Barsky, 2013, p. 308). Usage of flint increased and quartz is found in abundance. Bipolar flaking and direct hammer technique were the main production methods. From the bottom to the top of the Unit, size of flakes, the frequency of whole and broken pebbles, hammerstones and pebble-tools reduced, cleavers were fewer and handaxes were irregular, partial and asymmetrical and the flake-core index was low. Characteristics denoting technologies used throughout the Unit find an exception in level D because of the reduction in the size of the industries.

Fig 2.4: Caune de l'Arago. A: Level G handaxes made on sandstone-quartzite at the top and level P handaxes made on quartzite (Barsky, 2013, p. 310); B: Level P handaxes made on quartzite (Barsky, 2013, p. 311); C: Excavation floor with exposed faunal remains and lithic industry (personal communication Anne Marie Moigne).

2.2.5 Faunal remains

The cave floor, similar to Isernia is rich in faunal remains (Fig 2.4C). Arago faunal assemblage at different levels translates to variations in palaeoenvironmental conditions, from harsh steppe-like to temperate forested. For instance, the former climatic conditions are represented by reindeer, musk ox and arctic fox while the latter is depicted by fallow or red deer. Dry and open environment existed is evidenced by rhinoceros or horse. Human exploitation of large herbivores after bringing them into the cave can be seen in the treatment of their carcasses in the form of cut-marks and intentional fractures. These anthropic modifications on faunal remains reveal the characteristics and evolution of hunting and butchering techniques over time (Barsky and de Lumley, 2010, p. 71).

At the beginning of Middle Pleistocene, glacial and interglacial periodic cycles were more distinct as revealed by faunal renewals. Other animals apart from large mammals from Arago have further contributed to the understanding of palaeoenvironmental dynamics during these faunal renewals. Their association highlights the emergence of small and micro mammal communities from Eastern Europe, Siberia and the mountains of Central Asia (*Ochotona pusilla*, *Citellus* sp. and *Microtus* (*Stenocranius*) *gregalis*) and Northern Europe (*Dicrostonyx torquatus* and *Microtus oeconomus*). The cycles were modulated by a periodicity of 100 Ma and resulted in a recurring dispersion of associations of fauna with hot-humid affinities (interglacial) and cold-dry (glacial) in western Europe. In other parts of Europe, including the west and the Mediterranean zones, a comparison of the appearance of micromammal species with large mammal species allows for attesting that small mammal species sensitively reacted primarily to climate change at the end of the first half of the Middle Pleistocene (MIS 14 to 12). This reaction recorded through faunal renewals is well demonstrated in Arago, mainly because of its location at the eastern end of Pyrenees and proximity to the Mediterranean Sea. Neighbouring regions/countries of Spain and Italy were less impacted by these new species and limited their expansions because of geographical barriers located in these countries such as the Pyrenees and the Apennines respectively, which lessened the influence of the glacial climatic conditions in these southern zones (Hanquet and Desclaux, 2011). The study of Lebreton et al. (2015) focused on both birds and small mammals (Lagomorpha, Erinaceomorpha, Soricomorpha, Rodentia and Chiroptera). They have identified 34 small mammal taxa in P and Q-R levels of Arago. Exclusive to the former level, correlated with a cold environment with steppe trend were 12 taxa namely, *Crocidura* sp., *Marmota marmota*, *Spermophilus* cf. major; *Arvicola* gr. *cantiana-terrestris*, *Chionomys nivalis*, *Microtus oeconomus*, *Microtus* (*Stenocranius*) *gregalis*, *Rhinolophus* gr. *euryale-mehelyi*, *Rhinolophus hipposideros*, *Ochotona pusilla*, *Lagopus* sp., and *Turdus* sp. To the Q-R levels, with a temperate climate and woody trend, eight taxa were assigned namely *Talpa europaea*, *Pliomys episcopalis*, *Myotis* sp., *Pipistrellus* sp., *Anas* sp., *Aquila chrysaetos*, and *Pyrrhocorax graculus*, none of which could be found in cold conditions.

The Ensemble I at the bottom of the Middle Stratigraphic Complex sequence, containing levels K to Q), and having a cold, very dry palaeoclimate, dated at around 550,000 years (de Lumley et al., 2000) is primarily composed of four major canids namely, *C. mosbachensis* (mosbach wolf), *C. priscus* (dhole), *Vulpes vulpes* (fox) and *Vulpes praeglacialis* (fox). The good representation of bear remains (*Ursus deningeri*) is attested to the observation that the Arago cave could have served as a resting den for bears in winter. Another species of bear (*U. arctos*) has also been identified in the assemblage, and its appearance in these levels is it's very first in Western Europe. *Lynx spelaea* (lynx), *Panthera* cf. *pardus* (leopard) and *Panthera leo* (lion) are the representative felids while Hyenidae and Mustelidae are absent in these levels. Three bovids, *Hemitragus bonali* (thar), *Ovis ammon antiqua* (wild sheep) and *Bison schoetensacki* are present. *Rangifer tarandus* (reindeer) at Arago in this ensemble is one of the oldest representatives of Mediterranean Europe. Horse, *Equus ferus mosbachensis*, is of a robust appearance. Rhinoceros (*Stephanorhinus hemitoechus*) population comprises mainly young individuals. Overall, the faunal remains are less fragmented in these levels (Moigne et al., 2006). In case of micromammals, these levels show the predominance of steppe taxa (*Microtus (Stenocranius) gregalis*, *Citellus* sp. and *Allocricetus bursae*) and a cold climate (*Microtus* gr. *oeconomus*), corresponding to the glacial optimum of MIS 14 (Hanquet and Declaux, 2011) (Fig 2.5).

Dated at around 500,000 years (de Lumley et al., 2000), Ensemble II of the Middle Stratigraphic Complex containing levels H, I and J, is associated with fauna marked by the Mediterranean climatic character of temperate and humid conditions. The faunal spectra were characterised greater numbers of rhinoceros (*Stephanorhinus hemitoechus*), a complete skeleton of bear (*Ursus deningeri*), the disappearance of small canids, the appearance of *Felis silvestris*, the presence of the great Pleistocene deer, *Dama clactoniana* associated with the deer, *Cervus elaphus*. Levels J to H, in terms of micromammals, suggest a drastic change in environmental and climatic conditions. Taxa from temperate and closed environments are better represented, to the detriment of steppe species. These levels may be associated with an interglacial period within MIS 13 (Hanquet and Declaux, 2011) (Fig 2.5). The Ensemble III of Middle Stratigraphic Complex containing levels D, E, F and G, dated between 450,000 to 400,000 (de Lumley et al., 2000), has yielded many humans' remains. The faunal assemblage from these levels, marked by their diversity, point to different modes of occupation by humans and carnivores. This is evidenced by the discovery of intact articulated long bone remains of carnivores such as *Canis mosbachensis* and *Cuon priscus* at the top of the archaeological levels. Rare presence marks the remains of *Felis silvestris*, *Lynx spelaea*, *Panthera pardus* and *Panthera leo spelaea*. Bears *U. deningeri* and *U. arctos* are represented by fractured remains. Boreal species are in much larger numbers as seen in the remains of muskox (*Praeovibos priscus*), reindeer (*Rangifer tarandus*) and chamois (*Rupicapra* cf. *pyrenaica*). Steppe bison (*Bison priscus*). the horse (*Equus ferus mosbachensis*), argali sheep (*Ovis ammon antiqua*) and the rhinoceros (*Stephanorhinus hemitoechus*) are abundantly represented. Some skeletal parts of the elephant, species not determined, were also found in these levels (Moigne et al., 2006). Levels G to D demonstrate the return of colder and more arid conditions associated with a more open environment, with the presence of Arctic and Siberian taxa, correlated with MIS 12. Forest and Mediterranean species are still present in the level G. The specific diversity observed in these levels suggests that the recorded cooling, contemporaneous with MIS 12, is less pronounced than at MIS 14, at least in this part of the Mediterranean (Hanquet and Declaux, 2011) (Fig 2.5).The Ensemble IV faunal assemblage can be associated with the temperate periods of early Upper Pleistocene it consists of deer, horse, bison, rhinoceros, thar, Tibetan bear and macaque. Reindeer and argali sheep are noted for their disappearance. The uppermost levels, the summit complex, is characterized by the presence of *Ursus spelaeus*, a hyaena, boar, ibex and thar. The horse continues but is a different species (Moigne et al., 2006).

Age (ka B.P)	MIS	Stratigraphical Unit		Archaeological Level	Fauna	Climate
93 120	5	SUMMIT COMPLEX			*Ursus spelaeus* *Crocuta crocuta* *Panthera pardus* *Sus scrofa* *Cervus elaphus* *Hemitragus cedrensis* *Capra* aff. *caucasica* *Equus* sp.	TEMPERATE HUMID
230	7	UPPER COMPLEX		A	*Macaca sylvanus* *Canis lupus* *Vulpes vulpes* *Ursus arctos* *Lynx spelaea* *Panthera pardus* *Cervus elaphus* *Bison priscus* *Equus ferus mosbachensis* *Stephanorhinus hemitoechus*	TEMPERATE HUMID
340	9			B		
400	11			C		
450	12	MIDDLE COMPLEX	ENSEMBLE III	D E F G	*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* *Ovis ammon antiqua* *Bison priscus* *Equus ferus mosbachensis* *Stephanorhinus hemtoechus* Elephantidae gen. et sp. indet.	COLD DRY
	13		ENSEMBLE III	H I J	*Canis mosbachensis* *Cuon priscus* *Vulpes vulpes* *Felis silvestris* *Lynx spelaea* *Ursus deningeri* *Cervus elaphus* *Dama clactoniana* *Hemitragus bonali* *Bison* sp. *Stephanorhinus hemitoechus*	TEMPERATE HUMID
	14		ENSEMBLE I	K L M N O P Q	*Canis mosbachensis* *Cuon priscus* *Vulpes* cf. *praeglacialis* *Lynx spelaea* *Panthera leo spelaea* *Panthera* cf. *pardus* *Ursus deningeri* *Ursus arctos* *Cervus elaphus* *Rangifer tarandus* *Hemitragus bonali* *Ovis ammon antiqua* *Bison schoetensacki* *Equus ferus mosbachensis* *Stephanorhinus hemitoechus*	COLD VERY DRY
	15	LOWER COMPLEX			Not excavated	TEMPERATE
	16					COLD HUMID
690	17					TEMPERATE

Fig 2.5: Caune de l'Arago: Appearance and disappearance of large mammal fauna in the context of stratigraphy and geochronology of the Middle Pleistocene infilling (Moigne et al., 2006, p. 793).

Converging results obtained from studies of the thickness of archaeological deposits; dating; human remains; faunal assemblages and seasonality; the morpho-techno-typological character of lithic industries, raw materials used, territory exploited and state of conservation of remains of Arago allowed for the identification of four types of habitat. They were defined as the long duration habitat (cave provided a home base); the temporary seasonal habitat (the cave was set up as a secondary campsite); the hunting stopover and the bivouac (cave served as a refuge for short-term stays) (Fig 2.5). The type of habitat and chief activity of hunting had a direct relationship with the behavioural patterns of the ancient inhabitants. The duration of stay in the cave, whether it was prolonged or temporary seasonal occupations, determined the diversity of activities, specialised or reduced, carried out by the inhabitants. Generally, The characteristics studied show that the Caune de l'Arago Cave site had multiple uses over time for Anteneandertalian family groups and hunters who left traces of their activities, allowing us to better understand their lifestyle (de Lumley et al., 2004, p. 159).

2.3 Review of GIS studies in Isernia La Pineta

Lembo (2014, p. 89) reviews the history of establishment and progress of better and faster methods of documentation of data at the site of Isernia. He divides it into three distinct phases: the initial period corresponding to the excavation campaigns between the years 1979 and 1993; the second phase which began in 1999 when a permanent pavilion to cover the excavation was constructed followed by the setting up of a total station for the registration of the coordinates of the archaeological remains and the organization of a computerized workstation directly on the site; the third, from 2012 and still in progress, sees the application of new documentation and archiving procedures.

At Isernia, the first stage in the computerisation and digitalisation of data documentation was aimed primarily at removing the disadvantages of traditional hard copy registration protocols. This was done using two important methods. Firstly, the use of computers for documentation of data consisted of a review of the already-existing database (Peretto et al., 2000), utilising the present systems of RDBMS (Relational Data Base Management System), in this case the Microsoft Office Access (Peretto et al., 2010; Gallotti and Lembo, 2007). The database is composed of the same number of tables as the typologies of forms used for cataloguing the material recovered in the excavation, such as lithic artefacts, faunal remains etc. The advantage of this system lies in the feature that although each table contains specific data, it is inter-connected with the other.

Secondly, an integrated data recording system at the site using free devices and applications available in the electronic and digital market such as smartphones, tablets, etc. was introduced. Such a system was not only based on a modular architecture for recording excavation data but also transferred them to a central archive (Lembo, 2014). The electronic devises contain a free online form (Google Doc application) where basic information such as date of discovery, identification code, preliminary description and size of the finding can be entered. The total station and all mobile devices are connected wirelessly to the server by Bluetooth and Wi-Fi. Additionally, the archive of photographic documentation of the excavation is separately structured and managed in categories according to the subject (excavation, sifting, washing, restoration, etc.). The system used for acquisition of excavation planimetries and digital photos, since 2002, was specially organised to act as a catalyst of various documentation stages. This ensured greater precision in registration of the position of finds despite their high concentration. The support of the total station also favours recording of the planimetric coordinates of the remains. The recording of the orientation and inclination, in degrees, of each find from the excavation stage which comprises the blueprint for its computerised image is performed in AutoCad. Peretto et al. (2010) explain, "*the digital photograph, in fact, which adopts a specially designed software package for restitution (Rollei Metric), is later acquired in AutoCad; the individual finds are redrawn, vectorialised with a layer identified by specific code number, then reproduced in their exact location, just as they were found on the excavation surface. This method has undoubtedly reduced planimetric documentation times, has provided an optimal answer to the management of deposits similarly dense in archaeological material, and has considerably reduced the errors that may occur in manual drawing during excavation, by several different hands*".

It was GIS, and not other cartographic systems, that came to be applied for the site of Isernia as it made possible the association of data of various types: geometrical elements, alphanumeric, images, etc. The primary advantage of GIS is that it not only restitutes cartographic information, but that it can represent themes and query relational databases. GIS serves as an effective interpretative tool since it runs on the basis of functional characteristic attributes which allow to perform most of the statistical and spatial analyses and to devise predictive models. In other words, to produce thematic maps in graphical format, tables can be correlated with different attributes to create new types of information and relationships. Attributes are generally based on relational databases and can be queried using SQL (Structured Query Language) languages. Lembo (2014, p. 45) observes, "*the integration of attributes related to different databases, through relational structures and according to SQL formalisms, allows extremely interesting analyzes to be carried out. The data not included in the attributes, even if displayed separately, cannot be reached through specific queries ("Geographic Information System," 2014). A graphic object and the attributes connected to it must have a unique code in order to be associated* (Lembo and Peretto, 2012; Gallotti, 2004; Forte, 2002; DeMers, 1997)". The following paragraphs summarize the results of GIS application in the archaeological context of Isernia.

Archaeosurface 3c

The series of fractures and tectonic activity that occurred during the deposition of archaeosurface 3c reflected in the spatial trends of the archaeological finds from this level. An in-depth spatial visualization of its finds was restricted by a relatively small part of the archaeological layer having been excavated. Disturbance in spatial trends was particularly visible in the central and eastern part (Lembo, 2014; Peretto, 1999).

Distribution maps: all remains, lithic industry according to typology, limestone tools, flint tools, faunal species, anatomical parts of all species.

Archaeosurface 3a

From a general viewpoint, the spatial distribution of 3a finds was not uniform (Peretto, 1999). In other words, areas with dense concentration alternating with areas of less concentration of lithic and faunal remains is the norm. GIS of archaeosurface 3a revealed some interesting trends such as the high concentration of the lithic industry in the south/south-west area of the excavation and that of all the other finds in the central area. Peretto et al. (2004) observed that the overall distribution trend was more homogenous in those areas where the remains where still *in situ*. An opposite pattern was noticed for the other parts which were completely removed. In the eastern part of the removed area, materials were more dispersed and their size reduced. The same phenomenon, thinning out of remains was also observed in the northward direction. The concentration of lithic industry was close to a sinkhole, although this factor, is assumed, should not have significantly compromised the distribution of the finds. This is so since their state of preservation is excellent and can attest to the presence of an area of chipping due to the presence of a large quantity of processed objects (nuclei and flakes). The archaeosurface 3a lies directly over travertine in quadrants 2 and 3 which has eld to the formation of this sinkholes. The second zone of concentration was found in the central area of the area explored and concerns all materials (bones, travertine, limestone, worked and unworked flints). Finds with the largest size were concentrated more in the N-S direction in the western part of the part still *in situ*. The dimensions of limestone however decreased proceeding eastwards. Flint was concentrated more in quadrant 2. Since a major portion of the archaeosurface 3a is still embedded in its original provenance at the site for public viewing, the depth dimension of the finds is missing and hence, a 3D density map cannot be developed. The distribution of faunal remains revealed a high concentration of skulls and fragments of the skull (teeth, mandibles and horns) of bison, rhinoceros and the elephant (especially teeth) in the maximum density area of the removed portion. The faunal remains, it appeared from the maps, were not placed differently according to size. Spatial analysis in relation to different species is greatly compromised by the high percentage of undetermined finds. Considering the distribution of the three most representative species – bison, elephant and rhinoceros – their overall diminution is clearly visible close to the N–E border of the portion left in place, and eastward in the removed portion (Peretto et al., 2004, p. 205).

Distribution: all remains, travertine, all lithic industry remains, lithic industry according to typology, lithic materials (worked and unworked), limestone, flint, all faunal remains, faunal species, all faunal remains (axial and appendicular), anatomical parts of bison, elephant and rhinoceros.

The frequency of remains per quadrant: all remains, all remains with relationship between different types of material, lithic materials (worked and unworked), all faunal remains, anatomical parts of bison, elephant, rhinoceros and relationship between flint and limestone.

Area of density: all remains, travertine, limestone, flint, flint flakes, flint nuclei, flint debris and all faunal remains.

Concentration: all lithic industry remains and all faunal remains.

Layer 3 colluvium

The spatial study of layer 3 coll finds was done for a partially defined area as the entire area south-west of the excavation was removed during the completion of the Naples-Vasto highway and could not be documented. From the spatial distribution, frequency and concentration maps it was evident that the central area of the excavated floor had a higher number of remains, both of fauna and lithic industry, with an N-S trend. Three sectional maps visualising the vertical XY plane, longitudinal XZ plane and the YZ transversal place helped to detect a slope in the southern direction. This slope contributed to the distribution of finds during the downward movement (Lembo, 2014).

Distribution: all remains, limestone, flint and all faunal remains.

Concentration: all remains, vertical section of all remains at different altitudes (from top to bottom: 0, -40, -80 and -120 cm), transversal section of all remains, vertical section of faunal remains at different altitudes (from top to bottom: 0, -40, -80 and -120 cm), transversal section of faunal remains, vertical section of flint remains at different altitudes (from top to bottom: 0, -40, -80 and -120 cm), transversal section of flint remains, vertical section of limestone remains at different altitudes (from top to bottom: 0, -40, -80 and -120 cm), transversal section of limestone remains, limestone, flint and all faunal remains.

Layer 3s6-9

The spatial distribution of finds from this layer does not yield any particular pattern, rather the randomness of the dispersion of the finds is underlined (Lembo, 2014).

Distribution: all remains, travertine, limestone, flint and all faunal remains.

Layer 3s1-5

Similar to layer 3s6-9, the layer 3s1-5 finds also displayed random distribution patterns (Lembo, 2014).

Distribution: all remains, limestone, flint and all faunal remains.

2.4 Review of dental mesowear studies

Since the method of dental mesowear was propounded, it has been implemented for many extinct and extant animal species from various time periods, geographic locations and climatic zones. The method has proved to be effective and robust in most cases. The method functions on the principle that abrasive food such as grasses, which forms the chief diet of grazers, cause tooth shape to be blunt and tooth relief to be low whereas the contrary is linked to browsers. Mesowear of teeth occurs over the entire course of an animal's life. A major advantage of this method is that it is low-cost and easy to learn and practice. Furthermore, it can be applied to wide range of sample sizes to obtain a fairly quick assessment of the palaeoecology of the extinct species. Given below is a review of some prominent studies and their results concerning methodological advances and the application of the mesowear method all over the world in a variety of contexts for various faunal species.

Kaiser and Solounias (2003) extended the mesowear method to other maxillary teeth singularly and in combinations to expand the scope of this method. They chose Vallesian hipparionine horse *Hippotherium primigenium* Meyer, 1829, and two populations of recent zebra *Equus burchelli* Gray, 1824 dental remains to test their statistical efficiency. They concluded that a combination of P^4, M^1, M^2 and M^3 was the most consistent for reconstruction of paleo diets. To further this line of thought and research, Kaiser and Fortelius (2003), attempted a calibration of the upper and lower teeth mesowear signals to incorporate them in the same model. Croft and Weinstein (2008) explored the correlation between crown height and diet in three notoungulates of late Oligocene (Deseadan Salma) fauna of Bolivia. Louys et al. (2011) studied qualitative mesowear variables in 33 species of extant African antelope and compared the results with the original mesowear score of Fortelius and Solounias (2000). Since teeth do not wear at same rate and pace, upper M3 was found to have most promising inferences, among which frugivores showed unique mesowear signals. Fraser et al. (2014) expanded the mesowear method to mandibular elements other than maxillary elements and tested its efficiency on a large sample of ruminants. They proposed a new scoring method based on mandibular teeth and additional wear categories. Pérez-Crespo et al. (2016) used the mesowear approach along with stable isotope analysis to understand the diet and habitat preferences of dwarf pronghorn (*Capromeryx mexicana*) from the Late Pleistocene site of Cedral, San Luis Potosí, Mexico.

The dental remains apart from other anatomical parts of the Pleistocene horse, *Equus* aff. *Steinheimensis*, from Orgnac 3 was analysed by Forsten and Moigne (1998) and the results compared with horse remains from contemporaneous sites in Europe. Dental remains, in the majority at this site, were studied with the mesowear method to determine the ontogenetic age of the population. Kaiser et al. (2000) conducted a blind test to check the robustness of the mesowear method by several independent scholars and applying it to the study of *Hippotherium primigenium*, an equid from Vallesian Dinotheriensande (Germany) and see if they had similar scores. It was found that this species had a mixed diet similar to the Impala (*Aepyceros melampus*) and the mesowear method was found to be efficient and robust. Kaiser and Kahlke (2005) researched the dietary habits of *Stephanorhinus etruscus* from faunal assemblages of Voigtstedt and Süßenborn (early Middle Pleistocene). Mesowear method was employed to examine the teeth of extinct hypsodont antilocaprid *Stockoceros onusrosagris* from Papago springs cave in Arizona and compared with the extant pronghorn *Antilocapra americana* (Rivals and Semprebon, 2006). A brachydont species (*Leptomeryx* sp.), a mesodont species (*Rangifer tarandus*), and a hypsodont species (*Bison priscus*) were examined for the relationship between crown height, age and mesowear. This study recommended keeping the age structure of the fossil assemblage in consideration while examining the mesowear signals to reconstruct paleo diet (Rivals et al., 2007). Two species of Chalicotheriinae (*Chalicotherium (Anisodon) grande* and *Chalicotherium goldfussi*), and two species of the Schizotheriinae (*Metaschizotherium fraasi* and *Metaschizotherium* sp.) whose provenance were 20 Miocene vertebrate localities of Southern Germany were subjected to mesowear analysis (Schulz et al., 2007). Four taxa of hipparionine equids from As Sahabi assemblage were investigated, biostratigraphically placed at 6.5 ma (Bernor et al., 2007). Clauss et al. (2007) examined the mesowear of captive and free-ranging giraffes (*Giraffa camelopardalis*). Seven African bovids' paleo diet from Makapansgat Limeworks was subjected to mesowear analysis (Schubert, 2007). Mesowear and microwear methods to study the effects of diet on the morphology of dental remains was applied to *Equus stenonis*, cf. *Croizeteceros ramosus*, antelopes (genera *Gazella* and *Gazellospira*) from the late Pliocene site of Sésklo (Thessaly, Greece) (Rivals and Athanassiou, 2008). A study comparing 19 ruminant species both in captivity and free-ranging in relation to their mesowear was conducted at German zoological museums (Kaiser et al., 2009). The study showed that captive browsers exhibited a greater amount of abrasive wear than free-ranging ruminants. The opposite scenario was noted in case of grazers. Another study published by Bravo-Cuevas and Priego-Vargas (2009) focused extended mesowear research on *Cormohipparion aff. C. quinni*, a hipparionin horse from the middle Miocene El Camarón Formation of Oaxaca in southeastern Mexico. The resulting mesowear pattern was compared with 23 selected extant species and fossil hipparionins from the Neogene of North America, Europe, and Africa. In Europe, the diet of *Metaschizotherium bavaricum* (Chalicotheriidae, Mammalia) from the Upper Freshwater Molasse locality of Sandelzhausen (Germany) was investigated using the mesowear method (Schulz and Fahlke, 2009). Mesowear analysis was used to reconstruct the habitats and diets of late Miocene Bovidae from Toros-Menalla (Chad, Central Africa). Mesowear method was used to examine 117 specimens of bovids from the following tribes: Hippotragini, Reduncini, Antilopini and Bovini (Blondel et al., 2010). Apart from microwear, mesowear was used to study the palaeoecology of Late Pleistocene ungulate faunas of the Mammoth Steppe ecosystem in Fairbanks (Alaska) and

Brown Bank (North Sea) by Rivals et al. (2010). Using premaxillary shape, mesowear and microwear methods, the diets of Mongolian gazelle (*Procapra gutturosa*) and Tibetan antelope (*Pantholops hodgsoni*) were analysed and compared with arctic or subarctic ungulates such as musk ox (*Ovibos moschatus*) and caribou (*Rangifer tarandus*) (Rivals et al., 2011). In another study Rivals (2012), analysed ungulate remains from two middle Pleistocene localities in eastern Austra (Deutsch- Altenburg 1 and Hundseim) using the mesowear method. The sand gazelle (*Gazella marica*) from Mahazat as-Sayd in Saudi Arabia was the focus of a study based on eco-morphological method having two parameters- occlusal relief and cusp shape (Schulz et al., 2013). Yamada (2013) applied the mesowear method to study sympatric extant species of Japanese serow (*Capricornis crispus*) and sika deer (*Cervus nippon*) from Nikko National Park, central Japan. The late Miocene Maragheh ungulates were subjected to mesowear method of analysis and the results were compared with extant ungulates from parallel environments- Greek Pikermian faunas of Samos and Pikermi and late Miocene of China (Bernor et al., 2014). Extending the dental mesowear method application to marsupials, a study in Australia employed percentage indices of blunt, round and sharp cusp shape, high occlusal relief and discriminant function analysis of variance especially of first, second and third molars to infer the diets of these 24 species (Butler et al., 2014). Loffredo and DeSantis (2014) applied the mesowear method to study the dietary information in an extreme generalist herbivore, *Cormohipparion emsliei* from the Boen Valley at Florida housed in the Florida Museum of Natural History. Tooth microwear and mesowear methods were combined with tooth eruption patterns to study the dental remains of ungulates recovered from two Middle Palaeolithic sites of Teixonores (Northeastern Spain) and Portel-Ouest (Southern France) (Sánchez-Hernández et al., 2015). Researchers Kubo and Yamada (2017) investigated mesowear score, molar wear rate and M_3 hypsodonty index of 547 skulls, 740 mandibles from 16 populations of extant sika deer from different environments along with dental measurements. Mihlbachler et al. (2017) investigated the differences and similarities, strengths and weaknesses of the microwear and mesowear methods, keeping fossil and extant rhinocerotid mass-death assemblages as their case study. In the Eurasian region, five ungulate taxa were subjected to mesowear analysis from the early Pleistocene site of Ubeidiya and further collated with modern taxa (Belmaker and O'Brien, 2017).

Mesowear method applied for the study of bison, specifically, has a long history too. Kacimi (2003), for her thesis, studied the Pleistocene Ovibovini from Arago and L'Arbreda and applied the mesowear method to dental remains. At Arago, *Praeovibos priscus* was determined. Similarly, three species of Bovini were determined- *Bos primigenius*, *Bison schoetensacki* and *Bison priscus*. From the southeastern region of the State of Hidalgo, bison and horse dental remains were recovered from a fluvial environment. By employing the extended mesowear method which focused on the examination of buccal apices of P4-M3's teeth cusps, 22 cheek teeth were studied for their occlusal relief and cusp shapes. A cluster analysis comparing these ancient species with extant species demonstrated the horse and bison to be grazer species, similar to each other in their mesowear, comparable to the American plains bison (Bravo-Cuevas, 2007). Another study, with bison as focus subject, was conducted up north across America and Canada (Rivals et al., 2007). The study considered a mixed sample of extant bison from North American central plans and wood bison from Canada and bison palaeopopulations from Alaska, New Mexico, Florida and Texas along with some present day ungulates. Molar facet shape and wear suggested that fossil bison diet was close to a variety of typically mixed feeding ungulates, less abrasive than that of extant bison whose grazing diet is hyper-abrasive. Between the settlements of Port Katon and Podlyudki (Rostov region, Russia), with deposits from Early Pleistocene to the end of Pleistocene, a mass burial of European bisons was discovered in 2003. Through methods such as use wear degree, eruption stage of teeth and epiphyseal fusion, 47 individuals were estimated in the bison assemblage. These individuals, mostly females and young, were catastrophically hunted as a herd in the winter months (Baygusheva et al., 2012). Bison antiquus remains unearthed from the Viko Vijin local Fauna from northwestern Oaxaca, southern Mexico, were analysed in terms of their mesowear by Jiménez-Hidalgo and Cabrera-Pérez (2013). These species also coming from central Mexico, middle Central America and North America represent a variety of landscapes and diets. At Oaxaca, they were found to be grazers and/or mixed feeders, with a less abrasive diet than modern plains Bison. One of the several methodologies applied to reconstruct human predatory behaviour and communal hunting strategies were the mesowear study on dental remains from the bison bone bed at TD 10.2 of Gran Dolina (Atapuerca, Spain). Synthesis of the eruption, wear and dental microwear results indicated that a majority of the bison were killed during two restricted seasonal windows in the late spring and early fall (Rodríguez- Hidalgo et al., 2017). Mesowear studies on Pleistocene European bisons revealed that they mainly inhabited relatively open and dry environments. The Bisons were grazers but occasionally were able to exploit a variety of fairly wooded and open habitats, eating vegetation from a broad spectrum. On the contrary, grazing increased as aridity in the southeastern part of Epivillafranchian Europe increased (Maniakas and Kostopoulos, 2017). Another research on bison (*Bison menneri*) was conducted on its remains uncovered from the late Early Pleistocene type site of Untermassfeld (Central Germany) (van Asperen and Kahlke, 2017). This study helped to understand if the gradual climatic cooling from Early and early Middle Pleistocene in the western Palaearctic was reflected in the replacement of browsers by grazers as landscapes opened up partially. The study revealed that *Bison menneri* and the Late Pleistocene *Bison priscus* from Taubach were mixed feeders representing mosaic habitats of forest and open landscapes, similar to the North American wood bison. In comparison, the early Middle Pleistocene *Bison schoetensacki voigtstedtensis* from Voigstedt did not eat from the forests near the site. The same species however from Süssenborn, a more open environment was similar to extant European bison. The bisons from Pleistocene to present times are grazers to mixed feeders with high tolerance to browsing diet.

2.4.1 Review of dental mesowear studies in Isernia La Pineta

The bison at Isernia has been identified as *Bison schoetensacki* Freudenberg, 1914 (Sala, 1996; 1986). Also known as the woodland bison since its remains were mostly discovered in forest biotopes, it made its first appearance in the early Middle Pleistocene. In comparison with *Bison priscus*, morphologically, it was slightly different. The former's limb bones were more slender and its horns were shorter with a different shape (Palacio et al., 2017). At Isernia, the bison is invariably the species with a majority of bones attributed to it belonging to numerous individuals. Given the abundance of material available this bovine was the subject of a work including also a revision of the European bison (Sala, 1986). More frequent are the cranial remains, together with isolated teeth and the autopodial bones, while the vertebrae, the ribs, the long bones (epiphysis) are lesser in number. The pelvic and scapulae fragments are also in the assemblage. A previous age class study on the bison dental remains from Isernia la Pineta was conducted for archaeosurfaces 3c, 3a, 3S10 and layer 3 coll (Di Nucci et al., 2006). A summary of the results published by them is given here.

Among the five dental remains taken up for study from archaeosurface 3c, three fragments of teeth were unidentified. The remaining included one left P^3, one right M_3 which was well formed and used. There was no mandible or maxilla with teeth in connection with this assemblage. The MNI calculated was one adult bison. Archaeosurface 3a presented a slightly different picture. The dental assemblage consisted of both mandibular dental elements, both isolated and in a series connected to each other. The former were 83 and the latter- 22 in number respectively. The isolated teeth repertoire consisted of 16 inferior, 48 superior and 19 unidentified fragments of dental elements. Out of the 105 dental elements, 31 were suitable for this study, 12 inferior isolated and 19 mandibular fragments. The population comprised exclusively subadult and adult individuals. Archaeosurface 3S10 yielded eight suitable dental remains for this study. This small assemblage was composed of four crown fragments, two P^3 and two roots. The two P^3 suggested the presence of a minimum of one adult individual. The layer 3 coll dental assemblage selected for this study was composed of five mandibular dental elements, connected in series anatomically and 20 isolated inferior dental elements. The population, similar to archaeosurface 3a, was made of only subadult and adult individuals.

2.4.2 Review of dental mesowear studies in Caune de l'Arago

At Arago cave, two species of bison have been identified, *Bison schoetensacki* and *Bison priscus*. A third bison, species unidentified, co-existed with the steppe bison. It had a smaller form in comparison to *B. priscus*. Morphologically, *Bison priscus* is morphologically different particularly for horn cores and horn sheaths which are long, gracile, with an oval base and a moderately long groove distributed along the surface. In *Bison schoetensacki*, they are short, massive and slightly curved with deep grooves on the posterior surface. The section is oval for one-third of the horn sheath. It goes on to become triangular at one-half of the sheath and sub-circular at two-thirds distal (Sala, 1987). Morphologically, differences also lie in the carpus and tarsus bones. For eg., the scaphoid of *Bison schoetensacki* is smaller whereas in *Bison priscus* the anterosuperior articular surface is rather square, the anteroinferior articular surface is broad. In the unidentified smaller form of bison, even if the anterosuperior surface is more or less square, the anteroinferior articular surface is very fine (Kacimi, 2003). In case of cubonavicular, on the proximal side, the posteromedial articular surface is continuous. It forms an angle towards the lateral side of the bone in the two species of bison. However, in the distal view, the posterolateral articular facet is long and broad in *Bison priscus*. In the same species, the anterolateral articular facet has a recess on its medial border. This discrepancy is absent in the smaller form of bison (Kacimi, 2003). Considering general morphology, most of the bones belonging to *Bison priscus*, with some exceptions are robust. The comparison of the measurements of the Arago material with those obtained at several sites in the Pleistocene (Auguste, 1995) shows that *Bison priscus* lies between the variations of these two species in the other sites. Similarly, the small bison form of Arago lies within the range of Bison schoetensacki variation of the sites where it was determined (Sala, 1987, cited in Moigne et al., 2006, p. 812).

The microwear analysis of *Bison priscus* teeth, especially of CM3, done by Rivals et al. (2000), confirmed that Arago Bison was a mixed feeder. The category of mixed feeder corresponds to a variety of food availability such as grasses and leaves, although mesowear analysis shows the tendency to wear as that of grazers. Supportive evidence comes from palaeobotanical studies, in particular, pollen analysis conducted by Lartigot (2007) which revealed the strong tendency of warmer climate resulting in thermophilic forests which alternated with the open environment. Cold climatic conditions of Arago CM1 (MIS 14) supports the occurrence of *Bison schoetensacki*. Similarities in morphological features between the two species of bison at Arago shows that *Bison priscus* also thrived in cold conditions in CM3, although it developed a more robust body size. In other words, identification of variation in body sizes of both bison reiterates the finding that similar cooler climatic features were present in both CM1 and CM3 at Arago. As these periods correlate to glacial conditions of MIS 14 and 12, the bison species were more favourable to live and develop their population in cold climatic conditions. The Variability Size Index employed exclusively in *Bison priscus* demonstrated that this species was adaptable to rapid climate changes alternating between cooler–warmer conditions and that of an open and closed environment (steppe-like grassland landscapes). Along with body size, the dietary adaptation of bison was evidenced as it incorporated grazing along with mixed feeding. Similarly, adaptation in locomotor functions exhibited hat this species tended to live with a more limited movement. All these changes allowed them to develop their population without severe lack of food availability (Insani, 2013).

Monchot (1998) reported the results of the mortality profile of sheep slaughtered at Arago in the archaeological levels F and G. Based on the stage of wear of the occlusal surface of deciduous and permanent dentition, the profiles showed an overabundance of young adults in F level specifically. The lack of infants or young individuals could be attributed to a deliberate selection by the hunters. The mortality profiles thus reflect a cynegetic activity and are distinguished from the catastrophic mortality profile (L-shaped) and the natural death profile (U-shaped) (Stiner, 1990; Lyman, 1987; Moigne, 1983). Mortality profile of *Ovis ammon antiqua* (Argali) was constructed using a large number of dental remains of this species from F level of Arago (440,000 years) (Rivals, 2000). MNI combination, crown height measurements, age estimation based on the dental eruption, replacement and use wear both of isolated and teeth in connection with mandibles apart from seasonality, sex determination and weight estimation methods were used for this study. Catastrophic or ambush hunting type was recognised. Population primarily comprised 27% juveniles, 64% adult females and 9% adult males. A total of 206 individuals of wild sheep were hunted through ambush by a group of humans during spring and summer for several months while they occupied the cave. A year later, in a study published by Rivals et al. (2002), a numerically abundant assemblage of argali sheep and tahr from layers E, F and G of Arago cave were investigated to estimate the number of hunted animals, their age, sex and hunting season. A comparison of results from the three layers showed that selective hunting was practised by the Arago hunters. In another published research (Rivals and Deniaux, 2003), wild sheep (*Ovis ammon antiqua*) from Arago was analysed for its microwear in the form of pit and scratch densities and the results were compared with extant ruminants. The sheep dental remains came from level F of the middle complex. The results helped to identify grazing as a dominant form of the diet of the fossil wild sheep.

The equid dental remains from Arago in France (*Equus mosbachensis*) and Elandsfontein in South Africa (*Equus capensis*) were compared through mesowear analysis to determine their dietary regimes. While the former were grazers much like extant species, the latter was primarily mixed feeders. This study highlighted the importance of attrition-abrasion wear equilibrium as a potential habitat indicator (Kaiser and Franz-Odendaal, 2004). In the same year, another study was published (Rivals et al., 2004) which implemented the eco-ethological through the study of tooth eruption of reindeer from L Level, Cervini (red deer and fallow deer) from J level and musk ox and argali from G level to understand if they were preys of opportunistic or selective hunting at Arago. Data from extant wild herds about their population structure and their hunting in specific seasons was collated with Arago dental remains. The study established that there was no particular selection process by hunters on the site. Microwear method was chosen to be applied to two species of Caprinae, *Capra caucasica* from upper deposits (MIS 5 or 4) and *Rupicapra pyrenaica*, from level F of Arago. Mixed feeding was recognised as the main diet form of both species (Rivals and Deniaux, 2005).

In a study comprising both extant species (wild-shot caribou from eastern Canada) and fossil assemblages of caribou (*Rangifer tarandus*) from Pleistocene sites (Alaska, North America; Caune de l'Arago, France and Salzgitter, Germany), Rivals and Solounias (2007) examined tooth microwear to understand ecology, migration, glaciations and dental evolution of this species. The sample from Arago was sourced from two stratigraphical units (CM1 and CM3). CM1 corresponded to OIS 14 (570,000 – 530,000 years) and CM3 is dated to OIS 12 (480,000 – 400,000 years), the glacial cycle of the Pleistocene. In the former unit, the caribou population was made of 2/3 females and 1/3 male. They were hunted during the autumn, a season when the species bred and winter migrations began. The mesowear pattern of Arago sample was similar to the sample from Alaska associated with less browsing. Mesowear and microwear analyses were applied to the ungulates from CM1-3 of Arago with the aim of assessing the robustness of these methods on detecting the impact of climate changes on vegetation and community structure. The results revealed that the overlap or similarity in their feeding ecology was low even if some species had shared habitats or resources. Among the stratigraphic units, CM1 and CM3 units, which had a cold and dry climate based on pollen studies, displayed the lowest diversity in dietary characteristics. On the contrary, CM2 which has a more temperate and humid climate sheltered a wider range of dietary traits- grazers, browsers and mixed feeders (Rivals et al., 2008).

Microwear study can be an effective tool to distinguish single hunting versus multiple hunting events was archaeologically proven in the archaeofaunal assemblage from Arago (Rivals et al., 2009) as mesowear variations in the latter were much more than the former scenario. The equid dental wear from level G, a level representing several occupations of long-term and level P, a short-term occupation from Arago conformed with the above observation. Rivals et al. (2015) conducted a study to examine the paleodiet of horses from Schöningen 13 II-4 using microwear and mesowear. They compared their findings to other Pleistocene sites in Northern and Eastern Europe which included Arago. In another study, at the site of Schöningen 13 II-4, equid dental remains were examined using the mesowear, microwear and stable isotope analysis methods. The upper teeth revealed a low abrasion diet with a major input of browse in the equids' diet. Their assemblage was a consequence of multiple accumulation events at different points in time (Rivals et al., 2015).

Chapter 3

Material and Methods

3.1 Provenance of faunal material

The faunal material which was studied belonged to the archaeosurface 3a; layers 3 coll and 3s6-9, recovered from the excavation years 2000-2016. Later, the faunal database from the current study was fused with the older database from respective layers, wherever possible. For instance, the data obtained from layer 3 coll is an integration of previous degree theses (D'Argenio, 2015; Martino, 2015; Pesce, 2005; Secco, 2003; Ghirelli, 2000) with databases generated from these studies. Similarly, for completeness of information, the layer 3s6-9 faunal database also considered the remains analyzed before 2003 in the related squares. It is an amalgamation of previous thesis (Grandi, 2015) with database generated for this research. This study excluded faunal remains that are currently under the process of restoration.

Archaeosurface 3a
The faunal material from this archaeosurface came from the following squares (Fig 3.1).
Sector 1 Quadrant 1: 169, 177, 178, 179.
Sector 1 Quadrant 2: 12, 21, 22, 31 and 41.

3 colluvium
The faunal material from this layer came from the following squares (Fig 3.2A).
Sector 1 Quadrant 1: 58, 66, 69, 74, 76, 77, 78, 79, 83, 84, 85, 86, 87, 88, 89, 95, 96, 97, 98, 105, 106, 107, 108, 109, 116, 117, 126, 127, 128, 135, 137, 138, 146, 147, 148, 156, 157, 158, 166, 167, 168, 169, 176, 177, 178 and 179.
Sector 1 Quadrant 4: 31, 50, 51, 52, 71, 80, 90, 91, 100, 101, 102, 110, 111, 140 and 170.
During fusion with the old database, the following squares were added (Fig 3.2B).
Sector 1 Quadrant 1: 64, 65, 67, 68, 75, 93, 94, 99, 103, 104, 113, 114, 115, 119, 123, 124, 125, 133, 134, 145, 159, 174 and 175.
Sector 1 Quadrant 4: 60, 61,70 and 81.

3s6-9
The faunal material from this layer came from the following squares (Fig 3.3).
Sector 1 Quadrant 1: 86, 96, 98, 107, 109, 128, 129, 137, 139, 147, 148, 156, 157, 158, 166, 167, 168, 169, 174, 175, 176, 177, 178, 179, 188, 198 and 199.
Sector 1 Quadrant 4: 90, 100, 101, 110, 111, 120, 121, 130, 131, 140, 141, 151, 190 and 210.

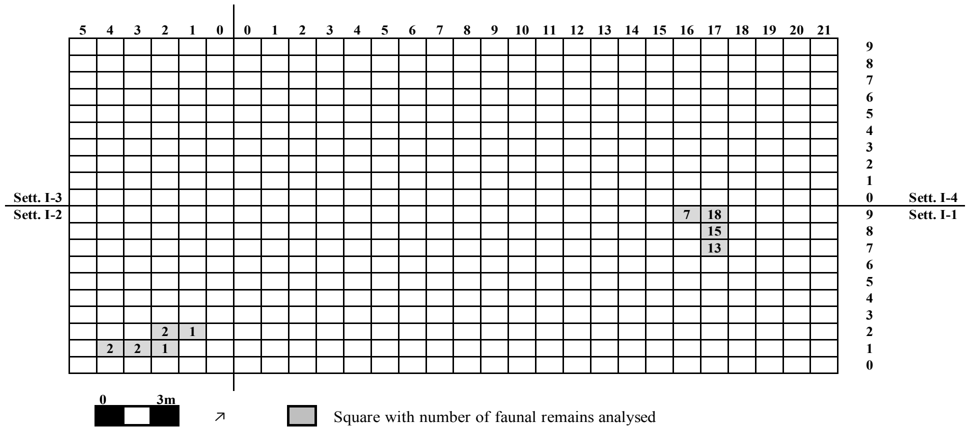


Fig 3.1: Isernia La Pineta: Distribution map of the provenance and number of faunal remains from excavated squares of Archaeosurface 3a (Sector I) – the subject of this study.

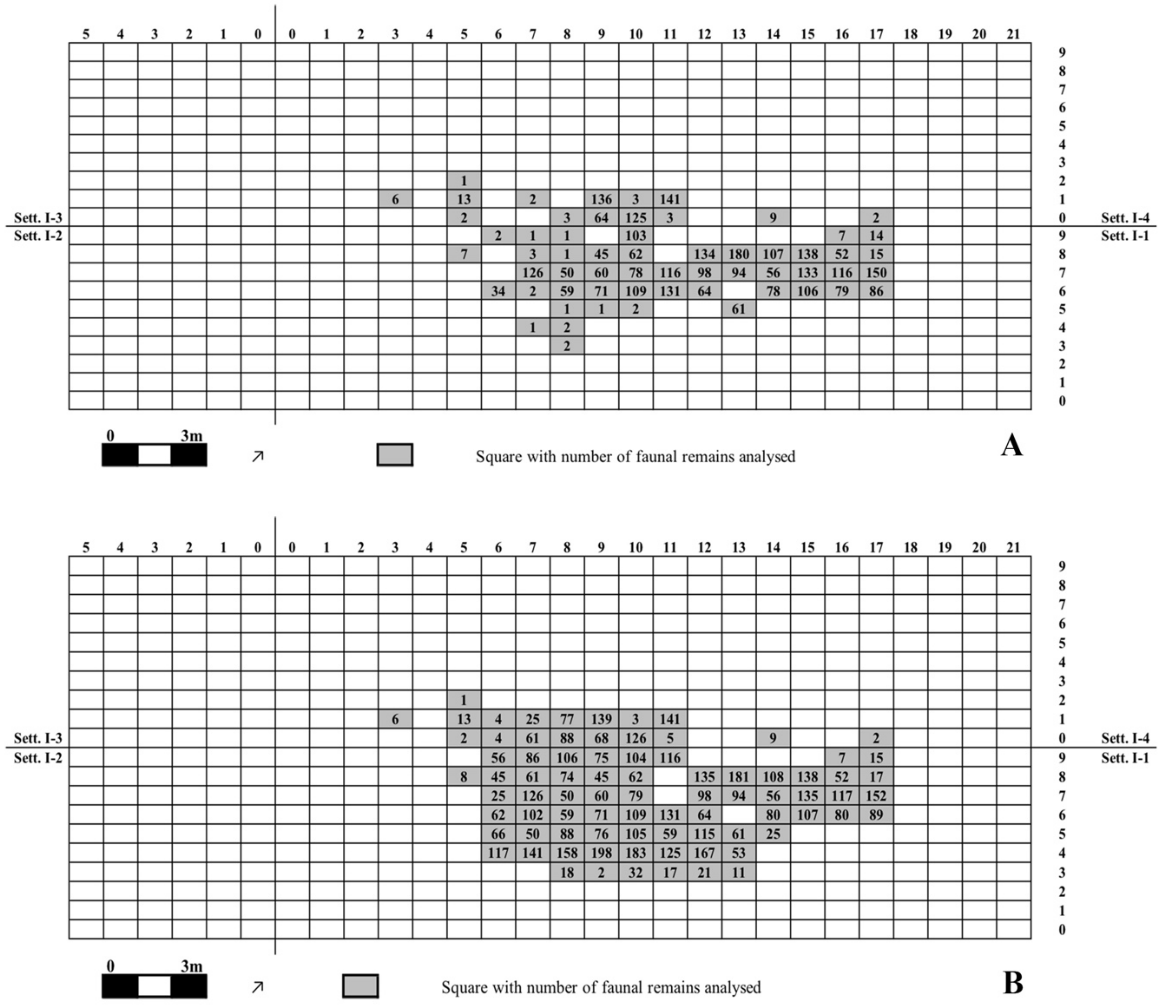


Fig 3.2: Isernia La Pineta: Distribution map of the provenance and number of faunal remains from excavated squares of layer 3 colluvium (Sector I) – the subject of this study, A- before fusion; B-after fusion.

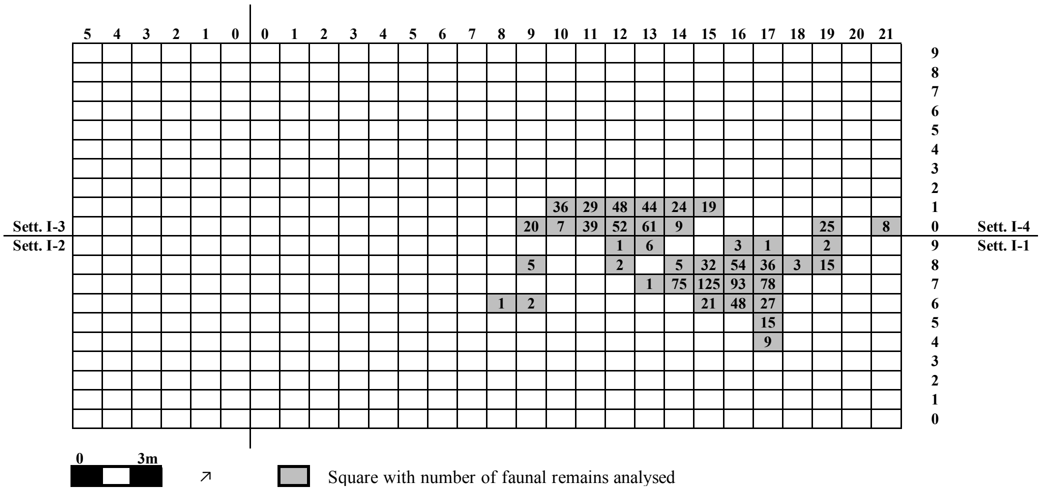


Fig 3.3: Isernia La Pineta: Distribution map of the provenance and number of faunal remains from excavated squares of layer 3s6-9 (Sector I) – the subject of this study.

3.2 Preservation and Conservation

Weak preservation characterizes the faunal remains of Isernia and have brought into force a process for their effective consolidation, removal and restoration. Faunal remains are restored with the primary objective to remove residual sediment concretised inside and on the bone surfaces which in turn enables diagnostic morphological features to become visible. The pointed end of a wooden skewer stick is wrapped in a small quantity of cotton and soaked in a solution of alcohol and acetone, both at 50%. Holding the other rounded end in between the fingers, the cotton end of the tool is gently rotated in a uniform singular motion and direction on the surface of the bone to eliminate the residual sediment. To remove calcareous concretions, other tools can be used such as metallic instruments or hammer and chisel in the most difficult cases. The restoration activity sometimes also includes the bonding of bone fragments using the German-made adhesive UHU-Extra monocomponent or UHU-Plus R bicomponent. If the bone contains deep and large fractures or cracks, they are filled with a stronger adhesive called Paraloid B72 at 5% or 10%, depending on the fragility of the bone (procedure described in Corti, 2003).

3.3 Methods of study

A multi-fold approach for the study of Isernia faunal material was adopted to cover its scope and fulfil the aims of the research. It ranged from macroscopic to microscopic levels and from data documentation to quantitative methods. The codification of all information related to each faunal remain was achieved through recording and storing of the said data in computerized data collection forms. This efficient database management stands verifiable at any future date and ensures the permanency of data. The data sheet came into existence in 1991, specifically for archaeozoological studies at Isernia (Anconetani, 1996). Later, in 2001, its content capacity to include more information concerning taphonomy was expanded (Thun Hohenstein, 2003). The program used is Microsoft Access (latest version). The lexicon is of an alphanumeric type, the layout used is open and permits entry/addition/deletion of attributes according to research requirements, continuous updating of data and their subsequent processing. Since its inception, the data collection sheet has undergone several modifications having taken into account the results of experiments and analyses that have been conducted on the remains, by adding new fields for a better understanding. Each remain is represented by a series of numbers that correspond to precise characteristics or attributes. Each faunal remain can be symbolized through a series of numbers immediately translatable to readable keys reported in the lexicon, following which, the greater the amount of information that can be acquired from the remain, the more extensive will be the set of numbers that identify it. The data collection sheet includes various cells both for archaeozoological analysis and for the identification of the remain in the original excavation context. A space to add notes or possible further observations has also been inserted at the end of each sheet.

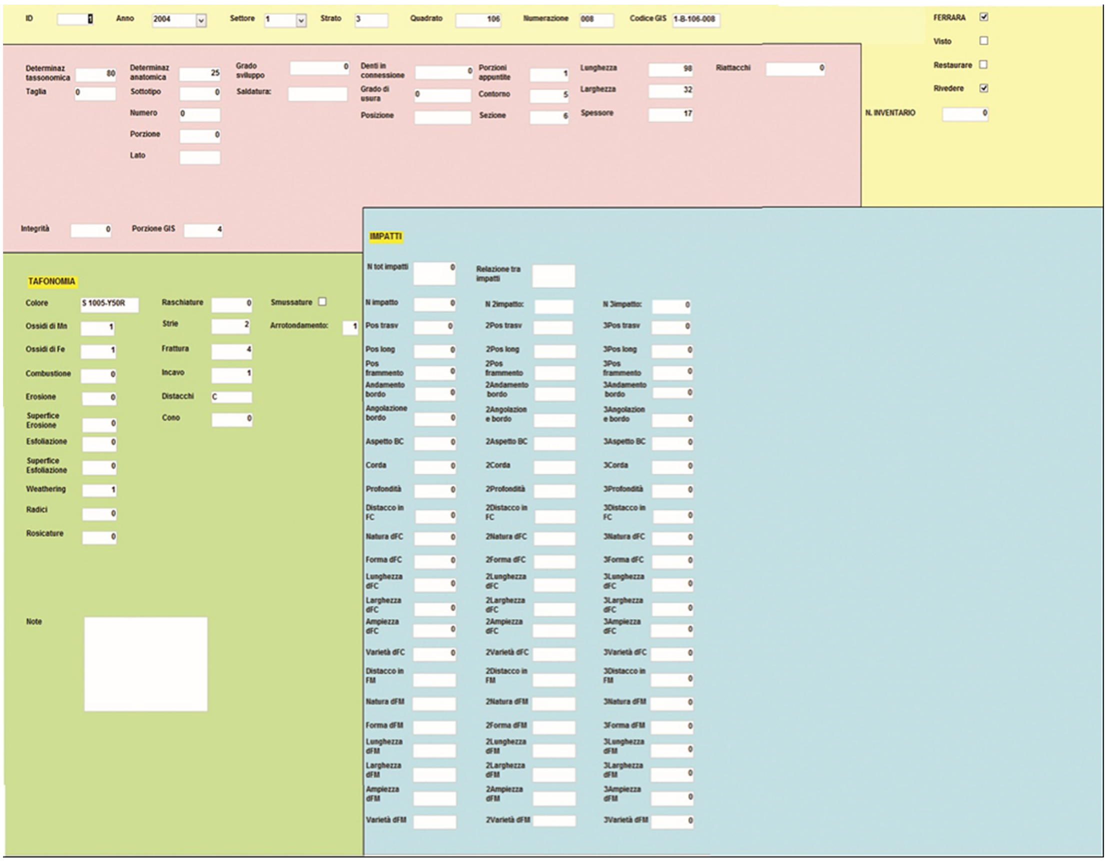
3.3.1 Context and coordinates

The basic format of the data collection sheet can be summarized as follows. In the figure (3.4) below, the section in yellow is related to information about the remain in the original stratigraphical context of the excavation. The cells provide information such as: excavation sector, quadrant, layer and square in which the remain is contained; accession/registration number and X, Y and Z coordinates of the remain; GIS code which identifies the remain with respect to data collected by the total station; year of the excavation season/campaign in which the remain was discovered and recovered; GIS portion which defines the anatomical element (which can be a generic fragment, an entire bone, a diaphysis or an epiphysis). This permits and summarises the spatial association of all categories of anatomical elements.

3.3.2 Macroscopic observations

Macro-level observation of the remains takes place for their anatomical and taxonomic determination as well as for the determination of shape, section, colour and taphonomic attributes. Shape refers to a geometric form (simple or compound) of the entire fragment and its transversal section both of which are represented by a numerical value. These two fields allow us to identify the morphotypes of intentional fracturing and are derived from the criteria formulated from experimental activities. The detachments and the identifiable alterations can be studied in detail even without the aid of the stereomicroscope.

The section in pink colour (Fig 3.4) encapsulates all the information concerned with anatomical and taxonomic determination. Identification keys available in publications (Breda et al., 2015; Breda and Ballatore, 2013; Breda and Lister, 2013; Lister et al., 2010; Di Nucci and Thun Hohenstein, 2007; Lacombat, 2006; Sala, 2006; 1996; 1990; 1987; 1986; Abbazzi and Masini, 1997; Sala and Fortelius, 1993; Anconetani et al., 1991) and reference comparative collections of large mammals housed at the Laboratory in University of Ferrara aided in determination. Atlases on anatomy were consulted (Varela and Rodriguez, 2004; Hillson, 1999; Pales and Garcia 1981; Barone, 1976; Driesch A. von den, 1976; Schmid 1972; Pales and Lambert 1971). It gives information on the type of bone, a portion of the fragment with respect to the whole bone and the species. Anatomical determination of the fragment is elaborated further through additional entries. Subtype refers to the structural unit to which the bone or fragment belongs in relation to a whole. For instance, bones such as phalanges, vertebrae, carpal, metacarpal, tarsal, metatarsal, and teeth. The number indicates the exact bone in relation to the structural unit. It concerns the vertebrae, ribs, metacarpals, metatarsals, phalanges and teeth. Portion refers to the fragments. The bone is divided schematically according to orthogonal and parallel planes in all possible combinations, the fragment is therefore considered in its original position with respect to the entire element. Side specifies the laterality to which the fragment or the whole bone belongs. State of integrity designates the transverse position of the fragment with respect to the whole bone.



ID 1
Anno 2004
Settore 1
Strato 3
Quadrato 106
Numerazione 008
Codice GIS 1-B-106-008
FERRARA ☑
Visto ☐
Restaurare ☐
Rivedere ☑
N. INVENTARIO 0

Determinaz tassonomica 80
Taglia 0
Determinaz anatomica 25
Sottotipo 0
Numero 0
Porzione 0
Lato
Grado sviluppo 0
Saldatura:
Denti in connessione 0
Grado di usura 0
Posizione
Porzioni appuntite 1
Contorno 5
Sezione 6
Lunghezza 98
Larghezza 32
Spessore 17
Riattacchi 0
Integrità 0
Porzione GIS 4

TAFONOMIA

Colore S 1005-Y50R
Ossidi di Mn 1
Ossidi di Fe 1
Combustione 0
Erosione 0
Superfice Erosione 0
Esfoliazione 0
Superfice Esfoliazione 0
Weathering 1
Radici 0
Rosicature 0
Raschiature 0
Strie 2
Frattura 4
Incavo 1
Distacchi C
Cono 0
Smussature ☐
Arrotondamento: 1
Note

IMPATTI

N tot impatti 0
Relazione tra impatti

N impatto	0	N 2impatto:		N 3impatto:	0
Pos trasv	0	2Pos trasv		3Pos trasv	0
Pos long	0	2Pos long		3Pos long	0
Pos frammento	0	2Pos frammento		3Pos frammento	0
Andamento bordo	0	2Andamento bordo		3Andamento bordo	0
Angolazione bordo	0	2Angolazion e bordo		3Angolazion e bordo	0
Aspetto BC	0	2Aspetto BC		3Aspetto BC	0
Corda	0	2Corda		3Corda	0
Profondità	0	2Profondità		3Profondità	0
Distacco in FC	0	2Distacco in FC		3Distacco in FC	0
Natura dFC	0	2Natura dFC		3Natura dFC	0
Forma dFC	0	2Forma dFC		3Forma dFC	0
Lunghezza dFC	0	2Lunghezza dFC		3Lunghezza dFC	0
Larghezza dFC	0	2Larghezza dFC		3Larghezza dFC	0
Ampiezza dFC	0	2Ampiezza dFC		3Ampiezza dFC	0
Varietà dFC	0	2Varietà dFC		3Varietà dFC	0
Distacco in FM		2Distacco in FM		3Distacco in FM	0
Natura dFM		2Natura dFM		3Natura dFM	0
Forma dFM		2Forma dFM		3Forma dFM	0
Lunghezza dFM		2Lunghezza dFM		3Lunghezza dFM	0
Larghezza dFM		2Larghezza dFM		3Larghezza dFM	0
Ampiezza dFM		2Ampiezza dFM		3Ampiezza dFM	0
Varietà dFM		2Varietà dFM		3Varietà dFM	0

Fig 3.4: Isernia La Pineta: MS Access data collection sheet for faunal remains updated in 2014.

Anatomy and taxonomy

Teeth in connection denote the specific numbers and positions of the teeth still present inside their alveolar sockets inside the maxilla or mandible. Position refers to the teeth, indicates if the tooth is positioned on the maxilla (inferior) or mandible (superior).

It is important to know the relative ages at which animals were killed or died while assessing the patterns in hunting/scavenging practices of ancient people. It is broadly recognised that different animal management regimes or hunting strategies will create faunal assemblages with specific age ranges and can be recognized through the identification of these age ranges. Cells/entries that describe the relative size and presumed age of the individual are, for e.g., the degree of development which indicates the presumed age of the individual. This is calculated or observed based on the state of fusion of epiphysis, the wear of teeth or presence of deciduous teeth. Fusion means the state of fusion of the epiphyses to the diaphysis and of the articular surfaces. The degree of wear refers to teeth. Size concerns the size of the animal. The criteria used to categorize as near a taxon as possible anatomically determined but taxonomically unidentified remain is according to the size of the bone section and cortical thickness. One aspect to keep in consideration is the size variability between current models taken as reference and past species. Five sizes have been set for Isernia faunal assemblage as follows.

- Very large size: *Palaeoloxodon antiquus* (elephant)
- Large size: *Bison schoetensacki* (bison), *Stephanorhinus hundsheimensis* (rhinoceros), *Ursus deningeri* (bear), *Hippopotamus* cf. *antiquus* (hippopotamus), *Panthera leo fossilis* (lion), *Panthera pardus* (leopard), *Hyaena* sp. (hyaena), *Praemegaceros solilhacus* (giant deer), *Cervus elaphus* cf. *acoronatus* (red deer), *Dama* cf. *D. Roberti* (fallow deer), Bison/Rhinoceros indeterminate, Cervidae indeterminate.
- Medium size: *Sus scrofa* (boar), *Hemitragus* cf. *bonali* (thar), *Capreolus* sp. (roe deer).
- Small size: birds/rodents.

Osteometry

Similar to quantitative methods, the metrical analysis is a vital tool in archaeozoological researches. It provides various archaeozoological information such as size changes in wild animals through time, differentiation of domestic and wild animals, identification of sex and sexual dimorphism, differentiation of animal species and individual variation and intra and inter-site comparison of faunal remains, etc. Measurements were taken when possible and required of specimens using a digital calliper having a least count of 0.01 mm. Osteometric data included general dimensions of the bone such as length, width and thickness for each remain. Shape or contour, section and the presence of any sharp portions in the remain are also indicated in order to identify fracture morphotypes. The reattachment field concerns fragments that are refitted with others, having another registration number, to form a single piece.

Taphonomy

The taphonomy section in green in the data collection sheet gathers data which helps to assess the taphonomic history of the remain (Fig 3.4). It documents the physical state of the remain and the degree of alteration due to various natural and anthropic taphonomic agents.

The criteria covered are:

- Colour for which a Munsell colour chart was consulted to choose the colour corresponding closest to the colour of the bone surface, in areas not discoloured by oxides.

- Manganese and iron oxides (0 absence, 1 presence): Studies have shown multiple causes for discolouration and staining of bone surfaces. The red colouration is caused by burial or contact of bones with iron-rich, oxygenated and biologically active soils. Black stains on bone surfaces, where the action of manganese is prominent, is because of total or partial immersion of bones in water or wet, organically rich (*humus*) soils, precipitated dry by bacterial growth or due to the formation of massive accretions. The staining can appear patchy, form dendritic or branching patterns imitating effects similar to root etchings. Black stains can also be because of microbial, mostly fungal, attacks, carbon deposition or combustion at different temperatures. The presence of manganese deposition is related to an environmental condition characterized by wet, mildly alkaline and oxidizing (Fernández-Jalvo and Andrews, 2016; López-González et al., 2006).

Natural factors are chiefly climatic factors such as temperature changes, humidity and exposure to the sun.

- Weathering: This process is termed ‘weathering’ and is defined as the phenomenon for which organic and inorganic bone components are destroyed by physical and chemical agents (Behrensmeyer, 1978). The effects are fractures or fissures termed ‘weathering cracks’. The process initiates on the bone surface and gradually extends into the skeletal tissue. The degree of intensity with which the weathering occurs is defined, starting from 2014, referred to the Behrensmeyer Index (1978) for large mammals (Lyman, 1994). According to her criteria, weathering proceeded in what was described as cracking/no cracking or flaking of bone surface, longitudinal and/or mosaic cracking present on surface, fibrous texture, cracked edges rounded, coarsely fibrous texture, splinters of bone loose on the surface, open cracks, bone crumbling *in situ*, and finally large splinters. Exfoliation occurred from stage 3 onwards with increasing intensity. Exfoliation, cracking and rounding of edges etc. are variables which otherwise are visible almost always together or in varying combinations. In the case of Isernia, during initial analysis, it was observed that Behrensmeyer’s criteria were not always applicable. Some bones had no evidence of cracking or fibrous texture or cracked rounded edges. They only demonstrated exfoliation and *vice versa*. Therefore, these closely-related descriptive criteria of exfoliation, erosion and weathering were considered as three separate specific variables for our analysis. This was done to have better analytical control over the taphonomic variables and their interpretation (Thun Hohenstein et al., 2004; 2002).

Weathering was essentially related to climatic factors and identified by so-called cracks and micro-cracks, in the order of increasing intensity from slight cracking /splitting in early stages to heavy cracking/deep splitting in later stages of the surface oriented according to the arrangement of the structural elements attributable to pre and post-depositional factors (loss of organic matter, temperature variations and humidity, etc.) (Fernández-Jalvo and Andrews, 2003; Denys, 2002; Littleton, 2000; Reitz and Wing, 1999; Andrews, 1995; Fisher, 1995; Lyman, 1994). To bring in precision and consistency in the subjective descriptions of these phenomena, categories of weathering were made denoting degrees and stages of its impact and extension on the bone surface. Weathering was described to be ‘slight’ if it had impacted 2% of the bone surface, ‘medium’ if its effects could be localised to 10% of the bone surface, ‘advanced’ if it was found to have impacted 50% of the bone surface and ‘very advanced’ if the impact had diffused over the entire surface of the bone and even invaded the bone deeply.

- Erosion: Similar to weathering, the phenomenon of erosion was categorised to streamline objective descriptions. Edaphic factors which produce traces on the bone are related to the nature of the soil. Soils with a very acidic pH cause the erosion process which causes more or less deep layers on the surface of the bone. Rolled edges and abrasions impacting bone surface integrity was considered as erosion. The impact was erosion was either described as ‘slight/mild’, ‘marked’ or ‘diffused’ according to the amount of compact bone surface or fabric altered by this phenomenon. In a few cases, this phenomenon had resulted in the formation of sub-circular eroded 'cups', isolated or arranged in groups of small units.

- Exfoliation: Removal of cortical/surficial bone material was associated with exfoliation. The degree of exfoliation was measured according to the categories ‘slight’, ‘marked’ and ‘diffused’ as was done for erosion. This phenomenon is tangible mostly on bone surfaces where they become apparent due to the lamellar structure of the external part which would otherwise seem well preserved when macroscopically observed. In reality, on the contrary, they could be the result of a complete loss of the uppermost surficial layers as a result of which an underlying comparatively better-preserved surface is exposed. Hence, the possibility of such alteration causing phenomena have to be taken into consideration when looking for cut-marks or any such traces of anthropic activity as they could have obliterated them completely.

In 2014, the field related to the identification of the percentage by which erosion and exfoliation effects the bone surface was added: 1 for 0-25% of the bone surface; 2 for 25-50% of the bone surface; 3 for 50-75% of the bone surface; 4 for 75-100% of the bone surface.

- Trampling: Bone surfaces are majorly modified by another agent of physical nature called trampling. It refers to linear traces ascribable to abrasive actions of granules of surrounding soil or sediment matrix on bone surfaces. This process may occur due to the water or aeolian transport of the particles. This matrix is sometimes composed of a variety of crystals such as sanidine, a phenocryst of volcanic origin, capable of making striations on the bones surface under human or animal trampling action. Uneven borders and a diverse range of length, width, thickness, depth, a 'U' section and arrangement in chaotic and irregular manner characterize these striations.

- Rounding: Abrasion refers to rounding of bones, specifically broken ends of bones, processes which protrude from the general level of bone and also a complete bone sometimes. This process usually occurs when a tool is being fashioned by hominins, as a consequence of trampling or transport. The rate of rounding/abrasion depends on the condition of the bone being modified (fresh, dry, weathered or fossilized) and the type of bone. Abrasion also varies according to the type of sediment (gravel, coarse sand, fine sand, clay and silt) (Fernández-Jalvo and Andrews, 2016; Olsen and Shipman, 1988). Causal agents can be summed up as inorganic processes such as water transport of bones in sedimentary environments, transport of sediment impacting bones, wind erosion, trampling by large animals and organic processes such as carnivore and human action, trampling in an organic substrate, bioturbation, plant roots, aquatic bioerosion and water corrosion (Fernández-Jalvo and Andrews, 2016). In 2014, the field defining the degree of rounding of fracture edges of the bone, anthropic or post-depositional, was defined with a number contained between 0 (absence of rounding) and 5 (very rounded).

Biological factors leave behind traces due to the intervention of animal and plant organisms on the bones. They are as follows:

- Root etchings: Irregular, branching, dendritic pattern of intersecting grooves, ramified furrows, sometimes shallow and other times deep enough to penetrate the bone to a moderate depth, rounded sections and corrugated ends are caused by roots. They can also leave simple traces of colour (Morlan, 1980). Plant roots secrete humic acid to break down and extract nutrients from nearby resources such as bones. Their dissolution associated with growth and decay can cause these grooves. The fungal action also causes dendritic patterns. They can potentially remove much of the periosteal layer and cancellous tissues of bone. As a result, they may obliterate other marks present on the bone before their impact. They may also cause splitting and fragmentation of bones (Lyman, 1994; White, 1992; Maltby, 1985; Behrensmeyer, 1978). The intensity of root etching is dependent on the depth of the burial of the bone assemblage, density of soil in which plant roots are growing, amount of water nourishing the roots, the configuration of roots which can attach to a given bone assemblage (Warren, 1975). For this assemblage they were classified as 0-absent, 1-mild/slight, 2-marked and 3- localized.

- Rodent/Carnivore marks (0 for absence, 1 for rodents, 2 for carnivores): Rodent teeth marks are characterized by short, smooth, closely parallel traces/grooves either present on one edge or on both edges with rounded edges. They have a ‘V’ shape or rectangular/quadrangular cross-section and the walls are fairly smooth. Rodents gnaw on bones with their incisors when scavenging for meat, extracting minerals or sharpening their incisors (Gautier, 1993; Brain, 1969). Carnivores usually cause tooth marks, sometimes claw marks on bones, fractures and chemical corrosion due to both gastric acids and salivary enzymes. Regarding tooth marks, we can distinguish between scores, pits, punctures, elongated furrows with ‘U’ section, fractured bones produced by molars, subcircular depressions caused by monocuspid teeth (Ardèvol and López, 2009; Blumenschine, 1995; Stiner, 1994; Haynes, 1983; 1980; Binford, 1981). Their absence was marked as ‘0’ and presence as ‘1’.

Anthropic modifications

A part of the green section and the entire blue section is dedicated exclusively to documenting all aspects and evidence of anthropogenic activities on faunal remains, which are substantially of two types, slaughter marks and intentional fractures (Fig 3.4). Fractures can originate due to pre-depositional agents such as anthropic activities of fresh bone breakage, carnivore chewing/gnawing or through post-depositional factors such as weathering, trampling when heavy objects fall or sometimes when roots penetrate through them. Fractures were divided into seven sub-categories as follows: 0-absent, 1- anthropic, 2- post-depositional, 3- from weathering, 4- anthropic + post-depositional, 5- anthropic + from weathering, 6- post-depositional + from weathering, 7- from weathering + anthropic + post-depositional.

- Non-anthropogenic fractures: Non-anthropic fractures, such as post-depositional or those resulting from weathering, were analysed numerically.

- Anthropogenic fractures: A fracture is termed anthropic if the bones display one or more notches along the fracture edge, suggesting strong evidence of intentional anthropic activity. A study of such evidence highlights the frequency in the positioning of the impact areas and their possible connection/association with the anatomical and taxonomic component of the bone. There are several fracture morphotypes. Fracture techniques can be deduced or reconstructed from such data. All notches that are present on the bone are therefore individually studied and their features recorded separately. Intentional fracturing produces numerous traces on the bone surfaces, which represent the diagnostic characteristics, listed below (Thun Hohenstein, 2001; Anconetani and Peretto, 1996).

- Impact point/percussion notch: It is a depression along the edge of an anthropic fracture which testifies to the percussion on the bone surface at that point. It can be more or less deep and possess variable characteristics, depending on the type of bone, the percussion used and the dynamics of the percussion. Measurements of the void created by the notch are taken, the position is described with respect to the fragment and the whole bone as well as the progress/direction/appearance of the edge and its angle. In case the impacts are two or more in the same bone their relationship is considered (if they are positioned on the same edge, spaced, consecutive or on opposite edges at the same height or at different heights). The appearance and the angle of the border of the impact point and the form, length, breadth, and depth of the impact point are also described in detail.

- Detachments: for the detachments (cortical C, medullary M, cortical and medullary CM); notches (0 absence, 1 presence) in the medullary and cortical face the dimensions are measured and nature, shape, length, width, amplitude with respect to the fragment are considered.

- Percussion cone: is reported if the fragment is a splinter/shard/flake that is produced in the area of impact due to intentional fracturing. In other words, it is a fragment created at the point of impact; its section is of trapezoidal shape and the extension of cortical surface conserved is very reduced compared to the thickness of the underlying compact bone.

- Bevel: the presence of any areas that have a rounding of the non-natural edge is noted.

- Scraping marks (0-absence, 1-presence) were considered to be those that demonstrated multiple, mostly parallel, light to moderately deep linear marks similar to cut-marks but more superficial in nature and appearance. These marks impact the bone during the butchery process while removing the periosteum prior to disarticulation of bones.

- Cut-marks: According to Binford (1981), cut-marks are the result of carcass processing activities: skinning and the marks thereof are found in bones placed at the extremities of the animal's body (phalanges, metapodials, jaws); disarticulation marks present on epiphyses, occipital condyles, vertebral surfaces, pelvic area for the recovery of muscle masses; usually parallel to the longitudinal axis of the bone and butchering striations produced by lithic tools with a sharp edge which are often not very evident and therefore only observable by the stereomicroscope or the SEM. The lithic instrument creates a groove which is elongated and has the characteristic "V" section with steep walls. The entry point is linear and the exit point is "dovetail". The depth of the cut mark varies gradually- at first it is light and deepens towards the end. Sometimes parallel striations within the main groove are visible due to micro-fracturing of the edge of the lithic instrument, which is created when it comes into contact with the bone (Shipman and Rose, 1984). In the datasheet, they were denoted with a '1' for the confirmed cut mark, '2' for trampling mark, '3' for the doubtful cut mark.

Photography

The macro photos were taken using a Canon EOS 600D digital camera, made available by the Laboratory of Archaeozoology and Taphonomy of the hard animal materials of the University of Ferrara (L.A.T.).

3.3.3 Microscopic observations

The observation of bone surfaces to confirm the macroscopic considerations made in the first phase of the study was continued with microscopic examinations. An optical stereomicroscope was used in order to recognize in more detail the traces on the surface and their nature. This activity was carried out in the Laboratory of Archaeozoology and Taphonomy of the hard animal materials in the University of Ferrara (L.A.T.), which made available the Leica S6D stereomicroscope. On a selection of remains, scanning electron microscope (SEM) analysis was conducted using replicas of bone surfaces bearing cut-marks requiring a deeper analysis to distinguish whether they were of natural origin or of anthropogenic origin. With this type of instrument, it is possible to have greater depth of field and sharper images. Bones surfaces are often consolidated with paraloid which makes them appear translucent under the stereomicroscope and cannot help to determine anthropogenic cut-marks (Giacobini, 1995). Therefore, replicas of the surface to be observed were prepared, after removing the paraloid from the surface because the sample must be metallized with a layer of gold-palladium having a thickness of 20 nm to facilitate the dispersion of electrons and placed in an observation chamber in which a vacuum is created. The surfaces with negative impressions of the surfaces were first made using PROVIL NOVO CD2 (Heraeus Kulzer) Light - Fast Set silicone elastomer. The positive replicas are in epoxy resin (LY 554 Araldite and HY 956 catalyst). A peculiar characteristic of these materials is their high definition to reflect bones surface, allowing the observation of details of less than 1 micron (Giacobini, 1995).

3.3.4 Long bone fracture and shaft fragmentation indices

A sample of the faunal material from Isernia, specifically long bone diaphyses and rib diaphyses fragments from archaeosurface 3a; layers 3 coll and 3s6-9, were subjected to further rigorous investigations to test concepts established primarily by Outram (2002; 2001; 1998), Villa and Mahieu (1991), Johnson (1985), Morlan (1984), Bunn (1983) (for review see Coil et al., 2017), which provide valuable analytical tools to assess fresh versus sub-fossil bone breakage and human versus carnivore activities. The diaphyses sampled for this study were greater than 5 cm in length. This minimum length cut-off was decided to lessen the disparity which arose on a regular basis, since fragments smaller than 5 cm were difficult to distinguish as those coming from long bone diaphyses or from other bones of the skeleton. The sample comprised those that were determined only anatomically and not taxonomically and those that were determined both anatomically and taxonomically. Also taken into account were fragments still having one intact or incomplete epiphyseal end with a portion of the diaphysis on the other end. Epiphysis without diaphysis was not considered. Complete long bones, if present in the sample, were excluded from this analysis. Diaphyseal fragments of medium or small sized animals if less than 5 cm were not considered as they were very few in number and their exclusion from the study did not impact the results. The datasheet was created in MS Excel to which was imported the stratigraphical context, GIS code, coordinates and general size dimensions of the sampled fragments from the MS Access faunal database for archaeosurface 3a, layers 3 coll and 3s6-9. The datasheet further contained columns with specific fields to record the following aspects for each fragment apart from their individual weight taken in grams. The five diagnostic attributes or defining criteria with respect to bone anatomy, breakage and fracture/fragmentation patterns developed by researchers in the past were implemented in this investigation and are described below.

Fracture angle

It is defined as the angle formed by the fracture surface and the bone cortical surface. In other words, it is the percentage of right angles formed on the fracture surface with respect to the medullary cavity. Obtuse or acute angles are commonly associated with green fractures while right angles are said to be preferentially associated with dry or mineralized bone fractures (Outram, 2002; Johnson, 1985; Morlan, 1984). Three types of angles were recorded based on their visual evaluation. They were marked in the datasheet with numbers. ‘0’ was for oblique (obtuse or acute-angled) fractures, ‘1’ for fractures with variable angles and ‘2’ for right-angled fractures (Fig 3.5).

Fracture outline

It refers to the gross shape or morphology of the fracture which forms on a bone with respect to the long axis of the bone. It is sub-divided into three types, represented by numbers in the datasheet as follows- ‘0’for curved, spiral fractures or parts of spiral fractures (Potts, 1988). They appear to be V or Y-shaped or pointed/oblique fractures. Studies have shown that longitudinal fractures which run along the long axis of the bone are also produced mostly due to human bone breaking actions, hence, this type of outline was clubbed with curved fractures and denoted as ‘0’. ‘1’ was for intermediate which includes fractures that display a straight morphology running diagonally and sometimes with a stepped outline. Intermediate fractures are usually irregular as they do not follow one fracture front, but rather form an outline that change direction many times. They are generally composed of multiple helical or oblique fractures. Irregular fractures have the appearance of multiple helical or oblique fractures or their combination but maintain a helical shape in general. The fracture departs from the long axis of the bone at a <90°, subparallel angle. '2' denoted transverse fractures describing features that are straight and transverse to the long bone axis or at right angles to the axis of the bone (Fig 3.5 and 3.6).

Fracture edge

This attribute refers to the texture of the fracture margin or surface: smooth marked as '0', jagged denoted by '1'or a mix of these two attributes (Fig 3.5). Green bone breakage is said to be characterized by smooth margins and surfaces; jagged edges are found on the dry bone (Johnson, 1985; Morlan, 1984).

Shaft circumference

A characteristic feature developed by Bunn (1983) to distinguish a bone assemblage accumulated by carnivores/scavengers (complete shaft diameter) and hunter/gatherers (splinters in the majority), it concentrated on documenting the remaining or surviving length and circumference of diaphyseal fragments (Fig 3.5).

C1. Bone circumference is less than half of the original.
C2. Circumference is more than half of the original in at least a portion of the bone length.
C3. Complete circumference in at least a portion of the bone length.

Shaft length

The following classes as defined by Villa and Mahieu's classification, in assemblages with a high degree of fragmentation which divides Bunn's class 1 (less than one-half of the original) into two, was used (Valensi, 2000) (Fig 3.5).

L1- corresponds to shafts that are less than one-quarter of the original length (length here refers to shafts only, the articular end is not taken into account).
L2- is between one-quarter and one-half of the original length.
L3- is between one-half and three-quarters of the original length.
L4- is more than three-quarters of the original length, essentially a complete or almost complete shaft.

Interpretatively, when shaft length and circumference indices are crossed against each other in bar charts, high frequencies of complete diameters (class C3) appear to characterize assemblages of post-depositionally broken bones or assemblages characterized by some cylinders produced by carnivores. Bone assemblages broken by hunter/gatherers are characterized by a majority of shards (classes L1 and L2 with incomplete circumferences C1) (Villa and Mahieu, 1991; Bunn, 1983, cited in Valensi, 2000).

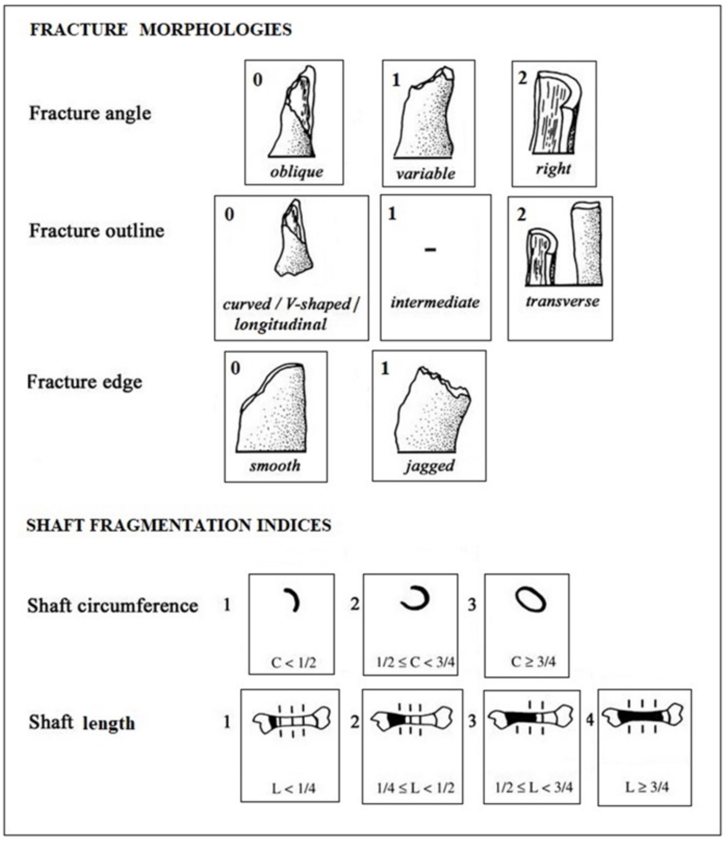


Fig 3.5: Codification for long bone fracture morphologies and shaft fragmentation indices (modified after Outram (2002; 2001; 1998), Villa and Mahieu (1991, cited in Valensi, 2000), Bunn (1984; 1983).

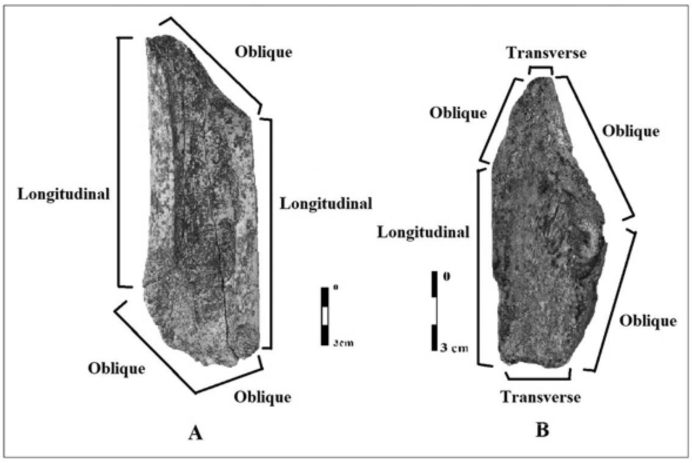


Fig 3.6: An example of diaphyseal fragments displaying oblique (A and B), longitudinal (A and B) and transverse (B) fracture outlines.

In this analysis, a diaphysis was generally found to be fractured in a manner resulting in it having four faces/planes or sides- the proximal and distal or two end fracture planes or sides and two lateral faces or sides. In several cases, there were fewer or more than the average four faces or sides. Fracture morphology criteria (angle, outline and edge) were documented for each face or side of the diaphysis fragment. Moreover, regarding fracture outline, an additional approach was also implemented, in which fracture outline exhibited by the proximal and distal ends of the fragment, denoted as ‘FI’ type and ‘F2’ type respectively, was observed and recorded according to nine frequent types of fracture outlines as elaborated by Marshall (1989, p. 14) and Grunwald (2016, p. 357) (Fig 3.7).

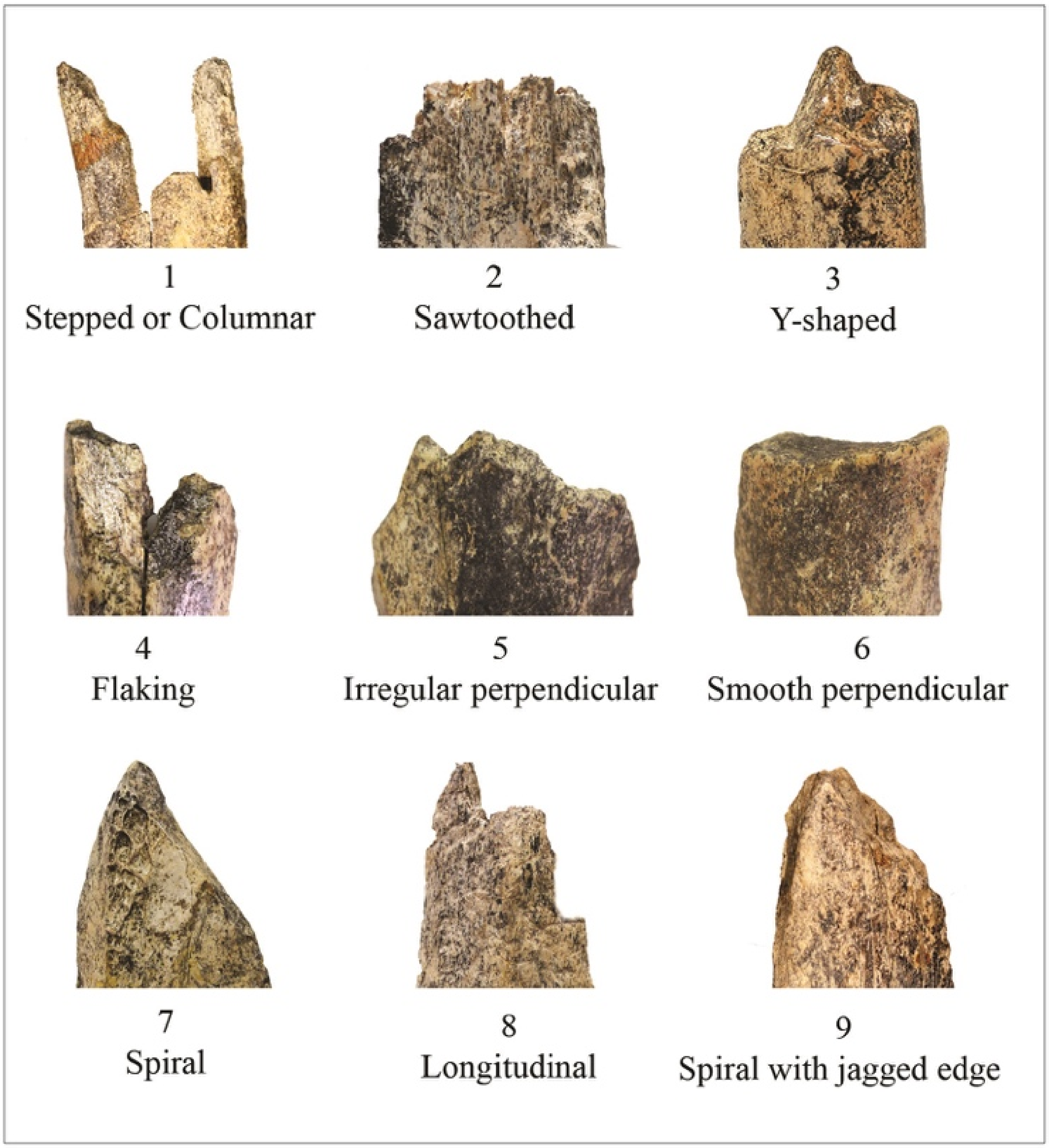


Fig 3.7: Fracture outlines (modified after Grunwald, 2016, p. 357; Marshall, 1989, p. 14).

1. Stepped or columnar: series of longitudinal breaks.
2. Saw-toothed: series of jagged breaks.
3. Y-shaped: two half-spiral fractures emerging and going downwards from a central peak.
4. Flaking: the cortical surface has the negative of a missing cortical flake bordering on the end of the fracture.
5. Irregular perpendicular: series of connected breaks that cut across the transversal plane of the shaft.
6. Smooth perpendicular: single smooth break that cuts straight across the transverse plane of the shaft.
7. Spiral: single smooth break that curves around the shaft.
8. Longitudinal: series of connected longitudinal breaks that curve around the shaft.
9. Spiral with a jagged edge: series of connected helical/spiral/diagonal breaks that curve around the shaft.

Classic fresh or green-bone fractures produce a helical or spiral fracture outline (in terms of gross morphology), where the fracture tends to be smooth and at an acute or obtuse angle to the bone's cortical surface (Outram, 2001, p. 403; Johnson, 1985; Morlan, 1984). As bones become less fresh, they develop split lines and lose their organic content, there is a greater tendency for fractures to be straight (whether diagonal, longitudinal or transverse), the fracture surface tends to be perpendicular to the cortical surface and the texture of the fracture tends to be rough. All these features tend to be present to their fullest extent in mineralized bone fractures (Outram, 2001, p. 403). Although this method reliably informs us about the condition of the bones when fractured (green or dry), it is still unable alone to inform about the agents of those fracturing events (Pickering et al., 2005, p. 249).

Diaphyseal fragments were intensively investigated for each attribute. A total count of each attribute would provide information whether they displayed fresh features, unfresh features or an amalgamation thereof. The total number of fracture planes were calculated for archaeosurface 3a, layers 3 coll and 3s6-9. Resulting data were shown as a series of histograms for each criterion in their archaeological context. The extent of fragmentation was expressed in terms of size classes versus the total number in each class and size classes versus the total mass of the number of fragments in that size class.

Freshness Fracture Index

Outram's (2002) Freshness Fracture Index (FFI) was applied to the sample from Isernia. The index was estimated by adding together scores of zero to two that were awarded for each of the criterion (fracture angle, fracture outline and fracture edge), to give a total range of zero to six. Values between zero and three represented fresh fractures whereas values between four to six represented post-depositional fractures. The mid-range value of three depicted presence of both anthropic and post-depositional fractures.

3.4 Bison dental analyses

3.4.1 Dental material

Isernia La Pineta

The current study supplemented the previous by considering dental remains recovered from the site after the conclusion of the previous study from layers 3 coll and 3s6-9 (Fig 2.1). The maxillae and mandibles (with and without teeth), isolated upper teeth and isolated lower teeth from these layers were segregated. Therefore, the squares of layer 3 coll studied by Di Nucci et al. (2006) were: 60, 64, 65, 66, 67, 68, 69, 74, 75, 76, 78, 79, 83, 84, 85, 88, 89, 93, 94, 95, 98, 99, 103, 104, 105, 107, 108, 113, 114, 115, 119, 123, 124, 125, 126, 127, 133, 134, 135, 137, 138 and 145 (Quadrant 1); 60, 61, 69, 70, 71, 78, 79, 80, 81 and 110 (Quadrant 4).

The squares incorporated in the present study were: 77, 86, 87, 96, 97, 106, 109, 116, 128, 147, 148, 156, 157, 158, 159, 166, 167, 176, 177 (Quadrant 1) and 80, 90, 91, 100 and 111 (Quadrant 4). Some squares such as numbers 88, 98, 107, 119, 137, and 138 from Quadrant 1 were common to the previous and current study. However, for tabulations and calculations, resulting in values for 3 coll from the previous and current study have been kept exclusive.

Caune de l'Arago

The dental remains for the current study were sourced from Caune de l'Arago. Bison dental remains coming from H to Q (lower levels) and levels F and G (upper levels) of the stratigraphy were separated and selected (Fig 2.3). Similar to Isernia, these included maxillae and mandibles (with and without teeth), isolated upper teeth and isolated lower teeth. The following levels were clubbed together:

1. H, I and J
2. K and L
3. M, N, O and P
4. Q

Hence, for the lower levels, there were totally four groups or units. In case of level F, there were three sub-divisions- F1, F2, and F3. Similarly, level G had four sub-divisions, namely, G1, G2, G3 and G4. These sub-divisions were studied separately during analyses and regrouped for interpretation.

3.4.2 Methods of study

The mandibular and maxillary dentition, those recovered isolated and/or in a connected series, were individually examined. Each tooth, be it an incisor or a cheek tooth, was evaluated based on certain defining qualitative and quantitative criteria. Taken into consideration were the stage of eruption, substitution of teeth; occlusal shape (macroscopic observation), enamel composition and degree of occlusal reduction; intensity of abrasion; crown height; and length and form of roots to determine various degrees of wear (Di Nucci et al., 2006; Kacimi, 2003; Moigne, 1983; Ellenberger and Baum, 1943). A summary of observations made from the above criteria led to assigning a particular degree of tooth wear to each tooth, and accordingly, the degrees were placed in an ordinal scale with seven stages described below (Table 3.1), ranging from a definable germinal tooth to specimens almost completely worn down (Forsten and Moigne, 1998, p. 319).

Table 3.1: Description of seven degrees of dental wear (modified from Di Nucci et al., 2006; Kacimi, 2003; Moigne, 1983; Ellenberger and Baum, 1943).

1	Germinal tooth in formation/undifferentiated dental bud, frequently broken, does not have root, smaller, thinner, no wear significance
2	Dental bud defined, enamel of the germinal tooth is formed, roots in formation, intact, rather small sized
3	The tooth has emerged and shows wear facets on the anterior cuspids. The roots are formed but not closed, it is seemingly intact but has started to wear. At this stage, the tooth attains its maximum height. The height can, therefore, serve as a reference height to define the wear in the following stages.
4	The profile of the wear surface becomes regular, the crown is still high, and the roots are closing, the buccal part has a triangular shape at the top, rather sharp.
5	The height of the crown is reduced by half, the occlusal surface shows small brown fossettes. The roots have closed, become longer, are well formed and thick. The buccal part intensively worn, flat
6	The height of the crown is a third or less of its initial height, the occlusal surface sometimes shows anomalies or a very oblique profile (P2); the roots are well developed, the root has bigger form than the other, the crown starts contacting the root
7	The crown is much worn, the enamel band is often interrupted, and the dentine is sometimes visible at the level of the pulp cavities. The crown almost disappears and almost reaches the root. The style cannot be distinguished. Roots appear spongy.

The various degrees of wear were consequently regrouped or categorised to form a correspondence with stages of growth. By definition, an association of degrees of wear of different teeth present on the same mandible or maxilla at a given moment in the life of that particular animal allows the establishment of different stages of growth. In fact, it has been observed that all the teeth present in a mandible or maxilla do not erupt simultaneously, nor do they wear in the same manner at the same time. In other words, teeth which erupt earlier are worn much quicker compared to the teeth which erupt later. This direct proportionality helped to create a correlation between the stage of growth and the tentative age of the animal. The age classes were generally applied in all series of the quarter jaw of teeth. However, an isolated tooth age class estimation could also be done by comparing it with the complete one.

Cornevin and Lesbre (1894) were consulted to determine the precise age of the individual through its incisors, if present, in the assemblage. Publications which aided in this study were Kacimi (2003); Lyman (1987); Klein and Cruz-Uribe (1983); Klein et al. (1981); Schmid (1972); Frison and Reher (1970); Fuller (1959). A synthesis of the degree of wear and stage of growth contributed to the formation of 'age classes'. There were seven age classes determined- infantile, juvenile, subadult, adult1, adult 2, adult 3 and senile.

To reinforce this study, several supplementary methods were devised when necessary. For the study of the style of deciduous premolars and permanent molars, a codification was devised. The height of the style at younger age classes was denoted with numbers 1, 2 and 3 for its growth from the base of the tooth to the occlusal surface of the tooth, respectively. After having reached the occlusal surface, the various phases of growth of the style into a circle and ultimately into a loop were also ascribed successive numbers (Fig 3.8). The overall height of the tooth was described as high (H), medium (M) and low (L) whereas the edges of the cusps were described as sharp (S), round (R) and flat (F).

Wherever possible, associations leading to refitting between remains documented in the excavation with different individual accession numbers was successfully attempted. These associations were established and confirmed after much comparison of the age class defining criteria for remains and the proximity of their provenance with the aid of 3-dimensional spatial visualisations. They were assigned a unique "association number" and registered in a different book. Associations were done only if the remains which could be refitted belonged to the same level and were not very far from each other in terms of their position when exposed during the excavation. If this criterion was not satisfied, they were considered as fragments coming from separate individuals and counted separately. This method not only helped to reconstruct complete or nearly complete maxilla and/or mandible and fill the missing teeth or gaps in the skeletal parts, but it also helped to reduce/avoid overestimation of the minimum number of individuals for these archaeological levels/layers. Macro photographs of every dental remain were taken from its occlusal, lingual, buccal, mesial and distal orientation.

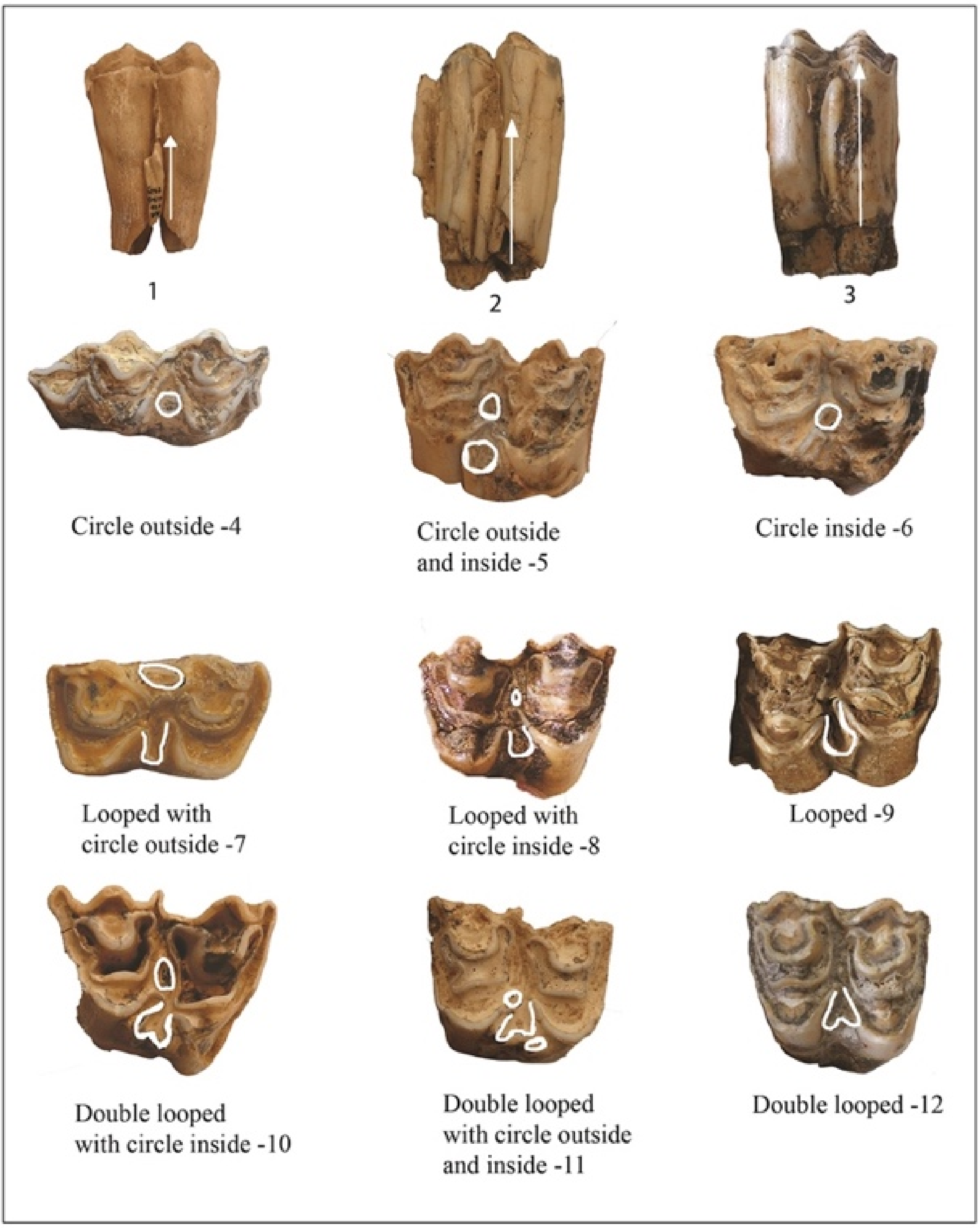


Fig 3.8: Style wear codification (not to scale).

The data was entered in MS Excel with separate sheets for lower right, lower left, upper right and upper left dentition respectively. In each excel sheet, the rows comprised the different age classes and the columns were assigned to each tooth type (deciduous and permanent dentition – incisors, premolars and molars). After studying an isolated tooth, for example, it was assigned a degree of wear and age class. If possible the age, in months or years, was estimated. Subsequently, the registration number of the tooth taken as an example was written in the row and column corresponding to the result of its analysis. The degree of wear was entered alongside the registration number of the tooth accompanied by a photograph of its occlusal view in that particular excel cell.

It was from the study of stages of growth that the possibility of investigating the mode and stage of the eruption of the tooth, the period of replacement of deciduous dentition with permanent dentition was enhanced. The minimum number of individuals (MNI) was calculated based on the above criteria. Further, the mortality profile of bison considering different age classes was obtained by visualising the MNI in the form of graphs.

3.5 GIS

GIS, applied in the archaeological context at Isernia, can perform simple and complex operations. For instance, it superimposes geological data and site type and combines both two-dimensional and three-dimensional data. However, for all the operations it is necessary to organize attributes in databases which can be read using relational database management systems. The attributes are organized in databases (Access, DB, Oracle, Informix, Filemaker Pro) that can be consulted through a special interface. A database record identifies an object, described by various fields containing numeric, logical (yes / no) or text (strings) information. Databases, whether containing vector or raster data, are read in tabular formats based on identification codes. Lembo (2014, p. 46) states, *"there must be a correspondence between the identification codes, i.e. the graphic element must possess a code common to corresponding database, in order to allow its association. The GIS functions allow a direct connection between the geographic system and the database. The query aimed at the search and selection of information, is a fundamental prerogative of the grammar of the GIS. The presence of a query field, an operator and a value allow to execute an SQL* (Gallotti, 2004)".

For this study, the faunal analyses data, present in MS Access database, was imported to MS Excel and modified to make it compatible with QGIS. In order to highlight a specific variable or phenomenon of alteration in detail, frequency maps were created. Creation of such maps was made possible through the power of SQL (Structured Query Language) of QGIS. The remains were grouped and counted per square not by querying the database, but by using the typological functions of GIS. An SQL procedure, starting from the topological overlay of the base of the excavation grid of 1 x 1 m on the thematic levels, automatically calculated the number of objects whose centroid fell in each reference square. This resulted in a new table comprising two fields, one containing the name of the square and the other containing the number of objects enclosed in it. This new table, always through SQL query, was connected to the table of the reference grid. By matching the names of squares, a new map was generated, in which were displayed the squares that contained at least one object. This new map was processed through the ‘create thematic map’ function and it generated a frequency map for a range of values. Each square was patterned according to a graduated colour scale depending on the range of values in which it fell. The intervals were created automatically or manually. The intersection of different frequency maps allowed the creation of relationship maps, in which using the form of a graph, the relationships between the number of remains of different categories contained in a square were created. Invariably, through SQL query, it was possible to connect by means of the square number, tables of several frequency maps related to various types of remains. As an example, the degree of intensity and localization, in case of taphonomic variables such as weathering, erosion and exfoliation, was denoted by ‘1’ if present and ‘0’ if absent. These agents either acted exclusively or in combination with each other. If they acted together, eight combinations (000, 100, 010, 001, 110, 101, 011 and 111) were possible which are shown on the map with different shades of the same colour.

3.6 Quantitative methods

The taphonomical and archaeozoological study integrates diverse approaches including quantifying the faunal remains recovered from the site to fulfil many objectives and make comparative interpretations. These include expressing the relative richness/abundance in faunal remains from particular proveniences, assessing the relative richness/abundance of particular taxa (or other categories, such as age or element), estimating the absolute nutritional or other value of the resources, indicating the statistical significance of any gaps in the range of materials that are represented in the assemblage and assessing changes in the characteristics of a particular population through time (www.sandiegoarchaeology.org). In this work, some primary methods elaborated below by which the relative proportions of animal bones belonging to different taxonomic categories can be quantified were used.

Relative frequencies of taxa

The number of identified specimens (NISp) and the minimum number of individuals (MNI) is used to estimate relative frequencies of taxa in faunal assemblages. Relative frequencies permit synchronic and diachronic exploration of environmental fluctuations, successions, taphonomy, recovery and sampling biases, and cultural differences. They are most commonly used to augment age and sex ratios, to identify specialized sites or activity areas, and to compare animal use by distinctive social groups through time and space. They also are used to evaluate the relative importance of animals in diets obtained through various subsistence strategies and are related to the number of identifiable elements in each animal, site-formation processes, recovery techniques, and laboratory procedures (Reitz and Wing, 2008, p. 202).

NISp (Number of Identified Specimens)

The most fundamental Unit by which faunal remains are tallied is the number of identified specimens, or NISp, the number of skeletal elements (bones and teeth) and fragments thereof – all specimens – identified as to the taxon they represent (Lyman, 2008). (For a detailed discussion on its applicability, advantages and disadvantages see Lyman, 2008; Reitz and Wing, 2008). Some remains which were only determined anatomically but not taxonomically were placed in the 'NRDa' category, a term used by Anconetani (1996).

MNI (Minimum Number of Individuals)

It is a method of assessing species abundance in faunal assemblages based on a calculation of the smallest number of animals necessary to account for all the identified bones within a particular taxon found on the site. It is usually calculated from the most abundant bone or tooth from either the left or right side of the animal (www.webref.org). Derivation of MNI can be done using several methods (for detailed analysis of this method see Lyman, 2008; Reitz and Wing, 2008). Two variations or rather possibilities were utilised in the calculation of MNI in this research. In this study, the combination method, which calculates the most abundant element with laterality, age, sex and size variations are taken into consideration, was used to arrive at the MNI value. Although in some cases the MNI frequency (counted as the most abundant element with laterality taken into consideration) equalled the MNI combination (Poplin, 1976), in some, whenever possible, individuals were added to the MNI frequency to arrive at the MNI combination value.

3.7 Study of unidentified remains

The layers 3 coll and 3s6-9 have also yielded thousands of fragments beyond the level of taxonomic and anatomic identification. Due to the paucity of time and restricted scope of this research work, these remains were quantified by mere counting. They have also been subjected to a spatial analysis.

Chapter 4

Results from archaeosurface 3a

4.1 Characteristics of the faunal assemblage

This chapter discusses in detail the results obtained from the archaeozoological and taphonomical analyses of the large mammal remains from archaeosurface 3a of Isernia following the methodology described in chapter 3. These remains are essentially those that were recovered from the excavation years 2000 to 2003 and had previously not been analysed as they were undergoing restoration. The information from these remains have at present not been synthesised with the results from the previous archaeofaunal analyses of this archaeosurface as a part of the archaeosurface 3a material has been recomposed in the on-site museum. As such, the number of remains for the current study is few and hence the calculation of Minimum Number of Individuals and spatial distribution analyses using GIS was not done. However, there is scope for this work in the future.

The faunal assemblage from 3a consisted of **61** remains (Table 4.1). The total number of determined remains were 37 (60.7%). The anatomically determined remains were 21 (34.4%). whereas the remains both taxonomically and anatomically determined were 16 (26.3%). The unidentified remains amounted to 24 (39.3%). The data evidently shows that the percentage of taxonomically and anatomically determined remains (NRDt% or NISp%) is much lesser than the percentage of the total number of determined remains (NRD%). The remains which were determined only anatomically are more numerous. The number of unidentified remains was lesser than identified remains which indicated that the remains were not very fragmented and still had some well-preserved diagnostic morphological features to be able to attribute them anatomically and taxonomically.

Table 4.1: Isernia La Pineta 3a: Composition of faunal assemblage.

TR	**Unidentified**	**%**	**NRD**	**%**	**NRDa**	**%**	**NRDt (NISp)**	**%**
61	24	39.3	37	60.7	21	34.4	16	26.3

The remains which were only anatomically determined (NRDa - 21) were dominated by cranial, rib and diaphyseal portions, each contributing 19% to the assemblage. They were followed by metaphyseal fragments (14.3%); mandible, vertebrae, pelvis, femur and epiphyseal ends contributing less than 10% each (Table 4.2). These anatomically determined remains were of the medium to large size classes of animals but not attributable to the very large size of fauna such as elephants. Unidentified remains were 24 in total (39.3%) of the assemblage.

Table 4.2: Isernia La Pineta 3a: Distribution of the number of remains by anatomic segment (not determined taxonomically) (NRDa 21).

Anatomical element	NRDa	NRDa%
Cranium	4	19.0
Mandible	1	4.8
Vertebra	1	4.8
Rib	4	19.0
Pelvis	1	4.8
Femur	2	9.5
Diaphysis	4	19.0
Epiphysis	1	4.8
Metaphysis	3	14.3
Total	**21**	**100.0**

The number of remains determined taxonomically and anatomically amounted to 16 (26.3% of the total number of remains). The ungulates, in particular, the Order Artiodactyla, were clearly dominant over the other Orders in the assemblage (Fig 4.1). More precisely, they contributed 68.9%, while the Order Proboscidea, with the species *Palaeoloxodon antiquus*, contributed to 12.5% of the determined remains in the assemblage. The Order Perissodactyla and Carnivora had equal representation, with the species *Stephanorhinus hundsheimensis* and *Ursus deningeri* respectively, both being represented by 6.3% of the determined remains.

4.2 The faunal spectra

Overall, the most represented taxon within the fauna assemblage was (Fig 4.1) *Bison schoetensacki* (56.3%). It was well-represented by both axial and appendicular elements (Fig 4.2). *Palaeoloxodon antiquus* (12.5%) was the next most represented species. There were two remains attributed to it, a vertebra and a rib. *Ursus deningeri*, *Stephanorhinus hundsheimensis* and *Praemegaceros solilhacus*, each had one remain (6.3%) attributed to them. A left M_3, a left fourth metatarsal and a right mandible fragment with P_2, P_3 and M_1 were attributed to them respectively. A fragment of antler was attributed to Cervidae (6.3%) while a rib fragment was placed in the Ungulate category (Figs 4.1 and 4.2).

4.3 State of integrity

The state of integrity was unidentified for 54 remains which represented 88.5% of the sample examined, forming the majority. For the remaining 11.5%, it was possible to specify the precise position and placement of the fragment with respect to the whole bone. In order of abundance: two fragments were of the posterior from left laterality (1.6%), while one fragment was the proximal part of the bone (1.6%), one was incomplete (1.6%) and three were complete (4.9%) (Table 4.3).

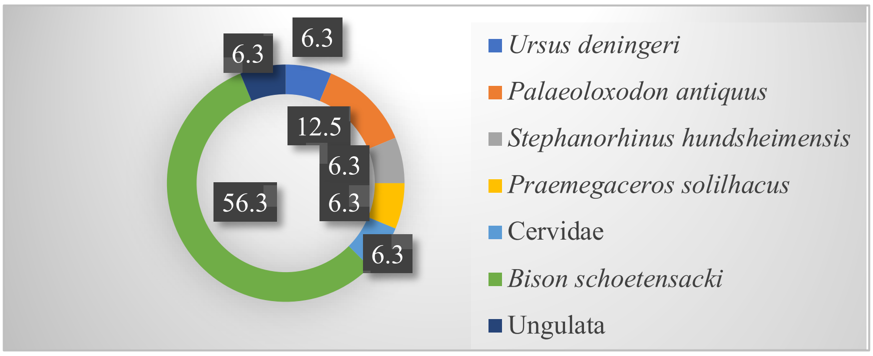


Fig 4.1: Isernia La Pineta 3a: Representation of faunal remains (NRDt/NISp-16).

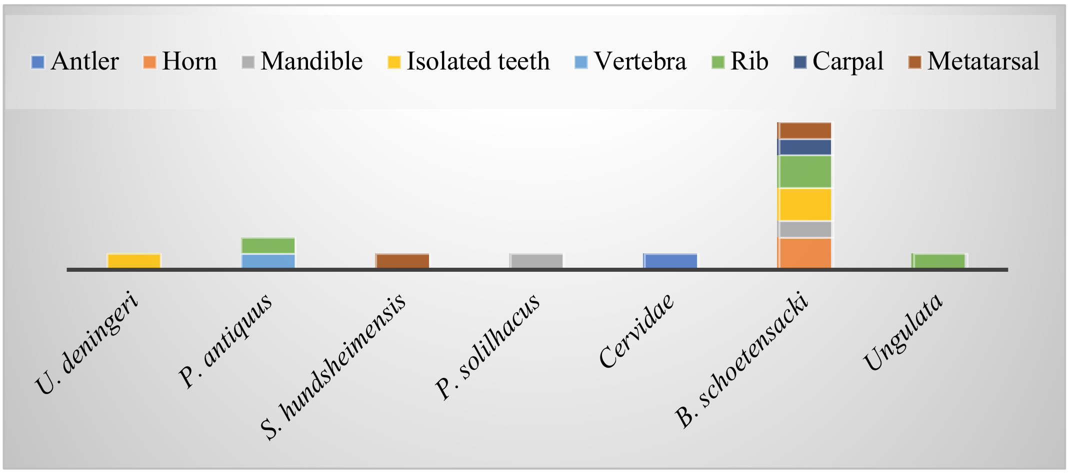


Fig 4.2: Isernia La Pineta 3a: Distribution of anatomical elements of determined taxa.

Table 4.3: Isernia La Pineta 3a: Distribution of remains based on their state of integrity (NR 61).

State of integrity	NR
Indeterminable	54
Complete	3
Incomplete	1
Proximal fragment	1
Left posterior fragment	2

4.4 Taphonomic analyses

To better understand the processes that impacted the faunal remains from their death, discard to discovery in an archaeological excavation, their taphonomic analysis was carried out at a macroscopic and microscopic level. The taphonomic analysis of the remains aimed at assessing the conservation status of the bone surfaces yielded interesting information.

4.4.1 Non-anthropic modifications

The faunal remains from 3a demonstrated several types of modifications imputable to natural factors. Weathering was absent in 25 remains whereas 28 remains were lightly weathered. Medium weathering was seen on eight remains, mostly rib fragments. Erosion was absent in 23 remains, light erosion was seen in 12 remains and 22 remains had marked erosion. Diffused erosion was documented on four remains. Exfoliation was absent in 57 remains whereas only four remains had light exfoliation. The oxides had also impacted the remains. Only two remains did not exhibit any deposits of oxides or discolouration. While one fragment had only manganese oxide on it, 58 fragments had both manganese and iron oxides on them. Root etchings were absent on 59 remains whereas only one remain had light impressions. Marked root etchings were seen on two remains. Rounding was absent in 13 remains. Long bones, ribs and unidentified remains showed light rounding. Similarly, mostly long bones and rib fragments, 28 in all, showed medium rounding.

No carnivore/rodent marks were present on the remains. Post-depositional and weathering related fractures were present on 49 remains. Merely four remains were devoid of any fractures. They were mostly teeth and carpals or tarsals. Marks attributed to trampling and abrasion were observed on 32 remains. Almost the same number of remains were devoid of such marks.

4.4.2 Anthropic modifications

Modifications caused by the impact of different carcass processing activities, anthropic in origin, were documented on these remains. Although no cut marks by lithic tools were confirmed, other pieces of evidence such as percussion notches (NR 2) and anthropic fractures (NR 8) were recorded. The two notches, on opposite borders at the same height, were present on a left femur diaphysis of an unidentified taxon. Both notches had linear-concave borders at acute angles.

Fracture analyses

Long bone fractures were investigated further. The distribution of portions of various identified and unidentified long bones, totally nine in number revealed that the diaphysis of femur nad unidentified long bones were better represented than others (Fig 4.3). Only two long bones, femur and metatarsal, were identified anatomically. Whole or complete long bones were not present in the assemblage. Out of the nine, two were epiphyseal portions so they were excluded from the fracture analysis. When compared to epiphysis, there was a 35% increase in representation of diaphyses.

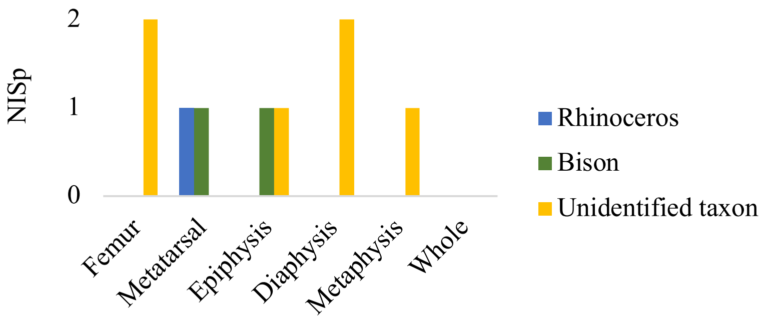


Fig 4.3: Isernia 3a: Frequency distribution identified and unidentified long bones (NR 9).

On the remaining seven remains, their shaft length and circumference was observed (Fig 4.4). The analysis showed that majority of the diaphyses had circumferences less than half of the original, hence C1 was more. Diaphyses with a shaft circumference more than half of the original in at least a portion of the bone length, C2, were none. The diaphyses with C3, complete circumference in at least a portion of the bone length, were fewer than C1. In case of the shaft length index, more number of diaphyses were in the classes of L1 and L3. The long bone shafts were mostly less than one-quarter of the original length or between one-half and three quarters. There was not a single diaphysis which was complete or almost complete. The long bones of identified taxa, rhinoceros and bison, had characteristics similar to bone assemblages created by hunting groups. They had a shaft circumference of either C1 or C3 and the shaft length was L1. In case of diaphyses with taxon not determined, the shaft circumference was always C1 and shaft lengths ranged between L1 and L3 similar to bone assemblages created by hunting groups.

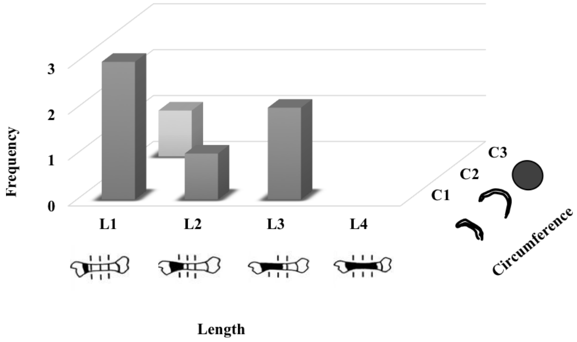


Fig 4.4: Isernia La Pineta 3a: Shaft fragmentation index length (L) vs circumference (C) of diaphyses fragments (NR 7).

The extent of fragmentation was analysed in terms of number and mass with respect to size classes (Fig 4.5). It revealed differences in results when a constant variable, in this case- size classes, was quantified according to frequency and mass. In the graph-A, it was clear that most of the fragments were between 5 - 13 cm. Diaphyses fragments in the larger size categories were fewer. As the size in terms of length increased, the number of fragments decreased. When size classes were quantified in terms of mass, it was observed from the graph- B that fragments in the 5 - 9 cm size class relatively represented lesser amount of bone than fragments in the 17 - 21 cm size class which represented greater amount of bone. The fragments of large size were few but weighed more as they probably belonged to adult individuals of large size taxa category.

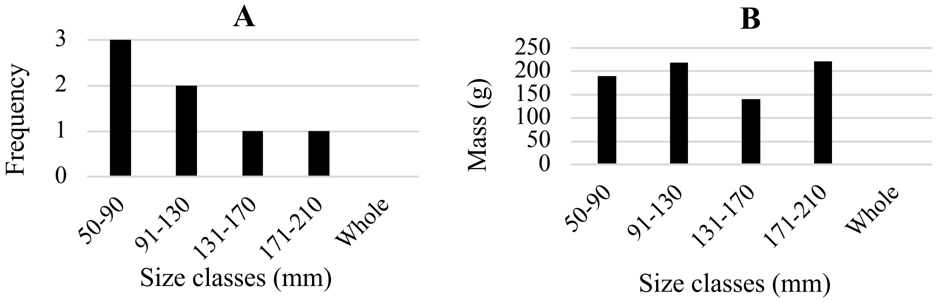


Fig 4.5: Isernia La Pineta 3a: Proportions of diaphyses fragments in different size classes quantified by A - number and B- mass (NR 7).

An analysis of the fracture type was conducted on the 13 proximal and distal ends of the seven diaphyses. Some diaphyses still had an intact or partially intact epiphysis so they had only one fractured end. An analysis of the fracture type of the seven diaphyses showed that the spiral fracture type, characteristic of bones with anthropic fractures, was the dominant type (Fig 4.6). This type of fracture was present on 10 diaphyses. While seven had a smooth edge, three had a slightly jagged edge. One diaphysis had a smooth perpendicular fracture and another had a flaking fracture type, also due to possible anthropic activity. The remaining diaphysis had a fracture type typical of post-depositional breakage such as irregular perpendicular.

The fracture angle, outline and edge of the seven diaphyses along all their fracture planes/surfaces revealed an interesting and mixed pattern (Fig 4.7). A total of 26 fracture planes from the seven diaphyses were analysed for these criteria. Five diaphyses had four fracture planes, one diaphysis had five fracture planes and one diaphysis had one fracture plane as the other end was the epiphyseal end. While the fracture outline analyses showed clearly that more than 20 fracture planes demonstrated characteristics of anthropic breakage since they had a curved or longitudinal outline, the other two outlines- transverse and intermediate were seen on less than five fracture planes. However, in terms of fracture angle and edge, it was clear that in case of these two criteria, the diaphyses demonstrated a mix of both anthropic and post-depositional fractures. It can also be inferred that the original anthropic fractures have been altered by post-depositional fractures and the latter have obliterated evidence of the former. Right angles in fractures were more than oblique or variable angles. Jagged edges, a diagnostic criterion for post-depositional fractures was almost the same in number as smooth edges- a diagnostic criterion for anthropic breakage

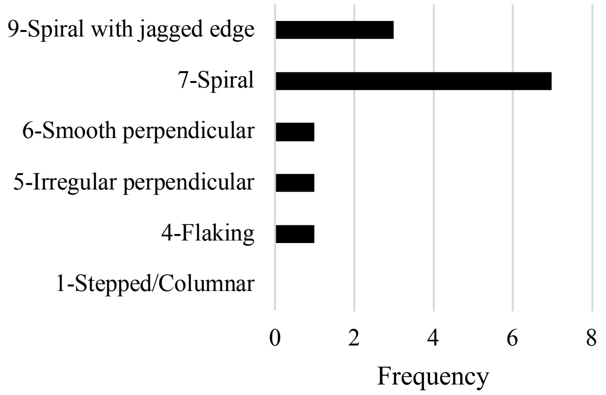


Fig 4.6: Isernia La Pineta 3a: Relative frequencies of different fracture types on diaphyses fragments.

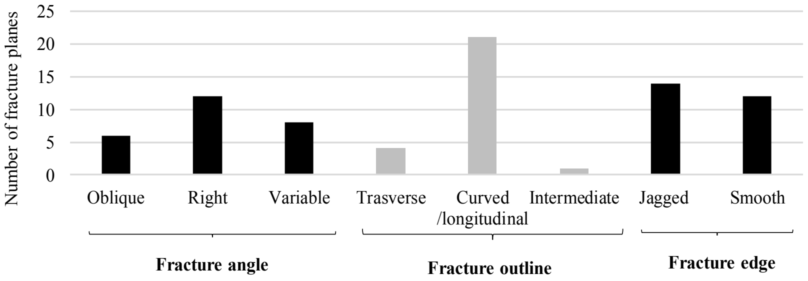


Fig 4.7: Isernia La Pineta 3a: Relative frequencies of fracture angles, outlines and edges of diaphyses fragments.

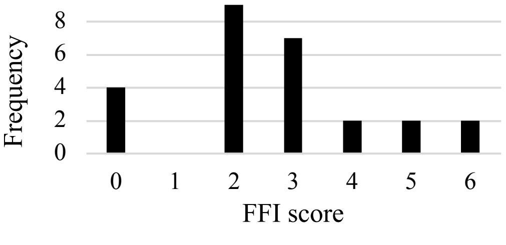


Fig 4.8: Isernia La Pineta 3a: Number of diaphyses fragments assigned different fresh fracture index scores.

The freshness fracture index for the 26 fracture planes from seven diaphyses also revealed a similar picture (Fig 4.8). The sum of scores assigned to the criteria described above (fracture angle, fracture outline and fracture edge) gave a range of values from 0 - 6. From the graph (Fig 4.8), it was observed that 13 fracture planes gave a score of either 0 or 2. These planes clearly demonstrated characteristics of anthropic breakage. With a score of 3, seven fracture planes demonstrated characteristics with a mix of both anthropic and post-depositional fracturation. Scores of 4, 5 and 6 calculated from six fracture planes definitely showed all characteristic signs of post-depositional fracture.

Chapter 5

Results from layer 3 colluvium

5.1 Characteristics of the faunal assemblage

This chapter discusses in elaboration the results obtained from the archaeozoological, taphonomical and spatial distribution analyses of the remains of large mammals from layer 3 coll of Isernia, following the methodology described in chapter 3. The spatial distribution of all recorded recovered remains- limestone, flint, bone and travertine, from the excavated layer 3 coll (Fig 5.1A) showed that they were dispersed over the entire floor in no particular pattern. There were some areas of dense concentration alternating with areas of sparse concentration of remains. Most of the remains, however, appeared to be present in larger numbers in the central, north western, north eastern, western and southern squares. Large bone fragments were conspicuous in the south-western, southern and north-eastern areas. The spatial distribution map of only faunal remains, excluding other remains, revealed some patterns of distribution (Fig 5.1B). It illustrated a non-uniform distribution of all faunal remains analysed till present. The concentration of remains alternately ranged from being relatively homogenous in the central and eastern parts of the excavated area to a gradual increase in density towards the southern limit. The western and south-western periphery revealed the sparse accumulation of remains. Small circular gaps in the central and south central part exist because the remains recovered from there are currently under analyses. Gaps or holes present in certain squares in these two maps represent squares that have not been excavated, pillars of an old structure that covered the site, faunal material that is yet to be restored and remains from 2017 excavation season which is yet to be analysed. The faunal assemblage analysed for the present study does not include them, hence, in the subsequent spatial distribution maps only the faunal assemblage taken up for this study have been depicted. The faunal study, furthermore, excluded some remains which were recovered during the sorting of washed sediments of layer 3 coll, termed as 'non-coordinated' since their X, Y and Z values were not recorded.

The faunal assemblage of large mammals from 3 coll consisted of **6167** remains (Table 5.1 and Fig 5.2). The total number of determined remains were 3628 (58.8%). The anatomically determined remains without taxonomic specificity were 2522 (40.9%) whereas the remains both taxonomically and anatomically determined were 1107 (17.9%). The unidentified remains amounted to 2538 (41.1%). The spatial distribution of unidentified faunal remains did not elucidate any particular pattern. The unidentified remains were concentrated specifically in the southern area of the excavated floor (Fig 5.4A). In the rest of the areas, they were distributed in lesser concentrations. The data evidently shows that the percentage of taxonomically and anatomically determined remains (NRDt (NISp) %) is much lesser than the percentage of the total number of determined remains (NRD%).

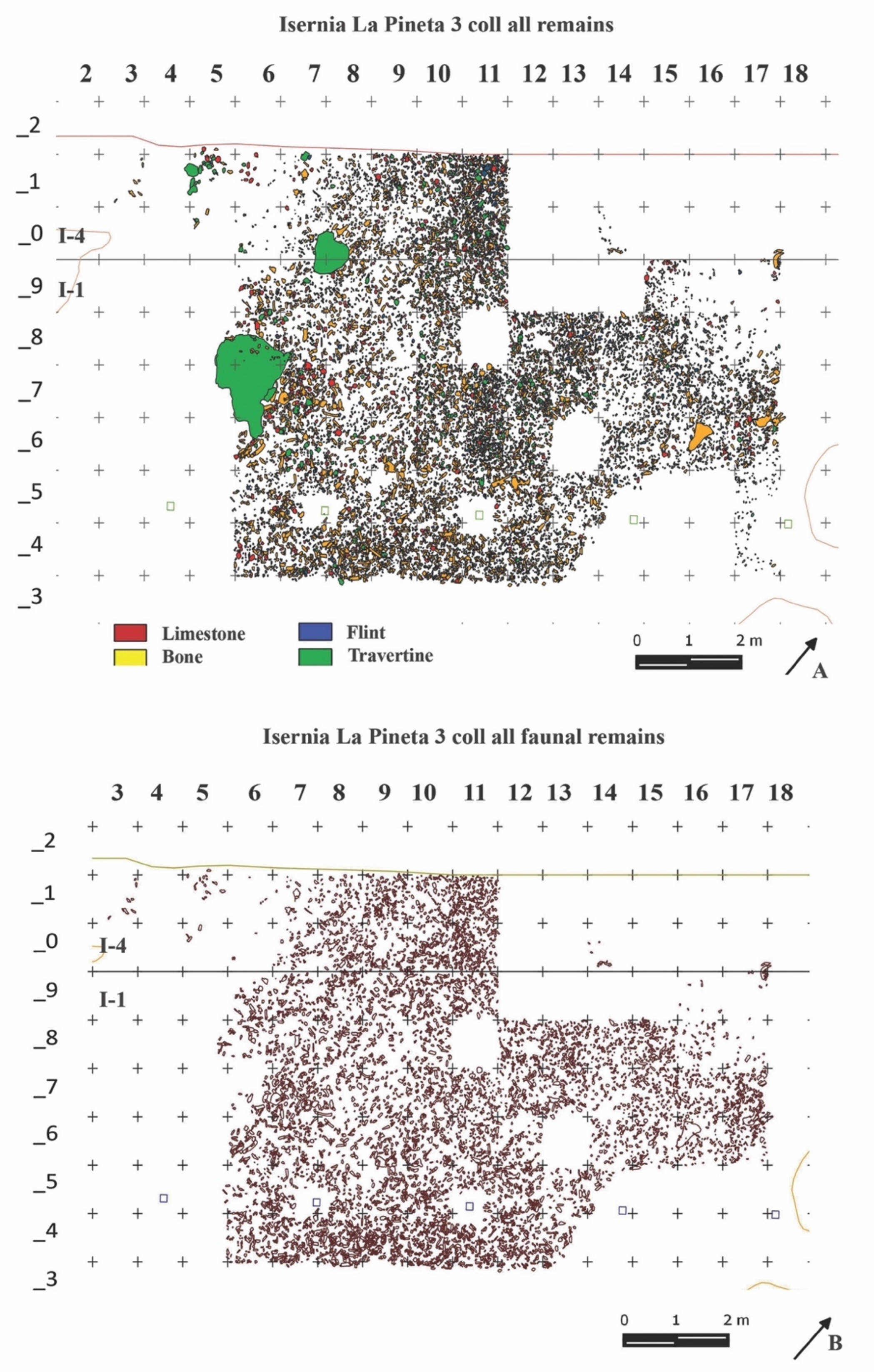


Fig: 5.1: Isernia La Pineta 3 coll: A- Spatial distribution of all remains; B- Spatial distribution of all faunal remains.

The remains which were determined only anatomically were more numerous. This disparity is by virtue of the state of integrity that characterizes the remains, which, in a majority of the cases, are very fragmented. The remains which were only anatomically determined (NRDa - 2522) were dominated by diaphyseal portions (52.8%), rib (13.8%), cranium (9.6%) while the remaining anatomical parts contributed less than 9% each (Table 5.2).These anatomically determined remains were of the medium to large size classes of animals but not attributable to the very large size of fauna such as elephants.

Table 5.1: Isernia La Pineta 3 coll: Composition of the faunal assemblage.

TR	**Unidentified**	**%**	**NRD**	**%**	**NRDa**	**%**	**NRDt (NISp)**	**%**
6167	2538	41.1	3628	58.8	2522	40.9	1107	17.9

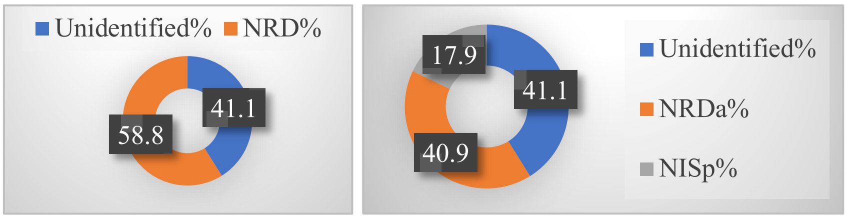


Fig 5.2: Isernia La Pineta 3 coll: Representation of the faunal assemblage.

The number of remains determined taxonomically and anatomically amounted to 1107 with a percentage of 17.9 of the total number of remains. A varied spectra comprising 4 Orders, 7 Families, 11 Genera and 10 Species embody this faunal assemblage. The ungulates, in particular, the Order Artiodactyla, were clearly dominant over the other Orders in the assemblage (Fig 5.3). More precisely, they contributed 55.4%, while the Order Perissodactyla, with the species *Stephanorhinus hundsheimensis*, was represented by 17.8%. The carnivores were the next better represented with a percentage of 14.3% of the assemblage. The determined carnivores were the bear (*Ursus deningeri*) and the leopard (*Panthera pardus*). The Order Proboscidea, with the species *Palaeoloxodon antiquus*, contributed to 12.4% of the assemblage.

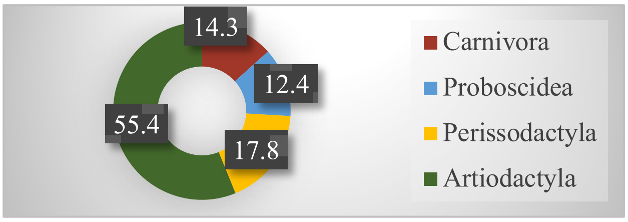


Fig 5.3: Isernia La Pineta 3 coll. Representation of faunal remains (NISp-982).

Table 5.2: Isernia La Pineta 3 coll: Distribution of the number of remains by anatomical segment (not determined taxonomically) (NRDa 2522).

Anatomical element	**NRDa**	**NRDa%**
Antler	5	0.2
Horn	9	0.4
Cranium	243	9.6
Mandible	47	1.9
Isolated teeth	147	5.8
Vertebra	57	2.3
Rib	347	13.8
Scapula	34	1.3
Humerus	29	1.1
Radio-ulna	2	0.1
Ulna	9	0.4
Radius	15	0.6
Carpal	4	0.2
Metacarpal	3	0.1
Pelvis	21	0.8
Femur	22	0.9
Patella	1	0.0
Tibia	35	1.4
Fibula	5	0.2
Tibia/fibula	1	0.0
Tarsal	2	0.1
Metatarsal	2	0.1
Diaphysis	1332	52.8
Epiphysis	55	2.2
Metapodium	26	1.0
Sesamoid	3	0.1
Carpal/tarsal	6	0.2
Phalanx indeterminate	4	0.2
Metaphysis	56	2.2
Total	**2522**	**100**

5.2 The faunal spectra

Overall, the most represented taxa within the fauna assemblage were *Bison schoetensacki* (42%), *Stephanorhinus hundsheimensis* (15.8%), *Ursus deningeri* (11.8%) and *Palaeoloxodon antiquus* (11 %) (Table 5.3). There were a few fragments categorised as 'Artiodactyla' (1.4%), a category that was chiefly composed of fragments of long bone diaphyses. Similarly, some remains attributable to a few anatomical parts probably belonged to bison or rhinoceros, but for the lack of diagnostic morphological features, it was not possible to specify the genus or species. Hence, they were placed in the ‘Ungulata’ category and represented 9.9% of the assemblage. Among the artiodactyls were also the remains of indeterminate cervids, with a percentage of 4.4%. The remaining identified taxa contributed in lesser percentages to the total NISp. In terms of the number of individuals that make up the remains of each species, 23individuals were estimated (Table 5.3). *Bison schoetensacki* (6, 25%) was closely followed by *Stephanorhinus hundsheimensis* (5, 20.8%) while *Ursus deningeri* and *Palaeoloxodon antiquus* were represented by the same number of individuals (2, 8.3%). The rest of the species had just one individual each. The spatial distribution of the anatomically determined remains of the four major species with better representation than the other taxa on the excavated floor showed that they were mainly concentrated in the southern, south western and a little in the central areas (Fig 5.4B).

Table 5.3: Isernia La Pineta 3 coll: Summary of faunal composition.

Order	**Family**	**Taxon**	**NISp**	**%**	**MNI**	**%**
Carnivora	Ursidae	*Ursus deningeri*	131	11.8	2	8.7
	Felidae	*Panthera pardus*	1	0.1	1	4.3
		Carnivora	10	0.9		
Proboscidea	Elephantidae	*Palaeoloxodon antiquus*	122	11.0	2	8.7
Perissodactyla	Rhinocerotidae	*Stephanorhinus hundsheimensis*	175	15.8	5	21.7
Artiodactyla	Hippopotamidae	*Hippopotamus* cf. *antiquus*	9	0.8	1	4.3
	Suidae	*Sus scrofa*	3	0.3	1	4.3
	Cervidae	*Praemegaceros solilhacus*	8	0.7	1	4.3
		Cervus elaphus cf. *acoronatus*	4	0.4	1	4.3
		Dama cf. *D. roberti*	1	0.1	1	4.3
		Capreolus sp.	1	0.1	1	4.3
		Cervidae	49	4.4	2	8.7
	Bovidae	*Bison schoetensacki*	465	42.0	6	26.1
		Hemitragus cf. *bonali*	4	0.4	1	4.3
Artiodactyla			15	1.4		
Ungulata			109	9.9		
Total NISp and MNI			**1107**	**100.0**	**23**	**100.0**

Bison schoetensacki FREUDENBERG 1910

The most represented species in the faunal assemblage of 3 coll was the bison (*Bison schoetensacki*), with 465 remains determined for a percentage of 42 (Tables 5.3 and 5.4) of the total NISp.

Table 5.4: Isernia La Pineta 3 coll: Distribution of anatomical elements of all taxa.

Anatomical element	**Bear**	**Elephant**	**Rhinoceros**	**Hippopotamus**	**Wild boar**	**Giant deer**	**Red deer**	**Fallow deer**	**Roe deer**	**Bison**	**Tahr**
Antler						2	1				
Horn										3	
Cranium	8		9	1						20	
Mandible	15		7		2	1				39	
Isolated teeth	63	107	108	7	1	3	1			140	2
Hyoid		1								1	
Vertebra	3	3	1							19	
Rib	1		1							16	
Scapula								1		13	
Humerus		1	1						1	25	
Radio-ulna										5	
Ulna										6	
Radius										11	
Carpal	1		2							10	
Metacarpal	2									8	
Anterior phalanx	5	1	8				1			10	
Pelvis										8	
Femur			1							16	
Patella	2										
Tibia			1			2	1			31	
Fibula			1							2	
Tibia/fibula										1	
Tarsal	6	1	6	1						16	1
Metatarsal	6		6							9	
Posterior phalanx	1		4							6	
Diaphysis		7								2	
Epiphysis										1	
Metapodium	2		3							13	
Sesamoid	1	1								6	
Os penis	1										
Malleolare										4	
Carpal/tarsal			2							1	
Phalanx inderterminate	14		14							22	1
Metaphysis										1	
Total	**131**	**122**	**175**	**9**	**3**	**8**	**4**	**1**	**1**	**465**	**4**

In particular, the most abundant anatomical part corresponded to the isolated teeth with 140 remains, which contributed to 30.1% of the total NISp for this species. Following them were the fragments of the mandible, 39 in all, which made up 8.3% of the total NISp for this species (Plate 1A). There were also 20 fragments of the cranium. The axial skeleton was represented by 16 ribs, 19 vertebrae, 13 scapulae (Plate 1B) and eight pelvic fragments. The appendicular skeleton was represented by the anterior and posterior limbs, of which, the fragments of the tibia were more abundant with 31 remains (6.6%) of the total NISp of this species. It was followed by 25 humeri (5.3%), and 16 femurs (3.4%). The other anatomical elements had scarce representation.

Remains which were complete and incomplete were 35 in sum and were mainly teeth, vertebrae, ribs, scapula, carpals, tarsals and phalanges. A large amount of dental remains recovered and their good state of preservation and integrity allowed the calculation of the Minimum Number of Individuals (MNI). All three molars were taken into consideration: in particular, there were four right M_3 and four left M_3 which gave an MNI of 4. However, there were also present six right and left M^3 which gave an MNI of six. The calculation of the MNI on the basis of the other anatomical elements returned values lower than 6. Moreover, the high fragmentation of the elements of the post-cranial skeleton and the impossibility to specify their precise anatomical position, rendered them unreliable in the calculation of the MNI. The spatial distribution of bison remains on the excavated floor of the layer showed that they were mainly present in the southern areas and their concentration further reduced as they moved westwards and northwards. Larger remains of bison were found in the southern squares and south central squares. (Fig 5.4B).

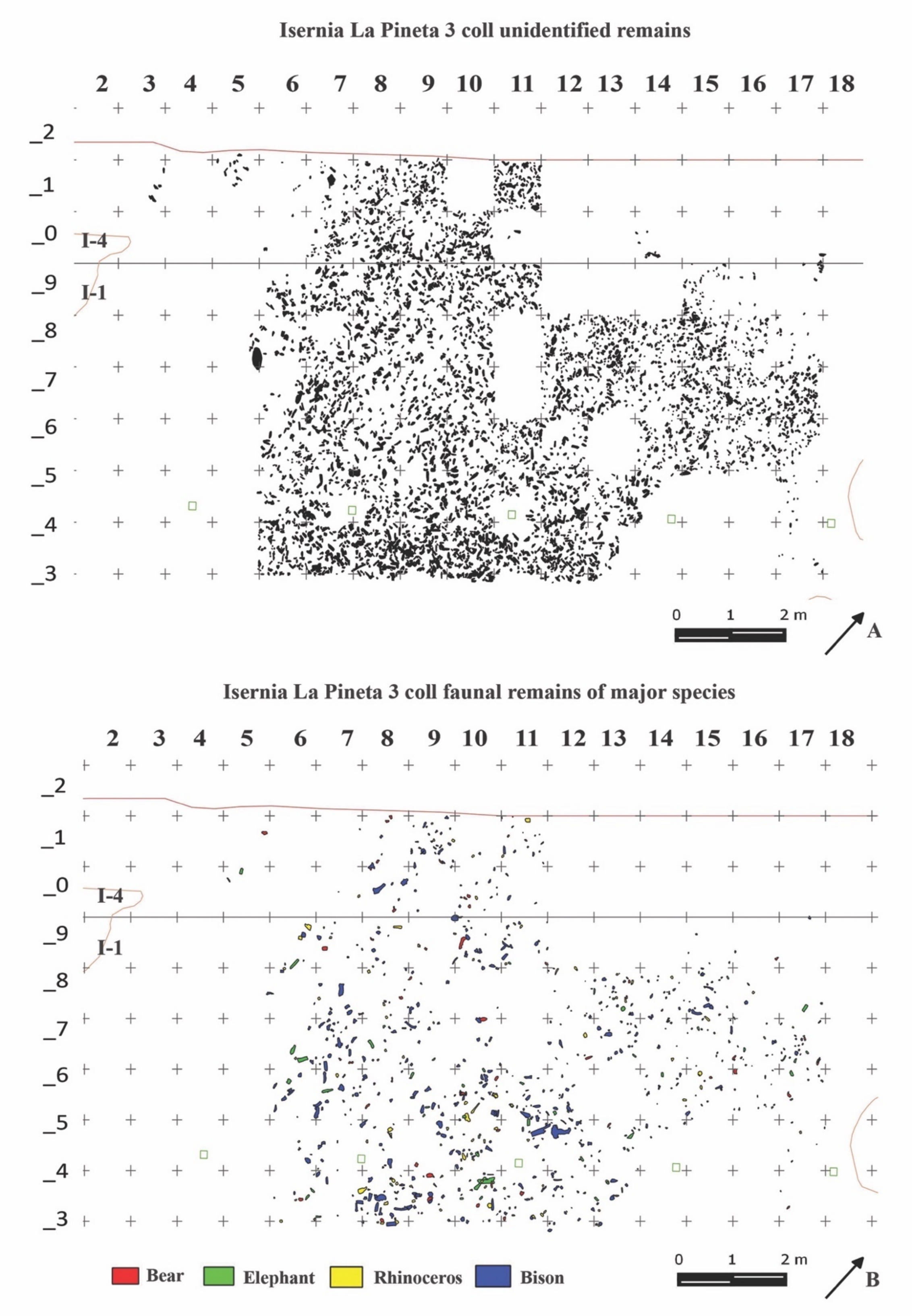
Stephanorhinus hundsheimensis (TOULA 1902)

The second most represented species was the rhinoceros (*Stephanorhinus hundsheimensis*), with 175 remains determined by a percentage of 15.8% of the total NISp (Tables 5.3 and 5.4). Similar to bison, cephalic elements were identified in larger numbers and appeared to represent this species better than other anatomical elements. The dental remains were the most numerous: 108 remains for a percentage of 61.7 of the total NISp of this species followed by cranial and mandibular fragments. The axial elements comprised one vertebra and rib each. The short bones- carpals, tarsals and phalanges were present in more numbers than elements of the appendicular skeleton. Among the 175 remains, nearly half the number of remains, mainly teeth and the small compact bones like carpals, tarsals, metapodia and teeth were either complete or incomplete. The calculation of the Minimum Number of Individuals was based on the post-cranial elements. The dental remains were not taken into account, as they exhibited high fragmentation which rendered them unreliable. In particular, the mandibular teeth were considered: the presence of 5 left mandibular portions returned an MNI equal to 5. The spatial distribution of this species on the excavated floor of 3 coll revealed a similar pattern as bison remains. The rhinoceros remains were randomly distributed though notable was the presence of larger fragments in the southern areas of the floor (Fig 5.4B).

Ursus deningeri VON RICHENAU 1906

The bear (*Ursus deningeri*) is the third most represented species in the faunal assemblage of layer 3 coll with a percentage of 11.8% of the total NISp. It is the only recognized species of carnivore in the assemblage. The total number of remains is 131 (Tables 5.3 and 5.4). The most abundant anatomical element belonged to the cephalic portion. In particular, 63 dental remnants were recognized (48.1% of its total NISp), 15 mandible fragments (11.5%; Plate 1C), 8 cranial fragments

(6.1%). The axial skeleton was represented by a few vertebrae and one rib. The appendicular skeleton was represented by metapodia, carpals, tarsals, a patella and phalanges. The remains of this species,


Isernia La Pineta 3 coll unidentified remains

Isernia La Pineta 3 coll faunal remains of major species

Fig 5.4: Isernia La Pineta 3 coll: A- Spatial distribution of all unidentified faunal remains; B- Spatial distribution of faunal remains of four major species.

nearly 71%, were either complete or incomplete, a rate much higher when compared to other taxa. An os penis was also found. This denoted the presence of at least one male individual in the bear population. The small number of complete dental remains did not allow the calculation of the MNI which was thus made using the remains of the mandible. In fact, there were two right and two left mandibular portions; the presence of at least 2 individuals was deduced from this. The spatial distribution of the remains of this species on the excavated floor of layer 3 coll highlighted no particular pattern. They were scattered in a random fashion (Fig 5.4B).

Palaeoloxodon antiquus FALCONER & CAUTLEY 1847

The elephant, with the species *Palaeoloxodon antiquus*, was present in the faunal assemblage with a percentage equal to 11 of the number of taxonomically determined remains (Tables 5.3 and 5.4). Of the 122 elephant remains, the dental fragments were by far the most numerous: 107 in total, 87.7% of its total NISp of this species (Plate 2A). Most of these were tusk fragments apart from one deciduous premolar and one permanent premolar. To them were added three vertebrae which represented the axial skeleton; seven diaphyses; one humerus, phalanx, tarsal, sesamoid and hyoid each which represented the appendicular skeleton. Cumulatively, they probably represented one individual at a minimum. The spatial distribution of these remains revealed that most of them were present on the south western, southern and northern squares of the excavated floor (Fig 5.4B).

Other species were recognised in the faunal assemblage, which were few in number (Table 5.3). Because of scarcity of remains, they were not depicted on the spatial distribution maps. They were:

- The hippopotamus, with the *Hippopotamus* cf. *antiquus* species, present with a percentage of 0.8, with a total number of remains of nine, including one fragment of skull, one tarsal and seven teeth (Plate 2B). The MNI was evidently equal to one.
- The giant deer, with the species *Praemegaceros solilhacus*, present with a percentage of 0.7, with a total number of remains of eight, including two fragments of the antler, three teeth (a right M^3, an upper right molar) two tibiae and two mandible fragments (one with right M_3 and another right with M_2). The MNI was evidently equal to one.
- The tahr, *Hemitragus* cf. *bonali*, present with a percentage of 0.4%, with a total number of remains of four: of which there were two teeth, one tarsal, one indeterminate phalanx. The MNI is evidently equal to one.
- The deer, *Cervus elaphus* cf. *acoronatus*, present with a percentage of 0.4%, with a total number of remains of four: of which there was one antler, one tooth, one tibia and one phalanx fragment. The MNI was evidently equal to one.
- The wild boar, *Sus scrofa*, present with a percentage of 0.2%, with a total number of remains of three-two mandible (Plate 2C) and one dental fragment. MNI was equal to one.

- The fallow deer, with the species *Dama* cf. *D. roberti*, was represented with a single fragment of the scapula.
- The roe deer, with the species *Capreolus* sp., was represented with a single fragment of the humerus.

Some fragments, for which the precise anatomical location was recognized, were not attributed to a taxon in particular as they did not possess sufficient diagnostic features. But they have been included in some orders or categories such as (Table 5.3):

- Carnivora: some remains such as teeth, mandible, vertebra, and metapodia were placed in this category. There were a total of 10 remains contributing to 0.9% of the total NISp.
- Cervidae: to this category belonged all those remains (49, 4.4% of the total NISp) that surely belonged to the order of Artiodactyla and more precisely to the family of cervids, and not to that of the bovidae, for some recognized diagnostic characteristics, which, however, did not allow to determine the remains at the species level. The most abundant finds were the antler and dental fragments followed in order of abundance by mandible, long bones and phalanges.
- Artiodactyla: 15 remains (1.4% of the total NISp) coming from various anatomical regions were placed in this group for the lack of taxonomically distinct morphological features.
- Ungulata: 109 remains (9.9% of the total NISp), mainly dental fragments, long bone diaphyses and cranial fragments were categorised as ungulata as they were too fragmented to be assigned to any taxon, but yet retained enough characteristics to be identified as an ungulate.

5.3 State of integrity

The state of integrity was not determinable for 4048 remains which contributed to 65.6% of the sample examined, clearly comprising the majority. For the remaining 34.4%, the anatomical placement of the fragment with respect to the entire bone was determinable. (Table 5.5). In this assemblage, medial fragments (22.4%) were more abundant than the rest. Incomplete fragments (3.2%) were better represented than complete fragments (2.8%). Following them in the order of abundance, 1% of the remains were from the proximal part of the bone while 0.7% of the remains belonged to the proximal-medial portion. Further, 0.6% of the remains were from the distal part. The rest of the remains ascertained with other states of integrity were recognised in a smaller number of remains, contributing less than 0.6%. The state of integrity was determined for few remains which revealed that they had been modified by different pre and post-depositional processes to an extent where identifying their laterality and portion with respect to the whole bone was not possible.

Table 5.5: Isernia La Pineta 3 coll: Distribution of remains based on their state of integrity (NR 6167).

State of integrity	NR	NR%
Indeterminate	4048	65.61
Complete	174	2.82
Incomplete	196	3.18
Proximal fragment	63	1.02
Proximal-medial fragment	43	0.70
Medial-distal fragment	17	0.28
Distal fragment	37	0.60
Left lateral fragment	7	0.11
Right lateral fragment	15	0.24
Left medial fragment	13	0.21
Right medial fragment	8	0.13
Left anterior fragment	17	0.28
Right anterior fragment	11	0.18
Left posterior fragment	8	0.13
Right posterior fragment	16	0.26
Lateral fragment indeterminate	5	0.08
Medial fragment indeterminate	3	0.05
Anterior fragment indeterminate	15	0.24
Posterior fragment indeterminate	13	0.21
Medial fragment	1378	22.34
Diaphysis + proximal and distal metaphysis	57	0.92
Lateral, anterior and medial fragment	16	0.26
Lateral or medial fragment indeterminate	3	0.05
Lateral, posterior and medial fragment	4	0.06
Total	**6167**	**100.0**

5.4 Taphonomic analyses

To better comprehend the various processes that altered the faunal remains from their death, discard to discovery in an archaeological excavation, taphonomic analyses were implemented at a macroscopic and a microscopic level. The primary objective of this analysis was assessing the conservation status of the bone surfaces and the results yielded some interesting information.

5.4.1 Non-anthropic modifications

The faunal remains from layer 3 coll demonstrated several types of modifications imputable to natural factors. Post-depositional modifications caused by natural agents contributed varyingly. Weathering (58.3 %) and erosion (54.9 %) had a greater impact than other agents such as rounding (25.6 %) and exfoliation (18.2 %).

Weathering

Weathering was absent in 2,410 (stage '0'). However, 3,761 remains exhibited either one of the successive 4 stages while none had reached the stage "5". Slight weathering- stage "1", was seen on 2,545 remains whereas more advanced characteristic cracking was observed on 929 remains- stage "2", 239 remains- stage "3", and 48 remains-stage "4".

Erosion

No erosion was seen on 2,700 remains while 3,471 remains demonstrated varying degrees of erosion. Light erosion was seen on 1,859 remains, marked erosion on 879 remains and diffused erosion was documented on 733 remains.

Exfoliation

Exfoliation was absent in 4,993 remains and present in 1,178 remains. Light exfoliation was observed in 554 remains, marked exfoliation in 394 and diffused exfoliation was documented for 230 remains.

Considering that weathering, erosion and exfoliation played a major role in the post-depositional taphonomic history of the assemblage, the eight "WEE" combinations revealed interesting results (Table 5.6). While the absence of all three agents, corresponding to good preservation (combination 000) was documented for 898 remains, on the contrary, 623 remains were clearly impacted by them (combination 111) corresponding to weaker preservation. Single-agent impact with no visible effect of other two agents varied in quantity. Only weathering (combination 100) was found in 1,052 remains, only erosion (combination 010) on 794 remains and only exfoliation (combination 001) was recorded on the least number of 133 remains. A number of remains with a combination of the presence of two agents and absence of one agent fluctuated. Both weathering and erosion (combination 110) were the highest- 1,852 remains. Impact of weathering and exfoliation but no erosion (combination 101) was recorded on 220 remains. Erosion and exfoliation with the absence of weathering (combination 011) were seen on 188 remains.

Table 5.6: Isernia La Pineta 3 coll: Number of faunal remains impacted by combinations of weathering, erosion and exfoliation.

Combination	Natural agent	NR
000	Absent	898
111	Weathering + Erosion + Exfoliation	623
100	Only weathering	1052
010	Only erosion	794
001	Only exfoliation	133
110	Erosion + Exfoliation	1852
101	Weathering + Exfoliation	220
011	Erosion + Exfoliation	188

The 2D frequency map (Fig 5.5A) focused on the relationship between altered (Weathering+Erosion+Exfoliation) in black and unaltered in light grey. It highlighted areas, particularly in the central and extreme western limit of the excavated surface, of the major concentration of altered remains. In the eastern area, several squares represented the nearly equal number of remains with both good and bad preservation respectively. Comparatively fewer aggregates of altered remains were found in the central western and southern areas, with remains from two squares totally devoid of modifications.

The next 2D map (Fig 5.5B) displayed pie charts for each square demonstrating relationships between remains affected by each of the three agents (Weathering-Black, Erosion-dark grey and Exfoliation-light grey) while the colour of the squares indicated higher concentrations (darker hues of grey) or lower concentrations (lighter hues of grey) of altered remains. It became apparent that the centrally located, more or less homogenously distributed, lower concentration of remains, demonstrated greater modifications. The south eastern, south western and western periphery areas (except for 4 squares in the south) comprising more densely accumulated remains had undergone fewer modifications. The north eastern situated squares also had fewer modifications to demonstrate. Visual assessment of pie charts in each square showed that weathering ranging from one-thirds to two-thirds was invariably present in all squares. A similar observation held true for erosion, with exceptions of squares with less than one-third eroded remains randomly present in the excavated area. Exfoliation, on the contrary, was found in one-third or less than one-third remains in most squares. In the western squares with no colour (0 - 60 remains), exfoliation was visibly more or equal to the other two modifications. The remains in the central, north eastern and south central squares had undergone less exfoliation. In the south and south eastern squares, the number of exfoliated remains fluctuated with remains in some squares being devoid of it.

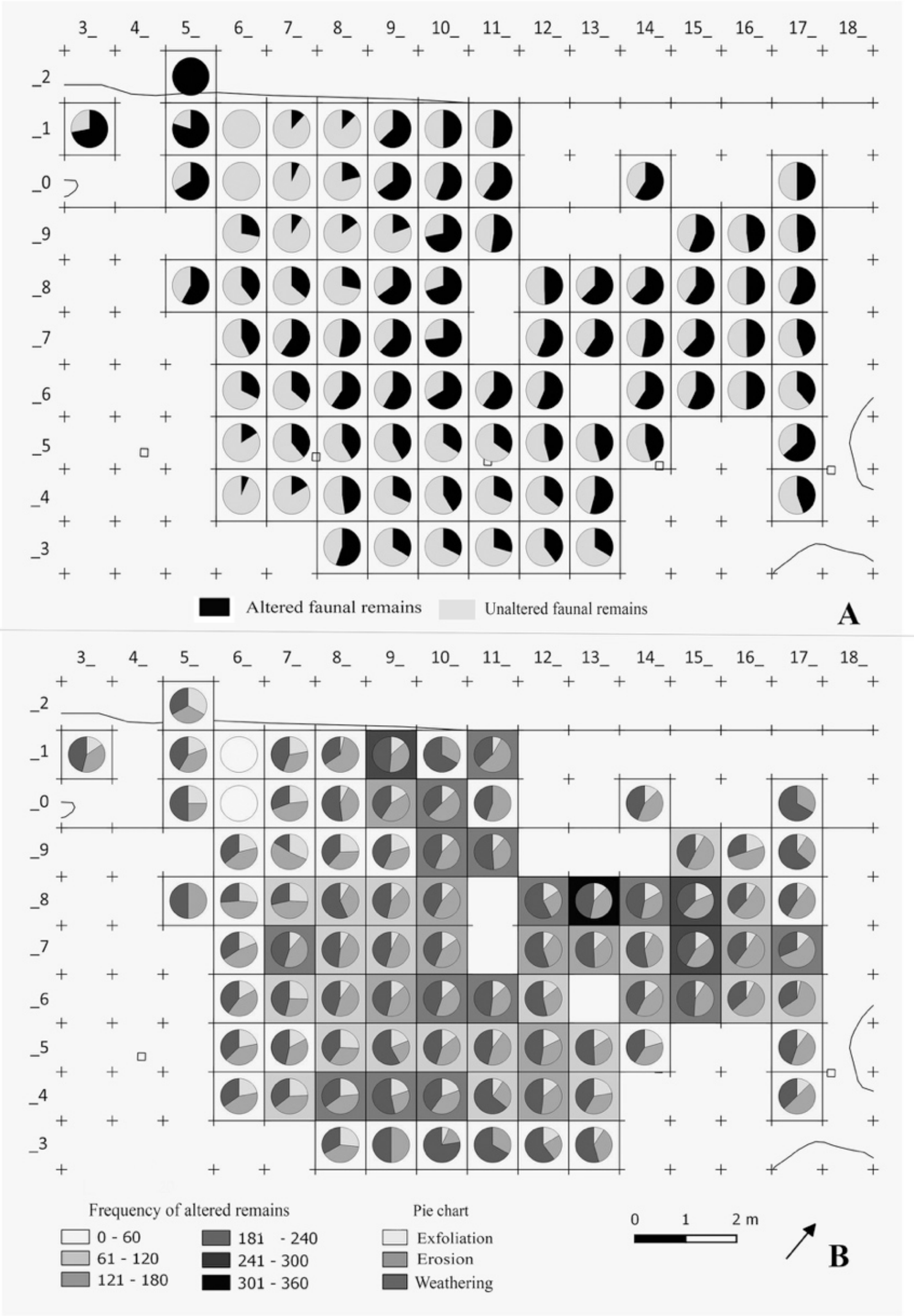


Fig 5.5: Isernia La Pineta 3 coll: A-Two-dimensional frequency map showing the relationship between faunal remains altered by weathering, erosion and exfoliation and the unaltered faunal remains in black and light grey colours respectively for each excavated and analysed square; B-Two-dimensional map showing frequency of faunal remains altered by all three natural taphonomic agents - weathering, erosion and exfoliation in each excavated and analysed square with the colour of the square indicating higher concentrations (darker hues of grey) or lower concentrations (lighter hues of grey) of altered remains. Pie charts within each excavated and analysed square demonstrate the relationship between remains effected individually by each of the three agents (Weathering-Black, Erosion-dark grey and Exfoliation-light grey).

Rounding

The degree of rounding of the bone surfaces is linked to the physical factors connected to post-depositional processes. More precisely, it bears direct consequence of action of transport by water and the abrasive action of loose sediments, which act on the bones, rounding the edges. In the assemblage, 73% (NR 4503) of the remains were devoid of rounding, while 14% (NR 859) showed a degree of slight rounding. Medium rounding was present on 12.1% of the remains (NR 749; Plate 3A). An advanced rounding was present on 0.8% (NR 52) of the remains and a very advanced rounding was observed on 0.3% (NR 8) of the remains. The spatial distribution of remains with the four degrees of rounding revealed a unique pattern. In general, since a majority of the remains did not exhibit any degree of rounding, this was translated to large gaps in the distribution map. The gaps could also translate to a possibility that these observations for this variable were not recorded in the previous studies which were synthesized with the current study. However, some information, though skewed, can be obtained from this map. Most of the remains with rounding were found in the northern, north eastern, western, southern and central areas but in specific squares. Large fragments with a lesser degree of rounding were present in the southern areas. On the contrary, remains which were rounded and present in the central and north western areas of the excavated floor were of smaller size. (Fig 5.6).

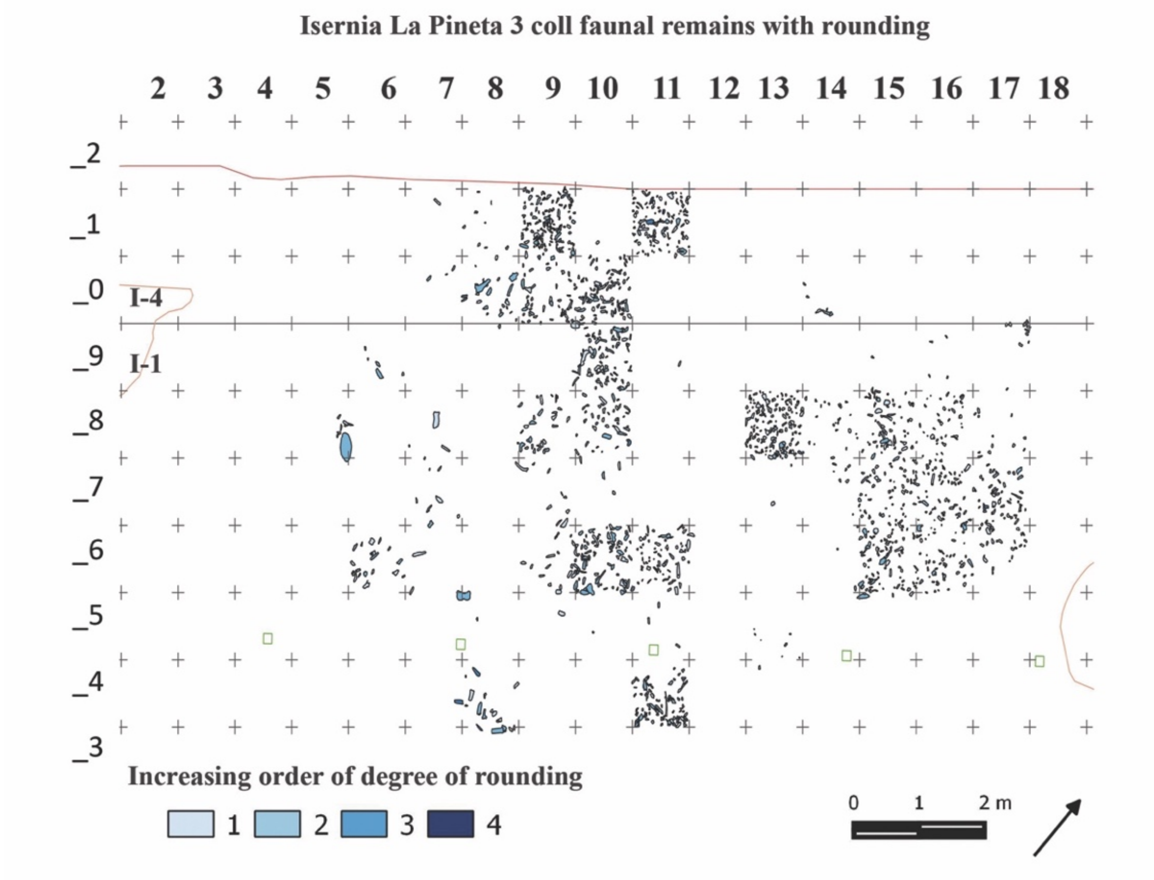


Fig 5.6: Isernia La Pineta 3 coll: Spatial distribution of faunal remains with rounding.

Oxides

The bone surfaces gave ample evidence of the presence of two oxides, in particular, manganese and iron. The presence of these two compounds is the result of chemical and biological factors. Manganese oxide comes in the form of very small, dark black and gray blotches, and through microstriations of black-dark gray. These are the result of the filling of weathering cracks by the manganese oxide. Iron oxide occurs in the form of red-orange patches, due to its deposition in some specific points of the bone surface due to physical and chemical phenomena. The remains on which the oxides were completely absent were only 232 (3.6%) in the total assemblage. Manganese oxide occurred on 808 remains (13.1%); Iron oxide, not associated with Manganese, occurred on 15 remains (0.2%), while the association manganese + iron was present on 5116 remains (82.9%; Plate 3B). The spatial distribution of the remains impacted by oxides showed that they were present in large numbers in all areas of the excavated floor. They were found on remains mainly concentrated in the southern areas of the excavated floor.

Trampling marks

The examination of each remain under an optical microscope helped to highlight the diagnostic and micromorphological characteristics that allowed to recognize their nature and source of origin. Here, in this section, the linear marks due to natural factors are discussed in detail. The absence of linear marks was ascertained in 4105 remains (66.5%). In 1609 remains (26%) were exhibited marks of trampling by sediments (Plate 3C). On 376 remains (6.1%) abrasion marks were recognized. They were found on the surface of all types of anatomical parts and came from nearly all areas of the 3 coll excavated floor.

Carnivore/rodent marks

In this assemblage, 44 carnivore marks were documented mainly on bison, bear and ungulate remains and remains of unidentified taxa. They were present mainly on the femur, tibia, radio-ulna of bison, sesamoid of bear (Plate 3D), mandible and tarsal bones of ungulates. Carnivore marks were also found on different anatomical elements of taxonomically indeterminate remains (Plate 3E). Their provenance was from different squares of the excavated floor and did not indicate any specific zone pertaining to carnivore activity. Scanty data for this variable did not warrant a spatial distribution map.

Root etchings

The dendritic impressions imputed to the chemical or mechanical action of sub-terranean roots on bone surfaces were recognised on 7.6% of the faunal remains. The remaining 92.4% were devoid of it. In 287 remains (4.7%) they were manifested lightly. In 50 remains (0.8%), they were more marked (Plate 3C). In the remaining 131 remains (21.4%), they appeared diffused. They were found on the surface of all types of anatomical parts and came from nearly all areas of the 3 coll excavated floor.

Fractures

The fracturing of remains is caused by both anthropic factors and natural factors. During the compilation of the database, the type of fracture was discriminated based on the morphological characteristics of the fragmentation. However, the remains often do not present a single type of fracture although it is possible to recognize both the anthropic factor and the subsequent post-depositional factor. Consequently, when calculating the fracture percentages, it must be taken into account that the same fragment can have more than one type of fracture and therefore an overlap between the values.

Non-anthropic fractures

Fractures due to natural causes were recorded in 641 remains. Out of them, 54.7% (NR 592) of the remains were documented with post-depositional fractures and 4.1% (NR 44) remains were fractured due to weathering. A combination of these factors was observed to have fractured 0.5% (NR 5) of the remains. Teeth, small compact bones such as phalanges, carpals, tarsals, and some other anatomical elements comprising 4.3% (NR 47) of the remains were documented with not recorded fractures. The spatial distribution of non-anthropic fractures showed their dense concentration particularly in the northern, north western, north eastern and western areas of the excavated floor of this layer (Fig 5.7A). Within the areas of denser concentration, certain squares had particularly larger fragments with non-anthropic fractures. They were squares located in the west, south west and north.

5.4.2 Anthropic modifications

Human activities are represented by cut-marks, scraping-marks, anthropic intentional fractures, impact points, notches, detachments and percussion cones.

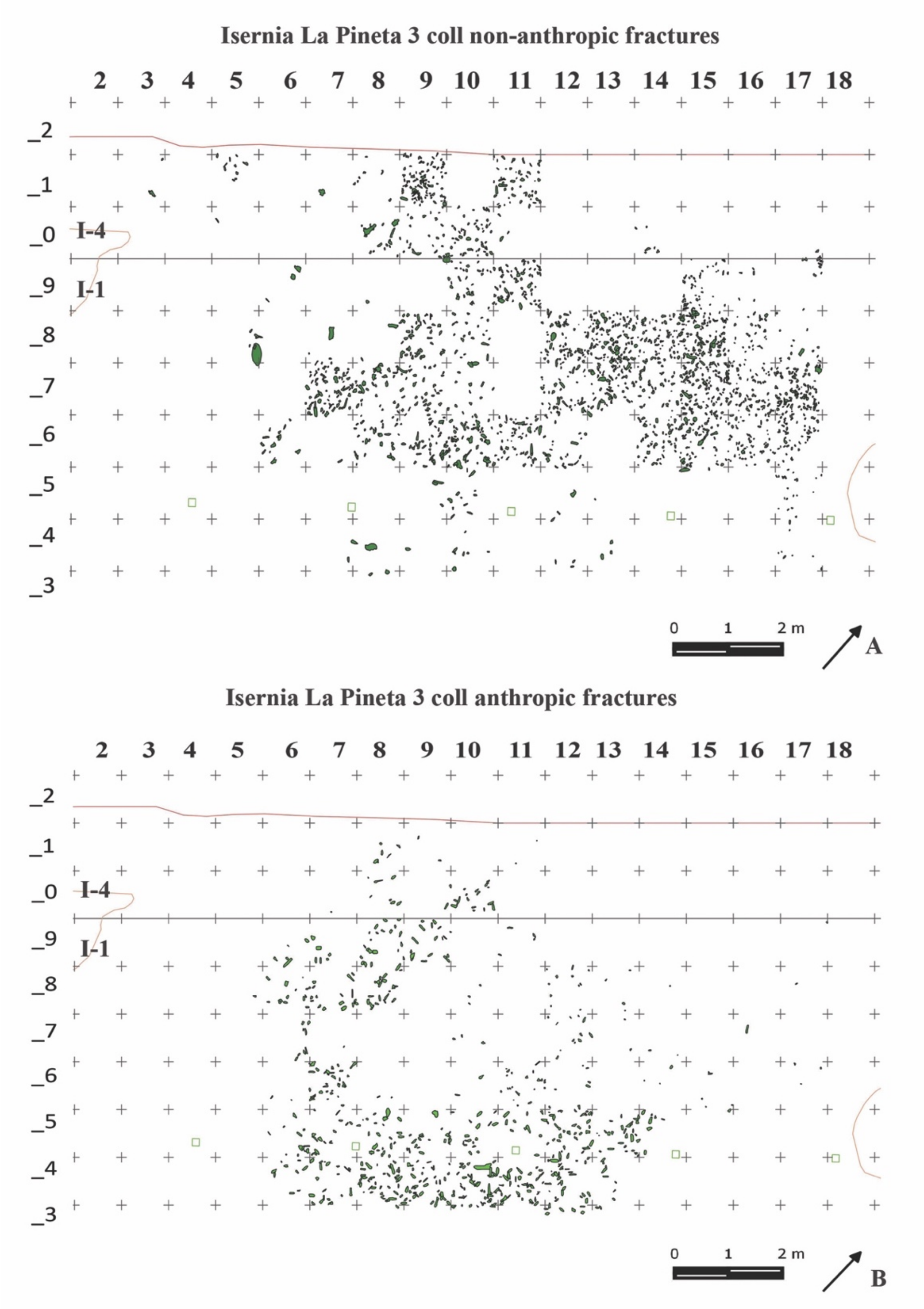


Fig 5.7: Isernia La Pineta 3 coll: A- Spatial distribution of non-anthropic fractures; B- Spatial distribution of anthropic fractures.

Cut-marks and scraping-marks

A total of 29 remains were selected as possible cut-marks. After examining them under the stereo microscope, 19 cut-marks were confirmed at the L. A. T. The remaining 10 were analysed under the SEM, out of which three were confirmed as cut marks, three were confirmed as trampling marks and remaining four were doubtful. The 22 cut marks confirmed as evidence of the use of lithic tools by hominins for the treatment of animal carcasses either for skinning or removal of muscle and/or periosteum (Table 5.7). Anatomically, they were mainly identified on diaphyseal fragments of unknown taxa. Three cut-marks were recognised on fragments of unidentified anatomy and taxonomy. Among the faunal spectra, most of the major species yielded evidence of this anthropic activity. Bison remains had three cut-marks whereas rhinoceros remains had two. The other two species- bear (Plate 5) and elephant had one each. Scraping marks were observed, both macroscopically and microscopically, on three remains. They were a rib, a metapodium and a long bone diaphysis of unidentified taxon (Plate 6A and B).

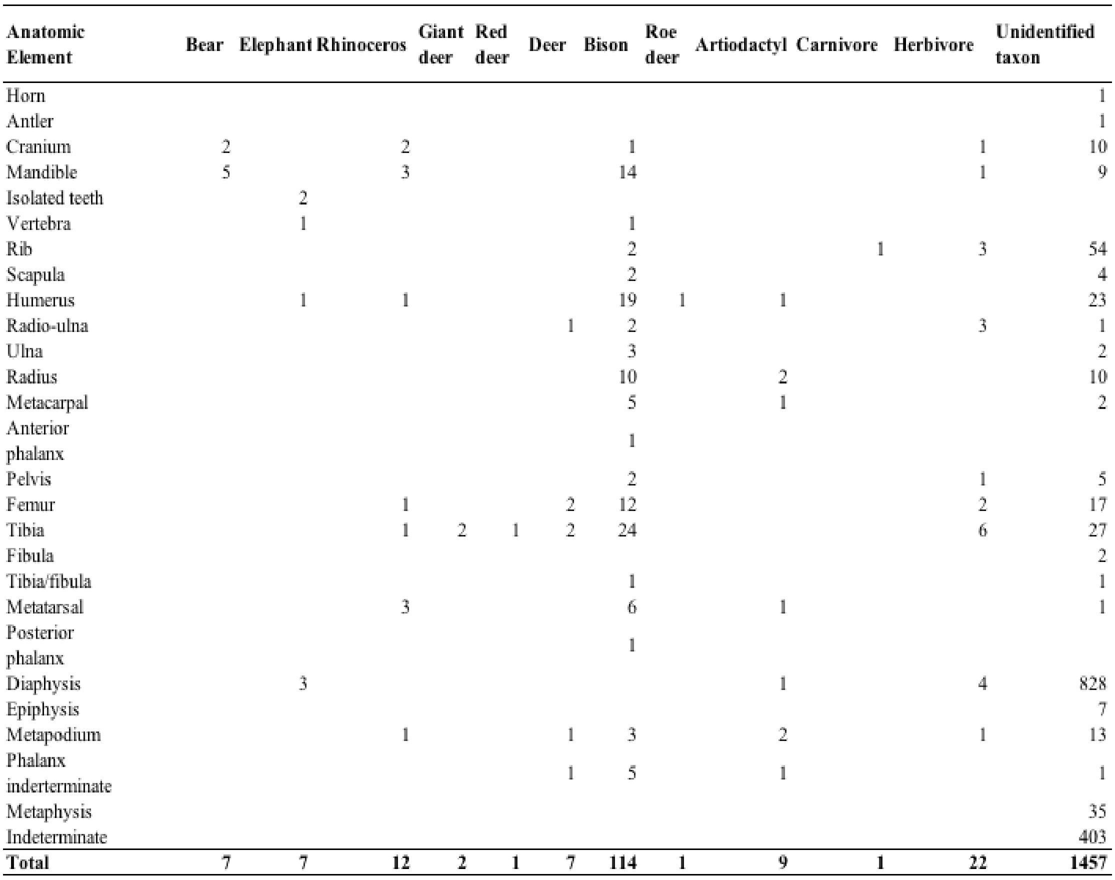
Table 5.7: Isernia La Pineta 3 coll: Frequency distribution of cut-marks and scraping marks.

	Cut-marks						**Scraping marks**
Anatomical element	**Bear**	**Elephant**	**Rhinoceros**	**Bison**	**Ungulate**	**Unidentified taxon**	**Unidentified taxon**
Cranium			1			1	
Mandible				1			
Vertebra					1		
Rib						1	1
Scapula						1	
Humerus				1			
Femur			1				
Tibia				1			
Diaphysis		1				8	1
Metapodium	1						1
Indeterminate						3	
Total	**1**	**1**	**2**	**3**	**1**	**14**	**3**

Intentional fractures

The remains with anthropic fractures amounted to 1640 and contributed to 26.5% of the entire faunal assemblage. Anatomically, appendicular elements yielded more evidence of the fractures contributing 67% to the total number of anthropic fractures (Table 5.8). Axial skeletal elements provided 4.6% and the cephalic component provided 3.1%. Among the appendicular elements, most of the fractures were ascertained on diaphyses (NR 836-50.9%) followed by tibia (NR 63- 3.8%), metaphyses (NR 35- 2.1%), humerus (NR 46- 2.8%) and femur (NR 34- 2.1%). However, other appendicular elements also had anthropic fractures, though in smaller numbers. The axial skeleton presented fractures made by hominins which were found mainly on ribs (NR 60- 3.7%), scapulae and pelvic fragments (NR six each- 0.4%). Mandible and cranial fragments also displayed these fractures (NR 32 - 2% and NR 16- 1% in total respectively). Taxonomically, they were well-represented in almost all anatomical elements of bison (NR 114- 7%). The mandible, tibia, humerus, femur and radius preserved good evidence of anthropic fracture. Rhinoceros with 12 remains- mainly long bones mandible and cranium and seven elephant remains, with mostly tusk, vertebra and diaphyses, gave clear evidence of anthropic breakage. This evidence also extended to carnivore remains, including the only species identified- bear. Cranial, mandible and rib fragments displayed such fractures.

Table 5.8: Isernia La Pineta 3 coll: Distribution of anthropic fractures based on the anatomical element and species (NR 1640).



Anatomic Element	Bear	Elephant	Rhinoceros	Giant deer	Red deer	Deer	Bison	Roe deer	Artiodactyl	Carnivore	Herbivore	Unidentified taxon
Horn												1
Antler												1
Cranium	2		2				1				1	10
Mandible	5		3				14				1	9
Isolated teeth		2										
Vertebra		1					1					
Rib							2			1	3	54
Scapula							2					4
Humerus		1	1				19	1	1			23
Radio-ulna						1	2				3	1
Ulna							3					2
Radius							10		2			10
Metacarpal							5		1			2
Anterior phalanx							1					
Pelvis							2				1	5
Femur			1			2	12				2	17
Tibia			1	2	1	2	24				6	27
Fibula												2
Tibia/fibula							1					1
Metatarsal			3				6		1			1
Posterior phalanx							1					
Diaphysis		3							1		4	828
Epiphysis												7
Metapodium			1			1	3		2		1	13
Phalanx inderterminate						1	5		1			1
Metaphysis												35
Indeterminate												403
Total	**7**	**7**	**12**	**2**	**1**	**7**	**114**	**1**	**9**	**1**	**22**	**1457**

The spatial distribution of anthropic fractures for layer 3 coll brought to light a particular pattern which was different and rather opposite from the distribution of non-anthropic fractures (Fig 5.7B).

The western, south western and the southern squares were the primary areas of concentration. The large sized fragments were found relatively in greater numbers in the south.

Fracture analyses

Long bone fractures were further investigated to delineate characteristics typically attributed to anthropic and post-depositional taphonomic agents. Long bones, identified taxonomically amounted to105 whereas long bones taxonomically unidentified were 706 in number. A comparison of the identified and unidentified long bones for identified and unidentified taxa highlighted some similar and some dissimilar trends (Fig 5.8). In both cases, for instance, when considering anatomically distinguishable long bones- humerus, radius, femur, tibia and epiphyses were better represented than other long bones or their portions. The differences lie in the fact that there were no metaphyses identified taxonomically although there were 36 of them in the unidentified taxa category. While epiphyses were better recognised and attributed taxonomically, in the undentified taxa category, diaphyses were in much larger numbers. In both identified and unidentified taxa category, there were no complete or nearly complete long bones. Taxonomically, both front and hind limb bones were present in varying number, among which, tibia, humerus femur and epiphyseal portions were well represented in decreasing order of abundance (Fig 5.9). Rhinoceros, following bison, had one of humerus, femur and tibia each attributed to it. Most of the long bones of elephant were large diaphyses fragments except for one humerus. In collation with epiphyses, diaphyses were 82% better represented.

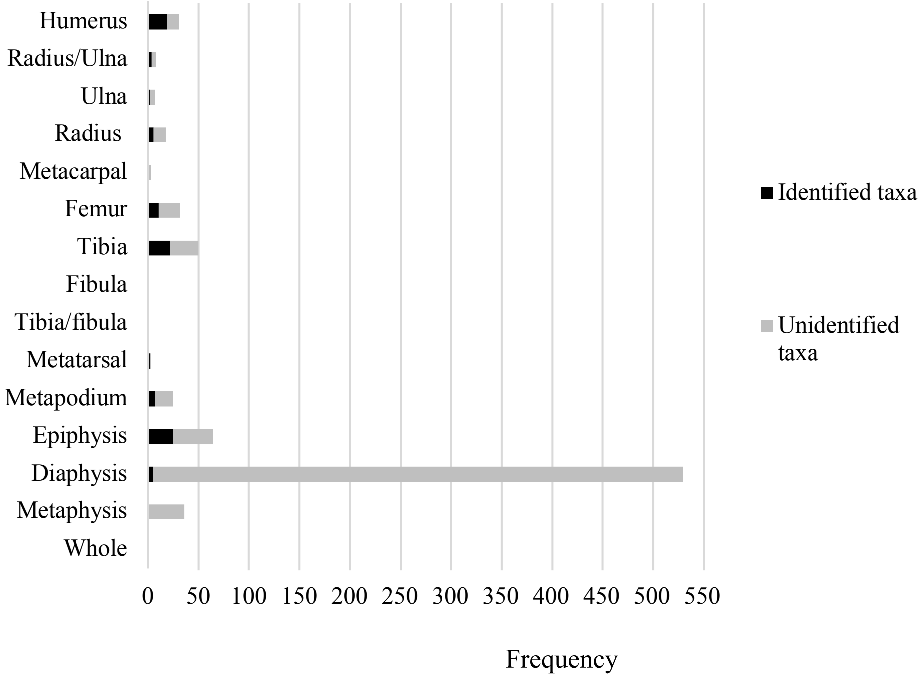


Fig 5.8: Isernia 3 coll: Frequency distribution of long bones for identified and unidentified taxa (NR 811).

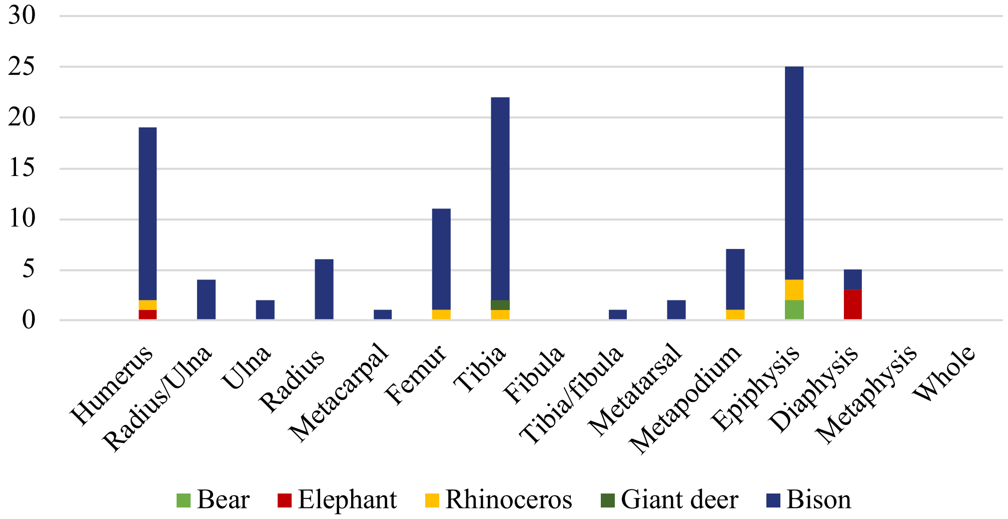


Fig 5.9: Isernia 3 coll: Species-wise distribution of long bones (NR 105).

The epiphyses were excluded from the fracture analyses. Hence, the number of diaphyses available for study were 746 in total, 666 coming from unidentified taxa and 80 from identified taxa. In this sample, a few of the selected diaphyses also had one intact or partially intact epiphyseal end. The diaphyses which were not taxonomically determined had a shaft circumference mostly less than half of the original (C1- 331) and a shaft length less than one-quarter of the original length (Fig 5.10). Keeping the same circumference, 243 diaphyses had a slightly longer length between one-quarter and one-half of the original length (L2). In comparison, diaphyses with the same circumference of C1, but with shaft lengths between one-half and three-quarters (L3) and more than three-quarters (L4) were 72 and three respectively. This highlighted the high fragmentation of diaphyses rendering them taxonomically and anatomically unidentified. There were no diaphyses with complete circumference and complete length preserved. The diaphyses with circumference more than half of the original in at least a portion of the bone length (C2) were very few. Nearly equal number of diaphyses with C2 circumference had either shaft lengths of one-quarter of the original length (L1) or lengths between one-half and three-quarters (L3).

In case of diaphyses which were taxonomically identified, a majority of them (77) had a shaft circumference of less than half of the original (C1) (Fig 5.11). With a small circumference, out of the 77, an equal number of diaphyses (23) had a shaft length of less than one-quarter of the original length (L1) or a shaft length of one-half to three-quarters of the original length (L3). Only one diaphysis had a slightly larger circumference of more than half of the original (C2) and a length less than one-quarter of the original (L1) and two diaphyses had longer lengths between one-half and three-quarters of the original length (L1) with the same circumference. There was also only one diaphysis with shaft length more than three-quarters of the original length (L4) but its circumference was small, less than half of the original (C1). In both scenarios, a synthesis of shaft length and circumference indices brought to light that the majority of the long bone diaphyses had less than half of the original circumference and less than one-half of the original length. Moreover, complete or nearly complete bones were absent. These results are typical of an assemblage created by anthropic agents rather than carnivores as the actions of the latter would have reflected an opposite scenario.

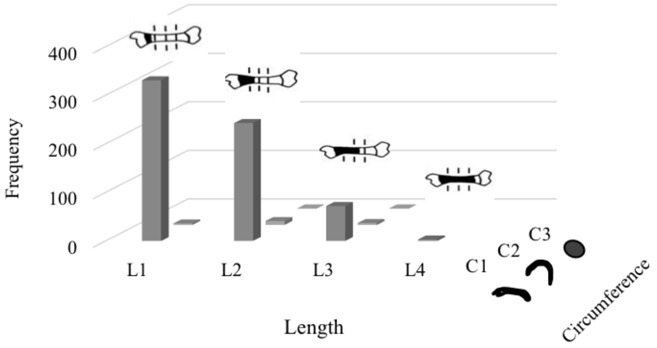


Fig 5.10: Isernia La Pineta 3 coll: Shaft fragmentation index length (L) vs circumference (C) for unidentified taxa (NR 666).

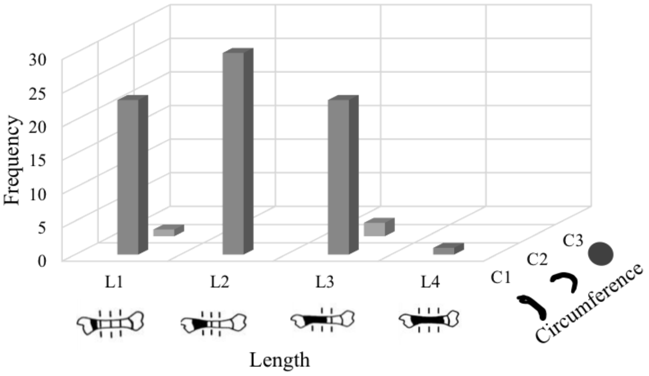


Fig 5.11: Isernia La Pineta 3 coll: Shaft fragmentation index length (L) vs circumference (C) for diaphyses of identified taxa (NR 80).

In the next part of this study, the diaphyses were analysed for their extent of fragmentation which was estimated by categorising them in size classes and comparing them with respect to their frequency and combined mass. When diaphyses were quantified according to their sizes in terms of length, as shown in graph A (Fig 5.12), the small-size classes with fragments measuring between 5 and 10 cm were predominant. It was inferred that either a large number of diaphyses were reduced to smaller pieces as a result of smashing them open for marrow or that the fragments, originally larger, had subsequently undergone further fragmentation due to the impact of post-depositional processes. Their state of preservation was not favourable for determination. Size classes and their frequency were indirectly proportional. Smaller the size, larger was the number of fragments. Conversely, large-sized diaphyses were very few. It reflected two possibilities- either that the hominins selectively did not exploit a few long bones for marrow or that these fragments survived the post-depositional impacts better than the rest. A different result emerged when the diaphyses were quantified according to their mass (Fig 5.12B). Here, the diaphyses fragments between lengths of 7 to 15 cm, on an average, represented a proportionally large amount of bone. They probably belonged to large sized animals. The contrary held true. A few number of large sized fragments had a relatively low combined mass. These fragments probably belonged to the young individuals of large sized animals or *vice versa*.

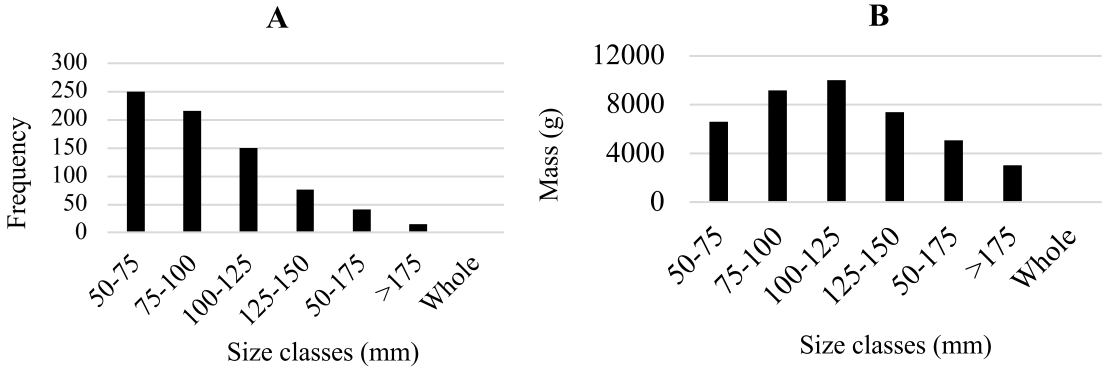


Fig 5.12: Isernia La Pineta 3 coll: Proportions of diaphysis fragments in different size classes quantified by A - number and B- mass (NR 746).

An analysis of the fracture type was conducted on the 1476 proximal and distal ends of the 746 diaphyses. Some diaphyses still had an intact or partially intact epiphysis so they had only one fracture end. The results obtained from this analysis showed that a majority of the diaphyses had a spiral fracture and/or a spiral fracture with slightly jagged edge (Fig 5.13), which is characteristic of anthropic breakage of fresh bones resulting in green fractures. Other lesser dominant types were irregular perpendicular, Y-shaped, smooth perpendicular and flaking. The spiral fracture type was definitely positive evidence of anthropic fractures, while the others were linked mostly to post-depositional and weathering related fractures. Longitudinal, sawtoothed and stepped/columnar fracture types were observed on a small number of diaphyses.

The study of the fracture angle, outline and edge of the 746 diaphyses along all their fracture planes/surfaces revealed an interesting and mixed pattern (Fig 5.14). A total of 3272 fracture planes from the 746 diaphyses were analysed for these criteria. In the assemblage, 355 diaphyses had four fracture planes, 206 diaphyses had five fracture planes, 80 diaphyses had three fracture planes, 74 diaphyses had six fracture planes, 15 diaphyses had seven fracture planes, 10 diaphyses had two fracture planes, five diaphyses and one fracture plane and one diaphysis had eight fracture planes.

With a small margin of a majority, 1200 fracture planes were at right angles whereas a slightly lesser number of fracture planes, 1124 in total, had variable angles. Fracture planes with an oblique angle were 948. While the angle showed a mix of both anthropic and post-depositional causes of fracturation, the outline revealed a clearly anthropic cause of fracturation of these diaphyses as curved/longitudinal outlines dominated (NR 2632) over transverse (NR 491) and intermediate (NR 149) outlines. Fracture edge, similar to angle, also revealed a mix of both anthropic and post-depositional causes of fracturation as the two types- jagged and smooth, were observed on an almost equal number of fracture planes, with 1654 and 1618 diaphyses respectively.

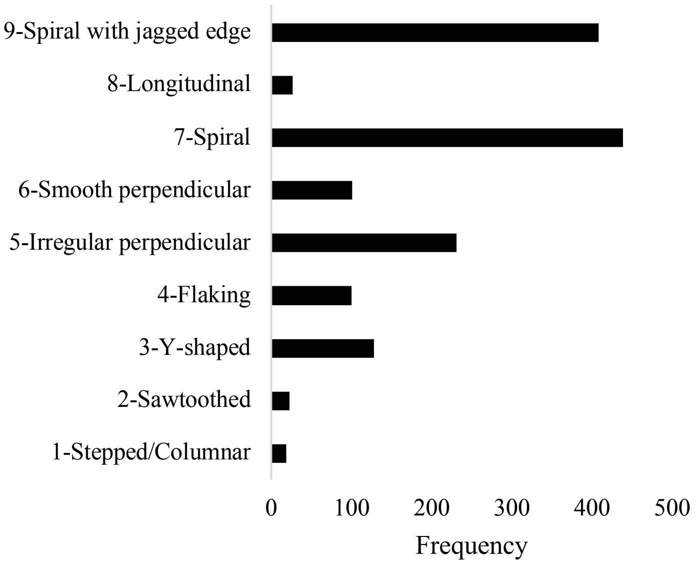


Fig 5.13: Isernia La Pineta 3 coll: Relative frequencies of different fracture types on diaphysis fragments.

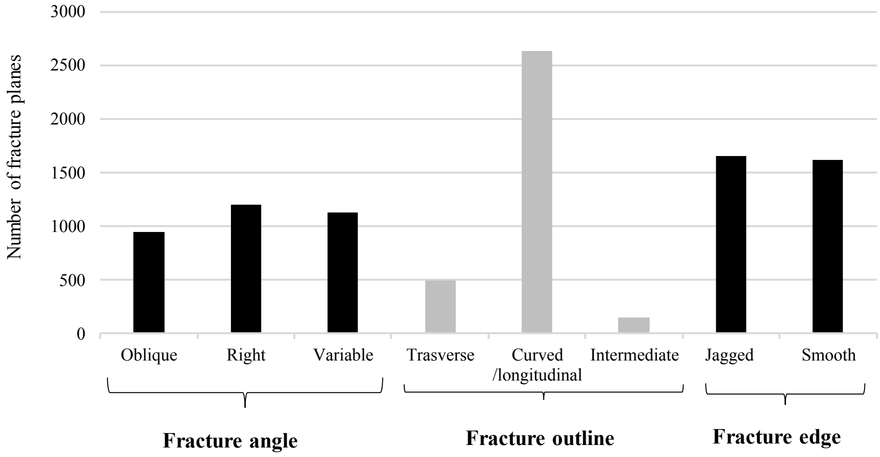


Fig 5.14: Isernia La Pineta 3 coll level: Relative frequencies of fracture angles, outlines and edges of diaphyses fragments.

The freshness fracture index for the 3272 fracture planes from 746 diaphyses brought to light an assemblage characterised by a mix of anthropic and post-depositional fracturation. The sum of scores assigned to the criteria described above (fracture angle, fracture outline and fracture edge) gave a range of 0 - 6 values. From the graph (Fig 5.15), it was observed that 2819 fracture planes- 1124 with 0 scores, 224 with 1 score, and 485 with 2 scores clearly demonstrated well-preserved characteristics of intentional breakage by hominins. With a score of 3, 634 fracture planes demonstrated a mixture of both anthropic and post-depositional fracturation. On the other side of this range, with a score of 4 for 541 fracture planes, 5 for 217 fracture planes and 6 for 47 fracture planes, 1427 fracture planes in total demonstrated typical features of post-depositional breakage.

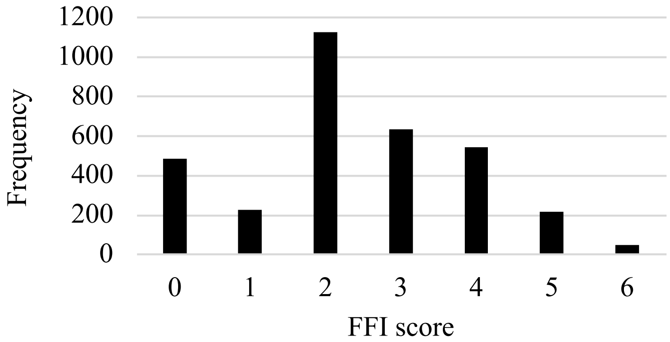


Fig 5.15: Isernia La Pineta 3 coll level: Number of diaphyses fragments assigned different fresh fracture index scores.

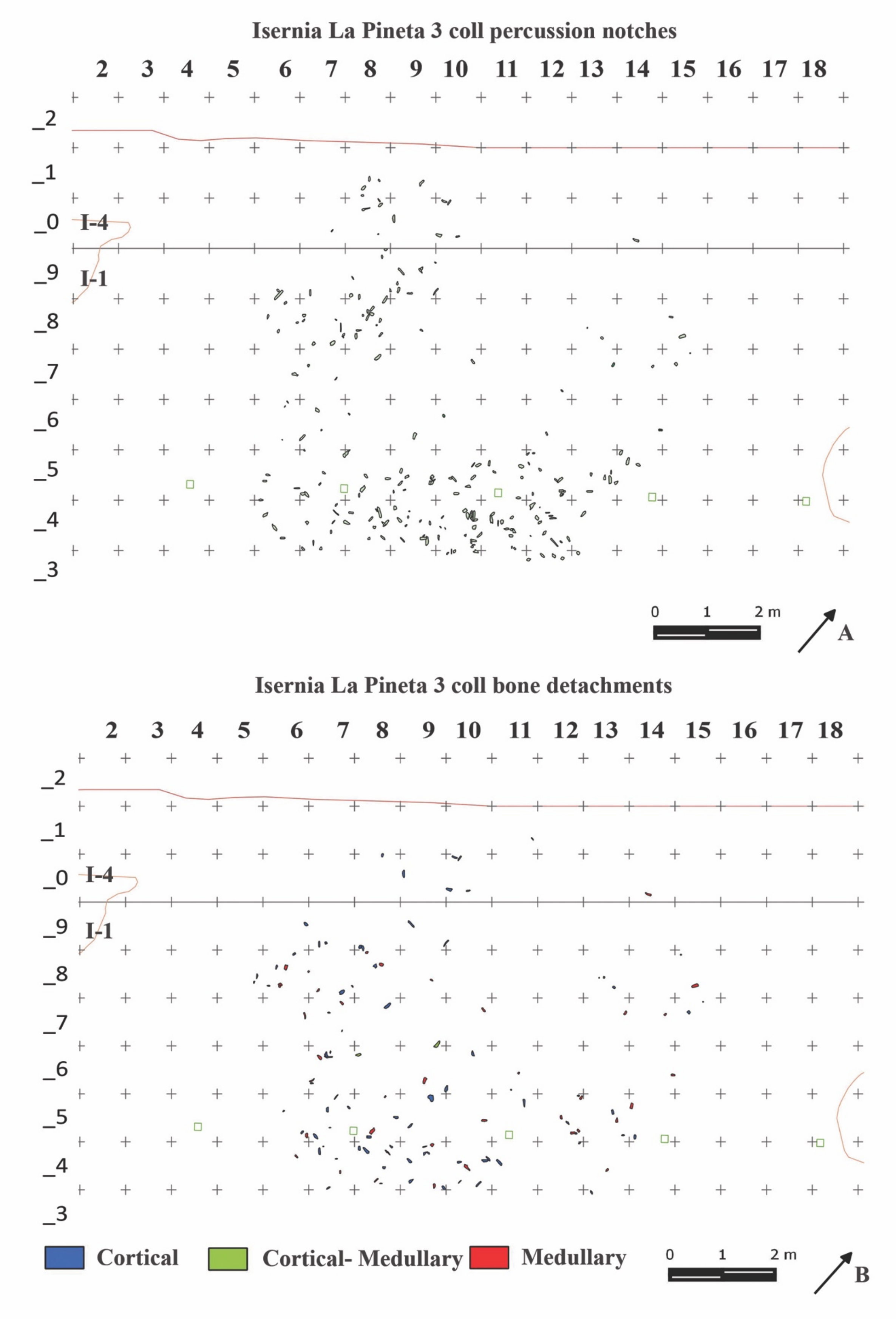
Percussion notches

Percussion notches were recognised in 222 remains that composed 3.6% of the total faunal assemblage. Single notches were present on 214 remains such as a mandible of bear, a vertebra of elephant, a tibia of giant deer, mandible and long bones of bison, long bones of ungulatess and artiodactyls and nearly all anatomical parts which were not identified taxonomically. Seven remains had two notches and they included bison femur and humerus, cranial and long bone diaphyses of an unidentified taxon. Only one remain, a rhinoceros femur, had three notches. A more detailed frequency distribution can be viewed in the table (5.9). The spatial distribution of percussion notches showed that they were mostly concentrated in the western, south eastern and southern areas of the excavated floor (Fig 5.16A).

The macro study of the remains with focus on the precise and detailed description of some fundamental characteristics of the impacts that were found on the bone surfaces yielded interesting information. A total of 199 remains with impact(s) were registered. Remains with a single impact were 161 in total whereas remains with two impacts were 34 in all. There were four remains with three impacts. As regards the remains that had two impacts, the relationship between impacts was analyzed. Specifically, two impacts on nine remains were situated consecutively. Two impacts on 14 remains were present on opposite borders at the same height. Two impacts on 11 remains were present on opposite borders at different heights. Among the 199 impacts, in particular, the transverse positioning of the impact with respect to the whole bone was analysed. Impacts situated in the medial part, 20 in all, were in majority. The longitudinal positioning with respect to the whole bone was possible to analysed. Impacts on the medial and ventral-caudal part were the most with 12 and 10 documented in total. The positioning of impacts with respect to the fragment was specified. Most of the impacts were placed in the medial position (NR 102), followed by proximal and then distal. A majority of the impacts, 129 in all, had a linear-concave shape, while 55 had a linear-sinuous shape and 26 were punctiform in shape. A majority, 160 impacts were at an acute angle. Further, regarding the appearance of the cortical border, a majority of them (NR 162) were without any stigmata.

Table 5.9: Isernia La Pineta 3 coll: Distribution of percussion notches based on the anatomical element and species.

Anatomical element	**Bear**	**Elephant**	**Rhinoceros**	**Giant deer**	**Bison**	**Artiodactyl**	**Ungulate**	**Unidentified taxon**
Cranium								2
Mandible	1				3			4
Isolated teeth		1						
Vertebra		1						
Rib								1
Humerus					4	1		4
Radio-ulna					1			
Radius					1			2
Metacarpal								1
Femur			1		3			3
Tibia				1				2
Fibula								2
Metatarsal					3			1
Diaphysis							1	125
Metapodium					1	1		1
Phalanx indeterminate					1			
Metaphysis								2
Indeterminate								47
Total	**1**	**2**	**1**	**1**	**17**	**2**	**1**	**197**



Isernia La Pineta 3 coll percussion notches

Isernia La Pineta 3 coll bone detachments

Fig: 5.16: Isernia La Pineta 3 coll: Spatial distribution of percussion notches and detachments.

Impacts associated with cortical face detachments were 66 whereas those associated with medullary face detachments were 206 in total. Most of the cortical face detachments were simple in nature, semicircular in form, near the impact point in terms of amplitude and lamellar in appearance. Detachments on the medullary face were also mostly simple, with a mix of laminate and semicircular form, near the impact in terms of amplitude, and lamellar in appearance.

Detachments not associated with percussion notches

During the macroscopic observation of the faunal remains, detachments were identified not associated with percussion notches on 81 of them. More specifically, 48 remains were present with detachments in the cortical face. These remains included a bison tibia and radius; rib, humerus and long bones of unidentified taxa. While 16 remains, mostly long bone diaphyses and a rib presented detachments in the medullary face, the combination of cortical and medullary detachments, found in four remains, was primarily present on humerus, tibia and long bones diaphyses fragments of unidentified taxa.

Detachments associated with percussion notches

In the faunal assemblage, 40 detachments were identified in association with percussion notches. The relationship between the notches and detachments was explored further. There were 36 remains with one notch, three remains with two notches and one remain with three notches were present in association with detachments. It was observed that 23 remains had detachments in the cortical face. They were present on a mandible and a radius fragment of bison, and long bones of unidentified taxa. Detachments in the medullary face were found on 16 remains consisting of rhinoceros femur, bison humerus, radius and femur apart from long bones of unidentified taxa. A combination of cortical and medullary detachments was observed on only one remain, a diaphysis fragment of an unidentified taxon. The spatial distribution of all detachments (associated + not associated with percussion notches) on the excavated floor highlighted their concentration in the south western, south eastern and southern areas, coinciding with the distribution of other anthropic bone-modifying evidences (Fig 5.16B). A scarce number of remains with detachments were present in the northern squares. The three categories of detachments- cortical, medullary and cortical-medullary, were found in a random scatter within these areas of concentration.

Percussion cones

In 3 coll, 40 percussion cones were identified. Apart from light erosion and weathering of stage 1 or 2 and no exfoliation, visible on approximately 31.7% of them, they appeared to be preserved well. Five of them had trampling marks made by sediment. One was a medullary cone of percussion. They also had deposits of manganese and iron oxide on them. Their length ranged between 26 to 83 mm, width was between 10 to 34 mm and thickness ranged between 6 to 20 mm. They were mostly found in the areas where other evidences of anthropic modification of bones were documented. Their provenance was squares situated in the western, south western and southern limit of the excavated floor of layer 3 coll.

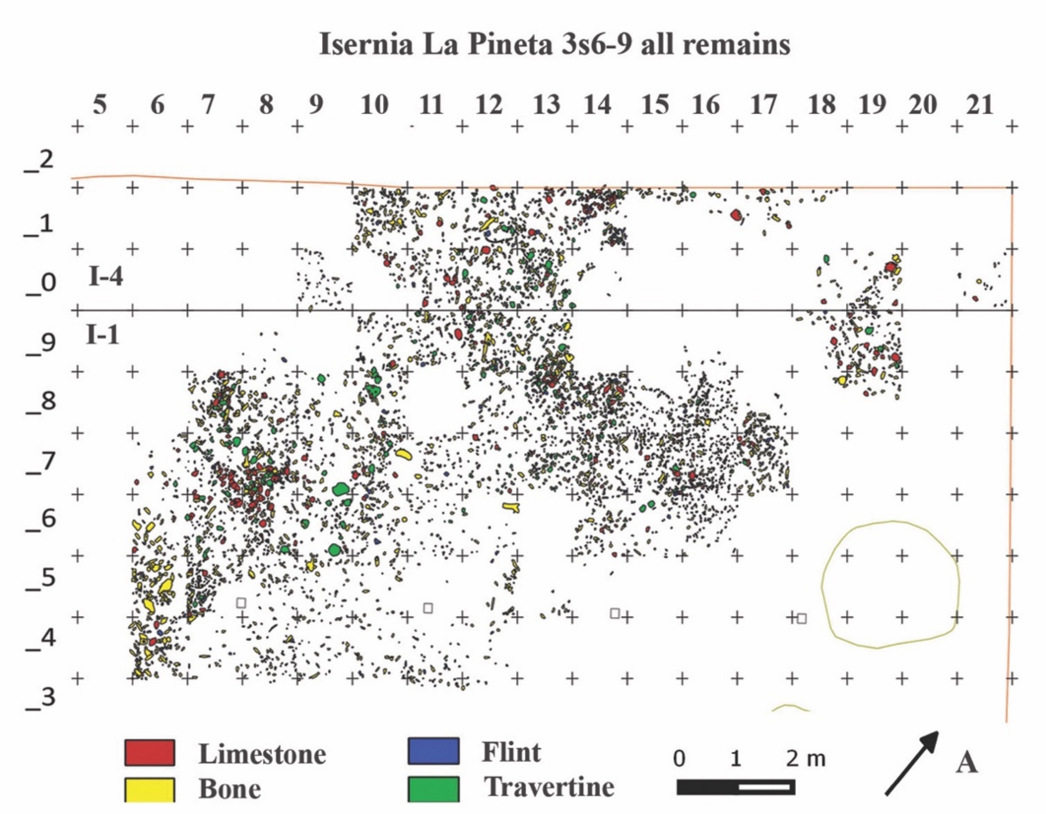
Chapter 6

Results from layer 3s6-9

6.1 Characteristics of the faunal assemblage

This chapter discusses in elaboration the results obtained from the archaeozoological, taphonomical and spatial distribution analyses of the remains of large mammals from layer 3s6-9 of Isernia following the methodology described in chapter 3. The spatial distribution of all recorded recovered remains- limestone, flint, bone and travertine, from the excavated 3s6-9 layer (Fig 6.1A) showed that they were dispersed over the entire floor in no particular pattern. There were some areas of dense concentration alternating with areas of sparse concentration of remains. Most of the remains, however, appeared to be present in larger numbers in the central, north western, western and south western squares. The spatial distribution map of only faunal remains, excluding other remains, revealed a similar picture (Fig 6.1B). This map showed the distribution of all layer 3s6-9 faunal remains recorded till date in the main database of the site, including the remains recovered in the 2017 excavation season. Gaps or holes present in certain squares in these two maps represent that have not yet been excavated or faunal material that is yet to be restored and/or remains from 2017 excavation season which is yet to be analysed. The faunal assemblage analysed for the present study does not include them, hence, in the subsequent spatial distribution maps, only the faunal assemblage taken up for this study have been depicted. The faunal study, furthermore, excluded some remains which were recovered during the sorting of washed sediments of layer 3s6-9, termed as 'non-coordinated' since their X, Y and Z values were not known.

The faunal assemblage from 3s6-9 consisted of **1081** remains (Table 6.1 and Fig 6.2). The total number of determined remains were 705 (65.2%). The anatomically determined remains without taxonomic specificity were 492 (45.5%) whereas the remains both taxonomically and anatomically determined were 213 (19.7%). The unidentified remains amounted to 376 (34.8%). The spatial distribution of unidentified faunal remains did not elucidate any particular pattern. The unidentified remains were concentrated specifically in the central, northern, north western and western areas of the excavated floor (Fig 6.4A). The data evidently shows that the percentage of taxonomically and anatomically determined remains (NRDt% or NISp%) is much lesser than the percentage of the total number of determined remains (NRD%). The remains which were determined only anatomically were more numerous. This deficit is by virtue of the state of integrity that characterizes the remains, which, in a majority of the cases, are very fragmented. The remains which were only anatomically determined (NRDa - 492) were dominated by diaphyseal portions (42.7%), cranial (15.7%), ribs (10.8%) and metaphyseal portions (10.2%) while the remaining anatomical parts contributed less than 10% each (Table 6.2). They were remains that were attributable to medium to large sized animals but not to very large sized animals like the elephant.


Isernia La Pineta 3s6-9 all remains

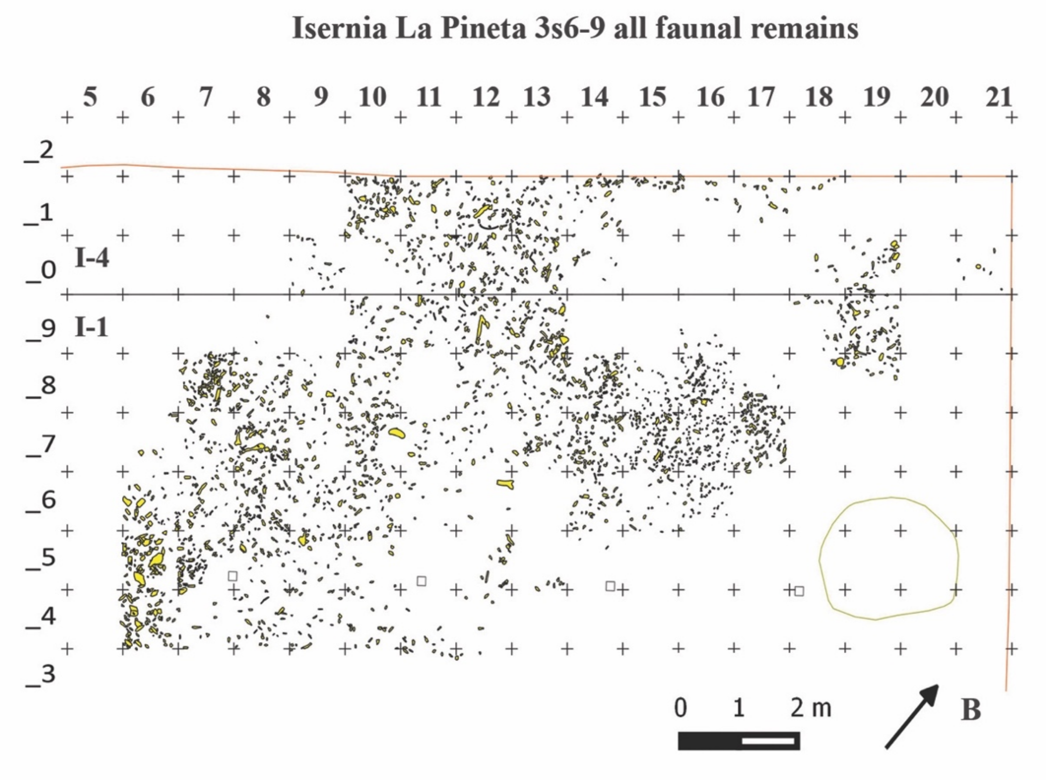

Isernia La Pineta 3s6-9 all faunal remains

Fig: 6.1: Isernia La Pineta 3s6-9: A- Spatial distribution of all remains; B- Spatial distribution of all faunal remains.

Table 6.1: Isernia La Pineta 3s6-9: Composition of the faunal assemblage.

TR	Unidentified	%	NRD	%	NRDa	%	NRDt (NISp)	%
1081	376	34.8	705	65.2	492	45.5	213	19.7

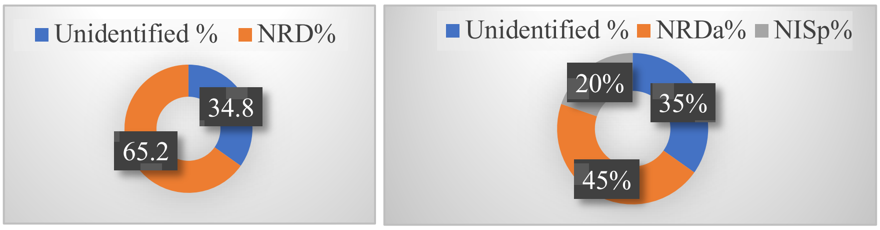


Fig 6.2: Isernia La Pineta 3s6-9: Representation of the faunal assemblage.

Table 6.2: Isernia La Pineta 3s6-9: Distribution of the number of remains by anatomic segment (not determined taxonomically) (NRDa 492).

Anatomical element	NRDa	NRDa%
Antler	1	0.2
Cranium	77	15.7
Mandible	15	3.0
Isolated teeth	13	2.6
Hyoid	2	0.4
Vertebra	13	2.6
Rib	53	10.8
Scapula	4	0.8
Humerus	5	1.0
Ulna	2	0.4
Radius	2	0.4
Metacarpal	1	0.2
Pelvis	7	1.4
Femur	6	1.2
Patella	1	0.2
Tibia	6	1.2
Metatarsal	1	0.2
Diaphysis	210	42.7
Epiphysis	10	2.0
Metapodium	9	1.8
Sesamoid	3	0.6
Carpal/tarsal	1	0.2
Metaphysis	50	10.2
Total	**492**	**100.0**

The number of remains determined taxonomically and anatomically amounted to 213 with a percentage of 19.7 of the total number of remains. The ungulates, in particular, the Order Artiodactyla, were clearly dominant over the other Orders in the assemblage (Fig 6.3). More precisely, they contributed 64.8%, while the Order Proboscidea, with the species, *Palaeoloxodon antiquus*, contributed to 14.6% of the assemblage. The Order Perissodactyla, with the species *Stephanorhinus hundsheimensis*, was represented by 11.7%. The carnivores were the least represented with a percentage of 8.9 of the assemblage. The only determined carnivore was the bear (*Ursus deningeri*).

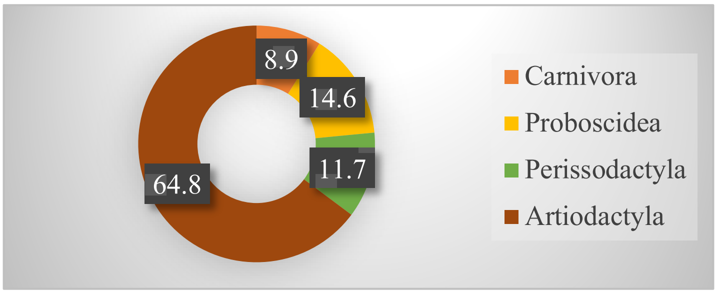


Fig 6.3: Isernia La Pineta 3s6-9. Representation of faunal remains (NRDt (NISp)-213).

6.2 The faunal spectra

Overall, the most represented taxa within the fauna assemblage were *Bison schoetensacki* (41.8%), *Palaeoloxodon antiquus* (14.6%), *Stephanorhinus hundsheimensis* (11.7%) and *Ursus deningeri* (8.9%) (Table 6.3). There were a few fragments categorised as 'Artiodactyla' (3.8%), a category that was mainly composed of fragments of cranium, long bone diaphyses and some isolated teeth. Similarly, some anatomical elements such as long bones, vertebrae and isolated teeth probably belonged to bison or rhinoceros, but for the lack of diagnostic morphological features, it was not possible to specify the genus or species. Hence, they were placed in the 'Ungulata' category and represented 6.6% of the assemblage. Among the artiodactyls were also the remains of indeterminate cervids, with a percentage of 8.5%. Identified in the assemblage was one remain of *Hippopotamus* cf. *antiquus*; one remain of *Sus scrofa*; one remain of *Praemegaceros solilhacus*; four remains of *Cervus elaphus* cf. *acoronatus* and two remains of *Capreolus* sp. In terms of the number of individuals that make up the remains of each species, *Ursus deningeri* was represented by the same number of individuals (3, 21.4%) as *Bison schoetensacki* (3, 21.4%), closely followed by *Stephanorhinus hundsheimensis* (2, 14.3%) (Table 6.3). The rest of the species had just one individual each. The spatial distribution of the anatomically determined remains of the four major species with better representation than the other taxa on the excavated floor showed that they were, similar to unidentified remains, mainly concentrated in the central, northern, north western and western areas (Fig 6.4B).

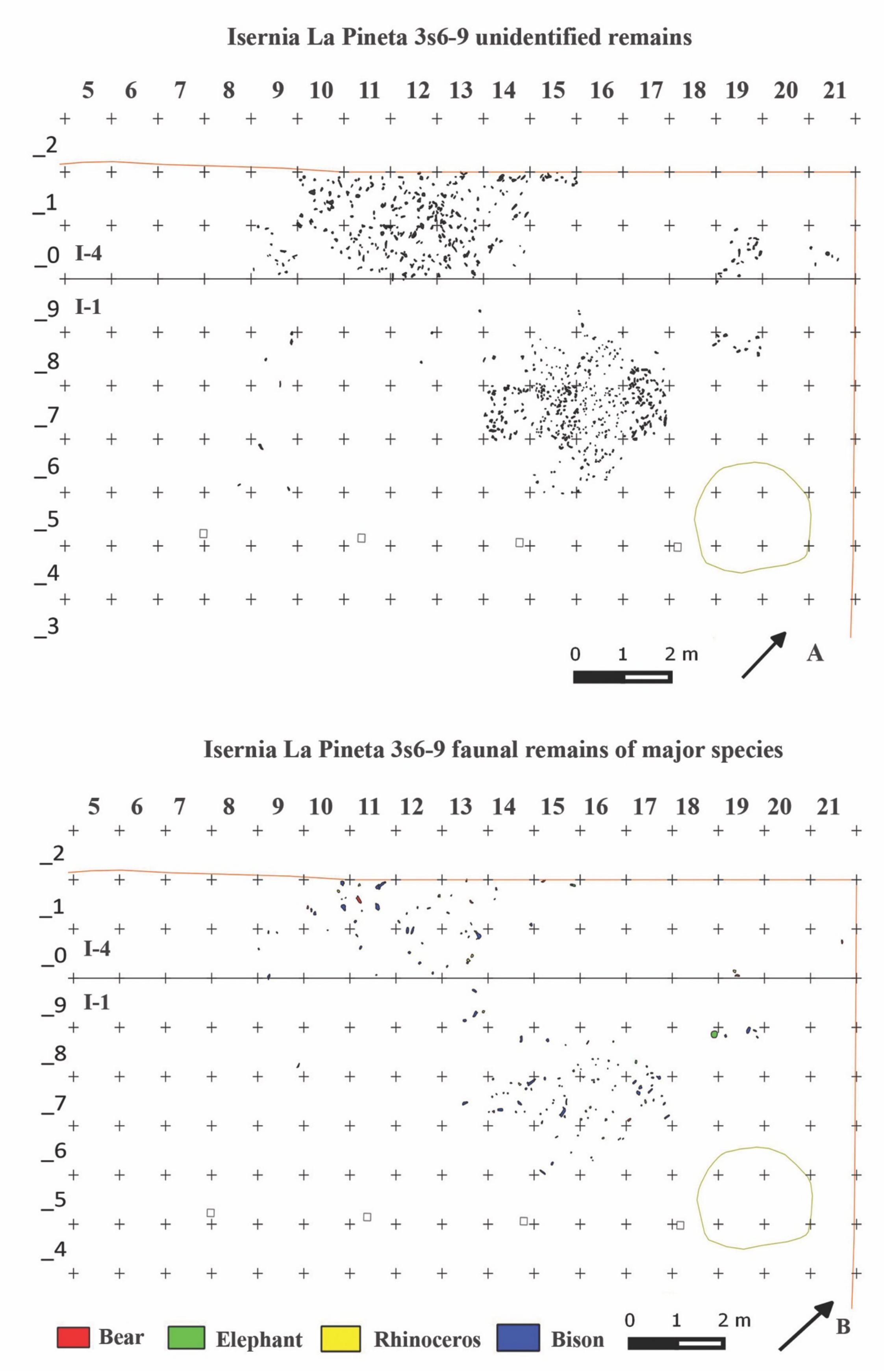


Fig: 6.4: Isernia La Pineta 3s6-9: A- Spatial distribution of all unidentified faunal remains; B- Spatial distribution of faunal remains of major species.

Bison schoetensacki FREUDENBERG 1910

The most represented species in the faunal assemblage of 3s6-9 was the bison (*Bison schoetensacki*), with 89 remains determined for a percentage of 41.8 (Tables 6.3 and 6.4) of the total NISp. The cephalic part was the most represented. In particular, the most abundant anatomical part corresponded to the isolated teeth with 33 remains, which represented 37.1% of the total NISp for this species. Following them were the fragments of the mandible, eight in all, which made up 9% of the total NISp for this species. There were also four fragments of the cranium. The axial skeleton was represented by three ribs and four pelvic fragments (3.4% and 4.5% respectively) of the total NISp of this species. The appendicular skeleton was represented by 37 remains (41.6%) belonging to the anterior and posterior limbs, of which, the fragments of the tibia were more abundant with 12 remains (13.5%). It was followed by five femurs (5.6%), four ulnae (4.5%), four posterior phalanges (4.5%) and three humeri (3.4%). The other anatomical elements had scarce representation.

Remains which were complete and almost complete were 35 in sum and were mainly teeth, carpals, tarsals and phalanges. The rest were fragmented. The large number of dental remains recovered and their good state of preservation and integrity allowed the calculation of the Minimum Number of Individuals (MNI). Based on the presence of three M^2 of the left laterality and three P^4 of the right laterality, the MNI was estimated to be three. The calculation of the MNI on the basis of the other anatomical elements such as mandible and tibia returned values lower than 3. Moreover, the high fragmentation of the elements of the post-cranial skeleton and the difficulty in specifying their precise anatomical position rendered them unreliable in the calculation of the MNI.

Palaeoloxodon antiquus FALCONER & CAUTLEY 1847

The elephant, with the species *Palaeoloxodon antiquus*, was present in the faunal assemblage with a percentage equal to 14.6 of the number of taxonomically determined remains (Tables 6.3 and 6.4). This is the second most represented species of the analysed osteological material. Of the 31 elephant remains, the dental fragments were by far the most numerous: 30 in total, 96.8% of its total NISp. Most of these were tusk fragments. To them was added one vertebra which represented the axial skeleton. Cumulatively, they probably represented one individual at a minimum. None of the remains were complete.

Stephanorhinus hundsheimensis (TOULA 1902)

The third most represented species was the rhinoceros (*Stephanorhinus hundsheimensis*), with 25 remains determined by a percentage of 11.7% of the total NISp (Tables 6.3 and 6.4). The dental remains representing the cranial skeleton were the most numerous: 19 remains for a percentage of

76 of the total NISp. The axial skeleton had no representation. The appendicular skeleton was on the other hand represented by six remains of which the most abundant element was the diaphysis of unidentified long bones, followed by two metatarsal and one posterior phalanx. Among the 25 remains, 10 remains were either complete or incomplete. They included mainly teeth and phalanges. The calculation of the Minimum Number of Individuals was made on the basis of dental elements. The presence of two P^3 from the left maxilla gave an MNI of two.

Ursus deningeri VON RICHENAU 1906

The bear (*Ursus deningeri*) is the fourth most represented species in the faunal assemblage of layer 3s6-9 with a percentage of 8.9% of the total NISp. It is the only recognized species of carnivore in the assemblage. The total number of remains is 19 (Tables 6.3 and 6.4). The most abundant anatomical element belonged to the cephalic portion. In particular, 11 dental remains were recognized (57.9% of its total NISp); 1 mandible fragment (5.3%); 2 cranial fragments (10.5%). The axial skeleton was not present in the assemblage. The appendicular skeleton was represented by two metatarsals, two phalanges and one carpal. Teeth, phalanges and the carpal were either complete or almost complete. A minimum of three individuals was estimated on the basis of the presence of three upper canines of the left laterality.

Table 6.3: Isernia La Pineta 3s6-9: Summary of faunal composition.

Order	**Family**	**Taxon**	**NISp**	**%**	**MNI**	**%**
Carnivora	Ursidae	*Ursus deningeri*	19	8.9	3	21.4
Proboscidea	Elephantidae	*Palaeoloxodon antiquus*	31	14.6	1	7.1
Perissodactyla	Rhinocerotidae	*Stephanorhinus hundsheimensis*	25	11.7	2	14.3
Artiodactyla	Hippopotamidae	*Hippopotamus* cf. *antiquus*	1	0.5	1	7.1
	Suidae	*Sus scrofa*	1	0.5	1	7.1
	Cervidae	*Praemegaceros solilhacus*	1	0.5	1	7.1
		Cervus elaphus cf. *acoronatus*	4	1.9	1	7.1
		Capreolus sp.	2	0.9	1	7.1
		Cervidae	18	8.5		
	Bovidae	*Bison schoetensacki*	89	41.8	3	21.4
Artiodactyla			8	3.8		
Ungulata			14	6.6		
Total NISp and MNI			**213**	**100.0**	**14**	**100.0**

Table 6.4: Isernia La Pineta 3s6-9: Distribution of anatomical elements of the four major species.

Anatomical element	Bear	Elephant	Rhinoceros	Bison
Cranium	2			4
Mandible	1			8
Isolated teeth	11	30	19	33
Vertebra		1		
Rib				3
Humerus				3
Radio-ulna				1
Ulna				4
Carpal	1			2
Anterior phalanx				1
Pelvis				4
Femur				5
Patella				1
Tibia				12
Tarsal				1
Metatarsal	2		2	
Posterior phalanx			1	4
Diaphysis			3	1
Phalanx inderterminate	2			2
Total	**19**	**31**	**25**	**89**

Other species with a few number of remains were identified in the assemblage. They are as follows

- *Hippopotamus* cf. *antiquus* (hippopotamus) was present with solely one remain (0.5%), a fragment of canine tooth. Hence, there was a minimum of one individual.
- *Sus scrofa*, the wild boar, was represented by one remain (0.5%)- a diaphyseal fragment of the humerus. This remain represented a minimum of one individual.
- *Praemegaceros solilhacus*, the giant deer, was also represented by one remain (0.5%), a diaphyseal fragment of tibia. Thus, a minimum of one individual was represented by this fragment.
- *Cervus elaphus* cf. *acoronatus*, the red deer, was represented by four remains (1.9%) which probably belonged to the same individual. A right M^3, a right I_1, two diaphyseal fragments- one of a tibia and the other unidentified, belonged to this species.

- *Capreolus* sp., the roe deer, was represented by two remains (0.9%), probably belonging to a minimum of one individual. They were a fragment of a pelvis and the distal epiphysis of a metapodial.

The category Cervidae consisted mostly of fragments of antler, teeth, vertebrae and diaphyses.

6.3 State of integrity

The state of integrity was unidentified for 854 remains which represented 79% of the sample examined, forming the majority. For the remaining 21%, it was possible to specify the precise transversal and longitudinal position and placement of the fragment with respect to the whole bone (Table 6.5). In order of abundance: medial fragments (7.9%) were more than the rest. Incomplete fragments (3.9%) were more than complete fragments (2.5%). In the total assemblage, 2.3% of the remains were from the proximal part of the bone while 1.6% of the remains were from the distal part. The state of integrity was identified for few remains which revealed that the remains were fragmented to an extent where identifying their laterality and portion with respect to the whole bone was difficult.

Table 6.5: Isernia La Pineta 3s6-9: Distribution of remains based on their state of integrity (NR 1081).

State of integrity	**NR**	**NR%**
Indeterminate	854	79.0
Complete	27	2.5
Incomplete	42	3.9
Proximal fragment	25	2.3
Proximal-medial fragment	12	1.1
Medial-distal fragment	3	0.3
Distal fragment	17	1.6
Left lateral fragment	1	0.1
Right lateral fragment	1	0.1
Right medial fragment	1	0.1
Left anterior fragment	1	0.1
Right anterior fragment	1	0.1
Left posterior fragment	4	0.4
Right posterior fragment	2	0.2
Lateral fragment indeterminate	2	0.2
Medial fragment	85	7.9
Diaphysis + proximal and distal metaphysis	1	0.1
Lateral, anterior and medial fragment	2	0.2
Total	**1081**	**100.0**

6.4 Taphonomic analyses

To better understand the processes that impacted the faunal remains from their death, discard to discovery in an archaeological excavation, taphonomic analyses were carried out at macroscopic and microscopic levels. The taphonomic analysis of the remains aimed at assessing the conservation status of the bone surfaces and yielded some interesting information.

6.4.1 Non-anthropic modifications

The faunal remains from layer 3s6-9 demonstrated several types of modifications imputable to natural factors.

Weathering

Weathering was absent (stage '0') in 395 remains (36.5%) which belonged to both axial and appendicular anatomical elements from identified and unidentified taxa. However, 686 remains (63.5%), again belonging to different anatomical elements, exhibited either one of the successive 4 stages while none had reached stage '5'. Slight weathering- stage '1' was seen on 391 remains (36.2%) whereas more advanced characteristic cracking was observed on 264 remains- stage '2' (24.4%), 30 remains- stage '3' (2.8%), and 1 remain, a rib fragment at stage '4' (0.4%).

Erosion

No erosion was seen on 157 remains (14.5%) while 924 (85.5%) remains demonstrated varying degrees of erosion. All anatomical elements appeared to be impacted by this agent. Light erosion was seen in 553 (51.2%) remains, marked erosion on 351 (32.5%, Plate 4A) remains and diffused erosion was documented in 20 (1.9%) remains. The last group of heavily eroded remains was mostly diaphyses of long bones, crania, ribs, vertebrae and flat anatomical elements such as pelvis and scapula.

Exfoliation

Exfoliation was absent in 799 (73.9%) remains and present in 282 (26%) remains. Light exfoliation was observed in 146 remains (13.5%), marked exfoliation in 126 remains (11.7%; Plate 4B) and diffused exfoliation was documented for 10 remains (0.9%). Remains profoundly effected by diffused exfoliation included diaphyses fragments of long bones, rib, antler and elephant's incisor (tusk) fragments.

Considering that weathering, erosion and exfoliation played an important role in the post-depositional taphonomic history of the assemblage, the eight 'WEE' combinations revealed interesting outcomes (Table 6.6). While the absence of all three agents, corresponding to good preservation (combination 000) was documented for 40 remains (3.7%), on the contrary, 174 remains (16.1%) were clearly impacted by all of them (combination 111) corresponding to weaker preservation. Single-agent impact with no visible effect of other two agents varied in quantity. Only weathering (combination 100) was found in 79 remains (7.3%), only erosion (combination 010) on 272 remains (25.1%) and only exfoliation (combination 001) was recorded on the least number of 13 remains (1.2%). Erosion had a nearly three-fold greater impact on remains than weathering or exfoliation. A number of remains with a combination of the presence of two agents and absence of one agent fluctuated. Both weathering and erosion (combination 110) were observed the highest- 408 remains (37.7%). Impact of weathering and exfoliation but no erosion (combination 101) was recorded on the smallest number of remains- 25 (2.3%). Erosion and exfoliation with the absence of weathering (combination 011) were seen on 70 remains (6.5%).

The 2D frequency map (Fig 6.5A) displayed the relationship between altered (Weathering + Erosion + Exfoliation) in black and unaltered in light grey. A major visible impact of the three natural agents was documented for every square that was analysed for its faunal remains. Excluding four squares, most of the squares from the central, northern, north western and south western areas displayed 100% altered remains in terms of complete black circles. Unaltered remains, in light grey were represented by small slices within the circles. The four squares with less than one-quarter of unaltered remains represented areas in the centre, extreme north and the western limit of the excavated floor.

The 2D map (Fig 6.5B) depicted pie charts for each square signifying relationships between remains impacted by each of the three agents (Weathering-Black, Erosion-dark grey and Exfoliation-light grey) while the colour of the squares indicated higher concentrations (darker hues of grey) or lower concentrations (lighter hues of grey) of altered remains. It highlighted certain interesting patterns of distribution and concentration of altered remains. The squares with the smallest number of altered remains, between 1- 30, were clearly present in the northern, north western and south western areas of the excavated floor. They were 19 such squares showing that most of the squares analysed had altered remains, but in fewer numbers. These areas or squares with relatively fewer altered remains seemed to encircle or were at the periphery of areas or squares with the higher number of altered remains. Squares with darker hues of grey, containing between 31 to 60 altered remains were specifically found in the central and western areas of the excavated floor. They appeared to be concentrated in a horizontal or linear fashion. In comparison, only four squares comprising 61 to 90 altered remains were found intensively in the central area of the distribution map. Only one square denoted by black colour, representing the highest number of altered remains was mapped in the central area of the excavated floor.

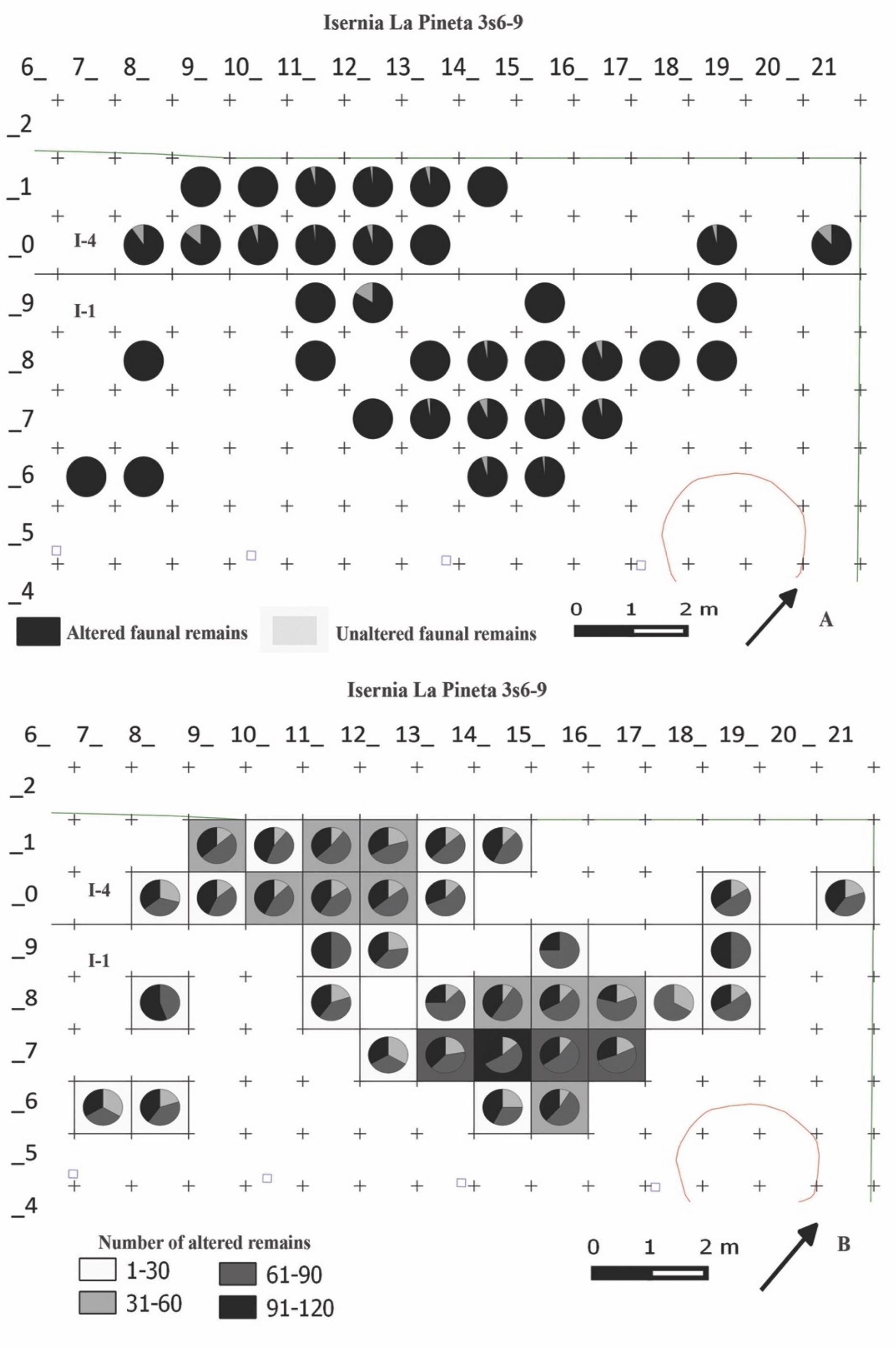


Fig: 6.5: Isernia La Pineta 3s6-9: A-Two-dimensional frequency map showing the relationship between faunal remains altered by weathering, erosion and exfoliation and the unaltered faunal remains in black and light grey colours respectively for each excavated and analysed square; B- Two-dimensional map showing frequency of faunal remains altered by all three natural taphonomic agents - weathering, erosion and exfoliation in each excavated and analysed square with the colour of the square indicating higher concentrations (darker hues of grey) or lower concentrations (lighter hues of grey) of altered remains. Pie charts within each excavated and analysed square demonstrate the relationship between remains effected individually by each of the three agents (Weathering-Black, Erosion-dark grey and Exfoliation-light grey).

Table 6.6: Isernia La Pineta 3s6-9: Number of faunal remains impacted by combinations of weathering, erosion and exfoliation.

Combination	Natural agent	NR
000	Absent	40
111	Weathering + Erosion + Exfoliation	174
100	Only weathering	79
010	Only erosion	272
001	Only exfoliation	13
110	Erosion + Exfoliation	408
101	Weathering + Exfoliation	25
011	Erosion + Exfoliation	70

A glance at the pie-charts within the squares also brought to the forefront some interesting patterns of natural taphonomic agents at work (Fig 6.5B). Remains with weathering, shown in black in the circles, were clearly present in nearly all the squares analysed except for one square in the central area, slightly tending towards the northern direction. A similar observation held true for remains impacted by erosion which had clearly impacted all areas analysed from the excavated floor. Between the three agents, weathering and erosion had a greater impact on the remains as has been numerically reported in the previous paragraphs. In squares with fewer altered remains (1-30), weathering and erosion were dominant over exfoliation. As an exception, two squares, one in the north and the other in the south western area, were devoid of exfoliated remains. Furthermore, in squares with the higher number of altered remains, erosion appeared to be more active than the other two agents. Exfoliated remains were comparatively lesser in the central area of the excavated floor.

Rounding

The degree of rounding of the bone surfaces is linked to the physical factors connected to post-depositional processes. More precisely, it is linked to the action of transport by water and the abrasive action of loose sediments, which act on the bones, rounding the edges. In the assemblage, 13.4% (NR 145) of the remains were devoid of rounding, while 42.2% (NR 457) showed a degree of slight rounding. Medium rounding was present on 36.5% of the finds (NR 395; Plate 4C). An advanced rounding was present on 7.6% (NR 83) of the remains and a very advanced rounding was observed on 0.09% (NR 1) of the remains. The spatial distribution of remains with the four degrees of rounding revealed a pattern similar to the oxides. In general, the remains which were rounded where found to be present in the central and north western areas of the excavated floor. However, some remains from squares 124, 134, 144, 154 (in a horizontal area), 198 in quadrant I and squares 121 and 191 of quadrant 4 displayed medium to advanced rounding (Fig 6.6).

In this assemblage, 19 remains were devoid of rounding, weathering, erosion and exfoliation. This can be reasoned since all of them were dental elements, invariably the better preserved elements of the skeleton. The remaining anatomical elements had all been impacted by one or the other pre and post-depositional bone modifying agents.

Oxides

The bone surfaces gave ample evidence of the presence of two oxides in particular, manganese and iron. The presence of these two compounds is the result of chemical and biological factors. Manganese oxide comes in the form of very small, dark black and grey blotches, and through microstirations of black-dark grey. These are the result of the filling of weathering cracks by the manganese oxide. Iron oxide occurs in the form of red-orange patches, due to its deposition in some

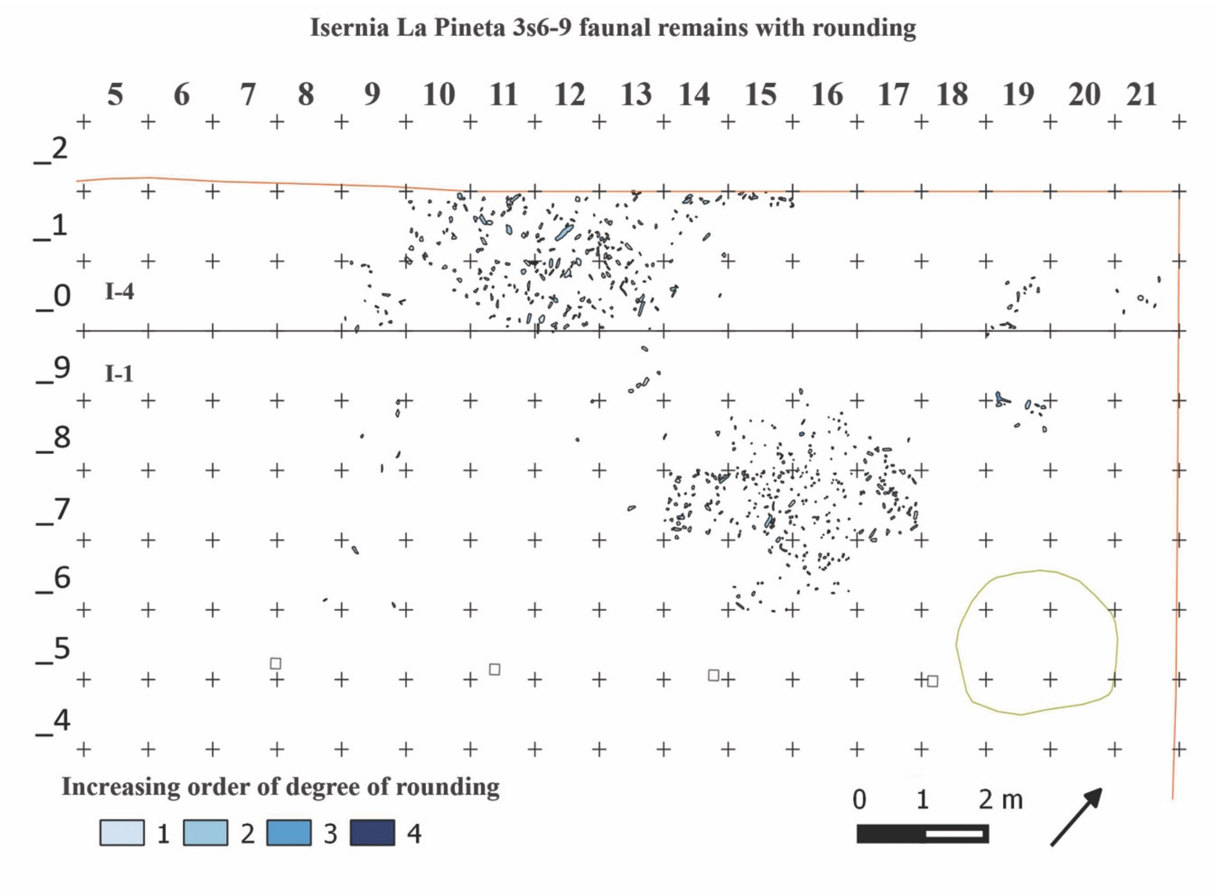


Fig: 6.6: Isernia La Pineta 3s6-9: Spatial distribution of faunal remains with rounding.

specific points of the bone surface due to physical and chemical phenomena. The remains on which the oxides were completely absent were only two (0.9%) in the total assemblage. These remains were a rhinoceros metatarsal and an unidentified taxon's tooth. Manganese oxide occurred on 157 remains (14.5%); Iron oxide, not associated with Manganese, did not occur on any remain, while the association manganese + iron was present on 922 remains (85.3%). The spatial distribution of the remains impacted by oxides showed that they were present in large numbers in quadrants 1 and 4 of Sector I. They were found on remains mainly concentrated in the central and north western areas of the excavated floor. Very few remains with oxides were found in the northern most area of the excavated floor.

Trampling marks

The examination of each remain under an optical microscope helped to highlight the diagnostic and micromorphological characteristics that allowed to recognize their nature and source of origin. Here, in this section, the linear marks due to natural factors are discussed in detail. The absence of linear marks was ascertained in 351 remains (32.5%). On 491 remains (45.4%) were exhibited marks of trampling by sediments. On 10 remains (0.9%) abrasion marks were recognized. A combination of all types of marks caused by natural agents was recognized on 217 remains (20.1%). They were found on the surface of all types of anatomical parts and came from nearly all areas of the 3s6-9 excavated floor.

Carnivore/rodent marks

In this assemblage, 10 carnivore marks were documented mainly on bison remains and remains of unidentified taxa. They were present mainly on the mandible, rib, femur, tibia and carpal bones. Carnivore marks were also found on the metaphyses and mandible of taxonomically indeterminate remains (Plate 4D). Their provenance was from different squares of the excavated floor and did not pertain to any specific zone indicating carnivore activity. Scanty data for this variable did not warrant a spatial distribution map.

Roots etchings

The dendritic impressions imputed to the chemical or mechanical action of sub-terranean roots on bone surfaces were recognised on 17.6% of the faunal remains. The remaining 82.3% were devoid of it. In 37 remains (3.4%) they were manifested lightly. In 67 remains (6.2%), they were more marked. In the remaining 87 remains (8%), they appeared diffused. They were found on the surface of all types of anatomical parts and came from nearly all areas of the 3s6-9 excavated floor.

Fractures

The fracturing of remains is caused by both anthropogenic factors and natural factors. During the compilation of the database, the type of fracture was discriminated based on the morphological characteristics of the fragmentation. However, the remains often do not present a single type of fracture although it is possible to recognize both the anthropic factor and the subsequent post-depositional factor. Consequently, when calculating the fracture percentages, it must be taken into account that the same fragment can have more than one type of fracture and therefore exists an overlap between the values.

Non-anthropic fractures

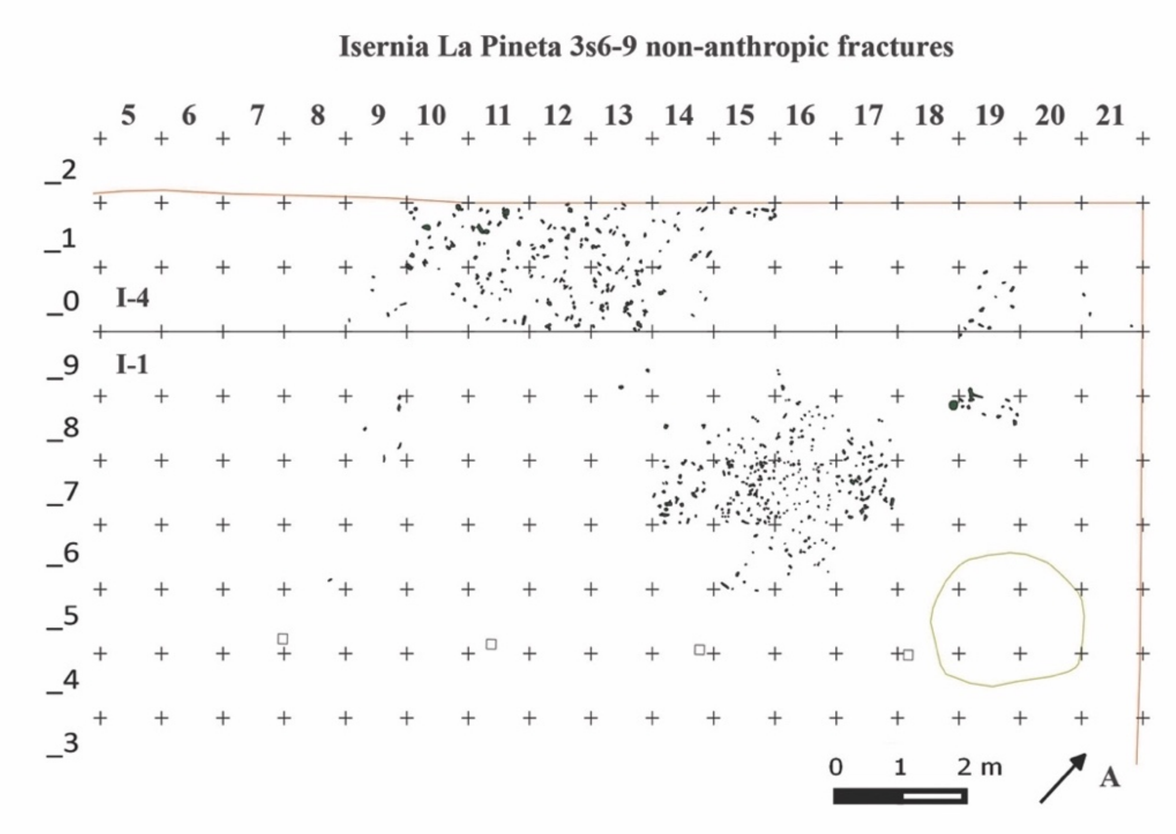
Fractures due to natural causes were recorded in 877 remains. Out of them, 54.7% (NR 592) of the remains were documented with post-depositional fractures and 4.1% (NR 44) remains were fractured due to weathering. A combination of these factors was observed to have fractured 0.5% (NR 5) of the remains. The presence of both anthropic and post-depositional fractures were present on 236 remains (21.8%). Teeth, small compact bones such as phalanges, carpals, tarsals, and some other anatomical elements comprising 4.3% (NR 47) of the remains were documented with an absence of fractures. The spatial distribution of non-anthropic fractures showed their dense concentration particularly in the central, western and north western areas of the excavated floor of this layer (Fig 6.7A). A few remains were also found to be distributed in two specific squares- 198 in quadrant 1; 190 and 210 in quadrant 4. Within the areas of denser concentration, certain squares had chiefly larger fragments with non-anthropic fractures. They were squares 101 and 111 in quadrant 4; squares 198, 147 and 177 in quadrant 1.

6.4.2 Anthropic modifications

Human activities are represented by cut-marks, scraping-marks, anthropic intentional fractures, impact points, notches, detachments and percussion cones.

Cut-marks and scraping-marks

In some cases, bone surfaces do not allow a clear distinction between cut-marks and marks due to trampling. The observation of the resin casts carried out at the SEM helped to distinguish between the actual and pseudo cut-marks, while in the former, albeit partially, the possible micro-striations. Of the 13 cut-marks under analyses, four were confirmed, while six were dubious and the rest confirmed as not cut-marks. The confirmed ones were present on a bison mandible fragment (1.139.016), a diaphyses fragment of an unidentified taxon (1.175.005), a tibia of an unidentified


Isernia La Pineta 3s6-9 non-anthropic fractures

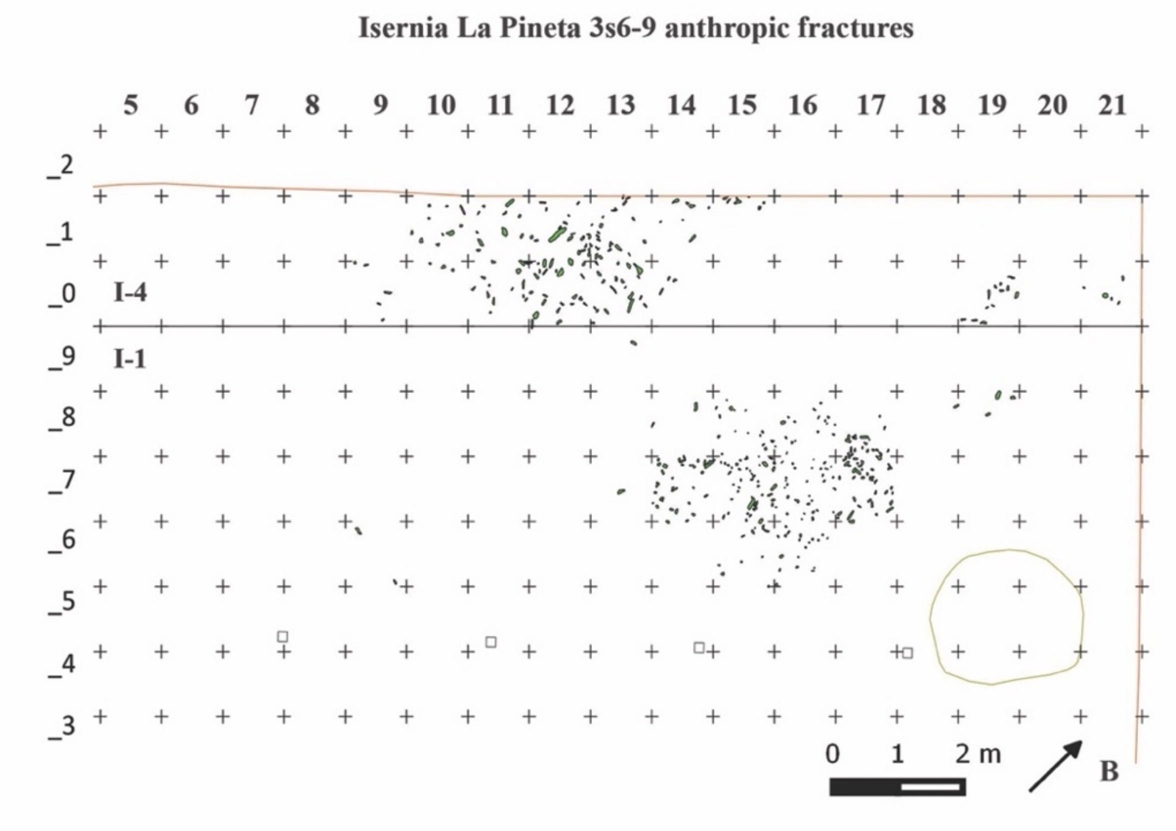

Isernia La Pineta 3s6-9 anthropic fractures

Fig: 6.7: Isernia La Pineta 3s6-9: A- Spatial distribution of non-anthropic fractures; B- Spatial distribution of anthropic fractures.

taxon (4.120.146) and the third right metatarsal proximal epiphysis of rhinoceros (4.111.1). Doubtful ones were present on a diaphysis of an unidentified taxon (1.147.175), an unidentified remain (4.101.118), a diaphysis fragment of an unidentified taxon (1.96.016), a pelvic fragment of an unidentified taxon (1.157.107), a bison femur (4.111.16) and a bear mandible (4.111.34).

Scraping marks were observed, both macroscopically and microscopically, on three remains. They were the diaphysis of a giant deer tibia, the diaphysis of a bison tibia and a metaphyseal fragment of an unidentified taxon.

Intentional fractures

The remains with anthropic fractures amounted to 393 and contributed to 36.4% of the entire faunal assemblage. Out to this 36.4% remains, 14.5% (157) had only anthropic fractures and 21.8% (236) has both anthropic and post-depositional fractures. Most of them were unidentified diaphyseal portions, which were a total of 162, or 41.2% of the total remains with anthropic fractures (Table 6.7). This evidence was also recorded on 106 unidentified remains, 44 metaphyseal fragments whereas the other anatomical elements yielded evidences on less than 10 remains each. There were a total of 46 taxonomically determined remains bearing evidence of anthropic fractures (12.2%). The dominant species in terms of fractures was certainly bison, with a total number of fractured remains equal to 27 (7.1%). The categories of deer and ungulate followed in order of abundance with six remains each (Plate 6C). Artiodactyl with three remains came next, while the rest of the species had one remain each (Table 6.7). The spatial distribution of anthropic fractures showed their dense concentration, similar to the distribution of non-anthropic fractures, more specifically in the central, western and north western areas of the excavated floor of this layer (Fig 6.7B). However, unlike the non-anthropic fracture distribution where the areas of concentration were composed of mostly fragments of smaller sizes, the areas of concentration of anthropic fractures in terms of the size of fragments was unique. It was noticed that the area of concentration in the western squares of quadrant 4 and in squares 157 and 158 in quadrant 1 was particularly composed of large fragments. In the central area of concentration, the fragments, except for a few as mentioned above, were mostly small. The same observation held true for the fragments with anthropic fractures found in the northern squares 190 and 210 of quadrant 4.

Fracture analyses

Long bone fractures were further examined to delineate characteristics typically attributed to anthropic and post-depositional causal agents. Long bones, identified taxonomically were 40 in number whereas long bones taxonomically unidentified amounted to 232 in number. An examination of the distribution of long bones among identified and unidentified taxa showed that diaphyses (54%)

and metaphyses (13.7%) and epiphyses (8.8%), not determined taxonomically, were more in number when compared to others (Fig 6.8). Long bones that were determined only anatomically but not taxonomically accounted for 11.5% of the sample. The long bones that were determined anatomically but not taxonomically were humerus, radius/ulna, radius, ulna, metacarpal, femur, tibia and metatarsal. Among long bones that were identified taxonomically and anatomically- tibia (7.4%), femur (1.9%) and humerus (1.5%) were better represented than others. With respect to epiphysis, diaphyses had 60% more representation.

Table 6.7: Isernia La Pineta 3s6-9: Distribution of anthropic fractures based on the anatomical element and species (NR 393).

Anatomical element	**Bear**	**Wild boar**	**Giant deer**	**Red deer**	**Deer**	**Bison**	**Artiodactyl**	**Ungulate**	**Unidentified taxon**
Antler					1				
Cranium	1					1			
Mandible						3			6
Rib						1			6
Scapula									1
Humerus		1			1	2	1	3	4
Radio-ulna						1			
Ulna						1			1
Radius					1		1		1
Metacarpal					2				
Pelvis						2			
Femur						5		1	6
Tibia			1	1		11		2	5
Metatarsal					1				1
Diaphysis							1		162
Epiphysis									1
Metapodium									3
Metaphysis									44
Inderterminate									106
Total	**1**	**1**	**1**	**1**	**6**	**27**	**3**	**6**	**347**

Among the long bones that were identified taxonomically, it was observed that most of the long bones (77.5%) were identified as bison (Fig 6.9). A few number of long bones were identified as belonging to the remaining determined species. Anatomically determined long bones were not identified for bear and roe deer, which were otherwise represented by epiphyses. Wild boar and giant deer were not represented by epiphyses but with anatomically determined long bones.

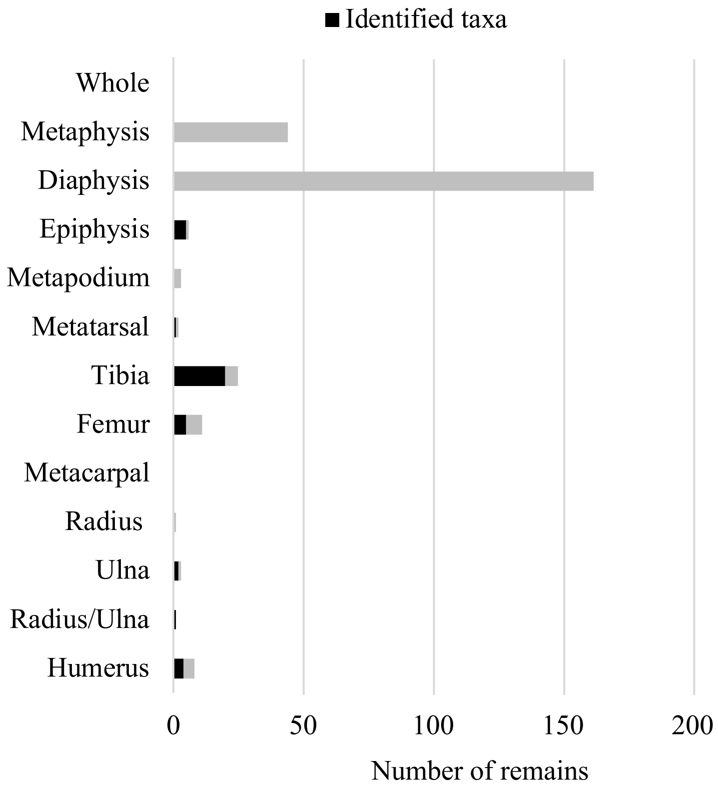


Fig 6.8: Isernia 3s6-9: Frequency distribution of long bones for identified and unidentified taxa (NR 270).

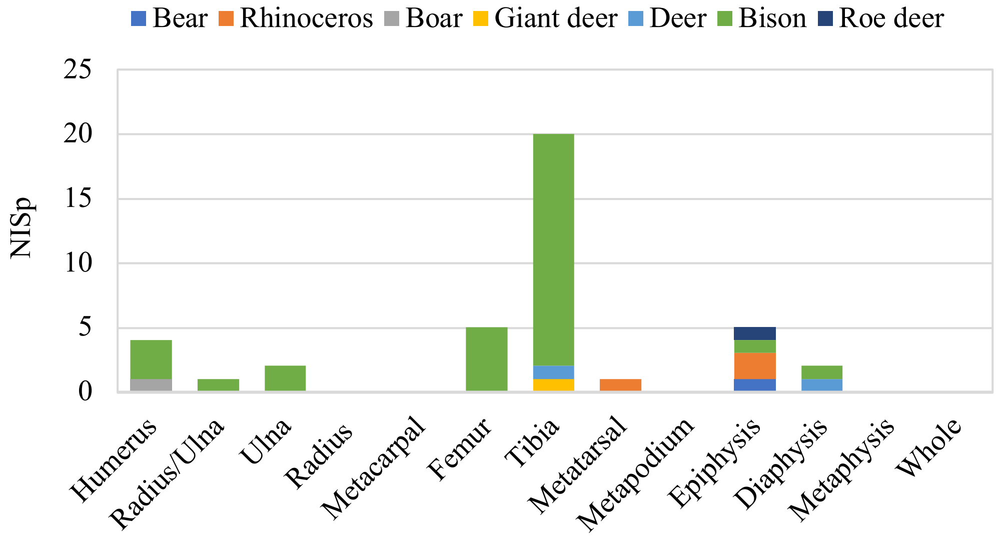


Fig 6.9: Isernia 3s6-9: Species-wise distribution of long bones (NR 38).

The epiphyses were not included in the fracture analyses. Hence the number of diaphyses available for this study were 213 in case of unidentified taxa and 33 for identified taxa, amounting to 246 diaphyses. Some of the selected diaphyses also had one intact or partially intact epiphyseal end. The diaphyses which were not taxonomically determined had a shaft circumference mostly less than half of the original (C1- 206) (Fig 6.10). This partially explains why they were fragmented beyond recognition and could not be assigned to a specific taxon. Only five and two diaphyses had a shaft circumference more than half of the original (C2) and complete circumference (C3) respectively. The shaft length analyses showed that 127 diaphyses had a shaft length less than one-quarter of the original length (L1). A shaft length of one-quarter to one-half of the original length (L2) was observed in 68 diaphyses. In comparison, very few, only 18 of the diaphyses had a shaft length of one-half to three-quarters of the original length (L3). There were no diaphyses with more than three-quarters of the original length, a complete or almost complete long bone.

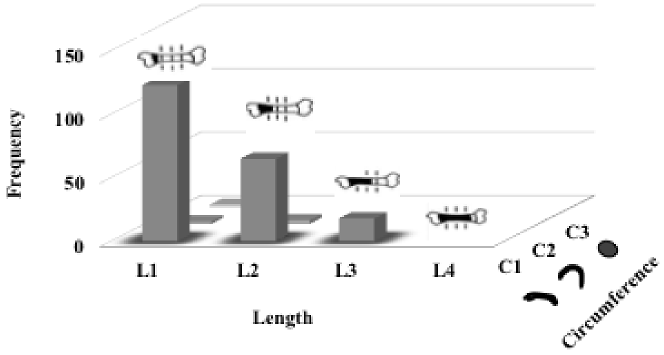


Fig 6.10: Isernia La Pineta 3s6-9: Shaft fragmentation index length (L) vs circumference (C) for diaphyses of unidentified taxa (NR=213).

In case of diaphyses which were taxonomically identified, a majority of them, 16 in all, had a shaft circumference of less than half of the original (C1) and a shaft length of one-quarter to one-half of the original length (L2) (Fig 6.11). A nearly equal number of diaphyses, 15 in all, had the same shaft circumference less than half of the original (C1) but different shaft lengths. While seven of them had a shaft length less than one-quarter of the original length (L1), the other seven had a shaft length between one-half and three-quarters of the original length (L3). Only two diaphyses had a shaft circumference more than half of the original (C2) but with shaft lengths either less than one-quarter (L1) or between one-half and three-quarters (L3). In both of the above cases, a synthesis of shaft length and circumference indices reveal that the majority of the long bones had less than half of the original circumference and less than one-half of the original length. These results concord with an assemblage created by anthropic agents rather than carnivores as the actions of the latter would have reflected a contrary picture.

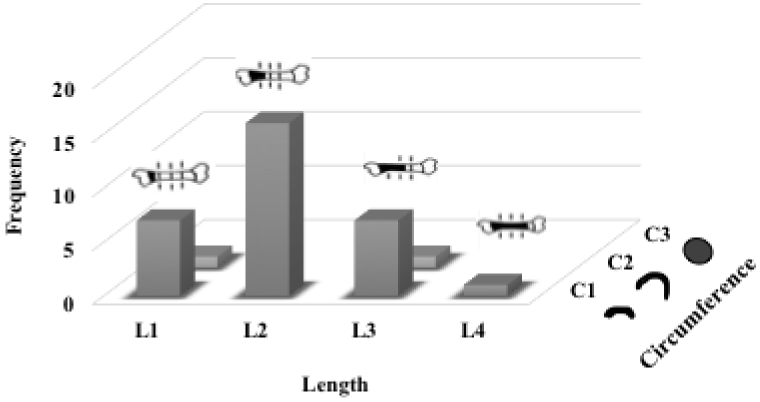


Fig 6.11: Isernia La Pineta 3s6-9: shaft fragmentation index length (L) vs circumference (C) for diaphyses of identified taxa (NR 33).

Next, the diaphyses were analysed for their extent of fragmentation which was derived by grouping them in size classes and comparing them with respect to their frequency and combined mass. When diaphyses were quantified according to their lengths, as shown in graph A (Fig 6.12), the small-size class was predominant which showed that the diaphyses were heavily fragmented and the state of conservation of the bones was not good. Large-sized diaphyses were very few. Moreover, complete or nearly complete bones were absent. A similar result emerged when the diaphyses were quantified according to their mass. Again, the small-size class was predominant over other size-classes. When the results presented in graphs A and B (Fig 6.12) below were merged, it showed that the proportion of a relatively large number of small diaphyses fragments in the size-classes of 5 - 9 cm represented a proportionally large amount of bone in terms of mass. On the contrary, the few number of diaphyses, longer than 13 cm, were not very heavy. These diaphyses probably belonged to medium or small-sized animals or young individuals of large-sized animals.

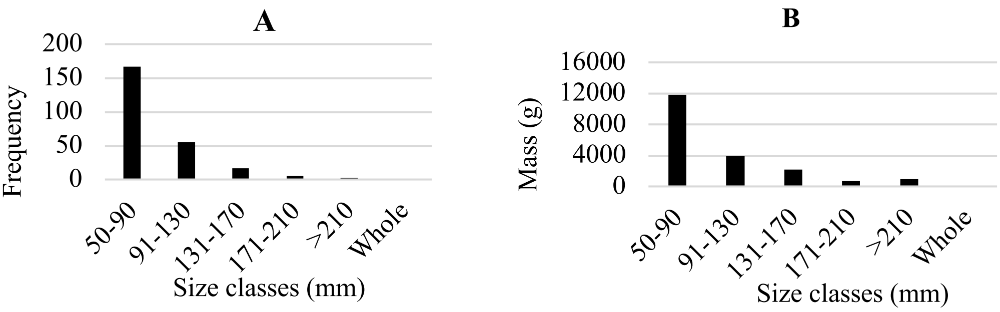


Fig 6.12: Isernia La Pineta 3s6-9 level: proportions of diaphysis fragments in different size classes quantified by A - number and B- mass (NR 246).

An analysis of the fracture type was conducted on the 490 proximal and distal ends of the 246 diaphyses. Some diaphyses still had an intact or partially intact epiphysis so they had only one fracture end. The analysis revealed that most of the diaphyses had a spiral fracture and/or a spiral fracture with a jagged edge (Fig 6.13), which is characteristic of anthropic breakage of fresh bones resulting in green fractures. Other lesser dominant types were Y-shaped, irregular perpendicular, smooth perpendicular flaking. While the spiral fracture type was definitely representative of anthropic fractures, the others were attributed mostly to post-depositional and weathering related fractures. Longitudinal, sawtoothed and stepped/columnar fracture types were observed on few diaphyses.

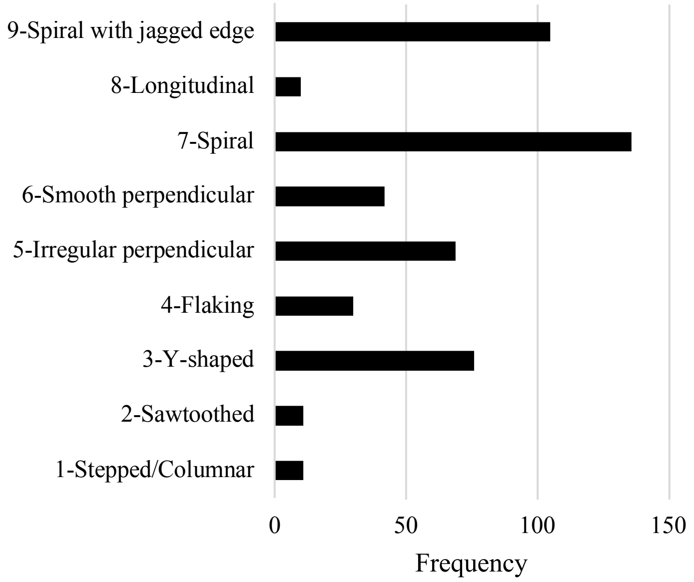


Fig 6.13: Isernia La Pineta 3s6-9 level: relative frequencies of different fracture types on diaphysis fragments.

The fracture angle, outline and edge of the 246 diaphyses along all their fracture planes/surfaces revealed an interesting an mixed pattern (Fig 6.14). A total of 1078 fracture planes from the 246 diaphyses were analysed for these criteria. In the assemblage, 118 diaphyses had four fracture planes, 70 diaphyses had five fracture planes, 29 diaphyses had three fracture planes, 24 diaphyses had six fracture planes, two diaphyses had seven fracture planes and one diaphysis each had eight, two and one fracture plane(s) each. Nearly equal number of fracture planes exhibited the three types of fracture angles. Oblique angle was observed on 360 fracture planes, right angles were recorded for 340 fracture planes and a variable angle was observed on 378 fracture planes. While the angle showed a mix of both anthropic and post-depositional causes of fracturation, the outline revealed a clearly anthropic cause of fracturation of these diaphyses as curved/longitudinal outlines dominated (NR 861) over transverse (NR 152) and intermediate (NR 65) outlines. Fracture edge, similar to angle, also highlighted a mix of both anthropic and post-depositional causes of fracturation as they were observed on an almost equal number of fracture planes, 538 and 540 respectively.

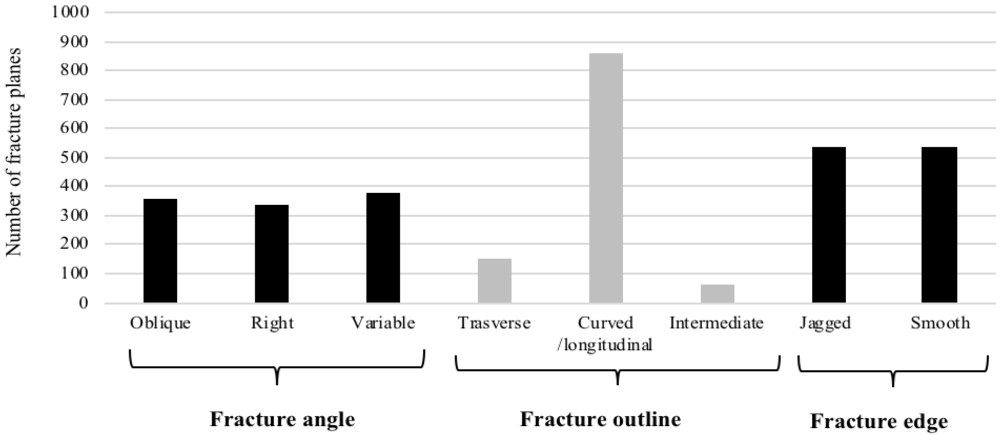


Fig 6.14: Isernia La Pineta 3s6-9 level: relative frequencies of fracture angles, outlines and edges of diaphyses fragments.

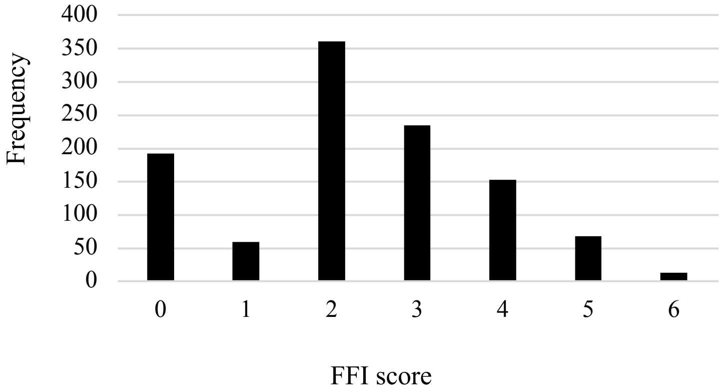


Fig 6.15: Isernia La Pineta 3s6-9 level: number of diaphyses fragments assigned different fresh fracture index scores.

The Freshness Fracture Index (FFI) for the 1078 fracture planes from 246 diaphyses brought to light an assemblage characterised by a mix of anthropic and post-depositional fracturation. The sum of scores assigned to the criteria described above (fracture angle, fracture outline and fracture edge) gave a range of 0 - 6 values. From the graph (Fig 6.15), it was observed that for 611 fracture planes, 192 with 0 scores, 29 with 1 score, and 360 with 2 scores clearly demonstrated well-preserved characteristics of intentional breakage by hominins. With a score of 3, 234 fracture planes demonstrated an amalgamation of both anthropic and post-depositional fracturation. On the other side of this range, with a score of 4 for 152 fracture planes, 5 for 68 fracture planes and 6 for 13 fracture planes, 233 fracture planes in total demonstrated typical features of post-depositional breakage.

Percussion notches

Percussion notches were identified in 53 remains that composed 4.9% of the total faunal assemblage. Each notch was exclusively present on one faunal remain each. As can be viewed in the table (Table 6.8), the percussion notches were mostly identified on anterior and posterior limbs and one mandible. Within this majority, the notches were mostly present identified on bison tibiae; diaphyses, metaphyses and unidentified fragments of unidentified taxa. For each of the other determined taxa such as wild boar, deer, an artiodactyl and an ungulate, at least one long bone bore the evidence of anthropic activity in the form of a percussion notch. The spatial distribution of percussion notches showed that they were mostly concentrated in certain squares such as 110, 111, 121, 130, 131 in quadrant 4 and squares 157, 167 and 198 in quadrant 1 (Fig 6.16).

Table 6.8: Isernia La Pineta 3s6-9: Distribution of percussion notches based on the anatomical element and species.

Anatomical element	**Unidentified taxon**	**Wild boar**	**Deer**	**Bison**	**Artiodactyl**	**Ungulate**
Mandible				1		
Humerus		1		1	1	
Radius	1				1	
Metacarpal			1			
Femur	2			1		
Tibia	1			7		1
Metapodium	1					
Diaphysis	19					
Metaphysis	8					
Indeterminate	6					
Total	**38**	**1**	**1**	**10**	**2**	**1**

The macroscopic observation of the remains concerned the precise and detailed description of some fundamental characteristics of the impacts that were found on the bone surfaces. A total of 58 remains with impact(s) were documented. Remains with a single impact were 40 in total whereas remains with two impacts were 13 in all. There were five remains with four impacts. As regards the remains that had more than one impact, the relationship between impacts was analyzed. More precisely, six impacts were consecutively on the same fracture edge. While one impact occurred as non-consecutive on the same fracture edge, three impacts were on opposite fracture edges at the same height, three other impacts were placed on opposite edges at different heights. Among the 58 impacts, in particular, the transverse positioning of the impact with respect to the whole bone was analysed. Impacts situated in the medial part, 13 in all, were the most. The longitudinal positioning with respect to the whole bone was possible to ascertain. Impacts on the ventral-caudal part were the most with 15 documented in total. The positioning of impacts with respect to the fragment was specified. Most of the impacts were placed in a median and/or distal position. A majority of the impacts, 42 in all, had a linear-concave shape while 46 of the impacts were at an acute angle. Further, regarding the appearance of the cortical border, a majority of them were without any marks.

Impacts associated with cortical face detachments were 22 whereas those associated with medullary face detachments were 66 in total. Most of the cortical face detachments were simple in nature, either semicircular or a mix of semicircular and laminate in form, either deep or spread in terms of amplitude and lamellar in appearance. Detachments on the medullary face were also mostly simple, with a laminate and/or semicircular form, deep in terms of amplitude, lamellar and/or scalariform in appearance.

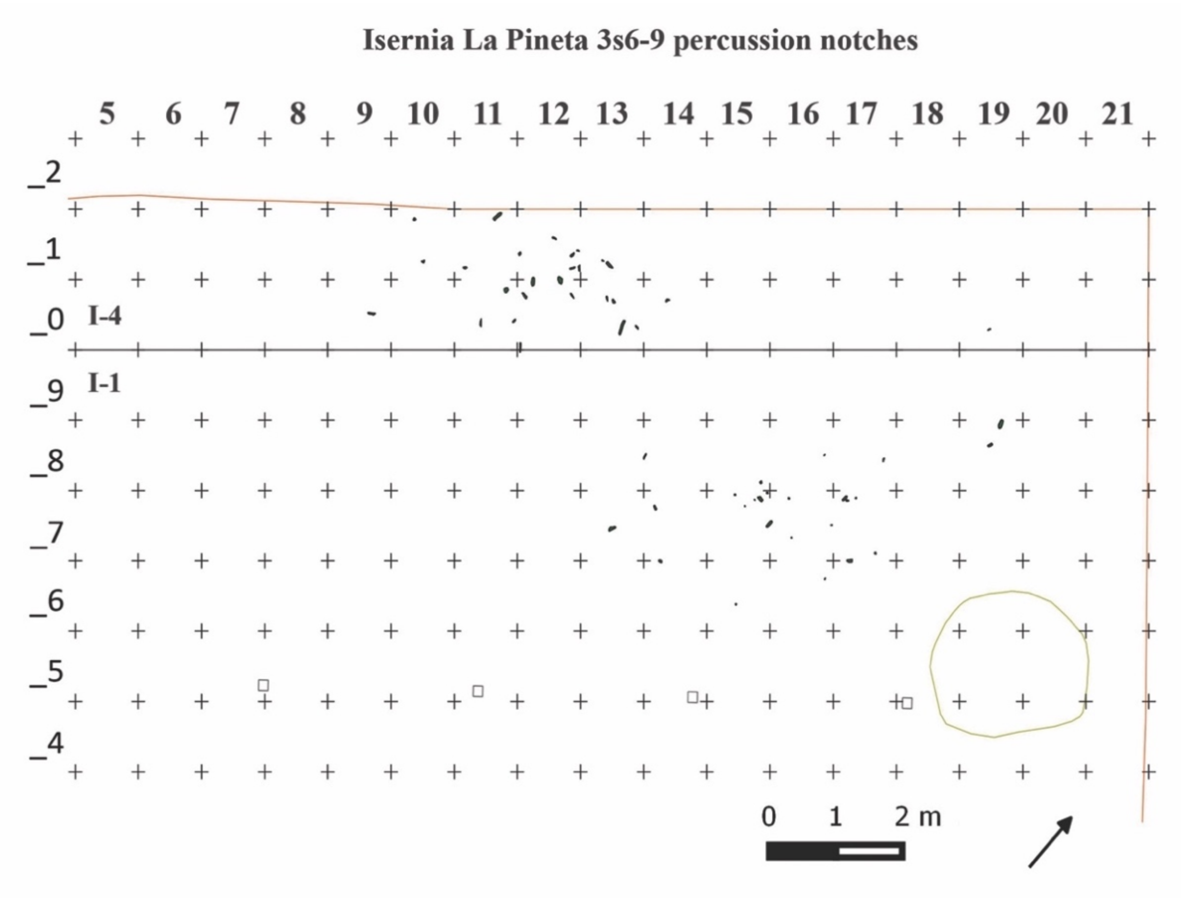


Fig: 6.16: Isernia La Pineta 3s6-9: Spatial distribution of percussion notches.

Detachments not associated with percussion notches

During the macroscopic observation of the faunal remains, detachments were identified not associated with percussion notches on 17 of them. More specifically, four remains were present with detachments in the cortical face. These remains included a rhinoceros metatarsal fragment and long bones of unidentified taxa. While seven remains, including a tibia of megaceros, long bones of unidentified taxa and unidentified fragments, presented detachments in the medullary face. The combination of cortical and medullary detachments, primarily on long bones of bison and unidentified taxa, was found in 6 remains.

Detachments associated with percussion notches

In the faunal assemblage, 52 detachments were identified in association with percussion notches. It was observed that five remains had detachments in the cortical face. They were a femur of bison, and long bones of medium and large size animals. Detachments in the medullary face were found on 16 remains consisting of long bones such as humerus, metacarpal and tibia of wild boar, deer and bison respectively apart from long bones of unidentified taxa. A combination of cortical and medullary detachments was observed on 31 remains primarily comprising long bones of identified and unidentified taxa. The spatial distribution of all detachments (associated + not associated with percussion notches) on the excavated floor highlighted their concentration in the central and western areas. Specifically, they were present in squares 147, 157, 177 and 199 of quadrant 1; squares 100, 101, 110, 111, 121, 130 and 131 of quadrant 4. The three categories of detachments- cortical, medullary and cortical-medullary, were found in a random scatter within these areas of concentration.

Percussion cones

A by-product of the process of smashing a bone with a lithic tool, percussion cones were produced when a conical fragment from the cortical and/or medullary portion of the bone got detached leaving in its original place a negative scar called the impact point. In 3s6-9, seven percussion cones were identified (Plate 6D and E). Apart from light erosion and weathering of stage 1 or 2 and no exfoliation, they appeared to be preserved well. Two of the seven had trampling marks made by sediment. Two of the seven were medullary cones of percussion. They also had deposits of manganese and iron oxide on them. Their length ranged between 28 to 73 mm, width was between 14 to 35 mm and thickness ranged between 5 to 20 mm. Since they were few in number, a spatial distribution map was not made. Their provenance was from squares situated close to each other from the central, northern and western area of the excavated floor. The squares in which they were found were 158, 168, 174 and 178 from quadrant 1 and squares 90, 101 and 190 from quadrant 4 of Sector I.

Chapter 7

Bison dental analyses

7.1 Isernia La Pineta

The total number of maxillary and mandibular remains including isolated teeth were 184 for layer 3 coll and 84 for layer 3s6-9 in the present study. When results from the previous study for the archaeosurfaces in Isernia were taken into consideration, it was clear that, type of remains, which were the focus of the study, had been recovered in more numbers in the last decade of excavation. However, it would be skewed to observe this as a large part of archaeosurface 3a, the richest among the occupational layers, was not excavated completely and remains pertaining to this study are still *insitu*, laying exposed at the site. The debris flow layer covering this archaeosurface- 3 coll, has yielded more dental remains. In comparison, the other two archaeosurfaces, 3c and 3S10, have yielded scarce number of bison dental remains. However, not all remains aided to fulfil the aims of this study. Some of them were broken or were covered in concretion, therefore making it difficult to observe diagnostic characteristics in them to place them in any age class. The others not taken into consideration included osseous fragments from cranium, maxilla and mandible. From layer 3 coll, 76 remains and 34 remains from layer 3s6-9 were counted to be suitable for age class study (Table 7.1).

A frequency distribution of number of dental remains studied according to type and laterality revealed four interesting observations (Table 7.1). It showed a clear dominance of permanent dentition over deciduous dentition. This domination also held true for molars, especially maxillary, over premolars and incisors. Mandible with teeth were only seven while there was no maxilla with teeth in this select assemblage. Isolated teeth formed the majority share of the assemblage. In this assemblage, no deciduous maxillary teeth were present. In 3s6-9, except for two incisors, there were no other teeth from the right laterality.

The MNI estimation obtained from this study showed that the remains accounted for a minimum of 49 bison individuals in the entire Isernia assemblage excavated and recovered till 2016 (Table 7.2). In layer 3 coll, 16 individuals were accounted for while eight bison individuals were estimated in the layer 3s6-9. These individuals belonged to all age groups. However, their distribution was not even. For instance, in the layer 3s6-9, they belonged to age classes from subadult to senile with no young (infantile and juvenile) individuals.

Table 7.1: Isernia La Pineta: Layers 3 colluvium and 3s6-9, frequency distribution of number of dental remains by type and laterality for age class study.

	3 colluvium		**3s6-9**	
Inferior isolated	Right	Left	Right	Left
i_1		1	1	1
i_2				
i_3				
d_2	1			
d_3				
d_4				
I_1		2	1	
I_2	1	1		
I_3				1
P_2		2		1
P_3	6	1		1
P_4	2	1		1
M_1	2	1		1
M_2	2	2		1
M_3	5	4		3
Mandible with teeth	5	2		
Superior isolated	Right	Left	Right	Left
P^2	2		1	1
P^3	2	1	1	2
P^4	5	1	2	1
M^1	2	5		1
M^2	3	2	2	2
M^3	4	3	1	1
Maxilla with teeth				
Indeterminate dental fragment	5		2	
Tooth root			5	
Total	**47**	**29**	**16**	**18**

7.1.1 Layer 3 colluvium

Infantile and Juvenile

The young bison population was scarce. It comprised solely one infant and no juvenile from this level. The infant was represented by a single right d_2 (1.157.069).

Subadult

In the subadult age class, one individual was accounted for on the basis of a left i_1 (1.156.047) estimated to be 40 months old.

Table 7.2: Isernia La Pineta: Archaeosurface 3c, 3a, 3S10 and layers 3 coll and 3s6-9: reported in the table are the total number of dental remains (NR), number of dental remains selected for the estimation of age class (NR for study of age class) and the Minimum Number of Individuals calculated in relation to the different age classes (MNI). "- previous study (Di Nucci et al., 2006, p. 49), *-present study.

	NR	**NR for study of age class**	**MNI**			
			Young	Subadult	Adult	Senile
3s6-9*	84	34	0	1	5	2
3S10"	8	1	0	0	1	0
3coll*	184	76	1	1	11	3
3coll"	25	25	0	2	7	0
3a"	83	31	0	1	13	0
3c"	5	1	0	0	1	0
Total	**389**	**168**	**1**	**5**	**38**	**5**

Adult

The Adult 1 (A1) age class was composed of four individuals calculated from four incisors of different ages and lateralities. The first individual was represented by a right I_2, 57 months old (1.177.187). The second individual was represented by a 52 month old left I_2 (1.177.143) whereas the third individual was accounted for by a left I_1, 66 months old (4.100.249). A left I_1, 72 months of age (1.166.133) was attributed to the fourth individual. To one or two of these individuals could also be associated a right P_3 (1.157.001) and a left P_2 (1.109.265). Among the maxillary dental remains, a P^3 (1.166.043) and M^2 (1.087.082) belonging to the right laterality, could also be added to the first or second individual. In terms of years, they ranged between 4.3 to 6 years.

The Adult 2 (A2) age class consisted of three individuals. This estimation could be accounted for by the presence of three right M_3 (1.128.017, 4.100.011 and 1.096.143; Fig 7.1), the last of which was found to associate with a right mandible fragment containing a P_4 (1.086.104; Fig 7.1) and M_1 (1.086.104). To the second and third individuals, probably also belonged two right P_3 (1.077.109; Fig 7.1) and 1.138.182), another right M_1 (4.100.021; Fig 7.1), a right M_2 (1.077.179; Fig 7.1), and two left M_3 (1.086.118 and 1.158.126). In case of maxillary dental elements, associations were possible between a right P^2 and P^3 (1.137.045 and 1.086.031 respectively), a right M^2 and M^3 (1.157.023 and 1.137.130 respectively) and finally between a left M^2 and M^3 (4.100.268 and 1.116.098 respectively) adding to the dental arcade of the first individual in all probability. Other maxillary teeth could be added to the second or third individual such as a right P^2 (4.090.041), two right P^4 (4.111.206 and 1.106.155 respectively) and a right M^2 (1.167.138). From the left side, a P^3 (1.116.177) could be associated with the second or third individual.

The Adult 3 (A3) age class had the same number of individuals as A1 age class. The four individuals which composed this mature adult age class were calculated from four right M_3. One of them (1.148.140) was associated with a right M_1 present inside the mandibular ramus (1.167.137; Fig 7.1) and a right M_2 (1.086.169; Fig 7.1). Individuals two, three and four were obtained from three other M_3 of right laterality (1.098.065-present inside the ramus, 1.097.105; Fig 7.1) and 1.098.063). Some isolated teeth such as two P_3 (1.098.064 and 4.090.029; Fig 7.1), two P_4 (4.080.140; Fig 7.1) and 1.128.267), an M_2 (1.128.257) of the right mandible could account for the remaining dental elements of the second, third or fourth individual. On the contralateral mandibular ramus, one P_2 (1.138.180), one M_1 (1.138.031), two M_2 (1.116.312 and 1.156.058) and an M_3 still present in the ramus (1.177.200) could be additional associations to the above remaining individuals. From the right laterality, maxillary isolated dental remains were represented by three P^4 (1.116.140, 1.166.095 and 1.106.106), two M^1 (1.077.082 and 4.091.104) and three M^3 (1.159.058, 1.177.105 and 4.111.129). The opposite maxillary ramus yielded one P^4 (1.156.070), two M^1 (1.087.077 and 1.077054) and one M^2 (1.106.158). The maxillary teeth could belong to any of the above four individuals.

Senile

The senile bison population denoted by Adult 4 (A4) age class is also well represented when compared to other age classes. A total of three individuals could be calculated from this assemblage dominated by premolars and molars. The first individual was represented by a left mandibular ramus (1.157.013; Fig 7.1) preserving three of its teeth- P_3, P_4 and M_1. Possible additions to this mandible come from one of the two unilateral M_3 (1.147.032; Fig 7.1 and 4.080.165), a left P_3 (4.091.202) and a P_4 (1.087.064). From the contralateral mandibular ramus, an incomplete P_3 (1.137.033) and an M_1 (1.147.093) could be associated with the three senile individuals. To the first individual could be attributed a left M^1 (1.148.170) and (1.107.183) M^3 that were found to be associated with each other. To the second and third individual of this age class could also be attributed two additional left M^1 (1.159.082 and 1.148.137).

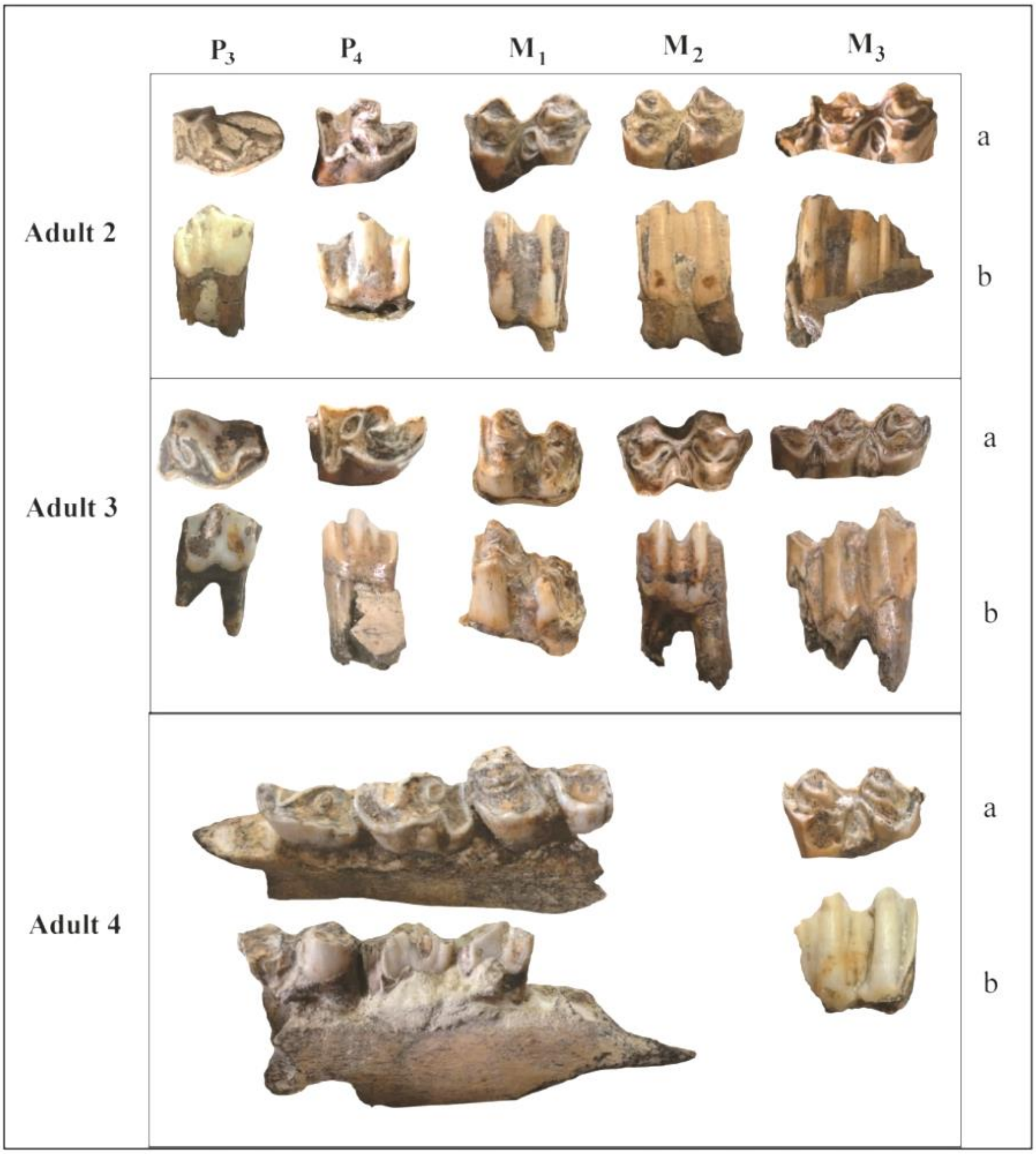


Fig 7.1: Isernia La Pineta layer 3 colluvium mandibular dental remains: Adult 2- P_3 (1.077.109), P_4 (1.086.104), M_1 (4.100.021), M_2 (1.077.179) and M_3 (1.096.143); Adult 3- P_3 (4.090.029), P_4 (4.080.140), M_1 (1.167.137), M_2 (1.086.169) and M_3 (1.097.105); Adult 4- left mandible with P_3, P_4 and M_1 (1.157.013) and M_3 (1.147.032). a- occlusal view, b- lingual/buccal view (not to scale).

7.1.2 Layer 3s6-9

Subadult

This age class was represented merely by one individual accounted by two i_1 (4.121.006; Fig 7.2A) and 4.131.068) of either laterality. The precise age was estimated to be 40 months based on their use-wear.

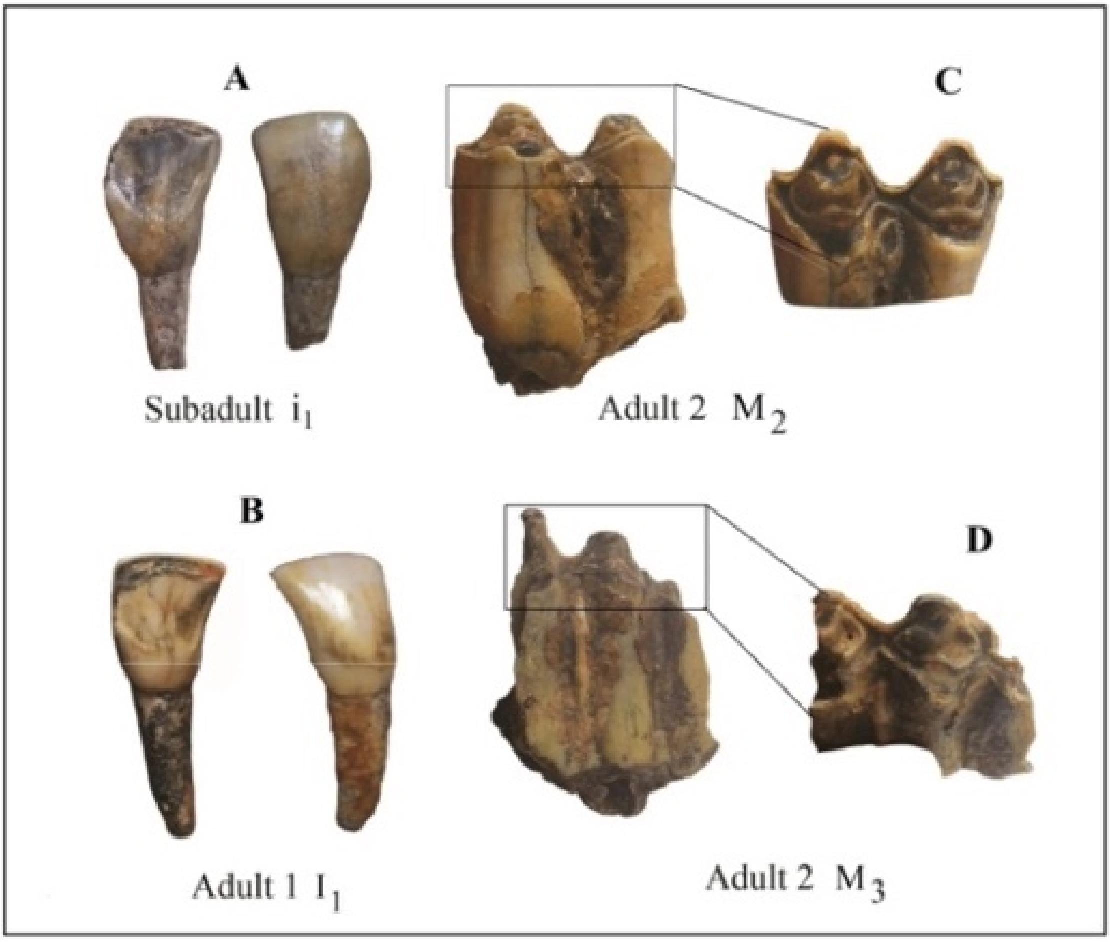


Fig 7.2: Isernia La Pineta layer 3s6-9 mandibular dental remains: A- Subadult right i_1 (4.121.006) lingual (left) and distal (right) view; B- Adult 1 right I_1 (1.147.138) lingual (left) and distal (right) view; C- Adult 2 M_2 (1.157.176); D- M_3 (1.168.099) buccal (left) and occlusal (right) view (not to scale).

Adult

The Adult 1 (A1) age class also comprised one individual with a 57 month old right I_1 (1.147.138; Fig 7.2B) and a left M_3 (1.158.063). This age class had more maxillary than mandibular dental elements with a possible association between a P^2 (1.167.101; Fig 7.3), a P^3 (1.168.134; Fig 7.3) and an M^2 (1.147.124; Fig 7.3) of left laterality. A single P^4 (1.147.090) could possibly also belong to this individual.

The next age class, Adult 2, was composed of two individuals. A precise age of 96 months could be given to the first individual on the basis of a left I_3 (4.101.095). An association between two

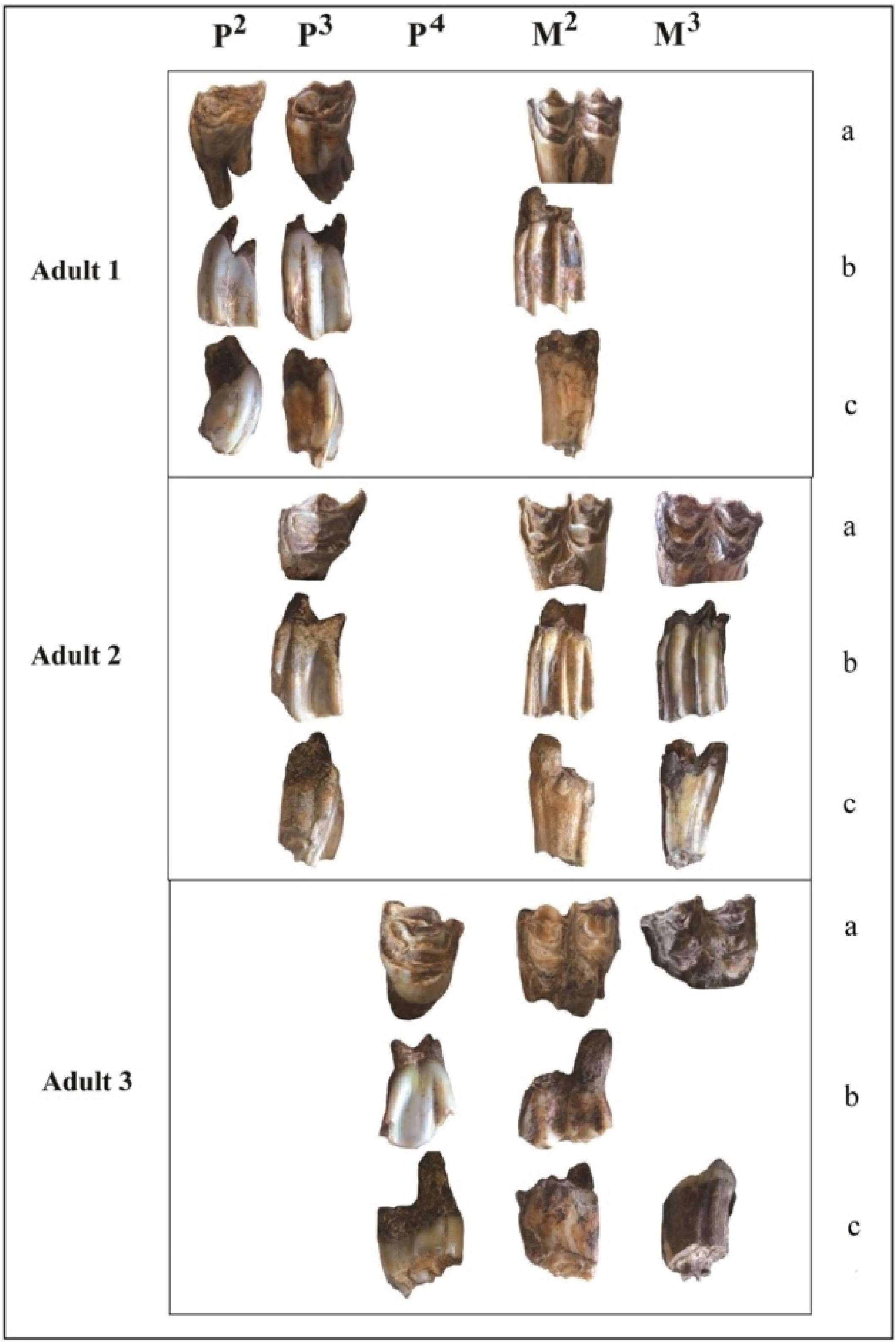


Fig 7.3: Isernia La Pineta layer 3s6-9 maxillary dental remains: Adult 1- P^2 (1.167.101), P^3 (1.168.134), M^2 (1.147.124); Adult 2- P^3 (1.177.035), M^2 (1.178.047) and M^3 (4.110.052); Adult 3- P^4 (1.157.071), M^2 (1.147.071) and M^3 (4.111.046). a- occlusal view, b- lingual/buccal view, c- mesial/distal view (not to scale).

mandibular teeth such as a left M_2 (1.157.176; Fig 7.2C) and a left M_3 (1.168.099; Fig 7.2D) along with isolated teeth like a left P_3 (4.141.068) were also attributed to the first individual. The second individual was denoted by a mandibular left M_3 (4.130.056). Maxillary dental remains attributed to the first individual included two left teeth found to be associated with each other and a right M^2 (1.156.009). They were a P^3 (1.177.035; Fig 7.3) and an M^2 (1.178.047; Fig 7.3). To the other individual could be attributed another maxillary tooth- a left M^3 (4.110.052; Fig 7.3).

Two individuals were calculated and categorised into the Adult 3 (A3) age class. The mandibular dental elements were few and probably belonged to just one individual. They consisted of a left P_2 (1.168.131) and a left M_1 (1.147.146). Among the maxillary dental elements, two right teeth- a P^4 (1.157.071; Fig 7.3) and an M^2 (1.147.071; Fig 7.3) were found to be associated with each other and the first individual. To the second individual could be attributed a right M^3 (4.111.046; Fig 7.3). An isolated left P^4 (1.147.166) could belong to either of the two individuals.

Senile

The last age class also had two individuals similar to the other adult age classes. Three dental elements demonstrated similar use wear and a possible association between them allowed to attribute them to the first individual. These elements included a left P_4 (1.166.079), a right P^2 (1.177.029) and a left M^1 (4.120.128). A right P^3 (1.147.054) accounted for the second individual.

7.2 Caune de l'Arago

7.2.1 Lower levels H to Q

The total number of maxillary, mandibular and isolated dental remains recovered from levels HIJ, KL, MNOP and Q were 105, 17, 61 and 67, respectively (Table 7.3). However, not all these remains were suitable for this study as they did not have the diagnostic characteristics. Therefore, four remains from level HIJ, none from level KL, 17 remains from level MNOP, and 50 remains from level Q were chosen for this study. A frequency distribution of dental remains selected for this study according to type and laterality showed that deciduous teeth had scarce presence (Table 7.4). The assemblage was mostly mde of permanent teeth. Maxillary isolated molars and mandibular isolated premolars were more in number. Moreover, most of the isolated mandibular dental remains were of the laterality while the contrary was observed for the isolated maxillary dental remains. Results obtained showed that a minimum of 22 individuals were exploited during the occupation levels from H to Q by prehistoric humans who inhabited the cave during these levels (Table 7.3). These 22 individuals of bison belong to all age groups. However, their distribution is not even.

Infantile and Juvenile

The young bison population was scarce. It comprised one infant and one juvenile from Q1and P2 level respectively. The infant was represented by a right M_1 (B12.932), a left mandible fragment containing d_3, d_4, P_2 and an M_1 (H9.673; Fig 7.4E and F) belonging to the same individual. To this individual was added a right M^1 (G8.2075) aged roughly around two months. The juvenile was represented by a right d^4 (C10.454).

Subadult

In the sub adult age class, two individuals could be estimated. Their remains come from Q1 and Q3 levels. In Q1 level, the individual was represented by a left i_1 (I8.1551) and i_2 (D11.661), a right i_2 (G8.1530) and a right P^2 (E11.1082). In Q3 level, the individual was represented by an M_2 (G16.7862).

Table 7.3: Caune de l'Arago: Lower levels (H-Q) and upper levels (F and G). Reported in the table are the total number of dental remains (NR), number of dental remains selected for the estimation of age-class (NR for study of age-class) and the Minimum Number of Individuals calculated in relation to the different age classes (MNI).

	Level	**NR**	**NR for study of age class**	**MNI**			
				Young	**Subadult**	**Adult**	**Senile**
Upper Levels	**F1**	110	48	3	2	6	1
	F2	160	63	3	1	7	2
	F3	121	47	4	2	5	1
	G1	203	106	7	1	8	1
	G2	234	136	6	2	10	2
	G3	199	98	3	1	8	2
	G4	124	64	8	1	8	2
Lower Levels	**HIJ**	105	4			2	2
	KL	17					
	MNOP	61	17	1		3	2
	Q	67	50	1	2	7	2
	Total	**1401**	**633**	**36**	**12**	**63**	**16**

Adult

The Adult 1 (A1) age class was composed of four individuals. Their remains were recovered from levels J; P3 and Q1. From level J was identified a right M^2 (C11.R10004) belonging to the first individual. In P3 level, interestingly, an association was made between a right P^2 (I9.251); a fragment of right maxilla (I9.258) containing P^4 and M^1 (association number 3281) with another maxillary fragment having M^2 and M^3 intact inside. A right M_3 (H10.239) was also classified as A1. These remains could be attributed to the second individual. In Q1 level, the remaining two individuals could be accounted for due to the presence of two P_2 with the same laterality- right (E8.555 and G13.1525). To one of these individuals could also be attributed a left I_1 (G8.2051) and a left M_1 (D11.1760).

The Adult 2 (A2) age class consisted of two individuals. Both came from the same level- Q1. This estimation could be accounted for by the presence of two P_3 having the same laterality- left. The remains of these two individuals include an association (number 3138) between a left P_3 (B12.496) and a left P_4 (B12.540) (Fig 7.4C and D). To this could be added a left M_1 (B12.491) to amount to one individual (Fig 7.4C and D). The second individual was estimated from a left mandible with P_2, P_3 and P_4 intact (E8.304; Fig 7.4G and H). Additionally, two left incisors, an I_1 (G10.1940), an I_2 (G10.1946) and a left M_2 (G10.2777) completed the mandibular repertoire. To one or both of these two individuals probably also belonged three maxillary teeth; a right P^4 (I13.1796), a right M^1 (D12.1877) and a right M^2 (D9.1758). The Adult 3 (A3) age class had a higher number of MNI when compared to previous age classes. At the same time, it equalled the MNI for the successive age class, that of A4 (senile). The six individuals that made up this mature adult age class came from levels H, P and Q. The individual from level H was represented by a left P^2 (H18.6277). Individuals two and three came from levels P2 and P3. The second individual from P2 level was represented by a left P_4 (I8.202) and a left M^3 (I10.197). The dental remains of the third individual from P3 level was characterised by a right M_2 (F12.1749); a left I_2 (G8.611) and lastly a left M^3 (B13.1300). To any of the above two individuals from level P could also belong a right P^3 (J9.325). Level Q yielded three more individuals. The fourth individual from Q1 level was composed from an association between different dental elements. These included (association number 3279) a right I_3 (G10.1430) with a left I_1 (G10.1977), a left P_2 (G10.1752) and a left M_2 (G10.1609). A left P_3 (I8.1264) accounted for the fifth individual. The sixth individual was represented by a left M_1 (B13.1345) and a left M_3 (D9.1424). To any of these individuals from Q1 level could be added a right P_3 (G10.2519, a right P^4 (E10.1341); a left P^2 (G8.1690); a left M^1 (J9.1315), a left maxilla containing M^2 and M^3 (G10.2767), and lastly, a left M^2 (G9.600).

Senile

The senile bison population denoted by Adult 4 (A4) age class was better represented when compared to other age classes. A total of six individuals could be calculated from the select assemblage dominated by premolars and molars. At least one individual each came from levels I, J, N and P while two individuals were estimated for level Q. The individual from I1 level was represented by a left M^2 (H13.256). A left maxilla with P^4, M^1, M^2 and M^3 (B12.64; Fig 7.4A and B) which accounted for the second individual was recovered from level J. In N2 level, a solitary right M_2 (I13.1538) was attributed to the third individual. From P3 level, the fourth individual was estimated from an association (number 3280) between a left M_2 (I8.618) and a left M_3 (H8.460). To this could be linked a left P_2 (I9.326) and a left P_3 (I10.283). To the same individual could also be attributed a right M^2 (J10.554bis). The fifth and sixth individuals could be estimated from two teeth with same laterality.

Table 7.4: Caune de l’Arago: Lower levels (H-Q), frequency distribution of number of dental remains by type and laterality for age class study.

Level	**HIJ**		**MNOP**		**Q**	
Inferior isolated	Right	Left	Right	Left	Right	Left
i_1						1
i_2					1	1
i_3						
d_2						
d_3						
d_4						
I_1						3
I_2				1		2
I_3					1	
P_2				1	2	1
P_3				1	2	2
P_4					1	2
M_1					2	3
M_2			2	1	1	2
M_3			1	1	1	1
Mandible with teeth				1		2
Superior isolated	Right	Left	Right	Left	Right	Left
d^2						
d^3						
d^4			1			
P^2		1	1		2	1
P^3					1	
P^4					3	
M^1					3	1
M^2	1	1	2		3	2
M^3			1	2	2	1
Maxilla with teeth		1	1			

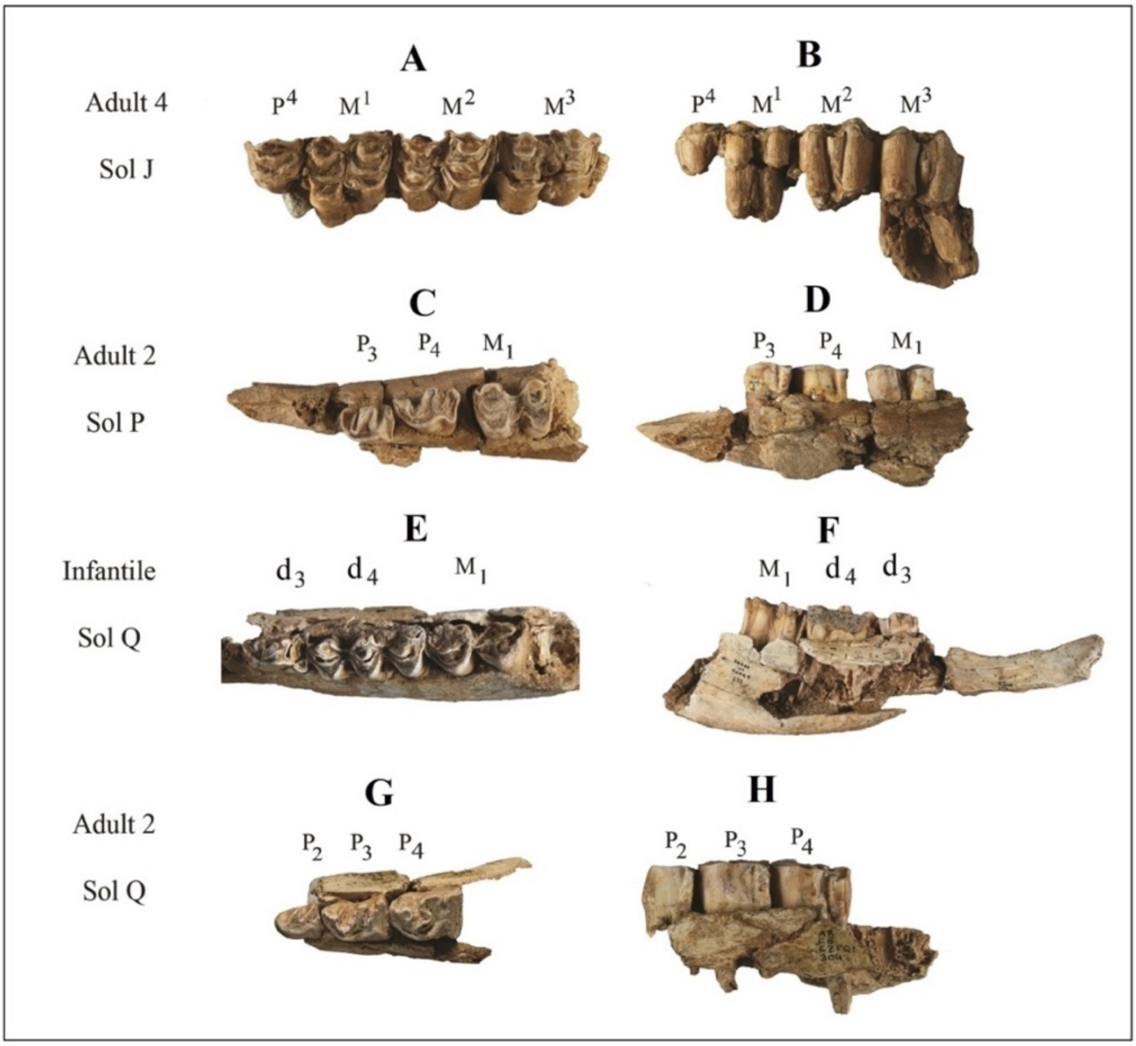


Fig 7.4: Caune de l'Arago: Lower levels (H-Q) dental remains: A- occlusal view and B-lingual view of left maxilla (B12.64); C- occlusal view and D- buccal view of left mandible (B12.496 (P_3), B12.540 (P_4) and B12.491 (M_1)); E-occlusal view and F- lingual view of left mandible (H9.673); G-occlusal view and H- buccal view of left mandible (E8.304) (not to scale).

This was the case with right M^2 and M^3 coming from two separate old individuals. The fifth individual, on one hand, was represented by a right maxillary fragment (E8.328) containing M^2 and M^3 which also formed an association with right P^2 (E8.697), right P^3 (E8.578) and a right M^1 (E8.989) (association number 3248). The sixth individual, on the other hand, was represented by a right maxillary fragment (G10.1548) with P^4, M^2 and M^3 still present inside. The same fifth and sixth individuals could also be associated with mandibular elements from either literalities. Right side elements included a P_3 (I8.2465), an M_3 (G9.608), an association (association number 3254) between a P_4 (I8.2490+I8.2491+I8.2493+I8.2779) and an M_1 (I8.2492). Left side mandibular elements included an I_2 (H9.717) and a P_3 (E8.408).

7.2.2 Upper level- G

There are four sub-levels in level G. From sub-levels G1, G2, G3 and G4 were recovered 203, 234, 199 and 124 cranial, maxillary and mandibular remains. However, out of them, 106 from G1, 136 from G2, 98 from G3 and 64 from G4 were considered as they fulfilled the diagnostic criteria established for this study (Table 7.3).

A glance at the table encapsulating the frequency distribution of number of dental remains by type and laterality for age class study for level G revealed some interesting observations (Table 7.5). Sub level G2 had the highest number of dental remains (100) followed by G1 (83), G3 (75) and G4 (58). Apart from isolated teeth, there were mandibles and maxillae with teeth still intact inside, much more present in level G when compared to other levels. In level G, such partially complete mandibles and maxillae were almost equal in count. Among the deciduous mandibular teeth, incisors were more than premolars. On the other hand, among the permanent mandibular teeth, sub level G2 had the highest number. Generally speaking, deciduous mandibular teeth were eight times greater in count in collation with maxillary deciduous teeth. Further, left laterality teeth were more than right laterality teeth, exception being G3 sub level. Also, not only were permanent molars more than premolars and deciduous teeth, right mandible with teeth were more than left mandible with teeth. If maxilla was taken into consideration, deciduous teeth were less compared to permanent teeth.

An estimate of MNI from these selected remains gave a figure of 70 bison individuals which were hunted and their carcasses processed for meat and marrow during level G occupation (Table 7.3). Unequal distribution reflected varying preferences for bison of different age classes.

Sub level G1

This sub-level yielded 17 bison individuals. Subadult and senile individuals were clearly not as preferred as young and adult individuals (Table 7.3).

Foetal, Infantile and Juvenile

A set of deciduous left incisors- i_1 (I16.2579), i_3 (I16.2581) and canine (I16.2454) brought together by possible association (number 3356) defined the solitary foetal bison individual.

There were four infants in the sub level G1 population. These infants were well represented by incisors, premolars and molars. The first individual was accounted for by a right i_1 (E15.1875) with use wear equivalent to one month old infant. The second individual had a right i_2 (G14.866) and a left i_1 (I16.2579) attributed to it, both with use wear of a four month old infant. A minimum of two individuals could also be attested to by the presence of two M_1 (F19.2610; Fig 7.5A) and D18.3859) from the same laterality- right. The former M_1 was part of a mandible with other teeth such as d_2, d_3

Table 7.5: Caune de l’Arago: Upper level (G), frequency distribution of number of dental remains by type and laterality for age class study.

Level	**G1**		**G2**		**G3**		**G4**	
Inferior isolated	Right	Left	Right	Left	Right	Left	Right	Left
i_1	1	3	1	1		2	1	2
i_2	1			1		2	2	1
i_3		2		3		1		
d_2		3				1		1
d_3			1	1				1
d_4				2	1			1
I_1		2	2	2	1	1		1
I_2		2	3	3	1			2
I_3		2	2	2	1	1		
P_2	1	1		1				2
P_3		2				1		
P_4	1	2	2	1	1		1	
M_1	2	2	4	2	2	1		
M_2	1		3	2	1	2	2	1
M_3	1	1	7		4	1	1	7
i_1	5	3	5	2	3	2	1	4
i_2	1	3	6	2	1	1		5
Mandible with teeth	4	1	2	2	1	1	2	1
Superior isolated	Right	Left	Right	Left	Right	Left	Right	Left
d^2	1				1			
d^3	1				1			1
d^4	1		2					1
P^2	2	2		5	2	2	1	2
P^3	3	1		5	1	1		
P^4	1	1		2	1	1	1	1
M^1	4	3	1	6	5	1	1	1
M^2	4	4		7	3	3	3	2
M^3	5	1		6	6	4	1	2
Maxilla with teeth		2	1		5	3	1	1
Unidentified root					1			

and d_4 still intact. The third and fourth infants were calculated on the basis of two deciduous canines of left side (I18.2137 and I16. 2454), both of the same age- six months. To either of the third or fourth individual could also be added an i_3 (I16.2581), use wear equivalent to six months. A right M_2 (C17.537) and a left d_4 (F20.3830) could be added to the dental arcade of either the third or the fourth individual. From the maxillary repertoire, a left maxilla (D19.3890) containing d^3 and d^4 could also be similarly attributed to any of the individuals in this sub level.

There were two juvenile individuals in the sub level G1 population. They were calculated from the presence of two M_2 (D20.2832 and H19.1104) from the same side-right. A right mandible fragment with M_1 and M_2 (D18.851; Fig 7.5B) still intact inside it, a left M_2 (H14.2031), a worn out d^2 (I19.3989), d^3 (I15.1485) and d^4 (H15.3469)-representatives of right maxilla, and a left M^2 (I16.2092) could be added to any of the two juvenile individuals. One of the two individuals to which a left i_1 (I16.2247) belonged, was given a more precise age since the use wear of this tooth was equivalent to a 19 months old individual.

Subadult

The single subadult individual was accounted for by few dental elements. These included an M^1 (I16.2460), an M_2 (D18.709) and an M^3 (I19.4347) from the right laterality. From the contralaterality, a d_4 (G16.3310) and an M_3 (D8.6292) were the representative dental elements.

Adult

In the Adult 1 (A1) age class, there were three individuals estimated based on incisors and canine, all from the left side. An I_2 (E20.3860) and I_3 (E19.2286), associated with a number- 3355, was attributed to the first individual. As observed from their use wear, this adult was 57 months old. The second individual, aged 60 months or five years was represented by a left I_1 (D17.789) and I_2 (D18.6172). Aged 72 months old as estimated from the use wear, the third individual was accounted for by a canine (H16.2864). To any of these individuals could be attributed a P_2 (I18.1818), a P_3 (J16.952), a mandible fragment with M_2 and M_3 (F18.2120), a P^2 (D7.1033), an M^3 (D17.1159) from the right laterality. Further, from the left side, a P_2 (D20.3212), a P_3 (F15.1002), an M^1 (H16.3594), and another M^1 (D18.4857) in possible association with an M^2 (D18.3770) probably belonged to one of the three individuals.

The next age class, Adult 2 (A2), was composed of two individuals. This was made clear due to the presence of two teeth of the same type from the same side. From the left mandible came two M_2 (I18.1579 and I15.4179) and two M_3 (D19.2510 and D20.2644) belonging to the two individuals. A P^2 (I15.595), P^3 (D17.3218), a P^2 (D17.1515), P^3 (H19.3286), an M^1 (F15.894), an M^2 (G15.R.10320), a P^2 (E20.4271) and P^3 (E20.4274) with possible association, were the other dental elements contributing to the dental arcade of these individuals. With the use wear displayed by a left I_1 (I16.3065), C (D18.3094), one of the two individuals was given a more precise age- 120 months.

The Adult 3 (A3) age class, after the infantile class, had the second highest number of individuals- three. In total, 33 dental elements were placed under this age class. The estimation primarily came from the evidence of the same type of tooth from the same side in multiple numbers. For instance, among the mandibular dental elements present were three P_3 (H16. 2888, D20.2400 and E15.453) and three M_2 (D20.2400, C17.422 and I17.2376) from the right side. Among the maxillary dental elements, three M^3 (K20.2659, E19.2066 and F15. 2058) from the right laterality and three M^2 (F18.4016, I20.3613 and D20.2291) from the left side added to the minimum number of individuals count. One of the M_2 came from a right mandible (D20.2400) which also had P_3, P_4 and M_1 still intact inside it. The other mandibular dental elements included two right mandibular fragments (E15.453 and I17.2376) brought together by possible association. The former fragment contained a P_2 and P_3 while the latter had an M_2 and M_3 in it. Furthermore, there was a right P_4 (D16.3264) inside a mandibular fragment with other neighbouring teeth absent, a left mandible (D18.3939) with P_2, P_3, P_4, and M_1 present in it and a left M_1 (I16.2560) which could belong any of these three individuals. Among the maxillary elements, a P^3 (D18.696), an M^1 (D20.3081), an M^2 (E19.2066), and a maxilla fragment (H14.1067) with P^4 and M^1 present in it from the right ramus could be included in the dental arcade of any of these three individuals. Similarly, some maxillary dental elements from the left side such as P^2 (H18.4475), P^4 (D18.849), and an M^1 (C16.717) could be additions to the dental arcade of these individuals. One of the left M^2 (D20.2291) was part of a maxillary fragment in connection with other teeth such as a P^4 and an M^1. One of the individuals could be aged much more precisely to that of 144 months from the use wear demonstrated by a right I_3 (J17.1883).

Senile

The last age class, Adult 4 (A4) comprising the oldest bison individuals in the population of sub level G1 were accounted by solely maxillary dental elements and amounted to one individual. There was a P^3 (E17.1877) and M^3 (F18.4015) attributable to this individual.

Sub level G2

There were 20 bison individuals comprising this sub level. From their numerical distribution across age classes it was evident that young and adult individuals were more or less equally preferred whereas the senile were not so preferred for consumption (Table 7.3).

Infantile and Juvenile

A minimum of two infantile individuals were calculated for this sub level. This was established on the basis of the presence of two teeth of the same type from the same laterality. Coming from the maxillary ramus, they included- two d^4 (G14.490 and D18.3485) from the right side and from the contralateral side - two d^3 (G18.4033 and E19.3773). The only other maxillary dental element remaining was an M^1 (H15.7290) of the right side which could be either of the first or the second individual. Similarly, several mandibular dental elements could be attributed to these individuals.

Among them were an M_2 (E17.2505) of the right side, a left d_4 (J16.557), and an association (number 1401) between a right d_2 (E17.2640), a right d_4 (D17.1719+D17.1720+D17.2388) and a left d_3 (E17.21176). The use wear on right d_3 indicated that one of the infant individuals was tentatively around one month old.

In the Juvenile age class, the minimum number of individuals estimated were four. The dental elements ascribed to this age class were interesting as there was clear evidence of replacement of deciduous teeth with permanent dentition within the same mandible or maxilla. The first individual was represented by a right i_1 (F15.949) observed to be eight months old from its use wear. The second individual was denoted by a left maxilla (D20.4626; Fig 7.6B), nearly complete as in it were still intact d^3, d^4, M^1 and M^2. The P^3 and P^4 were in a state of eruption and lying underneath the d^2 and d^3. The third individual was represented by a left i3 (G20.3105) estimated to be of a 20 month old individual. A right P_3 (K19.5829) affirmed a fourth individual. To either the first, second or third individual belonged an association found between a right d_4 (E20.3638) and M_1 (D19.4047). Diagonally beneath the d_4 were present the permanent P_2 and P_3 yet to replace the deciduous counterparts. An association between isolated mandibular elements from the left laterality (number 3053) could be attributed to any of the four individuals. This association was composed of a d_2 (D17.1421), a d_3 (D17.1800), a d_4 (C17.546), an M_2 and M_3 (C17.550), a P_2 (D17.1433) and a P_3 (D17.1800). Another right maxilla with d^3, d^4, P^4, M^1 and M^2 (G17.3034) could belong to any of the four individuals. On the contralateral ramus, a tentative association of elements such as a d^2 (H16.5896), a d^3 (H17.2270) and a d^4 (H17.2426); and isolated elements such as two M^2 (F20.3595 and E17.2660) could also be assigned to any one or more of the four individuals.

Subadult

Two individuals composed this age class in sub level G2. On the basis of use wear exhibited by incisors and canines, these individuals could be given a more precise age. By association (number 3226), a left i_1, i_2, i_3 (E20.5474, E20.5539 and E20.5468) were clearly between 60-72 months old. Hence, one of the two individuals was of this age. The second individual was represented by a 40 month old left i_3 (D20.3516). To any of these individuals could also be attributed a right M_1 (D20.5007) and some dental elements from right maxilla such as a P^2 (D17.2409), an M^2 (F15.1636), and an M^3 (C20.2729).

Adult

The Adult 1 (A1) age class consisted of three individuals. Each individual was well represented by incisors and hence their use wear could be studied to determine a precise age for them. The first individual, aged around 36-40 months, was denoted by a right I_1 (I16.2524) and a right I_2 (I16.2648). A right I_2 (G14.1707) and a right I_3 (G14.1606) associated together (1405) represented the second individual with a use wear of a 52 month old. A right I_1 (G14.1841), aged between 60-72 months, was that of the third individual. A nearly complete mandible (D17.1422; Fig 7.5C) from the left laterality could belong to either of these three individuals. It had intact premolars and molars. A minimum of two individuals was reaffirmed from maxillary dental remains, which were more than one from the same side and of the same type. They were two left P^2 (D20.5983 and E20.5760) and two left M^3 (D20.6108 and D16.3568). There could be a possible association between themselves and with another isolated dental element – a left P^4 (D18.3518). A right P^2 (F19.4553) could be added to the dental arcade of any of these three individuals.

The next age class, Adult 2 (A2) was composed of three individuals. This estimation was made on the basis of three right M_2 (H17.2694, F19.5740 and E19.2989). Each of these M_2 were part of mandible fragments or brought together in association with other isolated mandibular dental elements. For instance, the first M_2 (H17.2694) was in connection with an M_3. The second M_2 (F19.5740) was associated (number 2368) with P_2 (F19.5735), P_3 (H17.3042), P_4 (F19.5740) and an M_2 (F19.5740). The third M_2 (E19.2989) was also an association (number 2210) between dental elements such as an M_1 (E19.3483) and an M_3 (E19.3243). On the contralaterality, two left I_1 (E15.643 and E15.643 TER) and two left I_2 (E15.643 BIS and E15.859) could be attributed to two of the three individuals. All incisors demonstrated a use wear of 120 months. Maxillary dental elements included only isolated elements, some in association. From the right side, a P^3 C17.1176), a P^4 (C17.1012), an M^1 (C17.1008), an M^2 (C17.R10092) and an M^3 (C17.1144) came together to form an association (number 1406). Apart from them, a right P^2 (F19.4553), a right M^2 (D17.2628), a right M^3 (H16.4475), a left P^2 (H15.5285) and a left P^3 (D18.1185) could be assigned to any of these three individuals.

The Adult 3 (A3) age class had more individuals than the previous adult age classes. The four individuals were calculated from the four M^2 of the right laterality (D17.2103, I17.3755, I16.2624 and H17.2752). The second M^2 (I17.3755) formed an association (number 1408) with the right M^1 (I17.3754). Several other isolated dental elements could be added to the dental repertoire of any of these four individuals. From the left ramus, they were, a P^3 (D18.1594), a P^4 (D18.4624), and two M^1 (I20.4341 and G18.1380). On the contralateral ramus, they included, two P^2 (E16.1649 and H17.3309), two P^3 (H15.5855 and J20.4595), an M^1 (C16.979) and three M^3 (J20.4525, F17.2775 and D17.1203). Among the mandibular dental remains, a P_2 (H14.366), an M_1 (D16.3056) and two M_3 (E17.2400) from the right ramus could be assigned to any of these four individuals. Similarly, from the opposite ramus, a P_3 (D16.4129), two P_4 (G15.3712 and F17.3101), an M_2 (D16.3983) and a mandibular fragment (G18.1362) with P_2 and P_3 still intact in it also had the possibility of being added to the dental arcade of any of these individuals. Two associations were possible from among the right side dental elements. The first was an association (number 2209) between a right P_4 and M_1 (E18.3034) and a right M_2 (D18.1367). A probable association was also attempted between a P_3 (H19.4858), a P_4 (H19.5442), an M_1 (H18.5250), an M_2 (H17.2623) and an M_3 (H17.2623), all elements coming from the right side of the mandible. These two associations could belong to any two out of the four individuals. Two incisors aided in defining the age of these individuals more precisely. A right I_1 (E18.3431) was of a 120 months old individual while the left I_1 (J19.6792) was that of a 144 month old individual. Hence, out of the four individuals, two individuals were of 10 and 12 years respectively.

Senile

A minimum of two individuals were calculated to be of senile age class. This was attested by the presence of two M^2 (E15.1279 and I17.2358) with right laterality. The latter was found to be in association (number 1409) with a few more isolated right side dental elements such as P^2 (I17.2348), P^3 (I17.2356) and P^4 (I17.2355). Some mandibular dental remains could be added to the dental arcade of this individual. They consisted of a P_3 (E17.2234), an M_1 (H16.5552), and a fragment with M_2 and M_3 still connected to each other (D20.4992).

Sub level G3

In this sub level, there were a total of 14 bison individuals with an unequal distribution over age classes. Young individuals were half the number of adult individuals while the senile were very few (Table 7.3).

Infantile and Juvenile

The infantile population consisted of two individuals, four and nine months old each, based on the use wear of their teeth. To the four month old individual could be assigned a complete set of left incisors and canine (J18.6302) and a right d_4 (G19.2530). To the nine month old individual were attributed a left d_4 (F18.2125) and M_1 (F18.2120) brought together by an association (number 2161), an i_1 (G15.5792) and an i_2 (H17.3965). The minimum number of two individuals could also be reaffirmed with the presence of the same tooth type from the same laterality in multiple numbers. For instance, two d^2 (E16.2580) and two M^1 (E16.2580 and F18.1993) from the right side belonged to both of the individuals. The d^2 and M^1 (E16.2580) were part of a maxilla fragment also having the d^3 and d^4 (Fig 7.6A).

The single juvenile individual was represented by merely three dental elements. They were- a right d_3 (E15.2144), a right d^3 (H19.5954) and a right M^1 (H19.5188). The two maxillary dental elements were probably associated with each other.

Subadult

There was a single individual estimated for this age class. This individual was represented by some isolated dental elements such as an M_1 (H19.5809) and M_2 (J16.1247) from the right side; a right maxilla fragment containing M^1 and M^2 (D20.2429) with an M^3 (D20.3829) in connection and a left P^2 (I16.4130).

Adult

The first age class, Adult 1 (A1) was composed of three individuals. This was established from the occurrence of the same tooth in multiple numbers originating from the same laterality. For instance, from the left side were found three M3 (G18.5591, I20.5366 and I16.3461). The first M^3 was part of a maxilla also comprising connecting teeth such as P^2, P^3, P^4, M^1 and M^2 (Fig 7.6C). Another maxillary fragment associating two elements (number 1413) - M^1 (F16.2569) and M^2 (F16.2058) from the same laterality as above elements, a right maxilla with P^4 and M^1 (C19.204), another right maxilla (association number 2365) with P^2 (I19.7018), P^3 (I19.6586), M^1 (I19.6585), M^2 (I19.6584) and M^3 (I19.6583) could belong to any of these three individuals. Among the mandibular dental elements, there were both fragments with teeth present inside and isolated elements in this sub level G3. From the left laterality came a P_3 (I19.2333), P_4 (E20.6459), a mandible fragment (G15.7472) with M_1, M_2 and M_3. From the right laterality were attributed a mandibular fragment (F18.1954) with P_4 and M_1 associated (number 1142) with an M_2 (F18.2124) and an isolated M_1 (C20.1260).

The Adult 2 (A2) comprised a minimum of two individuals. Two right M^3 (D18.6093 and E20.7074) allowed to confirm this. The latter was part of a maxilla fragment and found in connection with P^2, P^3, P^4, M^1 and M^2. On the contralateral ramus, a P4 (G17.3822) and an association (number 2513) between an M2 (D20.7649) and M3 (D20.8115) could be added to the dental arcade of any of these two individuals. A right I2 (I15.3894) based on its use wear was given the age of 96 months. Hence, one of the two individuals was definitely of this age.

The minimum number of individuals estimated for the next age class, Adult 3 (A3), was three, on the basis of the presence of three right M^3 (D19.6807, H14.1095 and F18.1951). The first M^3 was part of a maxillary fragment in connection with other teeth such as P^2, P^4 and M^2. The second M^3 was found to be associated with an M2 (G14.1964, association number 1411). The third M^3 was also a part of an association with an M^1 (F18.1959). This sub level G3 for this age class was characterised by some examples of complete or nearly complete mandibles and maxilla. For instance, an association was made between the right side elements- P_2, P_3 and P_4 (D16.5339), M_1 (D20.7556), M_2 (E19.4865) and M_3 (E19.4865) to form a nearly complete set of mandibular teeth. A similar association (number 1402; Fig 7.5D) was made between P_2 (C19.372+C19.348), P_3 (C19.350+C19.349), P_4 (C19.370+C19.347) and M_1 (C19.371), elements from the left ramus. Along with the above mentioned mandibles and maxilla, a left maxillary fragment with M^2 and M^3 (H16.5383) could belong to any one of the three individuals. To this could be added a few isolated elements such as a left P_4 (F17.2969), a right P^3 (H14.1223), a left P^2 (C20.1243), a left P^3 (D19.5425) and a left M^3 (E20.6498). The presence of a dental element that could be attributed an age based on the use wear it displayed aided in giving a more precise age to one of the three individuals. A left canine (F18.2077) exhibited use wear equivalent to a 144 month old individual and could belong to any of the three individual.

Senile

There were a minimum of two individuals in this sub level G3. The presence of the same tooth from the same laterality aided in determining the MNI. There were two M^2 (D19.5783 and H16.7242) from the left side and two M^3 (J19.8315 and C16.2191) from the right side. However, these dental elements were not isolated but were recovered in association with other dental elements. For instance, the right M^3 (J19.8315) was part of a mandible with M^1 and M^2 in connection. Similarly, the M^2 (D19.5783) was in conjunction with P^3, P^4, M^1 and M^3 as a maxilla fragment (Fig 7.6D). An association (number 2520) was found between mandibular dental elements such as I_1, I_2, I_3 (D20.7221, D20.7223, D20.7224 respectively) from the right laterality with the left I_2 (D20.7976). To any of these individuals could be tentatively added another association of dental elements (number 1137) comprising P_3 (I16.3987), P_4 (I16.4236) and M_1 (I16.3965). To any of these individuals could also be attributed a right P^2 (J19.8216) and a right P^4 (G16.5159).

Sub level G4

In this sub level G4, the population of bison consisted of 19 individuals. Interestingly, there were more number of young individuals when compared to adult and old individuals (Table 7.3).

Infantile and Juvenile

The minimum estimation of four individuals of infantile age was done on the basis of dental elements mostly from the left laterality. The first individual estimated was the youngest at one month and on the contrary the dental element attributed to it was from the right side, an i_2 (F16.3277) with least use wear. The second infantile was calculated to be around two-three months old. It was represented by a d_4 (J19.8950). Another tooth, an M_1 (G14.2004) could probably be associated with the same individual. Among maxillary dental elements, a d^3 (E20.786), a d^4 (E20.7728) and an M^1 9E15.4227) from the left maxilla were estimated to be around three months of age and could possibly belong to this individual. The third individual was represented by a left d_2 (G19.6650) and d_4 (G18.2248) which were assigned an age of six months based on their use wear. An M_1 and M_2 from the same mandible fragment (F14.1499) estimated to be 10 months old was attributed to the fourth individual. A left additional M_1 (H14.2814) probably belonged to the first or third individual.

Among the four juvenile individuals calculated, their ages ranged from three months to three years. The first individual, aged at three months was represented by an i_1 (G17.4171) from the left side. From the right laterality, an i_1 (I16.4675), an i_2 (I16.4674), a c (G17.4172) and a d_3 (H17.5290) accounted for the second individual of six months age. At 15 months old, a right M_2 (I15.2173) was attributed to the third individual. A left P_4 (j16..6129), its use wear estimated to be that of an individual of 36 months was the fourth individual. There were no maxillary dental remains for these individuals.

Subadult

One individual was estimated at a minimum for this age class in sub level G4. It was represented by both mandibular and maxillary dental elements in association. They included, among the mandibular dental elements- a P_2 (H15.5958) and P_3 (H15.5959) in association (number 3364). Association (number 1412) of a P^4 (E17.3763), M^1 (E17.3762) and an M^2 (E17.3569) also formed a part of the dental arcade of this individual.

Adult

In the Adult 1 (A1) age class, the dental elements accounted for a minimum of two individuals. This was arrived at from the presence of two M^2 (I16. 4342 and E16.4285) from the left laterality. The first individual was assigned an age of 84 months on the basis of a left I_3 (J20.4767). The second individual was estimated to be 54 months old as observed from the use wear of a right maxilla fragment (F19.4888) containing M^1, M^2 and M^3. To one or the other individual could also be associated a right mandible fragment (E20.7046) with M_2 and M_3 still intact inside and an isolated tooth- a left M_2 (C18.114).

The next age class, Adult 2 (A2), two individuals accounted for the dental elements placed in this age class. The first individual was represented by a right M^2 (H18.6060) and a right M^3 (H18.6061) found to be associated together (number 1728). To the second individual was attributed a left P^2 (F15.4341), a left P^3, P^4 and M^1 (D18.4974). A right P^2 (G18.3991), a left M^2 and M^3 (E19.5609 and E19.5405 respectively) associated (number 2366) could be attributed to any of these two individuals.

The Adult 3 (A3) age class was composed of a minimum of four individuals. This was established on the basis of the presence of four left M_3 (E20.4790, H15.6396, C20.4790 and F20.4965). Two out of these four individuals could be more precisely aged to 132 months (11 years) based on the use wear exhibited by two I_1 (F19.5722 and F19.5723). The latter was possibly associated with an I_3 (F19.5724) also demonstrating use wear equivalent to 132 months. To one of these two individuals could be added a left P_4 (E15.2508). The second M_3 (H15.6396) was brought together in association (number 1139) with other isolated dental elements such as a P_3 (H15.6352), a P_4 (H15.6352), and an M_1 (H15.6421), all from the left ramus and a P_4 (D16.5382) from the right ramus. Similarly, the third M_3 (C20.4790) was found to be in association (number 3250) with a left M_1 (C20.4780). To either the first or the fourth individual could be added a left M_1 (C15.2357). Among the maxillary dental elements, a right M^2 (C16.2558), a left P^2 (J19.9486), a left P^4 (F15.4174) and a left M^3 (G18.2231) could be added to the dental repertoire of any of these individuals.

Senile

In this sub level, two individuals were accounted for due to the presence of two M_1 (G15.7145 and F15.1638) from the right mandible ramus. The latter was part of a mandible fragment and was found in connection with P_3, P_4, M_2 and M_3. On the contralateral side, an M_1 (F15.4663), an M_2 (F15.4679) and an M_3 (F15.4680) formed an association (number 1138) between themselves and with the right mandible (F15.1638; Fig 7.5E). A single maxillary dental element, a left M^3 (E16.4285) could belong to either of these two individuals.

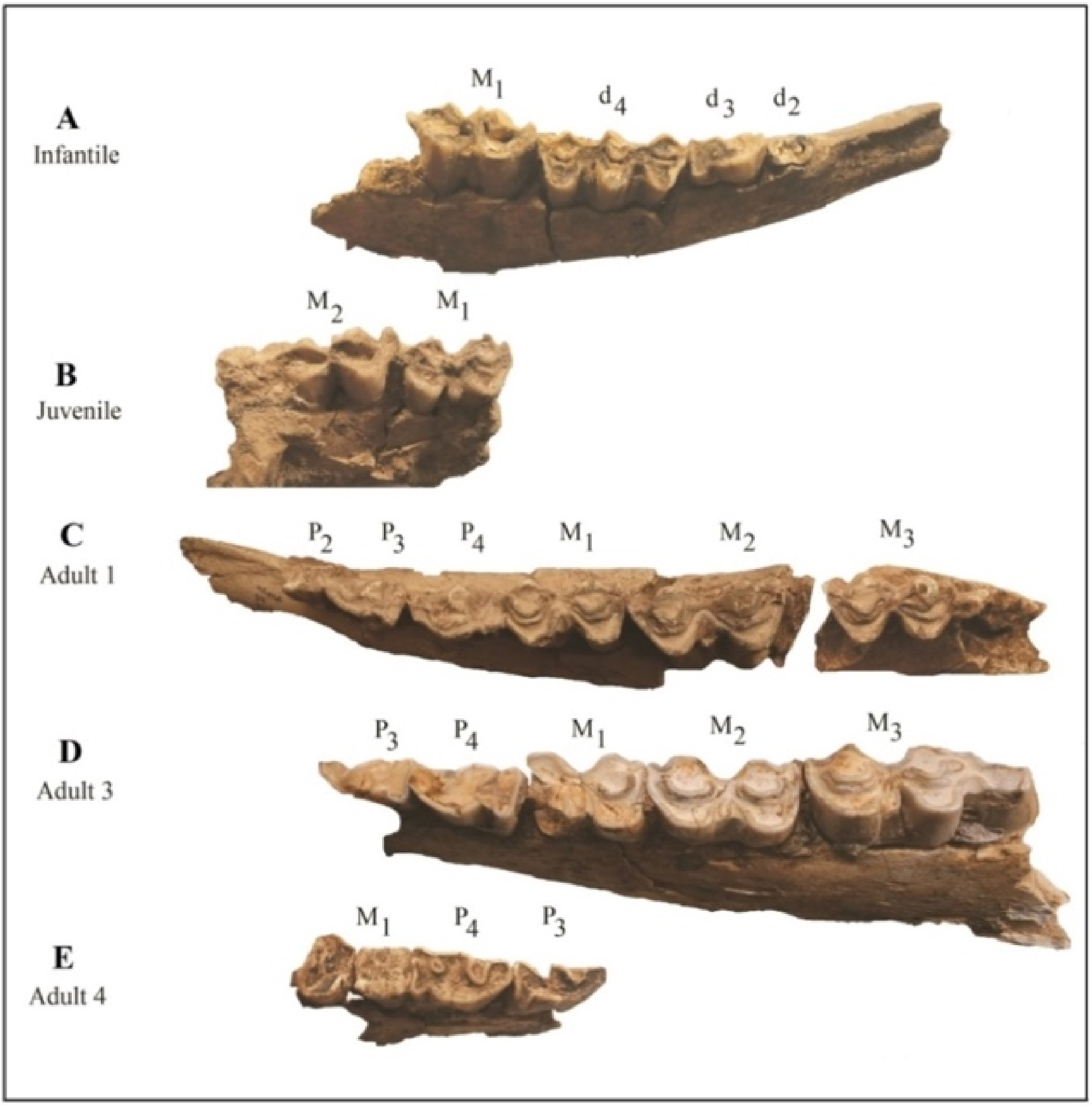


Fig 7.5: Caune de l'Arago: Level G mandibular dental remains: A- occluso-buccal view of right mandible (F19.2610) from sub level G1; B- occluso-buccal view of right mandible (D18.851) from sub level G1; C-occlusal view of left mandible (D17.1422) from sub level G2; D-occluso-ligual view of left mandible (C19.372) from sub level G3; E- occlusal view of right mandible (F15.1638) from sub level G4 (not to scale).

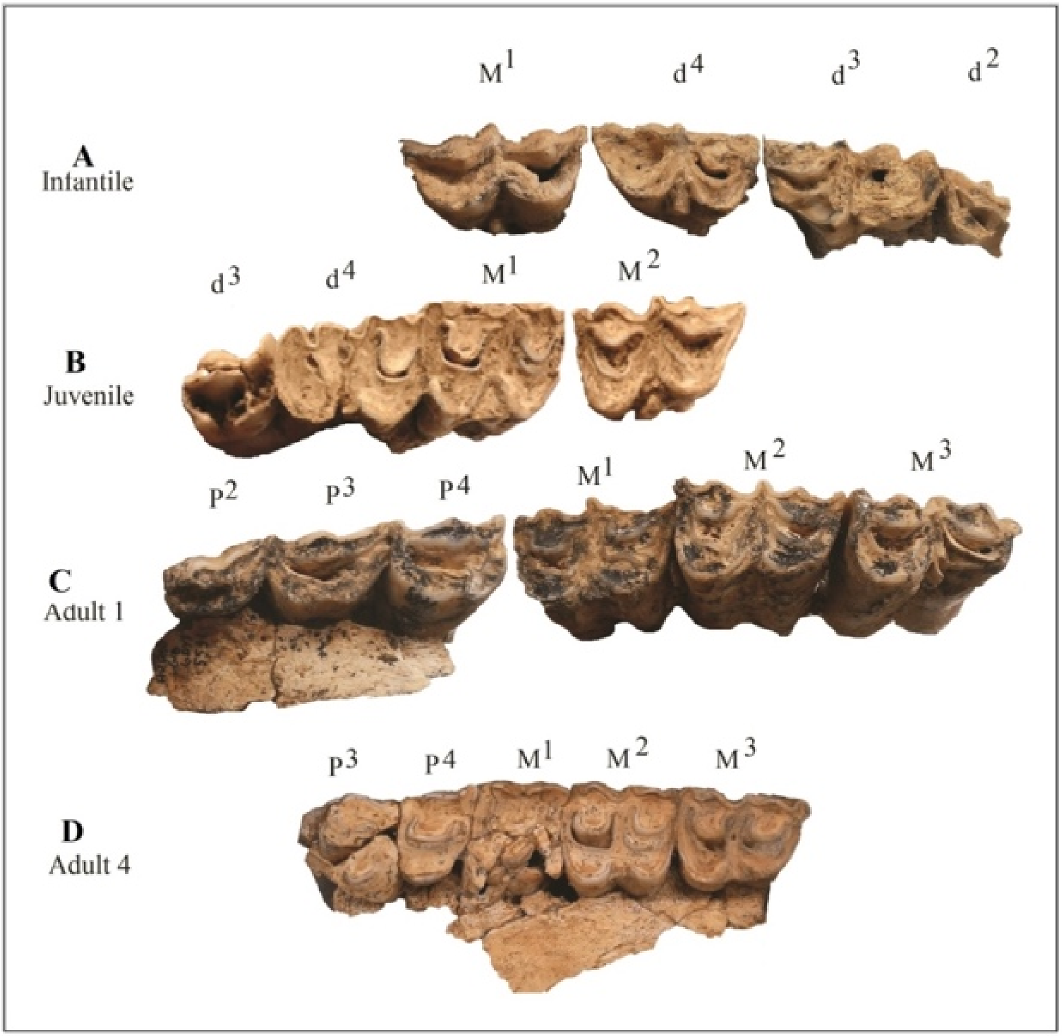


Fig 7.6: Caune de l'Arago: Level G maxillary dental remains: A- occlusal view of right maxilla (E16.2580) from sub level G3; B- occlusal view of left maxilla (D20.4626) from sub level G2; C- occluso-buccal view of left maxilla (G16.5591+5729) from sub level G3; D-occluso-ligual view of left maxilla (D19.5783) from sub level G3 (not to scale).

7.2.3 Upper level F

There are three sub-levels in level F. From sub-levels F1, F2 and F3 were recovered 110, 160 and 121 cranial, maxillary and mandibular remains. However, out of them, 48 from F1, 63 from F2, 121 from F3 were considered as they fulfilled the diagnostic criteria established for this study (Table 7.3). The table encapsulating the frequency distribution of number of dental remains by type and laterality for age class study for level F revealed some interesting observations (Table 7.6). Sub level F2 had the highest number of dental remains (53) followed by F1 (41) and F3 (40). Apart from isolated teeth, there were mandibles and maxillae with teeth still intact inside. In the sub levels of F, such partially complete mandibles and maxillae were almost equal in count except for F2 which had just one more mandible with teeth when compared to other sub levels. Overall, the count of teeth from right laterality was more than left laterality in sub level F1 and F2, whereas they were equal in sub level F3. Also, permanent dentition was much better represented than deciduous dentition. Permanent mandibular isolated dental elements were almost double the deciduous mandibular isolated dental elements. Further, molars were more in count than premolars. In case of maxillary dentition, the permanent dental elements were almost double or nearly seven times the number of deciduous dental elements. Here too, the molars were in greater numbers than premolars. In sub level F1, permanent mandibular dental elements were more than permanent maxillary dental elements. The contrary was calculated for sub level F2. In sub level F3, the permanent mandibular and maxillary dental elements were equal in number.

An estimate of MNI from these selected remains amounted to 37 bison individuals which were hunted and their carcasses processed for meat and marrow during level F occupation (Table 7.3). In level F, most of the age classes had either one or two individuals. Unequal distribution reflected varying preferences for bison of different age classes.

Sub level F1

In this sub level, there were a total of 12 bison individuals with an unequal distribution over age classes. Adult individuals were double the number of young individuals while the senile were very few (Table 7.3).

Infantile and Juvenile

The individuals in this age group were estimated to be two, primarily from an i_2 and c, both from right side, with slightly different use wear. The i_2 (I15.308) was estimated to be that of a six-month old individual and the c (K17.321) from an 8-month old individual. To one of these two individuals could also be attributed a left d^4 (H18.272). In the juvenile population, there was only one individual. The dental remains attributed to this individual were recovered isolated but later associated with a number (1143). They included left d_3 (J17.311), d_4 (J17.1441), m_1 (J17.552) and a right d_4 (G18.3821).

Subadult

In this age class, two individuals were calculated. A right P_4 (G20.957), P^3 (I17.61) and P^4 (H20.728) composed one individual with permanent mandibular teeth. The second individual was represented by a single tooth, a d_4 (D19.1447 + D19.1441; association number 3345).

Table 7.6: Caune de l’Arago: Upper level (F), frequency distribution of number of dental remains by type and laterality for age class study.

Level	**F1**		**F2**		**F3**	
Inferior isolated	Right	Left	Right	Left	Right	Left
i_1						
i_2	1	1	1			2
i_3			1		1	
d_2	1	1				
d_3			1	1	1	
d_4		1	1	1		
I_1	1	1			1	1
I_2						
I_3	1		2			
P_2						
P_3			1		1	1
P_4	1		1	2		
M_1	2	1	1	1	1	1
M_2	2	1	1	2		
M_3		2	2	4	1	1
i_1	1	1	2	1		3
i_2	1		2	2	1	5
Mandible with teeth	1			2	1	
Superior isolated						
d^2	1			1		
d^3	1			1	1	
d^4		1	2	1	1	
P^2	1	1		2	2	
P^3	1	2	1		2	
P^4					1	1
M^1	2	3	1	1		1
M^2	2	1	1	1	1	2
M^3	2	1	1	1	3	2
Maxilla with teeth		1	1		1	

Adult

In the Adult 1 (A1) age class, the presence of two right M^3 (F20.631 and J18.3813) allowed for the determination of two separate individuals. The latter M^3 was probably associated with a left P_3 (J18.501). One of these two individuals was precisely aged eight years based on a left C (I15.1996) to which it belonged. The remaining teeth from this age class attributable to either of these two individuals included a left P_4 (G20.1020), a left P^2 (H15.1162), a right M^1 (E19.572) and a right M^2 (D16.2013).

In the next age class, Adult 2 (A2), the dental remains amounted to two individuals. This was arrived at because of the same dental element from the same laterality being more than one in number. A left maxilla (J20.1934; Fig 7.7A) with M^1, M^2, and M^3 was associated with a left P^4 (J19.2856) and comprised the first individual. The second individual was composed of similar teeth, a left M^1 (I19.1527) and a left M^2 (J18.3635). To either of the two individuals also belonged a left P^3 (I19.839) and I_2 from both lateralities (J17.313 and H15.1133). These incisors were found to be eight years old, thus giving a precise age to the adult individual.

Similar to infantile, subadult, A1 and A2 age classes, there were two individuals estimated in this age class, Adult 3 (A3), too. To the first individual were attributed right side mandibular premolars and molars brought together by an association (number 601). This association was made between a P_2 (E19.613), P_3 (E19.702), P_4 (E20.1072), M_1 (E19.635) and a mandibular fragment (E19.635) with M_2 and M_3 present in it. From the same laterality came an additional P_3 (J16.228) and an M_2 (G19.1026) attributed to the second individual. On the contralateral side, an M_1 (H15.515) and an M_2 (H19.651BIS) probably added to the dental arcade of either of the two individuals. Among the maxillary dental elements, two left M^1 (G15.396 and H19.640) reinforced the MNI estimation for this age class. Other maxillary elements such as a right P^2 (H14.137) and an M^1 (G20.83) could be associated with either the first or the second individual.

Senile

The dental elements attributed to this age class accounted for a single individual. Only one mandibular dental element – an M_3 (G17.167) was present while the maxillary elements included a P^3 (I19.1247), an M^2 (J16.313) from the right side and from the contralateral a P^3 (I19.1247) and an M^3 (I19.884).

Sub level F2

In this sub level, there were a total of 13 bison individuals with an unequal distribution over age classes. Similar to sub level F1, young individuals were half the number of adult individuals while the senile were very few (Table 7.3).

Infantile and Juvenile

The young bison population comprised three individuals, two infants and one juvenile. The former was estimated on the basis of two left M_1 (H15.1845 and D18.1715BIS). To these individuals' dental repertoire could be added a left d_2 (I18.667), a left M_2 (F20.797) and a solitary maxillary element- d^4 (G17.1166). The latter age class- juvenile, with one individual, was composed of isolated elements. Mandibular elements comprised a right d_2 (H18.712BIS), a right M_2 (J17.1315) a left d_3 (I16.2030). Maxillary elements included a d^2 (J18.4176), d^3 (I20.1456) and a d^4 (F19.1310).

Subadult

Dental elements attributed to this age class accounted for one individual. They included an i_3 (G16.608), P_2 (F19.2046) and P_3 (G20.1141) from the mandible. From the maxilla came a single element, a d^4 (H18.868).

Adult

The first age class, Adult 1 (A1), was composed of three individuals. The MNI was calculated on the basis of multiple occurrence of the same type of teeth with same laterality. For instance, three P_2 (G20.1183, E20. 2527 and I18.4906) and thee M_3 (G20.1077, H16.1568 and C17.255) from the left laterality belonged to three individuals. On one hand, one of the P_2 and an M_3 formed an association (number 2208) with a P_3 (G20.1111) and a P_4 (G20.1020). On the other hand, one of the three P_2 (E20.2527) was connected to a P_3 since they were together still intact inside the mandible ramus. This fragment could be possibly associated with a P_4 (H9.1434). Similarly, another M_3 (C17.255) was also found connected with an M_2 in the same mandible fragment. Some additional isolated teeth could belong any of these three individuals. They were a right P^3 (H19.1663) and a left M_1 (H19.1033). One of these individuals could be assigned a more precise age based on the use wear exhibited by a right I_2 (K20.2914), that of 60 months, to which this tooth belonged.

In the Adult 2 (A2) age class, the mandibular dental elements could be associated with two individuals. Apart from a left M_1 (D16.2317) which could belong either of the two individuals, a right I_2 (I17.193) was estimated to belong to an eight year old individual while a C (G15.293) was shown to exhibit wear attributable to a seven year old individual. A similar calculation was arrived at from maxillary dental remains from this age class. From the left laterality, two P^2 (H19.2914 and G15.1381) allowed to reiterate the MNI estimation to be two individuals. To either of these two individuals also belonged a right M^1 (F20.635).

The next age class, Adult 3 (A3), consisted of two individuals represented by two right M_3 (G9.1415 and J18.4191). Additional isolated mandibular remains which could be added to the dental repertoire of these individuals were a right M_1 (I7.1456 +I15.1237) and premolars with left laterality - P_2 (I15.1237), P_3 (I15.1538) and P_4 (I15.1997). Four maxillary dental elements also represented these individuals. For instance, on one hand, an M2 (J18.589) and M3 (H19.1500) from the right side, and on the other hand, an M1 (F19.1163) and M3 (H20.2241) from the left side could be added to the dental arcade of these individuals.

Senile

In the last age class, Adult 4 (A4), the MNI was estimated to be two individuals. Among the mandibular dental elements, a possible association emerged between a P_2 (H20.949), P_4 (F19.1486), M_1 (H16.1512+1589, association number 1400) and M_2 (H20.1217), coming from the right ramus belonging to the first individual. This individual could also be supplemented with other elements such as a P_3 (F17.860+F17.947, association number 2205) from the right side, a mandibular fragment containing M_1 and M_2 (D19.1710) intact inside and an isolated M_3 (G19.1860) from the left side. A right maxillary ramus with all three molars still intact (J19.4508; Fig 7.7C) probably belonged to the same individual. From the contralateral side was recovered an M^2 (H17.443) with abnormal use wear because probably the lower counterpart was missing, in which case there came into existence another individual in the estimation.

Sub level F3

In this sub level, there were a total of 12 bison individuals with an unequal distribution over age classes. Young individuals were almost the same in number as adult individuals while the senile were very few (Table 7.3).

Infantile and Juvenile

There were found to be three infants in this sub level. Each was represented by an incisor with different ages base on their use wear. A right i_3 (H15.2943) was of the first individual aged 9 months. From the other side, 2 i_2 were attributed to the second and third individual. One of the i_2 (K17.430) was of a five month old and the other i_2 (H17.917) of a one month old infant. From the same side were recovered three more isolated teeth which could be assigned to any of these three infants. The first was a d_4 (J19.5993), the second was an M_1 (J18.841) and the third was an M_2 (J18.4607). The maxillary dental elements included an M_1 (H15.3416) and an M_2 (D18.660).

The only one juvenile individual was represented by a right d_2 (H14.195), d_4 (H20.1656) and a left M_2 (G17.884). A worn out d^2 (H19.3087) and d^4 (I19.4135) from the right maxilla could be associated with the same individual.

Subadult

The presence of the same tooth, two in number from the same side allowed to estimate the MNI in this age class. The teeth were two M_3 (I19.3280 and G15.2192) from the left laterality. From the contralateral side an M_3 (G15.2192) and a maxillary left M^3 (G17.1055) could be associated with one of the two individuals.

Adult

The first age class, Adult 1 (A1), was represented by solely maxillary dental elements. A P^2 (E20.2863) and a maxilla fragment (I19.2700) which contains P^4, M^1 and M^2 were associated with this individual. From the other side, a P^4 (H16.2159) and an M^3 (J19.5508) could be added to the dental arcade of this individual.

In the next age class, Adult 3 (A3), all the dental elements together accounted for one individual. Among all the dental elements assigned to it, a left canine (J18.590) could be precisely aged to 10 years based on its use wear hence giving an age to this individual. A nearly complete right ramus (F20.1306; Fig 7.7B) with intact P_3, P_4, M_1 and M_2; a left P_3 (F20.1182), a right P^3 (F19.1552) and a left M^2 (H16.2159) could also probably be associated with this individual.

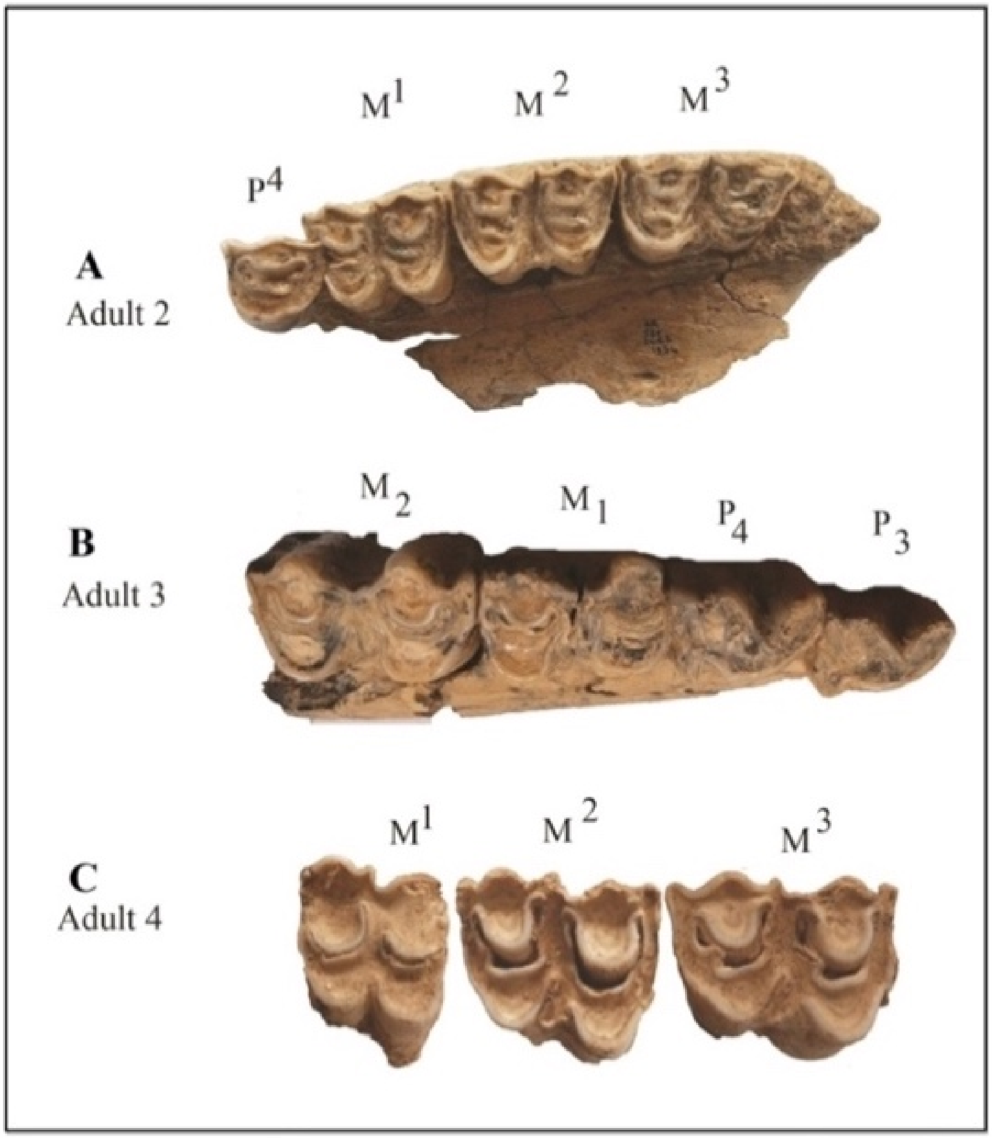


Fig 7.7: Caune de l'Arago: level F dental remains: A- occlusal view of left maxilla (J20.1934) from sub level F1; B- occlusal view of right mandible (F20.1306) from sub level F3 and C-occlusal view of right maxilla (J19.4508) from sub level F2 (not to scale).

Senile

Similar to A3, the senile population was represented by only one individual to which could be attributed one mandibular tooth and two maxillary dental elements. They were a right P_3 (I19.2500), a left M^2 (F20.1289) and a left M^3 (E20.2603) respectively.

7.3 Mortality curve

7.3.1 Isernia La Pineta

A glance at the MNI calculated in relation to different age classes (Table 7.2 and Fig 7.8) revealed similar mortality curves for archaeosurfaces and other levels at Isernia. The situation reflected an unnatural distribution with prominent representation of adult individuals in their prime over other age classes, hence indicative of their deliberate and economically profitable selection by humans.

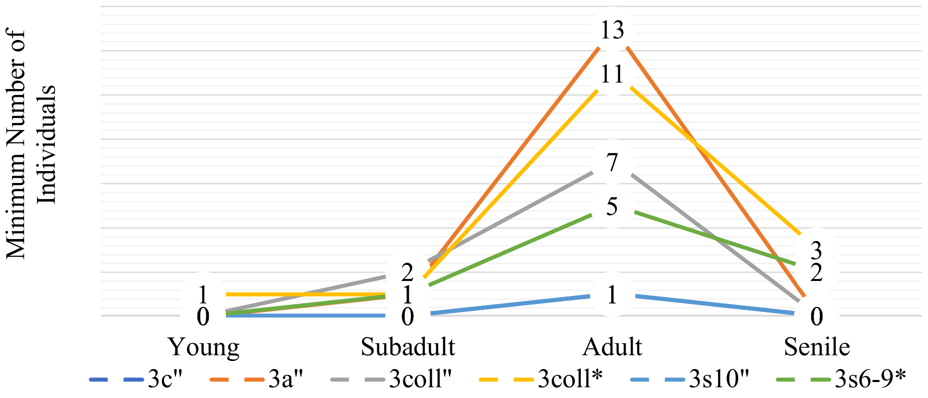


Fig 7.8: Isernia La Pineta: Archaeosurfaces 3c, 3a, 3S10; layers 3 colluvium and 3s6-9; mortality curve for *Bison schoetensacki* from previous study-“ (Di Nucci et al., 2006) and present study-*.

Young bison individuals in the population were almost negligible and were therefore not a preferred choice for dietary consumption. The singular exception to this was layer 3 coll where one infant individual was present. However, it was still negligible when compared to other age classes with less representation such as subadult and senile. Overall, when all archaeosurfaces and layers were cumulatively taken into consideration, individuals belonging to subadult and senile age classes were numerically equal, i.e. five each, but still very less when collated to the adult age class, the latter amounting to 38 individuals. A similar result was obtained when individual results from the previous study of layer 3 coll was combined with the results of the present study. The number of subadult and senile individuals estimated was equal, ie, three each. In layer 3s6-9, on the contrary, senile individuals were twice the number of subadults. As discussed earlier, in archaeosurfaces 3c, 3a and 3S10, there were no senile individuals. Meat and marrow from adult bisons was a preferred choice for consumption. Such a dominant trend was reiterated in each archaeosurface and the respective layers covering them.

7.3.2 Caune de l'Arago

Lower Levels H to Q

In the lower levels at Arago (Fig 7.9), the mortality profile revealed that adults were selectively hunted and consumed, especially in sub level Q. In the other sub levels- HIJ and MNOP, adults and senile bison were more or less equal whereas the young, very few in comparison to other age classes, formed a part of human's selection only in the lower parts of these occupation levels. Towards the upper part of the lower level, subadult individuals were being included and/or replacing the young bison in the economic choices of humans.

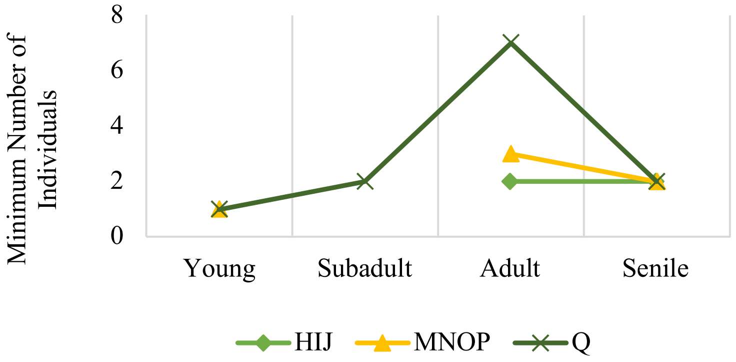


Fig 7.9: Caune de l'Arago: Lower levels H-Q; mortality curve for *Bison* sp.

Upper Level- G

Only in sub level G3, the number of young, subadult and senile individuals were more or less similar (Fig 7.10). In sub levels G1, G2 and G4, a change in preferences was noted. For instance, the number of young individuals in G2 was lesser than G1 and G4. However, the contrary was recorded in case of adults for the same levels. Adults were more in number in G2 whereas their numbers decreased in G1 and G4 sub levels.

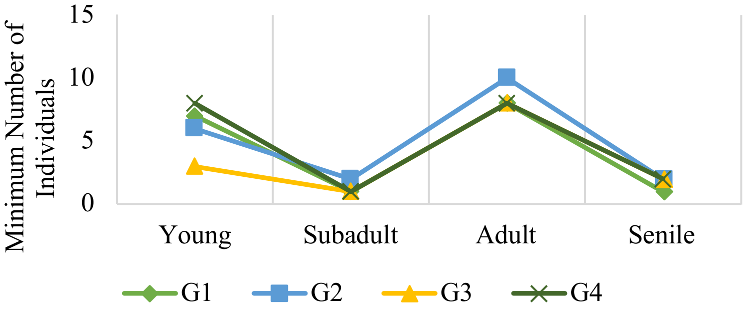


Fig 7.10: Caune de l'Arago: Upper level G; mortality curve for *Bison priscus.*

Upper Level- F

The mortality profiles of bison through the three sub levels of upper level F at Arago brought forth some interesting observations (Fig 7.11). A slight contrast in trend was visible from F2 to F3 sublevels in the number of young and adult bison selected for consumption by humans. As the number of adult individuals increased from F3 to F2, there was a decrease in the number of young individuals in the same two levels. On the whole, adult bison were clearly a more profitable choice, followed by young, subadult and lastly senile.

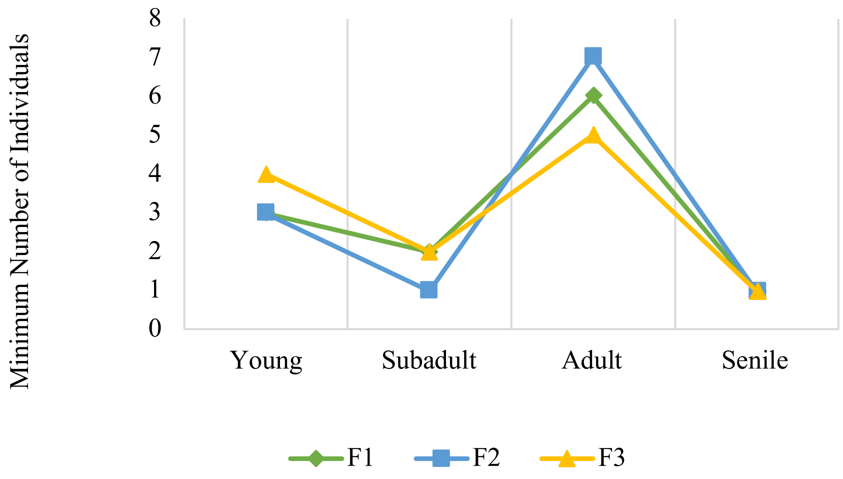


Fig 7.11: Caune de l'Arago: Upper level F; mortality curve for *Bison priscus.*

A cumulative mortality profile of Isernia and Arago highlighted a few similarities and differences between the two sites (Fig 7.12). At Isernia and Arago, adult individuals were clearly the preferred profitable choice for consumption. At Isernia, the other age classes were scarcely represented with fluctuations between consecutive layers of occupation. At Arago, in the lower levels, young individuals were not considered as a profitable economic choice. However, in the upper level G, there appeared to be a modification to this strategy as young were also hunted and consumed. Yet again, an alteration in the selection of certain age classes became apparent as the young were hunted and consumed less and less in the subsequent upper level F along with a decline in adult age class representation too. At Arago, akin to Isernia, the representation of subadult and senile fluctuated and remained much lower than other age classes through subsequent occupation layers.

7.4 Crown height and cusp edges

The study of two variables-crown height and cusp edges, allowed to surmise that with successive age classes, from infant to senile, they underwent progressive wear which could be qualitatively categorised and compared between the two sites for both deciduous and permanent dentition (Tables

7.7 and 7.8). These qualitative characteristics were found to be particular and could be associated to a certain age class for a certain tooth.

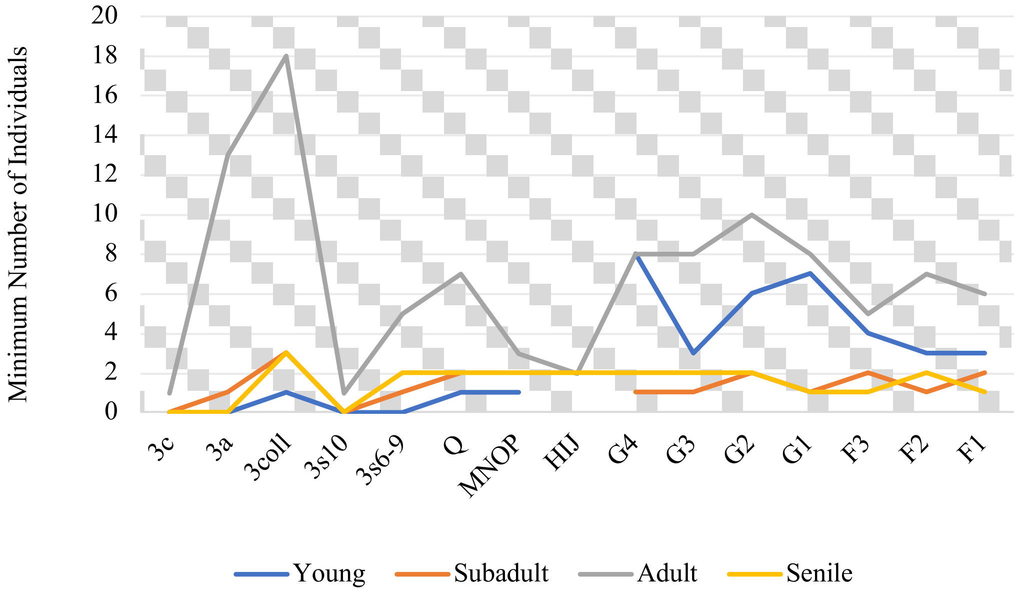


Fig 7.12: Caune de l'Arago: Mortality profile for *Bison schoetensacki* from Isernia La Pineta (3c, 3a, 3S10, 3 colluvium and 3s6-9); *Bison schoetensacki* and *Bison* sp. from lower levels (H-Q) and *Bison priscus* from upper levels (F and G) of Caune de l'Arago.

7.4.1 Mandible

To begin with, deciduous mandibular dental elements were taken into account. Data concerning these two variables was mostly available for Arago while Isernia provided less information for comparison. Apart from permanent incisors and canine in the infantile/juvenile age class and premolars in the subadult age class, there was better representation of data from Arago and Isernia in the mandibular permanent dentition.

Infantile

In this age class, the crown height and cusp edges were similar for incisors and canine from levels F and G of Arago. When the crown height was high the cusp edges were sharp or round. When the crown height reduced to medium, the cusp edges were round but never sharp. Between the three incisors and canine, the wear pattern was similar. The same observation was also made for deciduous premolars. The data for this set of dental elements was available primarily from Arago. In case of d_2, d_3 and d_4, the crown height wore from high to medium while cusp edges went from sharp to round. The only dental remain, a d_2 from 3 coll of Isernia conformed to the pattern observed its counterpart from Arago. Permanent molars- M_1 and M_2 which erupted in the infantile age class exhibited high to medium crown height and sharp to round cusp edges. While the M_1 from Arago was high and sharp, the M_1 from Isernia was medium in crown height and had round cusp edge. The M_2 present only in level F of Arago showed wear of crown height from high to medium but the cusp edge remained sharp. They continued to exhibit similar wear in the next age class.

Juvenile

Data for this age class was provided only from Arago and mostly from level G. The incisors and canine in this age class were observed to have a medium to low crown height whereas the cusp edges were either round or flat. Among the deciduous premolars there was evidence to show that d_2 wore slower than d_3 and d_4. The crown height was medium while the cusp edges wore from sharp to round in case of d_2. However, in the other two deciduous premolars, the crown height had already reached low and the cusp edges were flat in most of the dental elements attributed to this age class, with a few exceptions of high or medium crown height and sharp cusp edges.

Table 7.7: Isernia La Pineta (layers 3 colluvium and 3s6-9) and Caune de l'Arago (lower levels (H-Q) and upper levels (F and G)): Observed tooth crown height and cusp edges for mandibular deciduous dental remains. i- incisor, c-canine, d- deciduous premolar. H-high, M-medium, L-low for height. S-sharp, R-round, F-flat for cusp edges.

Age class	**Level**	**i_1**	**i_2**	**i_3**	**c**	**d_2**	**d_3**	**d_4**
Infantile	F	MR	HS-MR	MR		HS		HS
	G	HS-HR-MR	HS-MR	HR-MR	MR	HS-HR-MR	MS-MR	HS-MS
	H-Q					MR	MR	HS
	3s6-9							
	3coll					HS		
Juvenile	F					MS-MR	LR-LF	MS-LF
	G	MR-LR-LF		LF	MR	MR	HS-LF	HS-MF
	H-Q							
	3s6-9							
	3coll							
Subadult	F					HS	HS	HS-MF
	G						HS	
	H-Q	LF	MR					
	3s6-9							
	3coll	MR						

Subadult

Data for incisors came from the lower levels of Arago and Isernia whereas data for deciduous premolars was procured from the upper levels of Arago. While i_1 from Arago had a low crown height, the i_1 from Isernia was still at medium crown height. The cusp edge, similarly, showed more wear in Arago than Isernia. It was flat in Arago while still round in Isernia. The adjacent incisor, i_2 was less worn than i_1 with medium crown height and round cusp edge as seen on the i_2 from Arago. Among the deciduous premolars, the crown height was high and the cusp edges were sharp. Evidence of further wear cam in the same age class came from a d4 from level F which had medium crown height and flat cusp edges. In this age class, all three permanent incisors (from lower and upper levels of Arago and layer 3s6-9 from Isernia) and M_3 (from level F of Arago) for which data was available, showed the same wear for both crown height which was high and cusp edges which was sharp.

Adult 1

In the Adult 1 age class, Incisors, premolars and molars were found to have a high crown and sharp cusp edges predominantly. Departing from this general pattern was an i_2 and canine from level G of Arago as they had worn further to medium height and round cusp edges. Considering the incisors, it was found that the ones from Isernia were slightly more worn as the crown height had further worn to medium and the cusp edges were round. The premolars from both sites showed similar wear of crown height which ranged from high to medium and cusp edges which ranged from sharp to round to flat. The molars also followed this pattern but there was clear evidence of M_1 wearing faster than M_2 and M_2 wearing faster than M_3. M_1 had a medium crown height with sharp or round cusp edges. However, M_2 and M_3 still had a high crown and sharp cusp edges.

Adult 2

In Adult 2 age class, the incisors, premolars and M_1 demonstrated similar wear. The crown height ranged from medium to an exceptional low (as seen on an I_3 from layer 3s6-9 of Isernia). The cusp edges were found to be flat in case of I_1, sharp to round in I_2, and flat in I_3. The canine wear was more or less similar in A1 and A2 age class. Premolars exhibited high to medium crown height and sharp to round to flat cusp edges. Interestingly, M_1 displayed greater wear than M_2 and M_3 akin to the previous age class. The dental remains from layer 3 coll revealed a similar wear pattern. However, the data for incisors was obtained only from layer 3s6-9, which showed that the crown height had reduced to low and the cusp edges had flattened. A P_3 from the same age class and level had medium crown height and sharp to round cusp edges. Continuing further, while the M_2 had medium crown height and its cusp edges ranged from sharp to round; the M_3 from the same age class and level had a higher crown height and flat cusp edges. When the crown height got worn down to medium height, the cusp edges were either sharp or round. In this age class, the three molars were at different stages of wear. While M_1 had a medium crown height and round cusp edges, the crown height of M_2 ranged from high to medium and cusp edges were either sharp or round. The M_3 was similar to the M_2 with crown height ranging from high to medium and the cusp edges were sharp or round.

Table 7.8: Isernia La Pineta (layers 3 colluvium and 3s6-9) and Caune de l'Arago (lower levels (H-Q) and upper levels (F and G)): Qualitative description of tooth crown height and cusp edges for mandibular permanent dental remains. I/J- Infantile/Juvenile, SA- Subadult, A- Adult. I- incisor, C- canine, P- premolar, M- molar. H-high, M-medium, L-low, for height. S-sharp, R-round, F-flat, for cusp edges.

Age class	**Level**	**I_1**	**I_2**	**I_3**	**C**	**P_2**	**P_3**	**P_4**	**M_1**	**M_2**	**M_3**
I/J	F								HS	HS-MS	
	G										
	H-Q								HS		
	3s6-9										
	3coll								MR		
SA	F										HS
	G	HS	HS	HS							
	H-Q		HS								
	3s6-9	HS									
	3coll										
A1	F		HS			HS-HR	HS-HR	MR	MR	HS	HS
	G	HS	HS-MR	HS-HR	MR	HS-MR-MF	HS-MR	HS			
	H-Q	HS	HS			HS-HR	MR		MS-MR		HS
	3s6-9	HS									HS
	3coll	MR-MF	MR			HS	MR	MR			
A2	F		MS-MR		MS	MF			MS-MR	HS-MR	HS-HR
	G	MF	MR			HS	MR	MR			
	H-Q	MF	MR			MR	MR	MR	MR	MR	MR
	3s6-9			LF			MR			MS	MS-MR
	3coll						MR			HR	HS-HR-MR
A3	F					MR-MF	MR	MR-MF	MR-MF-LF	MS-MR	HS-MR
	G	MF-LF	MF-LF	LR-LF	MF-LF	MS-MR	MR-LR	MR-LR			
	H-Q		LR-LF	LF				MR	LF	MR	MR
	3s6-9					MR			MR		
	3coll					MS	MF-LR	MR	MS-MR	MS	MR-LR
A4	F					MR	MR-MF	LR	LF	MR-LR	LR
	G		LR-LF	LF			LR-LF	LR			
	H-Q	LF				LF					MR
	3s6-9							LF			
	3coll						LR-LF	LR	LF		LS-LR

Adult 3

The dental elements from both lower and upper levels of Arago and Isernia revealed wear patterns similar to previous age classes. The incisors, canine, premolars and molars demonstrated a crown height ranging from medium to low with round to flat cusp edges. M_2 was less worn than M_1. The height of the crown was medium but the cusp edges ranged from sharp to round. M_3, on the contrary, displayed slightly less wear than M_1 and M_2 since its crown height was high or medium and the cusp edges were still sharp or round but not flat yet.

Adult 4

In this age class, the different teeth revealed similar wear pattern. The incisors were at the lowest crown height and round to flat cusp edges. Majority of the premolars and molars from both sites had medium to low crown height and round to flat cusp edges. As observed in previous age classes, M_1 was more worn than M_2 and M_3.

7.4.2 Maxilla

The table below (Table 7.9) encapsulated the observations made regarding crown height and cusp edges for maxillary deciduous dental remains. The data was scanty with no representation from Isernia. Generally, in the infantile age class, as seen in upper level G of Arago, the crown height of d^3 ranged from high to medium whereas that of d^4 remained high. Similarly, while the cusp edges of d^3 wore from high to medium, they were found to be round in d^4. The following age class, juvenile, revealed that d^2 had worn much faster than d^3 and d^4. The height of the crown was low and cusp edges were already flat when compared to d^3 and d^4. The crown height of the latter from high to medium to low while the cusp edges were either sharp, round or flat. In level G of Arago, it seemed that d^4 had worn faster than d^3 but not as much as d^2.

Taking the maxillary permanent dentition into account, it was noticed that data was scarce for the initial age classes such as infantile, juvenile and subadult. However, more data for comparison was available in the adult age classes (Table 7.10).

Infantile and Juvenile

The data for maxillary permanent molars which erupted in the infantile age class came from level F of Arago and revealed that M1 was slightly more worn than M2. In the former, the crown height ranged from high to low whereas the cusp edges were either sharp or round. The latter also displayed similar wear but the crown height had not yet reduced to low.

Subadult

In this age class, data was available from Arago with no representation from Isernia. The premolars and molars demonstrated similar wear with high crowns and sharp or round cusp edges. A slightly advanced wear in crown height to reach the medium height was seen on M^1 and M^2. This observation was more apparent in level G of Arago.

Table 7.9: Isernia La Pineta (layers 3 coll and 3s6-9) and Caune de l'Arago (lower levels (H-Q) and upper levels (F and G)): Observed tooth crown height and cusp edges for maxillary deciduous dental remains. d- deciduous premolar. H-high, M-medium, L-low for height. S-sharp, R-round, F-flat for cusp edges.

Age class	Level	d^2	d^3	d^4
Infantile	F			
	G		HS-MR	HR
	H-Q			
	3s6-9			
	3coll			
Juvenile	F	LF		
	G	LF	HS-MS-MR-LF	MS-MR-LF
	H-Q			
	3s6-9			
	3coll			

Adult 1

In the Adult 1 age class, the crown height of dental elements such as premolars and molars ranged from high to medium while the cusp edges were either sharp, round or flat. Comparative data was available for P^2, P^3, and M^2 to observe similarities and differences between Arago and Isernia. There was no data for M^1 and M^3 from Isernia. Generally, wear among the three premolars was similar. However, among the molars, M^1 and M^2 were more worn than M^3.

Adult 2

Although the wear in crown height and cusp edges either remained the same or advanced slightly further, the pattern was similar for both premolars and molars. Again, the crown height now included low apart from high and medium whereas cusp edges were predominantly round with some exceptions having flat cusp edges.

Adult 3

In this age class, the premolars- especially P^3 and P^4 and molars, were well represented in all levels from Arago and Isernia. The crown height and cusp edges were similar for P^2, P^3 and P^4. The crown height fluctuated between medium and low while the cusp edges ranged from round to flat. Among the premolars, a P^4 from level as an exception still had a high crown but the cusp edge was round. The molars displayed similar wear with crown height moving from medium to low and cusp edges getting worn further from round to flat.

Table 7.10: Isernia La Pineta (layers 3 coll and 3s6-9) and Caune de l'Arago (lower levels (H-Q) and upper levels (F and G)): Qualitative description of tooth crown height and cusp edges for maxillary permanent dental remains. I/J- Infantile/Juvenile, SA- Subadult, A- Adult. P- premolar, M- molar. H-high, M-medium, L-low, for height. S-sharp, R-round, F-flat, for cusp edges.

Age class	Level	P^2	P^3	P^4	M^1	M^2	M^3
I/J	F				HS-LR	HS-MS-MR	
	G						
	H-Q						
	3s6-9						
	3coll						
SA	F		HS	HR			HS
	G	HS		HS	HR-MS-MR	HS-HR-MR	HS
	H-Q						
	3s6-9						
	3coll						
A1	F	HS	HS	HS-HR	HS-MR	HS	HS
	G	HS-HR-MR-MF	HR-MR		MS-MR	HS-HR-MS-MR	HS-HR
	H-Q	MR	HR	HR			
	3s6-9	MF	HS	HS		HS	
	3coll		HS			HS	
A2	F		MF	MS	MR		MS-MR
	G	HR-MR-MF	HR	HR	MR	HR-MR	HS-HR-MR-LR
	H-Q			HR		MS	
	3s6-9		MS			MR	HF
	3coll	MR-MF	MR	MR		MS-MR	MR
A3	F	LF	MF		MR-LF	MS-MR	MS-MR
	G	MR-MF-LF	MR-LF	HR-MR-LR-LF	MR-LR-LF	MR-LR	MR-LR
	H-Q	LF		LR	LR	MR	
	3s6-9			LR	LF	LR	MS
	3coll			MR-LR	MS-MR-LS	MR	MS-MR
A4	F		MR-LF		LR	LF	MS-MR-LR
	G		MR-MF-LF	LR	LR-LF	LR-LF	MR-LR
	H-Q	LF	MR-LR-LF	LR-LF	MR-LR-LF	MS-MR-LR	
	3s6-9	LF	LF				
	3coll			LR			MR

Adult 4

Data was available for P^3 and M^1 for comparison between the different levels of Arago and Isernia. For P^2, data was scanty and came from the lower level of Arago and layer 3s6-9 of Isernia. Therre was no data from Isernia for comparison with Arago in case of P^4 and M^2. while for the remaining teeth, observations were made for the In this age class it became evident that certain teeth wore much faster than others. For instance, M^1 and M^2 wore faster than M^3. The crown height for teeth that had worn more than the others, was low with round or flat cusp edges. M^3, which was on the contrary, had medium crown height with sharp to round cusp edges.

7.5 Style wear

A study of maxillary and mandibular molarian style, present between anterior and posterior cusps, and its progressive wear stages codified for this study, aided in refining the formation of bison age classes. Data available for different archaeosurfaces and layers of Isernia from the same teeth was scanty when compared with the same tooth type for both lower and upper levels of Arago (Tables 7.11 and 7.12).

7.5.1 Mandible

Infantile

In this age class, data was available only for Arago. In case of d_4, for which comparative data was available for the lower and upper levels of this site, the style wear was similar. The length of the style had either reached half the height of the tooth and/or grown to equal the level of the occlusal surface of the tooth. In the same age class, M_1 and M_2 from level G and F respectively, had styles which were still at the base of the tooth or grown to reach the midpoint of the total height of the tooth. Clearly, the d4 which erupted prior to the molars had undergone greater style wear.

Juvenile

Here again, data for style wear was procured only from Arago. In the juvenile age class, the style of d4 had worn further to form a loop in both the lower and upper levels. Among the molars, the style of the M_1 had reached the full height of the tooth while the style of M_2 was at the base of the tooth or had grown to reach the midpoint of the total height of the tooth.

Subadult

Data for style wear in molars was available for upper level of Isernia and Arago. The style of M_3 in subadult age class had reached half the height of the tooth, as observed on a specimen from layer 3s6-9 from Isernia and level G and F from Arago.

Adult

The upper levels of Arago, levels G and F, provided a series of style wear data for the three molars from Adult 1 age class. Evidently, while the style of M_3 was still at the midpoint of the total height of the tooth, the styles of M2 had reached the occlusal surface of the tooth in terms of height in level G and worn further to form a circle outside in level F. As the first molar had erupted before the other two molars, its style had worn much further to form a loop as demonstrated by a specimen from level G.

Table 7.11: Isernia La Pineta (layers 3 colluvium and 3s6-9) and Caune de l'Arago (lower levels (H-Q) and upper levels (F and G)): Mandibular style wear codes. d_4- deciduous fourth premolar, M_1- first molar, M_2- second molar, M_3- third molar.

Age class	**Tooth type/Level**	**d_4**	**M_1**	**M_2**	**M_3**
Infantile	F	3		1	
	G	2-3	1-2		
	H-Q	2			
	3s6-9				
	3coll				
Juvenile	F	9		2	
	G	9	3	1	
	H-Q				
	3s6-9				
	3coll				
Sub adult	F				2
	G			2	2
	H-Q				
	3s6-9				2
	3coll				
Adult 1	F			4	2
	G		9	3	2
	H-Q				
	3s6-9				
	3coll				
Adult 2	F		9	9	4
	G			3-4-9	4-9
	H-Q		9	4	4
	3s6-9		4	4	3-4
	3coll		9	3	4
Adult 3	F		9	4-9	4
	G		9	7-9	4-9
	H-Q			9	4
	3s6-9				
	3coll		4-9	9	4-9
Adult 4	F		9	9	
	G		9	9	9
	H-Q			9	9
	3s6-9				
	3coll		9		9

Further evidence for molarian style wear was available for all three mandibular molars which allowed them to be placed in the same age class, Adult 2. This evidence came from both sites and from all archaeosurfaces and levels. The only exception was M_1 from level G for which there were no molars present. The M_1 style, as seen on a specimen from layer 3 coll, was more worn out in this age class in relation to layer 3s6-9. In the former, the style was looped while in the latter it was a circle outside. In both lower and upper levels of Arago, the M_1 had same style wear and were looped. In case of M_2, the style was less worn and similar for Isernia and the lower levels of Arago. The style had grown to reach the occlusal surface of the tooth or formed a circle outside. In the upper levels of Arago, the style exhibited further wearing to form a loop. Style wear in the M3 was similar. In the molars from Isernia and Arago lower levels, it had worn further when compared to the previous age class to form a circleor a loop between the anterior and posterior cusps of the tooth. The M_2 and M_3 from layer 3s6-9 had similar style wear as their counterparts from layer 3 coll. While M_1 style demonstrated the most advanced wearing in this age class, the style were slightly less and less worn in M_2 and M_3 as expected since they had erupted after M1.

In the successive Adult 3 age class, data was available only from layer 3 coll from Isernia. However, both lower and upper levels of Arago provided data regarding style wear. The style wear ranged from a circle outside to a loop and became largely uniform for the three molars in both sites. At this stage, the reduction in crown height and occlusal wear became more decisive criteria for attributing age classes to the remaining dental elements in the assemblage as no significant further wear was observed in the style of the molars.

Senile

In the last age class, molarian style wear data was available from nearly all archaeosurfaces and layers from both sites except 3s6-9 of Isernia. The three molars showed similar wear pattern, wherein the style had formed a loop.

7.5.2 Maxilla

Infantile

The data for style wear was available from d^4 and M^1 only for the lower and upper levels of Arago. The d^4 which erupted before the M^1 showed more wear as the style had reached the same height as the tooth while the style of M^1 was still halfway high.

Juvenile

Again, scanty data characterised this age class. There was no data from Isernia. The d^4 from lower and upper levels of Arago exhibited further wear as the style had formed a circle or a loop between the anterior and posterior cusps of the tooth. The M^2, on the other hand, was a little less worn. It had grown to either half or full height as of the tooth.

Subadult

In this age class, style wear data from series of three molars was provided by level G of Arago. There was no data from Isernia for collation. It was observed that M^3 had the least

wear as it erupted last. The wear was similar to M^2 of juvenile age class. The style had grown to half the height of the tooth or was still at the base. However, M^2 style had grown further to reach the occlusal surface of the tooth. M^1 style showed maximum wear in this age class as it had after reaching the full height as of the tooth, worn more to form a loop.

Adult

In the Adult 1 age class, comparative data for both sites came from M^2. Style wear was also observed between molars from the upper levels of Arago. However, there was no data for the lower levels of Arago and Isernia for M^1 and M^3. Therefore, the style in M^2 in this age class was predominantly observed to have reached the same height as the tooth or formed a loop. In case of layer 3 coll from Isernia and level G of Arago, the style of M^2 had worn further to form a circle inside or a loop with a circle inside, respectively. The style of M^3 had not yet formed a loop. It was still in the initial stages as it was either at the base, had reached the midpoint or full height of the tooth. In level G, it had worn some more to form a circle inside. In the next age class, Adult 2, the style of M^1 was worn to a loop in both lower and upper levels of Arago. The M^2 from layers 3 coll and 3s6-9 from Isernia showed variations in style wear. The style of M^2 from layer 3 coll had already worn to a circle inside or a loop or a double loop with circle inside, while the style from the same tooth from layer 3s6-9 had formed a circle outside or a loop. Some M^3 from level G of Arago were less worn when compared to those from level F or Isernia. The style was at half the height of the tooth or had reached the occlusal surface of the tooth. In some cases, it had formed a circle outside, a circle outside and inside or a loop.

Senile

In the last age class, Adult 4, only first and third molars from the layer 3 coll of Isernia were available for study of style wear. From level G, all three molars were present while from level F only M^3 was available for study. The style all three molars had worn to form a single or a double loop. The lower levels of Arago provided M^2 and M^3 for style wear study. It was observed that all three molars from both sites demonstrated similar style wear. The style had formed a loop and in the specimen from 3 coll of Isernia, as an exception, had formed a double loop.

Table 7.12: Isernia La Pineta (layers 3 colluvium and 3s6-9) and Caune de l'Arago (lower levels (H-Q) and upper levels (F and G)): Maxillary style wear codes. d^4- deciduous fourth premolar, M^1- first molar, M^2- second molar, M^3- third molar.

Age class	Level	d^4	M^1	M^2	M^3
Infantile	F		2		
	G	3	2		
	H-Q				
	3s69				
	3coll				
Juvenile	F	4			
	G	9		2-3	
	H-Q				
	3s69				
	3coll				
Sub adult	F				2
	G		3-9	2-3	1-2
	H-Q				
	3s69				
	3coll				
Adult 1	F		4-9	3-4	1
	G		6-9-12	3-4-6-9	2-3-6
	H-Q			3	
	3s69			3	
	3coll			8	
Adult 2	F		9		4
	G		9	9	2-3-4-9
	H-Q		9		
	3s69			4-9	
	3coll			4-9-10	5
Adult 3	F		9	9	9-12
	G		9	6-9-11	6-9
	H-Q			4	6
	3s69		12	4	6
	3coll		12	9	8-9
Adult 4	F				9
	G		9	9	9
	H-Q			9	2-9
	3s69				
	3coll		9-12		9

7.6 Age classes and degree of wear

A synthesis of results obtained from the study of stage of eruption, substitution of teeth; occlusal shape (macroscopic observation), enamel pattern and degree of occlusal reduction; intensity of abrasion; crown height; style wear and length and form of roots aided in the determination of various degrees of wear. Specific degrees of wear were associated with each age class. Based on the results discussed so far, the following ages corresponding to the age classes have been proposed for bison from Isernia and Arago and a descriptive summary of the degrees of wear associated with each age class for mandibular and maxillary remains are given below.

Age class	Proposed age
Infantile	1-12 months
Juvenile	13-20 months
Subadult	21-40 months
Adult 1	3/3.5- 7/8 years
Adult 2	7-10 years
Adult 3	11-13 years
Senile	> 14 years

7.6.1 Mandible

As encapsulated in the Table (7.13) below, in case of deciduous and permanent mandibular dental remains, data was mostly available for Arago. Due to scarce data of similar nature from Isernia, possibility of comparisons was reduced. It was observed that among the mandibular dental remains coming from younger individuals, such as infants and juveniles, the degree of wear for deciduous and permanent dentition was similar. This observation held good for both lower and upper levels of Arago. In some cases, the degree of wear of dental elements from level G was one degree more from the one observed for level F. The degree of wear for deciduous incisors ranged from 3 or 4 during the infantile age class to 5, 6 or 7 in the subadult age class. The wear pattern for d_2, d_3 and d_4 was similar. Data showed that the degree of wear for deciduous premolars went from 2, 3 and /or 4 to 5 or 6 in the juvenile age class to 6 to 7 in the subadult age class. In this age class, deciduous incisors and canine were replaced by permanent counterparts. The degree of wear was either 2 or 3. Comparative data available from Isernia revealed that the results from Isernia also fell in the same degree range as Arago. Permanent mandibular premolars started to substitute their deciduous counterparts in the juvenile age class with a degree of wear between 1 and 2. Data for this observation was provided only from level G of Arago. In the subadult age class, additional data was present from Arago level F and layer 3 coll of Isernia. All premolars in this age class were assigned degree of wear between 2 and 3. P_2 wore much faster than P_3 and P_3 wore much faster than P_4, following the sequence of their eruption.

Table 7.13: Isernia La Pineta (layers 3 colluvium and 3s6-9) and Caune de l'Arago (lower levels (H-Q) and upper levels (F and G)): Degree of wear observed for mandibular deciduous and permanent dental remains. Inf- infantile, Juv- juvenile, SA- subadult. i/I- incisor, c/C- canine, d/P- premolar, M-molar. * - present study, "- previous study (Di Nucci et al., 2006, p. 49).

Age class	Level	i_1	i_2	i_3	c	d_2	d_3	d_4	I_1	I_2	I_3	C	P_2	P_3	P_4	M_1	M_2	M_3
Inf	F		3			2		4								2	1-2	
	G	3	3-4	2-3	2-3	3-4	2-4	2-3-4								1-2-3-4	1-2	
	H-Q															3		
	3s6-9																	
	3coll*					2-3												
	3coll"							4								3		
Juv	F				3	4-5	6	6								4	2-3	
	G					6	6	5					2	2	1	2-3-4	2-3	2
	H-Q																	
	3s6-9																	
	3coll*																	
	3coll"															3-4	3	
SA	F							6			3		3	2	2			3
	G	7						7	3		2		2	2			4	2-3
	H-Q									3								
	3s6-9	5																
	3coll*	5-6																
	3coll"									3	3	3		3	3	4	3-4	3

In case of permanent lower molars, data was mostly available from Arago for infantile and juvenile age class. Scanty data from Isernia, only from layer 3 coll was present for collation with Arago. The molars exhibited slower degree of wear. It ranged between 1 and 4 from infatile to subadult age class. M_1 wore faster than M_2 and M_2 wore faster than M_3. The wear followed the sequence in which they erupted. The degree of wear of permanent dental elements observed for the adult and senile age classes in case of both sites was similar (Table 7.14). Since data for comparison was not available for all teeth from both sites, some broad observations were made for age classes and tooth type with contiguous data. Generally, the incisors and M_1 demonstrated more wear in all age classes for both sites. Also, P_2 wore much slower than P_3 and P_4. In case of Adult 1 age class, the degree of wear ranged from 3 to 5 for all types of teeth wherein 3 and 4 were more frequently observed. In the next age class, Adult 2, degree of wear most commonly observed was 5 although some teeth exhibited lesser wear of 3 and 4. The M_1 from lower and upper levels of Arago showed slightly advanced wearing- with a degree of 6, in comparison with other teeth. In Adult 3 age class, while the incisors and M_1 exhibited a degree of wear equal to 6 or 7, P_3, P_4, M_2 and M_3 showed a 5 or 6 degree of wear. P_2 wore the slowest among all the teeth from this age class. Data regarding incisors for the last age class, Adult 4, was scanty and available only for level G of Arago. Broadly, the degree of wear ranged between 5 and 7, the latter degree being predominant.

Table 7.14: Isernia La Pineta (layers 3 colluvium and 3s6-9) and Caune de l'Arago (lower levels (H-Q) and upper levels (F and G)): Degree of wear observed for mandibular permanent dental remains. I- incisor, C- canine, P- premolar, M-molar. * - present study, "- previous study (Di Nucci et al., 2006, p. 49).

Age class	Level	I_1	I_2	I_3	C	P_2	P_3	P_4	M_1	M_2	M_3
Adult 1	F		3	2		3-4-5	4-6	4-5		5	4-5
	G	3-4	3-4	3	3-4-6	2-4	3-4	3-4	3-4	4	3-4
	H-Q	4	4			4			5		4
	3s6-9	5									3-4
	3coll*	4-5	4-5			3	5-6				5
	3coll"	4	4	4	4		3-4	3-4	4-5	4	3-4
Adult 2	F		5		4-5				5	5	5
	G		5	5		4	3-5	4-5	5-6	5	5
	H-Q	5	5				4	5	6	5	5
	3s6-9						5			4	4-5
	3coll*						5	4-5	5		4-5
	3coll"	5					4	4	5	5	4
Adult 3	F					4-5	5-6	5	5-6	5-6	5
	G	6-7	6-7	5-6	6-7	4-5	5	5-6	5-6-7	5-6	5-6
	H-Q	6	6	6			5	5	6	6	
	3s6-9					5			6		
	3coll*					4	5	5	6-7	5-6	5-6
	3coll"					4	5	5	6	5-6	5
Adult 4	F					7	5-6		7	5-7	7
	G	7	7	6-7			7	7	7		6
	H-Q					7	6-7			6-7	5-7
	3s6-9							7			
	3coll*						6-7	6-7	7		
	3coll"						6	6	7	6	5-6

.

7.6.2 Maxilla

The lower and upper levels from Arago yielded limited data on degree of wear for deciduous maxillary dental elements while there was no comparative data available from Isernia (Table 7.15). With this narrow corpus of data, some general observations were drawn. The deciduous premolars showed a degree of wear equal to 2 or 3 in the infantile age class. In the next age class, juvenile, the same teeth had worn further to degree 5 or 6. Among the permanent molars, M^1 wore faster than M^2 and M^3. In the infantile age class, M^1 was at a degree of wear of 2 or 3, while in the succeeding age classes, the degree of wear was 4 in the juvenile and subadult age classes. M^2 and M^3 exhibited similar progression of wear from infantile to subadult age classes, although lesser than M^1. It ranged between 2 and 3.

Table 7.15: Isernia La Pineta (layers 3 colluvium and 3s6-9) and Caune de l'Arago (lower levels (H-Q) and upper levels (F and G)): Degree of wear observed for maxillary deciduous and permanent dental remains. d- premolar, M-molar. * - present study, "- previous study (Di Nucci et al., 2006, p. 49).

Age class	Level	d^2	d^3	d^4	M^1	M^2	M^3
Infantile	F			3-4	3	2	
	G	2-4	2-3	2-3	2-3		
	H-Q				3		
	3s6-9						
	3coll*						
	3coll"						
Juvenile	F	5-6	6	5-6			
	G	5-6	5	5	4	2-3	
	H-Q						
	3s6-9						
	3coll*						
	3coll"						
Subadult	F						2-3
	G			6	4	2-3	2
	H-Q						
	3s6-9						
	3coll*						
	3coll"						

Among the maxillary permanent dental elements, the degree of wear assigned to the dental elements from Arago and Isernia revealed that they were similar to a large extent (Table 7.16). The maxillary permanent premolars, having replaced the deciduous premolars were in the second degree of wear in the subadult age class. In the same age class, the molars were slightly more worn, M^1 being the most worn at degree 4 while M^2 and M^3 were between 2 and 3. In the Adult 1 age class, the premolars and molars had worn to a similar degree ranging from 3 to 5. P2 wore lesser in the successive age class, Adult 2, with a degree of wear between 4 and 5. Other premolars and molars demonstrated similar wear in this age class. The wear fell between 4 and 6. This trend continued in the next age class- Adult 3. P2 was worn between a degree of 4 and 6 while the other premolars and molars ranged between 5 and 6. An exception to this was M1 which was worn more than the others with a degree of wear reaching 7. In the senile age class, all the teeth reached the degree of wear equal to 7.

Table 7.16: Isernia La Pineta (layers 3 colluvium and 3s6-9) and Caune de l'Arago (lower levels (H-Q) and upper levels (F and G)): Degree of wear observed for maxillary permanent dental remains. P- premolar, M-molar. * - present study, "- previous study (Di Nucci et al., 2006, p. 49).

Age class	Level	P^2	P^3	P^4	M^1	M^2	M^3
Sub adult	F		2	2			
	G	2		2	4	3	2-3
	H-Q						
	3s6-9						
	3coll*						
	3coll"						
Adult 1	F	4	4	3	5	4	4
	G	3-4	4	3-4-5	3-5	4	4-5
	H-Q	4		4	4	4	4
	3s6-9	4	3-4	4		4	
	3coll*		4				
	3coll"						
Adult 2	F	5	5	4	5	5	5
	G	4-5	5-6	4-5-6	5-6	4-6	5
	H-Q			5-6		5-6	6
	3s6-9		5			5-6	4-5
	3coll*	5	4-5	4-5		5-6	5-6
	3coll"						
Adult 3	F	4-5	5		6-7	5-6	5
	G	5-6	5-6	5-6	5-6-7	5-6	5-6
	H-Q				6	5	5-6
	3s6-9			6		6-7	5
	3coll*			5-6	6-7	5	5-6
	3coll"						
Adult 4	F		7		5	5-7	5-6
	G	5	7	7	7	6-7	7
	H-Q	7		6	7	6	6
	3s6-9	7	7		7		
	3coll*				7		6
	3coll"						

Chapter 8

Discussion and conclusions

The archaeozoological, taphonomical and spatial analyses carried out on the faunal assemblages of layers 3 coll and 3s6-9 from the Palaeolithic deposit of Isernia allowed to understand some aspects of the behaviour of human groups present in the Italian peninsula during the Pleistocene. The site is particularly well-known for its rich repertoire of faunal remains and lithic industry that provide testimony to intense phases of occupation by the human groups that inhabited it. These evidences on the one hand are particularly abundant in the archaeosurfaces 3c and 3a, and layer 3 coll. On the other hand, they are manifested with a lower density in the archaeosurface 3S10 and layers 3s6-9 and 3s1-5. The study of faunal remains, the focus of this thesis, has allowed to obtain data that, in conjunction with the data procured previously from the same archaeosurface and layers, has contributed to strengthening the hypotheses on several aspects of this site such as subsistence strategies adopted by human groups, the function and role of the site, its palaeoenvironment and its formation history. In general, the cumulative results and inferences from the analyses carried out in this research with respect to archaeosurfaces 3a and layers 3 coll and 3s6-9 are more or less in line with the known and previously conducted studies on the faunal remains from the site. However, some results can otherwise be said to characterize layers 3 coll and 3s6-9, the subject of this study, in particular.

Archaeosurface 3a

The assemblage presented here represents a faunal association compatible with the faunal list presented in previous studies of this archaeosurface. To an already rich faunal repertoire of more than 7,000 documented faunal remains were added another 61 remains which exhibited similar characteristics. Indeterminate remains were particularly frequent in the previously analysed assemblage from this archaeosurfaces. However, this assemblage, unlike the previous, had more determinable remains with well-preserved diagnostic morphological features which enabled more precise anatomical and taxonomical determination. As has been observed before, the bison remains dominated the assemblage followed by elephant, rhinoceros, and bear. With regards to bison, the anatomical composition of this species presents different results in this small assemblage, as post-cranial remains are predominant over cranial elements. While the former are rich in meat, muscle, marrow and fat, the latter also possess nutritive value for the brain and marrow (in mandible). It is inferred that this species was intensively exploited for all its nutritive value, either brought to the site in its entirety or in smaller segmented parts. A similar dominance of post-cranial elements was noticed for rhinoceros and elephant. Further deductions based on such few number of remains of these two species is difficult but from previous studies on archaeosurfaces 3a, certain observations can be made. In case of rhinoceros, intentional bone breakage was not well-documented due to high fragmentation whereas in the case of elephant, as observed before, axial skeletal elements continued to have better representation than cephalic or appendicular skeletal remains. This evidence points to a particularity in the mode of selection and exploitation of the carcasses of these species. In case of bear, giant deer, the converse scenario was observed in this assemblage and in the previous studies where these species were represented by mainly mandibular and dental fragments, again indicating a particular mode of acquisition and exploitation of their carcasses.

As regards evidence for the mode of acquisition of the carcasses of these species, several factors ruled out carnivores and favourably attributed hominins as the agents of accumulation of this assemblage and the results from this assemblage support this inference. As has been observed before, epiphyseal portions were either whole and well-preserved or at the maximum modified by psot-depositional processes. The meagre evidence of carnivore modification of bones was observed in the form of depressions, pitting and teeth marks on articulations or margins of bones formed after anthropic breakage. Supplementarily, several stages in the anthropic exploitation of carcasses such as intentional bone breakage and to a lesser degree, butchery indicated by cut-marks in anatomically significant positions have been documented and further reiterate this inference. Supporting evidence for an anthropic accumulation of faunal remains from this small assemblage of archaeosurfaces 3a comes with two sets of results. Firstly, no carnivore modifications were observed on the 61 remains. Secondly, anthropic modifications such as intentional fractures and percussion notches, even though in small numbers, were documented on long bone diaphyses, in cases of both identified and unidentified taxa. Furthermore, the fracture or fragmentation analyses of long bones diaphyses revealed higher frequencies of shaft fragments with small circumferences and lengths, spiral fractures, curved or longitudinal fracture outlines and an FFI score tending more towards the 0 - 2 range, all characteristic features of assemblages created anthropically and definitely not by carnivores.

The state of integrity of the faunal assemblage and taphonomical analyses of non-anthropic modifications give a fair idea of the post-depositional history of this assemblage. The former analyses revealed a higher number of remains whose state of integrity was not determinable. This is because several natural factors- physical, biological and chemical, came into play to modify the assemblage subsequent to its discard. Apart from anthropic causes, among these natural factors, light weathering and erosion more than exfoliation show evidence of subaerial exposure whereas trampling by sediments and post-depositional fractures indicate movement and displacement of the bones from their original places of deposition. Oxides and rounding of bones show that the remains were affected by water transport. These taphonomic agents have actively obliterated and compromised the integrity of evidence of anthropic activitied on the bones. As demonstrated by fracture morphotypes such as irregular perpendicular and stepped/columnar, right angled fractures, greater number of jagged fracture edges as well as FFI scores of 4 - 6 on some long bone diaphyses, post-depositional processes also played an active part in obliterating the evidence of what were originally anthropic fractures.

Layer 3 coll

The faunal assemblage from this layer provided a spectra compatible to the layers below and above it, though marginally more diverse when compared to the layer 3s6-9. The characteristics of the faunal assemblage from layer 3 coll was similar in terms of identified and unidentified remains when compared to the other two faunal assemblages from archaeosurface 3a and layer 3s6-9 from the current study. Prior to making inferences from the results obtained from this layer, it has to be taken into accont that the layer 3 coll does not represent a distinct archaeosurface but more of a palimpsest or redistribution of remains taken from archaeosurface 3a which lies underneath and which eventually underwent reexposure, displacement and reburial as the 3 coll debris flow moved from the north to the south depositing them from time to time.

In this assemblage, the percentage of determinable remains, both taxonomically and only anatomically, was higher than the perentage of unidentified remains. Similar to other archaeosurfaces and layers, based on the number of determined remains, bison was the dominant species again. It was followed by rhinoceros, bear and elephant in terms of species abundance. With a smaller number were represented the Cervidae, followed by meagre remains of hippopotamus, giant deer, red deer, tahr, wild boar, fallow deer and roe deer. The distribution of anatomical elements of the four major species revealed similarities with archaeosurfaces and other layers. In case of bison, the cranial and post-cranial skeletal elements found equitable representation which reflects that the entire carcass was imported back to the site for processing and consumption. The same observations were made for the rhinoceros. The bear was, as observed in previous faunal studies, represented mostly by the cephalic component whereas the appendicular elements were better represented than axial elements. The remains of elephant were mostly from the cephalic portion, dominated by tusk fragments and the appendicular portions. The anatomical composition of these species in conjunction with the evidence of anthropic modifications on them clearly point to a mode of acquisition of nearly all segments of the animal carcass. Evidently, some portions underwent more intense fragmentation while the others did not as a consequence of which the rate of determination varied since a large number of fragments could be identified anatomically but not taxonomically. The remains, which were complete or nearly complete, were teeth and short bones such as carpals, tarsals and phalanges which do not possess nutritive value and survive better than other elements. The remaining taxa, through scarce representation of both cranial and post-cranial remains depict a scenario where it appears that the entire carcass was exploited for brain, meat and marrow. However, apart from highlighting the diversity of fauna exploited by the occupants of Isernia they do not provide enough information on their mode of acquisition, process of exploitation and their post-depositional taphonomic history.

Among the four major species, determined remains allowed to estimate a minimum number of individuals that could account for their presence. In the faunal list, bison were represented by more individuals than the others. Rhinoceros followed closely whereas bear, elephant and deer came next. The remaining taxa, with scarce number of remains, were represented by one individual each. The population structure of determined taxa was composed of, based on the anatomical element considered for MNI estimation, both young and adult individuals. A young elephant individual was definitely present in the assemblage. The study of bison dental remains from layer 3 coll revealed a prominent representation of adult individuals whereas senile individuals were the same in number as subadult while there was only one young individual. Adult individuals in their prime were chosen over other age classes, hence indicative of their deliberate and economically profitable selection by hominins.

In the lithic studies from this layer, hammerstones and anvils (blocks with percussion marks) were observed and identified as pebbles with utilisation traces. Flake removals were few, and superficial, thus resulting in many flakes preserving their cortical cover. As reported in chapter 2, recently, a functional analysis on a limited sample of flint flakes, produced with the bipolar technique was conducted. Use-wear imputable to their use in working with soft animal material, animal tissues and butchering activities was recognised. The use of these tools and these techniques for skinning, muscle removal, disarticulation, removal of the periosteum and finally the breakage of animal bones by hominins, resulting in characteristic patterns, was well-documented in this assemblage. As a corollary to lithic studies, the experimental taphonomic study of bone breakage (explained in chapter 2) clearly demonstrated the use of above-mentioned tool types such as hammerstones and anvils and the associated techniques such as direct percussion and use of anvil for bone breakage for their optimum exploitation. Examples of all stages in the butchery process of animal carcasses by anthropic agents, especially intentional fractures, have been documented in these remains, both identified and unidentified and corroborate the findings from the lithic and experimental taphonomic studies. The presence of cut-marks and scraping marks on bone surfaces confirms the use of these tool types for skinning and removal of the periosteum. Cut-marks present on the cranial and post-cranial elements of the four majorly represented species throw light on the pre-meditated choice of certain anatomical parts of these species for the initial stages of skinning and butchery process before proceeding to other methods of carcass exploitation. These cut-marks were confirmed after being examined under the SEM as they possessed well preserved features of micro-striations, a tail like end at the entry and exit points as well as v-shaped sections. Impact points and percussion notches were mostly documented on long bones with a few exceptions of post-cranial remains of identified and unidentified taxa. They were mostly singular. More than one impact were more often found on the same height or at different heights on opposite borders. They were in the medial part of the fragments and mostly associated with medullary detachments rather than cortical detachments. The characteristics of impacts vary slightly between layers 3 coll and 3s6-9. It appears that such variations perhaps occurred due to the use of different types of anvils or change in the positioning of the bone on the anvil before smashing the bone open. Also, variables such as the physical strength of the individual, the force with which the blow was struck on the bone, freshness or dryness of the bone, thickness of the bone could have further influenced the impact area. The percussion notches were mostly found on unidentified remains referable to large ungulates, but a few remains of determined taxa also provided evidence of this anthropic activity. Percussion cones, another positive and well preserved evidence as a by-product of anthropic breakage of bones were found in this assemblage. A more in-depth study of the fracture or fragmentation analyses of long bones diaphyses of both identified and unidentified taxa revealed results similar to archaeosurfce 3a and layer 3s6-9. Higher frequencies of shaft fragments with small circumferences and slightly longer lengths, spiral fractures, curved or longitudinal fracture outlines and an FFI score tending more towards the 0 -2 range, all characteristic features of anthropic accumulated and definitely not carnivore accumulated assemblages were documented. Carnivore modifications in the form of scores, pits and puncture marks were present on very few remains and mostly on the diaphyseal fragments and short bones of identified taxa and unidentified diaphyseal shafts. These remains appeared to have been modified by carnivores after they underwent anthropic modifications. Their meagre presence along with intact epiphyses show that they were definitely not the accumulating agents of the layer 3 coll faunal assemblage.

The general state of integrity of the faunal assemblage of layer 3 coll gave a fair assessment of the pre- and post-depositional history of this assemblage. The analyses revealed a higher number of remains whose state of integrity was not determinable. This is because of not only intense intentional breakage of bones by hominins as part of the carcass processing activities but also due to several natural factors- physical, biological and chemical, that came into force to modify the assemblage from the time of its discard to the time of its discovery in the excavation. The presence of a large number of fragments suggests the intensity of exploitation and fragmentation of both cranial and post cranial elements for their marrow, brain and meat. However, a large number of remains had also been impacted by weathering, erosion, exfoliation, oxides and root-etchings. Subaerial exposure, movement and displacement due to wind, water and tectonics, trampling by sediments and other agents have contributed varyingly to their weak preservation. The modifications caused by natural agents obliterated the marks and impacts of anthropic activities on bones and compromised their state of preservation.

The spatial study of layer 3 coll remains was done for a partially defined area as the entire area south-west of the excavation was removed during the completion of the Naples-Vasto highway and could not be documented. From the previous spatial distribution analyses, frequency and concentration maps, it was evident that the central part/zone of the excavated area had a higher number of remains, both of fauna and lithic industry, with a N-S trend. Three sectional maps visualising the vertical XY plane, longitudinal XZ plane and the YZ transversal place helped to detect a slope in the southern direction. The spatial distribution maps from the current study of remains from layer 3 coll in general and some selected variables depicting anthropic and non-anthropic modifications of faunal remains revealed some conspicuous patterns. In these refreshed 2D spatial maps, all archaeological remains appeared to be present in larger numbers in the central, north-western, north-eastern, western and southern squares. Large bone fragments were conspicuous in the south-western, southern and north-eastern areas of the excavated floor. Faunal remains, when considered separately, illustrated a non-uniform distribution. The concentration of remains alternately ranged from being relatively homogenous in the central and eastern parts of the excavated area to a gradual increase in density towards the southern limit. The western and south-western periphery revealed the sparse accumulation of remains. These results were marginally different from the previous studies. The spatial distribution of the anatomically determined remains of the four major species with better representation than the other taxa on the excavated floor showed that they were mainly concentrated in the southern, south-western and a little in the central areas whereas those that were unidentified were particularly concentrated in the southern areas of the excavated floor. The singular aspect that was highlighted was the distribution of larger sized fragments of the four major species more towards the south than the other areas of the layer.

When the spatial analyses of anthropic related variables were put under this test, the resulting maps depicted a repeatedly unique pattern of distribution or concentration. The western, south-western and the southern squares were the primary areas of concentration. The same areas also coincided with evidences of percussion notches, bone detachments and percussion cones. Clearly, there appeared to be a zone with demarcatedly concentrated remains demonstrating nearly all characteristics of anthropic activity. It was further interesting to note that remains which showed post-depositional impact on the 2D spatial maps were clearly present in greater numbers in other parts of the excavated area. These areas included mostly the northern, north-western and north-eastern part of the excavated area. From the WEE (weathering + erosion + exfoliation) spatial maps, with the available results, it is tentatively inferred that fewer remains less densely distributed in the central part of the excavated area, probably remained exposed to the impact of these taphonomic factors for a longer period of time. Higher quantity of remains, more densely distributed in the southern, south-western and south-eastern part otherwise experienced a quicker burial. The N-S oriented slope of the debris-flow (layer 3 coll) contributed to the distribution of remains during their downward movement.

Layer 3s6-9

The faunal assemblage from this layer delivered a faunal spectra similar to the layers below and above it, though slightly less diverse when compared to the others. Similar to archaeosurfaces 3a, the percentage of determinable remains, both taxonomically and only anatomically, was higher than the perentage of unidentified remains. The latter represented nearly one third of the faunal assemblage because of the high fragmentation observed, together with the strong natural modifications suffered by the faunal remains, which posed limitations in assigning them to a particular taxon or anatomical element.

Similar to other archaeosurfaces and layers, based on the number of determined remains, bison was the most represented species. It was followed by elephant, rhinoceros and bear in terms of taxonomic richness. With a smaller number were represented the Cervidae, accompanied by sporadic remains of red deer, roe deer, giant deer, hippopotamus and the wild boar. The distribution of anatomical elements of the four major species revealed similarities with archaeosurfaces and other layers. In case of bison, the cephalic component was more or less as well-represented as the post-cranial remains which indicates that the entire carcass was exploited for consumption. The bear was represented by post-cranial remains but in much lesser numbers when collated with the cephalic component. As observed in archaeosurface 3a, the remains of elephant were most from the cephalic portion and the axial portion. The same observation was made for rhinoceros. These species, apart from bison, through their remains imply two possibilities. The variation in anatomical composition when compred to bison, could be either due to a different mode of acquisition practiced by hominins as only selected anatomical parts were brough to the site for carcass processing and consumption or that even if there was no divergence from the mode of acquisition and all anatomical parts were transported to the site, they were intensively exploited and hence resulted in a high degree of fragmentation which left the remains beyond recognition. But if the latter possibility held some substance, it would have been reflected in the anatomical composition of bison as well. When other less represented taxa are taken into consideration, a mixed picture is created since both cranial and post-cranial remains are present in the assemblage. They attest to the diversity of fauna exploited by the occupants of Isernia but are not sufficient enough to comment on their mode of acquisition, process of exploitation and their post-depositional taphonomic history.

Identified remains were sufficiently abundant to enable the estimation of the minimum number of individuals for the major species such as bison, bear and rhinoceros which were present in multiple numbers while the remaining taxa, with scarce number of remains, were represented by one individual each. The study of bison dental remains revealed a prominent representation of adult individuals whereas senile individuals were twice the number of subadults. Adult individuals in their prime were chosen over other age classes, hence indicative of their deliberate and economically profitable selection by hominins. The population structure of other taxa was composed of, based on the anatomical element considered for MNI estimation, only adult individuals.

The analysis of the lithic assemblage from this layer yielded evidence of cores, flakes, debris, and tools on flint from which the stages of reduction sequence could be reconstructed. The cores display two techniques of percussion – the direct hand-held hard hammer percussion technique and the bipolar-on-anvil percussion technique. The use of these tools and these techniques for breakage of bones by hominins, resulting in characteristic patterns, was evident in this assemblage. Experimental taphonomic study of bone breakage (explained in chapter 2) clearly showed the use of above-mentioned techniques of bone breakage for their optimum exploitation. In keeping with the results from the lithic and experimental taphonomic studies, nearly all stages in the butchery process on animal carcasses by anthropic agents, especially intentional fractures, have been documented in these remains, both identified and unidentified. The standardised tool-kit from layer 3s6-9 consists of a variety of tool types, including denticulate morpho-type, classical 'tools' and backed tools. The presence of cut-marks and scraping marks on bone surfaces confirms the use of these tool types for skinning and removal of the periosteum. Cut-marks present on a bison mandible, a rhinoceros metatarsal and and on the diaphyses of unidenditifed taxa clearly reflect on the deliberate choice of certain anatomical parts of these species for the initial stages of skinning and butchery process before proceeding to other methods of carcass exploitation. These cut-marks possess well preserved features of micro-striations, a tail like end at the entry and exit points as well as v-shaped sections. Prominently, well preserved evidences of impact points leaving behind percussion notches, resulting intentional gresh fractures in association with detchments and percussion cones are present on cranial and post-cranial remains. The analysis of impact points show that they were mostly single and more than one in few remains. In the latter case, they were either present on the same fracture edge or on opposite fracture edges at the same or different heights respectively. They were also present mostly on the medial or distal part of the bone. They were present on nearly all types of anatomical elements, except for certain short bones like carpals, tarsals, patella and phalanges and teeth, which have survived whole and intact in the assemblage. Clearly, these nutrition-deficient bones were discarded. The overall state of integrity of fragments, dominated by indeterminate fragments also suggests the intensity of exploitation and fragmentation of both cranial and post cranial elements for their marrow, brain and meat. A more in-depth study of the fracture or fragmentation analyses of long bones diaphyses of both identified and unidentified taxa revealed results similar to archaeosurfce 3a and layer 3 coll. Higher frequencies of shaft fragments with small circumferences and lengths, spiral fractures, curved or longitudinal fracture outlines and an FFI score tending more towards the 0 -2 range, all characteristic features of anthropic accumulated and definitely not carnivore accumulated assemblages were recorded. Further evidence is provided by percussion notches with were associated with detachements primarily on the cortical face of the long bones of identified and unidentified taxa. A combination of cortical and medullary detachments clearly showed the use of the bipolar-on anvil technique of bone breakage. Percussion cones were also documented. To reiterate the inference that this assemblage was created due to anthropic activity with more supporting data, carnivore modification of bones were relatively scarce in comparison with the anthropic modification of the assemblage. Their tentative identification was based on the observation of some scores, pits and puncture marks observed mostly on diaphyseal and mandible fragments and not on epiphyseal ends as expected. They appeared to have been made in succession to anthropic modifications.

The analysis of non-anthropic modifications revealed results similar to archaeosurfaces 3a and layer 3 coll. Nearly all remains, excluding dental remains, had been impacted by different non-anthropic taphonomic agents. Apart from light weathering and light erosion, the remains from this layer were relatively more impacted by exfoliation. Nearly three-quarters of the remains exhibited degrees of rounding. This clearly showed that the remains were subjected to subaerial exposure before burial, movement and displacement and transport by water and trampling by sediments and possibly other agents.

The depositional history of this layer, as reconstructed on the basis of sedimentological, geological and geomorphological studies show that this layer interacted with natural factors such as water transport which resulted in its burial since some of the larger artefacts show particular distribution and some of the bones and few lithics show weathering caused by water. In this layer, there is a substantially homogenous distribution of finds, with a quantitative increase where the thickness of sediments increases. Spatial analyses, using GIS, of certain chosen variables from the faunal database of this layer brought forth some interesting patterns of distribution. Generally, the remains from this assemblage were found to be randomly distributed over the excavated floor. This was observed for both faunal remains and other remains such as lithic, travertine and flint. In previous spatial studies, similar trends were observed as remains from this layer did not yield any particular pattern, rather the randomness of the dispersion of the finds was underlined. When certain variables were taken specifically into account, it was seen that areas of concentration were mainly in the western and central zones of the excavated area. These variables included the distribution of the four major species, unidentified remains, remains with rounding and remains with non-anthropic fractures. Anthropic fractures and percussion notches were also found to be distributed in the same areas as the other variables. Most of the areas, not only the central or the western, were impacted by weathering, erosion and exfoliation. On the contrary, very few areas were devoid of their impact. A synthesis of the patterns visible on the spatial distribution maps of WEE, rounding and non-anthropic fractures showed that remains in the northern, north-western and south-western areas were relatively less impacted or better preserved. In contrast, the remains in the central and western part of the excavated area had experienced greater impact of these bone-modifying agents and were weakly preserved. Most of the anthropic activity related evidences lie in the same areas as those heavily impacted by post-depositional processes and hence, as can be seen in the assemblage, have been more or less impacted too and demonstrate these modifications.

The detailed study on the species well represented in Isernia- bison with particular focus on its dental remains compared with a contemporaneous site of Arago in France yielded some interesting results. Apart from the study of post-cranial remains which invariably provide good evidence of anthropic modifications on them, the study of bison dental remains from Isernia and Arago also helped to better understand some facets of their exploitation. The palaeoclimate associated with *Bison schoetensacki* in the lower occupation layers of Isernia and at Arago in its lower levels is marked by a cold dry palaeoclimate. In Isernia, the palaeoclimate gradually warmed towards the upper layers but did not witness any evolutionary changes in this species. Even in the upper sandy layers, the bison remains were continued to be identified as *Bison schoetensacki*. At Arago, however, in the upper part of the lower levels, H to J, the palaeoclimate became temperate and humid and the bison associated with these levels is slightly different from the bison in the lower part of the lower levels, K to Q. Further, in the upper levels with a return of the cold and dry climate in levels D to G, the bison identified is *Bison priscus*, a different species. Although Isernia and Arago in chronological continuity yield faunal remains of three different species of bison, the strategies adopted to either hunt them, trap them or gain primary access to their carcass did not differ much at both sites. A synthesis of results obtained from the study of stage of eruption, substitution of teeth; occlusal shape (macroscopic observation), enamel pattern and degree of occlusal reduction; intensity of abrasion; crown height; style wear and length and form of roots aided in the determination of various degrees of wear. Specific degrees of wear, associated with each age class were also similar for both maxillary and mandibular teeth for bison from Isernia and Arago from the lower to upper levels. It appears that they had a similar palaeodiet although this inference is skewed due to the paucity of dental remains of bison from Isernia when compared to Arago. This aspect has to be examined further with microwear analyses of bison dental remains from Isernia and Arago. Based on the results discussed so far, the following ages corresponding to the age classes have been proposed for bison from Isernia and Arago. Infantiles were within the ages of 1 - 12 months. Juveniles within 13 - 20 months, subadults within 21 - 40 months, prime adults between 3 - 13 years and senile adults older than 14 years of age. The cumulative mortality profiles of bison from Isernia and Arago highlighted a few similarities and differences between the two sites. At Isernia and Arago, adult individuals were clearly the preferred profitable choice for consumption. At Isernia, the other age classes were scarcely represented with fluctuations between consecutive layers of occupation. At Arago, in the lower levels, which were seasonal habitats, selective hunting halts, short stays or bivouacs, in the subsistence strategy involving this species, the young individuals were not considered as a profitable economic choice. However, in the upper level G, which is characterised by long term stays wit non species specific hunting, there appeared to be a modification to this strategy as young were also hunted and consumed. Yet again, an alteration in the selection of certain age classes became apparent as the young were hunted and consumed less and less in the subsequent upper level F, which were seasonal habitats with species specific hunting, along with a decline in adult age class representation too. At Arago, similar to

Isernia, the representation of subadult and senile fluctuated and remained much lower than other age classes through subsequent occupation layers.

To summarize, the results from the current research in conjunction with the results from previous studies concerning all aspects of archaeozoology, taphonomy and spatial distribution analyses of all faunal remains recovered from the archaeosurfaces and layers of Isernia are underlined by homogeneity and congruency. The homogeneity or similarity between archaeosurfaces and the layers covering them extendes not only to the subsistence strategies of human groups that occupied the site during the Pleistocene but also the composition of fauna, the dominance of the four major species -bison, bear, rhino and elephant, the anatomical representation of different taxa in the assemblages, the anthropic and non-anthropic modifications demonstrated by them, the butchery methods adopted by the occupants to exploit the animal carcasses and their state of integrity.

It is a difficult task to assign a precise time frame to the occupation layers and categorize them as short term or long term occupations. At the current juncture of our knowledge about the site, the archaeosurfaces and the layers covering them perhaps best represent episodic events or palimpsests of a singular occupational history. They deposition of remains was affected by tectonic movements, fluvial transport, or debris-flow. In this regard, it is safe to assume that the faunal remains from layer 3 coll maybe a reappraisal of faunal remains from the archaeosurface 3a which it covers more than being a unique archaeosurfaces in itself. Hence the results of 3 colluvium studies should take into consideration the results obtained from archeosurface 3a as they are fundamentally the same archaeological material but recovered from two distinct deposits. It is hypothesised that changes in the course of the river flowing through the site during Lower Palaeolithic created this displacement and redeposition of archaeological material from the primary occupational, discard and activity areas of hominins. The spatial analyses of layer 3 coll brought out distinct areas, especially in the southern limit, with concentrations of anthropic and non-anthropic modified faunal remains. It is interesting to see that these areas with concentration of faunal remains with anthropic modifications and their by-products could also reflect an anthropic activity area since their preservation is better than the remains from other areas of this excavated layer. Whether they were deposited by slow moving water or represent the primary anthropic butchery and discard area, it is clear that this part of the site underwent quicker burial when compared to the central, western and northern part of the excavated area where remains remained exposed to natural agents for a longer time. Similarly, the faunal remains recovered from layer 3s6-9 could be originally from another area of the site during its period of occupation. The climate changed from cold and dry in the archaeosurfaces 3c to warmer temperatures as depicted by the presence of the primate *Macaca sylvanus* in the upper sandy layers but it appears that the subsistence strategies of the human groups did not experience major changes. Perhaps the choice of transporting back certain anatomical parts or preference for a certain species over others changed seasonally depending on the availability of animals in the vicinity of the site, an example of which can be seen in the greater numbers of Cervidae remains in the archaeosurface 3c and layer 3s6-9 at Isernia.

Isernia continues to provide immense scope for further research in all aspects of archaeozoology, taphonomy and for the further understanding human-animal or human-environment dynamics in the Pleistocene in Italy and also in the context of European preshistory. In this research, the first attempts to incorporate some recent methodologies related to different anatomical parts of animals such as teeth and diaphyses was attempted and provided important results. Also, taphonomical aspects were explored for the first time on two- dimensional GIS maps in the context of Isernia. It would be useful to expand the scope of faunal research by including newer faunal material as they are recovered from excavations at Isernia and continuing analyses in these lines of enquiry.

References

Abbazzi, L. and Masini, F., 1996. Megaceroides solilhacus and other deer from the middle Pleistocene site of Isernia La Pineta (Molise, Italy). *Bollettino-Societa Paleontologica Italiana*, *35*, pp.213-227.

Accorsi, C.A., 1985. The contribution of Palynology in the reconstruction of the environment. *C. Peretto et al. (a cura di), Homo, Journey to the Origins of Man's History", Catalogo della mostra, Venezia*, pp.192-201.

Accorsi, C.A., Cremaschi, M. and Mercuri, A.M., 1996. Qualche dato sul paesaggio dell'accampamento paleolitico di Isernia (Molise, Italia Centrale): dati litostratigrafici e spettri pollinici della serie" Isernia-Fiume Cavaliere".

Alhaique, F., Bisconti, M., Castiglioni, E., Cilli, C., Fasani, L., Giacobini, G., Grifoni, R., Guerreschi, A., Iacopini, A., Malerba, G. and Peretto, C., 2004. Animal resources and subsistence strategies. *Collegium antropologicum*, *28*(1), pp.23-40.

Anconetani, P., Giusberti, G. and Peretto, C., 1991. Nuovi contributi alla fratturazione intenzionale dei reperti paleontologici del giacimento di Isernia La Pineta (Molise). *Isernia La Pineta. Nuovi Contributi scientifici, volume pubblicato in occasione della XXX Riunione Scientifica IIPP (C. Peretto, ed), Venosa–Isernia*, pp.43-49.

Anconetani, P., Crovetto, C., Ferrari, M., Giusberti, G., Longo, L., Peretto, C. and Vianello, F., 1992. Nuove ricerche nel giacimento di Isernia La Pineta (Molise) (1). *Rivista di scienze preistoriche*, (44), pp.3-41.

Anconetani, P., Giusberti, G. and Peretto, C., 1993. Su alcuni nuovi reperti di bisonte (Bison schoetensacki Freudenberg) con tracce di fratturazione intenzionale del giacimento paleolitico di Isernia La Pineta. *Atti della XXX Riunione Scientifica dell'Istituto Italiano di Preistoria e Protostoria*, pp.211-218.

Anconetani, P., 1996a. Lo studio archeozoologico del sito di Isernia La Pineta. *I reperti paleontologici del giacimento paleolitico di Isernia La Pineta, l'Uomo e l'ambiente. Cosmo Iannone Editore, Isernia*, p.8.

Anconetani, P. and Peretto, C., 1996b. La fatturazione intenzionale delle ossa lunghe e della mandibola come indice di attività umana nel sito di Isernia La Pineta. *I reperti paleontologici del giacimento paleolitico di Isernia La Pineta. Isernia*, pp.453-530.

Anconetani, P., 1999. An experimental approach to intentional bone fracture: A case study from the Middle Pleistocene site of Isernia La Pineta. *The role of early humans in the accumulation of European lower and middle palaeolithic bone assemblages*, pp.121-138.

Andrews, P., 1995. Experiments in taphonomy. *Journal of Archaeological Science*, *22*(2), pp.147-153.

Ardèvol, J.R. and López, R.B., 2009. Home sharing: carnivores in anthropogenic assembalges of the Middle Pleistocene. *Journal of Taphonomy*, *7*(4), pp.305-324.

Arzarello, M., Gallotti, R., Lembo, G., Minelli, A., Hohenstein, U.T. and Peretto, C., 2003. Metodologie informatiche applicate allo studio delle archeosuperfici di Isernia La Pineta (Molise, Italia). *C. Peretto (a cura di), Analisi informatizzata e trattamento dati delle strutture di abitato di età preistorica e protostorica in Italia, Istituto Italiano di Preistoria e Protostoria, Firenze*, pp.19-34.

Arzarello, M. and Peretto, C., 2010. Out of Africa: the first evidence of Italian peninsula occupation. *Quaternary International*, *223*, pp.65-70.

Arzarello, M., Peresani, M. and Fontana, F., 2011. *Manuale di tecnologia litica preistorica. Concetti, metodi e tecniche*. Carrocci editore.

Auguste, P., 1995. Chasse et charognage au Paléolithique moyen: l'apport du gisement de Biache-Saint-Vaast (Pas-de-Calais). *Bulletin de la Société préhistorique française*, pp.155-167.

Bahain, J.J., Yokoyama, Y., Falguères, C. and Sarcia, M.N., 1992. ESR dating of tooth enamel: A comparison with K/Ar dating. *Quaternary Science Reviews*, *11*(1-2), pp.245-250.

Ballatore, M. and Breda, M., 2013. Stephanorhinus hundsheimensis (Rhinocerontidae, Mammalia) teeth from the early Middle Pleistocene of Isernia La Pineta (Molise, Italy) and comparison with coeval British material. *Quaternary international*, *302*, pp.169-183.

Barone, R., 1976. Anatomie comparée des animaux domestiques. Tome 1: Ostéologie.

Barsky, D., 2013. The Caune de l’Arago stone industries in their stratigraphical context. *Comptes Rendus Palevol*, *12*(5), pp.305-325.

Barsky, D. and de Lumley, H., 2010. Early European Mode 2 and the stone industry from the Caune de l'Arago's archeostratigraphical levels “P”. *Quaternary International*, *223*, pp.71-86.

Baygusheva, V.S., Titov, V.V. and Timonina, G.I., 2012. Two skeletons of Mammuthus trogontherii from the Sea of Azov Region. *Quaternary International*, *276*, pp.242-252.

Behrensmeyer, A.K., 1978. Taphonomic and ecologic information from bone weathering. *Paleobiology*, *4*(2), pp.150-162.

Belluomini, G., 1985. Risultati e prospettive di un nuovo metodo di datazione basato sulla racemizzazione degli aminoacidi. *Acc. Naz. dei Lincei, Contr. Centro Interd. di Sc. Mat. e loro Appl*, *69*.

Belluomini, G., Manfra, L. and Palombo, M.R., 1997. A recent aminochronology of Pleistocene mammals from Rome area and Isernia-La Pineta deposits (Italy). *Geologica Romana*, *33*, pp.73-79.

Belmaker, M. and O'Brien, H.D., 2017. Mesowear study of ungulates from the early Pleistocene site of ‘Ubeidiya (Israel) and the implications for early Homo dispersal from Africa. *Quaternary International.*

Bernor, R.L., Kaiser, T.M. and Wolf, D., 2008. Revisiting As Sahabi equid species diversity, biogeographic patterns, and dietary preferences. *Circum-Mediterranean geology and biotic evolution during the Neogene period: the perspective from Libya. University of Garyounis, Benghazi*, pp.159-167.

Bernor, R.L., Semprebon, G.M. and Damuth, J., 2014, April. Maragheh ungulate mesowear: interpreting paleodiet and paleoecology from a diverse fauna with restricted sample sizes. In *Annales Zoologici Fennici* (Vol. 51, pp. 201-208). Finnish Zoological and Botanical Publishing.

Binford, L.R., 1981. *Bones: ancient men and modern myths*. Academic Press.

Binford, L.R., 1984. *Faunal Remains from Klasies River Mouth: Monograph*. Academic Press.

Blondel, C., Merceron, G., Andossa, L., Taisso, M.H., Vignaud, P. and Brunet, M., 2010. Dental mesowear analysis of the late Miocene Bovidae from Toros-Menalla (Chad) and early hominid habitats in Central Africa. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *292*(1-2), pp.184-191.

Blumenschine, R.J., 1995. Percussion marks, tooth marks, and experimental determinations of the timing of hominid and carnivore access to long bones at FLK Zinjanthropus, Olduvai Gorge, Tanzania. *Journal of Human Evolution*, *29*(1), pp.21-51.

Brain, C.K., 1969. The contribution of Namib Desert Hottentots to an understanding of australopithecine bone accumulations. *Scientific Papers of the Namib Desert Research Station*, *1969*(39), pp.13-22.

Brancaccio, L., Cinque, A., Di Crescenzo, G., Santangelo, N. and Scarciglia, F., 1997. Alcune osservazioni sulla tettonica quaternaria nell'Alta Valle del F. Volturno (Molise). *Il Quaternario*, *10*(2), pp.321-328.

Brancaccio, L., Di Crescenzo, G., Rosskopf, C., Santangelo, N. and Scarciglia, F., 2000. Carta geologica dei depositi quaternari e Carta geomorfologica dell'alta valle del F. Volturno (Molise, Italia Meridionale). Note illustrative. *Il Quaternario*, *13*.

Bravo-Cuevas, V. and Priego-Vargas, J., 2007, September. Preliminary investigation on the ancient dietary regime of Pleistocene horses from the State of Hidalgo, Central Mexico. In *Journal Of Vertebrate Paleontology* (Vol. 27, No. 3, pp. 52A-52A). 60 Revere Dr, Ste 500, Northbrook, IL 60062 USA: Soc Vertebrate Paleontology.

Bravo-Cuevas, V.M. and Priego-Vargas, J., 2009. Dietary evaluation of a hipparionin horse population from the middle Miocene of Oaxaca, southeastern Mexico. *Revista mexicana de ciencias geológicas*, *26*(2).

Breda, M. and Lister, A.M., 2013. Dama roberti, a new species of deer from the early Middle Pleistocene of Europe, and the origins of modern fallow deer. *Quaternary Science Reviews*, *69*, pp.155-167.

Breda, M., Peretto, C. and Thun Hohenstein, U., 2015. The deer from the early Middle Pleistocene site of Isernia la Pineta (Molise, Italy): revised identifications and new remains from the last 15 years of excavation. *Geological Journal*, *50*(3), pp.290-305.

Broglio, A., 1998. *Introduzione al paleolitico*. Bari: Laterza.

Bunn, H.T., 1983. Comparative analysis of modern bone assemblages from a San hunter-gatherer camp in the Kalahari Desert, Botswana, and from a spotted hyena den near Nairobi, Kenya. *Animals and archaeology*, *1*, pp.143-148.

Bunn, H., 1984. Meat-Eating and Human Evolution: Studies on the Diet and Subsistence Patterns of Plio-Pleistocene Hominids in East Africa.

Butler, K., Louys, J. and Travouillon, K., 2014. Extending dental mesowear analyses to Australian marsupials, with applications to six Plio-Pleistocene kangaroos from southeast Queensland. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *408*, pp.11-25.

Chiarabba, C., Jovane, L. and DiStefano, R., 2005. A new view of Italian seismicity using 20 years of instrumental recordings. *Tectonophysics*, *395*(3-4), pp.251-268.

Clauss, M., Franz-Odendaal, T.A., Brasch, J., Castell, J.C. and Kaiser, T., 2007. Tooth wear in captive giraffes (Giraffa camelopardalis): mesowear analysis classifies free-ranging specimens as browsers but captive ones as grazers. *Journal of Zoo and Wildlife Medicine*, *38*(3), pp.433-445.

Coltorti, M., 1983. Le fasi principali dell'evoluzione del paesaggio nel bacino di Isernia (Molise). *Isernia La Pineta, un accampamento più antico di*, *700*, pp.41-47.

Coltorti, M. and Cremaschi, M., 1981. Depositi quaternari e movimenti neotettonici nella conca di Isernia. *Contributi conclusivi alla realizzazione della carta neotettonica d'Italia. Roma: PFG, Sottoprogetto Neotettonica, CNR*, pp.173-188.

Coltorti, M., Cremaschi, M., Deiitala, M.C., Esu, D., Fornaseri, M., Mc Pherron, A., Nicoletti, M., Otterloo, R.V., Peretto, C., Sala, B. and Schmidt, V., 1982. Reversed magnetic polarity at an early Lower Palaeolithic site in Central ltaly. *Nature*, *300*, pp.173-176.

Coltorti, M., Feraud, G., Marzoli, A., Peretto, C., Ton-That, T., Voinchet, P., Bahain, J.J., Minelli, A. and Hohenstein, U.T., 2005. New 40Ar/39Ar, stratigraphic and palaeoclimatic data on the Isernia la Pineta Lower Palaeolithic site, Molise, Italy. *Quaternary International*, *131*(1), pp.11-22.

Coltorti, M. and Pieruccini, P., 2014. Guado San Nicola Acheulean site: preliminary remarks on the litho-, morphoand pedo-stratigraphical setting. *L'insediamento a bifacciali di Gudo San Nicola, Monteroduni, Molise, Italia. Annali dell'Università degli Studi di Ferrara*, pp.13-24.

Coil, R., Tappen, M. and Yezzi-Woodley, K., 2017. New analytical methods for comparing bone fracture angles: A controlled study of hammerstone and hyena (Crocuta crocuta) long bone breakage. *Archaeometry*, *59*(5), pp.900-917.

Cornevin, C., Lesbre, F.X. and Lesbre, X., 1894. *Traité de l'âge des animaux domestiques d'après les dents et les productions épidermiques*. Baillière.

Corrado, A., Bonanno, A. and Vella, N.C., 2004. 7. Bones and bowls: a preliminary interpretation of the faunal remains from the Punic levels in Area B, at the temple of Tas-Silg, Malta. *Behaviour Behind Bones: The zooarchaeology of ritual, religion, status and identity*, pp.47-53.

Corti, P., 2003. Il recupero e il restauro dei reperti paleontologici. *C. Peretto, A. Minelli (a cura di), Metodologie per lo scavo archeologico: il caso di Isernia La Pineta (Molise), Collana Ricerche del CERP*, *1*, pp.105-128.

Crégut-Bonnoure, E., 1991, January. Intérêt biostratigraphique de la morphologie dentaire de Capra (Mammalia, Bovidae). In *Annales zoologici fennici* (pp. 273-290). Finnish Zoological Publishing Board, formed by the Finnish Academy of Sciences, Societas Biologica Fennica Vanamo, Societas pro Fauna et Flora Fennica, and Societas Scientiarum Fennica.

Cremaschi, M., 1983. La serie stratigrafica pleistocenica di Isernia La Pineta e la posizione stratigrafica dei suoli d'abitato paleolitici in essa inclusi., in: Peretto, C., Terzani, C., Cremaschi, M. (Eds.), Isernia La Pineta, Un Accampamento Più Antico Di 700.000 Anni. Calderini Editore, Bologna.

Croft, D.A. and Weinstein, D., 2008. The first application of the mesowear method to endemic South American ungulates (Notoungulata). *Palaeogeography, Palaeoclimatology, Palaeoecology*, *269*(1-2), pp.103-114.

Crovetto, C., 1994. Le industrie litiche: Analisi tecnico-tipologica dei reperti di scavo. In C. Peretto ed., *Le Industrie Litiche del Giacimento Paleolitico di Isernia La Pineta.* Isernia: Cosmo Iannone Editore, pp. 183-354.

Crovetto, C. et al., 1994a. Le industrie litiche: La scheggiatura, descizione degli insiemi, i rimontaggi. In C. Peretto ed., *Le Industrie Litiche del Giacimento Paleolitico di Isernia La Pineta*. Isernia: Cosmo Iannone Editore, pp. 87-118.

Crovetto, C. et al., 1994b. Le industrie litiche: La sperimentazione litica. In C. Peretto ed., *Le Industrie Litiche del Giacimento Paleolitico di Isernia La Pineta*. Isernia: Cosmo Iannone Editore, pp. 119-182.

D'Argenio F. 2015, *Strategie di sussistenza adottate nel giacimento paleolitico di Isernia La Pineta. Analisi archeozoologica e tafonomica dei reperti faunistici provenienti dall'US 3coll del I settore di scavo*, Tesi di Laurea Magistrale, Dipartimento degli Studi Umanistici, Università degli Studi di Ferrara.

de Lumley, H., Fournier, A., Park, Y.C., Yokoyama, Y. and Demouy, A., 1984. Stratigraphie du remplissage Pléistocène moyen de la Caune de l'Arago à Tautavel. Etude de huit carottages effectués de 1981 à 1983. *Anthropologie (L') (Paris)*, *88*(1), pp.5-18.

de Lumley, H., Fournier, A., Abdessadok, S., Perrenoud, C. and Khatib, S., 2000. Cadre stratigraphique, géochronologique et paléoclimatologique du Pléistocène inférieur et moyen dans le Midi méditerranéen de la France d'auprès des formations quaternaires de sites préhistoriques†: Le Vallonnet, la Caune de l'Arago, Terra-Amata, Orgnac 3, La Baume-Bonne, Le Lazaret. *Tautavel (10–15 avril 2000)*, pp.15-17.

de Lumley, H., Grégoire, S., Barsky, D., Batalla, G., Bailon, S., Belda, V., Briki, D., Byrne, L., Desclaux, E., El Guenouni, K. and Fournier, A., 2004. Habitat et mode de vie des chasseurs paléolithiques de la Caune de l'Arago (600 000–400 000 ans). *l'Anthropologie*, *108*(2), pp.159-184.

de Lumley, M.A., 2015. L'homme de Tautavel. Un Homo erectus européen évolué. Homo erectus tautavelensis. *l'Anthropologie*, *119*(3), pp.303-348.

Delitala, M.C., Fornaseri, M. and Nicoletti, M., 1983. Datazioni Argon-Potassio sulla serie pleistocenica di Isernia la Pineta. *Isernia La Pineta, un accapamento più antico di*, *700*(000), pp.65-66.

DeMers, M.N., 1997. Fundamentals of Geographic Information Systems.

Denys, C., 2002. Taphonomy and experimentation. *Archaeometry*, *44*(3), pp.469-484.

Di Bucci, D., Corrado, S. and Naso, G., 2002. Active faults at the boundary between Central and Southern Apennines (Isernia, Italy). *Tectonophysics*, *359*(1-2), pp.47-63.

Diez Lomana, C., Rosell, J., Malerba, G., Thun Hohenstein, U., Giacobini, G. and Peretto, C., 1997. Indagini sulle tracce di macellazione sui reperti faunistici di Isernia La Pineta (Molise, Italia): metodologia e nuovi risultati. *Antropologia Contemporanea*, *20*(1-3), pp.85-87.

Di Nucci, A. 2003, Strategie di sussistenza adottate nel sito paleolitico di Isernia La Pineta. Analisi archeozoologica delle US 3s1-5. Tesi di Laurea, Facoltà di Scienze Matematiche e Naturali, Università degli Studi di Ferrara.

Di Nucci, A. and U. Thun Hohenstein., 2006a. I dati archeozoologici raccolti negi anni '80-'90. In preistoria in Molise. Gi insediamenti del territorio di Isernia (Eds. Carlo Peretto and Antonella Minelli): 40-43. Aracne editrice S.r.l.

Di Nucci, A. and U. Thun Hohenstein., 2006b. I nuovi dati archeozoologici: gli scavi degli anni 2000-2005. In preistoria in Molise. Gi insediamenti del territorio di Isernia (Eds. Carlo Peretto and Antonella Minelli): 43-48. Aracne editrice S.r.l.

Di Nucci A., Thun Hohenstein, U. 2007, *La fauna pleistocenica di Isernia la Pineta: analisi archeozoologica delle US 3S1-5*, in "Atti del Primo Convegno nazionale degli Studenti di Antropologia, Preistoria e Protostoria", (U. Thun Hohenstein, eds), in Annali dell'Università degli Studi di Ferrara, sez. Museologia Scientifica e Naturalistica, vol. Speciale 2007, pp. 71-71.

Di Nucci, A., Moigne, A.M. and Thun Hohenstein, U., 2006. Considerazioni archeozoologiche determinazione delle età di morte e delle abitudini alimentari di *Bison schoetensacki* (Freudenberg, 1914) di Isernia La Pineta. *Preistoria in Molise. Gli insediamenti del territorio di Isernia, Collana Ricerche*, *3*, p.3.

Ellenberger, W. and Baum, H.,1943. *Handbuch der vergleichenden anatomie der haussäugethiere*. 18. Auflage. Berlin.

Esu, D., 1983. Malacofaune continentali della serie 'La Pineta', Isernia. In M. Coltorti, C. Terzani, & M. Cremaschi, eds. *Isernia La Pineta, un accampamento più antico di 700.000 anni*. Bologna: Calderini, pp. 63-64.

Falguères, C., Yokoyama, Y., Shen, G., Bischoff, J.L., Ku, T.L. and de Lumley, H., 2004. New U-series dates at the Caune de l'Arago, France. *Journal of Archaeological Science*, *31*(7), pp.941-952.

Falguères, C., Bahain, J.J., Dolo, J.M., Mercier, N. and Valladas, H., 2007. On the interest and the limits of using combined ESR/U-series model in the case of very late uranium uptake. *Quaternary Geochronology*, *2*(1-4), pp.403-408.

Falguères, C., Shao, Q., Han, F., Bahain, J.J., Richard, M., Perrenoud, C. and Moigne, A.M., 2015. New ESR and U-series dating at Caune de l'Arago, France: A key-site for European Middle Pleistocene. *Quaternary Geochronology*, *30*, pp.547-553.

Fernandez-Jalvo, Y. and Andrews, P., 2016. *Atlas of taphonomic identifications: 1001+ images of fossil and recent mammal bone modification*. Springer.

Fisher, J.W., 1995. Bone surface modifications in zooarchaeology. *Journal of Archaeological method and theory*, *2*(1), pp.7-68.

Forte, M., 2002. *I sistemi informativi geografici in archeologia*. MondoGIS.

Forsten, A. and Moigne, A.M., 1998. The horse from the middle Pleistocene of Orgnac-3 (Ardèche, France) [Les chevaux du site du Pléistocène moyen d'Orgnac 3 (Ardèche, France)]. *Quaternaire*, *9*(4), pp.315-323.

Fortelius, M., Mazza, P. and Sala, B., 1993. Stephanorhinus (Mammalia: Rhinocerotidae) of the western European Pleistocene, with a revision of S. etruscus (Falconer, 1868). *Palaeontographia italica*, *80*, pp.63-155.

Fortelius, M. and Solounias, N., 2000. Functional characterization of ungulate molars using the abrasion-attrition wear gradient: a new method for reconstructing paleodiets. *American Museum Novitates*, pp.1-36.

Fraser, D., Zybutz, T., Lightner, E. and Theodor, J.M., 2014. Ruminant mandibular tooth mesowear: a new scheme for increasing paleoecological sample sizes. *Journal of Zoology*, *294*(1), pp.41-48.

Frison, G. C. and C. A. Reher., 1970. Age Determinations of Buffalo by Teeth Eruption and Wear. In The Glenrock Buffalo Jump, 48CO304, edited by G. C. Frison. *The Plains Anthropologist* Memoir 7:pp 46-50.

Fuller, W.A., 1959. The horns and teeth as indicators of age in bison. *The Journal of Wildlife Management*, *23*(3), pp.342-344.

Gagnepain, J., 1996. *Etude magnétostratigraphique des sites du pléistocène inferieur et moyen des Alpes maritimes et d'Italie: la grotte du Vallonnet, Marina Airport, Ca'Belvedere di monte Poggiolo, Isernia la Pineta, Venosa Loreto* (Doctoral dissertation, Paris, Muséum national d'histoire naturelle).

Gallotti, R., 2004. *Analisi spaziali e metodologie computazionali per un approccio cognitivo ai modelli di frequentazione antropica del giacimento di Isernia La Pineta (Molise, Italia)* (Doctoral dissertation, Ph. D. Thesis, Ferrara: Ferrara University).

Gallotti, R., Peretto, C., Minelli, A., Arzarello, M., Corti, P., Durand, D. and Lembo, G., 2004. Informatic management of the excavation data of Isernia La Pineta (Molise, Italia). In *XIVe*

Congres de l'Union Internationale des Sciences Prehistoriques et Protohistoriques (pp. 57-62). Archaeopress.

Gallotti, R. and Lembo, G., 2007. Analisi spaziali intra-site e Geographical Information System per un approccio cognitivo ai modelli di frequentazione antropica del giacimento di Isernia La Pineta (Molise). *ANNALI DELL'UNIVERSITÀ DI FERRARA. SEZIONE: MUSEOLOGIA SCIENTIFICA E NATURALISTICA*, pp.171-174.

Gallotti, R., Lembo, G. and Peretto, C., 2012. Mapping three-dimensional density patterns for analyzing artefact (re) distribution trends in Palaeolithic sites. *Advances in Anthropology*, *2*(02), p.39.

Gallotti, R. and Peretto, C., 2015. The Lower/early middle Pleistocene small débitage productions in western Europe: new data from Isernia La Pineta t. 3c (Upper Volturno Basin, Italy). *Quaternary International*, *357*, pp.264-281.

Giusberti, G., Guerreschi, A. and Peretto, C., 1983. Le strutture d'abitato dell'accampamento Paleolitico di Isernia La Pineta. Prime considerazioni. *Isernia La Pineta. Un accampamento piuantico di*, *700*, pp.95-103.

Ghirelli E. 2000, *Strategie di sussistenza nel giacimento paleolitico di Isernia La Pineta. Studio archeozoologico dei reperti provenienti dai tagli 3s10 e 3coll*, Tesi di Laurea Magistrale, Dipartimento degli Studi Umanistici, Università degli Studi di Ferrara.

Grandi F. 2015, *Strategie di sussistenza adottate nel sito paleolitico di Isernia La Pineta. Analisi archeozoologica dell'US 3s6-9*, Tesi di Laurea Magistrale, Dipartimento degli Studi Umanistici, Università degli Studi di Ferrara.

Gautier, A., 1993. Trace fossils in archaeozoology. *Journal of Archaeological Science*, *20*(5), pp.511-523.

Giacobini, G., 1995. Identificazione delle tracce di macellazione con strumenti litici. Analisi di microscopia elettronica a scansione. *Atti del Ië Convegno di Archeozoologia I, Padusa Quaderni*, *1*, pp.29-37.

Giusberti, G., Ferrari, M. and Peretto, C., 1991. Tipologia, frequenza e distribuzione dei reperti paleontologici e paletnologici della paleosuperficie T. 3a del Io settore di scavo di Isernia La Pineta (Isernia, Molise). *Isernia La Pineta. Nuovi contributi scientifici. Istituto Regionale per gli Studi Storici del Molise, Firenze*, pp.5-42.

Gliozzi, E., Abbazzi, L., Argenti, P., Azzaroli, A., Caloi, L., Barbato, L.C., Di Stefano, G., Esu, D., Ficcarelli, G., Girotti, O. and Kotsakis, T., 1997. Biochronology of selected mammals, molluscs and ostracods from the Middle Pliocene to the Late Pleistocene in Italy. The state of the art. *Rivista Italiana di Paleontologia e Stratigrafia (Research in Paleontology and Stratigraphy)*, *103*(3), pp.369–388

Grunwald, A.M., 2016. Analysis of fracture patterns from experimentally marrow-cracked frozen and thawed cattle bones. *Journal of Archaeological Science: Reports*, *8*, pp.356-365.

Hanquet, C. and Desclaux, E., 2011. Analyse paléoécologique des communautés de micromammifères de la Caune de l'Arago (Tautavel, France) dans le contexte des migrations de faunes en Europe méridionale au cours du Pléistocène moyen. *Quaternaire. Revue de l'Association française pour l'étude du Quaternaire*, *22*(1), pp.35-45.

Haynes, G., 1980. Evidence of carnivore gnawing on Pleistocene and Recent mammalian bones. *Paleobiology*, *6*(3), pp.341-351.

Haynes, G., 1983. A guide for differentiating mammalian carnivore taxa responsible for gnaw damage to herbivore limb bones. *Paleobiology*, *9*(2), pp.164-172.

Hillson, S., 1999. *Mammal bones and teeth: an introductory guide to methods of identification*, Institute of Archaeology, University of London.

Insani, H., 2013. *Ecomorph Characterisation of Middle Pleistocene Large Bovids of Caune de l'Arago, Pyrenée-Orientale, France* (Master thesis, Università degli Studi di Ferrara).

Jiménez-Hidalgo, E., Cabrera-Pérez, L., MacFadden, B.J. and Guerrero-Arenas, R., 2013. First record of Bison antiquus from the Late Pleistocene of southern Mexico. *Journal of South American Earth Sciences*, *42*, pp.83-90.

Johnson, E., 1985. Current developments in bone technology. In *Advances in Archaeological Method and Theory, Volume 8*(pp. 157-235).

Kacimi, S., 1999. Les grands bovidés et les ovibovinés pléistocènes de la Caune de l'Arago (Tautavel, Pyrénées-Orientales). Etude paléontologique, biostratigraphique, paléoécologique et archéozoologique. *Mém. DEA Mus. Nat. Hist. Nat. et Univ. Perpignan (unpublished).*

Kacimi, S., 2003. *Les grands bovidés au Pléistocène en Languedoc-Roussillon et en Catalogne: étude paléontologique, biostratigraphique, archéozoologique et paléoécologique* (Doctoral dissertation, Perpignan).

Kaiser, T.M., 2000. Tooth mesowear analysis on hippotherium primigenium from the Vallesian Dinotheriensande (Germany). *Carolinea: Beiträge zur naturkundlichen Forschung in Südwestdeutschland*, *58*, pp.103-114.

Kaiser, T.M. and Fortelius, M., 2003. Differential mesowear in occluding upper and lower molars: opening mesowear analysis for lower molars and premolars in hypsodont horses. *Journal of Morphology*, *258*(1), pp.67-83.

Kaiser, T.M. and Solounias, N., 2003. Extending the tooth mesowear method to extinct and extant equids. *Geodiversitas*, *25*(2), pp.321-345.

Kaiser, T.M. and Franz-Odendaal, T.A., 2004. A mixed-feeding Equus species from the Middle Pleistocene of South Africa. *Quaternary Research*, *62*(3), pp.316-323.

Kaiser, T.M. and Kahlke, R.D., 2005. The highly flexible feeding strategy of Stephanorhinus etruscus (Falconer, 1859) (Rhinocerotidae, Mammalia) during the early Middle Pleistocene in Central Europe. *Berichte des Institutes für Erdwissenschaften, Karl-Franzens-Universität Graz*, *10*, pp.50-53.

Kaiser, T.M., Brasch, J., Castell, J.C., Schulz, E. and Clauss, M., 2009. Tooth wear in captive wild ruminant species differs from that of free-ranging conspecifics. *Mammalian Biology-Zeitschrift für Säugetierkunde*, *74*(6), pp.425-437.

Klein, R.G., Wolf, C., Freeman, L.G. and Allwarden, K., 1981. The use of dental crown heights for constructing age profiles of red deer and similar species in archaeological samples. *Journal of Archaeological Science*, *8*(1), pp.1-31.

Klein, R.G. and Cruz-Uribe, K., 1983. The computation of ungulate age (mortality) profiles from dental crown heights. *Paleobiology*, *9*(1), pp.70-78.

Kubo, M.O. and Yamada, E., 2014. The inter-relationship between dietary and environmental properties and tooth wear: comparisons of mesowear, molar wear rate, and hypsodonty index of extant sika deer populations. *Plos One*, *9*(3), p.e90745.

Kurten, B., 1968. *Pleistocene mammals of Europe*. Chicago: Aldine Transaction.

Lacombat, F., 2006. Morphological and biometrical differentiation of the teeth from Pleistocene species of Stephanorhinus (Mammalia, Perissodactyla, Rhinocerotidae) in Mediterranean Europe and the Massif Central, France. *Palaeontographica, Abt. A*, *274*(3-6), pp.71-111.

Lartigot, A.S., 2007. *Taphonomie pollinique en grotte de sédiments détritiques et de spéléothèmes: potentiels et limites pour la reconstitution de l'environnement végétal de l'homme préhistorique sur le pourtour Nord-Ouest méditerranéen: Application aux sites français de la Caune de l'Arago (Tautavel, Pyrénées-Orientales), de la Baume Bonne (Quinson, Alpes-de-Haute-Provence), de la grotte du Lazaret (Nice, Alpes-Maritimes) et de la grotte italienne de la Basura (Toirano, Ligurie)* (Doctoral dissertation, Paris, Muséum national d'histoire naturelle).

Lebreton, V., 2001. *Paysages et climats contemporains des premiers hominidés en Italie: analyse pollinique des sites du Pleistocène inférieur et moyen de Ca'Belvedere di Monte Poggiolo (Forli, Emilie-Romagne) et de la Pineta (Isernia, Molise)* (Doctoral dissertation, Paris, Muséum national d'histoire naturelle).

Lebreton, L., Desclaux, E., Hanquet, C., Moigne, A.M. and Perrenoud, C., 2015. Environmental context of the Caune de l'Arago Acheulean occupations (Tautavel, France), new insights from microvertebrates in Q–R levels. *Quaternary International*, *30*, p.1e11.

Lee, R.B. and DeVore, I., 1968. Problems in the study of hunters and gatherers.

Lembo, G., 2015. *Metodologie Informatiche Applicate Agli Scavi Archeologici* (Doctoral dissertation, Università degli Studi di Ferrara).

Lembo, G. and Peretto, C., 2012. Applicazioni GIS per l'interpretazione della paleosuperficie di Isernia La Pineta. *Annali Dell'università Di Ferrara. Sezione: Museologia Scientifica E Naturalistica*, *8*, pp.109-115.

Littleton, J., 2000. Taphonomic effects of erosion on deliberately buried bodies. *Journal of Archaeological Science*, *27*(1), pp.5-18.

Lister, A.M., Parfitt, S.A., Owen, F.J., Collinge, S.E. and Breda, M., 2010. Metric analysis of ungulate mammals in the early Middle Pleistocene of Britain, in relation to taxonomy and biostratigraphy: II: Cervidae, Equidae and Suidae. *Quaternary International*, *228*(1-2), pp.157-179.

Loffredo, L.F. and DeSantis, L.R., 2014. Cautionary lessons from assessing dental mesowear observer variability and integrating paleoecological proxies of an extreme generalist Cormohipparion emsliei. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *395*, pp.42-52.

Longo, L., 1994. Le industrie litiche: L'analisi delle trace d'uso. In C. Peretto ed., *Le Industrie Litiche del Giacimento Paleolitico di Isernia La Pineta*. Isernia: Cosmo Iannone Editore, pp. 355-452.

Longo, L., Peretto, C., Sozzi, M. and Vannucci, S., 1997. Artefacts, outils ou support épuisés? Une nouvelle approche pour l'étude des industries du paléolithique ancien: le cas d'Isernia La Pineta (Molise, Italie Centrale). *L'Anthropologie*, *101*, pp.579-596.

Longo, L., Peretto, C., Sozzi, M. and Vannucci, S., 1997. Artefacts, outils ou support épuisés? Une nouvelle approche pour l'étude des industries du paléolithique ancien: le cas d'Isernia La Pineta (Molise, Italie Centrale). *L' Anthropologie*, *101*, pp.579-596.

López-González, F., Grandal-d'Anglade, A. and Vidal-Romaní, J.R., 2006. Deciphering bone depositional sequences in caves through the study of manganese coatings. *Journal of Archaeological Science*, *33*(5), pp.707-717.

Louys, J., Meloro, C., Elton, S., Ditchfield, P. and Bishop, L.C., 2011. Mesowear as a means of determining diets in African antelopes. *Journal of Archaeological Science*, *38*(7), pp.1485-1495.

Lyman, R.L., 1984. Bone density and differential survivorship of fossil classes. *Journal of Anthropological archaeology*, *3*(4), pp.259-299.

Lyman, R.L., 1987. On the analysis of vertebrate mortality profiles: sample size, mortality type, and hunting pressure. *American Antiquity*, *52*(1), pp.125-142.

Lyman R.L. 1994, *Vertebrate taphonomy*, Cambridge manuals in archaeology.

Lyman, R.L., 2008. Quantitative paleozoology. Cambridge University Press, Cambridge.

Malerba, G., Thun Hohenstein U., Diez Lomana C., RoselL J., Giacobini G., Peretto C., (2000). Cut marks e pseudocutmarks. Il problema del riconoscimento di tracce di origine antropica e non sui reperti faunistici del sito di Isernia La Pineta. Atti del II Convegno Nazionale di Archeozoologia, Asti, 1997. Abaco Edizione, Forlì, pp. 91-97.

Maltby, J.M. 1985. Patterns in Fannal Assemblage Variability. In: Barker, G. and Gamble (eds). Beyond Domestication in Prehistoric Europe. Academic press, London, pp. 34–74.

Maniakas, I. and Kostopoulos, D.S., 2017. Morphometric-palaeoecological discrimination between Bison populations of the western Palaearctic. *Geobios*, *50*(2), pp.155-171.

Marshall, L. G. 1989. Bone modification and "the laws of burial." In Bonnichsen, R., and Sorg, M. H. (eds.), *Bone Modification*, Center for the Study of the First Americans, Orono, pp. 7-24.

Martino C. 2015, *Zooarchaeological and taphonomical analyses of the faunal assemblage from SU 3coll of Isernia La Pineta (Molise, Southern Italy)*, Tesi di Master Erasmus Mundus in Quaternary and Prehistory, Dipartimento degli Studi Umanistici, Università degli Studi di Ferrara.

McPherron, A., Schmidt, V., Peretto, C., Terzani, C. and Cremaschi, M., 1983. Paleomagnetic dating at Isernia la Pineta. *Isernia la pineta: un accampamento piu antico di*, *700*, pp.67-69.

Mihlbachler, M.C., Campbell, D., Chen, C., Ayoub, M. and Kaur, P., 2017. Microwear–mesowear congruence and mortality bias in rhinoceros mass-death assemblages. *Paleobiology*, pp.1-24.

Minelli, A., 2003. Il giacimento di Isernia La Pineta (Molise) per lo sviluppo delle conoscenze del popolamento antico in Italia: i reperti litici e le archeosuperfici (PhD dissertation). *Universita di Ferrara, Ferrara*.

Minelli, A. and Peretto, C., 2003. Metodologie per lo scavo archeologico. Il caso di Isernia La Pineta (Molise).

Minelli, A., Longo, L., Arzarello, M., Olle, A., Verges, J.M. and Peretto, C., 2004. New data on the litich industry of Isernia La Pineta: typology, technology and functional analysis. In *XIV Congrès UISPP* (pp. 59-68). BAR International Series.

Moigne, A.M., 1983 . *Taphonomie des faunes quaternaires de la Caune de l'Arago, Tautavel.* Université Pierre et Marie-Curie Paris-VI, Paris (Ph. D dissertation). pp.345.

Moigne, A.M., Palombo, M.R., Belda, V., Heriech-Briki, D., Kacimi, S., Lacombat, F., de Lumley, M.A., Moutoussamy, J., Rivals, F., Quilès, J. and Testu, A., 2006. Les faunes de grands mammifères de la Caune de l'Arago (Tautavel) dans le cadre biochronologique des faunes du Pléistocène moyen italien. *L'anthropologie*, *110*(5), pp.788-831.

Monchot Hervé. Les petits bovidés de la Caune de l'Arago (Tautavel, France) : intérêt biostratigraphique, archéozoologique et taphonomique [Exploitation of caprinae during the lower paleolithic at the Arago cave site (Tautavel, France)]. In: Quaternaire Volume 9 - Numéro 4 - 1998. pp. 369-377.

Morlan, R.E., 1980. Taphonomy and archaeology in the Upper Pleistocene of the Northern Yukon Territory: A glimpse of the peopling of the New World. *Musée National de l'Homme. Collection Mercure. Commission Archéologique du Canada. Publications d'Archéologie. Dossier Ottawa*, (94), pp.1-380.

Morlan, R.E., 1984. Toward the Definition of Criteria for the Recognition of Artificial Bone Alterations 1. *Quaternary Research*, *22*(2), pp.160-171.

Olsen, S.L. and Shipman, P., 1988. Surface modification on bone: trampling versus butchery. *Journal of archaeological science*, *15*(5), pp.535-553.

Outram, A.K., 1998. *The identification and Palaeoeconomic context of prehistoric bone marrow and grease exploitation* (Doctoral dissertation, Durham University).

Outram, A.K., 2001. A new approach to identifying bone marrow and grease exploitation: why the "indeterminate" fragments should not be ignored. *Journal of archaeological science*, *28*(4), pp.401-410.

Outram, A.K., 2002. Bone fracture and within-bone nutrients: an experimentally based method for investigating levels of marrow extraction. Consuming Passions and Patterns of Consumption. P. Miracle and N. Milner. Cambridge, McDonald Institute for Archaeological Research: pp.51-65.

Palacio, P., Berthonaud, V., Guérin, C., Lambourdière, J., Maksud, F., Philippe, M., Plaire, D., Stafford, T., Marsolier-Kergoat, M.C. and Elalouf, J.M., 2017. Genome data on the extinct Bison schoetensacki establish it as a sister species of the extant European bison (Bison bonasus). *BMC evolutionary biology*, *17*(1), p.48.

Pales, L., 1971. *Atlas Ostéologique Pour Servir À L'identification Des Mammifères Du Quaternaire, Par Léon Pales Et Charles Lambert.* Paris: Éditions du Centre national de la recherche scientifique.

Pales, L. and Garcia, M.A., 1981. *Atlas Ostéologique pour servir à l'identification des Mammifères du Quaternaire [: II. Tête-rachis, ceintures scapulaire et pelvienne: membres*. Centre National de la Recherche Scientifique.

Peretto, C. ed., 1992. *Il più antico popolamento della Valle Padana nel quadro delle conoscenze europee: Monte Poggiolo.* Jaca Book.

Peretto, C., 1994. Le industrie litiche del giacimento paleolitico di Isernia La Pineta. La tipologia, le tracce di utilizzazione, la sperimentazione. Cosmo Iannone Editore, Isernia.

Peretto, C. (Ed.), 1996. I reperti paleontologici del giacimento paleolitico di Isernia la Pineta. Cosmo Iannone, Isernia.

Peretto, C., (Ed.), 1999. I suoli d'abitato del giacimento paleolitico di Isernia La Pineta: natura e distribuzione dei reperti.

Peretto, C., (Ed.), 2010. *Isernia La Pineta: 30 Anni di Ricerche*. Isernia: Centro Europeo di Ricerche Preistoriche.

Peretto, C., 2013. *Isernia La Pineta*, Isernia & Ferrara: Cosmo Iannone Editore & Università degli Studi di Ferrara.

Peretto, C., Terzani, C., Cremaschi, M., 1983. Isernia La Pineta: un accampamento più antico di 700.000 anni. Calderini Editore, Bologna.

Peretto, C., Anconetani, P., Crovetto, C., Evangelista, L., Ferrari, M., Giusberti, G., Thun Hohenstein, U. and Vianello, F., 1996. Approccio sperimentale alla comprensione delle attività di sussistenza condotte nel sito di Isernia La Pineta (Molise-Italia). La fratturazione intenzionale - I reperti paleontologici del giacimento paleolitico di Isernia La Pineta, l'uomo e l'ambiente; in Peretto C. Istituto Regionale per gli Studi Storici del Molise "V. Cuoco", Cosmo Iannone Editore, Isernia, pp. 187-309.

Peretto, C., Benvenuti, C., Bisi, F., Cavallini, E., Corti, P., Evangelista, L., Ferioli, V., Guerreschi, A., Longo, L., Milliken, S. and Hohenstein, U.T., 2000. Isernia La Pineta (Molise): type and distribution of the finds on the living floor 3a in sector I of the excavation. In *Atti del II Congresso Internazionale CNR, II, Parigi* (Vol. 1999, pp. 995-998).

Peretto, C., Arzarello, M., Gallotti, R., Lembo, G., Minelli, A. and Thun Hohenstein, U., 2004. Middle Pleistocene behavioural strategies: The contribution of Isernia La Pineta site (Molise, Italy). In *Miscelanea en homenaje a Emilianoa Aguirre. Volumen IV: Arqueologia*. Alcala de Henares: Museo Arqueologico Regional, pp. 368–381.

Peretto, C., Arzarello, M., Gallotti, R., Lembo, G., Minelli, A. and Thun Hohenstein, U., 2010. Intra-Site Analysis of the Palaeolithic Site of Isernia La Pineta (Molise, Italy). In *Beyond the artifact. Digital interpretation of the past. Proceedings of CAA 2004* (pp. 201-206). archaeolingua.

Peretto C., Arnaud J., Moggi-CEcchi J., Manzi G., Nomade S., Pereira A., Falgueres C., Bahain J.-J., Grimaud-Herve D., Berto C., Sala B., Lembo G., Muttillo B., Gallotti R., Thun Hohenstein U., Vaccaro C., Coltorti M. and Arzarello M., 2015 - A Human Deciduous Tooth and New 40Ar/39Ar Dating Results from the Middle Pleistocene Archaeological Site of Isernia La Pineta, Southern Italy. PLoS ONE 10 (10), e0140091.

Pérez-Crespo, V.A., Barrón-Ortiz, C.R., Arroyo-Cabrales, J., Morales-Puente, P., Cienfuegos-Alvarado, E. and Otero, F.J., 2016. Preliminary data on the diet and habitat preferences of Capromeryx mexicana (Mammalia: Antilocapridae) from the late Pleistocene of Cedral, San Luis Potosí, Mexico. *The Southwestern Naturalist*, *61*(2), pp.152-155.

Pesce D. 2005, *Strategie di sussistenza adottate nel sito paleolitico di Isernia La Pineta. Studio archeozoologico dell'insieme faunistico proveniente dall'US 3coll del I settore di scavo*, Tesi di Laurea Magistrale, Dipartimento di Scienze MM.FF. NN, Università degli Studi di Ferrara.

Pickering, T.R., Domínguez‐Rodrigo, M., Egeland, C.P. and Brain, C.K., 2005. The contribution of limb bone fracture patterns to reconstructing early hominid behaviour at Swartkrans Cave (South Africa): archaeological application of a new analytical method. *International Journal of Osteoarchaeology*, *15*(4), pp.247-260.

Poplin, F., 1976. A propos du nombre de restes et du nombre d'individus dans les échantillons d'ossements. *Cahiers du centre de recherches préhistoriques*, *5*(61), p.e75.

Potts, R., 1983. Foraging for faunal resources by early hominids at Olduvai Gorge, Tanzania. *Animals and archaeology*, *1*, pp.51-62.

Potts, R., 1998. Early Hominid Actiuities at Olduuai. New York: Aldine de Gruyter.

Radinović, M., 2015. Microwear analysis of flint artifacts made by bipolar knapping on an anvil, from layer 3colluvio of Isernia La Pineta site (Italy). Unpublished Masters' dissertation at the University of Ferrara, Ferrara.

Reitz E.J., Wing E.S. 1999, *Zooarchaeology*, Cambridge manuals in archaeology.

Reitz, EJ and Wing, ES, 2008. Zooarchaeology. Cambridge Manual in Archeology.

Rivals, F., 2000, October. The Argali of the 'Caune de l'Arago' (southern France). Palaeoecology of a 440,000 years old population. In *Proceedings of the 3rd International Symposium on Mouflon* (pp. 27-29).

Rivals, F., Moigne, A.M. and de Lumley, H., 2002. La chasse aux petits bovidés à la Caune de l'Arago (Tautavel, France): opportunisme ou sélection des proies. Anthropozoologica, 36, pp.3-12.

Rivals, F. and Deniaux, B., 2003. Dental microwear analysis for investigating the diet of an argali population (Ovis ammon antiqua) of mid-Pleistocene age, Caune de l'Arago cave, eastern Pyrenees, France. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *193*(3), pp.443-455.

Rivals, F., Kacimi, S. and Moutoussamy, J., 2004. Artiodactyls, favourite game of prehistoric hunters at the Caune de l'Arago Cave (Tautavel, France). Opportunistic or selective hunting strategies? *European Journal of Wildlife Research*, *50*(1), pp.25-32.

Rivals, F. and Deniaux, B., 2005. Investigation of human hunting seasonality through dental microwear analysis of two Caprinae in late Pleistocene localities in Southern France. *Journal of Archaeological Science*, *32*(11), pp.1603-1612.

Rivals, F. and Semprebon, G.M., 2006. A comparison of the dietary habits of a large sample of the Pleistocene pronghorn Stockoceros onusrosagris from the Papago Springs Cave in Arizona to the modern Antilocapra americana. *Journal of Vertebrate Paleontology*, *26*(2), pp.495-500.

Rivals, F., Testu, A., Moigne, A.M. and De Lumley, H., 2006. The Middle Pleistocene argali (Ovis ammon antiqua) assemblages at the Caune de l'Arago (Tautavel, Pyrénées-Orientales, France): were prehistoric hunters or carnivores responsible for their accumulation? *International Journal of Osteoarchaeology*, *16*(3), pp.249-268.

Rivals, F., Mihlbachler, M.C. and Solounias, N., 2007. Effect of ontogenetic-age distribution in fossil and modern samples on the interpretation of ungulate paleodiets using the mesowear method. *Journal of Vertebrate Paleontology*, *27*(3), pp.763-767.

Rivals, F. and Solounias, N., 2007. Differences in tooth microwear of populations of caribou (Rangifer tarandus, Ruminantia, Mammalia) and implications to ecology, migration, glaciations and dental evolution. *Journal of Mammalian Evolution*, *14*(3), p.182.

Rivals, F., Solounias, N. and Mihlbachler, M.C., 2007. Evidence for geographic variation in the diets of late Pleistocene and early Holocene Bison in North America, and differences from the diets of recent Bison. *Quaternary research*, *68*(3), pp.338-346.

Rivals, F. and Athanassiou, A., 2008. Dietary adaptations in an ungulate community from the late Pliocene of Greece. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *265*(1-2), pp.134-139.

Rivals, F., Schulz, E. and Kaiser, T.M., 2008. Climate-related dietary diversity of the ungulate faunas from the middle Pleistocene succession (OIS 14-12) at the Caune de l'Arago (France). *Paleobiology*, *34*(1), pp.117-127.

Rivals, F., Schulz, E. and Kaiser, T.M., 2009. A new application of dental wear analyses: estimation of duration of hominid occupations in archaeological localities. *Journal of human evolution*, *56*(4), pp.329-339.

Rivals, F., Mihlbachler, M.C., Solounias, N., Mol, D., Semprebon, G.M., de Vos, J. and Kalthoff, D.C., 2010. Palaeoecology of the Mammoth Steppe fauna from the late Pleistocene of the North

Sea and Alaska: Separating species preferences from geographic influence in paleoecological dental wear analysis. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *286*(1-2), pp.42-54.
Rivals, F., Solounias, N. and Schaller, G.B., 2011. Diet of Mongolian gazelles and Tibetan antelopes from steppe habitats using premaxillary shape, tooth mesowear and microwear analyses. *Mammalian Biology-Zeitschrift für Säugetierkunde*, *76*(3), pp.358-364.

Rivals, F., 2012. Ungulate feeding ecology and middle Pleistocene paleoenvironments at Hundsheim and Deutsch-Altenburg 1 (eastern Austria). *Palaeogeography, Palaeoclimatology, Palaeoecology*, *317*, pp.27-31.

Rivals, F., Julien, M.A., Kuitems, M., Van Kolfschoten, T., Serangeli, J., Drucker, D.G., Bocherens, H. and Conard, N.J., 2015. Investigation of equid paleodiet from Schöningen 13 II-4 through dental wear and isotopic analyses: Archaeological implications. *Journal of Human Evolution*, *89*, pp.129-137.

Rivera Pérez, P., 2016. *Comportamiento, cultura y ambiente: variabilidad en las industrias líticas del Paleolítico Inferior de la Europa Meridional. Los casos de Isernia la Pineta, Ribeira da Ponte da Pedra y Fonte da Moita* (Doctoral dissertation, Università degli Studi di Ferrara).

Rodriguez-Hidalgo, A., Saladie, P., Olle, A., Arsuaga, J.L., de Castro, J.M.B. and Carbonell, E., 2017. Human predatory behavior and the social implications of communal hunting based on evidence from the TD10. 2 bison bone bed at Gran Dolina (Atapuerca, Spain). *Journal of human evolution*, *105*, pp.89-122.

Rufo, M.A., Minelli, A. and Peretto, C., 2009. L'industrie en calcaire du site Paléolithique d'Isernia la Pineta: un modele interprétatif de stratégie comportementale. *L'Anthropologie*, *113*(1), pp.78-95.

Saarinen, J. and Lister, A.M., 2016. Dental mesowear reflects local vegetation and niche separation in Pleistocene proboscideans from Britain. *Journal of Quaternary Science*, *31*(7), pp.799-808.

Sala, B., 1983. La fauna del giacimento di Isernia La Pineta. In: Coltori, T. (Ed.), IserniaLaPineta.Unaccampamentopiu`antico di 700.000 anni. Calderini, Bologna, pp. 71–79.

Sala, B., 1986. *Bison schoetensacki* Freud. from Isernia la Pineta (early Mid-Pleistocene, Italy) and revision of the European species of bison. *Palaeontographia Italica*, *74*, pp.113-170.

Sala, B., 1990. Panthera leo fossilis (v. Reich., 1906) (Felidae) de Isernia la Pineta (Pleistocene moyen inferieur d'Italie). *Geobios*, *23*(2), pp.189-194.

Sala, B., 1996. Gli animali del giacimento di Isernia La Pineta. *I reperti paleontologici del giacimento paleolitico di Isernia La Pineta (C. Pinetto ed.) Cosmo Iannone Editore, Isernia, Italy*, pp.25-49.

Sala, B., 2006. *Le nuove specie rinvenute alla Pineta*. In Preistoria in Molise, insediamenti del territorio di Isernia. C.E.R.P., Collana Ricerche 3, Aracne Editrice, pp. 36-38.

Sala, B., Masini, F., Ficcarelli, G., Rook, L. and Torre, D., 1992. Mammal dispersal events in the Middle and Late Pleistocene of Italy and Western Europe. *Courier Forschungsinstitut Senckenberg*, *153*, pp.59-68.

Sala B., Fortelius M., 1993. *The rhinoceroses of Isernia La Pineta (Early Middle-Pleistocene, Southern Italy)*. Paleontographia Italica, 80, pp. 157-174.

Sánchez-Hernández, C., Rivals, F., Blasco, R. and Rosell, J., 2016. Tale of two timescales: combining tooth wear methods with different temporal resolutions to detect seasonality of Palaeolithic hominin occupational patterns. *Journal of Archaeological Science: Reports*, *6*, pp.790-797.

Schmid, E., 1972. Atlas for the idenification of animal bones. Elsevier, Amsterdam.

Schulz, E., Fahlke, J.M., Merceron, G. and Kaiser, T.M., 2007. Feeding ecology of the Chalicotheriidae (Mammalia, Perissodactyla, Ancylopoda). Results from dental micro-and mesowear analyses. *Verhandlungen des Naturwissenschaftlichen Vereins zu Hamburg*, *43*, pp.5-31.

Schulz, E. and Fahlke, J.M., 2009. The diet of Metaschizotherium bavaricum (Chalicotheriidae, Mammalia) from the MN 5 of Sandelzhausen (Germany) implied by the mesowear method. *Palaeontologische Zeitschrift*, *83*(1), pp.175-181.

Schulz, E., Fraas, S., Kaiser, T.M., Cunningham, P.L., Ismail, K. and Wronski, T., 2013. Food preferences and tooth wear in the sand gazelle (Gazella marica). *Mammalian Biology-Zeitschrift für Säugetierkunde*, *78*(1), pp.55-62.

Schubert, B.W., 2007. Dental mesowear and the palaeodiets of bovids from Makapansgat Limeworks Cave, South Africa.

Sevink, J., Hebeda, E.H., Priem, H.N.A. and Verschure, R.H., 1981. A note on an approximately 730,000-year-old mammal fauna and associated human activity sites near Isernia, central Italy. *Journal of Archaeological Science*, *8*(1), pp.105-106.

Shao, Q., Bahain, J.J., Falguères, C., Peretto, C., Arzarello, M., Minelli, A., Hohenstein, U.T., Dolo, J.M., Garcia, T., Frank, N. and Douville, E., 2011. New ESR/U-series data for the early Middle Pleistocene site of Isernia la Pineta, Italy. *Radiation Measurements*, *46*(9), pp.847-852.

Secco F. 2003, *Strategie di sussistenza adottate nel sito paleolitico di Isernia La Pineta. Indagine archeozoologica dei reperti faunistici provenienti dall'US 3coll del I settore di scavo*, Tesi di Laurea Magistrale, Dipartimento degli Studi Umanistici, Università degli Studi di Ferrara.

Shipman, P. and Rose, J.J., 1984. Cutmark mimics on modern and fossil bovid bones. *Current Anthropology*, *25*(1), pp.116-117.

Srinivas, A., 2016. *Technological Variability and the Western European Lower Palaeolithic: A technological analysis of the lithic artefacts of layer 3s6-9 of Isernia La Pineta, Molise, Southern Italy* (Master thesis, Università degli Studi di Ferrara).

Stiner, M.C., 1990. The use of mortality patterns in archaeological studies of hominid predatory adaptations. *Journal of anthropological archaeology*, *9*(4), pp.305-351.

Stiner, M.C., 1994. Honor among thieves: A zooarchaeological study of Neandertal ecology. *Princeton NJ: Princeton*.

Thun Hohenstein, U., 2001. *Strategie di sussistenza e comportamento dell'uomo di Neanderthal. Analisi archeozoologica dei livelli musteriani del Riparo Tagliente, Grotta della Ghiacciaia (Italia) e Abric Romani (Spagna)* (Doctoral dissertation, Tesi di Dottorato, Università degli Studi di Ferrara).

Thun Hohenstein, U., Malerba, G., Ghirelli, E., Giacobini, G. and Peretto, C., 2002. Attività di sussistenza nel Paleolitico inferiore di Isernia La Pineta: archeozoologia delle US 3S10 e 3 coll. *Rivista di Scienze preistoriche*, *52*, pp.3-20.

Thun Hohenstein, U., Malerba, G., Giacobini, G. and Peretto, C., 2004. Bone surface micromorphological study of the faunal remains from the Lower Palaeolithic site of Isernia La Pineta (Molise, Italy). In *XIV Congres de l'Union Internationale des Sciences Prehistoriques et Protohistoriques* (pp. 123-129). Archaeopress.

Thun Hohenstein, U., Di Nucci, A. and Peretto, C., 2005. Lo sfruttamento di Ursus deningeri nel sito paleolitico di Isernia La Pineta. In *AIAZ 2003* (pp. 23-29). Museo Archeologico Pordenone.

Thun Hohenstein, U., Di Nucci, A. and Moigne, A.M., 2009. Mode de vie à Isernia La Pineta (Molise, Italie). Stratégie d'exploitation du Bison schoetensacki par les groupes humains au Paléolithique inférieur. *L'anthropologie*, *113*(1), pp.96-110.

Tonon, M., 1989. Note sull'avifauna del deposito di Isernia La Pineta. *Il Quaternario*, *2*, pp.171-173.

Valensi, P., 2000. The archaeozoology of Lazaret Cave (Nice, France). *International Journal of Osteoarchaeology*, *10*(5), pp.357-367.

van Asperen, E.N. and Kahlke, R.D., 2017. Dietary traits of the late Early Pleistocene Bison menneri (Bovidae, Mammalia) from its type site Untermassfeld (Central Germany) and the problem of Pleistocene 'wood bison'. *Quaternary Science Reviews*, *177*, pp.299-313.

Van Otterloo R.H., Sevink J., 1983. The quaternary evolution of the Upper-Volturno Basin - Isernia La Pineta: un accampamento più antico di 700.000 anni. Catalogo della mostra omonima, *Edizioni Calderini, Bologna,* pp.35-39.

Varela, S. and Rodríguez, J., 2004. Atlas osteológico, carnívoros ibéricos. *MNCN, Madrid.*

Villa, P. and Mahieu, E., 1991. Breakage patterns of human long bones. *Journal of human evolution*, *21*(1), pp.27-48.

Von den Driesch, A., 1976. *A guide to the measurement of animal bones from archaeological sites: as developed by the Institut für Palaeoanatomie, Domestikationsforschung und Geschichte der Tiermedizin of the University of Munich* (Vol. 1). Peabody Museum Press.

Warren, C.P., 1975. Plants as decomposition vectors of human skeletal remains. In *Indian Academy of Sciences, 91 Annual Meeting, Butler University.*

White, T.D., 2014. *Prehistoric cannibalism at Mancos 5MTUMR-2346*. Princeton University Press.

Yamada, E., 2013, August. Effects of dietary differences between sympatric Japanese serow and sika deer on environmental reconstruction by means of mesowear analysis. In *Annales Zoologici Fennici* (Vol. 50, No. 4, pp. 200-208). Finnish Zoological and Botanical Publishing.

Yokoyama, Y. and Nguyen, H.V., 1981. Direct dating by non-destructive gamma-ray spectrometry of fossil human skull Arago XXI, fossil animal bones and stalagmites of the Caune de l'Arago at Tautavel. *Proceedings Pretirage*, pp.355-375.

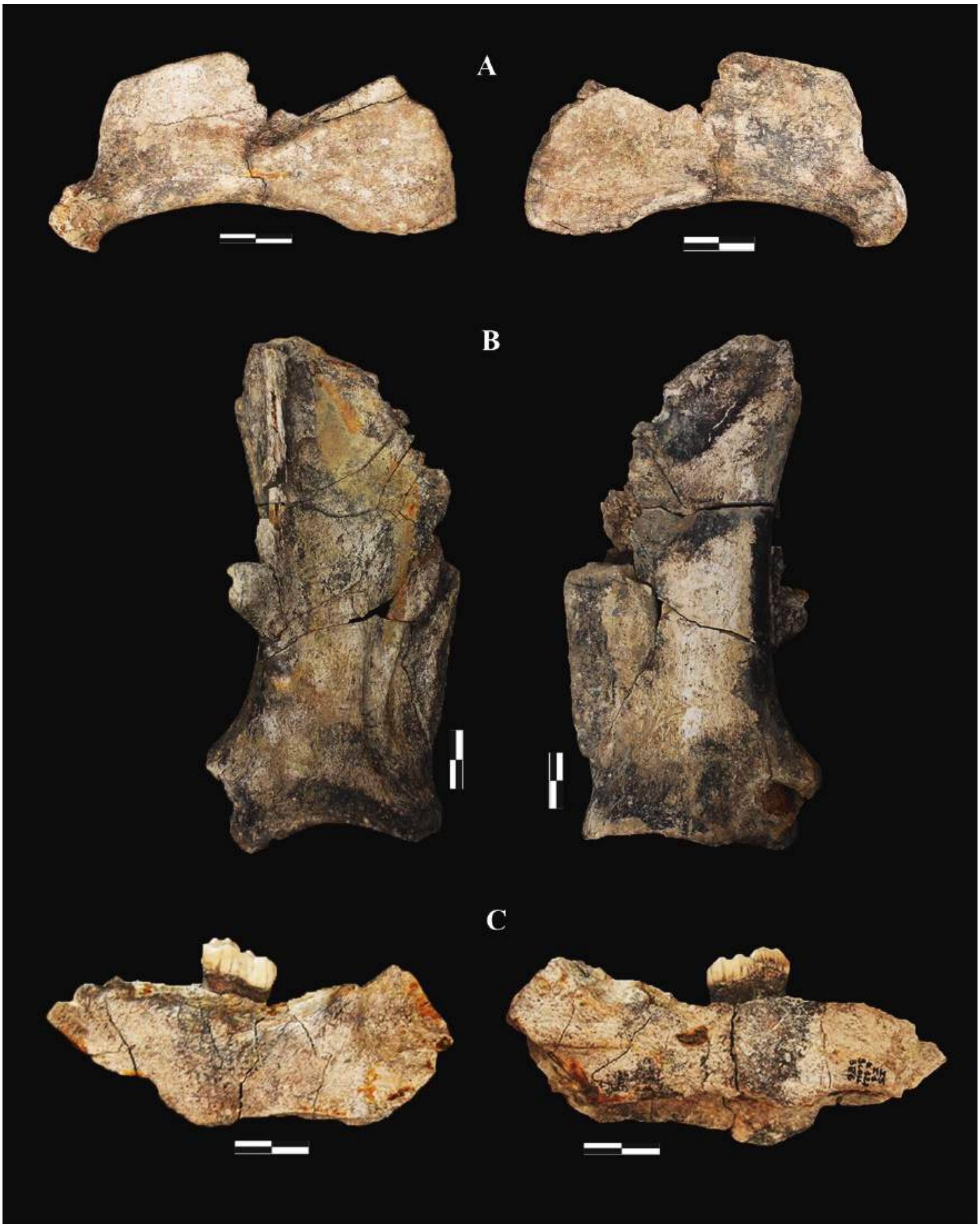
Yokoyama, Y., Falgueres, C. and Quaegebeur, J.P., 1985. ESR dating of quartz from Quaternary sediments: first attempt. *Nuclear Tracks and Radiation Measurements (1982)*, *10*(4-6), pp.921-928.

Zanazzi, A., Fletcher, A., Thun Hohenstein, U., Berto, C, Sala, B., Lembo, G., Peretto, C., 2015, Paleoclimate and paleoenvironment of Isernia La Pineta (Molise, Italy). Abstracts with Programs, Geological Society of America vol. 47, no. 7

www.webref.org
www.archeologicamolise.beniculturali.it
www.whc.unesco.org/en/tentativelists/5020
www.sandiegoarchaeology.org

Plate 1

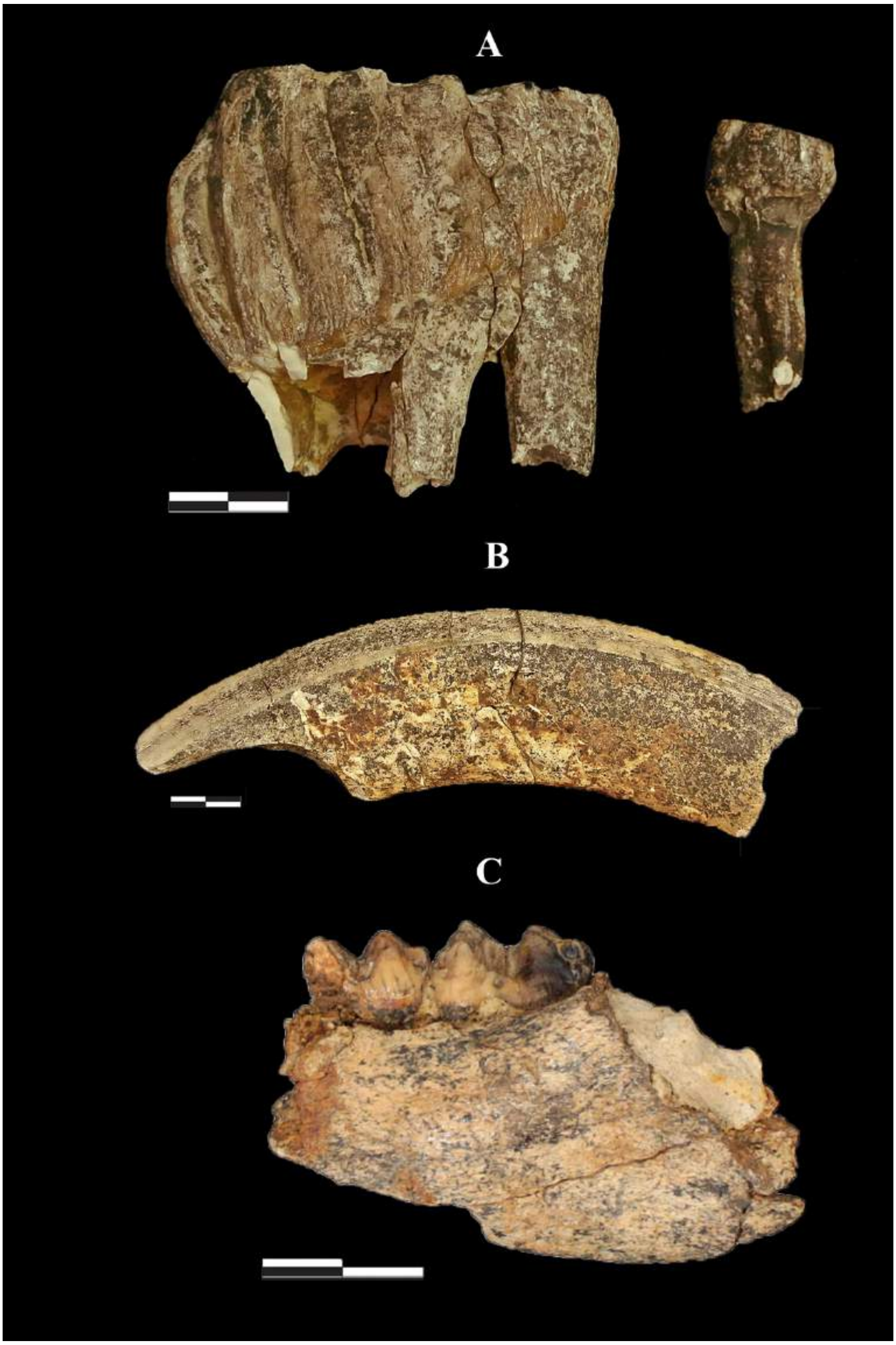
Faunal remains from layer 3 colluvium



A: Left mandible (1.106.110) and B: Left scapula (1.078.060) of *Bison schoetensacki*;
C: Left mandible with M_2 (1.127.386) of *Ursus deningeri* (scale 2 cm).

Plate 2

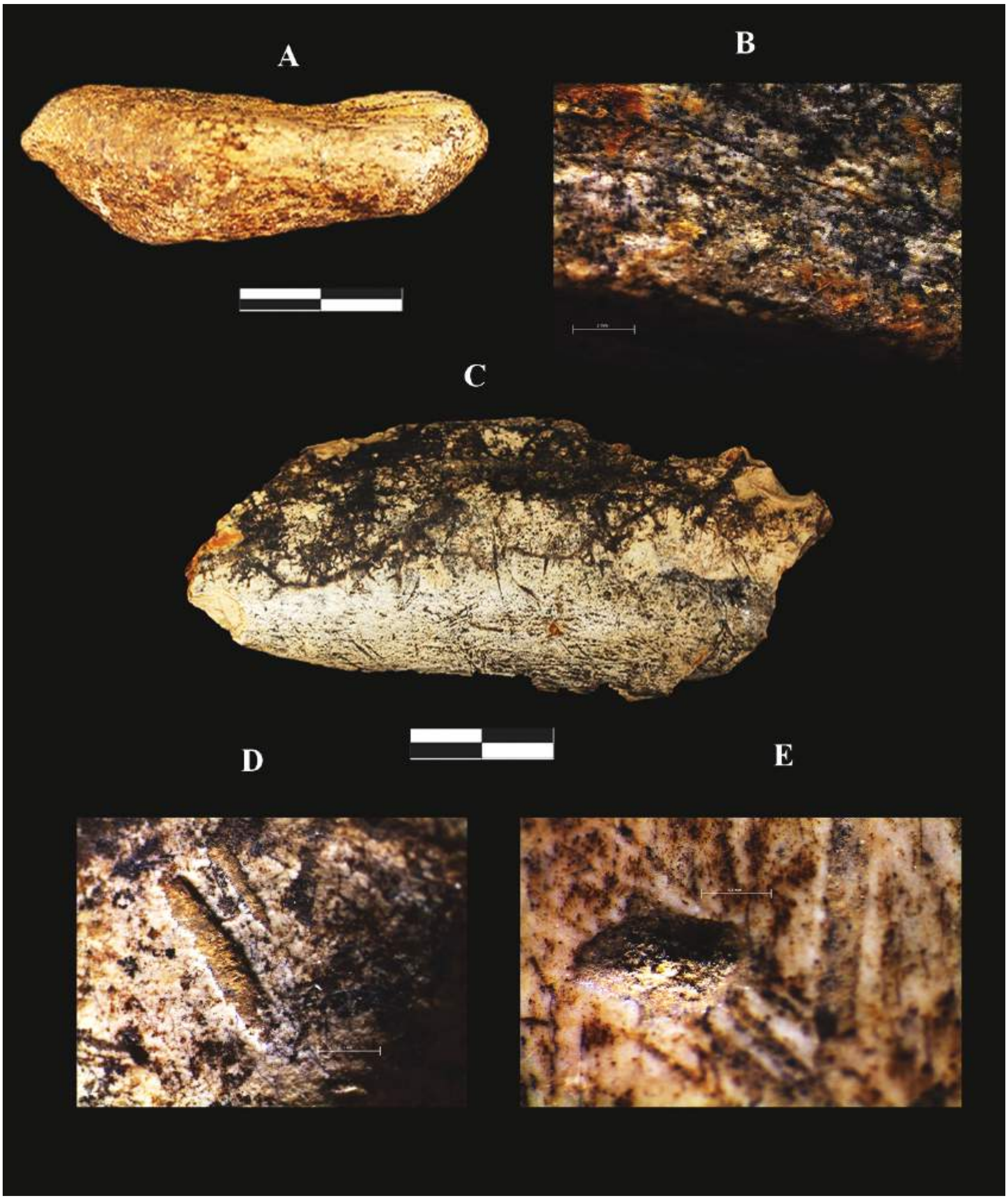
Faunal remains from layer 3 colluvium



A: Deciduous premolars (on left - 1.167.059, on right - 1.109.062) of *Palaeoloxodon antiquus*; B: Dental fragment (1.167.228) of *Hippopotamus* cf. *antiquus*; C: Left mandible (1.147.039) of *Sus scrofa* (scale 2 cm).

Plate 3

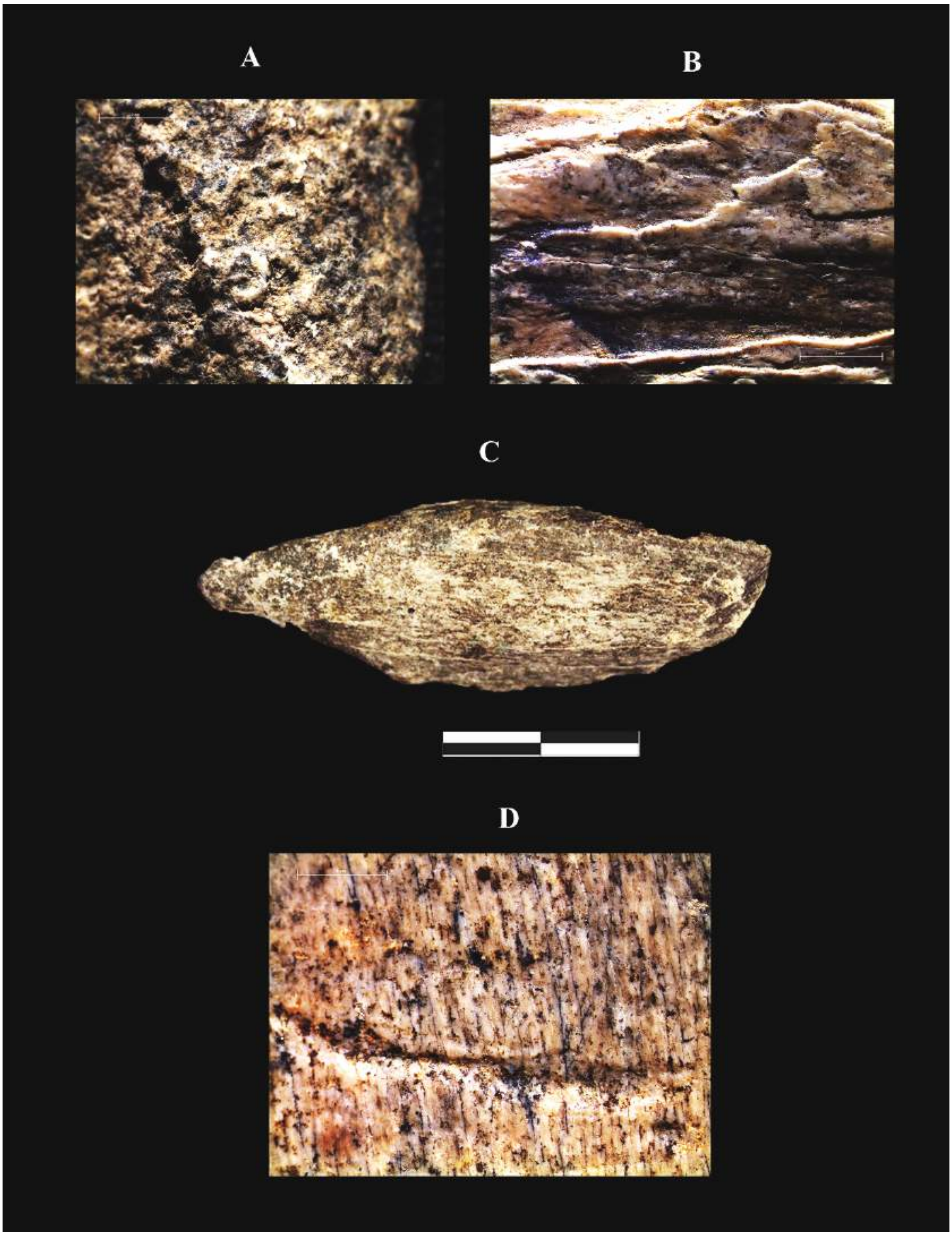
Non-anthropic bone modifications from 3 colluvium



A: Unidentified fragment with rounding (1.177.238); B: Tibia of *Bison schoetensacki* with deposits of manganese and iron oxide (1.137.83); C: Fragment of femur with trampling marks and root etchings on its surface (1.066.076); D: Sesamoid of *Ursus deningeri* with carnivore score (mark); E: Diaphysis fragment with carnivore puncture (mark). Scale A and C - 2 cm; B, D and E - 2 mm.

Plate 4

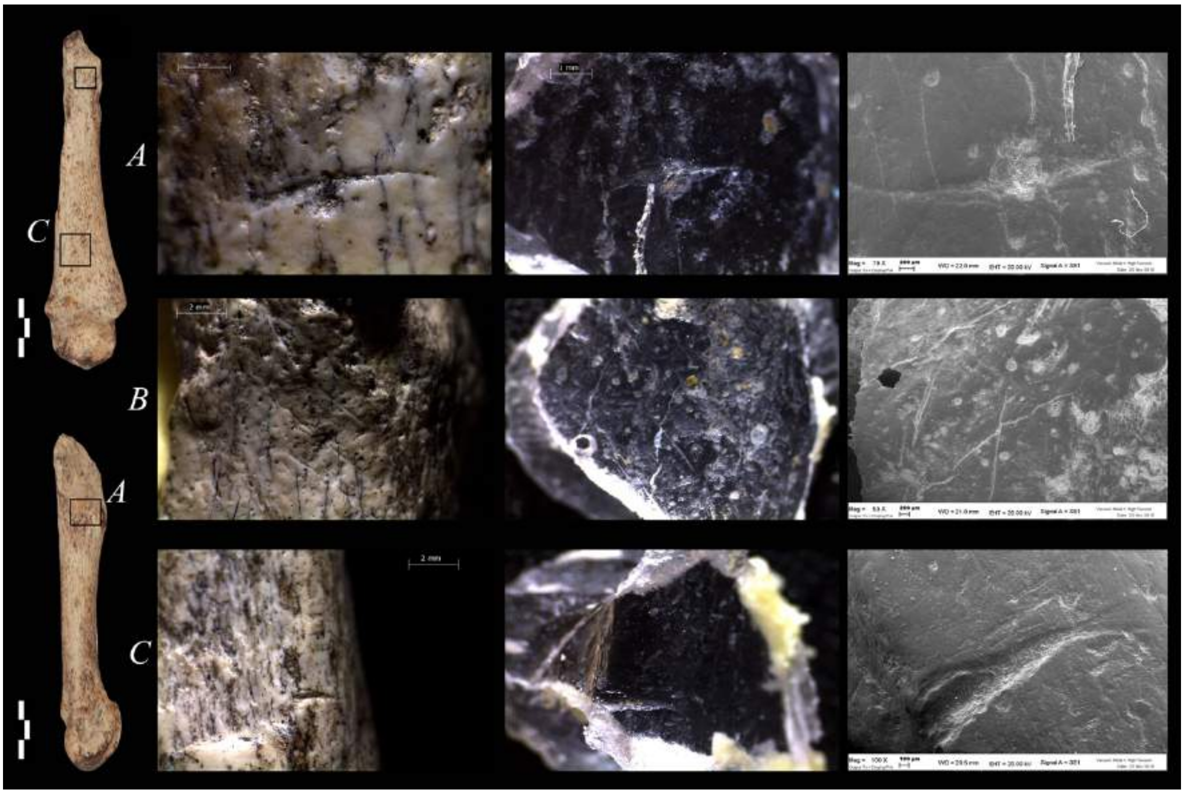
Non-anthropic modifications from layer 3s6-9



A: Unidentified fragment with marked erosion (1.177.91); B: Unidentified fragment with exfoliation (4.111.029); C: Rib fragment with rounding (1.168.096); D: mandible fragment with carnivore score (mark) (4.121.045). Scale A, B and D - 2mm; C - 2cm.

Plate 5

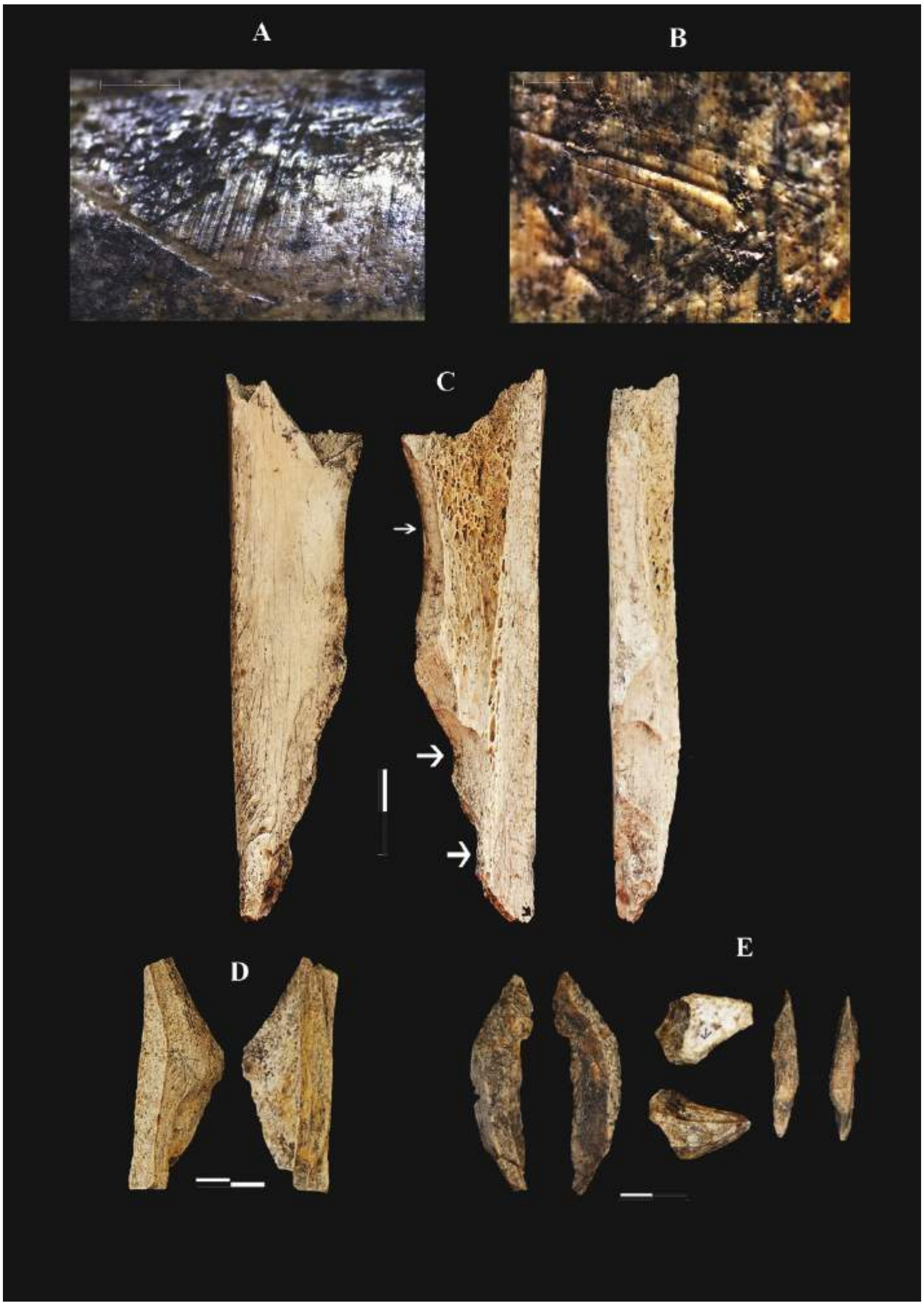
Anthropic modifications on a faunal remain from layer 3 coll



A, B and C: Cut-marks identified on the medial and distal portion of the metapodium of *Ursus deningeri* (4.091.159).

Plate 6

Anthropic modifications from layers 3 coll and 3s6-9



A: Diaphysis fragment with scraping marks (1.138.259); B: Fragment of ulna with scraping marks (1.158.82); C: Femur of Cervidae with impact point, percussion notches and medullary face detachments (1.110.009); D and E: percussion cones from layer 3s6-9. Scale A and B - 2 mm; C, D and E - 2 cm.