Universidade de Évora - Instituto de Investigação e Formação Avançada
Università degli Studi di Roma "La Sapienza" Aristotle University of Thessaloniki

Mestrado em Ciência dos Materiais Arqueológicos (ARCHMAT)

Dissertação

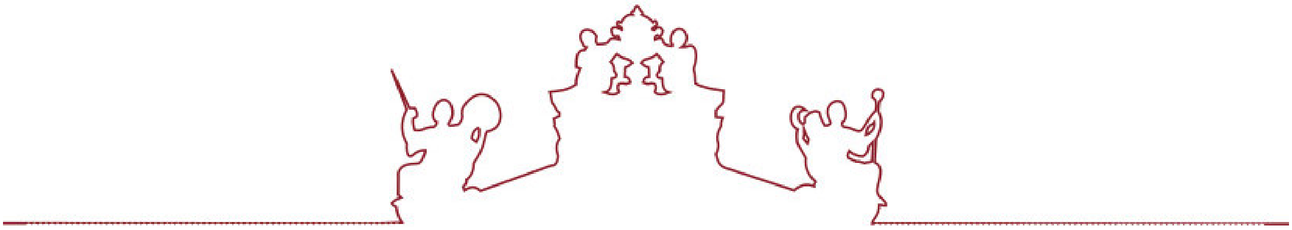
Pathways to pig isotopic signature change during Neolithic: variability in domestications actions and feeding practices. Caminhos para a mudança da assinatura isotópica do porco durante o Neolítico: variabilidade na s ações de domesticação e práticas alimentares.

Sopio Paatashvili

Orientador(es) | Vanessa Navarrete Belda
Anne-France Maurer
Cristina Barrocas Dias

Évora 2023

Esta dissertação não inclui as críticas e as sugestões feitas pelo júri.



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A dissertação foi objeto de apreciação e discussão p´ublica pelo seguinte júri nomeado pelo Diretor do Instituto de Investigação e Formação Avan¸cada:

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Resumo

Esta investigação tem como objectivo determinar as diferenças nas assinaturas isotópicas características da dieta entre o porco selvagem (*Sus scrofa*) e doméstico (*Sus domesticus*); investigar as diferentes vias e estratégias de gestão alimentaria em porcos domésticos durante o Neolítico Final e Calcolítico Inicial no Oeste da Península Ibérica a partir da análise de isótopos estáveis; e fornecer novas perceções sobre a interação humano-animal no processo de domesticação animal. Comparando assinaturas isotópicas em diferentes espécies animais, se podem identificar variabilidade nas ações de domesticação e práticas alimentares dos rebanhos.

Os materiais usados para este estudo correspondem ao sítio arqueológico de Porto Torrão (Alentejo, Portugal). Foram analisados 40 ossos de espécies animais domésticos e selvagens a partir dos métodos zooarqueológicos: taxonomia, anatomia, tafonomia, biometria e marcas antrópicas; e das análises isotópicas: $\delta^{13}C$ e $\delta^{15}N$.

Os resultados mostraram informações sobre os padrões alimentares da fauna durante o Neolítico Final e Calcolítico Inicial de Porto Torrão. Descobrimos que os porcos domésticos e selvagens, bem como os herbívoros domésticos e selvagens, têm assinaturas isotópicas semelhantes.

Abstract

During the Early Holocene, animal domestication led to significant changes in the subsistence strategies of Neolithic populations. In the Iberian Peninsula, researchers are currently studying the dynamics of animal domestication to better understand the neolithization phenomenon in the western Mediterranean. Pigs, being one of the first domesticated species, played a crucial role in providing a primary source of meat.

This research aims to determine the differences in the isotopic signatures between the wild and domestic pigs; to investigate the different pathways and management strategies in domestic pigs during the Late Neolithic and Chalcolithic period in the Western Iberian Peninsula from stable isotope analysis; to provide new insights into human-faunal interaction in the domestication process.

Materials for this study were taken from the archaeological site Porto Torrão, Alentejo, Portugal. 40 bones of domestic and wild species were analyzed using zooarchaeological methods such as taxonomy, taphonomy, biometry, butchery marks, and stable isotope analysis $\delta^{13}C$ and $\delta^{15}N$ for evaluating dietary composition.

The results provide insights into dietary patterns of the fauna during the Late Neolithic and Chalcolithic periods from this site. We found that domestic pigs as well as wild and domestic herbivores have similar isotopic signatures.

This research is part of the FoSNeC project. The research primarily aims to gather zooarchaeological data such as taxonomy, taphonomy, butchery marks, etc. Furthermore, researchers combine this data with stable isotope studies on the same samples to evaluate changes in pig management and exploitation strategies in the western Iberian Peninsula during the Neolithic period. By comparing isotopic signatures in different species, researchers can identify variability in domestication actions and feeding practices.

Keywords: zooarchaeology, C and N stable isotopes, Western Iberian Peninsula, *Sus domesticus*, *Sus scrofa*, diet, herding management, Porto Torrão, Portugal

1. Introduction

1.1 Origins of animal domestication: General view

In the early Holocene, animal domestication processes entailed essential changes to the subsistence strategies of Neolithic populations. Therefore, the dynamics of animal domestication processes on the Iberian Peninsula are studied profusely because this topic can contribute to the understanding of the Neolithization phenomenon in the western Mediterranean (Navarrete et al., 2017).

Domestication processes refer to the mutual relationship between humans and targeted plant or animal populations (Zeder, 2012). In the case of animals, domestication can be defined as appropriating the reproduction cycles to exploit all animal products in life (Ingold, 1988; Saña, 1997, 2005; Navarrete, 2017). In general, domesticates are considered productive assets in the socio-economic practices of past societies (Zeder, 2012; Russel, 2002, 2007). According to Zeder (2012), it's worth noting that the domestication process of certain plants and animals may have varied greatly among different populations and circumstances due to varying selective forces and rates. Controlling the capacity and output of animals and plants has been instrumental in reshaping the organization of societies.

Zeder (2012) outlines three distinct paths of domestication. The first is known as the "*commensal pathway*," which involves animals that feed on human waste or prey on other animals attracted to areas influenced by humans. The dog is a good example of a commensal pathway, originating from gray wolves and being the only domesticated animal before the rise of agriculture (Larsen and Fuller, 2014). In the specific case of pigs, archaeological evidence from the Near East suggests that pigs (*Sus* sp.) were likely domesticated as commensal animals. Specifically, pigs may have begun their relationship with humans by scavenging leftover human food in the first year-round settlements in forested regions. (Zeder, 2012:173). It is interesting to note that pigs, much like dogs, exhibit signs of domestication through a gradual reduction in the length of their molars (Evin et al., 2015). This change in skull morphology is likely due to the extended self-selection phase during the commensal pathway into domestication. Genetic evidence shows that multiple independent domestication events for pigs occurred in various regions. It is worth noting that pigs may have followed different pathways into domestication during these events (Larsen et al., 2007; Zeder, 2012). Larson and Fuller's (2014) review of multiple studies reveals that various animals, such as donkeys, horses, goats, sheep, and pigs, have experienced consistent bidirectional gene flow between wild and domestic stock, as indicated by archaeological and genetic evidence. It needs to be made clear which path pigs took in their domestication. While they were hunted, it is possible that they followed a commensal route due to their ability to consume human waste and use it for protein (Larson and Fuller, 2014). Early pigs in central China were linked to millet cultivators and sedentary gatherers in wetlands. Meanwhile, in Western Eurasia, they were associated with early cultivating villages in the oak woodland zone of the northern Fertile Crescent. The gradual morphological changes and changes in culling patterns suggest that domestication and commensalism lasted for at least 3,000 years (Larson and Fuller, 2014).

Secondly, Zeder (2012: 173-174) suggests that the "*prey pathway*" was the primary by which most livestock species were domesticated. While the early stages of the commensal pathway may not have required human intentionality, the prey pathway began with intentional human action. The absence of archaeologically detectable morphological changes in the first domestications processes can be attributed to the fact that the process occurred within the natural habitat of free-living progenitor species, with frequent introgression between free-living and managed animals, as well as restocking of captive animals from the wild (Zeder, 2012). Archaeologists have tracked changes in managing hunted animals such as sheep, goats, pigs, and cattle in the Fertile Crescent from the early Holocene about ca. 9600 cal BC. This has been made possible by measuring the size, sex ratios, and mortality profiles of zooarchaeological assemblages. It was observed that by ca. 8000 cal BC, people started selectively targeting young males of various species while allowing females to survive and produce more offspring (Zeder, 2012; Larsen and Fuller, 2014).

Through genetic analysis conducted by Naderi et al. (2008), it was discovered that all six lineages of domestic goats are present in populations of modern bezoar goats, which are the forebears of domestic goats, in eastern Turkey and central Iran. These results highlighted that even lacking the archaeologically detectable morphological impact on these animals, it nevertheless left a clear genetic imprint that can still be detected in the essentially fertilized descendants of these six founder lineages of domestic goats. According to Zeder (2012), genetic analyses indicate that the domestication of various lines of sheep, pigs (it is possible that pigs went through a period of being both seen as a commensal and a prey pathway during their early domestication), and cattle were also influenced by the same cultural context as goats.

In the specific case of pigs, determining the exact origin of pig domestication has been difficult due to their versatile nature and diverse interactions with humans. Furthermore, the intricacy of researching their biology and behavior has raised doubts among some scholars about the significance of studying pig domestication (Albarella et al., 2006). Prehistoric European domestic pigs descended from wild boars from Europe, northern Asia, and North Africa. Modern domestic pigs in Southeast Asia are more similar to local wild boars, which may be a different species. The dominant view of the mid-twentieth century was that pigs were domesticated in the Near East and brought to Europe by non-local farmers. The idea that pigs were only domesticated in specific areas has been challenged (Childe, 1958:34). The process of domestication is seen to be gradual and having many stages. This means that humans and pigs likely had closer relationships in various locations, and consequently, their domestication may be complex and unclear (Albarella et al. 2006).

Sheep, goats, and cattle were domesticated in Western Eurasia with cereals and pulses around 10,500-10,000 years ago. Animal management practices were established in Cyprus before domestication traits were detected. The bezoar goat and Asiatic mouflon are the ancestors of domestic goats and sheep, respectively (Larsen and Fuller, 2014; Zeder, 2006).

Bos taurus was domesticated 8000 years ago in Europe, West Africa, and northern Asia. Cattle was initially used for meat but later diversified for other purposes. Humans had already established a reliance on domestic plants and animals before intentionally creating a "direct pathway" to domesticate certain species. Horses were initially hunted but eventually became a deliberate addition for transportation purposes. They were domesticated several times in the Eurasian steppe (Bradley and Magee, 2006; Larsen and Fuller, 2014; Zeder, 2012).

1.2. First domesticates and early herds in the west of the Iberian Península

The first domestic animals in the western Iberian Peninsula can be traced back to the arrival of human groups that may have come from the western Mediterranean (Zilhão, 2000). These groups are believed to have first settled in Western Algarve and Estremadura in Portugal around 5500-5300 cal BC (Valente and Carvalho, 2019). Valente and Carvalho's (2014) and Valente’s (2016) zooarchaeological research indicates that those first communities primarily raised sheep and goats, with less focus on cattle. At the same time, determining the status of pig may be challenging. Specific morphometric and biometric data, particularly from the Carrascal site in Lower Estemadura (Portugal), strongly support the presence of pigs alongside sheep and goats (Cardoso, 2004, 2009; Valente and Carvalho, 2019).

The process of adoption of domesticates in Southwestern Iberia was a unique one. Recent research by Martín-Socas et al. (2018) and Navarrete et al. (2017, 2023) has identified various patterns of faunal abundance and animal management practices across the region, particularly in Andalusia. Recent data from Portugal highlight the diversity of domesticated animals prevalent in different areas, with Lower Estremadura (Carrascal and Lameiras) showing a higher prevalence of sheep (*Ovis aries*). At the same time, Middle Estremadura (Caldeirão) is abundant in pig (*Sus* sp.) and rabbit (*Oryctolagus cuniculus*). In the Algarve region (Vale Boi), caprines (mainly goats: *Capra hircus*) and rabbits are prevalent. These variations in animal prevalence are attributed to ecological features and varying densities in the human population (Valente and Carvalho, 2014; Davis and Simões, 2016; Valente, 2016).

During the Early Neolithic in Portugal, settlements were typically small in size and located in caves, rock shelters, or open areas. These settlements were likely inhabited by mobile human groups rather than completely sedentary communities (Bernabeu et al., 2003; Valente and Carvalho, 2014).

According to the faunal abundance data compiled by Valente and Carvalho (2014; 2019), we can observe a significant number of faunal remains from the Caldeirão, Carrascal, Pena d'Agua, and Vale Boi (Figure 1[1]). During this period, the domesticates were sheep, goats, and cattle. Most of the pig remains are uncertain or considered wild on a provisional basis. Valada Mato in the Alentejo region, is represented with fewer faunal remains of pigs (total NISP=5).

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[1] Values are based on NISP. Correspond to: area =ALE, Alentejo; ALG, Algarve; EST, Estremadura. Period= EN, Early Neolithic; MN, Middle Neolithic; LN, Late Neolithic; pre-BB, pre-Bell Beaker Chalcolithic; BB, Bell Beaker Chalcolithic. Taxa = E, most probably E. Ferus; CE, C. elaphus; CC, C. capreolus; S, swine (no species classification); SS, S. scrofa; SD, S. domesticus; B, bovines (no species classification); BP, B. primigenius; BT, B. taurus; C, caprines (no species classification); OA, O. aries; CH, C. hircus.

The Middle Neolithic period in Portugal marked a significant advancement with the construction of the first megalithic tombs. However, our understanding of this period is limited due to insufficient data from inhabited areas. Nonetheless, a few sites throughout the region demonstrate similar fundamental characteristics to those of the Early Neolithic period (Valente, 1998; Carvalho et al. 2004; Carvalho, 2008; Valente and Carvalho, 2014).

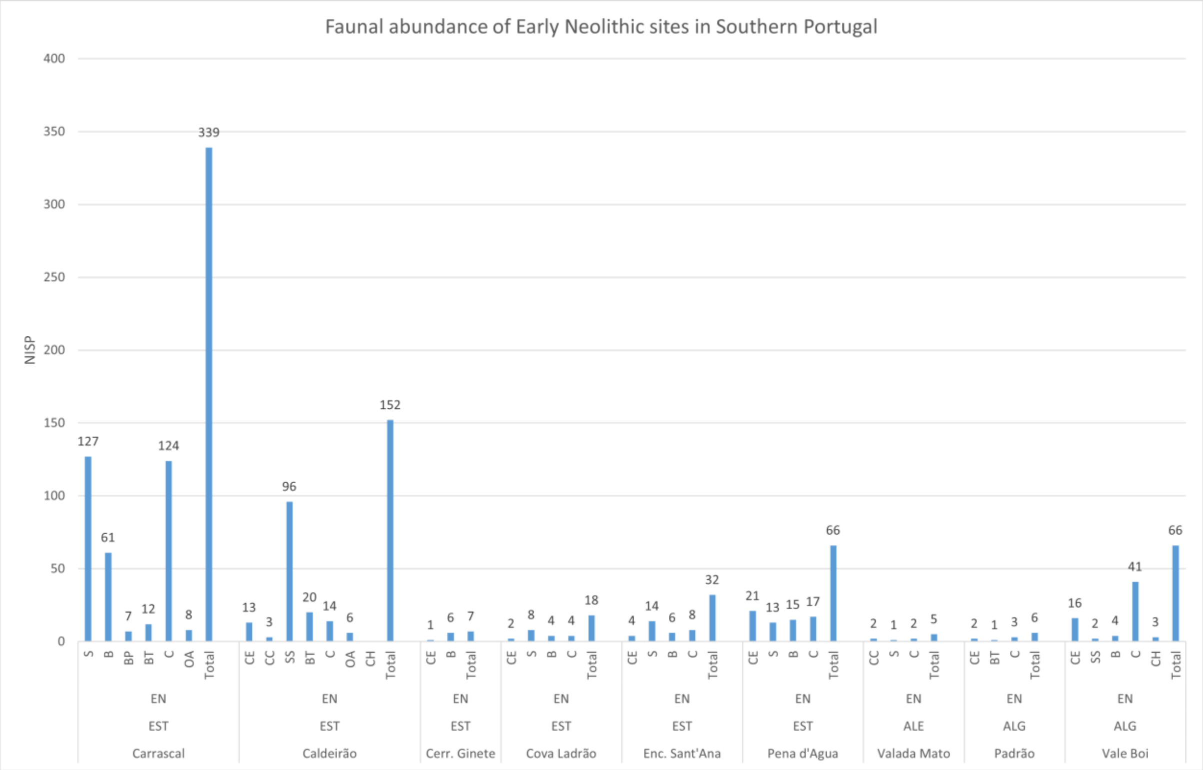

Figure 1. Faunal abundance of Early Neolithic sites in Southern Portugal. The data is taken from Valente and Carvalho (2014, table 2a. 2b; 2019, table 1). Taxa = E, most probably E. Ferus; CE, C. elaphus; CC, C. capreolus; S, swine (no species classification); SS, S. scrofa; SD, S. domesticus; B, bovines (no species classification); BP, B. primigenius; BT, B. taurus; C, caprines (no species classification); OA, O. aries; CH, C. hircus.

Faunal remains from this period are characterized according to five sites (Figure 2). These sites show contrasting patterns where caprine herding and hunting of red deer take turns in abundance (Valente, 1998; Carvalho et al. 2004; Carvalho, 2008; Valente and Carvalho, 2014). The faunal assemblages discovered at Cadaval Cave provide strong evidence of sheep and goat herding (NISP=90). In contrast, the Barrosinha in Alentejo (NISP=15) indicates minimal exploitation of ungulate resources and instead reveals an abundance of rabbits, fish, and mollusks from marine resources (Almeida, Ballesté, and Oosterbeck, 2015; Valente and Carvalho, 2019).

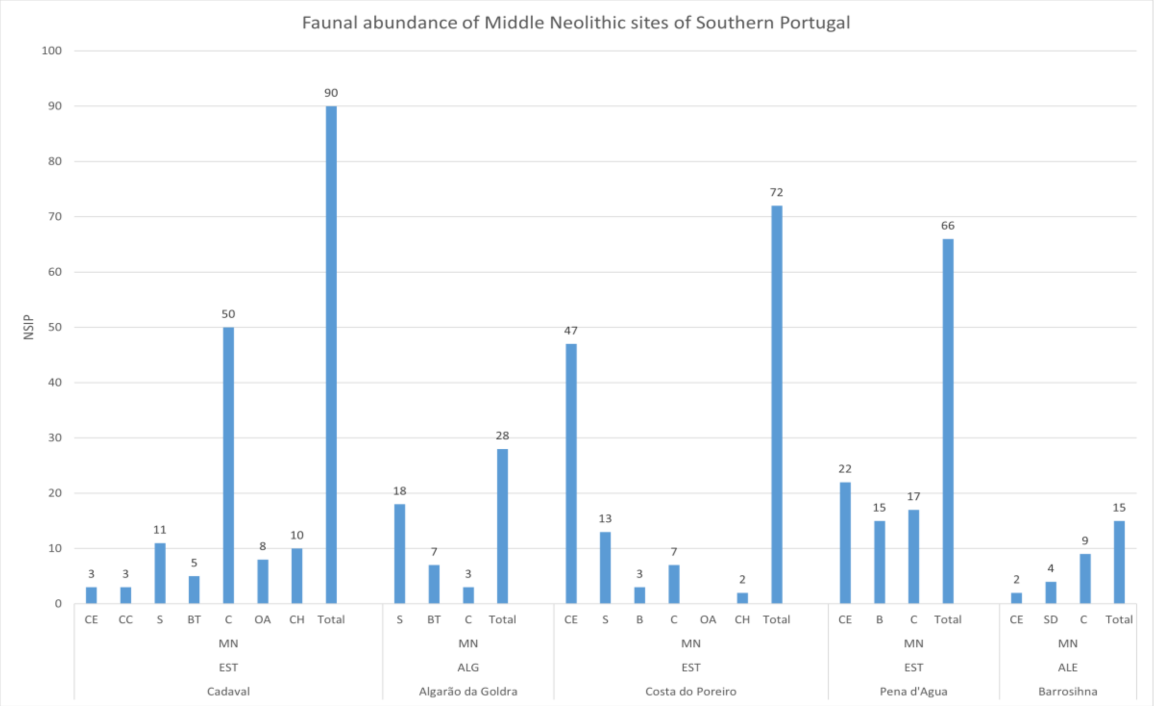

Figure 2. Faunal abundance of Middle Neolithic Sites of Southern Portugal. The data is taken from Valente and Carvalho (2014, table 2a. 2b; 2019, table 1). Taxa = E, most probably E. Ferus; CE, C. elaphus; CC, C. capreolus; S, swine (no species classification); SS, S. scrofa; SD, S. domesticus; B, bovines (no species classification); BP, B. primigenius; BT, B. taurus; C, caprines (no species classification); OA, O. aries; CH, C. hircus.

During the late 4th millennium BC, Alentejo witnessed the emergence of large enclosures and hilltop settlements. This was followed by a shift towards a sedentary lifestyle in the Late Neolithic period, which led to the establishment of a production-based economy (Valera, 2009; Valente and Carvalho, 2014).

Upon compiling data, it has been observed that there are distinct differences in animal management strategies between Alentejo and Estremadura (Figure 3). The primary collections in Alentejo sites, such as Juromenha, Moinho de Valaderes, and Predigões, show similar patterns emphasizing red deer hunting. It is uncertain whether pigs are wild, domesticated, or tamed, but they are numerous. Caprines are the most abundant domestic animal, while bovines are represented in much smaller quantities.

The settlements in Estremadura have a higher level of adaptation to husbandry and rely less on hunting, as Valente and Carvalho (2014) figured out. Domestic pigs are predominantly found in Leceia and Penedo do Lexim. Studies conducted by Cardoso and Detry (2001/2002), Albarella et al. (2005), and Moreno-García and Sousa (2013) reveal that during the Late Neolithic-Chalcolithic transition, the sizes of domestic pigs decreased while those of wild boars increased during the Chalcolithic period.

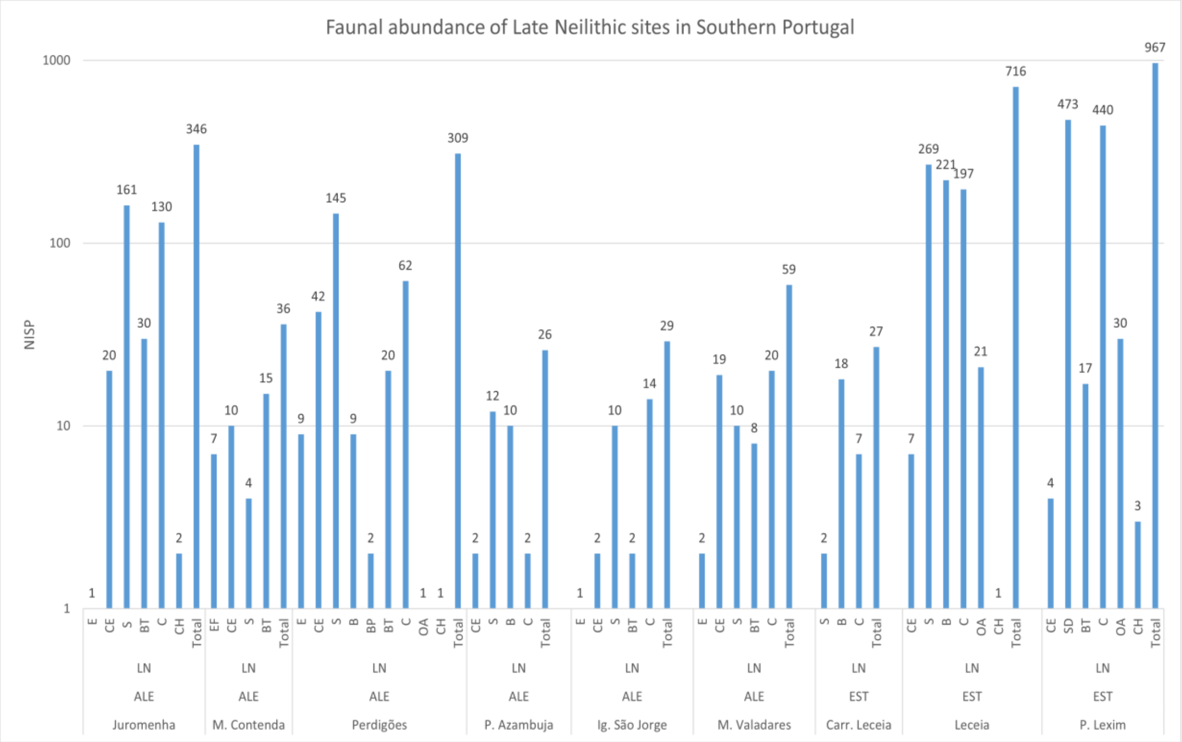

Figure 3. Faunal abundance of Late Neolithic sites in Southern Portugal. The data is taken from Valente and Carvalho (2014, table 2a. 2b; 2019, table 1). Taxa = E, most probably E. Ferus; CE, C. elaphus; CC, C. capreolus; S, swine (no species classification); SS, S. scrofa; SD, S. domesticus; B, bovines (no species classification); BP, B. primigenius; BT, B. taurus; C, caprines (no species classification); OA, O. aries; CH, C. hircus.

Between ca. 3000-2400 cal BC, the Pre-Bell Beaker Chalcolithic period witnessed a surge in the construction of sizable ditched enclosures and walled settlements. There was also a notable development in material culture, including textiles, which is evident from the finding of loom

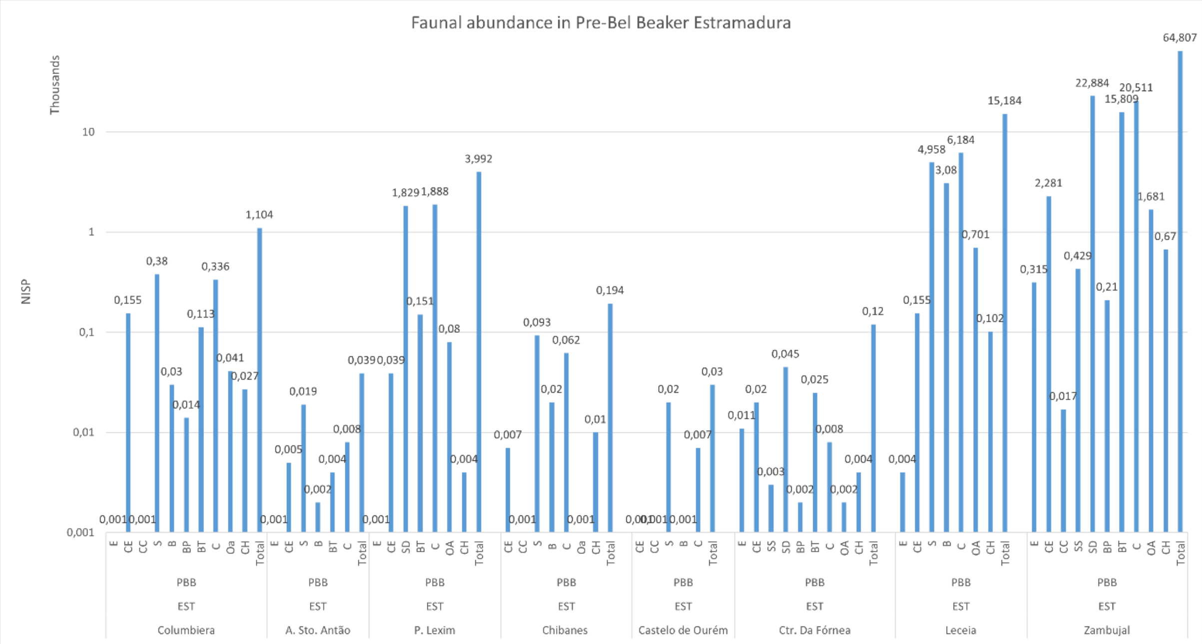

Figure 4. Faunal abundance in Pre-Bell Beaker Estremadura. The data is taken from Valente and Carvalho (2014, table 2a. 2b; 2019, table 1). Taxa = E, most probably E. Ferus; CE, C. elaphus; CC, C. capreolus; S, swine (no species classification); SS, S. scrofa; SD, S. domesticus; B, bovines (no species classification); BP, B. primigenius; BT, B. taurus; C, caprines (no species classification); OA, O. aries; CH, C. hircus.

weights (Valente and Carvalho, 2014). Leceia and Zambujal in Estremadura showed that domestic animals, especially pigs and caprines, were the most commonly present, with a comparatively lower number of cattle. Penedo do Lexim had similar patterns, with a significant presence of pigs and caprines and fewer bovines. Notably, wild game had no significant presence at these three sites (Figure 4) (Sousa, 2010; Valente and Carvalho, 2014).

In contrast, sites from the Alentejo region of this period display fewer faunal remains, with clear dominance of the pigs and the enduring existence of red deer, as it was noted also in the Late Neolithic period (Figure 5).

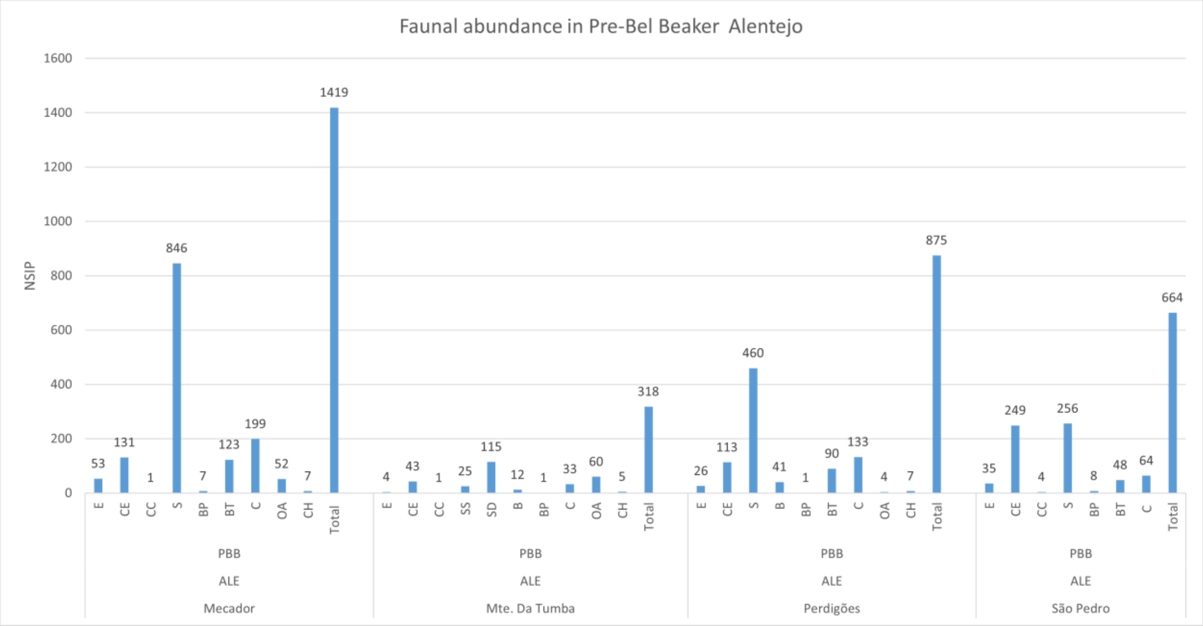

Figure 5. Faunal abundance in Pre-Bell Beaker Alentejo. The data is taken from Valente and Carvalho (2014, table 2a. 2b; 2019, table 1). Taxa = E, most probably E. Ferus; CE, C. elaphus; CC, C. capreolus; S, swine (no species classification); SS, S. scrofa; SD, S. domesticus; B, bovines (no species classification); BP, B. primigenius; BT, B. taurus; C, caprines (no species classification); OA, O. aries; CH, C. hircus.

1.3. The pig in the process of animal domestication: approaches from Zooarchaeology

This pigs significant capacity for adaptation undoubtedly helped its breeding in artificial conditions, and it soon became an essential component in farming strategies (Albarella et al., 2006). During the initial phases of domestication and early husbandry practices, crossing domestic animals with wild specimens may have been expected, as there were changes in mobility patterns due to constraints on movement, poorer diet, and an increase in stressful situations (e.g. wild boar (*Sus scrofa)* in contact with settlements) (Evin et al. 2015; Navarrete, 2017; Navarrete et al., 2017). Given the wide ecological adaptability of *Sus scrofa*, if wild animals approached or entered settlements, this would likely result in a change in their diet, with the addition of farming sub-products or the waste of human food products (Navarrete et al., 2017). Identifying their domestic or wild status can be challenging. In most regions worldwide, domestic pigs coexist with wild boars, leading to regular interbreeding. Furthermore, free-range domestic pigs often break free and establish completely feral populations. Therefore, it is not straightforward to classify pig populations as wild or domestic, and other factors must be considered (Albarella et al. 2006). According to Mayer and Brisbin (1991) and Mayer et al. (1998), there are four distinct categories of pig populations: wild, domestic, feral, and genetic hybrids, although variations may exist between them.

Domesticated pigs (*Sus domesticus*) have since become a primary source of meat due to their low-maintenance and easy husbandry practices and ability to adapt to various environments (Saña 1998; 2013). The practice of husbandry is versatile and can be carried out on multiple scales, from a small number of individuals kept in a household to extensive management of large herds across diverse landscapes like open areas and woodlands. This approach also involves seasonal foraging in cultivated fields (Balasse et al., 2015). Southeast Asia's islands are home to *Sus* species, namely *Sus scrofa*, *Sus celebensis*, *Sus cebifrons*, and *Sus barbatus*. Despite coexisting in the same region, these pig species display significant variations in their physical traits, ecological habits, and behaviors (Ruvinsky and Rothschild, 2011). Historical evidence strongly suggests that humans in the Holocene era exploited these pig species for various purposes, with *Sus scrofa* and potentially *Sus celebensis* even being transported by humans beyond their natural habitats. Classifying the island suids and their fossils is challenging, making it difficult to ascertain whether they are wild, feral, or domesticated (Albarella et al., 2006).

Research on pig genetics proves the S*us scrofa* species originated in Islands of Southeast Asia. Numerous *Sus scrofa* lineages still exist, from which modern domestic pigs are derived (Larson et al. 2005). This indicates that pig domestication happened independently in various geographically diverse locations across Eurasia. The most compelling evidence is from Europe, demonstrating the independent domestication of at least two wild lineages. These lineages are the foundation for all modern European breeds, which were subsequently improved by mixing with Asian types. Remarkably, all modern European species possess either a European or an Asian genetic signature and bear no resemblance to the sampled recent wild boar lineages from Armenia, Iran, or Turkey. It is reasonable to conclude that early farmers did not import Near Eastern domestic pigs into Europe (Albarella et al., 2006).

Several methodological approaches have been followed in archaeology to differentiate between wild and domestic forms and trace the beginnings of domestication in the faunal remains found at Neolithic sites (Albarella et al., 2006), such as:

- **Zoogeographic markers** - The presence of domestic animals as a primary indicator to determine if a species has appeared outside its natural range or in unlikely locations where it is believed human intervention was involved (Albarella et al., 2006; Zeder, 2006).
- **Biometry** – Changes in shape and size. Size analysis is a widely employed technique that zooarchaeologists rely on to explore various aspects of domestication (Albarella et al., 2006; Zeder, 2006).
- **Age estimation** – studying the lifespan patterns and changes within populations and determining their average lifetimes is essential (Albarella et al. 2006).
- **Bone structure** – It's been observed that domestication can change the internal bone structure of different animal species, which could serve as a valuable indication of domestication (Zeder, 2006).
- **Population genetics** – to identify the provenance of species (Zeder, 2006).
- **Anthropomorphic markers** – By examining animal characteristics, we can understand how domestication has impacted their evolution. Similarly, studying human-related traits offers valuable insights into our successful management of animals through selective breeding, proper care, and controlled movements. As a result, we have achieved increased safety and better access to animal resources, including artifacts, pathologies caused by tethering, nutritional stress, and the use of animals as beasts of burden (Zeder, 2006).
- **Tooth wear estimation** – Studying tooth wear on microscopic and macroscopic levels can reveal insights into changes in physical properties and diets (Albarella et al., 2006).
- **Stable isotope analysis** – we can gain insights into mammals' shifting dietary habits, geographic movements, modification of reproductive cycles and evolutionary adjustments, and further knowledge regarding their habitats (Albarella et al., 2006).

One of the most frequently used methods for distinguishing wild and domestic species in the Iberian Peninsula is the analysis of biometrics, slaughtering patterns, morphological traits, and the archaeological context (Navarrete and Saña, 2017). Extensive research on pig populations during the early and middle Holocene in the Iberian Peninsula is yet to be conducted. However, Portugal-based studies by Albarella et al., (2005, 2009), Davis and Mataloto (2012), and Davis and Detry

(2013) have examined the size changes of both wild and domestic pigs over an extended period. Meanwhile, Altuna and Mariezkurrena (2011) have provided a summary for northern Iberia, which is based on biometric differentiation between *Sus scrofa* and *Sus domesticus* from the Upper Paleolithic to the Middle Ages. The findings from these studies have revealed significant size discrepancies between the two populations (Navarrete and Saña, 2017). Navarrete and Saña (2017) reconstruct the history of suid populations (*Sus domesticus* and *Sus scrofa)* and their management in the Iberian Peninsula during Prehistory with an exhaustive analysis of the biometric data. According to Navarrete and Saña (2017), wild boar populations in the Mediterranean region are slightly smaller than those in Iberian Peninsula, particularly in older populations from the Epipalaeolithic/ Mesolithic periods. However, from 2500 to 800 cal. BC, this difference decreases, which suggests that the species may have adapted to the anthropic environment. In Iberia, analysis of Early Neolithic data reveals that various forms of husbandry were practiced in pig management. Although hunting of *Sus scrofa* intensified in some Neolithic cave sites in the north, such as Zatoya (5743–4590 cal. BC) and Marizulo (5214–4718 cal. BC), there was an increase in pig farming in other regions. An example of selective slaughtering of male animals during their meat optimum for maximized meat production has been observed at La Draga in the Northeastern Iberian Peninsula (5200-4720 cal. BC) (Saña 2011).

Additionally, studies in pig farming have shown that cross-breeding is a favored strategy, as described in ethnographic research by Albarella et al. (2006) and Marshall et al. (2014). Studies on the genetics of this species suggest that cross-breeding and intermixing were common occurrences during domestication (Larson and Burger, 2013). As more animal genome data becomes available, it's apparent that this phenomenon is widespread. Although we can now recognize these situations through advanced techniques such as geometric morphometrics and paleogenetic analyses (Evin et al., 2015), in this particular case, biometry can only provide insight into variability. Considering the variability and overlapping seen in the Early Neolithic, the potential contribution of Iberian Peninsula *Sus scrofa* populations to forming herds cannot be ignored. Several factors are often mentioned concerning the decrease in the size of specimens during the initial phases of domestication. These include changes in mobility patterns due to constraints on movement, as Lasota-Moskalewska et al. (1987) noted. A poorer diet and increased stressful situations have also been suggested (Davis and Detry, 2013; Dobney and Ervynck, 2000). Increased contact between pigs and human settlements could lead to various situations. However, archaeological evidence cannot accurately count the number of animals in the initial domestic herds. Semi-freedom strategies would encourage interactions with wild animals, and cross-breeding between animals of different statuses would be prevalent. As a result, transitional phenotypes would emerge, as Bartosiewicz et al. (2006) and Nakai (2012) noted.

The biometric analysis of faunal remains from the sites of the Iberian Peninsula dated 10,000 to 800 cal. BC confidently reveals a significant variation in pig management strategies during the Early Neolithic period (5700-3500 cal. BC). This variation was most likely due to the adoption of livestock farming, which brought economic and social changes that emphasized human influence. The noticeable changes in the size of *Sus scrofa* and *Sus domesticus* confidently suggest that pig farming was rapidly adopted during this time (Navarrete and Saña, 2017).

Unlike goats, sheep, and cattle, pigs were raised solely for their meat and raw materials. They were raised under artificial conditions to ensure a steady meat supply. The initial domestication and adoption of pigs by the first farming communities involved various converging factors, which were responded to differently by *Sus scrofa* and *Sus domesticus*. The analyses of archaeological faunal remains will aid the study of the management and dynamics of pigs in recent Prehistory (Navarrete and Saña, 2017).

1.4. Stable Isotopes in faunal remains: Carbon and Nitrogen in bone collagen

Bone is an intricate tissue that comprises inorganic calcium phosphates which settle in an organic collagen matrix. The structure of bone consists to 69% of inorganic materials, 22% of organic materials, and 9% of water (Triffitt, 1980). Around 90% of the organic portion of the whole cortical bone consists of protein collagen, while the remaining 10% represent noncollagenous proteins, lipids, carbohydrates, enzymes, and hormones (Pate, 1994).

Bone chemistry provides a powerful approach for documenting the diet and understanding the importance of specific food in past human and animal archaeological remains. Analyzing ratios of stable isotopes in bones and dental tissues of archaeological remains is an essential breakthrough in dietary and nutritional studies (Larsen, 2002).

Stable isotopes of carbon and nitrogen in bone collagen can be used as diet proxies, as they reflect average dietary protein during the last years of an animals life. Besides that, several factors should be considered as they can alter the stable isotope composition of bone collagen, e.g. local environmental variations in basal productivity and water availability, as well as metabolic factors

(Zavodny et al., 2014). An animals tissue reflects the isotopic composition of the food it consumes. The dietary information is indicated by the ratios of carbon and nitrogen isotopes in the bone collagen and the carbonate component of the inorganic calcium phosphate found in bone and tooth minerals (DeNiro and Epstein, 1981, 1981; Pate, 1994).

When discussing isotopic ratios, we use delta (δ) values expressed in parts per thousand (‰) relative to the isotopic composition of standards. The standards we use are Vienna Pee Dee Belemnite (VPDB) carbonate for $\delta^{13}C$ values and atmospheric nitrogen (AIR) for $\delta^{15}N$ values. If a substances isotope ratio is lower than the standard, it is given a negative δ value. Conversely, if a substance's isotope ratio is greater than the standard, it is given a positive δ value. A more positive δ value indicates a higher quantity of the heavier ^{13}C and ^{15}N isotopes. (Schwarcz and Schoeninger, 1991; Pate, 1994).

To accurately interpret isotopic data from animal remains, it is essential to consider the rate at which the tissues elements are replaced, known as the isotopic turnover rate. Without knowledge of this turnover, it becomes challenging to understand the factors that impact observed isotopic data (Matsubayashi and Tayasu, 2019). Obtaining data from bone collagen can provide information about an individual's average diet during the last 5-10 years of their life. The accuracy of this data depends on the bone turnover rate and the specific bone that is sampled (Pollard and Heron, 2015). The replacement process of bone collagen is longer than that of soft animal tissue. This duration significantly varies based on an organisms age, sex, and bone type (Hedges et al., 2007). As it is discussed in Tsutaya and Yoneda’s (2013) research, in the early years of life, bone minerals and collagen turnover rates are high. Additionally, bones with higher surface-to-volume ratios are expected to have higher turnover rates (Tsutaya and Toneda, 2013; Matsubayashi and Tayasu, 2019). According to Hedges et al. (2007), the rate of turnover is faster in adult females compared to adult males.

For past human-animal relations, stable isotope studies have been applied in zooarchaeological records with three main goals: reconstruction of the human diet, to explore herding and hunting strategies, and to analyze the influence of human hunting pressure on the foraging behavior of animals (Zangrando et al., 2014). However, as it appears, the most widely applied use of stable isotopes from zooarchaeological samples is to reconstruct human paleodiets. Such data allow to identify the food consumed by humans in the past and debating dietary changes or variations in landscape use by humans in different environments. Thus, the natural distribution of stable isotopes

– usually $\delta^{13}C$ and $\delta^{15}N$ from different contexts – helps to identify other food chains and ecosystems (Zangrando et al., 2014).

1.5. Carbon isotopes

Three isotopic forms of carbon are known: two stable ^{12}C, ^{13}C, and one radioactive ^{14}C. These isotopes enter the food chain as environmental carbon, which is incorporated into both terrestrial and aquatic plant tissues through photosynthesis (Pate, 1994).

Terrestrial plants exhibit three distinct photosynthetic pathways, namely C_3, C_4, and CAM. These pathways are characterized by specific $\delta^{13}C$ tissue values (Figure 6) (O'Leary, 1981, 1988). C_3 plants, which encompass most trees, shrubs, herbs, and cool-season grasses, are the primary sources of human food, such as barley, wheat, rice, beans, tubers, and nuts (Pate, 1994). On the other hand, C_4 plants are predominantly tropical and warm-season grasses such as maize, amaranth, sorghum, sugarcane, and some millets. CAM (crassulacean acid metabolism) photosynthesis is confined to arid-land succulents (Salisbury and Ross, 1991; Pate, 1994).

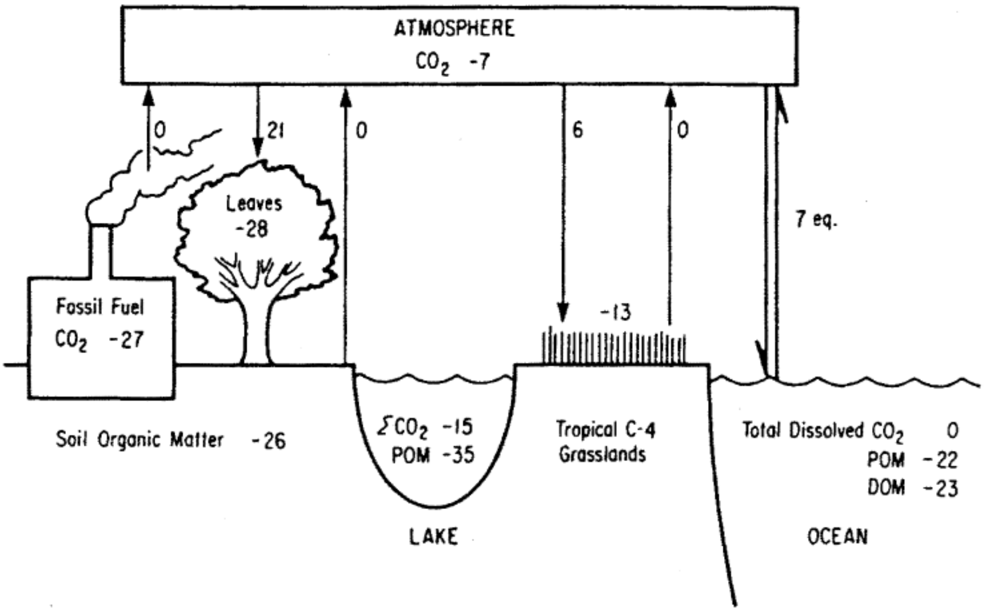

Figure 6. $\delta^{13}C$ distribution in ecosystems. (Pate, 1994).

C_4 and C_3 pathway plants yield distinct $\delta^{13}C$ values. A study by O'Leary (1988) showed that C_4 plants have a mean $\delta^{13}C$ value of -13.1‰ ± 1.2‰, while C_3 plants have a mean $\delta^{13}C$ value of -27.1 ± 2.0‰. It has been observed that the carbon isotope tissue ratio varies across different species and growing conditions. C_4 plants exhibit a variation of -7 to -16‰, while C_3 plants show a variation of -20 to -

35‰ (O'Leary, 1988; Pate, 1994). It's important to understand that freshwater aquatic plants have δ13C values comparable to terrestrial C_3 plants. However, since there is a difference in CO_2 values between atmospheric and marine bicarbonate, which varies by an average of 7-8‰, marine aquatic plants tend to have more positive $\delta^{13}C$ values than terrestrial plants (Pate, 1994).

C_3 plants have an average $\delta^{13}C$ value of -25‰, and most wild and cultivated plants of temperate, tropical, or subarctic regions are C_3; they can vary for several reasons, such as water use efficiency – when under water stress, plants have limited circulation of CO_2 through them, resulting in higher $\delta^{13}C$ values (Farquhar et al., 1989). Animals living in hotter, drier environments exhibit higher $\delta^{13}C$ values could be one of the results of water use efficiency effect (Schwarcz and Schoeniger, 2012).

The canopy effect happens when plants grow under dense trees, and CO_2 that they take up is partly derived from the decomposition of leaves from trees, which results to shifting $\delta^{13}C$ values of the plants as low as -35‰ (Murphy and Browman, 2009). The Canopy effect lowers the $\delta^{13}C$ values of the tissues of animals living in a forest.

1.6. Nitrogen isotopes

^{15}N and ^{14}N are two stable isotopes of nitrogen. In the biosphere, the majority of nitrogen is found as N_2 gas in the atmosphere. This atmospheric nitrogen supply is evenly distributed with a consistent isotope composition of around 0%. When dissolved in the ocean, N_2 has a $\delta^{15}N$ of approximately +1.0‰ (Figure 7) (Mariotti, 1983; Pate, 1994).

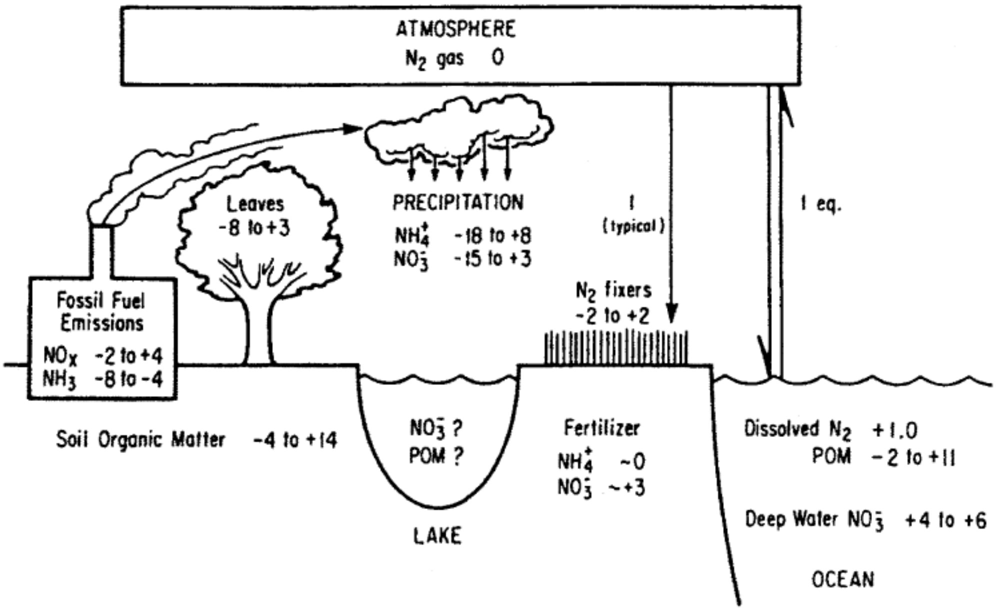

Figure 7. δ^{15}Ndistribution in ecosystems. (Pate, 1994)

As organic matter breaks down in soil and sea, there is a significant depletion of ^{14}N in comparison to ^{15}N. This leads to an increase of δ^{15}N by 5-10‰ as depth increases. The δ^{15}N values of soil organic matter range from -4‰ to +14‰, while suspended particulate organic matter in the oceans has values between -2‰ and +11‰ (Pate, 1994). As a result, aquatic organisms typically have more positive δ^{15}N values compared to terrestrial organisms. This is because the nitrates used by phytoplankton, which are at the bottom of the marine food chain, have higher levels of ^{15}N compared to nitrates used by plants on land (Mariotti et al., 1980; Pate, 1994). Terrestrial plants obtain their nitrogen from a range of sources. These include bacteria that convert N_2 gas into a usable form, bacteria that break down dead plant and animal matter, and nitrogen derived from atmospheric precipitation (Pate, 1994).

Terrestrial plants that fix atmospheric nitrogen have mean δ^{15}N values of -1‰ with a typical range of -2 to +2‰, while plants that obtain their nitrogen from the ^{15}N-enriched soil solution nitrate and ammonium ion have mean δ^{15}N values of about +3‰ (DeNiro and Hastorf, 1985; Pate 1994). Although there is a significant overlap, average δ^{15}N values can differentiate between marine plants and non-N_2-fixing terrestrial plants. These differences are passed along the food chain. Also, there is a 3-4‰ enrichment with each increase in trophic level, starting from the base of both marine and terrestrial trophic systems (Figure 8) (DeNiro 1987, 1984; Pate, 1994).

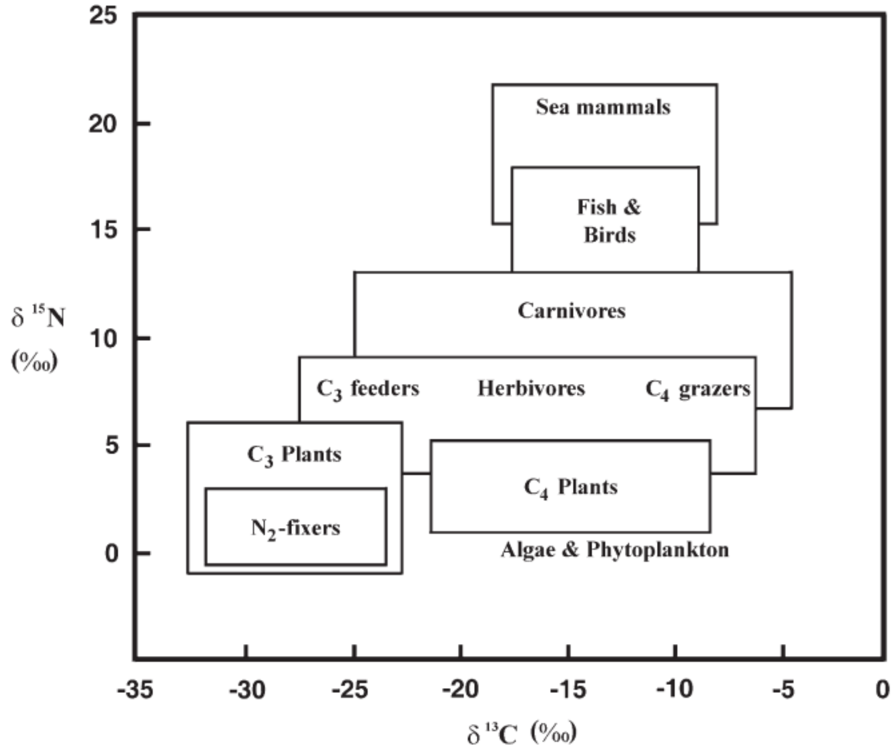

Figure 8. Generalized isotopic trophic level diagram for marine and terrestrial (Pate, 1994)

1.7. The pig in early livestock practices: an isotopic approach

Sus domesticus could have a different dietary isotopic signature than *Sus scrofa* in this context. Being omnivorous, domesticated pigs are highly adaptable to different ecological niches influenced by humans (Navarrete et al., 2017). When given the freedom to roam, they tend to have a diet resembling that of their wild counterparts, consisting primarily of plants with occasional animal components. However, pigs that are kept in proximity to human settlements or raised for the purpose of fattening in households may also consume food waste from humans and by-products of plant and animal cultivation (Balasse et al., 2016).

Different pathways and management methods could lead to different isotopic signatures, which can also provide valuable insights into human-faunal interaction in a domesticated landscape while offering new perspectives on animal domestication and the differences in management strategies between archaeological sites, such as environmental conditions, site use, and community organization (Navarrete et al., 2017). By comparing the δ^{15}N isotopes of domestic and wild animals in the local ecosystem, valuable insights can be gained regarding the trophic level of pig food sources and shifts in agricultural practices. Moreover, δ^{13}C values can effectively indicate the extent to which C_4 crops contribute to the diet, particularly in areas where the surrounding wild environment is dominated by C_3 plants (Balasse et al., 2016; Pechenkina et al., 2005; Ervynck et al., 2007; Hamilton et al., 2009; Madgwick et al., 2012; Frémondeau et al., 2013).

To conduct this research, it is crucial to examine past studies that have explored management strategies using the stable isotope method. According to a study conducted by Navarrete et al. (2017), Early Neolithic pigs in the Iberian Peninsula were fed a diet that was in line with C_3 plant ecosystems. This was determined through $\delta^{13}C$ analysis of pig samples, which ranged from -20.6 (±0.7‰) to -20.2‰. This dietary pattern was typical for the NE Iberian Peninsula during the early to middle Holocene period. It was suggested that herbivorous animals with the highest $\delta^{13}C$ values may have consumed drought-resistant vegetation, including shrubs. The study also pointed out that the $\delta^{15}N$ values of the pig samples ranged from +5.1 (±1.6‰) to +7.6 (±1.1‰) and were statistically similar to those of wild and domestic herbivores on some sites. However, pig samples from Can Sadurni and Reina Amalia-Caserna de Sant Pau had higher $\delta^{15}N$ values than the local herbivores by an average of 2.5‰ and 1.4‰, and in some cases were similar to the $\delta^{15}N$ values of carnivores which can be a result of home-base system management of pigs on these sites, where they might have the possibility to walk around the settlement (Navarrete et al., 2017).

On the other hand, Madgwick et al. (2012) study of isotopic signature in faunal assemblages of two midden sites (Llanmeas, Potterne) found that nitrogen values in pig samples showed a wide range, indicating the use of diverse husbandry and feeding methods. The isotopic results from both sites, Llanmeas and Potterne, showed that varied strategies were employed to raise large numbers of pigs. These findings suggest that different approaches were used to meet the challenges of pig farming. But, it's difficult to determine the feeding habits of pigs due to their varied herbivorous diets. In Llanmaes, most pig samples fall within the range of caprines and cattle, indicating that most pigs mainly consume plants. However, some adult pigs have higher $\delta^{15}N$ values than herbivores, suggesting they also consume animal protein regularly.

Interestingly, pigs with high $\delta^{15}N$ values have low $\delta^{13}C$ values, while those with common $\delta^{15}N$ values have high $\delta^{13}C$ values. This indicates a continuum between two diets: some pigs are omnivores who eat meat scraps or excreta, and others consume an herbivorous diet that includes saprotrophic and mycorrhizal fungi from woodland environments. Hamilton et al. (2009) found that Neolithic pigs in the British Isles consumed more woodland resources, while Iron Age pigs ate more plant and animal protein from open environments. Therefore, it's possible that the Potterne pigs were raised in woodland environments and had a more herbivorous diet, while the Llanmaes pigs were more omnivorous (Madgwick et al., 2012).

According to Balasse et al. (2015) research on three sites in Romania (Bordusani, Hârsova, and Vitânești), the $\delta^{15}N$ values measured in pig humeri varied between 8.2‰ and 9.5‰. These values are similar to those found in dogs, indicating that both are at similar trophic levels. The pigs observed in all three locations had a high trophic level, suggesting they consumed much animal protein. This implies that they likely consume human waste, possibly by scavenging in and around areas designated as refuse dumping grounds, and may also be fed leftovers intentionally. Pigs in traditional pastoral societies are often fed whey, hunted game, domestic stock, fish, and dairy by-products. The research suggests that the pigs are managed within households rather than through extensive herding and reside near the settlements.

While wild boars have $\delta^{13}C$ values comparable to those of red deer, aurochs, and horses, their values are consistently higher than -22‰ and usually above -21‰. This indicates that their $\delta^{13}C$ values, which range from -12.7‰ to -19.6‰ , are similar to those of other large wild herbivores living in open habitats.

In summary, pigs raised in a home-based system with complete or temporary stabling tend to have a more controlled diet than free-range ones. Enclosed pigs may primarily consume plant materials and be given leftover domestic food, including animal products, due to increased human control. As a result of this type of feeding management, it is expected that the collagen $\delta^{15}N$ values of the pig may be higher than that of local herbivores. However, this could also depend on their diet's quality and proportion of protein. On the other hand, pigs raised in semi-free or free-range systems are likely to obtain most of their nutrition from available plants, which may include some wild animal consumption. Within this strategy, it is expected that the collagen $\delta^{15}N$ values of the pig will be similar to those of local herbivores (Navarrete et al., 2017; Balasse et al., 2015; Madgwick et al. 2012).

2. The archaeological site: Porto Torrão (Ferreira do Alentejo, Beja, Portugal)

The archaeological site of Porto Torrão is located in Ferreira do Alentejo, Beja, Portugal (38º04’28.03’’ N; 8º07’35.80’’ W) (Figure 9).

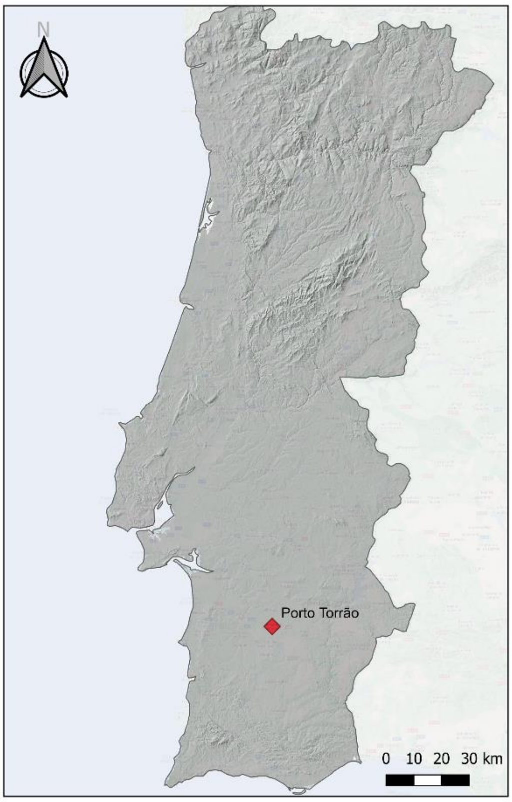

Figure 9. Location of site Porto Torrão (Paatashvili 2023)

In geomorphological terms, the Porto Torrão site is part of the Baixo Alentejo peneplain, bounded to the north by the Serra de Portel, to the west by the Serra da Vigia of the Sado River, to the south by the Serra do Caldeirão and to the east by the Serra de Barrancos (Valera, 2013). In addition, the archaeological site is crossed by the Ribeira do Vale do Ouro (stream). The latter runs across the archaeological site, which suggests a centralization of this natural source, making it critical for societies that set their economic subsystems upon agro-pastoral activities (Valera, 2013).

From a geological point of view, the archaeological site from Porto Torrão is implanted in the Ophiolitic Complex Beja-Acebuches (COBA), consisting of meta gabbros that rarely appear (Fonseca, 1995). The result of the chemical weathering of these rocks translates into an alteration layer, which in the region is commonly known as “Barros de Beja” due to its clayey matrix. However, these soils, with low permeability, are of exceptional fertility, thus detaining an excellent aptitude for agriculture (Fonseca, 1995; Duque, 2005; Rodrigues, 2015). Porto Torrão is situated in the Gabros de Beja Aquifer System, which is known for being a significant source of groundwater in the Alentejo region, with a shallow water table. In the particular area of Ferreira do Alentejo municipality, recent studies have shown an average annual recharge of 52-105 mm/year, allowing for the sustainable utilization of this resource today (Duque, 2005; Rodrigues, 2015). In certain areas, such as peneplains, drainage networks, and soils, it is common to experience poor drainage during winter, resulting in waterlogged soils. This is not solely due to a weak flow gradient but also because these soils have a high level of waterproofing, which causes them to retain water from precipitation or runoff from nearby areas (Duque, 2005; cited from Rodrigues, 2015).

According to Rodrigues' (2015) analysis of various paleoenvironmental indicators, the climate during Porto Torrão's occupation was warmer and drier than the current climate. Climatological data for lower Alentejo indicate an average annual high temperature of 15 to 17.5°C, with increased precipitation in autumn and winter and limited water during summer (Agency et al. of Meteorology of Spain / Institute of Meteorology of Portugal – Department of Meteorology and Climate, 2011). Thus, during the prehistoric occupation of Porto Torrão, the dry period could be severe, implying rigorous and planned water management for such a precious asset in agro-pastoral societies (Rodrigues, 2015).

2.1. Research history

The archaeological site of Porto Torrão has been widely recognized since the early 1980s for its immense size and historical occupation from the Late Neolithic to the Bell Beaker period. It was discovered in 1981, from archaeological prospection carried out by J.M. Arnaud, recognizing a settlement of about 50 to 100 hectares. The archaeological works conducted in 1982 and 1985, covering a total area of $34m^2$ next to an elevation in the center of the site, enabled the observation of the local stratigraphic sequence, detection of anthropic positive structures, numerous artifacts, and faunal data. Surveys on a small elevation revealed a 1-meter-thick stratigraphic sequence with three layers. Two phases of occupation were established, with Layer 1 being a pre-Bell Beaker context and Layer 3 being a Bell Beaker context. The site was continuously occupied without any significant gap (Arnaud, 1993, pp. 45-46; Rodrigues, 2015).

In 2002, ERA-Arqueologia, S.A. carried out a rescue intervention due to the high voltage line Alqueva-Ferreira do Alentejo-Sines in Porto Torrão. The original plan was modified to lessen the impact on the site, resulting in only two posts installed next to the site boundary and one inside. Of the three excavated posts, only post 181 would reveal well-preserved archaeological contexts and the identification of negative structures dug in the rocky substrate (ditch 1 and ditch 2) (Valera and Filipe, 2004). The full excavation was conducted at the deployment points, and the preliminary results of these interventions have already been published (Valera and Filipe, 2004). The project provided insights into the prehistoric occupation of the archaeological site. It was discovered that Porto Torrão was a ditched enclosure site type, contrary to earlier assumptions in the 1980s by J.M. Arnaud that a walled structure existed at the site (Rodrigues, 2014; Valera and Fillipe, 2004). Based on archaeological materials found in the fillings and deposits of structures, ditch 1 (outer) would have a chronology attributable to the second half of the 4th Millennium - beginning of the 3rd

Millennium (Late Neolithic) and ditch 2 (inner) during the 3rd Millennium (Chalcolithic) (Figure 10) (Valera, 2013).

From 2008 to 2010, multiple archaeological companies (Neoépica, Archaeo'Estudos and Crivarque Lda.) participated in the archaeological works, revealing over 3000m^2 of negative structures with various morphologies and chronologies. These findings required to reconsider the sites chronological frame, dating from the second half of the 4th Millennium to the Bronze Age. The site extends over 500 ha, displaying a double-ditch system, several pits (inside and outside the enclosed area), and some megalithic graves (Rodrigues, 2014). During the archaeological works, a multitude of structures were discovered. Significant ditches were identified in sectors 1, 2 (excavated by Neoepica), and 3 East (excavated by Crivarque). These sectors are situated on the left bank of Ribeira do Vale do Ouro. (Rodrigues, 2015) (Figure 11).

Figure 10. Location of the archaeological works. Blue: intervention by J. Arnaud; green: ERA Archeology; red= Neoépica, Crivarque, and Archaeo'Estudos. In yellow: possible orientation of the Pits (re-drawn by Pereira, 2016).

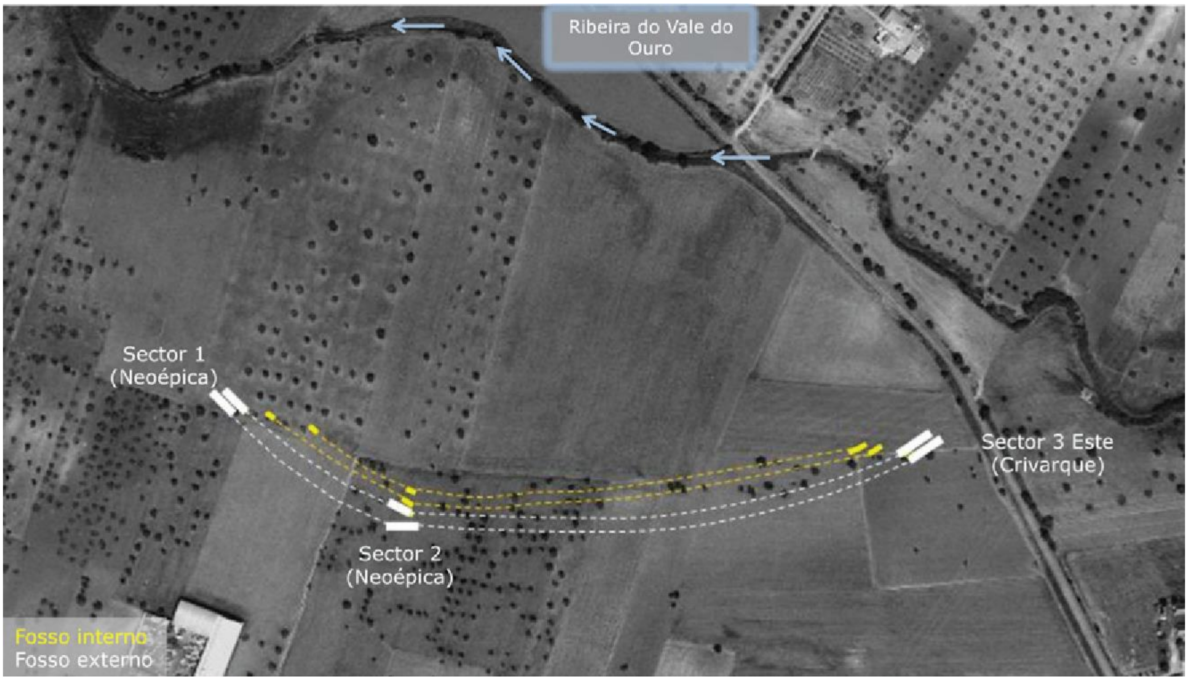

Figure 11. Location of ditches identified on the left bank of Bibeira do Vale do Ouro. In yellow its marked internal and external limits of the internal ditch, and in white are marked internal and external limits of outer ditch. (Rodrigues, 2020)

In this context, our research is part of the interventions carried out from 2003 by ERA-Arqueologia S.A. Archaeological works would focus on the total area over which each of the high voltage line posts. Although archaeological material was collected from the different posts, in this work we will focus on Post 181.

Post 181 is located in the most central area from the settlement, north of Ribeira do Vale do Ouro. Several negative structures were identified (dug in the rocky substrate), filled by sequences of preserved deposits, providing a set of new data relevant for understanding this site (Valera, 2004).

Two distinct periods were observed regarding the sites occupations (Valera, 2013):

1. Ditch 1 (inner ditch) corresponds to the Late Neolithic period (Sac-2232: 4390±50 3325-2901 cal. BC) (Figure 12).
2. Ditch 2 (outer ditch) corresponds to the Chalcolithic period (Sac-2233: 3910±80 2619-2141 cal. BC) Ditch 1 was identified in the SW corner of the excavated area (3,5 m x 2,5 m and 3 m deep). The stratigraphy observed in Ditch 1 demonstrates a sequence of several distinct moments in the process of filling the negative structure, corresponding to successive deposits of sediments (Valera, 2004) (Figure 13).

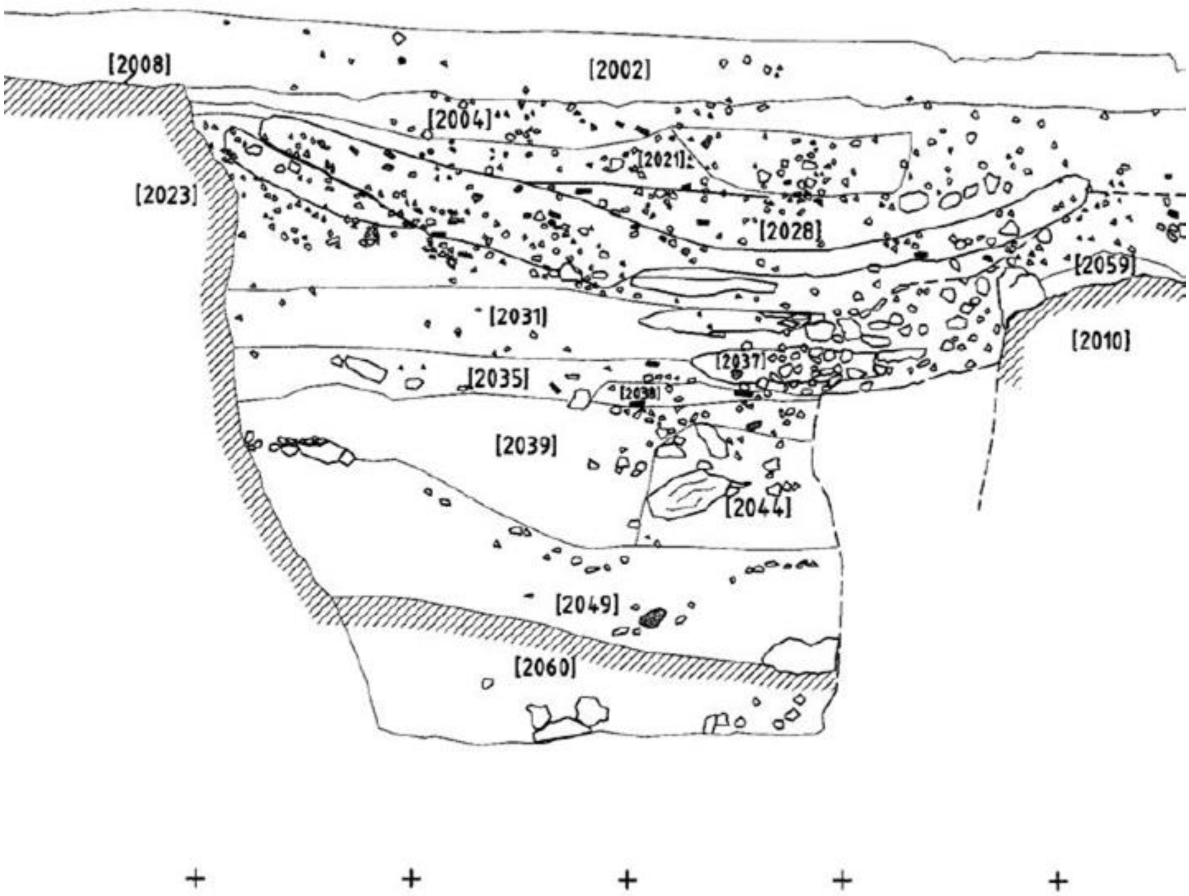

Figure 12. Location of the deposits from which the samples in Ditch 1 (Valera 2013)

Ditch 2 was identified in the NE corner of the excavated area (1 m x 10 m, and 1 m x 5,90 m and 3,40 m deep), roughly 8 m from Ditch 1. The stratigraphy of this Pit is limited to a succession of deposits, apparently with a very homogeneous artifactual assemblage (Valera, 2004) (Figure 13).

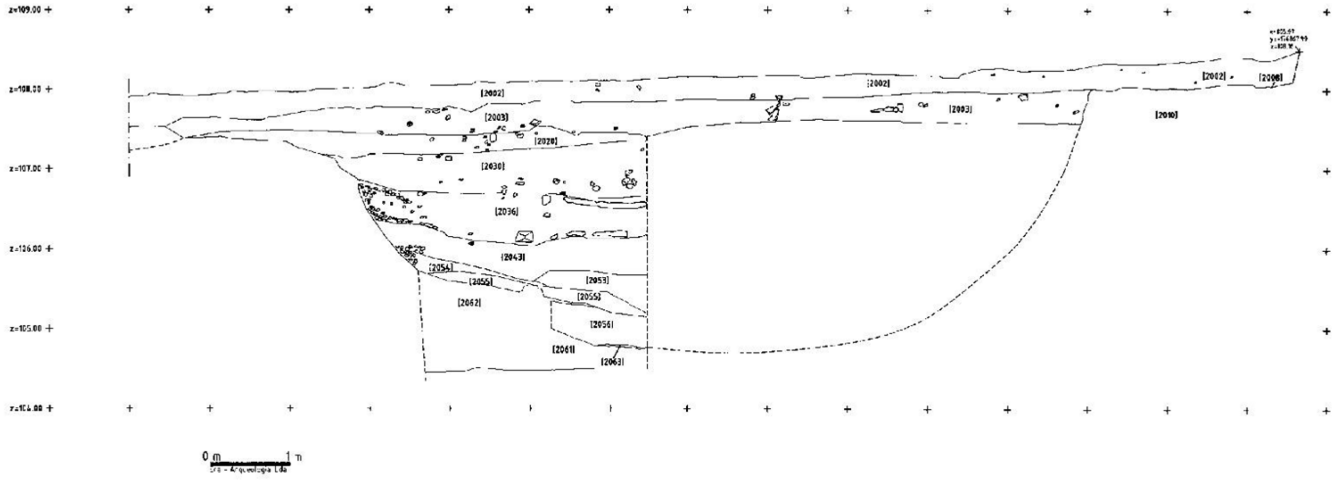

Figure 13. Location of the deposits from which the samples in Ditch 2 (Valera and Fillipe, 2004)

Ditch enclosures have been discovered exponentially in the southwestern of the Iberian Peninsula, sparking different interpretations and discussions about the negative structures surrounding them. One model proposes that the pit-type structures were used for water conduction and drainage, vital assets for agro-pastoral societies. However, other models reject this idea and offer alternative explanations, suggesting that the structures were used for delimiting space or had a symbolic and ritual significance in practices that involved opening and closing them (Rodrigues, 2015).

2.2. Zooarchaeological data

Porto Torrão was only the subject of a few zooarchaeological studies, including those done by Arnaud in the 1980s, and Correia et al. (2016). In 1993, José Arnaud presented the first archaeozoological analysis Angela von den Driesch conducted (Pereira, 2016). However, according to Pereira (2016), it is crucial to consider the sampling character of the data provided since the total dimension of the analyzed osteological assemblage and quantifications of NDR (Number of Determined Remains) and MNI (Minimum Number of Individuals). Although, the exact provenance of the faunal remains is missing in the data.

During the excavations carried out in the Poste 181 area, a large amount of mammalogical and malacological fauna was recovered. In 2002, Francisco Rosa Correia, Claudia Costa, and Antonio Valera studied the faunal remains of vertebrates found in Pit 1, dating back to the Late Neolithic (3325-2901 cal BC).

The faunal material in pit 1 shows: 15% Lagomorph; 3% *Canis familiaris*; 2% *Equus* sp.; 37% *Sus* sp. (Figure 3); The same study suggests anthropic marks in pit 1 as 171 green breaks, nine cut marks, two perforations, and four worked bones (Figure 14). According to the data available, suids were important in the Porto Torrão site during the Late Neolithic to the Bell Beaker period. The results suggest that during the Late Neolithic to the Pre-Bell Beaker period, there was an increase in cattle, a decrease in caprines and lagomorphs, and the continued importance of suids. However, from the Late Neolithic to the Bell Beaker period, there was a noticeable increase in cervids and equids, and caprines and lagomorphs continued to decline.

If we compare the results of Porto Torrão with the rest of the sites of similar chronology, we can see how the suids are the most prevalent group and the percentage of cervids is lower (Figure 14). Another significant research about faunal remains of Porto Torrão was done by Pereira (2016) as a part of a Ph.D. project, where the percentages shown are based on two distinct and well-dated

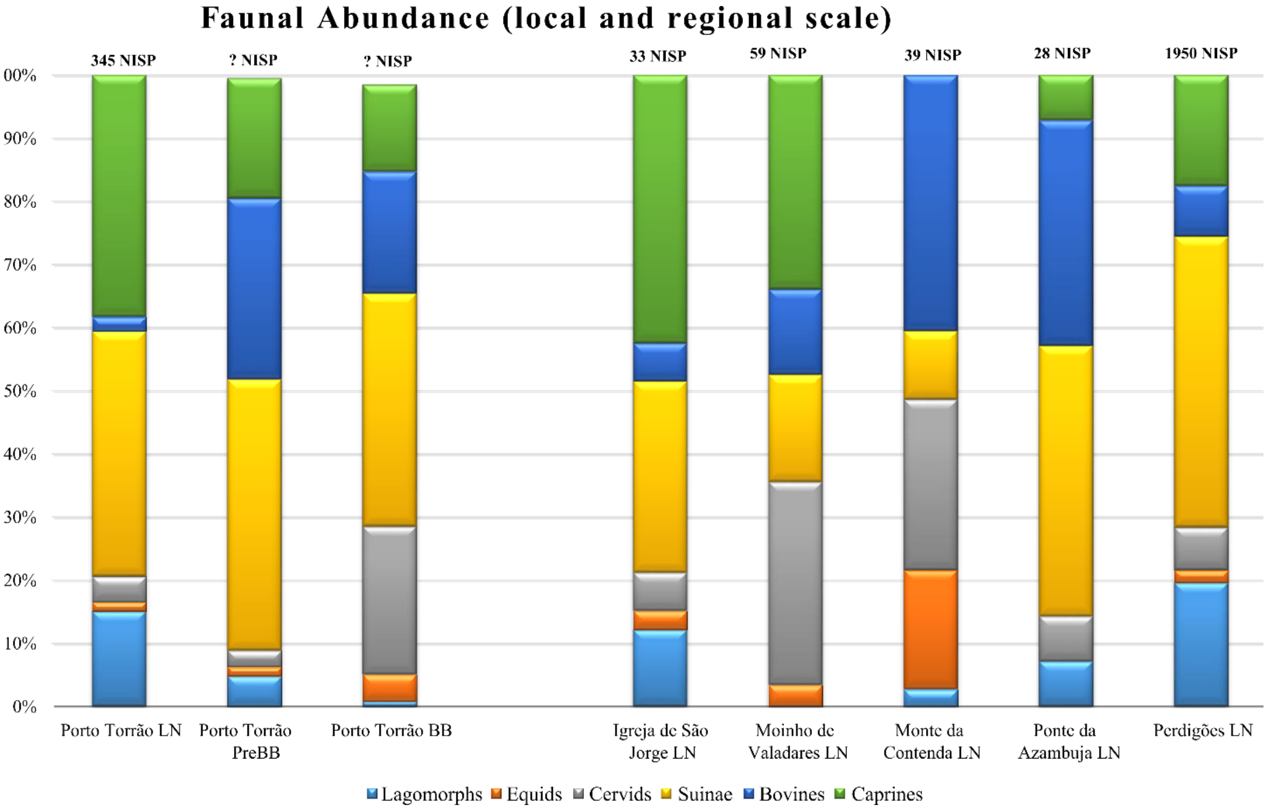

Figure 14. . Faunal abundance of Neolithic period sites in Portugal. (Coreira et al., 2019)

archaeological layers, which gives the possibility to point out significant differences in the presence and absence of species between the pre-Bell Beaker and Bell Beaker occupation.

The assemblage that was analyzed consists mainly of domestic animals, with the pig (*Sus* sp.) and cattle (*Bos taurus*), sheep (*Ovis aries*), and goats (*Capra hircus*) having significantly high percentages (Pereira, 2016).

On the other hand, the fauna appears to have significantly reduced quantifications, highlighting the red deer (*Cervus elaphus*) as the most hunted specie. Pereira (2016) also suggests an evident change in the subsistence strategies of the Porto Torrão site, from the pre-Bell Beaker to the Bell Beaker period, with the hunting of wild animals: red deer (*Cervus elaphus*), wild boar (*Sus scrofa*), horse (*Equus* sp.) and aurochs (*Bos primigenius*). Rabbit (*Oryctolagus cuniculus*) hunting decreased during the period analyzed. The archaeozoological analyses suggests that the slaughtering pattern is adult individuals for cattle (*Bos taurus*), caprines (*Ovis aries* and *Capra hircus*), red deer (*Cervus elaphus*), and wild boar (*Sus scrofa*). However, domestic pigs (*Sus domesticus*) are typically slaughtered at a much younger age of 18-24 months old.

The taxonomic list for the bones found in the Pits on the southern edge of the settlement is similar to the one previously presented by Arnaud (1993) for the interior. The faunal assemblage mainly consists of domestic animals, with pigs being the most prevalent, followed by sheep, goats, and cattle. This indicates that the population was primarily sedentary, relying on livestock for food subsistence, with some hunting activity as complementary.

Based on the slaughter ages, it is evident that the pig was primarily bred for meat production, as more than half of the analyzed remains were from animals under one year old. On the other hand, cattle were slaughtered at senile age, which could indicate their use for meat and milk production and traction power. Red deer hunting increased during the Bell Beaker period. A small number of small vertebrates have been documented; only the rabbit and crow have been identified. Leporids are believed to be present due to the remains of food. At the same time, the presence of crows requires clarification, as no signs of human manipulation have been found (Pereira, 2016).

3. Materials and Methods

3.1. Materials: Selection of faunal samples

In order to conduct this research, we carefully selected samples from the archaeological site Porto Torrão (from the sector/pit Poste 181). We chose 40 specimens of faunal remains from two distinct chronological layers: 20 samples from the Late Neolithic period and 20 samples from the Pre-Bell Beaker Chalcolithic period.

To establish the local $\delta^{13}C$ and $\delta^{15}N$ isotopic baselines of pigs, a diverse range of herbivores, omnivores, and carnivores has been selected for the isotopic analysis, including 16 domestic and wild herbivores, 21 omnivores, and 3 carnivores.

The samples consist of 20 specimens from the Late Neolithic, which includes 1 cattle (*Bos taurus)*, 3 *Ovis/Capra* (*Ovis aries/Capra hircus*), 8 pigs (*Sus domesticus),* 1 dog (*Canis familiaris)*, 1 deer (*Cervus elaphus)* and 4 wild boar (*Sus scrofa*) (Table 1). The other *20* samples, from the Chalcolithic period, consist of 2 cattle (*Bos taurus)*, 2 sheep (*Ovis aries)*, 1 *Ovis/Capra* (*Ovis aries/Capra hircus*), 7 pigs (*Sus domesticus)* 2 dogs (*Canis familiaris)*, 4 deer (*Cervus elaphus)* and 2 wild boar (*Sus scrofa*) (Table 2).

3.2. Methods

3.2.1. Zooarchaeology analysis

The zooarchaeological analysis of samples has focused on studying taxonomic and anatomical representation frequencies, estimates of the age of death of the domestic and wild taxa, butchering processes and techniques, and the characterization of natural processes on bone surfaces.

Each bone was classified anatomically and taxonomically using Barone (1999). The identification of taxa was followed by O'Connor (2000). Faunal remains of *Sus* were identified according to components of variation in measurements of pig bones and teeth and using measures to distinguish wild from domestic pig remains Schmid (1972). It should be mentioned that *Ovis* and *Capra* are anatomically very similar, which complicates their identification.

Table 1. Selected samples from the Late Neolithic period of Porto Torrão (sector/pit: Poste 181)

Specimen ID	*UE*	*Specie ID*
PT-2	2046	*Bos taurus*
PT-3	2031	*Sus domesticus*
PT-4	2031	*Ovis aries*
PT-5	2031	*Canis familiaris*
PT-7	2038	*Sus domesticus*
PT-8	2038	*Cervus elaphus*
PT-9	2039	*Sus domesticus*
PT-10	2034	*Sus scrofa*
PT-11	2031	*Ovis/Capra*
PT-12	2037	*Sus domesticus*
PT-13	2049	*Ovis/Capra*
PT-14	2044	*Ovis aries*
PT-16	2021	*Ovis/Capra*
PT-19	2047	*Sus domesticus*
PT-20	2035	*Sus domesticus*
PT-22	2059	*Sus domesticus*
PT-23	2021	*Sus scrofa*
PT-24	2031	*Sus domesticus*
PT-26	2044	*Sus scrofa*
PT-28	2049	*Sus scrofa*

Table 2. Selected samples from the Chalcolithic period of Porto Torrão (sector/pit: Poste 181)

Specimen ID	*UE*	*Specie ID*
PT-29	2003	*Sus domesticus*
PT-30	2054	*Ovis/Capra*
PT-31	2042	*Sus domesticus*
PT-33	2030	*Sus domesticus*
PT-34	2030	*Cervus elaphus*
PT-35	2053	*Sus scrofa*
PT-36	2053	*Sus domesticus*
PT-37	2053	*Bos taurus*
PT-38	2043	*Cervus elaphus*
PT-39	2043	*Sus domesticus*
PT-40	2043	*Canis familiaris*
PT-41	2045	*Cervus elaphus*
PT-42	2045	*Ovis aries*
PT-43	2055	*Bos taurus*
PT-44	2055	*Ovis aries*
PT-46	2057	*Cervus elaphus*
PT-47	2057	*Sus domesticus*
PT-48	2057	*Canis familiaris*
PT-68	2043	*Sus scrofa*
PT-69	2004	*Sus scrofa*

To differentiate between *Ovis* and *Capra*, various methods have been utilized. One such method is presented by Prummel and Frisch (1986), which collected morphological criteria to successfully identify skeletal remains of adult *Ovis* and *Capra* from early medieval sites in Western Europe. In another study, Zeder and Lapham (2010) evaluated criteria developed to distinguish between selected postcranial elements of sheep and goats using modern specimens from various collections. The features analyzed included the distal humerus, proximal and distal radius, distal tibia, distal metapodials, astragalus, calcaneus, and the first and second phalanx. Boessneck (1969) represents accurate research to identify specific *Ovis* and *Capra* morphology characteristics.

When examining an osteological assemblage, the Number of Identified Specimens (NISP) is the primary quantitative measurement that is recorded. Used initially in zooarchaeology, this method calculates the number of skeletal elements identified based on the bone type and taxon. The process involves sorting the bones into taxa and skeletal element categories to arrive at the NISP estimate. NISP is a fundamental technique commonly used to determine the relative abundance of specimens in a faunal assemblage collection. While some consider NISP to be a rudimentary classification of a site or skeleton, there are various approaches to compute it. However, when calculating sample sizes for inferential statistics, NISP should not be used as it can inflate statistical significance. A different approach for measuring samples, known as the Minimum Number of Individuals (MNI), was utilized. In 1953, White established this method, which determines the smallest number of animals present in a skeletal collection. This technique is highly useful in determining the minimum number of animals present in a group of bones. The principle behind MNI is as follows: if there are two bones of the same species, such as the left and right humerus of *Sus*, the MNI is 1. If there are two left humerus bones of *Sus*, the MNI is 2, and so on (Klein and Cruz-Uribe, 1984).

An essential part of the documentation of the bones is their measurement. Comparable measurements of samples can employ objective ideas of the size or form of the animal and its domestic or wild status, specifically for the determination of pigs in this context. Therefore, the standardized criteria published by von den Driesch (1976) were used for biometry.

The taphonomic analysis is essential to faunal assemblages from archaeological sites. The study of butchery marks can be crucial in characterizing the handling and consumption processes of animal carcasses. It also helps us to understand the general socio-economic conditions of societies (Rixson, 1988). Therefore, the location and orientation of each butchering mark was recorded. The collected data can identify signs of cutting, chopping, slicing, dismemberment, filleting, and skinning resulting from primary, secondary, or tertiary butchery (Rixson, 1988). When it comes to studying zooarchaeological materials, faunal bones can indicate thermal changes through alterations in color. The types of fractures, including longitudinal, transverse, and oblique, are crucial characteristics to observe. Bones that have been heated may exhibit changes in texture, morphology, and color, often appearing darker with shades of brown and black (Navarrete, 2020).

While studying the bones, the taphonomic analysis of natural agents provides a basis for assessing the potential value of bone weathering. It is well-known that a direct correlation exists between ambiental, chemical, and biological agents and the decomposition rate of organic matter. In other words, sediment type, pH value, temperature, atmospheric agents, and humidity directly influence the mineral matrix, collagen content, and structure of bone (Saña, 2014). To identify the taphonomic characteristics of our samples, we followed Behrensmeyer (1978), which presents a descriptive categorization of weathering based on systematic observations of recent bones. In his research, Behrensmeyer describes 5 stages of weathering starting from stage 0, when the bone surface shows no signs of cracking or flacking due to weathering, till stage 5, when a bone is falling apart, is very fragile and easily broken by moving.

When examining deposited faunal remains, one must consider the potential influence of biological agents such as carnivores and rodents. These creatures can significantly impact the distribution of remains across the ground (Saña, 2014). Carnivores and rodents can help break down carcasses and body parts that are left behind. It's essential to consider the condition where the waste, body parts, and carcasses were deposited (Hedges, 2002). Since the remains are mostly waste from consumption, there may not be much meat left on the bones after they are discarded (Saña, 2014).

Since isotopic analysis is destructive, proper documentation, including detailed descriptions and photographs, is crucial when studying specimens. Not only does it aids in interpreting and understanding the samples, but it also plays a crucial role in further research. The first step in this process is creating a database for the samples, which is essential for the second part of the research: stable isotope analysis.

3.2.2. Collagen extraction

At the HERCULES Lab at Universidade de Évora (Portugal), the process of collagen extraction was carried out. The bones were meticulously cleaned through the use of a Dremel® to eliminate any form of contamination and to prepare the samples. Subsequently, the samples were pulverized into smaller pieces, weighing approximately 0.5g.

The collagen extraction followed a modified Longin (1971) method (Brown et al., 1988). The bones were demineralized using 0.5 M HCl for two weeks. The samples were vortexed two times a day, in the morning and evening. During the day, the samples were stored at room temperature; at night, they were kept in the fridge. After one week, the 0.5 M HCl in the samples was changed. The rest of the procedure remained the same for a week. Then the samples were rinsed with ultrapure water (milli-Q®) until they were pH neutral. Afterwards, 0.125 M NaOH was added and kept for 20 hours. After that, the samples were rinsed again with ultrapure water (milli-Q®) until they were pH neutral.

Finally, the samples were gelatinized with 0.01 M HCl at 70°C for 48 h, filtered with Ezze filters, and frozen.

After being removed from the freezer, the samples were promptly frozen with liquid nitrogen and transferred to a highly efficient lyophilizer. This advanced equipment, known as a freeze-drier, executes a three-step process. Firstly, the samples are frozen below their triple point to maintain their physical structure during freezing. Secondly, the primary drying phase begins, which involves lowering the pressure and introducing heat to sublimate up to 95% of the water. Lastly, the secondary drying phase eliminates the ionically bound water molecules. Following a 48-hour freeze-drying process, the lyophilized collagen was weighed (~0.5mg) and deposited into tin capsules.

3.2.3. Analytical procedures

The samples (0.5 mg) were analysed at the University of Montpellier (France) – platform AETE-ISO of OSU OREME, using a ThermoFischer Delta Vplus coupled to a Flash Elemental Analyzer Isolink NCS.

Carbon and nitrogen contents (%) were obtained using a calibration based on acetanilide (C : 71.1 %; N: 10.36 %) and alanine (C : 40.4 %; N : 15.7 %). Carbon and nitrogen isotopes δ^{13}C and δ^{15}N were calibrated relative to VPDB and AIR, respectively, and analysed using a three-points calibration with USGS61 (δ^{13}C: -35.05 ‰; δ^{15}N : -2.87‰), USGS62 (δ^{13}C: -14.79 ‰; δ^{15}N : 20.17 ‰) and USGS63 (δ^{13}C: -1.17 ‰; δ^{15}N: 37.83 ‰). NIST 1577C was used to check %C (48.8%) and %N (10.3%) contents, as well as isotopic measurement error (δ^{13}C: -17.52 ‰; δ^{15}N : 8.21‰, Guiry and Szpak, 2017). Precision was 0.19 ‰ for δ^{13}C and 0.37 ‰ for δ^{15}N, while accuracy was 0.24 ‰ for δ^{13}C and 0.55 ‰ for δ^{15}N. The total analytical uncertainty was determined to be 0.30 ‰ for δ^{13}C and 0.66 ‰ for δ^{15}N. Precision, accuracy and analytical uncertainty were calculated according to Szpak et al. (2017).

3.2.4. Statistical analyses

Comparison between δ^{13}C values of wild and domestic herbivores, pigs, wild boars and carnivores was performed by using one-way ANOVA, and T-test. Statistical test was performed in PAST 4.03.

4. Results

4.1. Zooarchaeological characterization of the samples

4.1.1. Taxonomy and anatomy: Species variability

The samples (n=40) were identified anatomically and taxonomically. 5 domestic and 2 wild species were identified. The identified domestic species include pig (*Sus domesticus*), cattle (*Bos taurus*), sheep (*Ovis aries*), goat (*Capra hircus*), and dog (*Canis familiaris*). The deer (C*ervus elaphus*) and wild boar (*Sus scrofa*) were identified among the wild species (Table 3; Table 4).

In the selected samples from Porto Torrão (Late Neolithic and Chalcolithic), wild species represent 30% of the total. *Cervus elaphus* make up 12.5 % (NISP=5) of the total (Late Neolithic: NISP=1; Chalcolithic NISP=4). *Sus scrofa* represents 10 % of the samples that were analyzed for the Late Neolithic period (NISP=4) and 7.5 % for the Chalcolithic period (NISP=3). A total of 70% of the selected samples corresponds to domestic species: S*us domesticus, Ovis/Capra, Bos taurus, Canis familiaris* (Table 3). *Sus domesticus* was the most prevalent domestic species, making up 35% of the total samples (NISP=8 for Late Neolithic and NISP=6 for Chalcolithic). *Ovis/Capra* accounted for 15% of the samples (NISP=5 for the Late Neolithic and NISP=1 for Chalcolithic), while 2 bones of *Ovis aries* were identified from the Late Neolithic and 2 bones from the Chalcolithic. *Bos taurus* (NISP=1 for Late Neolithic and NISP=4 for Chalcolithic) was also present in the samples. Finally, *Canis familiaris* (NISP=1 for Late Neolithic and NISP=2 for Chalcolithic) has been analyzed.

All faunal bones correspond to different adult individuals older than 24 months. Among the samples recovered in the Late Neolithic levels, a bone of *Sus domesticus* (PT-12) has been determined as a female. This classification has been made based on the shape of the canines (Table 3 and 4).

Table 3. Samples of the Late Neolithic levels (UE= stratigraphic unit, F=female, N/A= not available).

Neolithic Specimen ID	*Post 181 UE*	*Specie ID*	*Fraction*	*Skeleton Part*	*Laterality*	*Fusion*	*Age (months)*
PT-2	2046	*Bos taurus*	Maxilla	Skull	Right	N/A	+24
PT-3	2031	*Sus domesticus*	Corpus	Mandible	Right	N/A	+24
PT-4	2031	*Ovis aries*	Maxilla	Skull	Right	N/A	+24

Neolithic Specimen ID	*Post 181 UE*	*Specie ID*	*Fraction*	*Skeleton Part*	*Laterality*	*Fusion*	*Age (months)*
PT-5	2031	*Canis familiaris*	Diaphysis medial	Radius	Right	N/A	Adult
PT-7	2038	*Sus domesticus*	Diaphysis medial to Epiphysis distal	Tibia	Right	YES	+24
PT-8	2038	*Cervus elaphus*	Diaphysis medial to Epiphysis distal	Tibia	Left	YES	+24
PT-9	2039	*Sus domesticus*	Epiphysis proximal to Diaphysis proximal	Radius	Left	YES	+12
PT-10	2034	*Sus Scrofa*	Diaphysis distal to Epiphysis distal	Humerus	Right	YES	Adult
PT-11	2031	*Ovis/Capra*	Diaphysis medial	Metacarpus	N/A	N/A	Adult
PT-12	2037	*Sus domesticus*	Diastema	Mandible	Right/ Left	N/A	Adult (F)
PT-13	2049	*Ovis/Capra*	Diaphysis medial	Tibia	Right	N/A	Adult
PT-14	2044	*Ovis aries*	Diaphysis distal to Epiphysis distal	Metacarpus	N/A	YES	+24
PT-16	2021	*Ovis/Capra*	Epiphysis proximal to Diaphysis medial	Metatarsus	Right	YES	Adult
PT-19	2047	*Sus domesticus*	Diaphysis medial to Diaphysis distal	Femur	Right	N/A	Adult

Neolithic Specimen ID	*Post 181 UE*	*Specie ID*	*Fraction*	*Skeleton Part*	*Laterality*	*Fusion*	*Age (months)*
PT-20	2035	*Sus domesticus*	Epiphysis proximal to Diaphysis proximal	Radius	Left	YES	+12
PT-22	2059	*Sus domesticus*	Epiphysis proximal to Diaphysis proximal	Metacarpus	Right	YES	Adult
PT-23	2021	*Sus Scrofa*	Corpus	Mandible	Left	N/A	Adult
PT-24	2031	*Sus domesticus*	Complete	3rd Phalanx	Right	YES	Adult
PT-26	2044	*Sus Scrofa*	Maxilla	Skull	Left	N/A	Adult
PT-28	2049	*Sus Scrofa*	Maxilla	Skull	N/A	N/A	Adult

Table 4. Samples of the Chalcolithic levels (UE= stratigraphic unit, F=female, N/A= not available).

Chalcolithic Specimen ID	*Post 181 UE*	*Specie*	*Fraction*	*Skeleton Part*	*Laterality*	*Fusion*	*Age (months)*
PT-29	2003	*Sus domesticus*	Epiphysis proximal to Diaphysis proximal	Radius	Right	YES	>12 month
PT-30	2054	*Ovis/Capra*	Coracoid, joint, neck, spine, corpus	Scapula	Left	YES	Adult
PT-31	2042	*Sus domesticus*	Diaphysis medial to Epiphysis distal	Humerus	Right	YES	+12

Chalcolithic Specimen ID	*Post 181 UE*	*Specie*	*Fraction*	*Skeleton Part*	*Laterality*	*Fusion*	*Age (months)*
PT-33	2030	*Sus domesticus*	Diaphysis distal to Epiphysis distal	Humerus	Left	YES	+12
PT-34	2030	*Cervus elaphus*	Diaphysis distal to Epiphysis distal	Radius	Right	YES	Adult
PT-35	2053	*Sus Scrofa*	Coracoid, joint, neck, spine, corpus	Scapula	Left	YES	+12
PT-36	2053	*Sus domesticus*	Joint, neck, spine, corpus	Scapula	Left	YES	+12
PT-37	2053	*Bos taurus*	Complete	2nd Phalanx	Left	YES	+18
PT-38	2043	*Cervus elaphus*	Diaphysis distal to Epiphysis distal	Tibia	Left	YES	Adult
PT-39	2043	*Sus domesticus*	Epiphysis proximal to Diaphysis proximal	Radius	Left	YES	+12
PT-40	2043	*Canis familiaris*	Diaphysis medial to Epiphysis distal	Radius	Right	YES	+12
PT-41	2045	*Cervus elaphus*	Epiphysis proximal to Diaphysis medial	Radius	Left	YES	Adult

Chalcolithic Specimen ID	*Post 181 UE*	*Specie*	*Fraction*	*Skeleton Part*	*Laterality*	*Fusion*	*Age (months)*
PT-42	2045	*Ovis aries*	Epiphysis proximal to Diaphysis media	Radius	Left	YES	+4
PT-43	2055	*Bos taurus*	Diaphysis distal to Epiphysis distal	Humerus	Left	YES	+20
PT-44	2055	*Ovis aries*	Diaphysis distal to Epiphysis distal	Humerus	Right	YES	+4
PT-46	2057	*Cervus elaphus*	Diaphysis distal to Epiphysis distal	Humerus	Right	YES	Adult
PT-47	2057	*Sus domesticus*	Diaphysis medial to Epiphysis distal	Humerus	Right	YES	+12
PT-48	2057	*Canis familiaris*	Diaphysis distal to Epiphysis distal	Humerus	Right	YES	+ 9
PT-68	2043	*Sus Scrofa*	Complete	Radius	Left	YES proximal/ NO distal	Adult
PT-69	2004	*Sus Scrofa*	Diaphysis distal to Epiphysis distal	Skull	N/A	N/A	Adult

The anatomical parts represented in each species have been selected for this work. For their selection, the following characteristics have been considered: I) characteristic features to differentiate between animal species; II) laterality of the bones to estimate the Minimum Number of Individuals (MNI); III) when possible, fragments of long bones that conserved the diaphysis have been selected.

4.1.2. Biometry: characterization of pigs

The long bones of pigs (*Sus domesticus and Sus scrofa*) were measured following von den Driesch (1976) (Table 5). The biometric analysis helped us to understand the differences in size and shape of the individuals and to discriminate between the wild and domestic form in the same faunal assemblage. When it was not possible to measure the bone remains (in the case of the mandibles), these were associated to the domestic or wild status according to the form. When the bone is broken and measurements are not available (PT-10, PT-19 and PT-20), it has been associated with the domestic or wild status according to the robustness and size of the bone.

Table 5. Biometrics of Sus from Neolithic and Chalcolithic periods in cm.[2]

ID Sample	***Period***	***Specie***	***Bone***	***GLP***	***GL***	***BG***	***Bp***	***Bd***	***BFp***	***BFd***	***Dd***	***Ld***	***LDS***
PT-7	Neo	*Sus dom.*	Tibia					3.1					
PT-9	Neo	*Sus dom.*	Radius				3.1						
PT-24	Neo	*Sus dom.*	Phalanx III									3.1	3.7
PT-31	Chal	*Sus dom.*	Humerus					3.9					
PT-47	Chal	*Sus dom.*	Humerus					3.4					
PT-33	Chal	*Sus dom.*	Humerus					2.8					

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[2] (GLP-greatest length of the Processus articularis (glenoid process); GL-greatest length; BG-Greatest breadth of the glenoid angle; Bp-breadth of proximal end; Bd-breadth of distal end; BFp-breadth of the Facies articularis distalis; Dd- depth of distal end; Ld- Length of the dorsal surface; LDS- (Greatest) diagonal length of the sole)

ID Sample	Period	Specie	Bone	GLP	GL	BG	Bp	Bd	BFp	BFd	Dd	Ld	LDS
PT-39	Chal	*Sus dom.*	Radius				2.5						
PT-29	Chal	*Sus dom.*	Radius				2.8						
PT-35	Chal	*Sus scrofa*	Scapula	3.2	2.5	2.4							
PT-36	Chal	*Sus dom.*	Scapula	2.5									
PT-68	Chal	*Sus scrofa*	Radius				4.9	5.5					
PT-69	Chal	*Sus scrofa*	Tibia					5.3					

Based on the measurements we have classified the pig remains into wild and domestic size, always according to the internal variability of the faunal assemblage and with the aim of observing differences between the pigs and their size.

4.1.3. Taphonomy: Anthropic alterations

A significant number of Late Neolithic and Chalcolithic faunal remains shows evidence of modifications related to butchering processes and cooking activities. In the Neolithic levels, 60% of the remains (n=12) display such modifications, with n=5 revealing cut marks and 45% (n=9) characterized by anthropic fractures. Similarly, anthropic modifications are observed in 65% (n=13) of the faunal remains from the Chalcolithic levels.

The cut marks on Late Neolithic faunal assemblage are mostly shallow slices and repeated cuts (annex 2). This may indicate filleting. During the Chalcolithic period, we observe multiple occurring cut marks with varying depths, ranging from shallow to moderate and deep (annexes 4, 6, 7). The type of mark is mostly sliced and, in some cases, chopped. Based on the cut marks, the Chalcolithic faunal remains may represent filleting and sometimes skinning signs.

From the macroscopic analysis of the remains, it has been documented that the intentionally fractured remains from the Late Neolithic specimens are mainly concentrated on *Sus domesticus* and *Ovis/Capra* species. We have identified 4 bones of *Sus domesticus* and 4 of *Ovis/Capra* with longitudinal, oblique, and transversal fractures (Table 1Table 6).

Also, we could identified various fractures in samples from the Late Neolithic. One sample of *Sus scrofa* (PT-10) displays an oblique fracture, while three samples of *Sus domesticus* (PT-9, PT-19, and PT-20) show longitudinal and irregular oblique fractures. Additionally, PT-24 (*Sus domesticus*) exhibits a diagonal fracture with a shallow cut mark.

Among the samples recovered at the Late Neolithic levels, four bones belonging to *Ovis/Capra* (PT-11, PT-13, PT-16) and *Ovis aries* (PT-14) were found to have fractures. Longitudinal fractures were identified in PT-11 and PT-16, while PT-13 had a transverse irregular fracture with a possible horizontal shallow slice mark. PT-14 also had a transverse irregular fracture with multiple horizontal shallow slice marks (Annex 10).

Table 6. Fractures of Late Neolithic samples.

Late Neolithic							
	Bos taurus	*Ovis aries*	*Ovis/ Capra*	*Sus domesticus*	*Cervus elaphus*	*Sus scrofa*	*Canis familiaris*
Longitudinal fractures			2	1	1		
Oblique fractures				3		1	
Transversal fractures		1	1				1
Cut marks			2	2	1		

During the analysis, it was determined that sample PT-8 belonged to the *Cervus elaphus* species. The bone displayed diagonal, shallow slice marks, a longitudinal fracture, and a partial termoalteration in brown color. Another sample, PT-5, was identified as *Canis familiaris* and exhibited a transverse irregular fracture.

The taphonomic analysis of the Chalcolithic samples has allowed the recording of abundant alterations in the surfaces of the skeletal remains of pig and deer (Table 7). Specifically, four samples of *Sus domesticus* (PT-29, PT-31, PT-36, PT-39) have displayed visible cut marks and fractures. PT-29 has a horizontal shallow slice, transverse irregular fracture, and a brownish color. PT-31 has multiple horizontal and diagonal moderate chop and slice marks and a longitudinal, V-shaped fracture. Therefore, PT-31 could represent dismemberment. PT-36 has several horizontal and diagonal moderate-depth slices. PT-39 has several horizontal, diagonal, and vertical moderate chops and longitudinal fractures. Only one sample of *Sus scrofa* (PT-35) has displayed several horizontal moderate chop/slices. These could be signs mostly of filleting practices. Four samples of *Cervus elaphus* (PT-34, PT-38, PT-41, PT-46) show some modifications. PT-34 has multiple moderate horizontal chops and transverse irregular fractions, while PT-38 has several shallow diagonal slices and oblique irregular fractures. PT-41 has multiple horizontal, diagonal, and vertical slices, depth from shallow to moderate, and transverse irregular fraction, and PT-46 displays several horizontal slices of depth from moderate to deep and longitudinal fraction. In the case of samples PT-34 and PT-38, it might be the practice of filleting, while sample PT-41 could represent a case of dismemberment, and PT-46 of skinning.

Table 7. Fractures of Chalcolithic samples.

Chalcolithic							
	Bos taurus	*Ovis aries*	*Ovis/ Capra*	*Sus domesticus*	*Cervus elaphus*	*Sus scrofa*	*Canis familiaris*
Longitudinal fractures				2	1		
Oblique fractures				1	1		
Transversal fractures	1			2	2		
Cut marks	1	1	1	4	4	1	1

A macroscopic analysis was made on *Bos taurus* remains (PT-43) that showed modifications. The bone exhibited several moderate horizontal and diagonal slices and irregular transverse fractions. Additionally, a hitting point was detected on the bone.

Upon examining the samples, it was observed that the PT-42 *Ovis aries* specimen had distinct moderate slices that were horizontal, vertical, and diagonal. Meanwhile, the PT-30 specimen, identified as *Ovis/Capra*, had moderate slices, appeared to be caused by filleting, precisely horizontal and diagonal slices.

Sample PT-48, identified as *Canis familiaris*, displays diagonal shallow slice marks that may suggest filleting, and the bone appears to be partially brownish. As for PT-40 (*Canis familiaris)* there are indications of biting.

4.1.4. Taphonomy: natural alterations

Based on Weathering Stages of Behrensmeyer (1978), it was noted that 67.5% of all samples displayed Stage 1; 10% represent Stage 1 and 2, such as samples PT-10, PT-11, and PT-12 from the Late Neolithic levels with noticeable features like cracks, porosity, flakes, and root marks. Sample PT-13, on the other hand, displayed Stage 2 and 3 with high porosity, flakes, and root marks. It wasn't easy to identify PT-23, while the rest of the samples demonstrated signs of Stage 1 (Table 8).

Samples collected from the Chalcolithic levels exhibited similar taphonomic Weathering Stages. The weathering stages were observed to be in Stage 1 to 3. Sample PT-35 had Stage 1 and 2 with porosity, flakes, and root marks. Samples PT-36, PT-43, and PT-46 displayed signs of Stage 2 and 3, while the remaining samples were in Stage 1 (Table 9).

Table 8. Weathering Stages and Taphonomic Modifications on Late Neolithic Samples (N/A= not available).

Specimen ID	***Specie***	***Weathering Stages***	***Cracks***	***Porosity***	***Flakes***	***Root marks***
PT-2	*Bos taurus*	1	+	+		+
PT-3	*Sus domesticus*	1	+	+		
PT-4	*Ovis aries*	1	+			
PT-5	*Canis familiaris*	1			+	+
PT-7	*Sus domesticus*	1		+		+
PT-8	*Cervus elaphus*	1			+	+
PT-9	*Sus domesticus*	1		+		+
PT-10	*Sus scrofa*	1-2	+	+		+
PT-11	*Ovis/Capra*	1-2		+	+	+
PT-12	*Sus domesticus*	1-2	+	+		+
PT-13	*Ovis/Capra*	2-3		+	+	+
PT-14	*Ovis aries*	1		+		+
PT-16	*Ovis/Capra*	1	+		+	

Specimen ID	***Specie***	***Weathering Stages***	***Cracks***	***Porosity***	***Flakes***	***Root marks***
PT-19	*Sus domesticus*	1	+			+
PT-20	*Sus domesticus*	1				+
PT-22	*Sus domesticus*	1				+
PT-23	*Sus scrofa*	N/A				
PT-24	*Sus domesticus*	1				+
PT-26	*Sus scrofa*	1				

Table 9. Weathering Stages and Taphonomic Modifications on Chalcolithic Samples.

Specimen ID	***Specie***	***Weathering stages***	***Cracks***	***Porosity***	***Flakes***	***Root marks***
PT-29	*Sus domesticus*	1		+	+	+
PT-30	*Ovis/Capra*	1	+			+
PT-31	*Sus domesticus*	1	+			+
PT-33	*Sus domesticus*	1				
PT-34	*Cervus elaphus*	1	+	+	+	
PT-35	*Sus scrofa*	1-2	+			
PT-36	*Sus domesticus*	2-3		+	+	+
PT-37	*Bos taurus*	1	+	+	+	
PT-39	*Sus domesticus*	1	+	+	+	
PT-40	*Canis familiaris*	1	+	+	+	+
PT-41	*Cervus elaphus*	1	+			
PT-42	*Ovis aries*	1	+			+
PT-43	*Bos taurus*	2-3		+	+	+
PT-44	*Ovis aries*	2	+	+	+	+
PT-46	*Cervus elaphus*	2-3		+	+	
PT-47	*Sus domesticus*	1				
PT-48	*Canis familiaris*	1	+	+	+	+
PT-68	*Sus scrofa*	1				
PT-69	*Sus scrofa*	1				

4.2. Isotopic results

4.2.1. Collagen preservation

The results of the stable isotopes and collagen quality indicators are reported in Table 10.

Table 10. Results of δ^{13}C‰ (VPDB) and δ^{15}N‰ (AIR) values of the samples.

Chronology	Specie ID	*Sample ID*	δ^{15}N‰ (AIR)	%N	δ^{13}C‰ (VPDB)	*%C*	*C:N ratio*	*Collagen yield %*
LN	*Bos taurus*	PT-2	6,28	10,08	-19,8	28,67	3,3	3,25
LN	*Canis familiaris*	PT-5	7,79	14,67	-18,76	40,37	3,2	5,21
LN	*Cervus elaphus*	PT-8	5,12	15,12	-19,39	41,29	3,2	5,57
LN	*Ovis/Capra*	PT-4	7,01	14,53	-20,35	40,23	3,2	5,93
LN	*Ovis/Capra*	PT-11	5,85	14,24	-21,11	39,67	3,2	5,64
LN	*Ovis/Capra*	PT-13	4,69	14,75	-19,72	41,35	3,3	9,69
LN	*Ovis/Capra*	PT-14	6,26	14,83	-19,61	41,01	3,2	5,51
LN	*Ovis/Capra*	PT-16	5,84	12,01	-21,97	36,31	3,5	5,64
LN	*Sus domesticus*	PT-3	4,47	14,58	-20,34	41,06	3,3	2,82
LN	*Sus domesticus*	PT-7	4,82	14,45	-19,07	40,94	3,3	7,16
LN	*Sus domesticus*	PT-9	5,82	14,42	-19,36	40,28	3,3	7,74
LN	*Sus domesticus*	PT-12	5,59	14,82	-20,08	40,56	3,2	1,24
LN	*Sus domesticus*	PT-19	6,29	14,91	-19,48	41,69	3,3	7,29
LN	*Sus domesticus*	PT-20	6,5	13,29	-20,02	37,71	3,3	2,21
LN	*Sus domesticus*	PT-22	6,08	13,13	-20,17	36,77	3,3	1,97
LN	*Sus domesticus*	PT-24	5,14	14,61	-20,67	40,83	3,3	5,7
LN	*Sus scrofa*	PT-10	6,71	14,64	-20,57	41,52	3,3	8,33
LN	*Sus scrofa*	PT-23	6,1	13,68	-21,25	38,66	3,3	2,79
LN	*Sus scrofa*	PT-26	4,79	13,62	-19,75	38,32	3,3	4,22
Chalcolithic	*Bos taurus*	PT-37	7,56	13,46	-21,38	37,66	3,3	3,68
Chalcolithic	*Bos taurus*	PT-43	5,83	14,61	-20,66	40,62	3,2	2,8
Chalcolithic	*Canis*	PT-40	9,36	13,62	-19,07	37,66	3,2	4,34
Chalcolithic	*Canis*	PT-48	8,43	13,61	-19,31	38,18	3,3	3,25
Chalcolithic	*Cervus elaphus*	PT-34	5,79	14,33	-20,54	39,97	3,3	2,22
Chalcolithic	*Cervus elaphus*	PT-41	4,23	13,87	-21,19	38,42	3,2	2,18
Chalcolithic	*Cervus elaphus*	PT-46	7,04	14,38	-20,13	39,72	3,2	3,78
Chalcolithic	*Ovis aries*	PT-42	5,16	14,03	-20,64	38,76	3,2	2,63
Chalcolithic	*Ovis aries*	PT-44	6,68	14,33	-20,81	40,01	3,3	3,48
Chalcolithic	*Ovis/Capra*	PT-30	5,81	14,64	-19,91	40,37	3,2	5,92
Chalcolithic	*Sus domesticus*	PT-29	5,8	12,63	-20,08	35,79	3,3	5,2

Chronology	Specie ID	*Sample ID*	δ^{15}N‰ (AIR)	%N	δ^{13}C‰ (VPDB)	*%C*	*C:N ratio*	*Collagen yield %*
Chalcolithic	*Sus domesticus*	PT-31	6,68	14,57	-20,04	41,03	3,3	4,49
Chalcolithic	*Sus domesticus*	PT-33	4,93	14,38	-19,55	40,18	3,3	6,68
Chalcolithic	*Sus domesticus*	PT-36	6,71	13,96	-20,72	39,53	3,3	4,72
Chalcolithic	*Sus domesticus*	PT-39	4,96	14,6	-19,96	39,92	3,2	3,01
Chalcolithic	*Sus domesticus*	PT-47	6,8	14,32	-20,37	39,94	3,3	1,5
Chalcolithic	*Sus scrofa*	PT-35	6	14,39	-19,91	40,19	3,3	5,33
Chalcolithic	*Sus scrofa*	PT-68	4,33	14,75	-19,97	40,97	3,2	5,92
Chalcolithic	*Sus scrofa*	PT-69	6,67	13,3	-20,34	37,39	3,3	1,63

Out of a total of 40 samples, collagen was successfully extracted from 38 samples (95%). The C% ranges between 28.67% and 41.52% (Table 10), and N% ranges from 10.08% to 15.12%, respectively. C:N ratios range between 3.2 and 3.5. These values are within the values suggested by DeNiro (1985) and Van Klinken (1999) for preserved collagen. Certain criteria have been added to the analysis to ensure the accuracy of the results. These criteria include concentrations of C (%C) and N (%N), which should be higher than 13% and 4.8% (Ambrose, 1990), respectively. Additionally, the collagen concentration should be greater than 0.5–2% (Ambrose, 1990; DeNiro and Weiner, 1988; Dobberstein et al., 2009; Van Klinken, 1999), which is measured as % yield of collagen extract relative to that of the initial sample. The collagen preservation of the samples is good; samples represent collagen yield of >2%.

We were able to extract collagen from 38 out of 40 samples successfully. However, we were unable to extract any collagen from the PT-38 (*Cervus elaphus*, Chalcolithic) and PT-28 (*Sus scrofa*, Neolithic) samples. It is possible that these bones were poorly preserved because they dissolved quickly in HCl during sample extraction preparation. We repeated the collagen extraction process in these samples, but we did not obtain any results.

4.2.2. Carbon and Nitrogen isotope results

From the results obtained, δ^{13}C‰ and δ^{15}N‰ values of our samples are represented in figures 15 and 16, figures 17 and 18Figure 17. Box plot of δ^{13}C‰ values of the samples., and compared with box plots in figures 17 and 18Figure 17. Box plot of δ^{13}C‰ values of the samples..

Table 11. Standard deviation and mean of δ13C‰ and δ15N‰ values of the samples.

	Late Neolithic		**Chalcolithic**	
	Standard deviation	Mean	Standard deviation	Mean
	Bos taurus			
δ^{13}C‰	N/A	-19,80	0,51	-20,61
δ^{15}N‰	N/A	6,28	1,2228	6,70
	Ovis/Capra			
δ^{13}C‰	0,9914	-20,55	0,48	-20,45
δ^{15}N‰	0,8414	5,93	0,77	5,88
	Canis familiaris			
δ^{13}C‰	N/A	-18,76	0,1686	-19,19
δ^{15}N‰	N/A	7,79	0,6571	8,90
	Cervus elephus			
δ^{13}C‰	N/A	-19,39	0,8338	-20,62
δ^{15}N‰	N/A	5,12	1,4058	5,69
	Sus domesticus			
δ^{13}C‰	0,5820	-19,90	0,3949	-20,12
δ^{15}N‰	0,7212	5,59	0,8821	5,98
	Sus scrofa			
δ^{13}C‰	0,7510	-20,52	0,2345	-20,08
δ^{15}N‰	0,9824	5,86	1,2036	5,66

From the Late Neolithic samples, the δ^{13}C‰ value for a carnivore (*Canis familiaris)* is -18.76‰; for wild herbivore (*Cervus elaphus),* it is -19.39‰; the samples of domestic herbivores (*Bos taurus, Capra hircus,* and *Ovis aries*) range between -21.97‰ and -19.61‰; Particularly, *Bos taurus* have the δ^{13}C‰ value -19.80‰; For *Ovis/Capra* it is range between -21.97‰ and -19.61‰. Omnivores are represented by *Sus domesticus* and *Sus scrofa*. Sus domesticus range between -20.67‰ and -19.07‰; Sus scrofa range between -19.75‰ and -21.25‰.

From the Chalcolithic samples, the δ^{13}C‰ value for carnivores (*Canis familiaris)* are -19.31‰ and -19.07‰; for wild herbivores (*Cervus elaphus),* it is -20.34‰ and -20.13‰; the samples of the bones of domestic herbivores (*Bos taurus, Capra hircus,* and *Ovis aries*) range between -21.98‰ and -19.91‰. *Bos taurus* sampels have the δ^{13}C‰ value between -21.38‰ and -20.66‰; for *Ovis/Capra* it ranges between -21.81‰ and -19.91‰. *Sus domesticus* range between-20.72‰ and -19.55‰, and *Sus scrofa* between -20.34‰ -19.91‰.

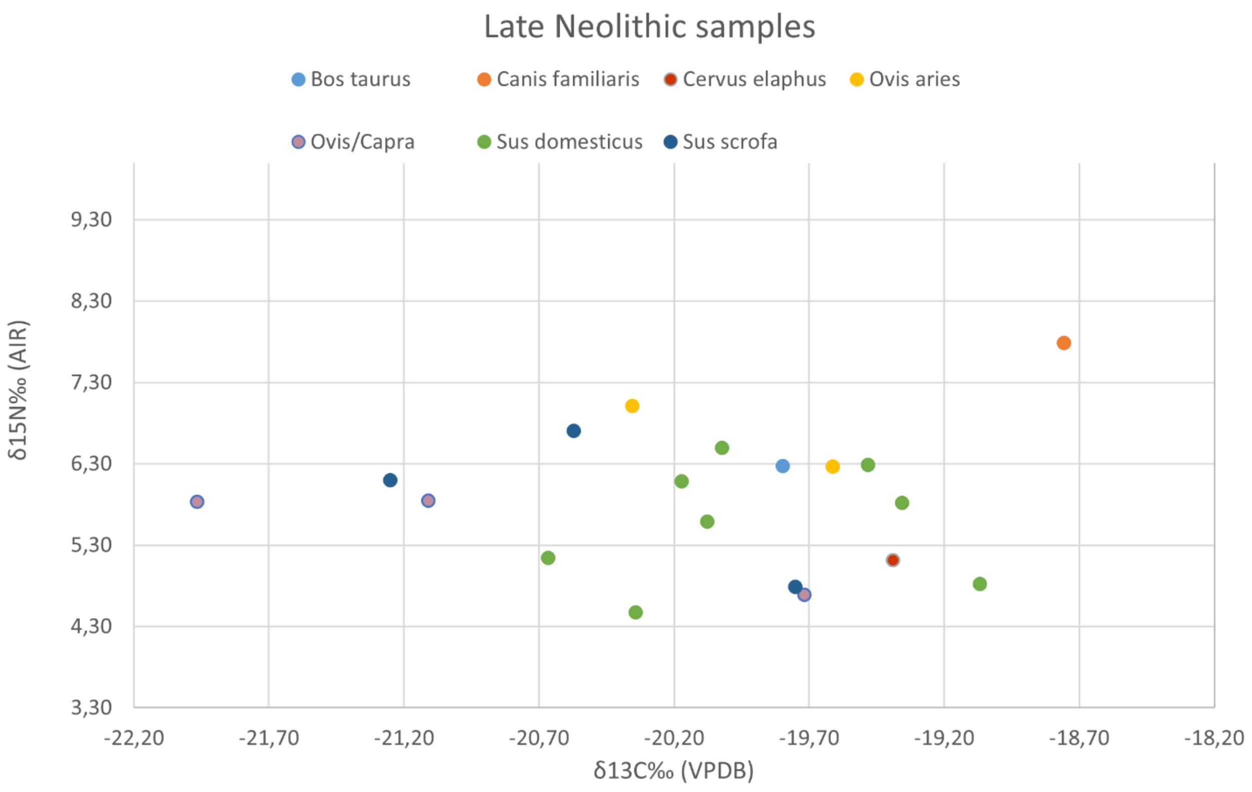


Figure 15. Distribution of δ^{13}C‰ (VPDB) and δ^{15}N‰ (AIR) values of the Late Neolithic samples

Taking a look at the general pig samples *(Sus domesticus* and *Sus scrofa)* combined, the values from the Late Neolithic period range between -21.25‰ and -19.07‰, while the Chalcolithic samples are between -19.75‰ and -20.72‰.

From the Late Neolithic samples, the δ15N‰ value for carnivores (*Canis familiaris)* is 7.79‰; for wild herbivores (*Cervus elaphus),* it is 5.12‰; the samples of the bones of domestic herbivores (*Bos taurus, Capra hircus,* and *Ovis aries*) range between 4.69‰ and 7.01‰; particularly, the δ^{15}N‰

value of *Bos taurus* is 6.28‰; for *Ovis/Capra* it ranges between 4.68‰ and 7.01‰. *Sus domesticus* range between from 4.47‰ to 6.50‰, and *Sus scrofa* from 4.79‰ to 6.71‰.

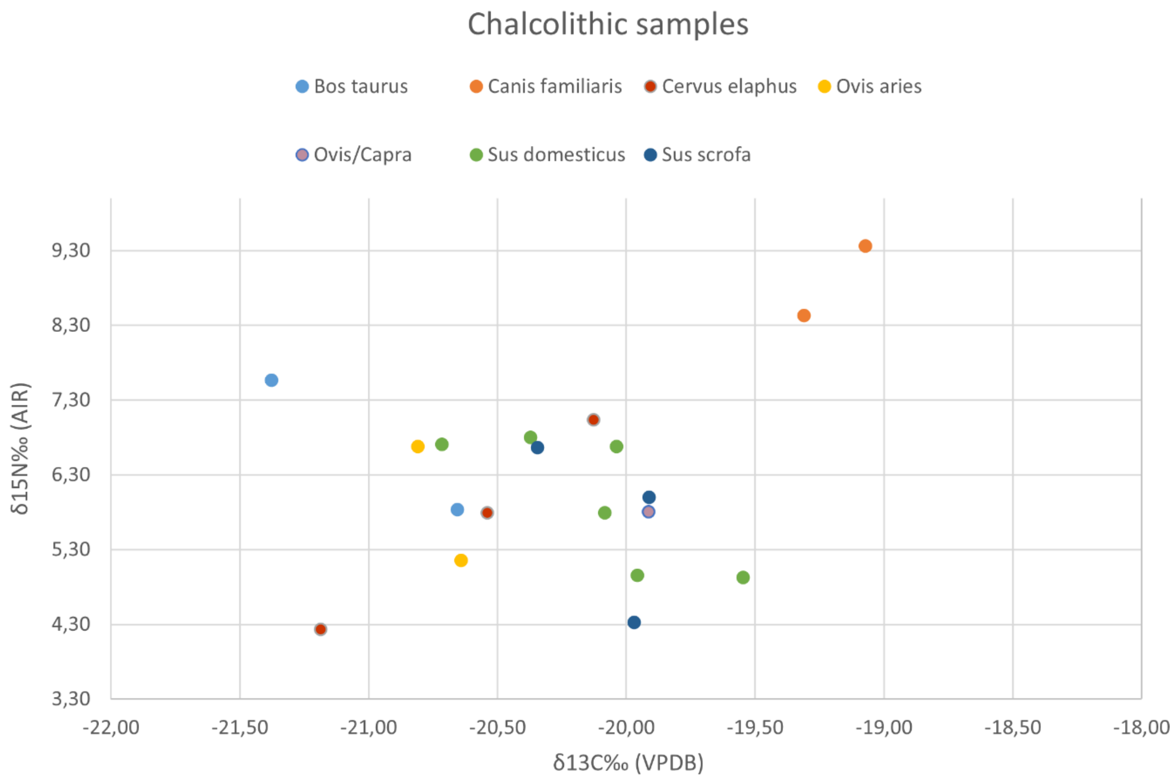


Figure 16. Distribution of δ^{13}C‰ (VPDB) and δ^{15}N‰ (AIR) values of the Chalcolithic samples

The Chalcolithic sample δ^{15}N‰ values for carnivores (*Canis familiaris)* are between 8.43‰ and 9.36‰; for *Cervus elaphus* it ranges between 4.23‰ and 7.04‰; for domestic herbivores (*Bos taurus, Capra hircus,* and *Ovis aries*) between 5.16‰ and 6.68‰; *Bos taurus* samples have δ^{15}N‰ values between 5.83‰ and 7.56‰; Samples of *Ovis/Capra* ranges in between 5.16‰ and 6.68‰; *Sus domesticus* ranges from 4.93‰ to 6.71‰, and *Sus scrofa* from 4.33‰ to 6.67‰.

If general pig *(Sus domesticus* and *Sus scrofa)* sample values are considered from the Late Neolithic period, they range between 4.47‰ to 6.71‰, and the samples from the Chalcolithic period between 4.33‰ to 6.80‰.

Sus domesticus and *Sus scrofa* (Neolithic and Chalcolithic periods) values are in the same range as wild and domestic herbivores. To be precise, *pigs* (domestic and wild) δ^{13}C‰ and δ^{15}N‰ values range between -21.25‰ and -19.07‰ and 4.33‰ and 6.71‰, compared to domestic herbivores with δ^{13}C‰ values between -21.97‰ and -19.61‰, and δ^{15}N‰ values between 4.69‰ and 7.56‰, while, wild herbivores δ^{13}C‰ values range between -21.19‰ and -19.39‰, and δ^{15}N‰ values from

4.23‰ to 7.04‰. In contrast, carnivores δ^{13}C‰ values range between -18.76‰ and -19.31‰, and δ^{15}N‰ values from 7.79‰ to 9.36‰.

By comparison of *Sus domesticus* and *Sus scrofa* from both periods, we can observe that carbon value variation was minimal between domestic and wild pigs during the late Neolithic. *Sus domesticus* from the Late Neolithic ranges between -20.67‰ to -19.07‰, while *Sus domesticus* samples from the Chalcolithic range between -20.72‰ to -19.55‰. Three samples of *Sus scrofa* of the late Neolithic period have δ^{13}C‰ values -21.25‰, -20.57‰ and -19.75‰, and three samples of *Sus scrofa* from the Chalcolithic period are -19.91‰, -19.97‰ and -20.34‰. In contrast, nitrogen values do not show a significant difference between them. δ^{15}N‰ value*s of Sus domesticus* from the Late Neolithic period range between 4.47‰ to 6.50‰, and *Sus domesticus* of the Chalcolithic period shows δ^{15}N‰ value*s* between 4.93‰ to 6.80‰. Late Neolithic period *Sus scrofa* values from 4.79‰ to 6.71‰, and the Chalcolithic ones from 4.33‰ to 6.7‰. The average δ^{13}C‰ and δ15N‰ values for *Sus domesticus* are -20.01‰ and 5.78‰, for *Sus scrofa* -20.30‰ and 5.76‰; the difference between them is 0.29 and 0.02.

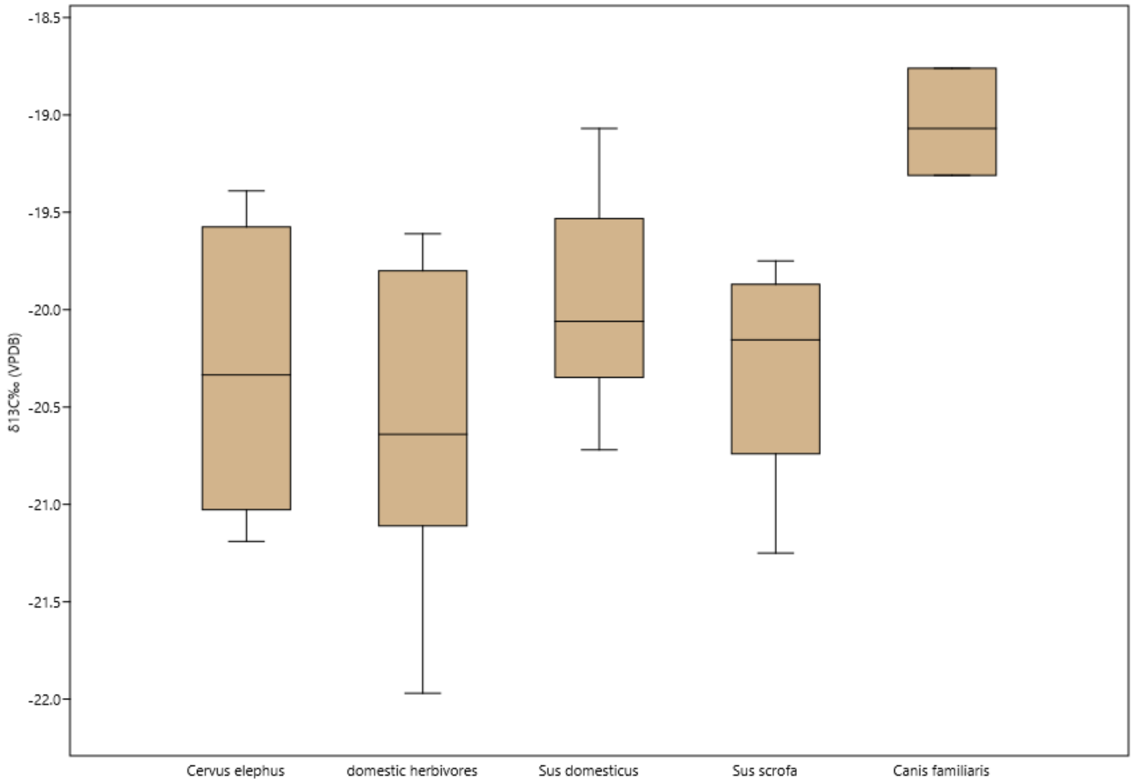


Figure 17. Box plot of δ^{13}C‰ values of the samples.

Two samples from the Late Neolithic *Sus domesticus* (PT-3) and *Sus scrofa* (PT-26), and one *Sus scrofa* (PT-68) from the Chalcolithic period demonstrate lower δ^{15}N‰ values compared to the rest of the pigs, precisely PT-3: 4.47‰, PT-26: 4.79‰, and PT-68: 4.33‰ (Figure 16).

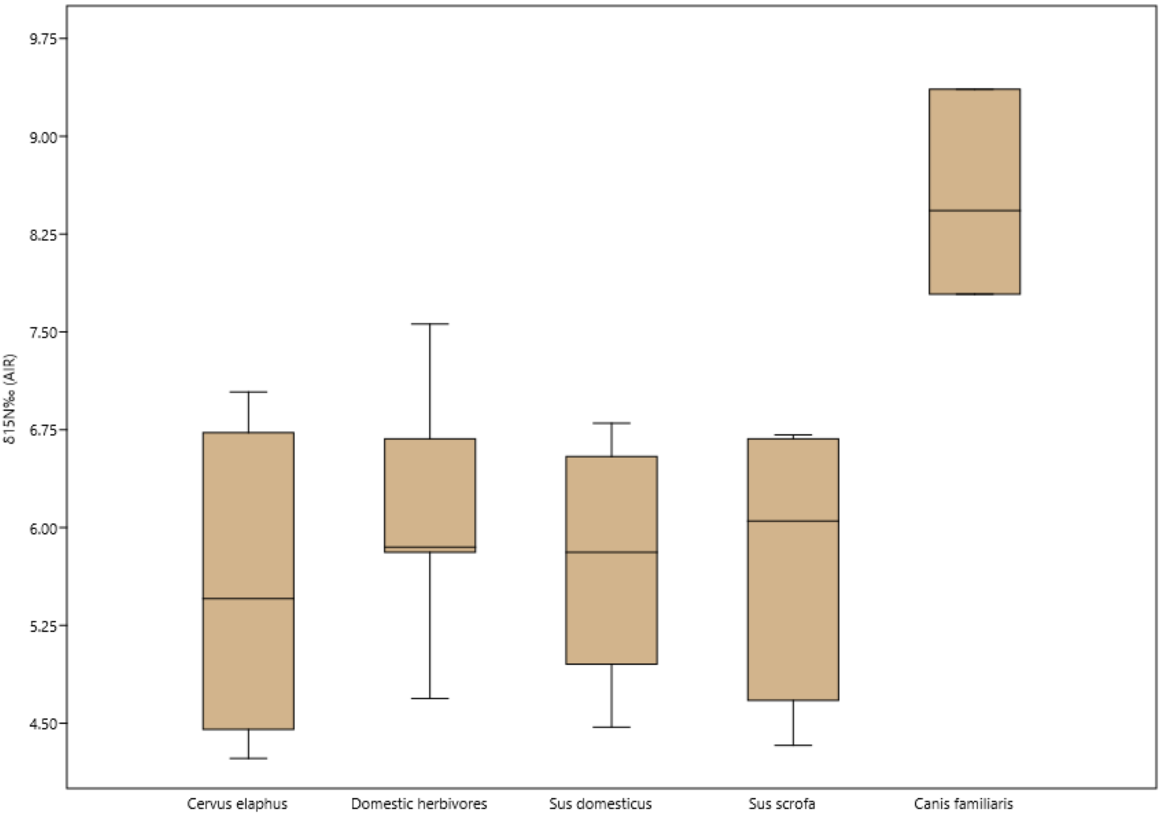


Figure 18. Box plot of δ15N‰ values of the samples.

One example of *Ovis/Capra* has the highest δ^{13}C‰ value represented by -21.97‰ and δ^{15}N‰ value of 5.85‰. One sample of *Bos taurus* has the highest δ^{15}N‰ value, and the rest of the herbivores are represented by 7.56‰. Also, one example of *Ovis/Capra* is a little bit excluded from the main group and represented by values δ^{13}C‰ value -21.97‰ and δ^{15}N‰ value 5.84‰.

No significant differences were found between the δ^{13}C‰ values of wild herbivores and domestic pigs (Neolithic p=0,91; Chalcolithic p=0,77), as well as between domestic herbivores and domestic pigs (Neolithic p=0,22; Chalcolithic p=0,25), and domestic pigs and wild boars (Neolithic p=0,91; Chalcolithic p=77); There is no significant difference between domestic pigs from the Late Neolithic and Chalcolithic periods (p=0,17) and wild boars from the Late Neolithic and Chalcolithic (p=0,66).

On the other hand, there is a significant difference between domestic carnivores (*Canis familiaris)* and *domestic pigs* from Chalcolithic (p=0,02), and between domestic carnivores and domestic herbivores from Chalcolithic (p=0,03), as well as within Neolithic domestic herbivores (p=0,02) (Table 12).

δ^{15}N‰ values have similar results with no significant difference between wild herbivores and domestic pigs from both periods (Neolithic p=0,77; Chalcolithic p=0,77), domestic herbivores and domestic pigs from both periods (Neolithic p=0,52; Chalcolithic p=0,83), as well as domestic pigs and wild boars (p=1). Theδ^{15}N‰ values of carnivores and domestic pigs are significant (Neolithic p=0,02; Chalcolithic p=0,02), as well as between carnivores and domestic herbivores (Neolithic p=0,02; Chalcolithic p=0,03) (Table 13).

Table 12. Mann-Whitney pairwise δ^{13}C‰ values of Neolithic and Chalcolithic samples comparison. LN – Late Neolithic; Chalc-Chalcolithic.

	Cervus elaphus	*Domestic herbivores (LN)*	*Sus domesticus (LN)*	*Sus scrofa (LN)*	*Domestic herbivores (Chalc)*	*Sus domesticus (Chalc)*	*Sus scrofa (Chalc)*	*Canis familiaris*
Cervus elaphus		0,9151	0,2193	0,5959	0,3913	0,7768	0,5959	0,05183
Domestic herbivores (LN)	0,9151		0,2246	0,6985	0,4113	0,9431	0,8973	0,02819
Sus domesticus (LN)	0,2193	0,2246		0,1715	0,03476	0,1792	0,7317	0,05199
Sus scrofa (LN)	0,5959	0,6985	0,1715		0,551	0,6485	0,6625	0,08086
Domestic herbivores (Chalc)	0,3913	0,4113	0,03476	0,551		0,2556	0,1771	0,03689
Sus domesticus (Chalc)	0,7768	0,9431	0,1792	0,6485	0,2556		0,4941	0,02265
Sus scrofa (Chalc)	0,5959	0,8973	0,7317	0,6625	0,1771	0,4941		0,08086

Canis familiaris	0,05183	0,02819	0,05199	0,08086	0,03689	0,02265	0,08086	

Table 13. Mann-Whitney pairwise $\delta^{15}N$‰ values of Neolithic and Chalcolithic samples comparison. LN – Late Neolithic; Chalc-Chalcolithic.

	Cervus elaphus	*Domestic herbivores (LN)*	*Sus domesticus (LN)*	*Sus scrofa (LN)*	*Domestic herbivores (Chalc)*	*Sus domesticus (Chalc)*	*Sus scrofa (Chalc)*	*Canis familiaris*
Cervus elaphus		0,4555	0,7768	0,8597	0,2703	0,7768	0,8597	0,05183
Domestic herbivores (LN)	0,4555		0,5203	0,8973	0,9273	0,8303	0,8973	0,02819
Sus domesticus (LN)	0,7768	0,5203		0,6485	0,4168	0,5229	1	0,02265
Sus scrofa (LN)	0,8597	0,8973	0,6485		1	0,909	0,6625	0,08086
Domestic herbivores (Chalc)	0,2703	0,9273	0,4168	1		0,4641	0,7656	0,03689
Sus domesticus (Chalc)	0,7768	0,8303	0,5229	0,909	0,4641		0,6485	0,02265
Sus scrofa (Chalc)	0,8597	0,8973	1	0,6625	0,7656	0,6485		0,08086
Canis familiaris	0,05183	0,02819	0,02265	0,08086	0,03689	0,02265	0,08086	

5. Discussion

5.1. Selected samples: Zooarchaeological characteristics approach

The importance of domestic species in the Porto Torrão site is reflected in the sampling carried out for this study. From a large sample of faunal assemblages of the Late Neolithic and Chalcolithic levels, mainly composed of domestic animals, 40 faunal remains were selected. These faunal samples are represented by pig (*Sus domesticus*), cattle (*Bos taurus*), sheep *(Ovis aries*), goat (*Capra hircus*), and dog (*Canis familiaris*), as well as two wild species: red deer (*Cervus elaphus*) and wild boar (*Sus scrofa*). One of the crucial aspects of this study has been to characterize and differentiate the remains of pigs. The size and shape of the pigs are key to differentiating between wild and domestic. Some of the faunal assemblages in the Western Iberian Peninsula have been characterized by not granting the status of domestic and wild to the remains of pigs due to the difficulty of separating the domestic form from the wild form from biometric analyses (Valente 2014, 2019). In this work, based on the biometric data and the characterization in shape and size of the sample studied, we have classified the pig remains into domestic and (expected) wild.

The zooarchaeological analyses carried out at the Porto Torrão samples reflect that during the Neolithic period, faunal assemblages were dominated by domestic species. Among domestic species, caprines (*Ovis aries* and *Capra hircus*) and bovines (*Bos taurus*) are the most represented. Hunting could be represented by cervids (*Cervus elaphus*). Pigs present high percentages of fauna, although it has not been possible to differentiate, in most cases, their domestic or wild status (Correia, 2016).

The analyses of Pereira (2016) suggest that the faunal group consists mainly of domestic animals, with pigs being the most common, followed by sheep, goats, and cattle. These animals provide evidence of a sedentary population relying on livestock as the primary source of food, along with some hunting.

There are no zooarchaeological studies for the Chalcolithic levels, which implies that we will not be able to relate our data with in-depth zooarchaeological analyses.

The zooarchaeological data obtained in this work through the meticulous analysis of the samples reinforce the data obtained in previous studies for the Late Neolithic levels. The samples analyzed correspond to sub-adult and adult individuals. Based on the slaughter patterns, the selected individuals could have been destined for meat production. These individuals were killed at their optimal meat yield. For example, *Bos taurus* were killed between 18 to 25 months old. Based on age estimation according to bone fusion, *Ovis aries* were killed at >4 months and >24 months old. *Sus domesticus* were killed between 12 and 24 months old. Wild animals are represented by adult individuals over 24 months old (for example, *Cervus elaphus* (PT-8)). Other *Cervus elaphus* samples (PT-34, PT-41, PT-46) age-at-death data are represented as adults. *Sus scrofa* age-at-death data are in the range between +12 months and adult age.

In summary, the selected samples, along with the previous zooarchaeological analyses, represent the four main domestic species (cattle, pig, sheep, and goat) with a production oriented mainly to the exploitation of meat. Wild animals, obtained from hunting practices, are also represented by adult individuals. These animals could have provided meat, in addition to other materials such as skin, bone, or tendons.

The study of anthropogenic alterations is essential to know the degree of alteration of the animal carcass and to be able to characterize that the individuals analyzed in this work have been destined for human consumption or other practices such as intentional deposition for social, political or religious purposes. For this purpose, the fractures and butchery marks (cuts and impacts) have been analyzed. The degree of concentration of bone fractures varied between Neolithic and Chalcolithic levels and animal species. In the Late Neolithic, the fractures were mainly concentrated on the *Ovis/Capra* and *Sus domesticus* remains. In contrast, in the Chalcolithic, the pattern changed, and fractures were abundant on the bones of *Sus domesticus* and *Cervus elaphus*. Regarding butchery marks, the Neolithic samples of *Sus domesticus (*PT-7, PT-9, PT-19, PT-20, PT-24) have several anthropic marks. For example, PT-7 demonstrates multiple shallow slices and oblique fracture, partly brownish, as a result of filleting practice. PT-9 has a longitudinal fracture. PT-19 and PT-20 show oblique irregular fractures. Moreover, PT-24 demonstrates a diagonal shallow cut. Only one *Sus scrofa* (PT-10) sample has a longitudinal fracture. Only *Sus domesticus* (PT-12, PT-22) and Chalcolithic (PT-47) had no signs of anthropic marks.

Some Chalcolithic samples of *Sus domesticus* show anthropic marks. For example, PT-29 demonstrates filleting practice with several horizontal shallow slices, stepped fracture, and brownish color. PT-31 has signs of dismemberment with multiple moderate-depth chops, slice marks, and a V-shaped fracture. PT-33 is characterized by longitudinal fracture. PT-36 and PT-39 display signs of filleting practice, with multiple horizontal, diagonal, and vertical moderate chops and slices. Two samples from six wild boars had fractures and multiple cutmarks, indicating filleting and skinning.

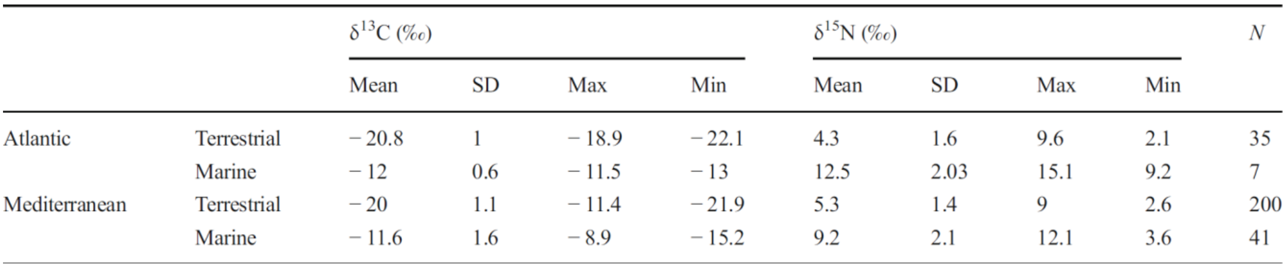
Furthermore, the context of recovery of the fauna remains analyzed in this work makes us hypothesize that they were waste pits (Rodrigues, 2014).

Regarding the bone surface alterations, natural and anthropic alterations were noted on samples. The results of weathering stages analysis showed that 67.5% of the samples exhibited Stage 1. Late Neolithic samples PT-10 (*Sus scrofa*), PT-11 (*Ovis/Capra*), and PT-12 (*Sus domesticus*) had both Stage 1 and 2 features. PT-13 (*Ovis/Capra*) showed signs of Stages 2 and 3. PT-23 (*Sus scrofa*) was difficult to identify, while the remaining samples showed signs of Stage 1. Similarly, Chalcolithic samples also showed Stages 1 and 3. PT-35 (*Sus scrofa*) had Stages 1 and 2, while PT-36 (*Sus domesticus*), PT-43 (*Bos taurus*), and PT-46 (*Cervus elaphus*) had Stages 2 and 3. The remaining samples were in Stage 1.

According to the analysis of the bone surfaces, the analyzed samples are well preserved which could indicate good conservation conditions of bone collagen in the faunal remains. However, collagen extraction was not successful for the samples PT-28 (Neolithic) and PT-38 (Chalcolithic). These samples presented results of stage 1 according to weathering analysis. In addition, flakes and root marks were characterized for PT-28, while PT-38 had porosity and flakes on the surface. Both samples had a partly brownish color.

5.2. Foddering practices

The results of stable isotope analysis of δ^{13}C and δ^{15}N values of the faunal remains fall within the expected values for C_3 plant vegetation. These data coincide with the South-Western Iberian Peninsula during the Neolithic period (Garcia-Rivero et al., 2019; Cubas, 2018) (Table 14[3]).



		δ^{13}C (‰)				δ^{15}N (‰)				*N*
		Mean	SD	Max	Min	Mean	SD	Max	Min	
Atlantic	Terrestrial	− 20.8	1	− 18.9	− 22.1	4.3	1.6	9.6	2.1	35
	Marine	− 12	0.6	− 11.5	− 13	12.5	2.03	15.1	9.2	7
Mediterranean	Terrestrial	− 20	1.1	− 11.4	− 21.9	5.3	1.4	9	2.6	200
	Marine	− 11.6	1.6	− 8.9	− 15.2	9.2	2.1	12.1	3.6	41

Table 14. Faunal δ13C and δ15N values grouped into two categories: terrestrial (ungulates), marine (fish and mammals) (Cubas, 2018, table 1).

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[3] Faunal δ^{13}C and δ^{15}N values are represented by 283 specimens from the Atlantic (n = 42) and Mediterranean (n = 241) regions (Cubas, 2018, table 1).

The highest $\delta^{13}C$ values in herbivores (> -19‰) could be a sign of consumption of drought-resistant vegetation, such as shrubs (Filella and Peñuelas, 2003). All samples of herbivores and pigs (both domestic and wild) are represented with $\delta^{13}C$ values > -19‰. In Mediterranean Portugal during the Early Neolithic period, lowland farming traditionally relied on rain-fed agriculture, with "hortas" (gardens) restricted to small plots (Carvalho, 2017). Winter (wheat, rye) and spring (barley, oat) cereals were grown in a cereal-fallow rotation, and the plots were also used as pasture for sheep during the fallow phase that lasted from two to five years (Carvalho, 2017). The absence of pollen or anthracological studies in the area limits the interpretation of the vegetation that made up the landscape. Palynological data of the region is limited to cores taken from specific environments, such as river banks and coastal lagoons. These cores display more local species changes and indirect human impact rather than direct evidence of farming. However, there are two exceptions: Cerealia pollens found in cores at Carvalhal in north-west Alentejo (Mateus, 1992) and at the Sizandro Valley in south-west Estremadura (Dambeck et al., 2015). Both show localized vegetation changes at around 5400 cal BC (Carvalho, 2017). During the Early Neolithic period in Portugal, there is no record of domestic plants in the archaeological and palaeobotanic records. Lower Estremadura sites have crop sets similar to southern Iberia. Lapiás das Lameiras has predominantly naked barley and pulses, with emmer, einkorn, and hulled barley in smaller quantities. São Pedro de Canaferrim site had even fewer remains (Carvalho, 2017).

It is worth highlighting the system called "montado" in the Alentejo region of Mediterranean Portugal involved clearing the evergreen oak forest for pig and sheep herding. The traditional landscapes were well-documented before mechanization in the 20th century (Ribeiro 1945,1968). Evidence of this system appears from the late 4th millennium BC in the arboreal composition of the natural landscape and faunal spectra at archaeological sites (Zilhão, 1997; Rodrigues, 2015: 301-308; Carvalho, 2017).

In the past, animal husbandry practices involved keeping herds in close proximity to settlements or allowing them to roam semi-freely or freely (Albarella et al., 2007). Such practices are still used in some traditional communities in the northern Mediterranean areas (e.g., Albarella et al., 2007), and have been postulated for prehistoric groups in Europe (e.g., Balasse et al., 2016). Pigs can be self-sufficient in their dietary requirements without losing their domestic status. Free-ranging pigs, living independently at certain times of the year, still represent the traditional pig-keeping systems in

Sardinia and Corsica (Albarella et al., 2006). In Old Saxony and Early Medieval England, free-ranging pigs were taken to pasture as part of a communal management system (Wiseman, 2000).

Given the freedom to roam in the field and forested environments, they will likely obtain their nutrients from available plants, and they will have an isotopic signature similar to wild herbivores, in this case *Cervus elaphus*. We can estimate that domestic animals from Porto Torrão were in the same areas as red deer in this context.

$\delta^{13}C$ and $\delta^{15}N$ results of herbivores (wild and domestic) and pigs (domestic and wild) are represented in the same group, meaning their diet was probably terrestrial plant-based. Also, no feeding strategy change is visible between the Late Neolithic and Chalcolithic periods. We can assume that domestic herbivores and pigs probably used the same semi-free or free strategy.

There are no significant changes between flocks during the Late Neolithic and Chalcolithic periods; isotopic signatures demonstrate the absence of a change in the feeding strategy of pigs and other domestic herbivores.

If we combine the results from Porto Torrão with other Neolithic and Chalcolithic sites from southern Portugal, similar feeding strategies can be observed (Figure 19).

a) Map of the location of Porto Torrão (red rhombus), Perdigões (1), and the sites described in Guiry et al. (2016a, 2016b) (Cadaval (2), Carrascal and Leceia (4), Moita da Ladra (5) and Penedo do Lexim (3)) and Waterman et al. (2016) (Feteira II, Paimogo I, Lapa da Rainha II (6), Bolores, Borracheira, Cabeço da Arruda, Cova da Moura (7)). The location of the Roman/late Antiquity site of Monte da Cegonha (8) is also presented; b) $\delta^{13}C$ and $\delta^{15}N$ isotope values of bone collagen showing mean values ±1σ of fauna from Perdigões in blue, sites mentioned in Guiry et al. (2016a, 2016b) in orange and sites mentioned in Waterman et al. (2016) in grey color. Data modified from Žalaitė et al., 2018, Figure 6.

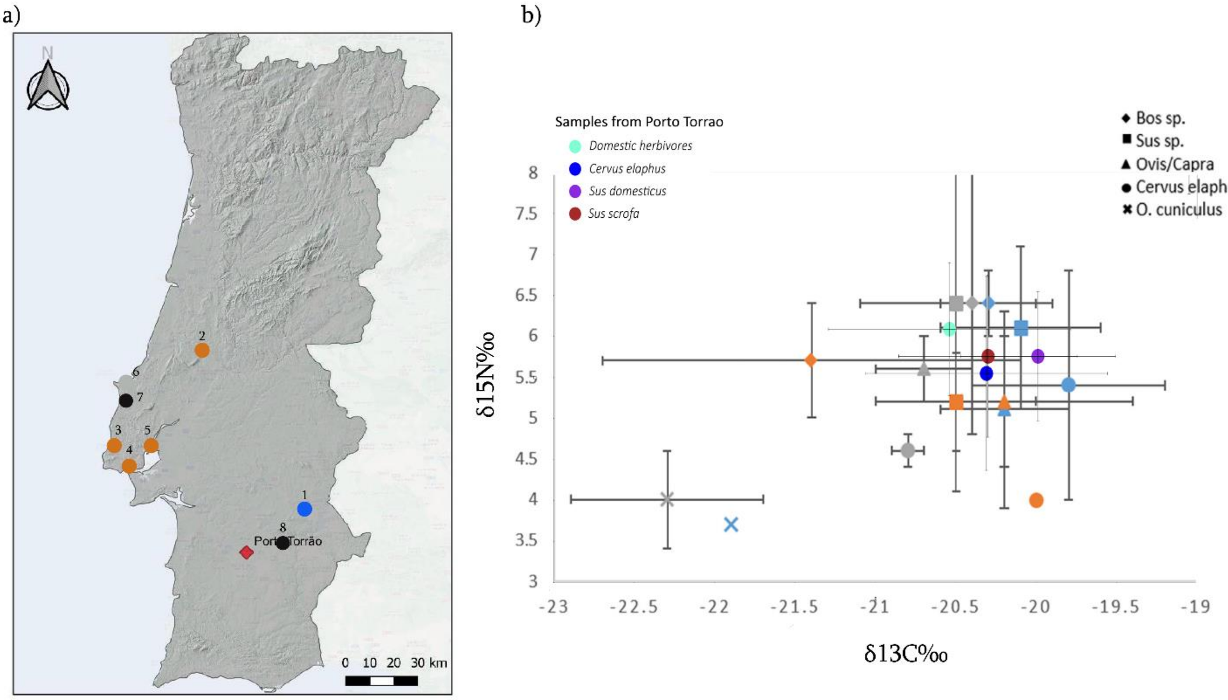

Figure 19. a) location of archaeological sites; b) δ 13C and δ 15N isotope values of fauna.

According to Žalaitė et al. (2018), Fauna from the archaeological site of Predigões during the Late Neolithic and Chalcolithic periods obtained protein primarily from C_3 plant sources, similar to Porto Torrão. Although the data indicate that Porto Torrão and Predigões could have same management strategies, it is difficult to compare these data. Predigões is the site characterized by ritual activities, however in Porto Torrão this type of activities has not been recorded at the moment. Even, so we can observe how the sites located in the inland area (Porto Torrão and Predigões) with drier enviroments, have more similar management practices.

The same feeding strategies can be observed in the NE Iberian Peninsula during the Early Neolithic. The $\delta^{15}N$ values of pigs from La Draga, Cova del Frare, and Serra de Mas Bonet, are similar to those of the local herbivores, indicating that they were raised in a free-range system. The pigs were primarily fed by plant products, suggesting they had access to forested environments and were free to roam (Navarrete et al., 2017). Contrarily, the $\delta^{15}N$ values of pigs at Reina Amàlia-Caserna de Sant Pau and Can Sadurní suggest that a significant proportion of their dietary proteins were sourced from animals. This could indicate a home-based management system, where the pigs are kept confined or allowed to forage freely within the settlement (Navarrete et al., 2017).

Although 38 samples for this research make it difficult to accurately represent the feeding practices of the site, our study, when combined with previously published literature on Porto Torrão faunal assemblages during the Late Neolithic and Chalcolithic period, still clearly shows that the results fit into Porto Torrão's farming tendencies during this timeframe.

According to Correira et al. (2016), there were visible changes between domestic species from the Late Neolithic to the Pre-Bell Beaker period, with bovids increasing and caprines and lagomorphs decreasing while suids maintained their importance. Pereira (2016) states that pigs were the dominant taxon from the Pre-Bell Beaker to the Bell Beaker period. The data shows that more than 50% of the pigs were slaughtered before reaching maturity. The pigs, named *Sus* sp., were the dominant taxon in Porto Torrão, with 119 remains identified. The study also revealed that more than 50% of the suids were slaughtered at an early age, before or up to 12 months of age.

Our research aimed to determine the differences in isotopic signatures between wild boars and domestic pigs. We integrated zooarchaeological data and isotopic analyses to reconsider the status of six *Sus scrofa* specimens, which were believed to be different according to taxonomic data. However, we found no significant differences between wild and domestic herbivores and domestic pigs. Hypothetically, domestic pigs should have different isotopic signatures from wild boars due to their access to animal by-products and different protein sources. We can conclude that two samples with the lowest δ^{15}N‰ values than the rest of the *Sus sp.* samples, from the Late Neolithic period PT-26 with 4.69‰ and PT-68 in the Chalcolithic period with 4.33‰, could be identified as wild species.

It is difficult to distinguish between domestic and wild pigs in the Iberian Peninsula, but taphonomic markers and the high percentage of juvenile animals in the sample suggest that most of the pigs were domesticated (Pereira, 2016).

The domestication of animals is not a simple process, with a clear distinction between wild and domestic forms. Animal domestication studies categorize animals into five groups: wild, captive, domestic, cross-bred, and feral. (Mayer et al., 1991; Price, 2002). Cross-breeds are genetic hybrids resulting from the breeding of wild and domestic parents. They offer valuable insights into the inheritance of traits since hybrids can assume intermediate forms between both parents, resemble one parent more than the other, or even manifest as unique forms distinct from either parent (McDade, 1990; Reiseberg, 1993). Hybrids can be bred intentionally for hunting or for producing meat with specific characteristics (Porter, 1993). On the other hand, unintentional hybrids can result from contact with wild individuals when domestic pigs are raised in free-range conditions (Apollonio, 1988; Genov,1991; Evin, 2015). Pigs kept in free-range conditions can escape and create entirely feral populations, making it difficult to classify them as wild or domestic, so other conditions must be considered (Albarella et al., 2006). Taking this into account creates the hypothesis that the samples from Potro Torrão which were identified as *Sus scrofa* (according to their anatomical characteristics) could also be cases of hybridization.

Distinguishing between *Sus domesticus* and *Sus scrofa* during the Neolithic period in the Iberian Peninsula can be challenging due to their similar anatomical features. However, this challenge can be more or less overcome by utilizing stable isotope analysis as an additional tool. By analyzing the zooarchaeological data such as taphonomy, taxonomy, biometry, butchery marks, and isotopic results, we can confidently estimate the production, management strategies, and domestication tendencies of the animals during the Late Neolithic and Chalcolithic transition in Porto Torrão, thereby determining their dietary signatures and re-evaluating their status.

6. Conclusion

The differentiation between *Sus domesticus* and *Sus scrofa* in the Iberian Peninsula during the Neolithic period can be difficult due to their similar anatomical features. To overcome this issue, stable isotope analysis can be utilized as an additional tool to determine their dietary signatures and re-evaluate their status. We estimate animals' production, feeding, management strategies, and domestication tendencies during the Late Neolithic and Chalcolithic transition in Porto Torrão by analyzing the zooarchaeological data and isotopic results.

By compiling zooarchaeological data and isotopic analysis of the faunal remains from the Porto Torrão, we found that from the expected *Sus scrofa* samples according to their shape and size, two individuals have lower $\delta^{15}N$ values than the rest of the pigs, which gives us the idea to reconsider their "wild " status, meaning that they had minimal animal proteins in their diet. Also, the data suggest that the pigs were raised in the same pasture areas as domestic and wild herbivores and, consequently, had a diet dominated by plant products.

No significant changes in feeding management during the Late Neolithic and Chalcolithic period transitions at Porto Torrão are noticeable. Most of the fauna were adults ranging between 12 and 24 months. Based on the previous archaeozoological analysis and the selected samples, it can be concluded that the four main domestic species (cattle, pig, sheep, and goat) were represented and that the production was primarily focused on meat exploitation. Additionally, wild animals, which were obtained through hunting practices, were also present, mainly in the form of adult individuals. These animals could have been a source of meat as well as other materials.

To provide new insights into human-faunal interaction in a domesticated landscape, more studies are needed to investigate domestic pigs' different pathways and management strategies during the Iberian Peninsula Neolithic and Chalcolithic transition.

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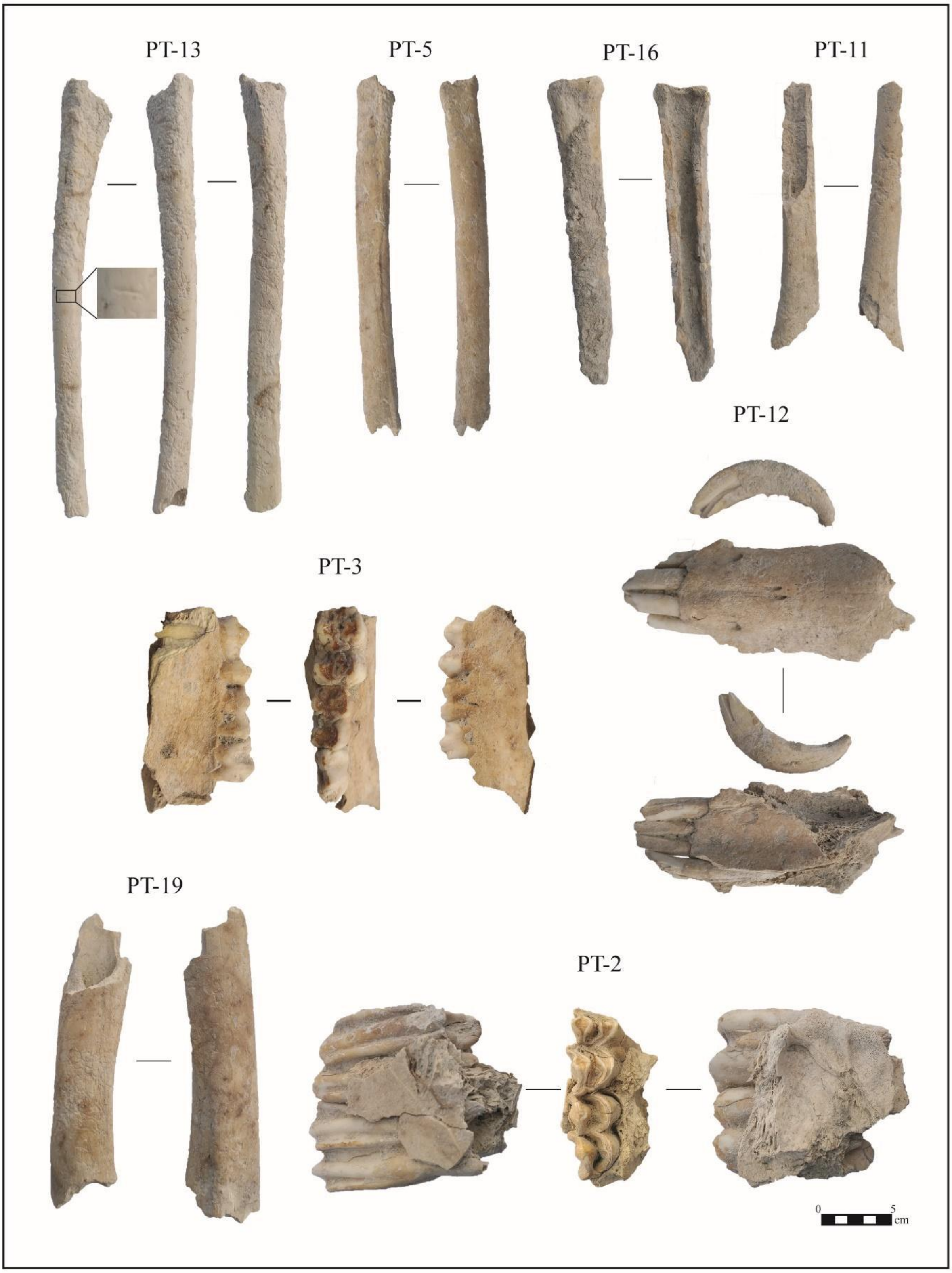
Annexes

Annex 1

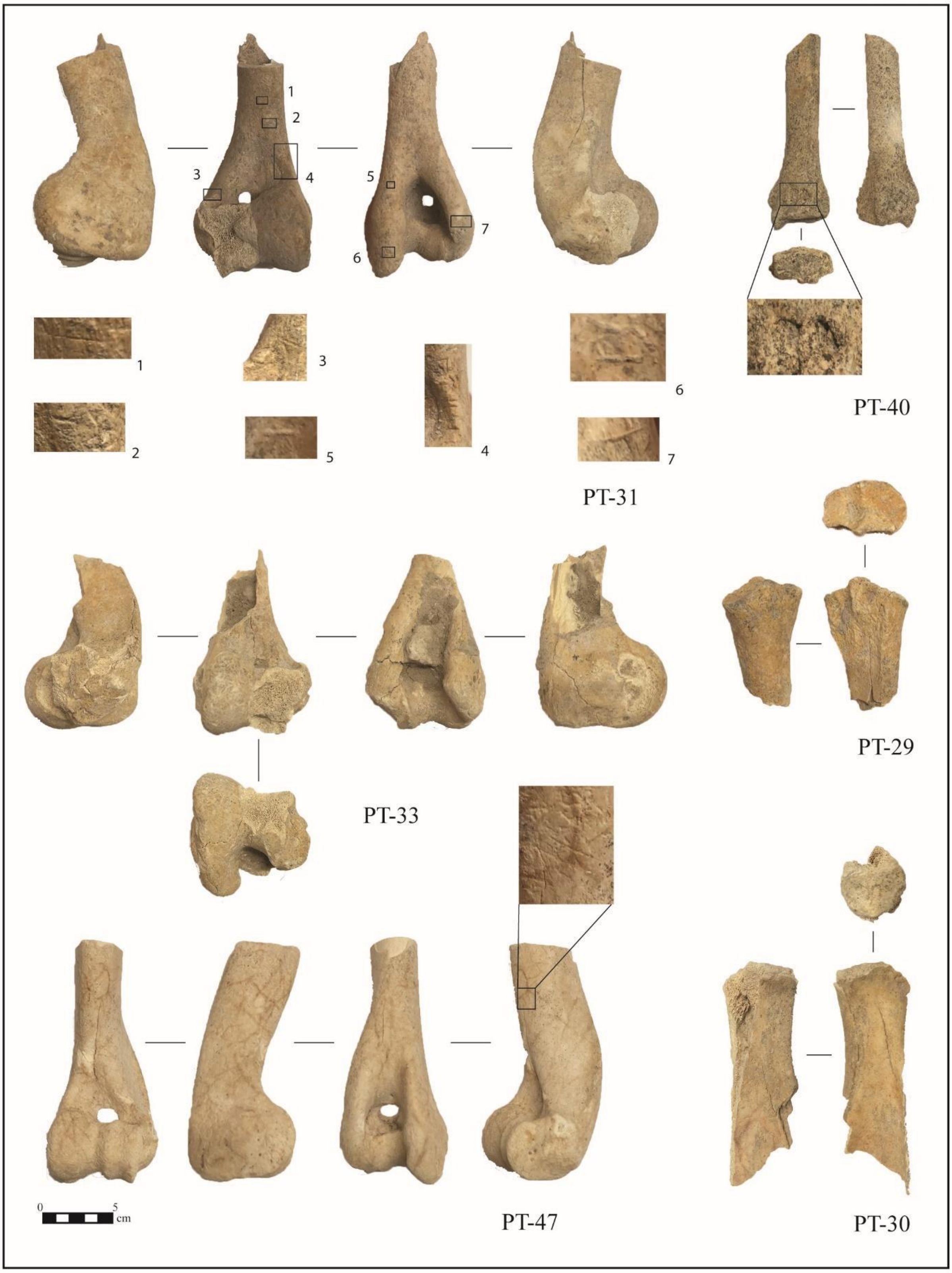


Porto Torrão. Scale 1:2. (detail photos without scale)
Samples: PT-2 - *Bos taurus* right Skull. PT-3 - *Sus domesticus* right Mandible. PT-5 - *Canis familiaris* right Radius. PT-11 - *Ovis/Capra* Metacarpus. PT-12 - *Sus domesticus* Right/Left Mandible. PT-13 - *Ovis/Capra* Right Tibia. PT-16 - *Ovis/-Capra* Right Metatarsus. PT-19 - *Sus domesticus* Right Femur.

Porto Torrão. Scale 1:1 (detail pictures without scale) .
Samples: PT-7 - *Sus domesticus* Right Tibia. PT-8 - *Cervus elaphus* Left Tibia.

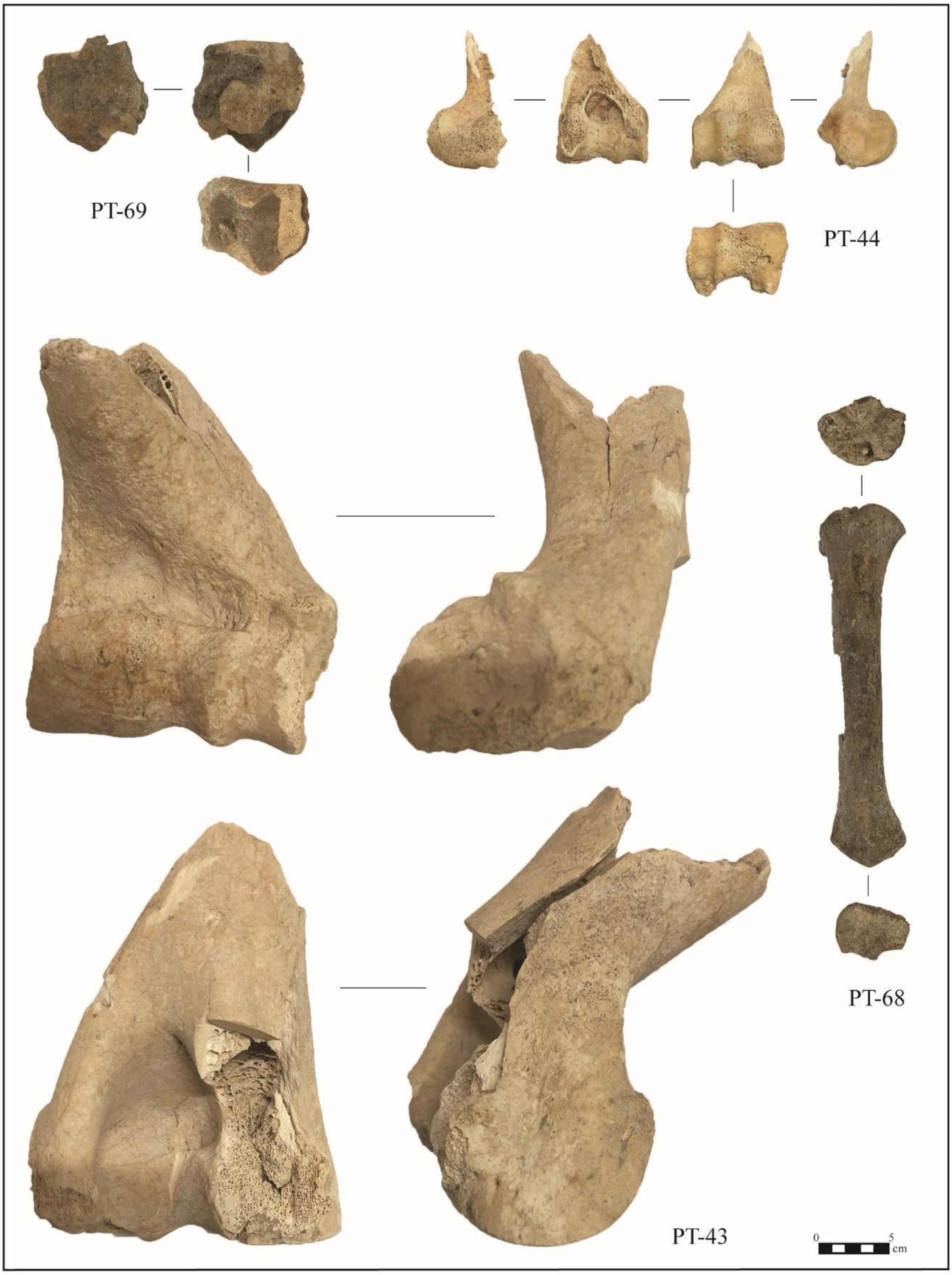
Porto Torrão. Scale 1:2 (detail pictures without scale).
Samples: PT-4 - *Ovis aries* Right Skull. PT-9 - *Sus domesticus* Left Radius. PT-10 - *Sus Scrofa* Right Humerus. PT-14 - *Ovi aries* Metacarpus. PT-20 - *Sus domesticus* Left Radius. PT-22 - *Sus domesticus* Right Metacarpus. PT-23 - Sus *Scrofa* Left Mandible. PT-24 - *Sus domesticus* Right 3rd Phalanx complete. PT-26 - *Sus Scrofa* Left Skull. PT-28 - *Sus Scrofa* Skull.

Annex 4



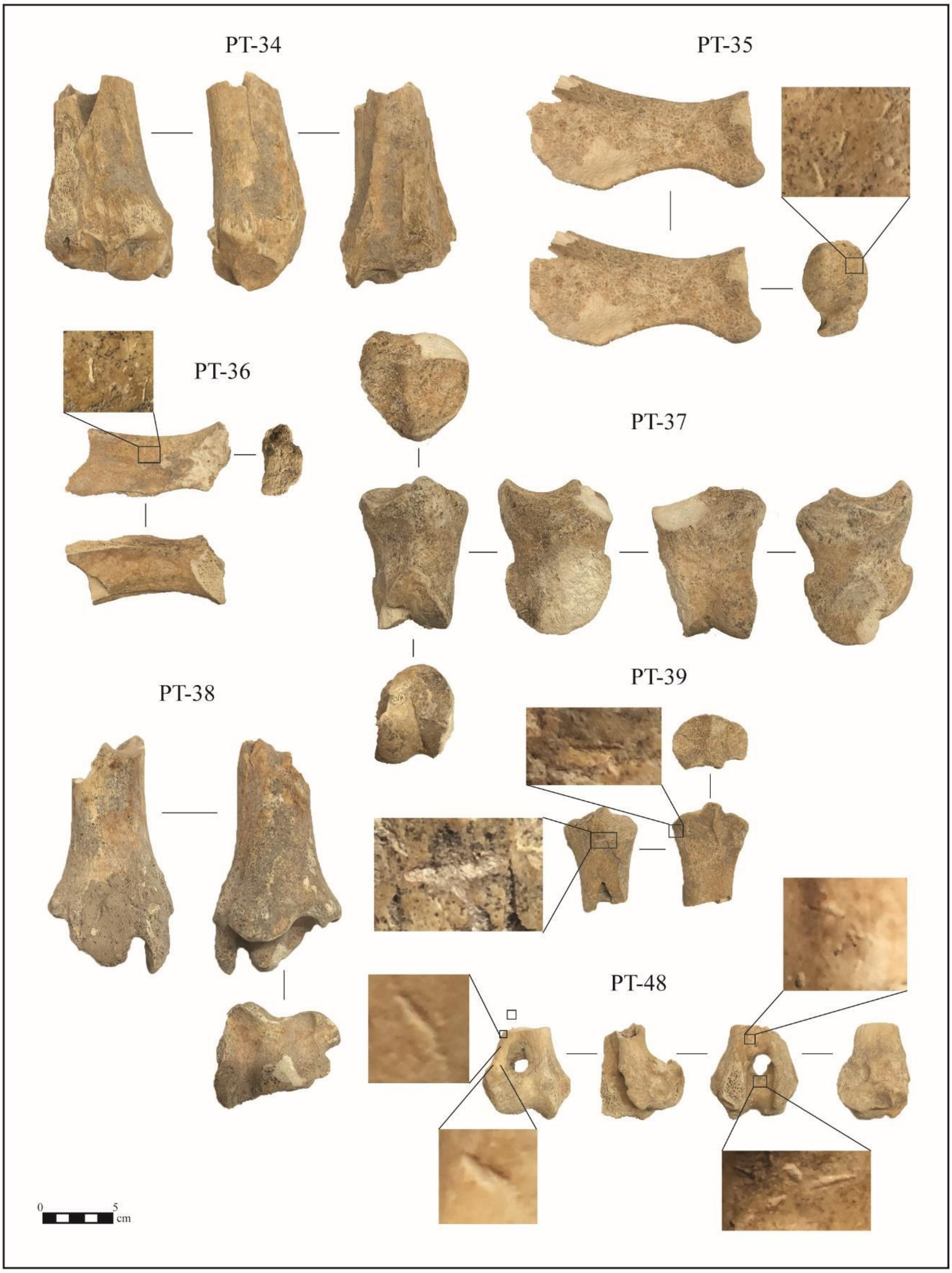
Porto Torrão. Samples: PT-29 - *Sus domesticus* Right Radius; PT-31, PT-47 - *Sus domesticus* Right Humerus; PT-33 - *Sus domesticus* Left Humerus; PT-30 - *Ovis/Capra* Left Scapula; PT- 40 - *Canis familiaris* Right Radius. Scale 1:2, details without scale.

Annex 5

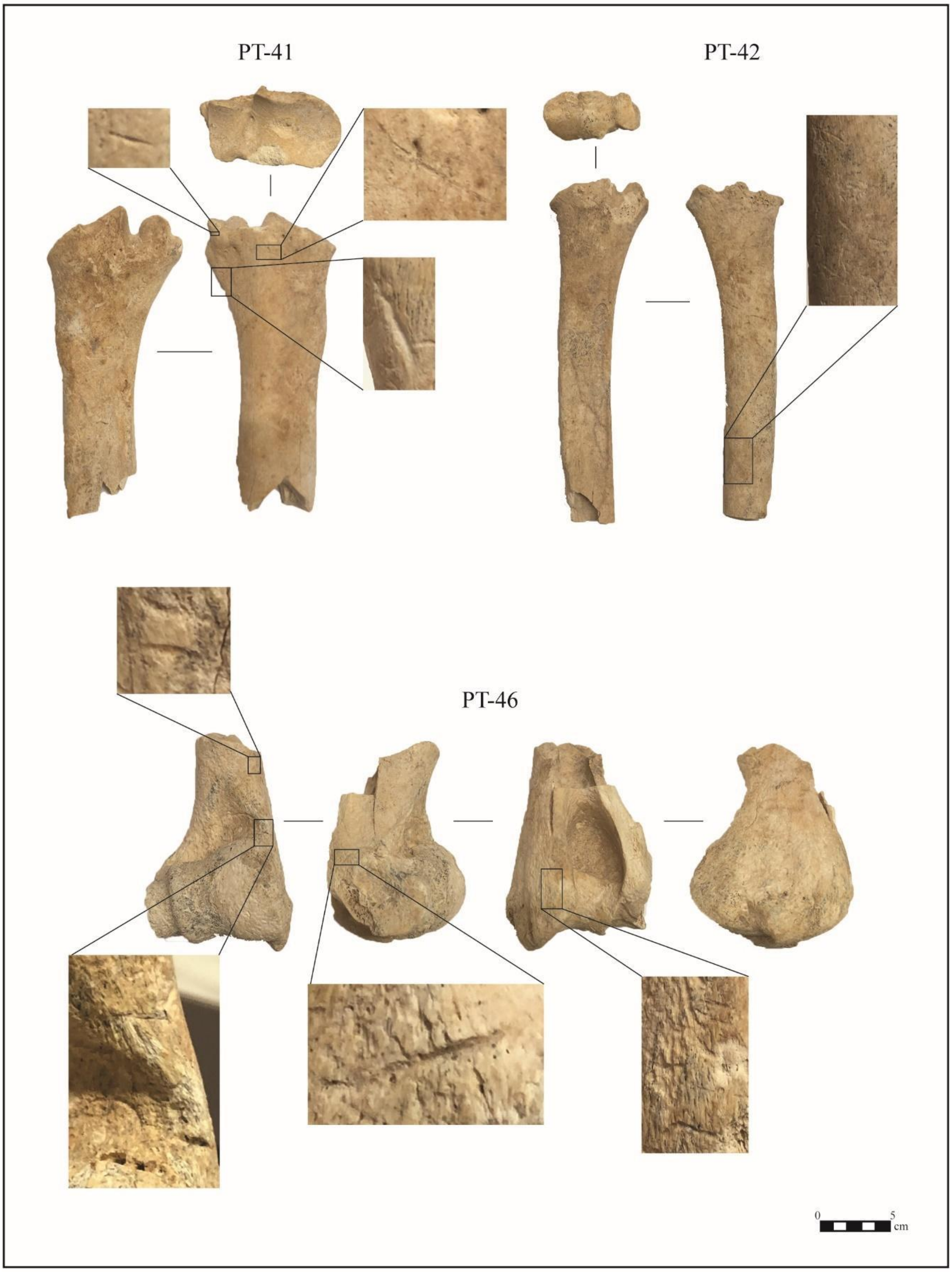


Porto Torrão. Samples: PT-43 - *Bos taurus* Left Humerus; PT-44 - *Ovis aries* Right Humerus; PT-68 - *Sus Scrofa* Complete Left Radius; PT-69 - *Sus Scrofa* Left Tibia. Scale 1:2.

Annex 6



Porto Torrão. Scale 1:2. (detail pictures without scale).
Samples: PT-34 - *Cervus elaphus* Right Radius. PT-35 - *Sus Scrofa* Left Scapula. PT-36 - *Sus domesticus* Left Scapula. PT-37 - *Bos taurus* Left 2nd Phalanx complete. PT-38 - *Cervus elaphus* Left Tibia. PT-39 - *Sus domesticus* Left Radius. PT-48 - *Canis familiaris* Right Humerus.



Porto Torrão. Scale 1:2. (detail pictures without scale).
Samples: PT41 - *Cervus elaphus* Left Radius. PT-42 - *Ovis aries* Left Radius. PT-46 - *Cervus elaphus* Right Humerus.

Sample Overview - General Information

Site	Specimen ID	Sector/Pit	UE	Period	Specie	expected wild	Skeleton Part	Fraction	Age
Porto Torrão	PT-2	Porte 181	2046	Late Neolithic	*Bos taurus*		Maxilla	Maxilla	Adult
Porto Torrão	PT-3	Porte 181	2031	Late Neolithic	*Sus domesticus*		Maxilla	Corpus	Adult
Porto Torrão	PT-4	Porte 181	2031	Late Neolithic	*Ovis/Capra*		Maxilla	Maxilla	Adult
Porto Torrão	PT-5	Porte 181	2031	Late Neolithic	*Canis familiaris*		Radius	Diaphysis medial	Adult
Porto Torrão	PT-7	Porte 181	2038	Late Neolithic	*Sus domesticus*		Tibia	Diaphysis medial to Epiphysis distal	Adult
Porto Torrão	PT-8	Porte 181	2038	Late Neolithic	*Cervus elaphus*	yes	Tibia	Diaphysis medial to Epiphysis distal	Adult
Porto Torrão	PT-9	Porte 181	2039	Late Neolithic	*Sus domesticus*		Radius	Epiphysis proximal to Diaphysis proximal	Adult
Porto Torrão	PT-10	Porte 181	2034	Late Neolithic	*Sus scrofa*	yes	Humerus	Diaphysis distal to Epiphysis distal	Adult
Porto Torrão	PT-11	Porte 181	2031	Late Neolithic	*Ovis/Capra*		Metacarpus	Diaphysis medial	Adult
Porto Torrão	PT-12	Porte 181	2037	Late Neolithic	*Sus domesticus*		Mandible	Diastema	Adult
Porto Torrão	PT-13	Porte 181	2049	Late Neolithic	*Ovis/Capra*		Tibia	Diaphysis medial	Adult
Porto Torrão	PT-14	Porte 181	2044	Late Neolithic	*Ovis/Capra*		Metacarpus	Diaphysis distal to Epiphysis distal	Adult
Porto Torrão	PT-16	Porte 181	2021	Late Neolithic	*Ovis/Capra*		Metatarsus	Epiphysis proximal to Diaphysis medial	Adult
Porto Torrão	PT-19	Porte 181	2047	Late Neolithic	*Sus domesticus*		Femur	Diaphysis medial to Diaphysis distal	Adult
Porto Torrão	PT-20	Porte 181	2035	Late Neolithic	*Sus domesticus*		Radius	Epiphysis proximal to Diaphysis proximal	Adult
Porto Torrão	PT-22	Porte 181	2059	Late Neolithic	*Sus domesticus*		Metacarpus	Epiphysis proximal to Diaphysis proximal	Adult
Porto Torrão	PT-23	Porte 181	2021	Late Neolithic	*Sus scrofa*	yes	Mandible	Corpus	Adult
Porto Torrão	PT-24	Porte 181	2031	Late Neolithic	*Sus domesticus*		Phalanx I	Complete	Adult
Porto Torrão	PT-26	Porte 181	2044	Late Neolithic	*Sus scrofa*	yes	Maxilla	Maxilla	Adult
Porto Torrão	PT-29	Porte 181	2003	Chalcolithic	*Sus domesticus*		Radius	Epiphysis proximal to Diaphysis proximal	>12 month
Porto Torrão	PT-30	Porte 181	2054	Chalcolithic	*Ovis/Capra*		Scapula	Coracoid, joint, neck, spine, corpus	Adult
Porto Torrão	PT-31	Porte 181	2042	Chalcolithic	*Sus domesticus*		Humerus	Diaphysis medial to Epiphysis distal	12-13 month
Porto Torrão	PT-33	Porte 181	2030	Chalcolithic	*Sus domesticus*		Humerus	Diaphysis distal to Epiphysis distal	>12 month
Porto Torrão	PT-34	Porte 181	2030	Chalcolithic	*Cervus elaphus*	yes	Radius	Diaphysis distal to Epiphysis distal	Adult
Porto Torrão	PT-35	Porte 181	2053	Chalcolithic	*Sus scrofa*	yes	Scapula	Coracoid, joint, neck, spine, corpus	>12 month
Porto Torrão	PT-36	Porte 181	2053	Chalcolithic	*Sus domesticus*		Scapula	Joint, neck, spine, corpus	Adult. N/A
Porto Torrão	PT-37	Porte 181	2053	Chalcolithic	*Bos taurus*		Phalanx II	Complete	15-18 month
Porto Torrão	PT-39	Porte 181	2043	Chalcolithic	*Sus domesticus*		Radius	Epiphysis proximal to Diaphysis proximal	>12 month
Porto Torrão	PT-40	Porte 181	2043	Chalcolithic	*Canis familiaris*		Radius	Diaphysis medial to Epiphysis distal	>12 month
Porto Torrão	PT-41	Porte 181	2045	Chalcolithic	*Cervus elaphus*	yes	Radius	Epiphysis proximal to Diaphysis medial	Adult
Porto Torrão	PT-42	Porte 181	2045	Chalcolithic	*Ovis aries*		Radius	Epiphysis proximal to Diaphysis media	3-4 month
Porto Torrão	PT-43	Porte 181	2055	Chalcolithic	*Bos taurus*		Humerus	Diaphysis distal to Epiphysis distal	15-20 month
Porto Torrão	PT-44	Porte 181	2055	Chalcolithic	*Ovis aries*		Humerus	Diaphysis distal to Epiphysis distal	3-4 month
Porto Torrão	PT-46	Porte 181	2057	Chalcolithic	*Cervus elaphus*	yes	Humerus	Diaphysis distal to Epiphysis distal	Adult
Porto Torrão	PT-47	Porte 181	2057	Chalcolithic	*Sus domesticus*		Humerus	Diaphysis medial to Epiphysis distal	>12 month
Porto Torrão	PT-48	Porte 181	2057	Chalcolithic	*Canis familiaris*		Humerus	Diaphysis distal to Epiphysis distal	8-9 month?
Porto Torrão	PT-68	Poste 181	2043	Chalcolithic	*Sus scrofa*	yes	Radius	Complete	Adult
Porto Torrão	PT-69	Poste 181	2004	Chalcolithic	*Sus scrofa*	yes	Tibia	Diaphysis distal to Epiphysis distal	Adult

UE = Unidad Estratigrafía (Stratigraphic unit)

Sample Overview - Weights and ratios

Specimen ID	bone sample (g)	tube Lyoph (g)	Col lyoph (g)	Col in Cap (mg)	Col obtained (g)	Col bone (%)	d^{15}N AIR (‰)	N (%)	d^{13}C VPDB (‰)	C (%)	C/N ratio
PT-2	0,5319	6,1776	6,1949	0,5180	0,0173	0,0325	6,2761	10,0775	-19,7974	28,6680	3,3189
PT-3	0,5526	6,2051	6,2339	0,5000	0,0288	0,0521	4,4748	14,5842	-20,3415	41,0573	3,2844
PT-4	0,5190	6,1905	6,2194	0,5510	0,0289	0,0557	7,0131	14,5339	-20,3547	40,2306	3,2294
PT-5	0,5991	6,2177	6,2532	0,5300	0,0355	0,0593	7,7901	14,6697	-18,7561	40,3688	3,2105
PT-7	0,5925	6,1146	6,1480	0,5380	0,0334	0,0564	4,8212	14,4461	-19,0669	40,9370	3,3061
PT-8	0,5924	6,2216	6,2790	0,5850	0,0574	0,0969	5,1156	15,1232	-19,3889	41,2889	3,1852
PT-9	0,5206	6,1923	6,2210	0,5530	0,0287	0,0551	5,8235	14,4191	-19,3552	40,2759	3,2588
PT-10	0,5868	6,2165	6,2496	0,5310	0,0331	0,0564	6,7067	14,6448	-20,5718	41,5180	3,3075
PT-11	0,5925	6,1693	6,1860	0,5820	0,0167	0,0282	5,8516	14,2421	-21,1107	39,6730	3,2499
PT-12	0,5348	6,1924	6,2307	0,5490	0,0383	0,0716	5,5892	14,8152	-20,0776	40,5570	3,1938
PT-13	0,5182	6,1629	6,2030	0,5510	0,0401	0,0774	4,6921	14,7543	-19,7169	41,3462	3,2694
PT-14	0,5220	6,1717	6,2152	0,5550	0,0435	0,0833	6,2641	14,8260	-19,6130	41,0135	3,2274
PT-16	0,5312	6,1381	6,1447	0,5790	0,0066	0,0124	5,8365	12,0051	-21,9666	36,3136	3,5290
PT-19	0,5787	6,1886	6,2308	0,6000	0,0422	0,0729	6,2871	14,9053	-19,4816	41,6887	3,2631
PT-20	0,5113	6,1587	6,1700	0,5900	0,0113	0,0221	6,4974	13,2860	-20,0236	37,7056	3,3110
PT-22	0,5779	6,1870	6,1984	0,5160	0,0114	0,0197	6,0839	13,1264	-20,1724	36,7697	3,2681
PT-23	0,5237	6,1946	6,2092	0,5350	0,0146	0,0279	6,1009	13,6797	-21,2513	38,6571	3,2969
PT-24	0,5504	6,1709	6,2023	0,5320	0,0314	0,0570	5,1436	14,6057	-20,6665	40,8264	3,2611
PT-26	0,5313	6,1860	6,2084	0,5490	0,0224	0,0422	4,7852	13,6195	-19,7516	38,3229	3,2828
PT-29	0,5790	6,1838	6,1930	0,5390	0,0092	0,0159	5,7955	12,6341	-20,0827	35,7893	3,3049
PT-30	0,4902	6,1882	6,2137	0,5750	0,0255	0,0520	5,8095	14,6429	-19,9146	40,3656	3,2161
PT-31	0,5656	6,1543	6,1878	0,5330	0,0335	0,0592	6,6826	14,5744	-20,0389	41,0345	3,2848
PT-33	0,5245	6,1813	6,2006	0,5150	0,0193	0,0368	4,9274	14,3790	-19,5478	40,1824	3,2603
PT-34	0,5245	6,1825	6,1972	0,5940	0,0147	0,0280	5,7935	14,3273	-20,5402	39,9662	3,2544
PT-35	0,5048	6,1703	6,1922	0,5930	0,0219	0,0434	5,9968	14,3908	-19,9126	40,1918	3,2584
PT-36	0,5368	6,1776	6,1895	0,5870	0,0119	0,0222	6,7117	13,9605	-20,7154	39,5276	3,3033
PT-37	0,5011	6,0970	6,1079	0,5700	0,0109	0,0218	7,5638	13,4612	-21,3777	37,6636	3,2643
PT-39	0,5105	6,1732	6,1925	0,5490	0,0193	0,0378	4,9584	14,5953	-19,9574	39,9163	3,1907
PT-40	0,5098	6,1789	6,1923	0,5790	0,0134	0,0263	9,3631	13,6169	-19,0720	37,6622	3,2268
PT-41	0,5374	6,1627	6,1814	0,5210	0,0187	0,0348	4,2335	13,8655	-21,1861	38,4156	3,2323
PT-42	0,5274	6,2064	6,2301	0,5900	0,0237	0,0449	5,1557	14,0287	-20,6410	38,7596	3,2234
PT-43	0,5147	6,2017	6,2361	0,5790	0,0344	0,0668	5,8345	14,6143	-20,6553	40,6243	3,2431
PT-44	0,5737	6,2055	6,2361	0,5190	0,0306	0,0533	6,6826	14,3295	-20,8091	40,0133	3,2578
PT-46	0,5618	6,1647	6,1912	0,5590	0,0265	0,0472	7,0391	14,3773	-20,1265	39,7223	3,2233
PT-47	0,4953	6,1884	6,2033	0,5520	0,0149	0,0301	6,8018	14,3213	-20,3721	39,9405	3,2537
PT-48	0,4656	6,1373	6,1443	0,5840	0,0070	0,0150	8,4339	13,6084	-19,3104	38,1760	3,2729
PT-68	0,5944	6,1725	6,2077	0,5890	0,0352	0,0592	4,3286	14,7515	-19,9706	40,9722	3,2404
PT-69	0,5961	6,2067	6,2164	0,6110	0,0097	0,0163	6,6656	13,2995	-20,3445	37,3871	3,2797

AIR = Atmospheric N_2 (as Isotopic Reference); C = Carbon; Cap = Tin Capsule; Col = Collagen; lyoph = lyophilized (freeze dryed); N = Nitrogen; VPDB = Vienna Pee Dee Belemnite (International Reference Standard for Carbon Isotopes)

Annex 10

Sample Overview - Butchery processes

Site	Specimen ID	Specie	Skeleton part	Butchery Location	Direction of Mark	Multiple Occurences	Depth	Type of Mark	Fractures	Color	Practice	Photo
Porto Torrão	PT-2	*Bos taurus*	Maxilla									A 1
Porto Torrão	PT-3	*Sus domesticus*	Maxilla									A 1
Porto Torrão	PT-4	*Ovis/Capra*	Maxilla									A 3
Porto Torrão	PT-5	*Canis familiaris*	Radius						transverse irregular			A 1
Porto Torrão	PT-7	*Sus domesticus*	Tibia		horizontal	yes	shallow	slice	oblique	partly brownish		A 2
Porto Torrão	PT-8	*Cervus elaphus*	Tibia		diagonal	yes	shallow	slice	longitudinal	partly brownish		A 2
Porto Torrão	PT-9	*Sus domesticus*	Radius						longitudinal			A 3
Porto Torrão	PT-10	*Sus scrofa*	Humerus						oblique			A 3
Porto Torrão	PT-11	*Ovis/Capra*	Metacarpus						longitudinal			A 1
Porto Torrão	PT-12	*Sus domesticus*	Mandible									A 1
Porto Torrão	PT-13	*Ovis/Capra*	Tibia		horizontal		shallow	slice	transverse irregular			A 1
Porto Torrão	PT-14	*Ovis/Capra*	Metacarpus		horizontal	yes	shallow	slice	transverse irregular	partly brownish		A 3
Porto Torrão	PT-16	*Ovis/Capra*	Metatarsus						longitudinal			A 1
Porto Torrão	PT-19	*Sus domesticus*	Femur						oblique irregular			A 1
Porto Torrão	PT-20	*Sus domesticus*	Radius						oblique			A 3
Porto Torrão	PT-22	*Sus domesticus*	Metacarpus									A 3
Porto Torrão	PT-23	*Sus scrofa*	Mandible									A 3
Porto Torrão	PT-24	*Sus domesticus*	Phalanx I		diagonal		shallow					A 3
Porto Torrão	PT-26	*Sus scrofa*	Maxilla									A 3
Porto Torrão	PT-28	*Sus scrofa*	Maxilla									A 3
Porto Torrão	PT-29	*Sus domesticus*	Radius	Rp	horizontal		shallow	slice	stepped	brownish	Filleting	A 4
Porto Torrão	PT-30	*Ovis/Capra*	Scapula		horizontal, diagonal	Yes	moderate	slice	irregular, flock		Filleting	A 4
Porto Torrão	PT-31	*Sus domesticus*	Humerus	Hd-2, Hd-3, Hd-4	horizontal, diagonal	Yes	moderate	chop, slice	V Shaped		Skinning, Dismemberment	A 4
Porto Torrão	PT-33	*Sus domesticus*	Humerus						longitudinal			A 4
Porto Torrão	PT-34	*Cervus elaphus*	Radius	Rd	horizontal	Yes	moderate	chop	V Shaped		Filleting	A 6
Porto Torrão	PT-35	*Sus scrofa*	Scapula		horizontal	Yes	moderate	chop, slice	irregular		Skinning, Filleting	A 6
Porto Torrão	PT-36	*Sus domesticus*	Scapula		horizontal, diagonal	Yes	moderate	slice	irregular		Filleting	A 6
Porto Torrão	PT-37	*Bos taurus*	Phalanx II									A 6
Porto Torrão	PT-38	*Cervus elaphus*	Tibia	Diaphysis	diagonal	Yes	shallow	slice	V Shaped, flock, hitting point		Filleting	A 6
Porto Torrão	PT-39	*Sus domesticus*	Radius	Rp	horizontal, diagonal, vertical	Yes	moderate	chop	stepped, flock		Filleting	A 6
Porto Torrão	PT-40	*Canis familiaris*	Radius									A 4
Porto Torrão	PT-41	*Cervus elaphus*	Radius	Rp	horizontal, diagonal, vertical	Yes	moderate, shallow	slice	stepped, V shape	partly brownish	Dismemberment	A 7
Porto Torrão	PT-42	*Ovis aries*	Radius	Rp	horizontal, diagonal, vertical	Yes	moderate	slice		partly brownish		A 7
Porto Torrão	PT-43	*Bos taurus*	Humerus	Hd	horizontal, diagonal	Yes	moderate	slice	V Shaped, flock, hitting point	partly brownish	Filleting	A 5
Porto Torrão	PT-44	*Ovis aries*	Humerus									A 5
Porto Torrão	PT-46	*Cervus elaphus*	Humerus	Hd	horizontal	Yes	moderate, deep	slice	irregular, flock, hitting point	partly brownish	Skinning	A 7
Porto Torrão	PT-47	*Sus domesticus*	Humerus									A 4
Porto Torrão	PT-48	*Canis familiaris*	Humerus	Hd	diagonal	Yes	shallow	slice		partly brownish	Filleting	A 6
Porto Torrão	PT-68	*Sus scrofa*	Radius									A 5
Porto Torrão	PT-69	*Sus scrofa*	Tibia									A 5

A = Annex; Hd = Humerus distal; Rd/Rp = Radius distal/Radius proximal; T = Tarsus; for the numerical codes, see Binford 1981, table 4.04