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A Taphonomic Approach to the Faunal Assemblage from the Pliocene Site of Baza-1, Andalucía, Southern Spain

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Abstract

This study is dedicated to examining the taphonomy of the Baza-1 paleontological site situated in Andalucía, Southern Spain. Its objective was to identify and interpret the agents and mechanisms responsible for the site's formation. Specifically, it seeks to comprehend the agents responsible for the accumulation of materials during the biostratinomic phase and to shed light on the major processes that influenced the assemblage in the diagenetic phase.

To achieve these research objectives, a comprehensive approach was employed, which included field observations, assessments of surface characteristics, and the collection of stratigraphic and spatial data. Within this methodological framework, taphonomic features were thoroughly documented, primarily by utilizing predefined set of criteria for recording these attributes. The selection of specimens for analysis was dictated by their preservation status and considerations regarding the extent of restoration. Additionally, density maps were created to visualize how specimens were distributed within the excavation grids.

The diverse taphonomic characteristics provided valuable information on the deposition processes. The dispersal patterns unveiled concentrations of remains from particular species, while others showed a more widespread distribution throughout the excavation area. Although a single potential mark, possibly caused by carnivores, has been recorded, their impact on the thanatocoenoses is deemed insignificant. Furthermore, the prevalence of non-weathered bones and the absence of indications of erosive deposition processes or post-depositional influences suggest the probability of rapid burial following the accumulation, thus minimizing the potential for surface bone deterioration. The transformation processes during the diagenetic phase of the site's history were significantly influenced by breakage, compression, and fractures of remains, which were attributed to seismic activity induced by earthquakes associated with the Baza Fault.

While this study provides valuable insights into the site formation processes at Baza-1, it is essential to note that ongoing research efforts at the site hold immense potential for further unraveling the intricate process of site formation. This site is of particular significance in the context of its chronological relevance, and future investigations are expected to contribute significantly to the understanding of its complex history.

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CHAPTER ONE

1.1 Objective of the research

The Guadix-Baza Basin, situated in the northern region of Granada Province, is renowned for yielding significant paleontological and archaeological discoveries of both regional and global significance. Among these, the Baza-1 site has emerged as a valuable addition to the already rich fossil-bearing formations within this basin. Although initial excavations at the site commenced during the 2000 and 2001 seasons, it was not until 2015 that research activities at the site gained substantial momentum. To date, the ongoing investigations have unearthed over 2000 large vertebrate remains, as well as a more extensive micro-faunal assemblage, in addition to plant and other records, all originating from fossil-bearing levels at the site. These findings have been documented and discussed in a handful of research papers (Martínez-Navarro et al., 2015; Piñero et al., 2017; Piñero & Verzi, 2020; Ros-Montoya et al., 2017).

1.1.1. General objective

The primary focus of this research centers on the taphonomy of Baza-1. The assemblage and the context from which the fossil remains originate present a complex array of taphonomic questions. Therefore, this study endeavors to elucidate the intricate processes of site formation at Baza-1. The overarching goal is to comprehend the agents and processes responsible for the accumulation of fossil remains at the site, as well as the significant post-depositional (diagenetic) alterations that have affected both the assemblages and the surrounding matrix.

To achieve these objectives, the research utilizes a range of technical and theoretical tools and methodologies. These tools are employed to construct a hypothesis regarding the manner in which the remains came to be deposited at the site. To this end, a sample of large vertebrate record and assessments of the sedimentological context are interwoven with spatial analysis to explore a viable path to an explanatory framework for the depositional contexts.

1.1.2. Specific objective

Specifically, the research endeavors to achieve the following objectives:

- Identifying Biostratinomic Aspects: This involves discerning the factors and agents associated with the biostratinomic phase of the assemblage. The aim is to determine the entities responsible for the accumulation of faunal remains at the site and assess the degree of their influence on the assemblage.

- Evaluating Sedimentological Context: The research seeks to assess the broader regional sedimentological context to gauge the impact of post-depositional (diagenetic) processes on the site.
- Analysing Spatial Distribution Trends: It aims to ascertain trends and patterns in the spatial distribution of the faunal record. This analysis identifies taphonomic variables and contribute to the development of a comprehensive interpretive framework based on the expected findings.

Furthermore, the research is guided by the following questions closely aligned with these objectives:

- What are the primary agents and processes responsible for the accumulation and alteration of the assemblages and related contexts at the site?
- What are the site and assemblage-scale effects of regional geological events and processes?
- Is it possible to establish a correlation between taphonomic observations and patterns of spatial distribution?

1.2 General Background

1.2.1 Guadix-Baza basin

This chapter offers a comprehensive overview of the paleogeographic and geological context of the Guadix-Baza basin. It highlights significant findings from various fossil-rich sites within the basin and probes into taphonomic studies of a couple among the numerous paleontological and/or archaeological sites within the Baza basin. The purpose of this review is to establish a foundational understanding of the region encompassing the Baza-1 site and underscore key themes relevant to the taphonomic inquiries addressed in this research.

1.2.1.1.Paleogeography

Situated in Southeastern Spain, the Guadix-Baza Basin occupies a central position within the Betic Cordillera, positioned at the boundary between the Cordillera's Internal and External Zones (Alfaro et al., 2008; García-Aguilar et al., 2014a). This basin spans approximately 100 kilometres in length (García-Aguilar & Martín, 2000). The emergence of the Betic Cordillera resulted in the isolation of the basin from the Mediterranean and Atlantic oceans during the late Miocene, specifically in the late Tortonian or Messinian period. This transformation marked a shift in sedimentation within the basin from marine to continental conditions. Over time, it evolved into two distinct depocenters during its continental phase (Haberland et al., 2017).

Within the basin, marine deposits, reaching depths of up to 1000 meters, are found underlying continental sedimentary formations comprised of alluvial, fluvial, and lacustrine deposits totaling approximately 600 meters in thickness. These deposits correspond to three distinct formations: the Guadix Formation, Gorafe-Huélago Formation, and Baza Formation (García-Aguilar et al., 2014a) (Figure 1).

The continental sedimentary deposits within the Guadix-Baza Basin are dated from the late Miocene (Late Turolian) to the late Pleistocene period, and they are organized into five tecto-sedimentary units (García-Aguilar & Palmqvist, 2011). These units are separated by periods of hiatus, some of which have been linked to tectonic activities (Alfaro et al., 2008). Starting from the late Pliocene (Early Villafranchian) and extending into the Early Pleistocene (Middle, Late, and Epi-Villafranchian), the Baza Basin saw continued continental sedimentation, leading to a threefold expansion of the basin's size compared to its catchment area during the earlier Early-Late Pliocene period (Ruscinian-Early Villafranchian) (García-Aguilar & Martín, 2000; Haberland et al., 2017).

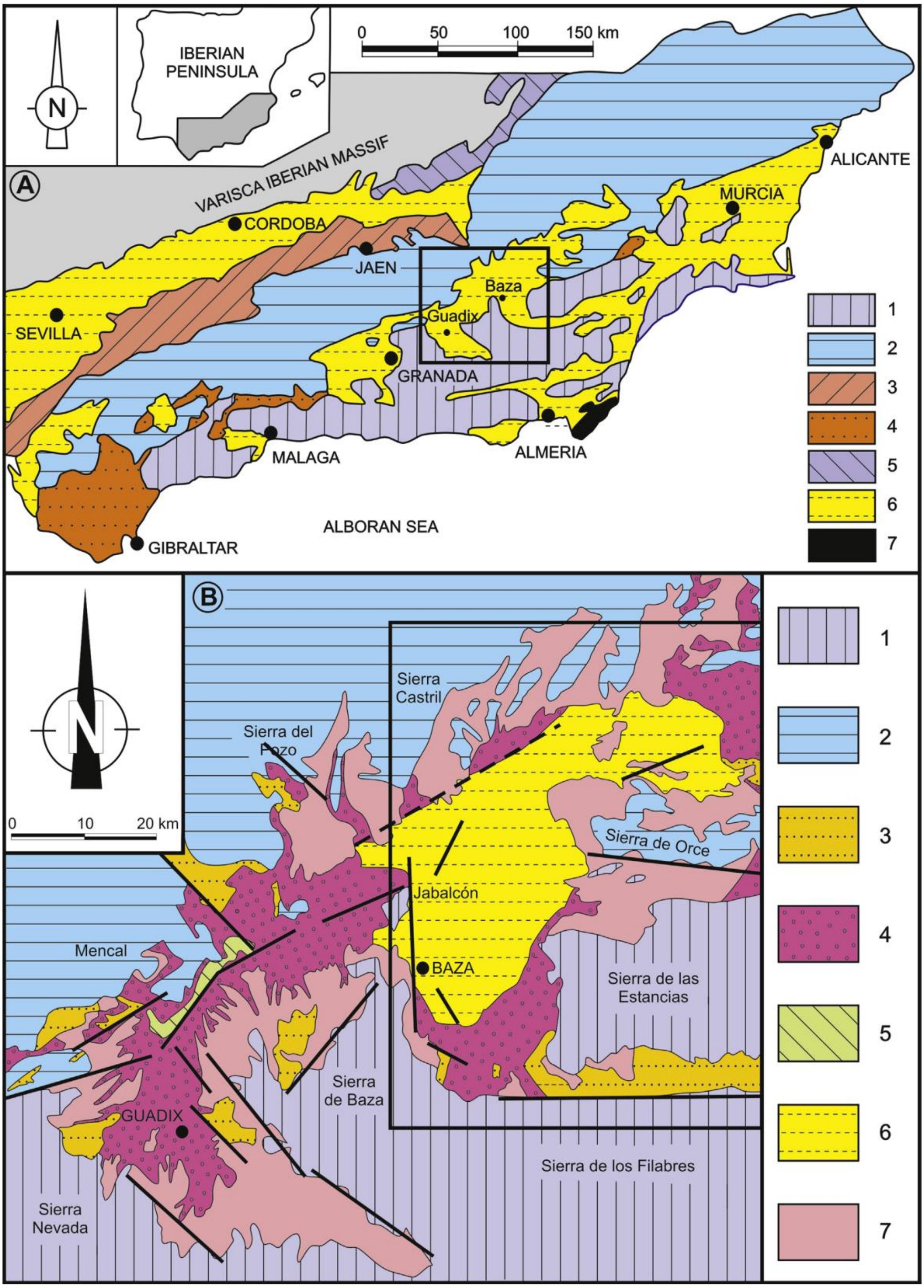


Figure 1: Geologic map of the Guadix-Baza Basin. A: 1; Internal Zones; 2. External Zones of the Betic Cordillera; 3. Subbetic olitostromes in Miocene deposits of the Guadalquivir basin; 4. Flysch of the Campo de Gibraltar units; 5. Sedimentary cover of the Iberian Massif; 6. Neogene postorogenic basins; 7. Neogene volcanic rocks. ***B****: 1. Internal Zones; 2. External Zones; 3. Marine sedimentary deposits of Miocene age; 4. Guadix Formation; 5. Gorafe-Huélago Formation; 6. Baza Formation; 7. Glacis surface. From García-Aguilar et al. (2014a).*

Details of the depositional secessions, composition, and configuration of the sedimentary units as well as the broader regional geological makeup of the basin, have been provided in several research works, including Viseras & Fernandez, 1992; Fernandez et al., 1996; Soria et al., 1998; García-Aguilar & Martín, 2000; Gibert et al., 2005, 2007; Alfaro et al., 2008; García-Tortosa et al., 2008; García-Aguilar & Palmqvist, 2011; García-Aguilar et al., 2014a; García-Aguilar et al., 2014b; Haberland et al., 2017.

The basin remained endorheic until the Late Pleistocene (cf. 43 ka). During this period, a tributary of the Guadalquivir River began diverting its water flow, causing the basin to transition into an exorheic system (Calvache et al., 1996; Calvache & Viseras, 1997; García-Aguilar & Palmqvist, 2011). An age as early as 180 ka has also been proposed based on the study materials originating from the upper terraces of the Guadalquivir River (García-Tortosa et al., 2008).

This shift from an endorheic to exorheic system had significant consequences. The once-active sedimentary basin underwent extensive erosion, a process noted in studies such as Viseras & Fernández (1992), Calvache et al. (1996), and Calvache & Viseras (1997). Consequently, the area gradually transformed into a dry “badland” with an annual precipitation level of approximately 200 mm (García-Aguilar & Palmqvist, 2011).

Although there is a widely accepted agreement regarding the events leading to the shift from an endorheic system to an exorheic one, there is a renewed interest in researching the nature and source of water supply for endorheic lacustrine environments. A noteworthy recent study by García-Aguilar et al. (2014b) has sparked fresh discussions on this topic (García-Aguilar et al., 2015; Gibert et al., 2015). This research has presented evidence that these lacustrine environments were, at least partly, sustained by hydrothermal inputs from hot springs resulting from extensive tectonic activity, challenging the previous assumption that they were solely dependent on runoff waters (García-Aguilar et al., 2014b).

The Guadix-Baza Depression exhibits tectonic features, marked by a complex and extensive fault system, a high rate of subsidence, and evidence of paleoseismites in the sediments (García-Aguilar et al., 2014a). Among the notable faults in this basin, the Baza Fault stands out as a significant player in shaping its geological history. This active normal fault spans 37 kilometres in length and has a predominant NW–SE to N–S orientation, contributing to the formation of the ancient Baza paleo-lake in its hanging wall (Alfaro et al., 2010). The fault effectively divides the Guadix-Baza Basin into two distinct Basins: the Baza sub-basin to the east, characterized by lacustrine sediments, and the Guadix sub-basin to the west, composed of alluvial and lacustrine deposits (Viseras & Fernandez, 1992). The Baza Fault cuts through materials ranging from the Miocene to the late Pleistocene. While there are documented deformations on Holocene materials, specific dates for these recent deformations have not been provided (García-Aguilar & Palmqvist, 2011).

The beginning of the faulting activity has been estimated to be during the late Tortonian (Alfaro et al., 2010). This faulting activity has persisted through to modern times, giving rise to seismic events associated with the fault. These seismic events have resulted in low to moderate magnitude earthquakes, which have been documented in towns such as Orce and Galera, where the dominant fault is the Galera Fault, and in Baza, where the Baza Fault prevails (Gibert et al., 2005). Among the notable earthquakes that have been historically recorded is the earthquake of 1531. This seismic event is documented to have caused significant damage to parts of the towns of Baza and Benamaurel, as well as structures in neighbouring areas (Alfaro et al., 2008; Gibert et al., 2005).

The research conducted by Alfaro et al. (2008) revealed two significant consequences attributed to the Baza Fault. Firstly, it led to the elevation of the Sierra de Baza and Jabalcon relief, while simultaneously creating areas of subsidence, with the Baza Basin depocenter being a notable one. Additionally, the liquefaction of soft sediments within the basin has been attributed to the influence of seismic-induced deformations (Alfaro et al., 2010). Consequently, the history of sedimentation in the basin is intricately connected to and influenced by the fault systems, as the tectonic activities along the margins and fluctuations in the lake level played pivotal roles in determining the resulting stratigraphic configuration of the basin (Fernandez et al., 1996).

The exploration of seismic activity and its influence on deposit alteration holds particular interest when it comes to assessing and interpreting the Baza-1 site and the effects it has had on the associated assemblage. Such inquiry examines interplay between geological forces and the preservation of the fossil record and sediments at the site.

To build a comprehensive framework for grasping the diagenetic processes at play, it is essential to consider not only the localized geological composition but also the broader context of tectonic activities. These tectonic phenomena have been subject to extensive investigation, as evidenced by the wealth of research findings discussed in the literature, including those that have been surveyed and reviewed in this study.

In essence, by integrating knowledge about the geological setting and the history of seismic events in the region, it is possible to gain a deeper understanding of how these factors have shaped the Baza-1 site and influenced the preservation and alteration of the fossil record over time. This approach enhances the ability to interpret assemblage within the broader geological and tectonic context.

1.2.1.2. History of research and notable discoveries

With over 90 fossiliferous levels reported to date, the Guadix-Baza basin provides a continental fossil record succession spanning the last 6 Ma (Maldonado-Garrido et al., 2017). The successions range from Vallessian to upper Biharian (=Late and Epi-Villafranchian) (Agustí, 1986; Martín-Suárez et al., 2012). The fossiliferous levels from the region had resulted in over 300 vertebrate species, with mammals dominating the list, which in turn is characterized by the abundance of rodents of two families (Muridea and Arvicolidea) (Maldonado-Garrido et al., 2017). This abundance has enabled the construction of long biostratigraphic sequences in the region (Agustí, 1986; Agustí et al., 2015; Minwer-Barakat et al., 2012; Oms et al., 2000; Piñero et al., 2018).

Overall, Pliocene records are best represented by 41 sites, followed by Early Pleistocene, represented by 31 sites. Late Miocene sites are scarce as they are represented by nine localities (Maldonado-Garrido et al., 2017; Minwer-Barakat et al., 2009). The youngest contexts have been dated to the Middle Pleistocene (Maldonado-Garrido et al., 2017). Consequently, the Guadix-Baza Basin stands out as one of the most comprehensive continental records available for this specific chronological period in Western Europe. Interestingly, there is a conspicuous scarcity of records related to large mammals from the Early Pliocene (Ros-Montoya et al., 2017). However, the basin compensates for this gap by offering an extraordinary stratigraphic sequence of micromammals, as highlighted by Piñero et al. in 2017.

The earliest evidence of Miocene mammals drives from fossil localities of Cortijo de la Piedra 1 and 2 (CP-1 and CP-2), which were identified from a small ~ 20m thick outcrop, in Orce, in the North-East part of the Baza Basin (Martín-Suárez et al., 2012). While CP-1 is represented by a handful of remains from rodent and insectivores, CP-2 yielded a large collection of small mammals, including seven rodent taxa (Martín-Suárez et al., 2012). An age of latest Vallesian age (MN10; early Tortonian) has been proposed for the fossil-bearing deposits of Cortijo de la Piedra (Maldonado-Garrido et al., 2017; Martín-Suárez et al., 2012).

Compared to earlier sequences, Ruscinian (MN 14 and 15) is characterized relative increase in the number of fossil-bearing localities within the Guadix-Baza Basin that recorded micromammals (Maldonado-Garrido et al., 2017 and references therein). However, the abundance in micromammals record, particularly rodents, is not replicated in macrofauna except few isolated instances. Early Ruscinian sequence of Gorafe-4 is known to have yielded an early association of micro and macromammals with the identification of *Gazella borbonica* and *Suinae indet* (Agustí, 1986). However, macrofauna have not been recorded in abundance until recently with the discovery of Baza-1, which yielded unparalleled richness of Early Ruscinian large mammals from contexts dated to the early Pliocene (Martínez-Navarro et al., 2015; Ros-Montoya et al., 2017). Located within the Baza sector, this site presents a unique opportunity in light of the gap observed in the Pliocene macrofaunal record of the Guadix-Baza Basin and beyond.

Early Villanyian (=Early Villafranchian) sites are scarce in the Guadix Basin compared to the Baza Basin, with Tollo de Chiclana 3 and 13 representing by far the most complete rodent and insectivore record from the Guadix Basin assigned to this age (Minwer-Barakat et al., 2012). Moreover, Late Villanyian (=Middle Villafranchian: MN 17) is characterized by an increment in the number of localities with macrofauna record across the Guadix-Baza basin (Agustí, 1986). Later, the sequences record of Late Villafranchian fauna (MN18) is abundant in the north-eastern sector of the Basin in the area of Orce, as is the case of Venta Micena, which is known to have provided unparalleled fossil lagerstätte including vast carnivore assemblage (Martínez-Navarro, 1991; Espigares, 2010; Palmqvist et al., 2022a, among others).

Furthermore, extensive research effort in reconstructing the palaeoecological contexts through sedimentological as well as micro and macrofauna remains has been reinforced through pollen studies (Altolaguirre et al., 2020; Ochando et al., 2022), which were proven to be futile until very recently. Pollen records from the Palominas core, obtained from a site in the Municipality of Baza, provided vital paleoenvironmental data regarding the prevailing environmental settings associated with key fossil-bearing units. From the samples retrieved, it has been attempted to reconstruct the paleoenvironmental settings of early hominid occupation sites in the Orce area (Altolaguirre et al., 2020).

Overall, multi-proxy records demonstrated the vital role of the various sites located in the Guadix-Baza Basin play about key questions such as the faunal exchange between the African continent and the Iberian Peninsula, the nature of early human dispersal into Western Europe as well as trends related to the early hominid technological and behavioural repertoire in western Europe. These key issues have been addressed in several publications that resulted from extensive research works, particularly from the sites in the Orce area, which is located in the North-eastern section of the Baza Basin (e.g., Moyà-Solà, 1987; Martínez-Navarro, 1991; Martínez-Navarro & Palmqvist, 1995; Martínez Navarro et al., 1997; Arribas & Palmqvist, 1999; Palmqvist et al., 2005; Espigares et al., 2013, 2019; Toro-Moyano et al., 2013).

1.2.1.3. An overview of a few key sites of taphonomic interest

A comprehensive examination of published works covering taphonomic aspects of Guadix-Baza Basin sites might seem both extensive and not directly pertinent to the Baza-1 research context. Therefore, this section provides a concise overview, focusing on sites with a loose connection to the specific research context and those that have garnered substantial attention in terms of research and interpretation. Particular attention is given to early Pleistocene sites in the Orce region. These sites are discussed partly due to the unique nature of their depositional settings, the abundance of preserved faunal remains, and their significant role in stimulating crucial taphonomic discussions.

Through research works over the years, the faunal assemblages recovered from the sites of Fuente Nueva 3, Barranco León, and Venta Micena have opened up series of essential questions, including carnivores-prey relation, the nature of inter-carnivore interaction in the sequences and stages of accumulations(e.g., Palmqvist et al., 1996, 2008; Arribas & Palmqvist, 1998) as well as evidences of hominid intervention in the modification and accumulation of faunal remains (Espigares et al., 2019, 2023; Palmqvist et al., 2022b; Palmqvist et al., 2023; Yravedra et al., 2021). In addition, the microvertebrate fossil record from the region plays an important role in the reconstruction of regional biostratigraphic successions (Agustí et al., 2010)

Venta Micena represents the earliest sequences of fossil-bearing units in the area, which have been dated to 1.65 my BP through faunal and palaeomagnetic records (Martínez-Navarro, 1991; Martínez-Navarro & Palmqvist, 1995). This early Pleistocene site is estimated to bear tens of millions of fossils preserved in the micritic limestones of the lithological unit (Arribas & Palmqvist, 1998; Palmqvist et al., 2022a). The primary agent of accumulation of the remains identified from the site is *Pachycrocuta brevirostris*, which selectively transported to the den limb bones and craniums with high mineral and fat content (Arribas & Palmqvist, 1998). The abundance of unworn deciduous hyena teeth in the accumulation context has been said to explain transportation rather than consumption on the kill site; this is partly based on inferences from modern hyenas' behaviour where the cubs do not accompany the adults (Palmqvist & Arribas, 2001). The abundance of tooth marks, including furrowing on epiphysis, scores, pits, crenulated edges, and the morphology of fractures surfaces, attesting to the fact that the short-faced hyena *P. brevirostris* as the main agent of accumulation (Arribas & Palmqvist, 1998; Palmqvist & Arribas, 2001; Espigares, 2010; Palmqvist et al., 2022a).

Taphonomic and ecomorphological studies regarding the inter-prey relationship revealed that Saber-toothed cats were top hunters while *P. brevirostris* survived as scavenger heavily relying on prey hunted by other hypercarnivores such as the sabertooths *Homotherium latidens* and *Megantereon whitei,* the jaguar *Panthera* cf. *gombaszoegensis,* and the wild dog *Lycaon lycaonoides* (Palmqvist et al., 2022a; Palmqvist et al., 2008; Palmqvist & Arribas, 2001). Results of isotope analysis (δ13C and δ15N) place *H. latidens* as the top predator at the site (Palmqvist et al., 2008).

Most bones from the site were buried very shortly after the death of the animals, with the majority of the bones falling within stage 0 of Behrensmeyer's (1978) weathering stages, suggesting that they were buried in less than a year (Espigares, 2010; Palmqvist et al., 2022a). Arribas & Palmqvist (1998) rule out fluvial transport as an agent of significant impact, citing the orientation and absence of traces of abrasions. They point to the fact that the bones are randomly oriented and show no traces of abrasion resulting from rolling or similar movements (Arribas & Palmqvist, 1998).

The Barranco León and Fuente Nueva 3 assemblages are among the sites that provide the earliest direct and indirect evidences of hominid presence in Western Europe (Martínez-Navarro et al., 1997; Oms et al., 2000; Palmqvist et al., 2005; Toro-Moyano et al., 2011, among others). Barranco León yielded the oldest early *Homo* record in Western Europe, dated ca. 1.4 Ma, represented by an isolated lower left first deciduous molar (specimen BL02-J54-100; Toro-Moyano et al., 2013). In addition, thousands of lithic artifacts in the form of cores, flakes, modified cobbles, and unmodified materials have been recovered from the site (Toro-Moyano et al., 2011; Barsky et al., 2015, 2022; Titton et al., 2018). Mode 1 materials recovered from contexts dated 1.4 Ma at Barranco León and 1.3-1.4 Ma at Fuente Nueva represent some of the earliest evidences of hominid presence in Western Europe. Together with similar sites where Mode 1 industries have been documented, such as Pirro Nord, characterized by lithic artifacts comprising cores and flakes and dated to a period between 1.6 and 1.3 million years ago (Arzarello et al., 2007), these archaeological sites provide compelling evidence supporting the claim that hominid groups had already established a presence in Western Europe during this time frame. This is particularly noteworthy considering the limited availability of hominid fossil records in Western Europe that date back to periods earlier than 1 million years ago.

During the Early Pleistocene, Venta Micena documents a significant faunal transition marked by the migration of ungulates, carnivores, and various other taxa from Asia and Africa into Europe. This phenomenon has been extensively studied and documented in the works of Martínez-Navarro (1991), Martínez-Navarro & Palmqvist (1995), as well as Martínez Navarro et al. (1997 & 2003).

A study combining the assemblages from Barranco León and Fuente Nueva 3 has revealed the nature and implication of breakage and cutmarks, which are mainly recorded on the diaphyseal shafts of limb bones and the external surface of ribs (Espigares et al., 2019). The analysis of the cut-marked bones is essential because it confirms the presence of hominins in the basin through their activity traces and represents the earliest record of such presence in Western Europe (Espigares et al., 2019). Furthermore, an interpretation of competition between *Homo* sp. and *P. brevirostris* for the exploitation a carcass of an old individual of *Mammuthus meridionalis* has been forwarded to a context excavated in the Upper Level of Fuente Nueva 3 (Espigares et al., 2013, 2019). The incomplete elephant skeleton was recovered surrounded by 34 coprolites and 17 lithic artifacts, posing a question of exploitation phases by the two agents, i.e., *Homo* and *P. brevirostris* (Espigares et al., 2013). Carnivore tooth marks have also been noted on faunal remains recovered from the site (Espigares et al., 2013; 2019; Yravedra et al., 2021).

Moreover, an interesting taphonomic assessment has been recently made on the coprolites recovered from FN-3 (Espigares et al., 2023). This new research is based on remains from layer 5 of the Upper Archaeological Level of FN-3 and those recovered from Barranco Leon. It concludes that the coprolites correspond to a latrine of *P. brevirostris.* Furthermore, a possible trap in quicksand has been suggested to justify the higher presence with respect to the Lower Archeological Level of Proboscideans and other mega-herbivorous species whose carcasses would attract *P. brevirostris* and other scavengers (Espigares et al., 2023).

Given that the general sedimentary contexts of the Orce sites and Baza-1 are closely related, an analysis of the biostratinomy and diagenetic phases of the fossil assemblages is equally important at this last site and demands a closer look, taking into account their differences related to their chronology and the faunal associations preserved in their fossil-bearing units.

In conclusion, the corpus of research carried out in the region, including recent researches such as those highlighted in this review, demonstrated the wealth of information stored in the remains and contexts from the sites within the Baza basin, particularly those in the Orce area and the implication beyond the individual sites.

1.3 Baza-1 site

1.3.1 Geographic and geological setting

The Pliocene site of Baza-1 is located on the outskirt of the town of Baza (Figure 2) in a valley called “Barranco de las Seguidillas – Cuesta del Francés (Ros-Montoya et al., 2017). The paleontological locality is situated on a hill overlooking Baza at 986 m a.s.l. and a portion of the extensive plain of the Baza basin to the East. The average altitude of the Baza basin is estimated to be between 900 and 1000 m a.s.l. The highest altitude of the surrounding mountains around the Guadix-Baza Basin is recorded in Sierra Nevada (3479 m a.s.l.) in the South and Sierra de la Sagra in the North (2382 m. a.s.l.). Close to the site and the city of Baza is the Sierra de Baza (2269 m.a.s.l.), whose slopes start less than 1 km from the site of Baza-1. The site is positioned at the Guadix and Baza sub-basins intersection, with the Baza Fault dividing these two basins into the west and east.

Figure 2: Location of Baza-1 paleontological site in Andalucía, South-eastern Spain.

Regarding the lithological context, the locality of Baza-1 is included in the lacustrine Baza Formation. As it has been pointed out in the previous discussion, the Baza sub-basin is generally characterized by sediments of lacustrine origin with diverse lithologies representing different deposits attributed to specific climatic, tectonic, paleogeographic and paleoecological conditions (García-Aguilar, 2014b).

The lacustrine deposits of the Baza Formation mainly comprise limestones, marls, and gypsum (Vera, 1970). These deposits correspond to Unit II, representing the Ruscinian-Early Villafranchian age, of the five tecto-sedimentary units identified in García-Aguilar & Martín (2000), and which was later further expanded to six (see García-Aguilar et al., 2014a). Limestones in Unit II (García-Aguilar et al., 2014a; García-Aguilar & Martín, 2000) are principally micrites and biomicrites with gastropods, bivalves, and oncolites, and locally, intraclasts and fenestrae, signalling contexts of very shallow-water conditions and even occasional emergence (García-Aguilar & Martín, 2000).

The deposits in which the Baza-1 site is located corresponds to the development of alluvial fans (Guadix Formation) coming from the reliefs of the Sierra de Baza, which connects distally with a lacustrine environment (Martínez-Navarro et al., 2015). The site is situated within a $\geq$ 80 m thick limestone-marly member (Ros-Montoya et al., 2017), representing Zanclean (=Ruscinian) and Piacenzian (Early Villafranchian) lacustrine units (García-Aguilar et al., 2014b).

As it has been stated in Ros-Montoya et al. (2017), the Limestone-marly member is composed of 25 m of massive marlstones interspersed with levels of marly limestones, limestones, and dark levels; followed by 10 m of marls at the bottom and limestone-marls or limestones at the top; which then succeeded by 15 m thick section very similar to the previous section with some fine detrital facies intercalated (brown or grey laminate clays and marly-silts); the upper interval, where Baza-1 is located, shows four dark levels with abundant remains, of which, the lower dark, 50 cm thick, is the fossil richest level of the site (Ros-Montoya et al., 2017) (Figure 3). The existence of marl-limestone interbeds, as recorded at the Baza-1 site, is one of the defining features of the lacustrine deposits across the basin (García-Aguilar & Martín, 2000). At Baza-1, the fossils bearing black layers are interbedded in limestone, marls, and calcilutites units (Ros-Montoya et al., 2017).

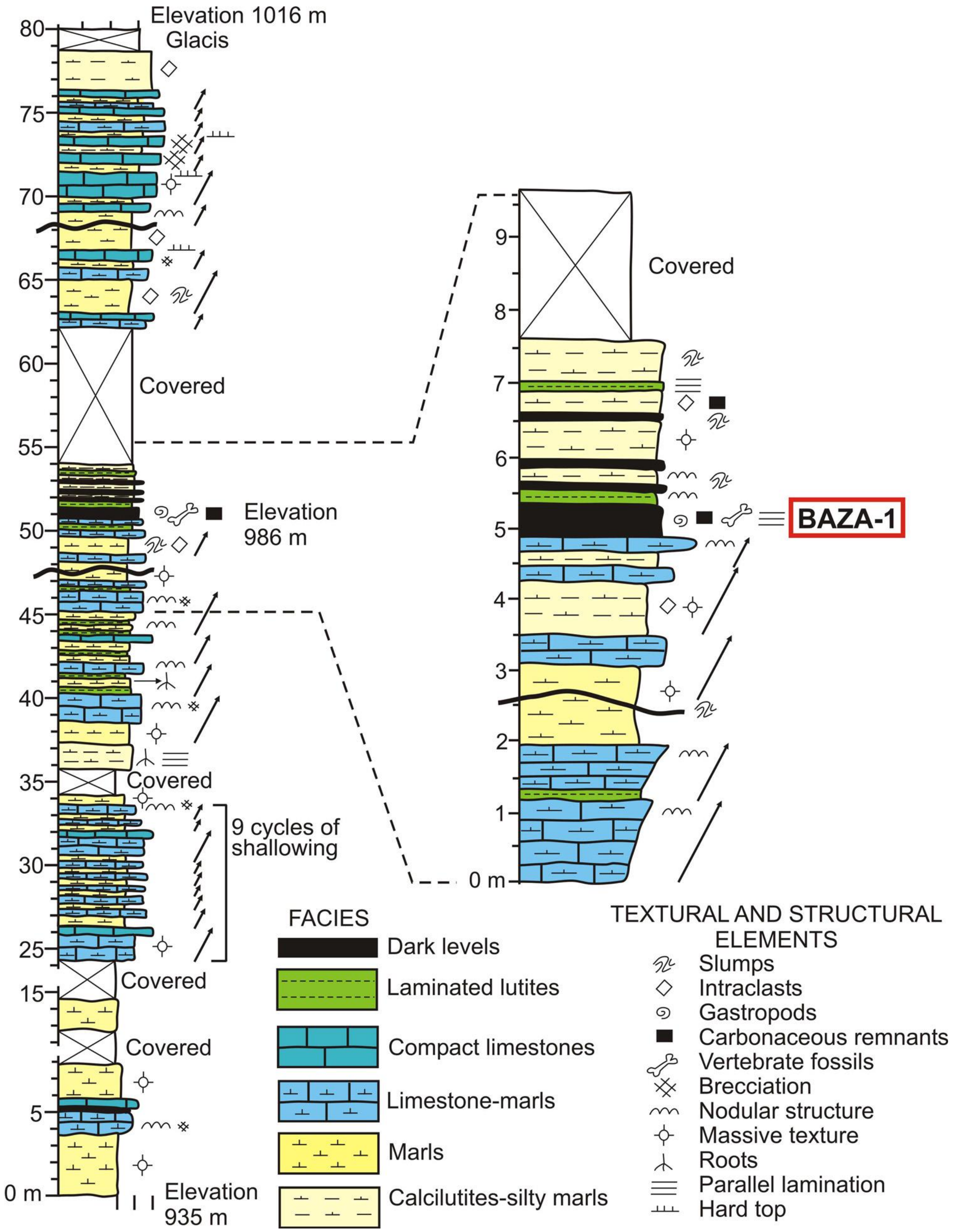


Figure 3: Stratigraphical column of Baza-1 site. From Ros-Montoya et al. (2017).

Generally, the sedimentary succession is marked by a shallowing process from highstand periods (marls) to lowstand ones (marly limestones), resulting in swampy-pedogenetic zones, which is characterized by phases of sediment upwelling and intensification of microbial activity (García-Aguilar & Palmqvist, 2011). Consequently, shallowness associated with swampy conditions allows vegetation to take root (García-Aguilar et al., 2014b). Furthermore, slumping and both syn-sedimentary and post-sedimentary deformations are well recorded in various levels (Ros-Montoya et al., 2017)

The lacustrine setting constantly fed by hydrothermal sources would have allowed a continuous water supply to the paleolake that sustained the vegetation and the fauna within the basin. The warmer and wetter Pliocene conditions in the Baza Basin would have favoured its role as a refuge for a diverse fauna (García-Aguilar et al., 2014b). The assemblage from Baza-1 seems to reinforce this assessment. Of the fossil-bearing units at the site, the one designated as the black layer records a dense accumulation of fossilized bones, making up an average of 50% of the entire thickness of this sedimentary unit (Ros-Montoya et al., 2017).

1.3.2 Discovery of the site and results of excavation

The fossil-bearing levels of Baza-1 were first identified by Bienvenido Martínez-Navarro in 1996, and the work there began in 1999 with a superficial survey of the area (Martínez-Navarro et al., 2015). The work at the site started in 2000, and an excavation area of 18 m^2 opened-up during the years 2000 and 2001. In May 2015, excavation was restarted with an extended excavation area, including the grids started in the previous excavations (Martínez-Navarro et al., 2015). Over two field seasons (2015 and 2016), the excavation area was expanded to 25 m^2, yielding ~ 400 vertebrate fossil remains by the end of 2016 (Ros-Montoya et al., 2017). The excavation continued on 2017, 2018, 2019, and 2022; nowadays, over 2000 large vertebrate remains have been unearthed from an area of over 49 m^2. A large number of microvertebrate remains, including 11 rodent taxa, have been identified until 2017 (Piñero et al., 2017; Piñero & Verzi, 2020). The excavations of the last years have greatly expanded the number of microvertebrate remains from the site which are currently being studied.

The relatively small excavation area at Baza-1 has produced unparalleled macrovertebrate fossil accumulation. In addition to the staggering density of fossilized remains per surface area, the abundance of diverse sizes of ungulates makes it stand out as the only site with such abundance of Ruscinian fauna. The majority of sites with Ruscinian or earlier (Turolian) fauna in the Guadix-Baza basin are characterized by the abundance of insectivores and rodents and a gap in the large vertebrate record (Maldonado-Garrido et al., 2017; Piñero et al., 2017). This fact has been noted to be common in Europe, where Early Pliocene large mammals sites between 5.3 and 3.4 Ma (Ruscinian) are known to be rare (Ros-Montoya et al., 2017). Therefore, the recovery of micro and macro fauna at Baza-1 from sequences dated to this period with the abundance that has been described shows the crucial position that the site holds in addressing key questions related to this chronology.

The Baza-1 site has yielded numerous vertebrate remains along with vegetal remains. The analysis of a large portion of the records awaits systematic restoration of the pieces, particularly large vertebrate remains, as they are severely deteriorated. Similarly, the identification and analysis of the enormous microvertebrate's assemblage are underway, with materials from recent excavations anticipated to provide more evidences on the context of the depositional environment at the site.

The large faunal list consists of the following taxa: *Mammut borsoni, Anancus arvernensis, Stephanorhinus* cf. *S. jeanvireti*. *Hipparion* sp., *Alephis* sp., Bovidae indet., small-middle size (cf. *Antilope* sp.), Cervinae indet. (Ros-Montoya et al., 2017). Carnivores are virtually non-existent, and only two specimens from the sample selected for this study have been assigned to Carnivora indet. The micromammals assemblage from the site is composed of at least 11 rodent taxa, two lagomorphs, four insectivores, and a bat (Chiroptera indet.), which is represented by a single tooth and is dominated by two rodent species representing two distinct families, *Paraethomys* aff. *abaigari* (Muridae) and *Apocricetus barrierei* (Cricetidae), accounting for 36.80% and 32.50% of the assemblage respectively (Piñero et al., 2017), while the herpetofauna association is represented by Anura indet., Anguidae indet., Lacertidae indet., Scolecophidia indet., *Naja* sp. (Piñero et al., 2017). The tortoise identified from the site has been assigned to *Chelonia* sp. The faunal association at Baza-1 places it in biozone MN14, with an age of ca. 4.5 Ma (Ros-Montoya et al., 2017)

A remarkable aspect of the faunal association of Baza-1 is the presence of two species of Proboscideans (*M. borsoni* and *A. arvernensis*). Baza-1 presents the first record of this association in the Iberian Peninsula (Martínez-Navarro et al., 2015). These two Proboscideans have been described as browsers of wooded environments, close habitat (A. *arvernensis),* and open habitat dweller (*M. borsoni)*. As a result, their recovery from the same context could partly be explained by different dietary niches for these megafaunal species, which allowed them to avoid ecological displacement (Ros-Montoya et al., 2017). Moreover, the micromammal assemblage, along with freshwater fish remains, assigned to the family Cyprinidae, appear to indicate a landscape principally characterized by open, grassy meadows with a limited forest patches and the development of stable water courses in the surrounding area of Baza-1 (Piñero et al., 2017)

Overall, Baza-1 has showcased its significant potential by revealing a high concentration of fossil remains and a wide range of fauna within its assemblage. Nevertheless, key questions related to the taphonomy of the site remain unexplored so far. Consequently, this research is specifically focused on investigating the origins and characteristics of the accumulation and alterations seen in the assemblages within the site.

CHAPTER TWO

2.1. State of the art

A widely accepted definition of taphonomy involves the study of the agents and processes responsible for influencing organic remains, ultimately leading to the formation of fossil deposits. In other words, it is an investigation into the agency and processes that act upon organic remains, resulting in the creation of fossil deposits (e.g., Gifford, 1981; Shipman, 1981; Wilson, 1988; Allison & Bottjer, 2010). Taphonomy originally emerged from the field of palaeontology, with early researches pointing towards the richness of the fossil record in deciphering the successive process that led to their accumulation (Stiner, 2008).

Efremov, credited with standardizing the term "taphonomy," described it as the study of the detailed transition of animal remains from the biosphere to the lithosphere (Efremov, 1940). Consequently, taphonomy was perceived as an exploration of the interplay between geological and biological phenomena, where the process of burial received as much attention as the remains themselves. However, it is important to note that research on post-mortem alteration processes of organic remains predates Efremov's contributions, and topics like biostratinomy were explored prior to the widespread use of the term "taphonomy" (Cadée 1991, and references therein).

Since the early work of Efremov, taphonomy had been constantly evolving in terms of the goals, and it has also seen refinement in the epistemological underpinnings. In terms of the scope, it is often treated to be composed of three sequential and, at times, overlapping stages (Lawrence, 1971). These are *necrolysis*, associated with the fate of the soft parts and organic skeletal materials upon the death of the organism; *biostratinomy*, characterized by the sedimentary transport and burial; and *diagenesis* which encompasses the chemical and mechanical processes that contribute to the alteration of the fossil remains within the sedimentary matrix (Seilacher *et al.*, 1985; Wilson, 1988).

Within this framework, the scope of taphonomy was delineated as the examination of processes that play a role in preserving fossil remains, leading to what has been termed "post-mortem information loss" (Kidwell & Behrensmeyer, 1993). An underlying theme in taphonomy is the notion of bias in the assemblage, which refers to the ways in which post-mortem processes can distort the fossil record (Behrensmeyer *et al.*, 2000).

Regardless of the perceived outcome, the alteration of the underlying biological signals due to successive filters applied through “preferential preservation” is often described as bias

(Fernández López, 1991; Kidwell & Holland, 2002). The inevitability of biases as a result of differential in intrinsic and extrinsic taphonomic components (Fernández-López, 2006) such as the biochemical make-up and preservation of organisms, biological evolution, depositional environments and processes (Millard, 2001; Allison & Bottjer, 2010) as well as those originating from research considerations (Behrensmeyer & Kidwell, 1985) makes it necessary for these factors to be accounted for a taphonomic analysis. In a nutshell, the taphonomic processes imposes sampling of its own, as does the research consideration, given the fact that the assemblage is determined by the extent of the excavation area and the final sample decided to be reported (Behrensmeyer *et al.*, 2000).

In evaluating bias, taphonomists often emphasize on sources such as transport, differential destruction of species and skeletal elements and time-averaging (Kidwell & Behrensmeyer, 1993). Consequently, the study of any assemblage recognizes temporal and spatial averaging, that is, the extent of mixing of generations and mixing of habitats, respectively (Kidwell & Holland, 2002). Once realizing the biases emanating from these controls, the objective would be demonstrating that the data incorporated within the fossil record is adequate to test theories, which in turn is dictated by the hypothesis to be tested (Paul, 1992). Moreover, the same data may be perfectly adequate for one purpose and inadequate for another (Paul, 1992).

In principle, minimal time averaging of individuals is expected in circumstances such as mass death of the entire or portion of a community, followed by permanent burial and sealing off the assemblage from subsequent inclusions (Kidwell, 1997). In an overly simplified representation, a low proportion of broken fossil specimens and a large number of articulated specimens are described to be classic features of mass burial of relatively short span (Brett & Baird, 1993).

In the context of relatively recent fossil assemblages, short-term time averaging could be observed based on the comparison with modern ones (Brett & Baird, 1993). Actualistic studies may be useful to carry out estimates that are based on analogy with modern processes. Actualism, the methodology that employs analogy of processes observable at present to infer the nature of past events, had been considered of prime importance (Cadée, 1991). Observations, for instance, on cases of mass-mortality of organisms resulting fossil-lagerstätten (Seilacher et al., 1985) were carried out as early as the mid-1920s by the likes of Weigelt (Cadée, 1991). Spurred on by early researches, actualist approach saw proliferation in the 1970s when innumerable studies started to be carried out based on modern observation.

However, inferences based on modern processes proved to be complicated when faced with parameters that are not easily measured by actualist studies. For instance, in the context of slow net sediment accumulation the prolonged process encompasses a period of environmental change which results in the mixing of more than one habitat into a single sedimentary context (“environmentally condensed”) (Brett & Baird, 1993; Kidwell, 1997; Kidwell & Holland, 2002) that could represent, in terms of temporal dimension, from a couple of seasons to thousands of years (Kidwell, 1997). In such instances, observations could further be remedied by the application of simulations to test the time needed to form buried bone accumulation (Behrensmeyer, 1982; Behrensmeyer & Chapman, 1993; Gifford, 1984)

The concept of taphonomic “gain” later emerged out of the realization that fossil preservation view of taphonomic processes and patterns to be a limiting in terms of the scope of taphonomy (Behrensmeyer et al., 2000; Wilson, 1988). Illustrative expressions such as “selective destruction”(Fernández López, 1991) or “selective preservation”(Kidwell & Holland, 2002) capture the kernel of the differing view on the outcome of taphonomic processes. While, taphonomic loss approach aims at reconstructing the original settings of fossilized remains, taphonomic gain approach focuses on the agents of taphonomic loss (Wilson, 1988). Consequently, taphonomic gain emphasizes on the favourable outcomes in the processes deemed to be obstructive such as loss of information by carnivore to be informative of that particular agent (Behrensmeyer & Kidwell, 1985). Therefore, the production of new taphonomic entities, alteration can be taken to be a positive force (Fernández-López, 2006).

The pioneering work of Behrensmeyer (1978) helped standardize weathering phases and mechanisms with far reaching consequence in the interpretation fossil assemblages and depositional environments. Weathering stages are often employed to estimate the amount of time that bones stayed exposed to weathering agents. It informs how long remained exposed or how quickly buried, what depositional environment they were buried in, what portion of stationary bone had been in contact with the soil before complete burial (Lyman & Fox, 1989; Pokines et al., 2018). The six stage approach uses a scale of 0 to 5 with each stage described with surface modifications anticipated to be observed in function of the time (presented in year) elapsed since the death of the animal and the subsequent decomposition of soft tissues (Behrensmeyer, 1978).

From the outset it has been noted that weathering varies based on the part and type of bone, taxa and body size (Behrensmeyer, 1978) as well as the deferential in the preservation environment, e.g. open savannah (Behrensmeyer, 1978), tropical rainforest (Tappen, 1994), temperate (Andrews & Armour-Chelu, 1998) and desert (Andrews & Whybrow, 2005). Moreover, biological controls of early “postmortem interval” (Janjua & Rogers, 2008) and micro components such as wetting-drying and freezing-thawing cycles (Pokines *et al.,* 2018) have been identified to be among the factors that dictate the weathering outcomes. Besides, the complexity of determining weathering stage when applied to prehistoric remains including variability resulting from subsurface or subaerial context has also been pointed out (Lyman & Fox, 1989). Finally, weathering observation can be rendered impractical when of subaerial weathering gets masked by bone decomposition in biostratinomy or/and diagenetic phases (Potts, 1986). Nonetheless, weathering stage still serves as a powerful tool in taphonomic analysis with researches paying due attention to limiting factors.

On the other hand, the depositional context plays vital role in the overall taphonomic process by controlling the quality and nature of fossil preservation (Behrensmeyer *et al.,* 2000). Hence, it is only through careful examination of regional and site scale sedimentological records that a relatively complete picture of the site formation processes, as well as, subsequent modifications could be recognized and interpreted. In this respect, taphofacies reflect the characteristic ensemble of preservation features of the fossils contained within sedimentary rocks (Martin, 1999). In terms of impacts on the fossil remain, the taphic processes result in chemical and physical changes which determine the quality of bone preservation upon burial (O’Connor, 2000). The variability in the preservation of fossils between facies is described to be indicative of the differential activity of taphonomic processes in different depositional contexts (Martin, 1999)

One of the almost inevitable outcomes of agencies and processes in the extended process between necrolysis and recovery of fossilized skeletal remains is breakage and associated traits. Breakage patterns often serves as a crucial component in the quest for the identification of the taphonomic agency and forwarding explanations on mechanisms of post-depositional processes (Villa & Mahieu, 1991). Nevertheless, distinguishing between various stages and associated characters of bone breakage and fragmentation poses multitude of challenges (Fernandez-Jalvo & Andrews, 2016). This is an area riddled with complexity as mimicking agents might be present for bones that could be attributed to one agency or another with a degree of confidence. As a result, taphonomic studies perceive equifinality as latent treat to the interpretation of fossil assemblages.

In the words of Lyman equifinality describes “the property of allowing or having the same effect or result from different events” that is, different agencies and processes resulting similar effects (Lyman, 1994). The equifinality problem is particularly acute in contexts where multiple agents, including hominins, are suspected (Olsen & Shipman, 1988). In light of the complexity posed by the presence of multiple agency, numerous researches based on fossil remains and controlled experiments have attempted to standardize identification mechanisms of the marks produced by various agents that could produce closely related outcomes (e.g., Haynes 1983; Capaldo & Blumenschine, 1994; Selvaggio, 1998; Selvaggio & Wilder, 2001; Domínguez-Rodrigo *et al.*, 2009). Thus, the problem of equifinality results in a situation where the researcher could not sidestep palimpsest effect.

To conclude, the general principles and laws governing taphonomic interpretations as well as methodologies employed to shape researches in taphonomy over the years are considered in framing the questions and the objectives set for this research. Furthermore, the key variables used in this research are based on evidences that the excavation at the site resulted as well as inspection of surfaces made afterward. Thus, the empirical evidences and anticipated as well as tested relationships dictate the research outcome.

CHAPTER THREE

3.1. Materials and Methods

This research relies on a dataset comprising 268 specimens from the faunal assemblage excavated from the Baza 1 site. These specimens have been selected to create a representative sample, which, in turn, is expected to yield valuable insights into the intricate processes that shaped the site over time. In addition to the faunal remains, the depositional context is evaluated in order to obtain critical information about their origin and the environmental conditions at the time of deposition. Furthermore, the study takes into account the broader geographical and geological characteristics of the site, providing a comprehensive framework for analysis. Detailed descriptions of the techniques and methodologies employed in this research are elaborated upon in subsequent sections of this study.

3.1.1. Data collection techniques

This section on data collection techniques encompasses a comprehensive overview of all the procedures, methods, and tools that were utilized both during and after the excavation process, as well as the specific set of methodologies applied for this particular research project. During the excavation phase, a range of tools and techniques were employed to facilitate the identification, documentation, preservation, and retrieval of the remains, along with recording their contextual information.

Equally, the techniques employed specifically for this research are multifaceted. They encompass considerations such as sample size determination, the procedures, and the criteria used to select the data sample for this study. In addition, various tools and instruments played a pivotal role in aiding the identification, documentation, and interpretation of the collected data.

3.1.2. Excavation

The excavation phase significantly influences the selection of materials for research purposes. Once a grid 18 square meters was set for the excavations in 2000 and 2001, conventional alphanumeric designations were applied to the squares. Subsequently, in 2015, this grid was expanded to cover an area of 25 square meters. The scope of excavation continued to expand, and by the 2019 field season, an extensive area measuring 49 square meters had been opened up for excavation. Up until 2019, precise coordinates for all in situ remains exceeding 2 centimeters in size were recorded using meter measurements for X and Y values, theodolite measurements for the Z axis. In the 2022 season, Total Station was introduced to enhance the accuracy of recording cartographic data. The length, width, and thickness of in situ recoveries were measured using both digital and analog calipers.

Specimens measuring less than 2 centimeters and remains with unknown provenance within the grid squares, were carefully collected and placed in level bags for subsequent analysis. Furthermore, to recover microvertebrate remains and any macro remains that might have been missed during excavation, sediments from the fertile fossil layers (as illustrated in Figure 3) underwent a water sieving process using mesh sizes of 5 and 1.25 mm. To maintain an organized record of all in situ materials throughout the years of excavation at the site, a comprehensive spreadsheet was compiled. This spreadsheet serves as a valuable repository of data, facilitating the tracking and analysis of materials over the course of the excavation project.

To ensure the preservation of the overwhelmingly delicate state of the majority of the recovered remains, comprehensive on-site conservation procedures were implemented. Consolidation was carried out using Paraloid® B 72 in acetone, with solutions of varying concentrations (5%, 10%, and 20%). In instances where the remains were exceptionally fragile, an additional layer of protection was applied through a gauze coating. It is noteworthy that non-reversible resins and adhesives were generally avoided, with the exception of epoxy resin specifically applied on a Proboscidean tusk. For particularly large and fragile Proboscidean remains, a polyurethane coating was expertly applied. This coating served a dual purpose, facilitating the safe transportation and storage of these substantial and delicate specimens.

3.1.3. Data Collection Techniques Employed in this Research

Once the research theme was established, a strategic selection of techniques was employed to effectively achieve the research objectives. The initial stage involved conducting field observations, which served as a foundational step to gain a comprehensive understanding of the regional geological setting and the broader implications of these geological factors at the site's scale. Additionally, active participation in the excavation activities of the 2022 field season aimed to provide familiarity with the depositional contexts and the characteristics of remains that were actively undergoing recovery. In essence, this observational phase constitutes a fundamental component of the data collection process.

Subsequently, following the conclusion of the 2022 field season, a decision was made to focus on the study of sample materials archived in the Baza and Granada Museums. During the winter of 2023, laboratory work was carried out at these institutions. The primary objective of the lab work was to precisely identify anatomical elements and determine the taxa represented in the samples. This was followed by a detailed assessment of bone surfaces, all conducted in alignment with the specific criteria established for this research project. To ensure accuracy, the collected data was cross-referenced with the corresponding inventory records of the site. Precise measurements were taken using a digital caliper, and an extensive set of photographs was captured to support the subsequent analysis and interpretation of the faunal record. The examination of bone surfaces was facilitated by the use of handheld lenses, allowing for thorough inspection and documentation of key details.

A total of eight criteria were established to guide the taphonomic observations made both prior to and during the laboratory work. These criteria encompassed various aspects, including the weathering stage, oxidation, trampling, plant root marks, sediment compression and crushing, fracture patterns, breakage patterns, and the presence of polish and rounding on the bone surfaces. In particular, the classification of weathering stages on bone remains adhered to the criteria set by Behrensmeyer (1978), while the framework for evaluating breakage patterns was adapted from Villa and Mahieu (1991).

3.1.4. Sampling strategy and sample size

The selection of the sample is primarily driven by considerations related to restoration. The sample is primarily determined based on restoration consideration. Restoration works were carried out only on a small portion of the remains from the previous years, with the overwhelming majority of them still being in a fragile state and are in storage facilities in Baza and Granada. For the purpose of this research, it has been decided to focus on those remains that have been fully restored, as well as those that, although not restored, are in relatively better states of preservation. These selections were made to ensure that the assessment procedures employed for this research would not adversely affect the condition of the specimens. It is important to note that the final sample encompasses restored pieces, unaltered specimens in better states of preservation, and those currently on display in museums.

Additionally, it is worth emphasizing that the assemblage from the site includes a mixture of large megaherbivore bones intertwined with those of smaller to larger-sized mammals. In cases where these various remains were unearthed from the same archaeological context, and the process of separating them was deemed potentially precarious, they were precisely documented individually and then carefully grouped together within a protective bundle, commonly referred to as a "momia." These bundled remains were subsequently transported with great care from the excavation site and set aside for future restoration. For the purpose of this research, the decision was made not to utilize these bundled packages that posed potential complications and risks when it came to disentangling their contents.

Another crucial consideration in determining the sample size was the impact of raising or decreasing the sample would have on the taphonomic parameters that have been used to test the two key objectives of the research i.e., determine agency and processes of accumulation and post-depositional processes. While preservation considerations undeniably played a significant role in defining the sample size, it was equally imperative to ensure that the selected sample size aligns with the research objectives.

Since the start of excavations at the site in 2000, a substantial number of materials, exceeding 2,200 in total, have been successfully recovered in situ. The first two excavation campaigns conducted in 2000 and 2001 yielded a combined total of 189 in situ materials. The number of recovered remains saw a notable increase with the resumption of excavations in 2015, resulting in the documentation of 206 in situ remains. The most extensive collection to date was amassed during the 2022 field season, with an impressive 619 in situ materials extracted from the site.

The selected sample, which constitutes 12.1% of the entire assemblage from the site (as indicated in Table 1), exhibits some variation in size. Notably, the largest sample originates from materials excavated in 2001, representing 37.9% of the selected sample, while the smallest sample is derived from materials excavated in 2015, comprising only three specimens. Additionally, it is essential to emphasize that the sample size excludes materials recovered during the 2019 and 2022 excavation seasons, as restoration work had not yet commenced on these remains.

In conclusion, the chosen sample size was carefully determined to strike a balance between adequacy and feasibility, ensuring that it aligns effectively with the research objectives while taking into account considerations of preservation and practicality.

3.1.5. Data analysis

The data collected through fieldwork, the assessments conducted on the assemblage, and the results of spatial analysis were thoroughly examined. To complement the interpretation, a comprehensive literature review was conducted. The inventory data was processed in three distinct manners, involving a thorough review of raw data to facilitate various analytical procedures.

The initial procedure entails working with the entire set of samples, encompassing all 268 specimens. This comprehensive approach aims to produce an overview of the dataset's contents. Then, descriptive statistics was employed to elucidate aspects such as the distribution of identified specimens across taxa and anatomical elements. The objective here is to offer a preliminary understanding of the dataset, laying the foundation for subsequent taphonomic and spatial analyses.

Year	**Total record**	***In situ***	**Sieve**	**Level bag**	**Total sample**	**Sample %**
2000	123	14			14	11.4
2001	66	23	1	1	25	37.9
2015	206	3	-	-	3	1.5
2016	215	6	2	-	8	3.7
2017	308	104	1	-	105	34.1
2018	351	111	2	-	113	32.2
2019	323	-	-	-	-	-
2022	619	-	-	-	-	-
Total	**2211**	**261**	**6**	**1**	**268**	**12.1**

Table 1:shows distribution the sample across year and provenience.

The second step in this process involved identifying specimens that are suitable for spatial analysis. Consequently, any remains lacking complete coordinate information or a square of provenience were excluded from consideration. The spatial analysis conducted within this study aims to create density maps that visually depict the distribution of the selected sample, including those specimens exhibiting taphonomic attributes. Additionally, it involved a comparative assessment with the entire assemblage from Baza-1, encompassing data from all field seasons spanning from 2000 to 2022. This comparative approach allows for an evaluation of how the distribution of the sampled remains compares to the distribution of the entire site assemblage. Furthermore, the study examines the distribution of indeterminate bone fragments to identify potential patterns in their distribution and assess if these patterns correspond to the taphonomic traits explored in this research.

The production of these maps was carried out using Golden Software Surfer® version 25.3.290. It entailed integrating the alphanumeric, X (numeric) and Y (alphabetic), 1 x 1-meter squares grid system to the working grid system generated in the software. In the process, the XY coordinates were set to the center of every square. In this context, square A1 serves as the reference point labeled "0,0." Consequently, when constructing the density grid, the Z value corresponds to the count of records documented within that specific square, serving as a representation of the data density. This method was employed to remedy the issue of missing coordinate points for 30 (11.2%) of the remains within the sample. While this tool has been primarily used to analyse the distribution of the sampled remains and make comparisons among various variables, it is important to note that the method does allow to analyse the remain in the stratigraphic profile.

The third step involved organizing the variables and exploring potential causal relationships within the observed patterns. For certain variables, the evaluation parameters were constrained. For example, the weathering stage, as defined by Behrensmeyer (1978), can only be applied to bones, leading to the exclusion of teeth, carapace, and tusk remains from the analysis. Detailed procedures regarding the selection of variables are presented in Chapter 3. Similarly, the assessment of the breakage pattern is exclusive to bone specimens.

CHAPTER 4

4.1. Presentation of results

This chapter serves as a comprehensive summary of the outcomes derived from both field observations and laboratory work. It commences by examining the composition of the sample chosen for this research, offering essential statistics concerning the identified specimens. Subsequently, the criteria established for taphonomic assessment are elaborated upon.

To enhance clarity in presentation and facilitate subsequent interpretation while avoiding redundancy, the description of taphonomic traits is organized by grouping comparable attributes together. Special emphasis is placed on taphonomic traits that have demonstrated a widespread impact on the fossilized bones, and these are examined in greater detail. Additionally, attention is directed towards taphonomic categories characterized by only a few isolated instances, ensuring a comprehensive coverage of the spectrum of taphonomic attributes observed.

4.1.1. An Overview of the Assemblage Composition

As previously noted, the sample chosen for this investigation comprises 268 specimens sourced from an excavation area spanning 49 square meters at the Baza-1 site. Within this sample, 78 specimens (constituting 29.1%) are categorised as indeterminate bone remains, further classified into long bone shaft fragments, flat bone fragments, and indeterminate bone fragments. The remaining 190 specimens have been identified to an anatomical resolution (as depicted in Figure 4).

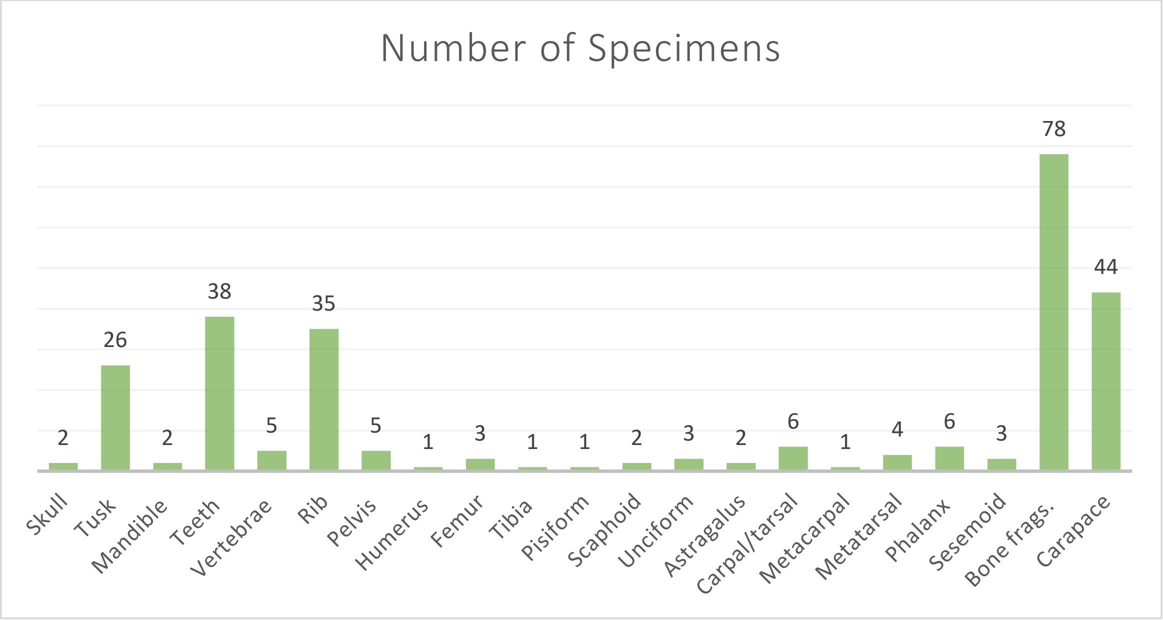


Figure 4: Distribution of anatomically identified specimens of the Baza-1 sample.

In terms of the Number of Identified Specimens (NISP), carapace fragments from *Chelonia* sp. dominate, constituting 44 (16.4%) pieces within the assemblage. Following closely are teeth, representing the second most abundant element, with a total of 38 (14.1%) remains. Among these teeth, 13 have been assigned to *Stephanorhinus* cf. *jeanvireti*, and 15 belong to one of the two Proboscidean species found at the site. The remaining 10 specimens are distributed among various artiodactyls.

Similarly, ribs are well-represented in this sample, accounting for 35 (13%) of the remains. Among these, only three are assigned to Proboscideans, while the remainder belongs to indeterminate mammals spanning from small to megaherbivore sizes. 22 specimens attributed to indeterminate mammals have been identified as originating from large-sized mammals. Notably, the sole large-sized mammal within the sample that has been identified at the genus level is *Alephis* sp.

Figure 5: Autopods within the sample. A. Right pisiform of Alephis *sp.; B. 2nd phalanx of indeterminate Suidae (*Sus *sp.); C. Proboscidean sesamoid, D. Proboscidean 1st phalanx.*

Among the identified postcranial elements, autopods (Figures 5 & 6) stand out as the most abundant, comprising 28 remains. In comparison, there are a total of five zeugopods and stylopods combined, excluding 24 long bone fragments. Out of the 28 autopods, 17 specimens are categorised as carpal/tarsal bones, with seven assigned to *Alephis* sp., five attributed to indeterminate large-size mammals, three originating from Proboscideans, and one each from indeterminate Bovidae and *Stephanorhinus* cf. *jeanvireti*. The remaining autopods are distributed among six phalanges and five metapodials. With the exception of metapodials, most autopods are remarkably well-preserved, with the entire anatomical element still fully intact.

Figure 6: A nearly complete right astragalus of indeterminate small size Bovid. From left to right: anterior, medial, and posterior views.

Within the sample, there are only three femoral remains, one tibia, and one humerus that constitute the limited number of determinate long bone specimens. These remains, although incomplete, represent some of the severely fragmented identified specimens within the assemblage. Additionally, five vertebrae have been identified, with one assigned to Cyprinidae, two categorised as mammal vertebrae, and one labelled as indeterminate. Furthermore, the sample includes five pelvis bones that have been attributed to a single individual of *Anancus arvernensis*, making them the only set of girdle bones within the sample.

In terms of taxa, the sample is predominantly composed of indeterminate mammal remains (Mammal indet.), which account for 96 specimens, constituting 36% of the sample (as shown in Figures 8 & 9). Out of these, 56 remains are derived from large mammals (weighing between 340-907 kg), followed by medium to large-sized and megaherbivore specimens (cf., Espigares, 2010: 32), each represented by 14 specimens. The remaining 40 remains are distributed among various size classes.

The list of specimens identified to the Order level is primarily dominated by Proboscideans, with 59 (22%) specimens recognized as originating from this Order. Although it was possible to distinguish between two species of Proboscideans based on 23 identified dental elements (17 for *A. arvernensis* and six for *M. borsoni*), distinguishing between them was not feasible for the remaining 37 specimens. The differentiation between these two Proboscideans relied on dental remains (as depicted in Figure 7). Tusk fragments are predominantly composed of small pieces, forming the majority of the Proboscidean remains. Specifically, these remains account for 24 out of the 37 specimens that could not be classified to either of the two Proboscidean species

Figure 7: Molars of Anancus arvernensis *and* Mammut borsoni. A. Anancus arvernensis *left M/3. 1: occlusal view, 2: lingual view;3: buccal view*. B. Mammut borsoni *right M/1. 1: occlusal view; 2: lingual view; 3: labial view. From Ros-Montoya et al., (2017).*

Chelonia sp. which is only recorded through plate fragments, makes up 17% of the total sample. On the other hand, *Stephanorhinus* cf. *jeanvireti* and *Alephis* sp. account for 6% (17 remains) and 5% (14 remains) respectively. *Stephanorhinus* cf. *jeanvireti* is primarily recorded through separate dental remains (13 plus one mandibular remain). This represents over 34% of separate dental remains recorded in the entire sample. Only three post cranial elements have been identified to be from this taxon.

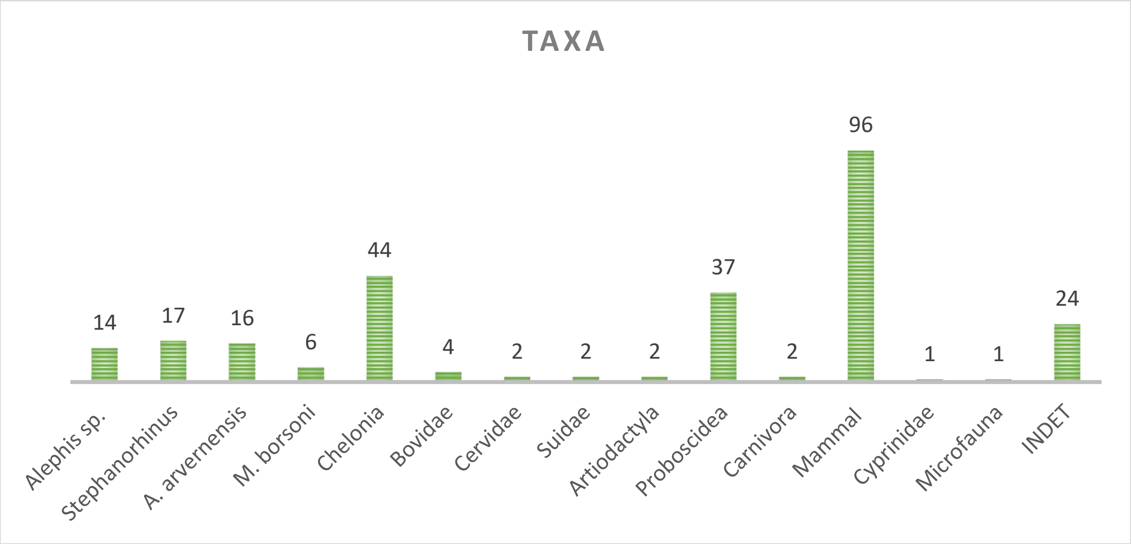


Figure 8: Distribution of remains by taxa.

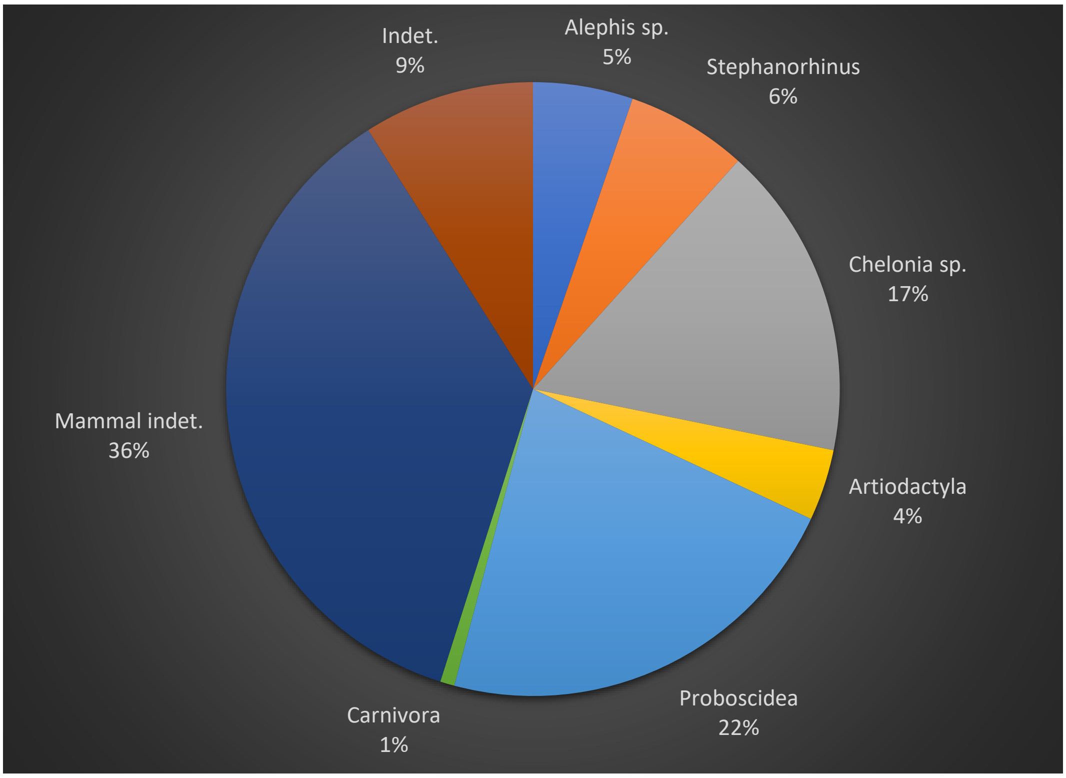


Figure 9: Distribution of remains across taxa excluding one Cyprinidae and one Microfauna, and merging three families into order Artiodactyla and two species into order Proboscidea.

Alephis sp. is exclusively represented by mandibular and carpal elements, along with two sesamoid bones, which have been assigned to two individuals (MNI). The sample includes only two specimens identified as belonging to Suidae (*Sus* sp.), specifically the 2nd phalanx of either the third or fourth digit and the right upper 2nd molar (Figure 10). Similarly, two specimens categorised as Carnivora indet. have been included in the sample, comprising one metatarsal (depicted in Figure 11) and the 3rd phalanx of small to medium-sized carnivores (size Class 2), following the classification by Lewis & Werdelin (2007).

It is essential to emphasize that the faunal inventory derived from the Baza-1 site comprises a diverse range of species including *Hipparion* sp. Additionally, there are other species documented in the broader faunal list that are not present in the analysed sample. These unrepresented species contribute to the overall biodiversity and ecological context of the site, suggesting a more complex paleoecosystem than what is observed solely within the examined sample. Further exploration of these additional species could yield valuable insights into the paleoenvironment and community dynamics at Baza-1.

*Figure 10: right M2/without root from indeterminate Suidae (*Sus *sp.). This represents one of the two specimens belonging to this taxon.*

Carapace fragments from *Chelonia* sp. are abundantly distributed throughout the entire assemblage originating from the Baza-1 (e.g., Figure 12). Consequently, a substantial number of carapace remains have been incorporated into the sample chosen for this research. It is worth noting that the turtle specimens within this sample are characterized by significant fragmentation, with some of these remains still partially embedded within the sediment layers, underscoring the challenges in their preservation and recovery.

Figure 11: Metatarsal of indeterminate small to medium size Carnivora.

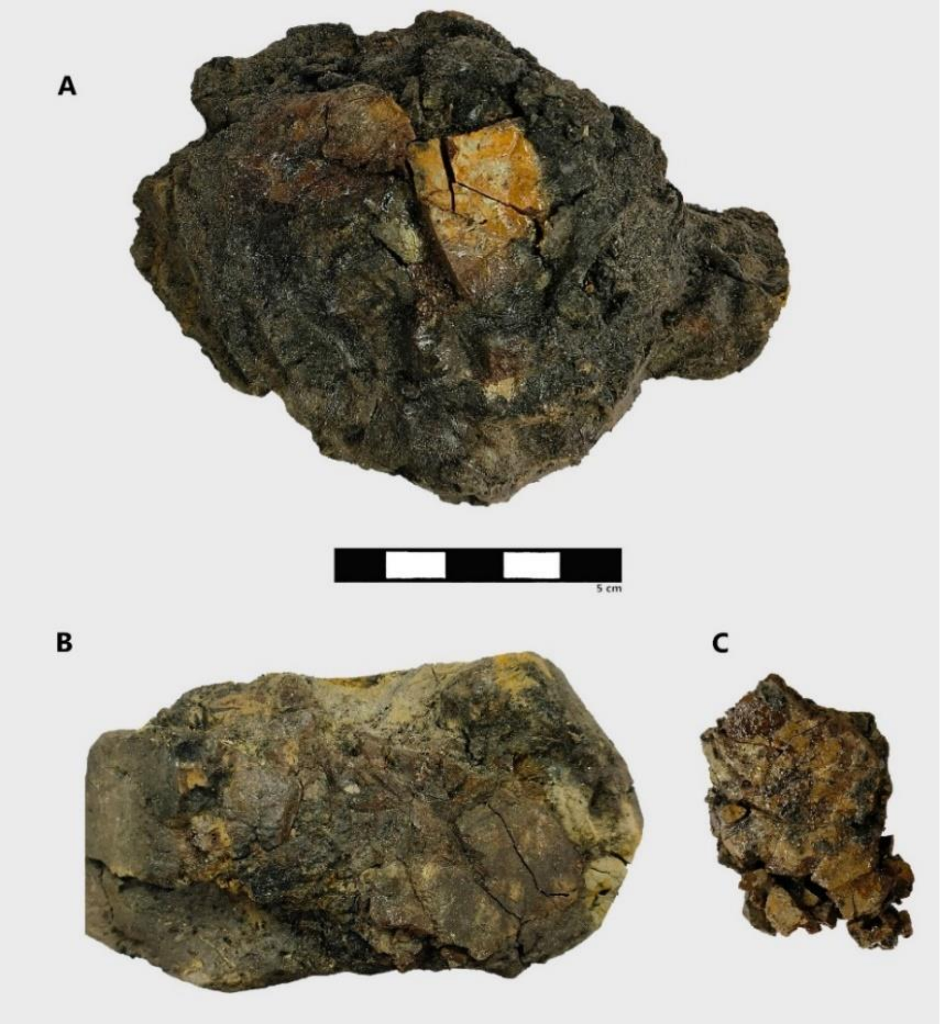


*Figure 12:*Chelonia *sp. carapace fragments embedded in sediment (A and B) and fragments pieced together with adhesive (C).*

In a broader context, the assemblage at the site is characterized by the prevalence of various sizes of ungulates, with a notable rarity of carnivores. The sample is markedly dominated by megaherbivores, defined as those weighing over 907 kg. This category encompasses 93 specimens. Among these, 76 specimens have been identified as belonging to the Proboscideans and *Stephanorhinus* cf. *jeanvireti*. Furthermore, an additional 17 specimens falling within this size class are inferred to be megaherbivores, based solely on their size category (Megaherbivore). This total of 93 specimens excludes remains that cannot be definitively distinguished between Large and Megaherbivores.

Age determination was applied to a limited subset of the sample, encompassing a total of 31 identified specimens. This age determination was principally guided by key factors, including the eruption patterns of teeth, the extent of wear observed on the cheek teeth, and the stage of fusion in postcranial elements. These criteria allowed for a relatively accurate estimation of the age of these specimens. However, the fragmentary condition of the majority remains within the assemblage posed significant challenges to achieving more precise age determinations. The absence well-preserved skeletal elements hindered the ability to conduct more detailed analyses that could provide deeper insights into the age composition within the assemblage.

Furthermore, MNE and MNI determination has been carried out (as summarized in Table 2) by considering age (attributes on teeth and fusion stage), lateralization, and occasionally body mass (size class) when enough attributes allow such identifications. However, extending the MNE and MNI calculations to encompass the entire assemblage posed considerable challenges. The complexity of the assemblage, particularly the presence of large-sized indeterminate fragmentary specimens, such as tusks and carapaces (as illustrated in Figure 13), made it impractical to apply MNE and MNI calculations across the entire sample. Consequently, the MNE and MNI calculations were primarily focused on specimens that could be identified to the Genus level, a more precise taxonomic classification, in order to mitigate the risk of overlap and inaccuracies in the results.

Figure 13: Indeterminate bone fragments (rib, flat bone and long bone frags.) assigned to various size indeterminate mammals

Taxa	**Age**					**MNE**	**MNI**
	A	I	J	YA	Total		
***Alephis* sp.**	6			2	8	6	2
Anancus arvernensis	1				1	1	1
Mamuth borsoni				5	5	1	1
Stephanorhinus* cf. *jeanvireti	3	1	1		5	4	3
Bovidae indet.	2				2	2	
Cervidae indet.	1				1	1	
Suidae (*Sus* sp.)	1				1	1	
Probosidean indet.	3	1			4	4	
Carnivora indet.	2				1	2	
Mammal indet.		1	2		3	3	
Total	18	3	3	7	31	24	7

Table 2: Age profile based on 31 remains. MNI only considers those identified to Genus level.

In terms of the age profile among the 31 specimens for which such determinations were possible, eight of these individuals were identified as adults, indicating a substantial representation of fully matured individuals within the sample. The remaining specimens were categorised as two young adults, two juveniles, and three infants, suggesting a diverse range of age categories beyond adulthood. There are no senile individuals identified within this subset of the sample, indicating a lack of aged individuals among the analysed remains. Therefore, the age profile is predominantly characterized by adult individuals.

Stephanorhinus cf. *jeanvireti* exhibits diversity across various age categories. This diversity encompasses adult, juvenile, and infantile individuals, reflecting a comprehensive age distribution within this specific taxon. A sex profile was not attempted as part of the study's objectives and methodology, and therefore, this attribute was not considered in the analysis. However, it is important to mention that the age profile is not significantly influenced by sex, as the primary parameters for age determination do not principally rely on size differences between males and females.

4.1.2. Criteria for breakage patterns and weathering observations

Taphonomic observations in this study were conducted using a set of eight predefined parameters, as outlined in Table 3. The subsequent sections examine in-depth the specific criteria utilized for two of these parameters. These particular parameters have been selected for detailed discussion due to several significant factors.

First and foremost, they exhibit widespread prevalence and considerable significance within the context of the study. This prevalence necessitated the establishment of standardized criteria for the identification and subsequent analysis of these attributes. Secondly, these two categories of attributes are closely related and share a common characteristic—they lack a uniform frame of reference that can be consistently applied to all specimens. For instance, the criteria for assessing breakage outline cannot be universally applied to both bones and teeth, as demonstrated in the following sections. Therefore, a more detailed examination of these two parameters is essential to ensure a comprehensive understanding of their implications within the taphonomic analysis.

Furthermore, the remaining parameters can be explained using straightforward criteria, or they are only evident on a limited number of remains. For instance, the occurrence of trampling has been observed on just one bone specimen. Consequently, the description of trampling is solely based on the characteristics of the mark found on this specific specimen.

Additionally, attributes such as crushing, fracture, and outline of broken edges, have been discussed collectively under the umbrella of breakage pattern. This grouping allows for a more cohesive analysis of these attributes, as they often intersect and provide valuable insights into the overall breakage patterns observed within the assemblage.

Square	Elements	Weathering			Oxidation		Trampling	Root	Crushed	Fracture	Edge breakage outline			Edge Rounding
		0	1	Indet	Iron	Mang.					Irregular transverse	Straight transverse	Oblique	
L10	1	1	0	0	0	0	0	0	0	1	0	1	0	0
L11	6	4	2	0	0	0	0	0	0	2	4	0	2	3
L12	4	0	1	3	0	0	0	0	1	2	1	0	0	0
L13	1	1	0	0	0	0	0	0	1	1	0	0	0	0
M12	3	3	0	0	0	0	0	0	0	2	2	0	0	0
M13	8	5	1	2	0	0	0	0	1	3	3	0	0	0
M14	3	2	0	1	0	0	0	0	0	0	0	0	0	0
M15	4	3	0	1	0	0	0	0	0	2	1	0	1	1
M9	10	10	0	0	1	0	0	1	1	4	6	3	2	0
N10	5	2	0	3	0	0	0	0	0	2	2	0	1	0
N11	16	7	0	9	0	0	0	0	2	3	4	0	2	0
N12	7	4	0	3	0	0	0	0	2	4	2	0	0	0
N14	3	1	1	1	0	0	1	0	1	2	2	0	0	1
N15	12	2	0	10	1	0	0	0	0	3	2	0	1	1
N16	3	0	0	3	0	0	0	0	0	0	0	0	0	0
N9	2	2	0	0	0	0	0	0	1	1	0	0	0	0
O10	49	15	2	32	2	0	0	1	9	20	13	1	3	0
O11	8	0	0	8	0	1	0	0	1	5	1	0	0	0
O12	13	4	0	9	0	1	0	0	2	2	0	0	0	0
O13	13	0	0	13	0	0	0	0	0	1	0	0	0	0
O14	1	0	0	1	0	0	0	0	0	0	0	0	0	0
O15	44	7	0	37	0	0	0	0	0	4	7	4	3	4
O16	36	6	1	29	1	0	0	2	0	7	2	5	3	1
P10	3	0	0	3	0	0	0	0	0	1	0	0	0	0
P12	1	1	0	0	0	0	0	0	0	1	0	1	1	0
P13	3	0	0	3	0	0	0	0	2	2	0	0	0	0
P14	3	0	1	2	0	1	0	0	0	0	0	1	0	0
P9	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Indet.	5	1	1	3	0	0	0	0	0	0	1	1	1	0
Total	**268**	**82**	**10**	**176**	**5**	**3**	**1**	**4**	**24**	**75**	**53**	**17**	**20**	**12**

Table 3: Taphonomic parameters set for this study and their distribution across squares

4.1.2.1. Weathering

Weathering analysis holds a pivotal role in this research, contributing significantly to the overall taphonomic assessment. The principal criterion for assessing the specimens' weathering stage hinges upon the presence or absence of cortical surfaces and related attributes. As a result, weathering stages in the sample have been categorised on a scale of 0 to 5, as originally proposed by Behrensmeyer in 1978. This categorisation is guided by several key considerations:

1. Weathering stages were assigned to specimens under specific conditions, where the presence of the cortical surface was evident and post-depositional processes that could obscure the weathering stage could be confidently ruled out. An example of this is when adhering matrix obstructs observations that could be made on bone surfaces (Capaldo & Blumenschine, 1994). Consequently, weathering stages were exclusively assigned to bones with clean surfaces and isolated patches of adhering sediments that did not impede such assessments. Bones that retained a significant amount of sediment on their surfaces and/or had completely lost their cortical surface (as illustrated in Figure 14: B) were excluded from weathering stage assignments.
2. Assessments were not conducted on porous bones that still retained either their entire cortical surface or a portion of it. Post-depositional deterioration, such as corrosion (depicted in Figure 14: A), would have already affected the subaerial weathering stage that might have been preserved on the fossilized bone before burial. Consequently, weathering stages were not considered when the impact of such factors was visibly apparent.
3. Teeth, tusks, and carapaces of chelonids were excluded from weathering stage assessments because the same observation parameters as outlined in Behrensmeyer (1978) could not be consistently applied. While cracking and splitting patterns on dental remains have been documented (Behrensmeyer, 1975; Fernandez-Jalvo & Andrews, 2016), the absence of standardized criteria for classifying teeth prevents precise weathering interpretations. Nevertheless, it is generally observed that teeth surfaces tend to withstand weathering better than other skeletal elements, although significant tooth splitting has been reported due to dehydration (Behrensmeyer, 1975).

Figure 14: A. proximal portion of Proboscidean 2nd phalanx and B. long bone epiphysis from indeterminate large size mammal. Several attributes on the surfaces of these bones render them unsuited for weathering observations.

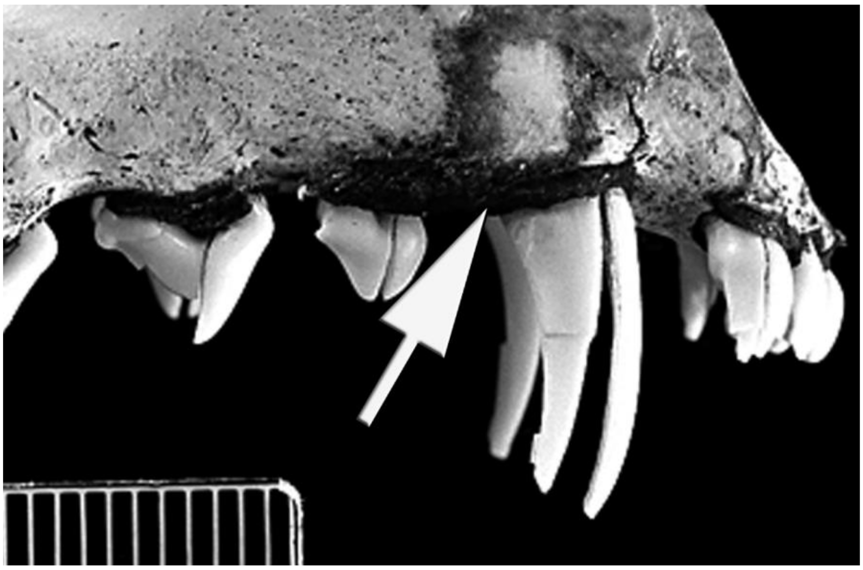


Figure 15: A maxilla with teeth of modern fox. Heavily cracking on the teeth is attributed to weathering. The teeth are in advanced state of weathering while the bone remains relatively intact (Fernandez-Jalvo & Andrews, 2016)

4.1.2.2. Breakage pattern

This study employs methods and conceptual frameworks commonly utilized in the characterization of breakage attributes (e.g., Johnson, 1985; Villa & Mahieu, 1991; Pesquero et al., 2013). However, the establishment of consistent parameters analogous to these studies proved challenging due to the limited number of identified long bone specimens available for comprehensive observations across all potential sides and circumferences. Consequently, given the predominantly fragmentary nature of the sample remains and the prevalence of unidentified components like splinters and indeterminate diaphysis fragments, certain aspects, such as the angle of fracture and shaft circumference (cf., Villa & Mahieu, 1991), were not included in the analysis. As a result, the primary basis for observation primarily relies on assessing the characteristics of the broken edges.

4.1.2.2.1. Outline of fracture edge

The methodology employed in this study places particular emphasis on attributes known to offer substantial insights and those commonly employed in the literature to distinguish between breakage that occurs during the "green" phase (fresh bone) and the "dry" phase (mineralized bone). This approach is applied irrespective of the specific agencies that these phases are interpreted to represent (Johnson, 1985). Consequently, the primary focus lies in the observation of the outline of the broken edges of the bones, ranging from irregular (jagged breakage) to spiral or curved breakage. These two fracture attributes play a pivotal role in discerning diagenetic breakage from breakage that occurs during the biostratinomic phase, which may include processes such as bone-breaking by carnivores, accidental falls, and other relevant factors.

To prevent any overlap with the fracture parameter, which is utilized to assess the presence or absence of fractures on the surfaces of the preserved portions of bones, the concept of breakage pattern in this context is specifically applied to the edges of the preserved portions of bones (as illustrated in Figure 16). In the case of identified elements, this involves evaluating the outline of transverse breakage (as depicted in Figures 17 & 18), while for splinters, the focus is on identifying the predominant diagnostic features (e.g., jagged or spiral) on either end of transversally broken edges. When both ends exhibit two equally distributed outline characteristics (as shown in Figure 19), both are duly recorded and taken into consideration.

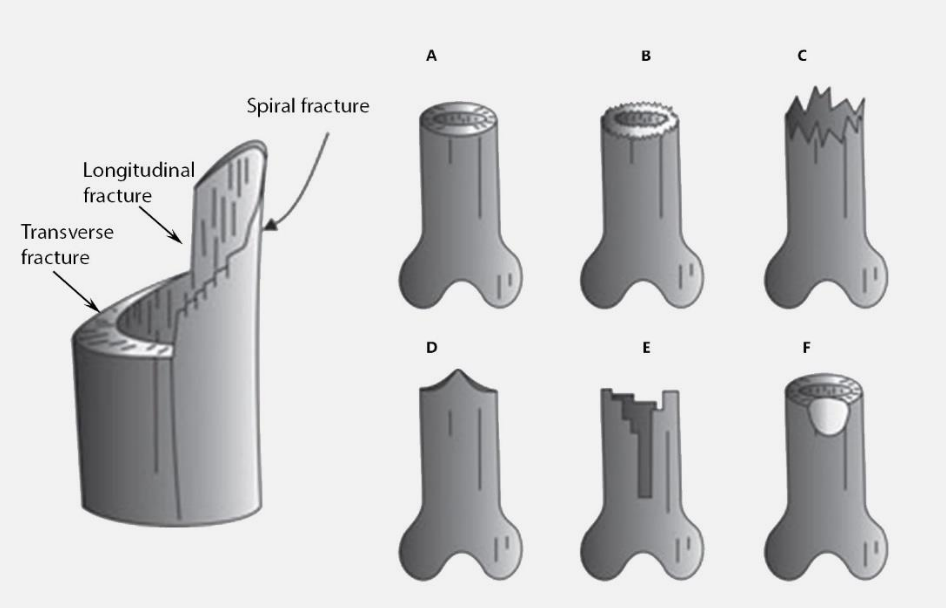


Figure 16: Fractured edge outlines modified from Pesquero et al. (2013). A. straight transversal; B. irregular transversal; C. saw toothed or jagged; D. inverse V; E. Stepped or columnar; F. flaking.

These edge outlines (Figure 16) have been applied to describe identifiable long bone specimens. However, this study has used them to describe the fragments from this type of break. Consequently, they provide numerous individual or mixed outcomes. Considering this, the discussion of these attributes is summarized into four types; straight transversal, irregular, steeped longitudinal (oblique), and spiral.

Figure 17: Distal portion of left tibia from small to medium size cervid. The magnification on the outline of the break shows what is often described as jagged or saw-toothed break (see Figure 13).

Figure 18: Metacarpal from small to medium size Bovid. The specimen combines several characters of breakage (indicated by the white arrows). From top to bottom; oblique, straight transversal and irregular breaks and sediment crush along with longitudinal break in the middle.

Furthermore, similar to the weathering parameter, observations have been limited to bones, with teeth and plate fragments of *Chelonia* sp. excluded from this analysis. However, the impact of sediment compression and fractures on the preserved bone portions has been documented.

A small number of identifiable long bone portions, exemplified by the specimen in Figure 18, provides valuable insights into the overarching patterns in original and outcome scenarios in bone breakage pattens at the site. The fragments are the products of the complete bones and retain the attributes described on the long bones as they come off in a series of breakage processes resulting from dynamic or static force. Thus, the diaphysis splinters, rib fragments, and indeterminate bone fragments reflect the trends of breaks through the edge outline observed on them.

In summary, the primary criterion employed in distinguishing between green bone breakage and dry bone breakage relies on the examination of the outline of broken bones. Green bone breaks typically exhibit spiral patterns, smooth margins, and surfaces, indicative of permineralized bone. Conversely, dry bone breakage is characterized by jagged and irregular transverse or oblique breaks (as detailed by Villa & Mahieu, 1991). Additionally, the fracture attribute pertains to the presence of visible deep cracking and splitting on the surfaces of preserved bone portions, irrespective of their orientation. These criteria have been carefully assessed in the context of a select few long bone portions specifically chosen for this study (e.g., Figures 17 & 18).

Furthermore, the observations related to these criteria have been limited to bone specimens, excluding teeth and plate fragments of turtles. However, the impact of sediment crush and fractures on the preserved portions has been documented. This comprehensive approach allows understanding of the taphonomic processes affecting the assemblage.

Figure 19: A rib fragment from medium to large size mammal. The rib, still embedded in the sediment, retains irregular outline on one end and relatively straight transversal outline on the other.

4.1.3. Description of the taphonomic attributes

4.1.3.1. Climato-edaphic

In the context of this study, climato-edaphic attributes encompass weathering and oxidation processes. The sample under examination revealed the presence of two distinct types of oxidations: iron and manganese oxides. In contrast to weathering, which was used to evaluate a relatively large number of specimens, oxidation was only observed in a limited number of cases within the sample.

4.1.3.1.1. Weathering

As outlined in the previous section, weathering observations were conducted according to the criteria established by Behrensmeyer (1978). These observations took into consideration the preservation state and composition of the selected remains for this study. Out of the total 268 samples used in this research, 92 specimens (34.3%) were deemed suitable for weathering assessment. Among these, 82 (89.1%) bones exhibited no discernible signs of weathering, while 10 bones (10.9%) were categorised as having reached weathering stage 1. Weathering stage assessments were not conducted on 176 remains (65.7% of the total). The observations excluded a category of remains encompassing all the carapace fragments from *Chelonia* sp. (44 specimens), teeth (38 specimens), and both determinate and indeterminate bone remains that did not meet the criteria established for weathering observation.

Bones categorised as weathering stage 0 exhibit surfaces that display no evidence of cracking or flaking resulting from prolonged subaerial exposure to weathering agents (Behrensmeyer, 1978). The majority of bones for which weathering stages were assigned exhibit these characteristics, as illustrated in Figures 17, 18, 19, & 20. These bones lack any attributes associated with later stages of weathering. Additionally, other surface modifications resulting from post-depositional and excavation processes were examined and differentiated from weathering features.

In contrast, bones in weathering stage 1 are characterized by the presence of cracks, often running parallel to the fiber structure. On long bones, this fibrous structure is oriented longitudinally along the bone's axis (Behrensmeyer, 1978). Within the sampled assemblage, bones assigned to weathering stage 1 exhibit incipient (fine) cracks and the presence of fibrous structures (Figure 21). These features can be described as transitional between stage 0 and stage 1 weathering. None of the remains classified as stage 1 weathering display advanced deep cracks, and the fibrous structures remain attached to the bone surfaces without any signs of flaking. Notably, no weathering stage beyond 1 have been recorded in any of the bones viable for such assessment.

In terms of the types of remains displaying weathering attributes, all complete small bones, including carpal and tarsal bones, sesamoids, and phalanges, exhibit surfaces corresponding to weathering stage 0. Additionally, a significant portion of bones at weathering stage 0 consists of rib fragments, accounting for 25 bones in total. Among these, only three specimens are from small to medium-sized animals, while the remaining 23 rib fragments originate from Proboscideans and large mammals. The second most prevalent remains with weathering stage 0 are long bone shaft splinters and indeterminate fragments, comprising 19 bones.

Conversely, remains categorised to weathering stage 1 exclusively include three flat bones and three identifiable and four non-identifiable portions of long bones from large and megaherbivore-sized animals. Within this sample, there are four megaherbivores, five unidentified large mammals, and one large bovid represented.

Figure 20: Rib fragment from a large mammal. The surface shows weathering stage 0 without any visible cracks and fractures that can be attributed to weathering. The adhering matrix with grey coloration does not hinder observation.

Figure 21: Distal portion of metacarpal from small to medium size bovid (anterior view). Weathering stage 1 with incipient (thin) cracks and rough fibrous surface.

Figure 22: Well-preserved left P/4-M/3 from Alephis *sp. (buccal and lingual views respectively).*

While systematic weathering observations were not conducted on teeth remains, an examination of this category within the sample reveals that complete teeth have well-preserved surfaces, with no significant cracks or fractures indicative of weathering. Among the 38 teeth remains, 20 are recognizable to the part of the dentition (e.g., Figure 22) and can be assigned to specific taxa. The remaining 18 consist of fragments of various sizes. The root is generally absent in nearly all of these specimens, with the exception of a single degraded root from a Proboscidean tooth.

4.1.3.1.2. Oxidation

Oxidation does not have a widespread impact on the remains selected for this study. Only a few patches of iron oxide (Figure 23) and manganese oxide have been noted on eight remains (five and three, respectively). However, iron oxide has a readily noticeable impact on bone surfaces than manganese oxide. Bones identified with iron oxide retain orange and yellowish coloration (Figures 14 A, 23, & 24). One of the bones impacted by iron oxide shows a corroded surface (Figure 14 A). Manganese oxide has dark colorations (Figure 16) and is present in few patches.

Figure 23: Iron oxide in a right unciform of Alephis *sp.*

4.1.3.2. Breakage

Complete bones are few in the sample. Out of a total of 160 bones examined, only 12 of them, accounting for approximately 7.5% of the sample, have been identified as complete or nearly complete, retaining a significant portion of their original anatomical structure. These well-preserved bones primarily consist of smaller bone including carpal/tarsal bones, phalanges, and vertebrae. Moreover, more than half of the individual and articulated tooth specimens possess complete crowns without roots.

Within the 26 tusk remains analysed in this study, three specimens display comparably better preservation. Among these, three specimens can be characterized by their recognizable medial and distal segments, exemplified in Figures 26 & 47, along with intact circumferences. The most sizeable tusk specimen documented at the Baza-1 site, as showcased in Figure 26 within this report, measures just over 1.1 meters in length. It bears substantial evidence of fracturing and breakage, manifestation of considerable impacts in post-depositional phase.

Three distinct characteristics converge when examining breakage: the presence of compressed or crushed surfaces, the presence of fractures on preserved portions, and the assessment of the edge outline of broken bones. The evaluation of broken edge outlines is specifically focused on bone remains, while attributes related to crushing and fractures were documented across various anatomical elements including carapace and tusk.

Compression or crushing is defined by the flattening of relatively rounded anatomical elements, as illustrated in Figures 18 & 26, and the formation of depressions on flat surfaces, as seen in Figure 24. Additionally, these effects can be observed on irregular as well as long bones, resulting in varying degrees offset from their original shapes. A total of 24 bones within the sample exhibit crushed surfaces, and these alterations have diverse impacts on the morphology of the preserved anatomical remains.

Fracture characteristic has been documented in a total of 75 specimens. Among the identified specimens, ribs exhibit the highest frequency of fractures, with 15 rib fragments displaying fractured surfaces. The criteria for recording this attribute do not consider factors such as the outline (whether longitudinal or transversal), the depth, or the number of fractures present on the surface of the remains. Additionally, all instances of compression are accompanied by various configurations of fractures. Several fragments from the remains show bending and tilting to varying degrees, as illustrated in Figure 25.

Figure 24: Left hemimandible of Stephanorhinus *cf.* jeanvireti. *The specimen shows compression, fracture and breakage on the ramus, without any significant impact on the mandibular body.*

Figure 25: Rib fragments from large size animal. They present several characteristics of post-depositional breaks and fractures.

Figure 26: medial portion of a tusk from unidentified Proboscidean. The red square illustrates highly fragmented pieces held in place with Paraloid® B 72.

The figure designated as Figure 26 vividly illustrates a combination of features related to diagenetic breakages, encompassing crushing, fracturing, and the presence of broken edges. The proximal section of the tusk has undergone compression, resulting in the production of several small fragments. Moreover, it exhibits both transversal and longitudinal fractures.

The description of these breakage attributes amalgamates the two edges for medial fragments, as exemplified in Figures 19 & 20. Conversely, when the epiphyseal portion is preserved on the opposing end, only one broken edge is evident, as depicted in Figures 17 & 18. In instances where multiple fitting portions of long bones are involved, as seen in Figure 18, three attributes are combined (irregular transverse, straight transverse and oblique) to record the patterns. Consequently, a total of 75 bones exhibit either one or a combination of these breakage patterns. In all these cases, the observed breakage patterns are indicative of post-depositional or dry (mineralized) bone breakage, characterized by rough, irregular, or straight breaks.

These breakage attributes are predominantly documented on bone fragments, including long, flat, and indeterminate bones. Notably, 33 bone fragments and 20 ribs exhibit features indicative of post-depositional breakage. Smaller bones such as carpal/tarsal, phalanges, and sesamoid bones are generally less affected by breakage, with only two carpal bones and one phalanx showing such characteristics, as depicted in Figure 14: A.

Two fragments of long bones, originating from animals ranging in size from small medium to large (cf., Espigares, 2010), exhibit characteristics indicative of green bone breakage, specifically a spiral break pattern. Both of these specimens display well-preserved cortical surfaces without any signs of weathering (stage 0) and possess smooth margins. One of these specimens, depicted in Figure 27, presents an isolated shallow depression measuring approximately 1.7 mm in diameter. This depression on the bone's surface is accompanied by a longitudinal concavity that carves into the medullary cavity. The smooth edge on the concavity is consistent with breakage occurring on green, or fresh bone.

Remarkably, this feature potentially represents the sole carnivore-inflicted mark on the bones within this assemblage. This assertion is partially rooted in the precise location of the impacted surfaces. In this particular scenario, the static force applied to the cortical surface seems to have resulted in the formation of a negative "flaked" surface characterized by the concavity beneath it.

Figure 27: Long bone fragment from medium to large animal. The arrow indicates the localization of a shallow depression on the cortical surface.

4.1.3.3. Plant root

Plant root marks are spares, with only four bones displaying characteristics that have been identified as potentially resulting from such interactions. Among these four specimens, three of them bear marks that can be attributed to recent root activity, as illustrated in Figure 28. In contrast, a solitary specimen exhibits an etching of relatively older origin, distinguished by its deeper outlines, as depicted in Figure 29. The modern root marks are characterized by patches of superficial white discoloration.

Figure 28: Flat bone fragment from megaherbivore. The arrow indicates the white marks identified to be from modern root.

The relatively older root etchings found on a mammalian medial rib fragment (Figure 29) are clearly discernible, with a considerable presence across the bone's surface. These etchings exclusively appear on the outer cortical layer of the rib's dorsal side. It is noteworthy that this bone has been identified alongside another rib fragment belonging to the same skeletal element and presumably the same individual. However, the second fragment does not exhibit the same feature, meaning it lacks any surface root marks. Both of these remains were recovered from the same source, although they became separated during the post-depositional phase and were individually documented during the excavation process.

Figure 29: Medial rib fragment from large size animal with root marks on it.

Figure 30: Rib fragments from the same element displaying different surface attributes. A. without root marks, B. with root marks, C. joined. Note the irregular breakage outlines on both fitting fragments.

The diversity in surface characteristics allows for the determination of the sequence of taphonomic factors influencing the bone. By considering the surface features in conjunction with the patterns of broken edges, it becomes possible to establish the influence of root activity on the bone following the diagenetic breakage of the rib. The outlines observed on both the matching and opposite ends of the ribs, as illustrated in Figure 30, unmistakably indicate breakage that occurred when the bone was already dry. In contrast, the presence of root marks exclusively on one fragment of the bone serves as evidence of the subsequent impact of root activity.

4.1.3.4. Trampling

There is a single instance of trampling evidence recorded on a specific specimen. This is characterized by a lone linear mark found on the distal portion of a Proboscidean humerus, precisely located on its lateral condyle (as shown in Figures 31 & 32). Additionally, the specimen displays fractures, compressions, and breakages that are in accordance with post-depositional phases.

The identification of the linear groove on the surface of this bone as a result of trampling primarily relies on its overall morphological characteristics. This assessment is principally conducted through visual inspection aided by handheld lenses, without taking into consideration microscopic features. Within this scope of visual inspection, the linear feature exhibits a shallow and broad outline on one end, while a relatively narrower outline is observed on the other end. It is presumed that the former represents the initiation point of the mark, whereas the latter signifies its termination.

In contrast to deeper cross-sections often associated with tool marks and certain predators like crocodiles (Njau & Gilbert, 2016), trampling typically results in broader and shallower marks, as highlighted by Domínguez-Rodrigo et al. in 2010. Carnivores, on the other hand, produce a range of marks depending on their teeth and the bone part involved, as discussed by Fernandez-Jalvo & Andrews in 2016. The configuration of the linear mark on the distal epiphysis of this humerus strongly suggests that it was most likely created due to animal trampling, resulting in scratching from contact with the substrate matrix.

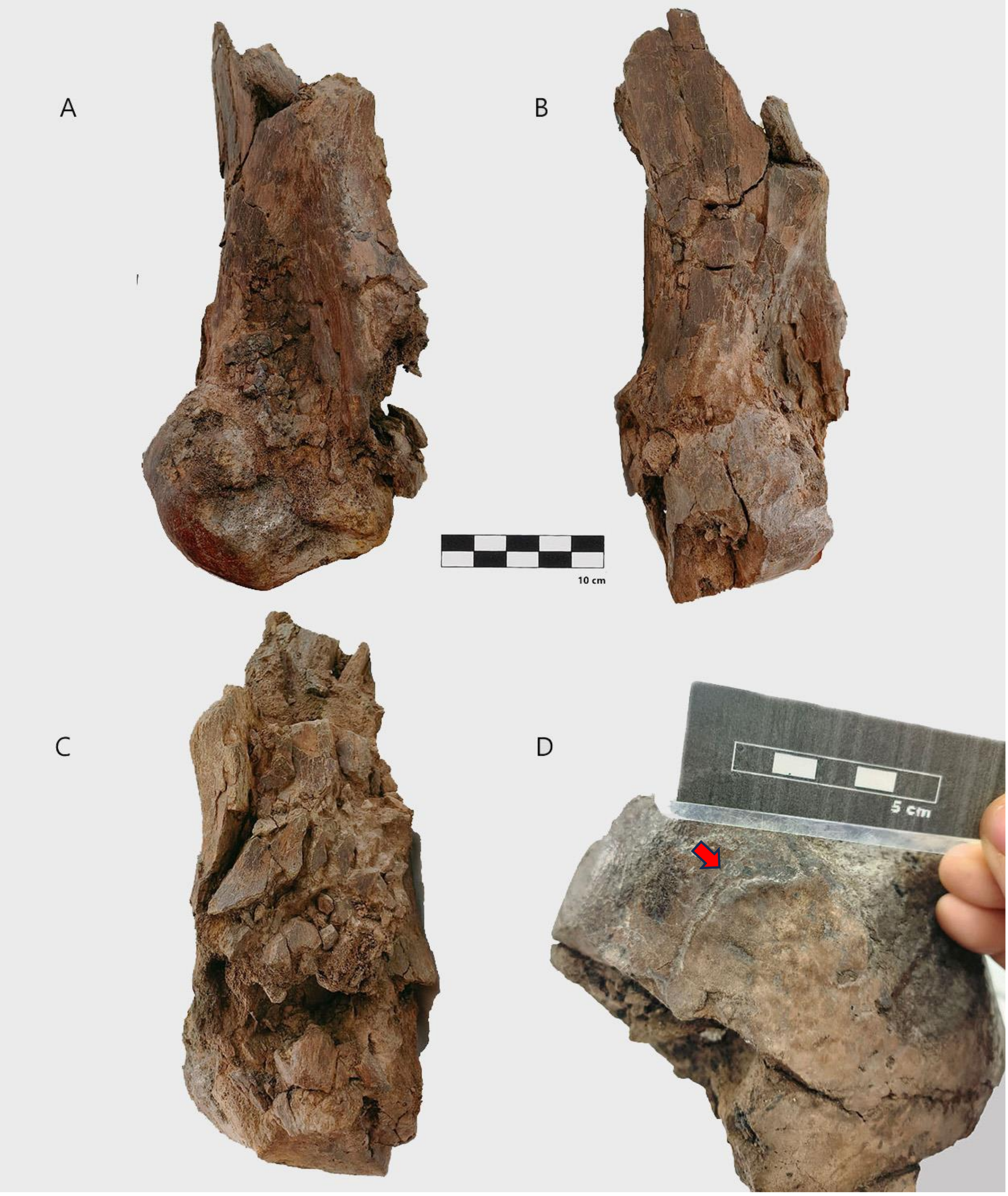


Figure 31: Distal portion of right Proboscidean humerus. A medio-anterior view, B. anterior view, C. posterior view D. distal epiphyses. The scale and the red arrow indicate the localization of the linear mark.

Figure 32: Distal portion of Proboscidean humerus with trampling mark on the epiphysis. The red dashed line indicates the extent of the mark while the white arrow points to a wider scratch which appears to be the initiation point.

4.1.3.5. Edge rounding

A few specimens within the assemblage exhibit clear indications of edge rounding, a phenomenon characterized by the presence of smoothly rounded edges and sporadically observable polished surfaces, as illustrated in Figure 33. In total, edge rounding has been documented on 12 skeletal remains, providing valuable insights into the post-depositional processes that have shaped these bones.

Out of these 12 instances, eight of them pertain to diaphysis splinters and indeterminate bone fragments. The remaining cases encompass two carpal bones, specifically an unciform bone from *Alephis* sp. and an articular surface derived from a large-sized animal, along with a Proboscidean humerus. The bones exhibiting signs of edge rounding predominantly originate from large-sized animals, constituting eight of the cases, while two instances are attributed to medium to large-sized animals, and a single instance belongs to a megaherbivore-sized animal.

The presence of rounded edges and polished surfaces on these bones suggests that such features could have emerged as a result of sedimentary abrasion, possibly stemming from the movement of the bones within the matrix surrounding them or from being displaced from their initial depositional context. The specific characteristics of these rounded edges, along with the notable distinctions between the primary matrix and areas with superficially adhering matrix (as depicted in Figure 33), strongly imply that these bones underwent some form of movement after their initial deposition.

Figure 33: Right unciform from an adult Alephis sp. *with sign of edge rounding*

4.1.4. Spatial distribution

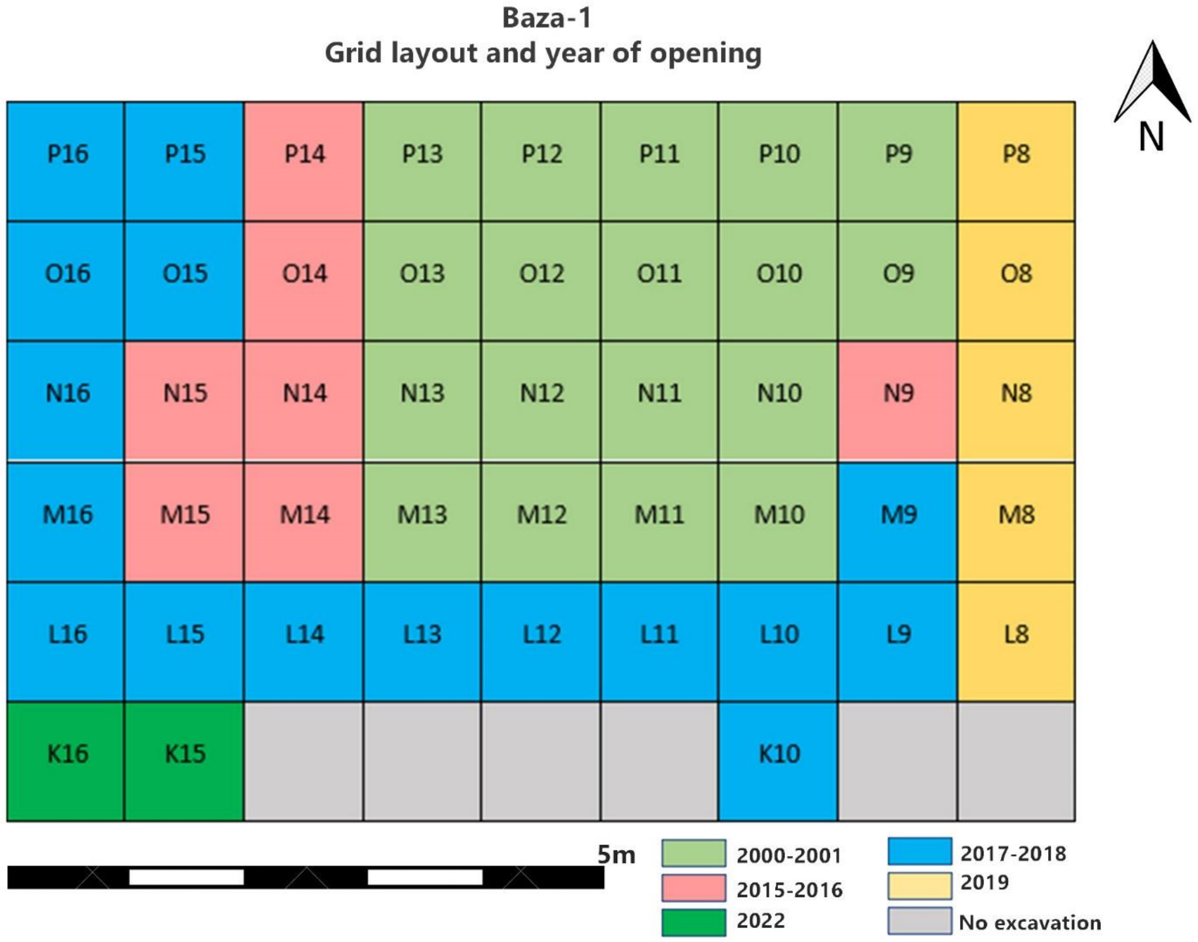
Spatial distribution, whether within anthropic or natural contexts, encompasses a range of analytical and illustrative methods designed to document the dispersion of the archaeological record. These methods also facilitate the connection between the distribution and cultural practices, as well as natural occurrences such as sedimentary accumulations linked to transport and deposition episodes. Within the context of the presented work at Baza-1, the application of graphic techniques of spatial archaeology serves the purpose of situating the site within the dispersion patterns of various observed and described taphonomic phenomena. It is important to note that the study conducted here does not encompass the archaeostratigraphic examination of the analysed sample. To clarify, we regard the entire sample as a part of the same palimpsest. This particular aspect is set aside for future exploration as it holds the potential to delve more deeply into both diachronic factors (pertaining to sedimentary events) and synchronous elements (in relation to biodiversity assemblages) within the deposit.

The examined sample in this study, is merely a segment of the complete Baza-1 record. Hence, the outcomes reached are not intended to be conclusive or definitive. The integration of this illustrative technique, involving the mapping of record dispersion and density according to analytical categories, has been introduced to present a methodological approach that we consider highly promising in our pursuit to understanding the formation and transformation processes at the site. It is pertinent to reiterate that the task of developing archaeostratigraphic profiles is still pending, and a comprehensive diachronic and synchronic analysis of the deposit remains a future endeavor. This dimension of the work remains to be undertaken in subsequent phases of research.

Currently, the Baza-1 record lacks a unified format for its topographical characteristics represented by XYZ coordinates. This lack of standardization poses challenges when attempting to portray the scattered data points, prompting the need for an alternative approach. The acquisition of topographical coordinates (XYZ) for the records is essential for the calculation of density grids and the creation of maps. However, the coordinate data available for the site is in the process of standardization and cannot be utilized within the scope of this study. Consequently, an alternative strategy has been adopted.

To illustrate the distribution of remains characterized by taphonomic attributes, density maps have been generated utilizing Golden Software Surfer® version 25.3.290. This software has been employed to visualize and depict the concentration of these remains in a spatial context, providing insights into their distribution patterns as discussed in the preceding section.

Starting from the archaeological grid, as delineated by the grid illustrated in Figure 34, and attributing to each record within the sample its respective position within the grid (for instance, N13), we assign XY coordinates to the center of each square. In this context, the square denoted as A1 serves as the reference point "0,0." Subsequently, when formulating the density grid, the Z value corresponds to the count of records documented within that particular square, as detailed in Tables 4 and 5.



Baza-1
Grid layout and year of opening

P16	P15	P14	P13	P12	P11	P10	P9	P8
O16	O15	O14	O13	O12	O11	O10	O9	O8
N16	N15	N14	N13	N12	N11	N10	N9	N8
M16	M15	M14	M13	M12	M11	M10	M9	M8
L16	L15	L14	L13	L12	L11	L10	L9	L8
K16	K15					K10		

🟩 2000-2001
🟥 2015-2016
🟩 2022
🟦 2017-2018
🟨 2019
⬜ No excavation

Figure 34: The grid system of Baza-1 site with the colour code showing the year the excavation at each section started

Taphonomic categories with a substantial sample size (Table 5) were chosen for representation using this methodology. Conversely, those categories with an insufficient number of records were excluded from the process. For instance, while a single bone exhibited trampling marks, only four remains displayed root marks. Consequently, categories featuring fewer than ten remains, except for stage 1 weathering, were omitted from the density analysis.

Square	X	Y	Z		
			Elements	Bone frags.	Carapace
K10	1050	1050	1	1	0
K15	1550	1050	7	3	0
K16	1650	1050	33	17	0
L8	850	1150	9	6	0
L9	950	1150	26	20	2
L10	1050	1150	15	7	2
L11	1150	1150	39	16	2
L12	1250	1150	55	16	8
L13	1350	1150	15	5	3
L15	1550	1150	1	0	0
M8	850	1250	12	8	1
M9	950	1250	24	7	0
M10	1050	1250	12	10	0
M11	1150	1250	10	7	1
M12	1250	1250	19	7	0
M13	1350	1250	73	37	9
M14	1450	1250	38	21	4
M15	1550	1250	123	79	3
M16	1650	1250	228	158	0
N8	850	1350	9	5	0
N9	950	1350	51	13	4
N10	1050	1350	66	27	10
N11	1150	1350	48	7	11
N12	1250	1350	32	4	2
N13	1350	1350	43	14	8
N14	1450	1350	60	17	11
N15	1550	1350	49	22	6
N16	1650	1350	44	24	0
O8	850	1450	43	39	0
O9	950	1450	2	2	0
O10	1050	1450	227	89	22
O11	1150	1450	108	39	14
O12	1250	1450	120	19	41
O13	1350	1450	40	2	33
O14	1450	1450	14	8	1
O15	1550	1450	100	54	6
O16	1650	1450	111	41	19
P9	950	1550	1	0	0
P10	1050	1550	19	1	2
P11	1150	1550	11	2	0
P12	1250	1550	4	0	2
P13	1350	1550	18	4	9
P14	1450	1550	52	32	2
P15	1550	1550	46	37	0
P16	1650	1550	4	4	0

Table 4: All the remains, bone and carapace fragments from Baza-1 and squares of origin.

Square	x	y	Z					
			Elements	Non-weathered	Crushed	Fractured	Irregular	Rounding
L10	1050	1150	1	1	0	1	1	0
L11	1150	1150	6	4	0	2	5	3
L12	1250	1150	4	0	1	2	1	0
L13	1350	1150	1	1	1	1	0	0
M9	950	1250	10	10	1	4	9	0
M12	1250	1250	3	3	0	2	2	0
M13	1350	1250	8	5	1	3	3	0
M14	1450	1250	3	2	0	0	0	0
M15	150	1250	4	3	0	2	2	1
N9	9050	1350	2	2	1	1	0	0
N10	1050	1350	5	2	0	2	2	0
N11	1150	1350	16	7	2	3	4	0
N12	1250	1350	7	4	2	4	2	0
N14	1450	1350	3	1	1	2	2	1
N15	1550	1350	12	2	0	3	3	2
N16	1650	1350	3	0	0	0	0	0
O10	1050	1450	49	15	9	20	15	0
O11	1150	1450	8	0	1	5	1	0
O12	1250	1450	13	4	2	2	0	0
O13	1350	1450	13	0	0	1	0	0
O14	1450	1450	1	0	0	0	0	0
O15	1550	1450	44	7	0	4	12	4
O16	1650	1450	36	6	0	7	8	1
P9	9050	1550	1	1	0	0	0	0
P10	1050	1550	3	0	0	1	0	0
P12	1250	1550	1	1	0	1	1	0
P13	1350	1550	3	0	2	2	0	0
P14	1450	1550	3	0	0	0	1	0

Table 5: Sampled remains and category of taphonomic attributes with sufficient records and square of origin.

Employing the same technique of assigning XY coordinates per square and using Z to signify the quantity of records in each square, a density map was generated encompassing 2067 remains. This map (Figure 35) represents the entirety of records sourced from Baza-1, spanning excavation campaigns from 2000 to 2022. This approach offers insights into the quantity and spatial dispersion of the sample specimens examined within this study in relation to the whole record from the site.

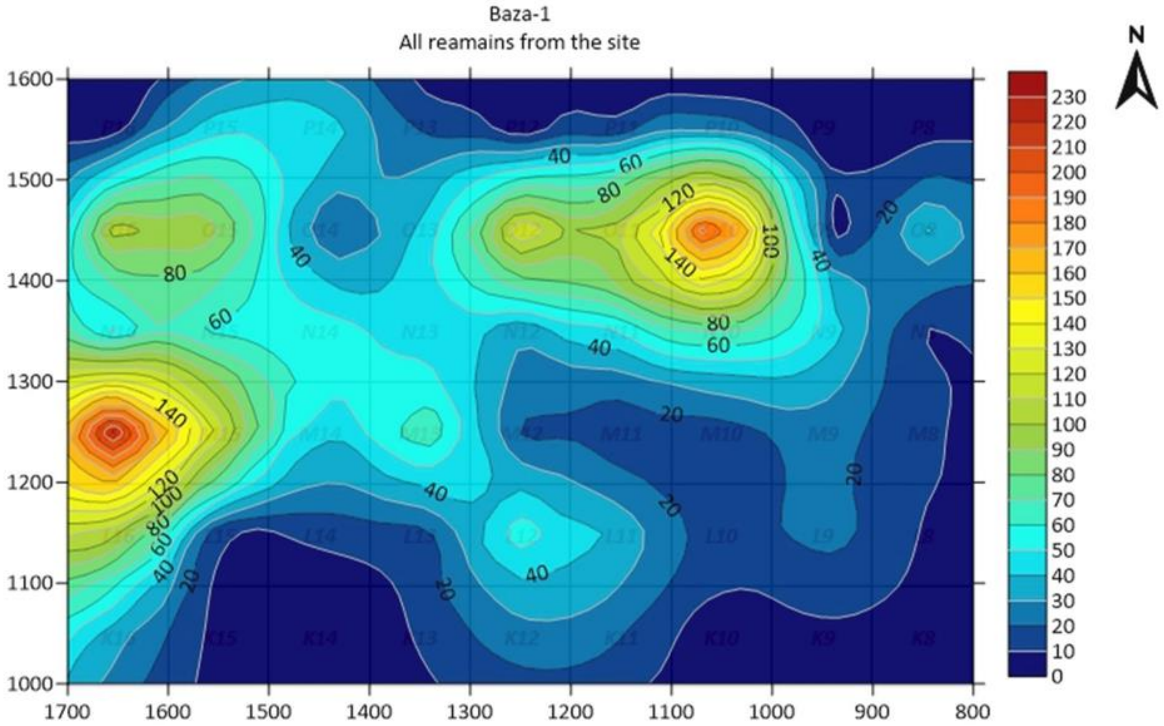


Figure 35: The distribution of all the remains with known square of origin, covering all the campaign seasons since 2000.

Compared to the overall distribution of the entire assemblage, as depicted in Figure 35, the sample for this study (Figure 36) appears to have emanated from two specific regions exhibiting a more concentrated prevalence of remains. It is worth noting that the sample extraction did not encompass the most densely accumulated sector of the excavation when comparing the distribution of the entire assemblage to that of the sample. Notably, in the density map portraying the whole assemblage, this particular section is characterised by a prevalence of indeterminate bone fragments. In fact, this segment alone accounts for over 900 (~ 45% of the entire assemblage) remains that have been tentatively categorised as such (as depicted in Figure 37). The high density of fractured remains in this section accentuates the extent to which post-depositional processes have influenced the preservation of remains at the site, mirroring observations recorded in other sections as well.

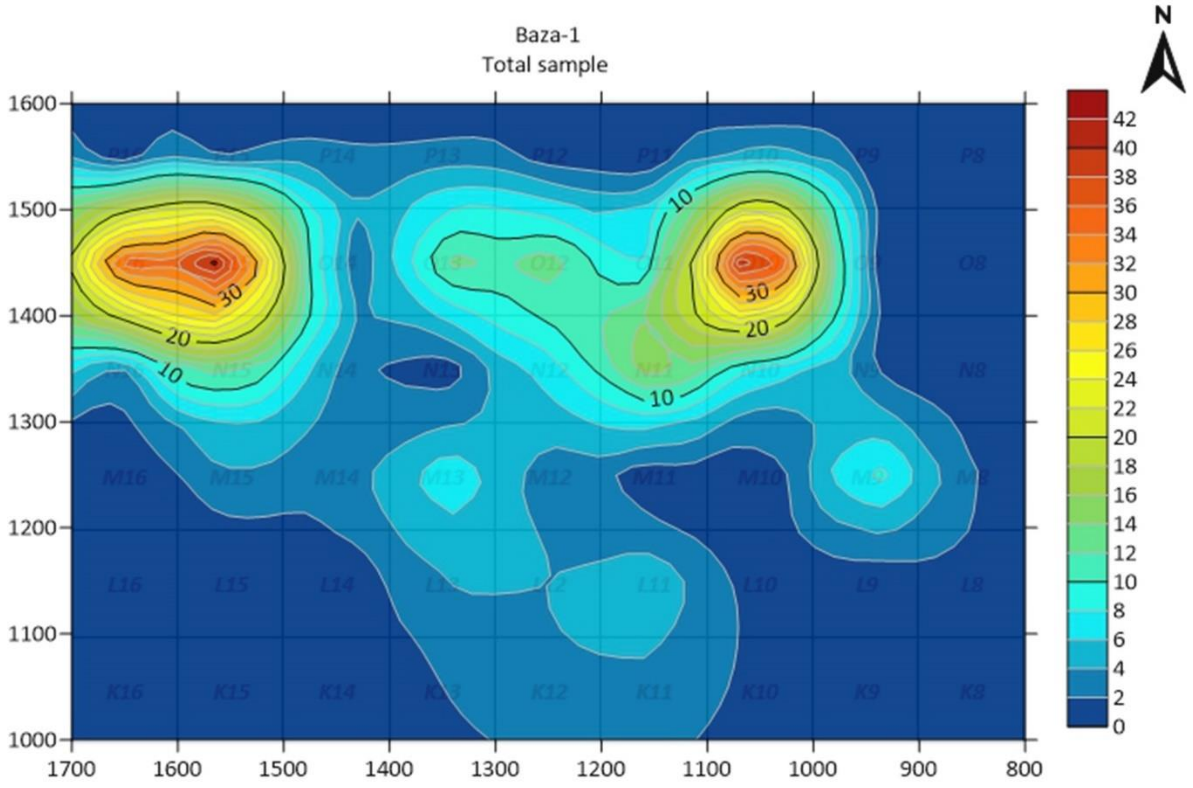


Figure 36: The distribution of the sample fossil remains used in this study.

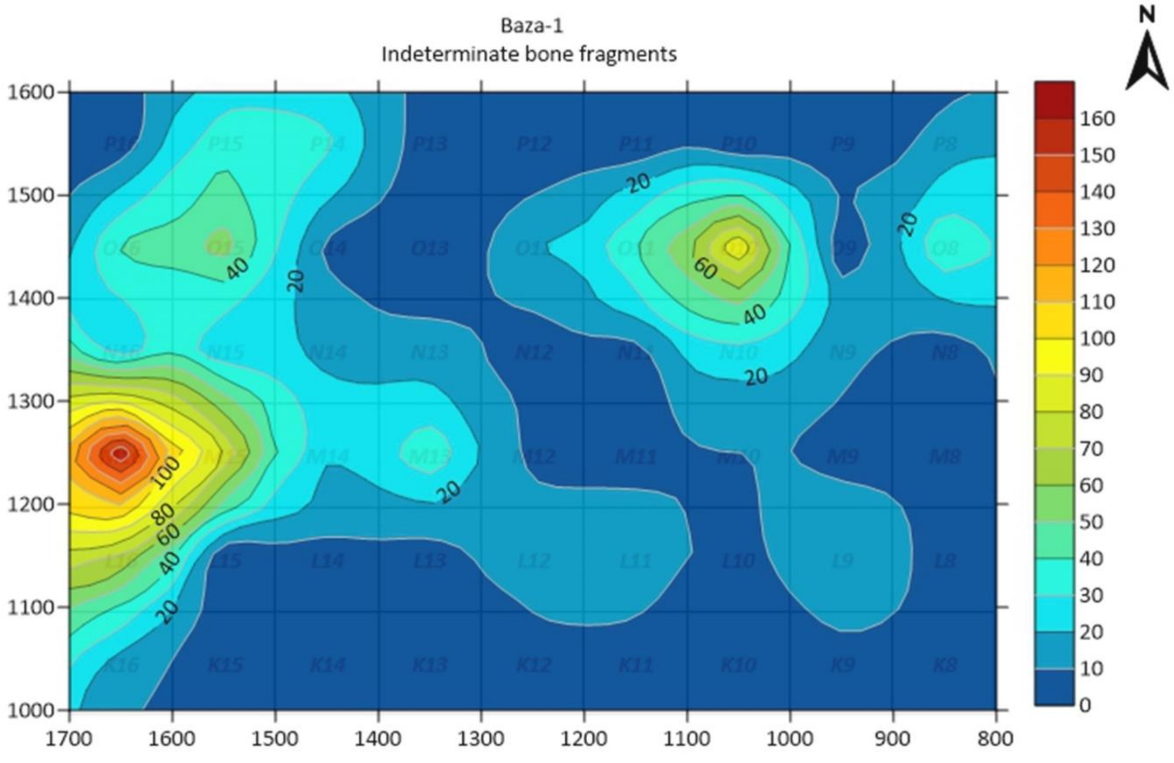


Figure 37: The distribution of indeterminate bone fragments within the whole assemblage.

Even though the distribution of bones showing characters of breakage (Figure 38) in the post-depositional phase is anchored around two areas, this parameter generally shows widespread spatial distribution across multiple squares, albeit in a sparser manner. Consequently, considering the parameters of the methodology, the distribution pattern implies that bones broken during the post-depositional phase are not confined to specific localized regions. This observed pattern could be attributed to the global impact of the agencies and processes responsible for the breakage and the horizontal dispersal of the remains.

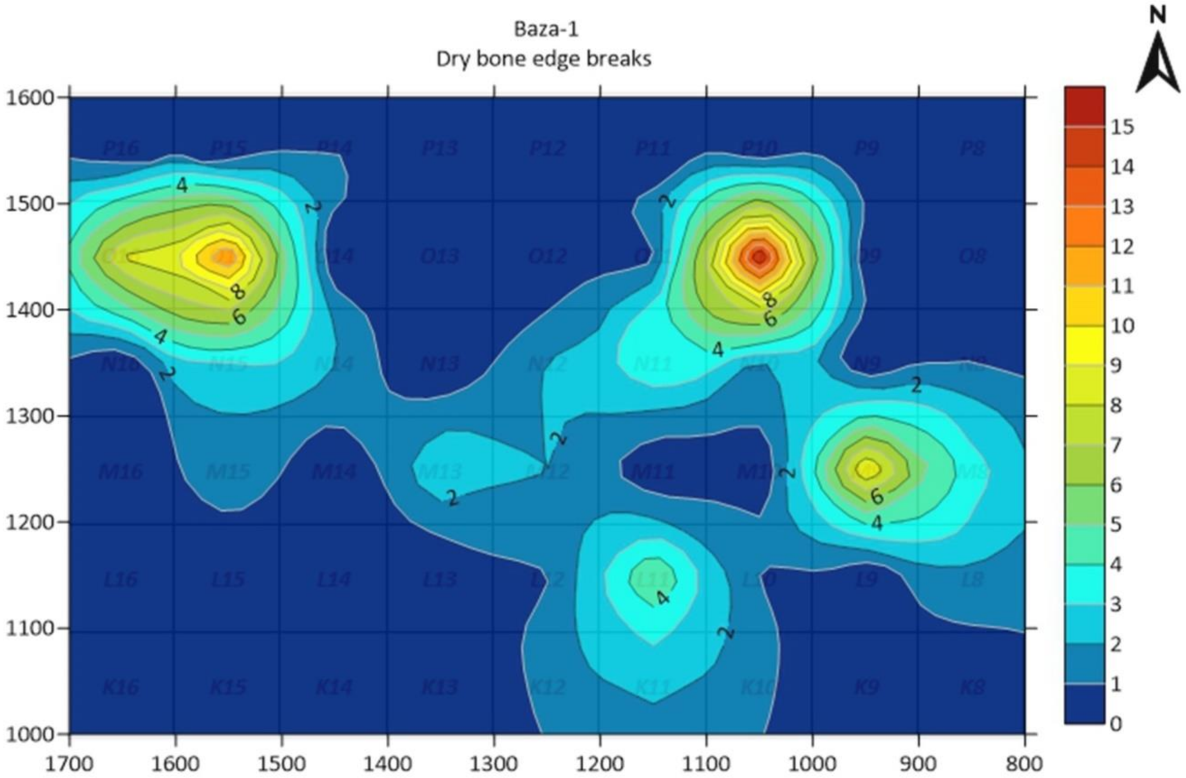


Figure 38:Remains with breakage outlines assigned to edge breaks on dry (mineralized) bones.

The amalgamation of jagged, transversely irregular, and irregularly oblique breakage outlines forms a composite representation of outlines that indicate dry (mineralized) bone breakage during the post-depositional phase. The distribution pattern of bones exhibiting these specific traits harmoniously aligns with the scatter observed within the sample. Interestingly, the sections where the highest concentration of remains is recorded also exhibit a more pronounced accumulation of bones showcasing characteristics synonymous with post-depositional bone breakage. Similarly, remains displaying fracture traits follow a comparable distribution pattern. On the other hand, remains demonstrating attributes linked to compression and sediment crushing primarily originate from a specific excavation area (as illustrated in Figures 39 & 40), even though instances of such features are relatively scarce within the sample. It is worth highlighting that all these taphonomic attributes intersect and coincide in their distribution and density, implying an intricate interplay of factors influencing their presence.

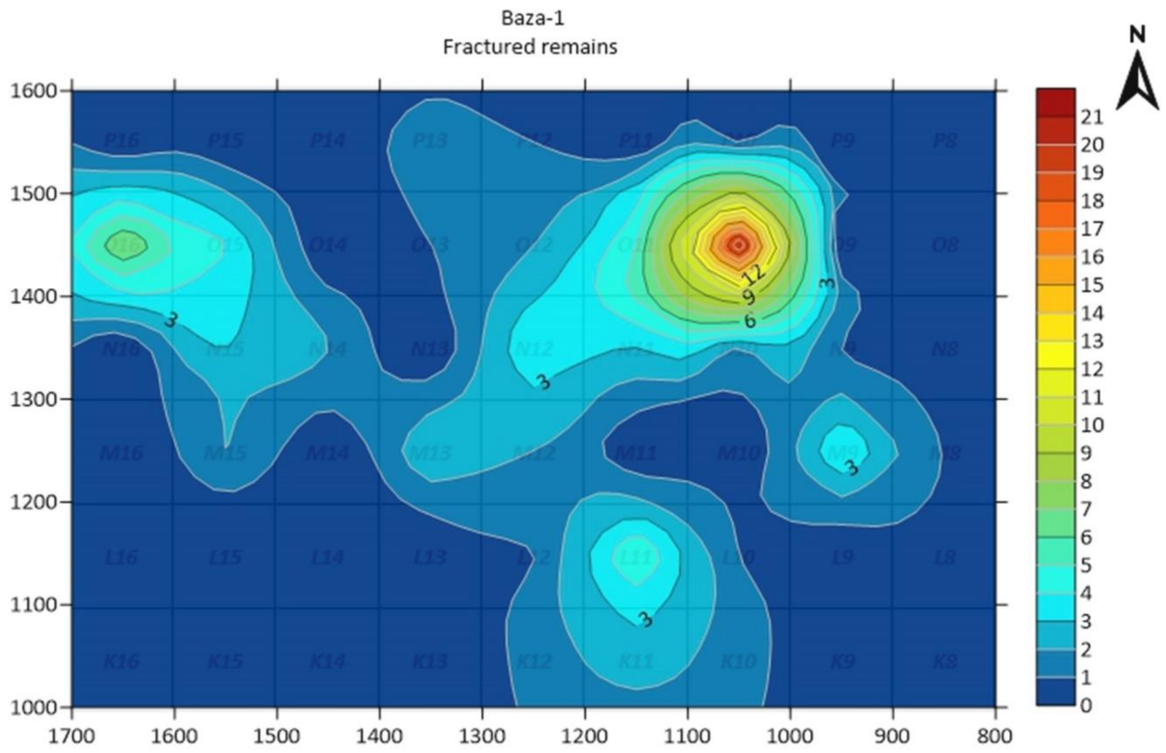


Figure 39: Distribution of fractured remains.

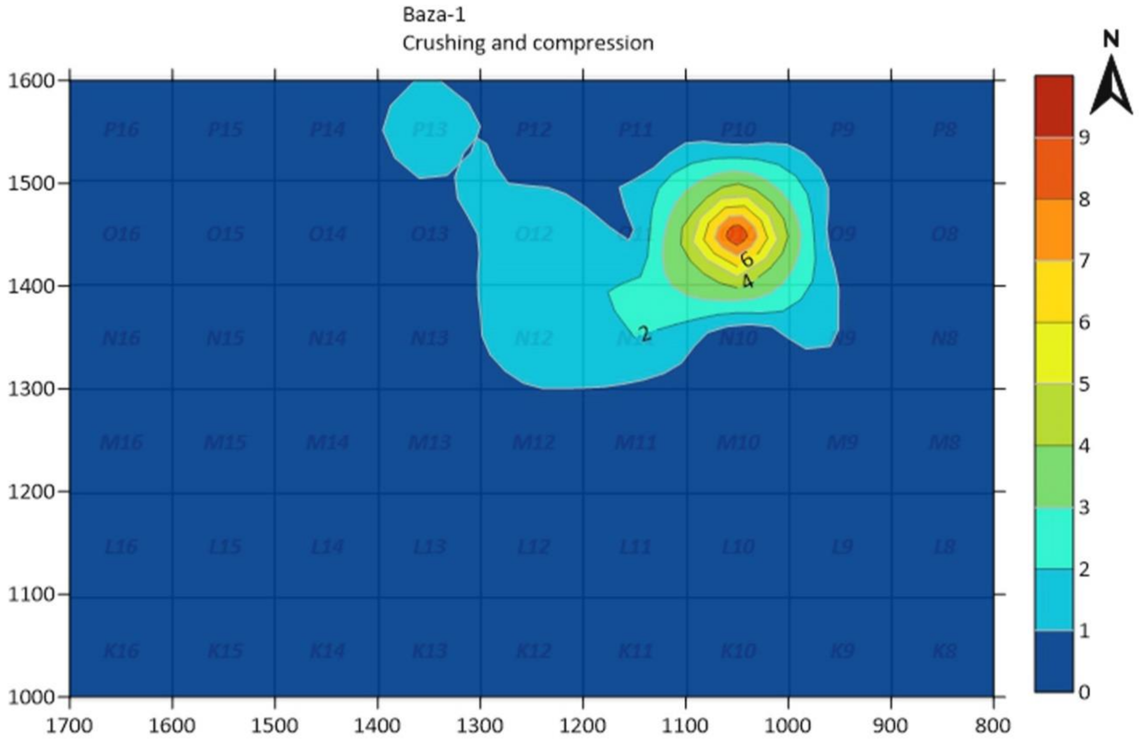


Figure 40: Remains with crushed and compressed surfaces

The significance of the distribution of remains featuring edge rounding and polished surfaces carries notable implications, particularly when examined in light of sedimentological observations. These observations indicate that the section from which these specific remains originate corresponds to sediment movements, a phenomenon mirrored on the remains themselves. The spatial distribution of remains exhibiting edge rounding is notably restricted to two specific localities (as illustrated in Figure 41), encompassing a total of 11 bones showcasing this particular characteristic. Consequently, the occurrence of edge rounding can be attributed to the movement of these remains in connection with the underlying sedimentary process, which is expected to be clarified through the ongoing detailed stratigraphic result of the site.

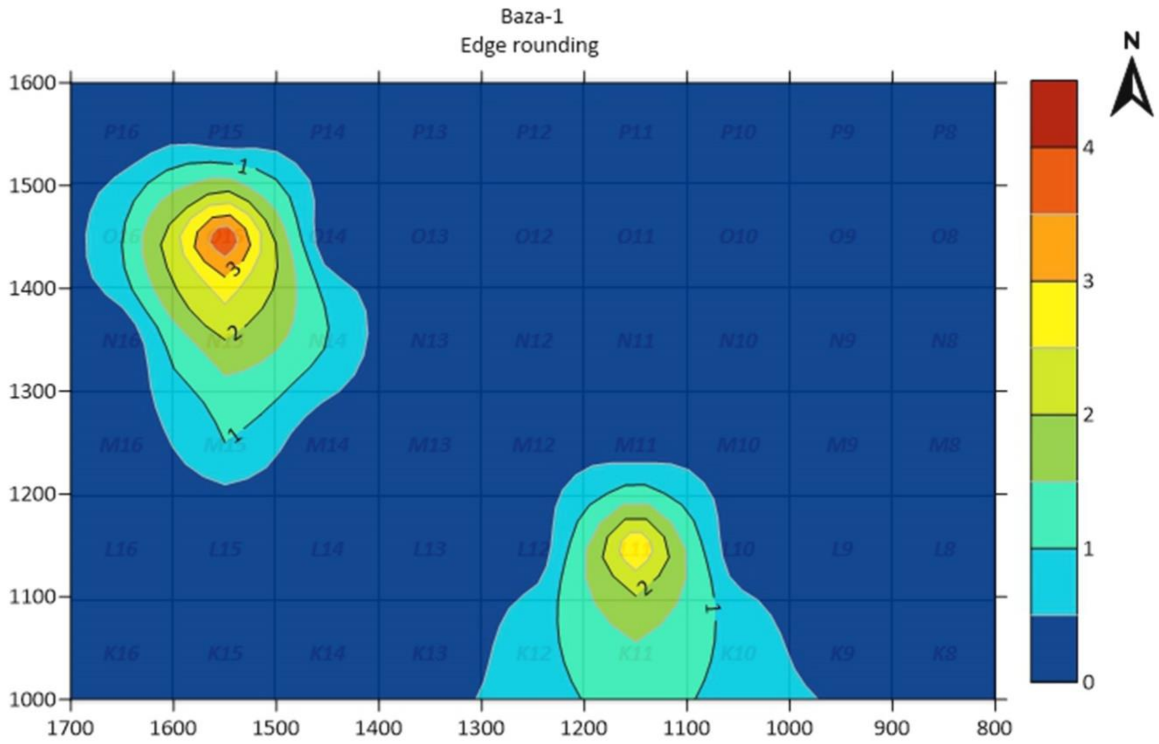


Figure 41: Remains with edge rounding and polished surfaces.

When considering weathering, only two stages (0 and 1) were documented from bones permitting such observations. Bones exhibiting these two distinct stages of weathering manifest slight variations in their distribution patterns (as evident in Figures 42 & 43). In the context of non-weathered bones, their presence is widespread across a majority of excavation squares, with points of high density closely correlating to the regions from which the samples were obtained. On the other hand, within the handful of bones categorised as stage 1 weathering, a slightly different dispersal pattern emerges, featuring points of low density.

Overall, the result indicates that there isn't a pronounced preference for the distribution of non-weathered bones when compared to the distribution pattern of the sample. This alignment implies a consistency in their deposition, signalling congruence in terms of the pace of burial and the micro-environmental factors that influenced their interment. However, the limited instances of stage 1 weathering, which deviate from the general trend, require further elucidation through detailed sedimentological data and a broader sample size. By expanding the dataset and delving deeper into the sedimentological context, a more comprehensive understanding of these outliers can be obtained, potentially shedding light on the factors that contributed to their distinct weathering stages.

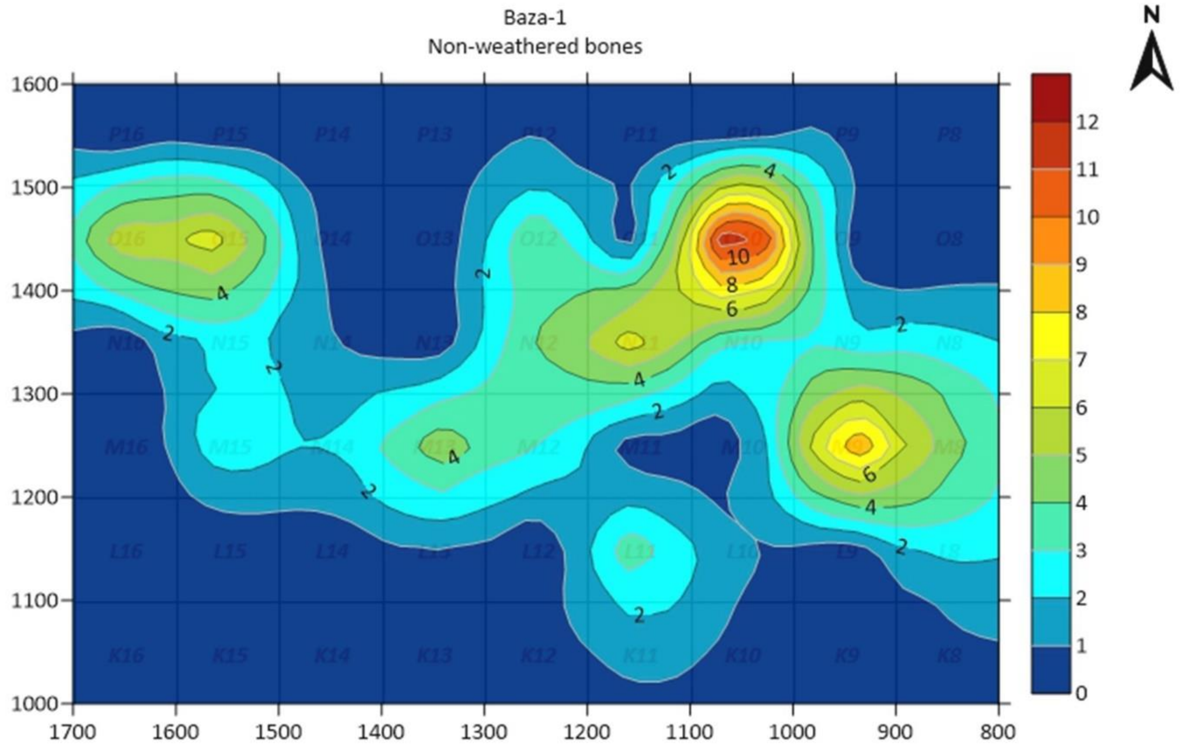


Figure 42: The distribution of bones with weathering stage 0

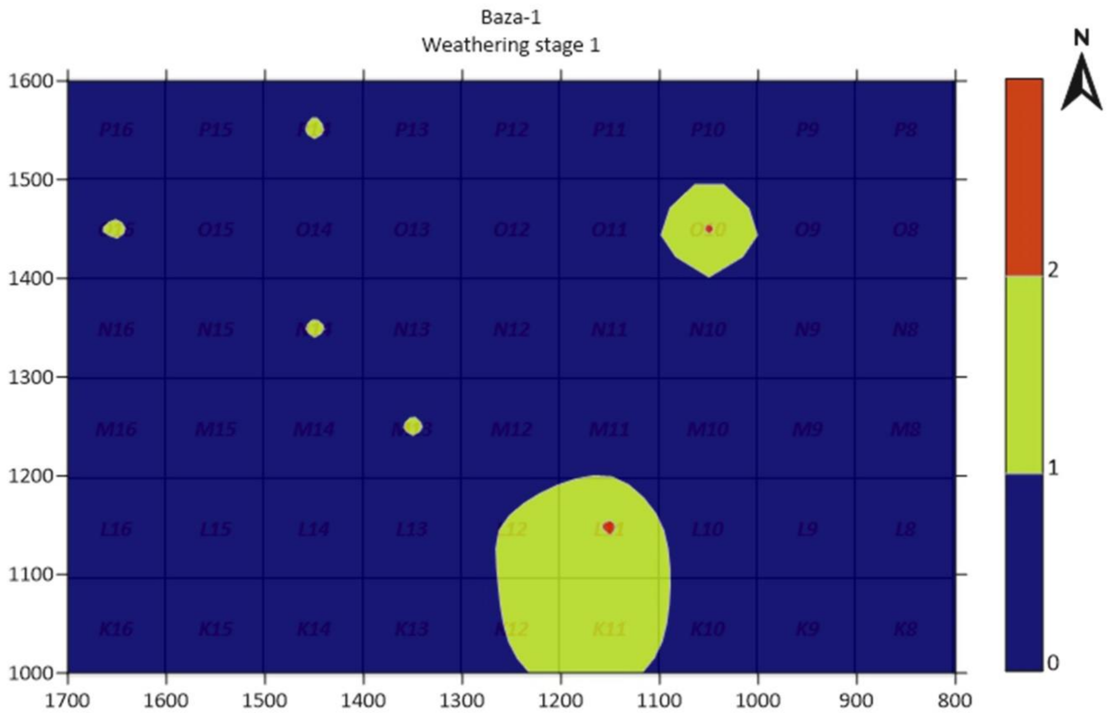


Figure 43: The distribution of bones in stage 1 weathering

In general, the spatial scattering and frequency of remains displaying taphonomic attributes align closely with the confines of the squares from which the sample was taken. The specimens under investigation display a noticeable clustering in two specific zones within the excavation site. The most significant accumulation is evident in squares O10, O15, and O16, contributing 49, 44, and 36 remains, respectively (Table 5 and Figure 36). These squares collectively account for nearly half (48.1%) of the entire fossil sample utilized in this research. This distribution reasonably mirrors the broader composition of the assemblage at the site (see Figure 35). Conversely, five squares are only represented by a single specimen each.

The density of bones displaying features of post-depositional edge breaks aligns with the distribution pattern of remains obtained from these particular squares. A similar trend is also evident in the case of fractured specimens and non-weathered bones. The dispersion of indeterminate bone fragments across the entirety of the assemblage serves as a complementary observation to that of the sample.

When considering all these variables collectively, the distribution pattern provides compelling evidence for a consistent pace of burial and preservation conditions, as well as the pervasive impact of post-depositional breakage processes during the diagenetic phase. The majority of remains exhibit characteristics indicative of dry bone breakage, with no signs of rounding or abrasion. This suggests that their motions were likely confined to lateral movements triggered by seismic events. In essence, the data suggests that the distribution of remains reflects a convergence of factors including burial pace, preservation condition, and the overarching influence of post-depositional breakage processes.

Situated within a regional context that is susceptible to seismic activity-induced earthquakes, the fracturing of a single long bone from a Proboscidean at the Baza-1 site would give rise to a several indeterminate shaft splinter. The process triggers a cascading series of consequences that reverberate throughout the paleontological record, creating a pattern that has been substantiated by the numerous instances of tusk and long bone specimen fragmentation observed within the sample.

The ramifications of this scenario are notably amplified when considering the taxonomic makeup of the identified fauna at the site. The preponderance of large and megaherbivore animals in this assemblage amplifies the likelihood fracture-induced fragmentation, as their robust skeletal structures are more prone to breaking apart under the influence of seismic forces. Consequently, the occurrence of bones that have experienced breakage during the diagenetic phase becomes a widespread representative within the sample.

To underscore this pervasive phenomenon, the spatial distribution and density analysis of the taphonomic parameters employed in this study yield vital insights. These analytical tools effectively portray the distribution pattern of these fragmented remains, substantiating the hypothesis that seismic events have left a lasting mark on the taphonomic makeup of the Baza-1 site.

CHAPTER 5

5.1. Discussion

Here, the implication of the descriptions detailing the surface attributes documented on the remains selected for taphonomic analysis is assessed in conjunction with the spatial scattering and concentration within the excavation area. These pieces of evidence are intricately linked with the sedimentological context of the Baza-1 site, aiming to provide a comprehensive explanatory framework for understanding the site’s formation process. The concluding section of this work serves to offer a summary of the findings, drawing together the various threads of analysis and interpretation to provide a more expansive perspective. This section not only encapsulates the key outcomes of the study but also offers a broader outlook by discussing potential implications, future avenues of research, and the significance of the results in a wider context.

5.1.1. Preservation state

The prevailing trend within the assemblage highlights a strong tendency toward the effective preservation of small bones across a range of taxa, particularly when compared with the long bone specimens. This pattern is substantiated by the presence of comparatively well-preserved autopods, particularly the carpal and tarsal bones, in addition to the phalanges. This stands in stark contrast to the highly fragile identifiable long bone specimens and the indeterminate fragments of long bones, both of which appear to be considerably deteriorated and reduced to small splinters. Equally noteworthy is the condition of the dental specimen. The teeth, for the most part showcases a substantial degree of preservation, manifested by their remarkable completeness. However, it is worth noting that this preservation isn't uniform across all dental components. While the crowns of the teeth remain impressively intact, the root sections are often absent or show signs of degradation.

Broadly speaking, teeth exhibit greater resilience in the face of taphonomic processes compared to bones (Behrensmeyer, 1975). The high density of dentine and enamel relative to bony tissue, coupled with their diminutive size when contrasted with other skeletal elements of a given animal, equips dental remains with the ability to withstand modifications arising from the conditions of deposition (Shipman, 1981). Moreover, it has been established that smaller tooth has a notably higher likelihood of survival than larger counterparts (Behrensmeyer, 1975).

Likewise, the preferential survival and preservation of these skeletal remains at the Baza-1 site can be attributed to the dimensions and mass of the smaller bones, as well as the biochemical composition of teeth. These inherent attributes have played a pivotal role in enhancing their likelihoods of enduring in an environment marked by pronounced and widespread post-depositional activities.

5.1.2. The implication of the weathering record

The composition of the sample assemblage predominantly comprises non-weathered bones, with approximately 89% of the bones designated for such observation falling under stage 0 classification. The remainder of the collection exhibits modest weathering effects consistent with stage 1. The attributes of weathering stage 1 within the assemblage are characterized by the presence of very few incipient cracks and a limited fibrous structure, both of which are indicative of this early weathering stage. This profile of stage 1 weathering suggests the influence of size bias on bones within this category, as only bones from larger and megaherbivore-sized animals exhibit stage 1 weathering characteristics. When considering the anatomical components, the prevalence of unidentified long-bone diaphysis fragments is notable in addition to three flat bones.

The patterns emerging from this observation appear to diverge from trends documented in other contexts (e.g., Behrensmeyer 1978), where mammals weighing less than 100 kg have reportedly undergone faster rates of weathering compared to their larger counterparts. Conversely, at the Baza-1 site, no small or medium-sized mammals exhibit weathering indicative of stage 1. However, it would be hasty to interpret this as a definitive departure, at least within the scope of this study, from the patterns observed in previous research. The sample size available for analysis is not sufficient to conclusively demonstrate whether the observed pattern remains consistent across the entirety of the Baza-1 site assemblage.

Furthermore, out of the ten bones displaying stage 1 weathering, six belong to the category of Mammal indet., and one has been tentatively attributed to Bovidae indet. The exact number of individuals represented by these ten specimens has yet to be determined. Nevertheless, the variance between the current sample and the established trends elsewhere might imply nuances in the deposition conditions, including factors such as temperature, humidity, and precipitation controls, as well as sedimentary environments. This divergence could equally stem from differences in the pace of burial for the same carcass, wherein certain portions might have remained exposed for slightly longer durations. This scenario holds merit, especially when considering that the majority of non-weathered remains from the site pertain to larger and megafauna animals.

Disparities in the progression of weathering stages tied to distinct depositional environments have been highlighted in both experimental and actualistic investigations (Tappen, 1994; Andrews & Armour-Chelu, 1998; Andrews & Whybrow, 2005). These studies offer evidence, demonstrating that the process of weathering unfolds at a comparatively slower rate in temperate locales (Andrews & Armour-Chelu, 1998) and arid desert regions, as evidenced by observations of individual carcass (Andrews & Whybrow, 2005), when contrasted with the more rapid pace characteristic of tropical environments. One of the distinguishing factors that set apart tropical and humid environmental contexts from arid and temperate surroundings is the temporal span encompassing the various weathering stages. For instance, the transformation into stage 1 weathering can transpire in under a year within tropical humid environments, whereas the same transition takes notably longer, ranging between 4 to 10 years in temperate and desert settings.

Variation across taxa, sizes, and the ages of species is known to exist (Lyman & Fox, 1989). Notably, it has been observed that equid bones with a denser structure weather at a markedly slower pace compared to bovid bones (Gifford, 1981). Additionally, Tappen (1994) has pointed out that elephant bones exhibit dissimilar weathering patterns in comparison to smaller and medium-sized mammals, although the specific contextual details behind this observation have not been provided. Furthermore, a proposition has been put forth that bones from small and medium-sized animals or juvenile individuals tend to undergo more rapid weathering compared to those from larger or adult animals (Behrensmeyer, 1978). At Baza-1, the determination of age was feasible for a subset of 14 specimens. Among these: 12 specimens, spanning across nine adult, two juvenile, and one infantile individual, display no discernible signs of weathering. Only two remains from adult individuals exhibit weathering consistent with stage 1 characteristics.

The multi-proxy approach employed in the Early Pliocene paleoenvironmental reconstruction of the Baza Basin unravels the complex picture of the past landscape, revealing a diverse composition. In close proximity to the Baza-1 site, the surrounding vegetation emerges as a blend of elements, including a mixture of modern Mediterranean elements in a context with higher humidity levels compared to the contemporary Guadix-Baza Basin (Saarinen et al., 2021). On the other hand, the micro-vertebrate and large faunal record from the site indicates prevailing warm and arid conditions, occurring within a backdrop of modest humidity (Piñero et al., 2017; Ros-Montoya et al., 2017). The coexistence of reptile species adapted to tropical and sub-tropical climates showcases a prevailing climate characterized by warm and aridity, interspersed with occasional humidity. This evidence is further reinforced by the presence of freshwater fish remains, particularly from the Cyprinidae family, which aligns well with the notion of perennial watercourses meandering nearby (Piñero et al., 2017).

In the broader context of the paleo-ecosystem, the large mammal records extracted from the site paint an image of mosaic-like surroundings. These surroundings were typified by expansive open herbaceous region punctuated by pockets of forested areas, thus reflecting a landscape that was varied and dynamic in its ecological makeup (Ros-Montoya et al., 2017).

Drawing from the paleoenvironmental reconstructions of the Baza-1 site, the conditions under which the bones were buried points to an environment characterized by warm and dry with characters of intermittent humidity. This combination of climatic conditions presents a potential deteriorating factor, as the presence of humidity, albeit limited, could potentially exert a detrimental impact on the bones, leading to weathering processes unless the bones were swiftly buried. In contrast to desert, temperate, and tropical rainforest settings, the environmental context proposed for Baza-1 appears to pave the way for relatively swifter weathering stages. The paleoenvironmental settings at Baza-1 resonates closely with the humid tropical savannah environments, that are known to trigger rapid weathering (Behrensmeyer, 1975, 1978). Thus, the confluence of warm and dry conditions along with modest yet vital humidity factor at the site suggests a context that allows an accelerated weathering process comparable to that seen in tropical environments.

The presence of a predominance of non-weathered bones, in contrast to the fewer instances of bones displaying stage 1 weathering, and the conspicuous absence of bones in more advanced weathering stages collectively hint a trajectory indicative of a swift burial process. The agents and processes that prompted a speedy burial ultimately prevented deteriorating effects of weathering processes.

Within the context of swampy settings, bones in stages 0 to 1 are indicative of burial within moist sediments and protection from vegetation characteristic of such habitats (Behrensmeyer, 1978). This natural embrace of vegetation has the effect of mitigating the effect of weathering. In a contrasting scenario, bones that come into direct contact with sunlight tend to experience an accelerated process of weathering, a stark comparison to those deposited in shaded areas, such as beneath the protective canopy of vegetation (Gifford, 1981).

Considering the paleoenvironmental conditions of the Baza-1 site, the bones were deposited within the lush surroundings of a vegetated swamp habitat along the fringes of the paleo-lake. This ecological niche would have facilitated a swift submersion of the bones into the sediment, minimizing any substantial impact of weathering. These findings align harmoniously with the anticipated burial processes that typify swampy margins within a lacustrine environment. This holistic scenario fits seamlessly into the broader narrative of the landscape, which during the accumulation of the fossil-bearing strata at Baza-1, was characterized predominantly by expansive open grasslands interwoven with pockets of forested areas, all the while accompanied by the steady flow of water courses in close proximity (Piñero et al., 2017).

No significant variability has been noted on non-weathered bones as their surfaces uniformly exhibit stage 0 weathering, signifying complete submersion within the sediment. This state of immersion implies that none of the specimen sections remained exposed to the fluctuations of ambient temperature and humidity. It is a common observation that bones buried beneath the surface typically avoid weathering. However, the exposed portions of these buried bones can exhibit varying degrees of weathering stages. Consequently, a bone in stage 0 could eventually showcase sections that have progressed to more advanced weathering stages (Behrensmeyer, 1978; Haynes et al., 2021). While acknowledging the inherent potential for variability in the condition of carcasses, a compelling consistency emerges from the specimens examined within this sample, corroborating the notion of the swift and nearly universal burial of the majority of these bones.

To conclude, the interplay of burial rate and the specific depositional setting within Baza-1 has exerted a significant influence over the relatively restricted weathering evident in the fossilized remains uncovered at this site. This intricate interplay of factors has led to a swift burial process, a process that unfolded within an anoxic sedimentary environment rich in organic matter – a combination that proved conducive to the process of fossilization. Dominantly, the fossilized remains recovered within the site derived from the organic-enriched black stratum (see Figure 3), with a staggering 88% of the entire assemblage extracted from this very layer. Within such a context, the remains would have been immersed and enveloped, effectively shielding them from the potential effects of fluctuating climatic conditions. This sequence could have effectively arrested the ramifications emanating from the agents and processes responsible for initiating subaerial weathering, thus preserving the bones with non-weathered (stage 0) surfaces, as evidenced within the sample assemblage.

Analogous circumstances resembling swamp environments of Baza-1, where the occurrence of active subaerial oxidation is curtailed and the presence of lacustrine deposits facilitates rapid burial, resulting in minimal weathering impact on bone surfaces, have been documented in other sites within and beyond the scope of the Guadix-Baza Basin (Arribas & Palmqvist, 1998; Alberdi et al., 2001; Badiola et al., 2009).

5.1.3. Context and implications of the breakage attributes

Upon deposition, preserved portions of hard tissues underwent substantial alterations, primarily evidenced by a range of fracture characteristics. In tandem with weathering, the attributes of dry bone breakage, fracturing, and compression emerge as an important taphonomic indicators examined within this study, playing a pivotal role in shaping processes during the diagenetic phase. While the remains exhibiting traces of compression seem to exhibit a relatively localized distribution, bones displaying indications of dry bone breakage extend across the sampled areas, effectively illustrating the pervasive influence of the agents and processes associated with these phenomena.

The interpretation of the breakage attributes is treated within the framework of well-recorded seismicity in the Baza Basin. As it has been presented in detail in the sections focused on the formation of the Guadix-Baza Basin, seismic data examination, and delineation of primary infilling stages, underscores the pivotal role of tectonic structures in shaping the Baza Basin's evolution. Notably, the earliest deformations trace back to a significant tectonic event documented during the Early to Middle Tortonian period (Haberland et al., 2017). Extensive geological investigations carried out in the Baza Basin further reinforce this assertion, revealing that the lacustrine deposits within the Baza sub-basin have experienced ongoing tectonic activity since the initiation of their infilling. These findings underscore the enduring influence of tectonic forces on the geological history of the Baza Basin.

The enduring effects of processes spanning millions of years also manifest in contemporary times, as witnessed by the occurrence of moderate-magnitude earthquakes in areas like Orce and Galera in 1964 and Baza in 2001 (Alfaro et al., 2010). These seismic events provide a tangible link between the geological history and the present-day landscape of the Baza-Basin. The evidence of these protracted geological processes is further unveiled through the identification of soft-sediment deformation structures within lacustrine facies, as illustrated in Alfaro et al. (2010). These structures stand as physical markers of geological transformation that reverberated through the very fabric of the sedimentary record.

The impact of these regional-scale processes is starkly evident in the stratigraphic profiles observed at the Baza-1 site. These profiles exhibit features such as truncations and dips, vividly displaying the result of tectonic-induced processes. While a comprehensive stratigraphic section is currently in preparation and not presented here, on-site observations corroborate the profound influence of these tectonic forces.

Moreover, the global ramifications of these geological dynamics are abundantly recorded in the composition of the fossil assemblage. More than 75% of the recovered specimens from the sample exhibit signs of breakage, including carapace fragments, rib fragments, skull fragments, and indeterminate bone fragments. These remains offer a testament to the far-reaching consequences of tectonic activity.

The thorough analysis of breakage-related factors vividly illustrates that the assemblage from Baza-1 has undergone fractures, compression, and breakage as a consequence of diagenetic processes. This assessment is grounded in the selection of specific variables designed to distinguish between breakage in dry, mineralized bone versus that in green bone. When bone is dry and mineralized, it tends to exhibit breaks that are perpendicular, parallel, or diagonal to its long axis, potentially resulting from either dynamic or static loading conditions (Johnson, 1985). These fracture and breakage patterns are distinct from the spiral or helical morphologies commonly associated with fresh, or "green," bone, although the alignment of split-lines within the cortical tissue on relatively straight limb elements, such as the femur and tibia, tend to be parallel to the bone's long axis (Haynes et al., 2021). Furthermore, research in actualistic studies has extensively demonstrated that irregular transversal breakage is a distinctive characteristic of breakage patterns observed in mineralized, or dry, bone. Such breakage typically arises from post-depositional processes like sediment movement or compaction (Fernandez-Jalvo & Andrews, 2016).

In line with the established characteristics identified in both fossil evidence and actualistic studies, the assemblage from the Baza-1 site largely displays features consistent with dry bone breakage, except for two specific bones that exhibit traits indicative of green bone breakage. This observation aligns with the broader understanding of how diagenetic processes influence the breakage patterns in an assemblage.

Although circumference characteristics were not initially taken into consideration in setting the taphonomic parameters, the observation of three long bones within the sample appears to provide complementary insights to the findings derived from the analysis of broken bone edge outlines. Specifically, post-depositional breakage tends to result in complete, tubular cuts that encircle the bone's entire circumference, as opposed to the formation of incomplete rims typically observed in fresh bones (Alcántara García et al., 2006).

One of these bones, in particular, a distal portion of a cervid tibia (Figure 17), notably exhibits this distinctive feature of complete circumference breakage. Similarly, the other two long bones (Figures 18 & 31) exhibit a combination of circumference attributes along with irregular edge outlines and fractures that can confidently be attributed to breakage in mineralized bone, aligning with established patterns in diagenetic processes.

Sedimentary pressure has been detected on numerous specimens, and notably, all the specimens exhibiting this characteristic also exhibit varying degrees of fractures. The impact of sedimentary pressure on these remains is observable through flattening and depressions that have formed on their surfaces. This pressure has had a cascading effect within the remains, resulting in the creation of multiple fractured pieces, some of which remain partially attached, while others have broken off entirely, forming splinters (as seen in Figure 44). Notably, this process of sedimentary pressure is evident in various specimens, including the Proboscidean tusk and humerus (Figures 46 & 47) and a mandible from a juvenile *Stephanorhinus* cf. *jeanvireti* (Figure 24). These specimens exhibit flattened and depressed surfaces, which can be attributed to the influence of sedimentary pressure during the diagenetic phase.

Figure 44: A restored Proboscidean femur showing post-depositional fragmentation.

Variability in the degree of compression affecting the same bones has also been noted, as exemplified in Figure 24. In this particular case, the mandibular body of *Stephanorhinus* cf. *jeanvireti* remains largely intact, while the flatter surface has undergone significant compression. This phenomenon appears to be linked to the inherent morphology and density of the bone, where flatter and thinner sections are more susceptible to pressure-induced breakage in contrast to the thicker portions, such as those found in the mandibular body of this specimen. However, a comprehensive stratigraphic analysis is essential for elucidating the specificities of the effects observed on specimens displaying such variability in breakage patterns within the same bone.

Fractures are extensively documented across bones, carapaces, and teeth within the dataset. However, while fracture characteristics were not systematically recorded in the same manner as they were for bones, carapaces exhibit pronounced fragmentation. The distribution pattern of the complete carapace remains, totaling approximately 250 pieces, from the Baza-1 site reveals a clustering of fragmented pieces within specific grid squares (as illustrated by Figure 45). These remains originate directly from the primary context within this section of the excavation grid. This observation suggests that these carapaces experienced fractures and compressions; however, there doesn't appear to have been significant lateral dispersion of the fragments. Instead, the accumulation of these remains is confined to a central core area, while a sparser distribution is noticeable in the surrounding vicinity.

Field observations further corroborate the clustering of Proboscidean remains in a manner analogous to what has been observed with carapaces. Several remains have been identified in close proximity to articular portions, underscoring a trend of primary deposition centered around specific excavation sections. Nonetheless, the scale and intricacies of deposition and dispersion are notably extensive, particularly for Proboscideans and other large mammals. This complexity arises due to the substantial impact of tectonic-induced seismic activity on the deposition of these remains.

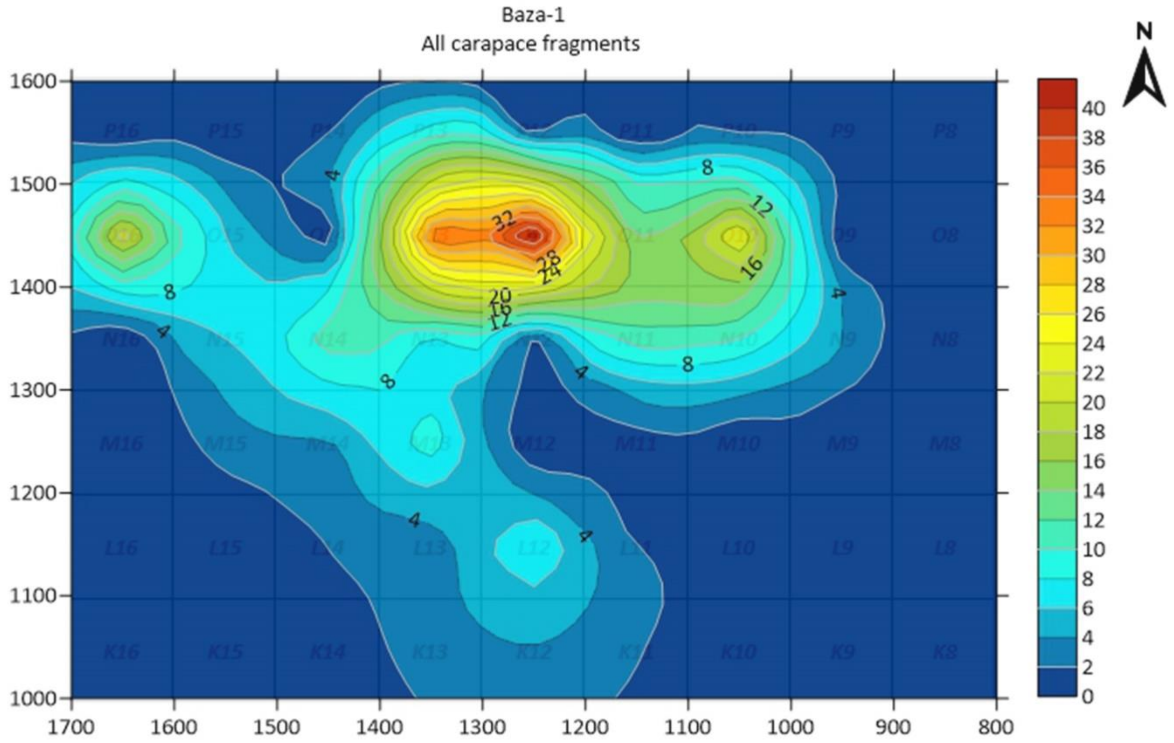


Figure 45: The distribution of the entire Chelonia sp. *carapace fragments (from 2000-2022) from Baza-1 site.*

Figure 46:Distal view of medial portion of a tusk with intense fragmentation

Deformation stands out as another compelling feature observed on select remains, as exemplified in Figures 25 & 47. In these cases, deformations are closely linked with other breakage characters including irregular, jagged breaks, transversal fractures of diverse configurations, and flattening evident in specific sections of the remains. These deformations, occurring in conjunction with post-depositional breakage and fracture attributes, collectively underscore the prevailing influence of seismic activity-related processes during the diagenetic phase.

The presence of deformations and the truncation of stratigraphic layers at the site serve as illustrations of the transformative processes responsible for the bending and overlapping evident in these specimens. These processes offer valuable insights into the mechanisms underlying the observed deformations, shedding light on how seismic forces have played a pivotal role in shaping the structural integrity of these remains over time.

Figure 47: Proboscidean tusk displaying multiple characters of the impacts in diagenetic phase including deformation, fragmentation and slight flattening (proximally).

The instances of pieces exhibiting fractures and breakage that can be confidently attributed to the biostratinomic stage are notably scarce. Within this limited category, only two shaft fragments exhibit what is commonly referred to as a "spiral fracture," a characteristic often associated with green bone breakage (Haynes, 1983). Spiral fractures typically occur when a bone is in a fresh state, shortly after the animal's death, and is not characterized by brittleness, in contrast to how bone behaves when it has thoroughly dried out (Johnson, 1985). In contrast to the irregular and linear transversal and longitudinal breaks commonly observed in mineralized bones, spiral fractures represent a distinct pattern. These fractures spiral along the bone (Haynes, 2017; Myers et al., 1980). This disparity in fracture patterns provides valuable clues about the state and condition of the bone at the time of the breakage event.

Within the sample assemblage, there exists a fragment of bone displaying characteristics associated with green bone, specifically featuring a spiral break. Notably, this fragment also exhibits a shallow depression, the origin of which cannot be definitively attributed based solely on its configuration (see Figure 24). While caution is exercised in interpreting the mark in isolation, the possibility of an impact by "durophagous" carnivores has not been entirely ruled out.

The assertion of carnivore-induced bone breakage gains credence when considering the concavity beneath the shallow mark, which carves into the medullary cavity of the bone. The convergence of these two distinctive attributes suggests that the resulting morphologies likely stem from the application of a static force to the bone. Such static forces, exerted by carnivores on bones, are known to generate a range of distinct marks, including punctures, pits, scores, and furrows (Binford, 1981). This application of force along the diaphysis, culminating in bone fracture and pitting of the diaphysis, emerges as a common characteristic in such carnivore-induced interactions. Punctures and furrowing are often noted on the epiphysis of long bones. Pitting occur on the diaphysis, and the termination on the diaphysis may be scalloped (Lyman, 1994).

Both punctures and pits can arise from closely related carnivore manipulation techniques. However, the specific features generated depend on factors such as the bone's integrity and the carnivore species involved (cf., Selvaggio, 1994; Selvaggio & Wilder, 2001; Andrés et al., 2012). In instances where bones are thin and porous, the carnivore's teeth can penetrate, causing the bone to yield under the pressure and resulting in holes within the cancellous bone structure. In contrast, pits are typically observed on gnawed bones, displaying shallow features primarily on the cortical surface, as outlined in Binford (1981).

Despite the isolated nature of the pit observed on the specimen from the site, meaning it lacks any accompanying marks on the bone's surface, a more coherent interpretation emerges when we take into account the discussed characteristics. Interpreting the pit in conjunction with the green bone breakage features identified on the shaft splinter provides a more comprehensive context. In light of these various strands of evidence, the specimen has been cautiously attributed to a "potential" instance of carnivore-induced bone breakage.

Furthermore, carnivores are notably scarce in the Baza-1 context, with just seven specimens attributed to this Order out of over two thousand remains recovered from the site. However, the precise number remains subject to further analysis since several remains were found within sediment blocks.

The influence of carnivory, if any, appears to be restricted to only one specimen within the sample. Consequently, predation and the subsequent transportation of carcasses to the site are not considered the primary mechanisms responsible for the accumulation and modification of bones at Baza-1.

In general, the prevalence of broken specimens within the sample can be ascribed to documented tectonic-induced seismic activity, which has led to breakage, fractures, and compression during the diagenetic phase. However, quantifying the contributions of other underlying factors, such as bone type, and environmental conditions (Karr & Outram, 2012) to the observed outcomes poses a complex challenge.

5.1.4. On the context trampling and abrasion

The 3 mm wide linear mark identified on the distal part of a Proboscidean humerus retains characters that can be interpreted as a result of trampling. The assessment of this feature primarily rests on its overall morphology, with microscopic characteristics not being taken into account. Additionally, considerations are given to the presence of breakage attributes observed on the lateral section of the bone.

Linear marks present a multifaceted challenge that demands a cautious approach. A comprehensive examination encompasses not only surface modifications but also considers associated attributes like notches, orientation, impact localization, and microscopic features before conclusive conclusions can be drawn (e.g., Lyman, 1994; Olsen & Shipman, 1988; Fernandez-Jalvo & Andrews, 2016). Due to their inherent complexity, linear marks often pose challenges in terms of interpretation. The problem of equifinality looms large, meaning that various processes can result in similar-looking marks. Consequently, distinguishing between marks generated through trampling and those produced by other activities, such as butchery, has been a point of contention among researchers (e.g., Behrensmeyer et al., 1986; Olsen & Shipman, 1988; Selvaggio, 1998; Domínguez-Rodrigo et al., 2010; McPherron et al., 2010).

This highlights the need for a meticulous and rigorous approach when examining linear marks, as well as a consideration of multiple lines of evidence and expert opinions to arrive at well-founded conclusions regarding their origins and implications. Research into trampling characteristics primarily focuses on the development of marks on bones, fractures, and spatial dispersion (Lyman, 1994). The occurrence of breakage is considered a valuable feature associated with trampled bones (Olsen & Shipman, 1988).

The linear mark observed in the specimen from Baza-1 exhibits characteristics consistent with the rolling of the condyle's head, likely the result of a force applied to the bone that initiated the scratch (see Figure 29). The broader and shallower shape of this feature aligns with the "U" cross-section commonly associated with trampling. While anthropogenic agency has been definitively ruled out primarily based on the site's chronology, carnivore-induced damage is also excluded due to the distinctive configuration of the scratch compared to marks typically produced by carnivore teeth. Additionally, carnivore involvement is discounted because there are no complementary traits such as perforations that would typically accompany an action resulting in such a prominently displayed effect on softer cancellous epiphyses (Selvaggio & Wilder, 2001). Furthermore, the notably more fragmented condition of the posterior surface (see Figures 28 & 48) compared to the anterior part implies variation in the impact of the agent(s) responsible.

Investigating the intricate microscopic characteristics and precise origin of this particular specimen within the excavated context holds the potential to offer valuable insights into the trampling conditions it endured, a subject expected to receive further clarification in future research endeavours. However, it is essential to acknowledge that the palaeoecological context of the site and the diversity of taxa found there significantly contribute to the formulation of a well-informed hypothesis. The contextual factors independently provide essential information on potential origin of the attributes noted on the fossil bone.

Figure 48: Proboscidean humerus anterior (left) and posterior (right) views.

The Baza-1 site is situated on the periphery of a paleolake, a well-known environment conducive to the congregation of animals. It is a well-documented phenomenon that herbivores frequently gather around lakeshores for activities such as drinking and grazing along the water's edge. Consequently, it has been observed that bones deposited in such environments can be subjected to trampling by these large animals. The trampling effect on bones by herbivores' hooves is multifaceted. Notably, it tends to crush flat and elongated bones while preserving the integrity of their constituent parts. Additionally, trampling often results in the displacement of smaller bone fragments within the sediment, typically without causing them to chip or fracture (Gifford, 1977, 1978). By leveraging insights from actualistic studies, the circumstances at the site present a scenario in which bones could have been influenced by animals of different sizes that likely frequented the environment along the edge of the paleolake.

Furthermore, contemporary elephants exhibit behaviours that influence carcasses at various stages of decomposition, even including aged bones(e.g., see Douglas-Hamilton et al., 2006; McComb et al., 2006; Goldenberg & Wittemyer, 2019). Elephants are known for revisiting the sites of deceased individuals, engaging in activities such as touching, moving, and transporting the carcass shortly after death or even over an extended period of up to twenty years (as documented by Goldenberg & Wittemyer, 2019). These actions have consequences for the bone surfaces, including trampling on decomposing carcasses, as the frequent handling results in alterations to the bones. However, it is important to emphasise that while this study acknowledges the existence of these intricate behaviours and their potential influence on bone assemblages, there is no information available regarding whether these behaviours observed in modern proboscidean species were already present in their lineage 4.5 million years ago. Furthermore, due to the limited occurrence of these markings, it is challenging to construct a dependable interpretative framework for their origins.

Abrasion involves the alteration and relocation of eroded materials, or the application of pressure within sedimentary deposits (Olsen & Shipman, 1988). This phenomenon encompasses the smoothing and polishing of bone surfaces, with or without noticeable signs of breakage (Fernandez-Jalvo & Andrews, 2016). Within the examined sample, we observe that specimens displaying a rounded and potentially polished appearance tend to cluster in areas where sediment movements have been identified. This clustering aids in attributing these bone alterations to the diagenetic phase, specifically sedimentary abrasion. Further support for this conclusion is drawn from an examination of the matrix adhering to the bone surfaces, where bones exhibit a mixture of colours (as illustrated in Figure 30).

5.1.5. Root marks

The presence of root marks is limited to just a few instances, although they provide valuable information on the depositional context, and the sequences of taphonomical processes. In this context, the terms "root etching" and "root marks" are employed to differentiate between an older incised specimen and modern superficial grey markings on bones, as depicted in Figures 25 & 26. The activities of plant roots can have varying effects on remains, sometimes causing them to split or fragment (Behrensmeyer, 1978).

In the context of the Baza-1 site, it is notable that root marks do not appear to have played a substantial role in causing bone breakage. Even when the deeper etchings found on a rib are considered, these features have not compromised the structural integrity of the bones. There are no discernible fractures corresponding to the outlines of these etchings. The breakage features observed in specimens linked to root activity serve as confirmation that all the etching took place after they had been broken during the post-depositional phase.

Upon closer examination of the particular case involving root etching found on one segment of the two corresponding rib fragments (illustrated in Figure 26), it becomes apparent that this etching transpired in the post-depositional phase, subsequent to the initial fragmentation of the rib. The characteristics displayed by the bone, including irregular transverse breaks, are consistent with the effects of dry bone breakage. The discrepancy in the presence or absence of root etching on different sections of the rib fragments can be attributed to the resting positions these fragments of the rib assumed within the sediment after their initial breakage, shedding light on the dynamic processes at play.

Conversely, the presence of modern root marks on three specimens can be attributed to the topography of the excavation area. Given that the excavations at Baza-1 commenced at a ravine face, it is inevitable that some remains would be exposed to contemporary root activity. Fossil-bearing layers located on the slope of the hill are eventually susceptible to modern environmental influences, including the intrusion of plant roots onto the bone surfaces, which emanate from this exposed section.

In conclusion, the comprehensive analysis of the samples under study has unveiled additional taphonomic features, including the presence of iron and manganese oxide, albeit on a notably small number of specimens. The rarity of these specific cases limits our ability to delve into a thorough exploration at this stage. Moreover, the significance of “phosphatine” layers observed at the site underscores the substantial and widespread effects of other processes, which were not within the scope of this study. These processes had played a central role in the deterioration of the skeletal remains, transforming them into powdery, unidentifiable masses. These significative findings serve to underscore the intricate interplay of multiple factors contributing to the preservation and alteration of skeletal remains within the context of the Baza-1 site.

5.1.6. Dispersion patterns and deposition mechanisms

Taking a broader perspective, the Baza-1 site presents a unique configuration characterized by the grouping of elements associated with specific taxonomic groups, such as *Chelonia* sp. and *Alephis* sp. (as depicted in Figure A-1), while other elements are dispersed more widely mainly due to the shattering of elements like teeth and tusks (Figure A-2). These distinctive clustering patterns, whether observed within a single anatomical feature like the carapace in the case of *Chelonia* sp. or across multiple anatomical elements as evident in *Alephis* sp., seem to provide indications of collections representing individuals or events, potentially suggesting a single event deposition. Such an event would have facilitated the initial accumulation of these remains without significant disarticulation and dispersal of skeletal parts.

Moreover, when assessing the composition of the assemblage in relation to potential hydraulic bone dispersal patterns (Voorhies, 1969), while considering variations in bone density and volume (Grayson, 1989; Lyman, 1994) among the recorded taxa, there is no evidence of selective accumulation. Notably, the abundance of rib fragments and small, lightweight bones (such as sesamoids) may suggest the absence of any significant current capable of transporting these types of elements.

Characters of sorting related to water current is not apparent in the assemblage as a mixed context of specimens that could be removed very easily and swiftly by current action as well as those that can be represented as lag deposits described by Voorhies (1969) represented in relative proportion. Furthermore, the surface features, especially those of the bones, do not exhibit widespread evidence of being influenced by movement or transport, which could have caused significant rounding of edges. Nonetheless, the prevalent edge rounding observed in the sample strongly indicates post-depositional movement within the sediment, which could have led to the mixture with the overlaying sediment.

The intriguing aspect of Baza-1 lies in the limited evidence of carnivore interactions with deceased carcasses. Typically, when megaherbivores meet their demise, it results in an abundant food source that lures carnivores and raptors (Behrensmeyer, 1975). Furthermore, instances where animals become trapped in sediments can trigger carnivorous scavenging frenzies (e.g., Stock, 1929; Spencer et al., 2003; McHorse et al., 2012; DeSantis et al., 2019). On the contrary, within the context of a maar deposit, the rapid burial followed by sinking to the sediment's bottom has been found to effectively prevent bioturbation (Sole et al., 2012). Similarly, swift burial of carcasses at Baza-1 may have led to their initial preservation without significant disturbance. However, comprehensively understanding the exact circumstances of the thanatic processes at the site necessitates the acquisition of more data and further investigation.

5.2. Conclusion and perspectives

The spatial distribution analysis conducted in this study underscores how the examined sample effectively mirrors the larger assemblage, allowing for valuable insights into the patterns of biostratinomic and diagenetic processes. Nonetheless, it is crucial to recognize that when the extensive potential of fossil-bearing units identified at Baza-1 and its surrounding region considered, the portion that has been excavated represents merely a minuscule fraction. Consequently, the insights gleaned from this excavation primarily shed light on the observed trends within this limited area, while achieving a more comprehensive understanding of the broader fossil record remains a goal for future research and exploration.

In this context, the conclusions drawn in this study are firmly grounded in the taphonomic records derived from the sample collected at this significant site. The aim is to offer a glimpse into the immense potential encapsulated within this small section of excavation. These records serve as a fundamental support for shaping the conclusions, providing valuable insights into both the depositional contexts and the post-depositional alterations that have played a pivotal role in influencing the preservation of remains at this site.

5.2.1. Conclusion

Baza-1 is lacustrine depositional context that demonstrates a remarkable diversity in species composition, which is evident from the variety of anatomical elements discovered within the assemblage. It is distinguished by the presence of a variety of terrestrial ungulates interspersed with aquatic and sub-aquatic species, highlighting its rich biodiversity.

Habitats situated along the shores of lakes have been often described to be attractive to a diverse range of species that depend on these water sources, as noted in Gifford (1977) and Shipman (1981). In line with this perspective, the mosaic environment of Baza-1 and its surrounding areas appear to have facilitated the coexistence of species from the immediate vicinity and those originating from nearby habitats. A compelling example of this coexistence is the presence of two Proboscidean species, which provides further evidence of adaptations to a range of different environments.

The sample's demographic makeup is predominantly comprised of a significant population of adult and young adult individuals, and interestingly, there is a conspicuous absence of senile individuals. This distinct age distribution observed at the site deviates from the typical pattern of attritional mortality typically associated with natural aging or increased susceptibility to predation, especially when considering the species composition found at Baza-1.

The absence of distinct markings and green (fresh) bone breakages that could be unequivocally linked to large carnivores capable of subduing such massive creatures, in conjunction with the conspicuously sparse presence of carnivores at the site, effectively rules out predation as a credible factor responsible for the accumulation of this extensive assemblage predominantly consisting of megaherbivores. Additionally, it is worth noting that contemporary hypercarnivores tend to avoid fully grown megaherbivores. Furthermore, the composition of the anatomical elements does not exhibit any discernible patterns indicative of carnivorous accumulation. Consequently, the impact of carnivores on the thanatocoenoses is negligible.

Field observations and previously published research (Ros-Montoya et al., 2017) indicate that the systematically examined Proboscidean remains likely originate from a small number of individuals representing two species clustered in the excavation areas. A similar clustering phenomenon has been observed for *Chelonia* sp. in certain sections of the site. On the other hand, represented by diverse age groups, *Stephanorhinus* cf. *jeanvireti* shows dispersion across the excavation squares, primarily through fragmented teeth. Similarly, there appear to be no discernible deposition patterns for Carnivores, Suidae, and Cervidae, as these remains are scattered sparsely throughout the excavated area.

Furthermore, there are currently no evident signs of transportation, erosive deposition, or substantial alterations tied to these processes. However, definitive findings will depend on the ongoing comprehensive analysis of the sedimentary contexts. The elements investigated in this study, in conjunction with the evaluation of the entire collection, indicate a mix of remains that could be easily transported by erosive forces and those that display greater resistance to such processes.

Taking into account all of these factors, the prevailing scenario at Baza-1 seems to be defined by a substantial accumulation, predominantly comprising fully grown large and megaherbivores interspersed with small and medium-sized species. Remarkably, there are no discernible indications of carnivore predation or significant weathering effects. This pattern strongly suggests a scenario characterized by natural mortality followed by rapid burial. Consequently, it appears that the conditions during the biostratinomic stage of deposition are closely linked to the demise of these animals and their subsequent interment without undergoing significant deterioration.

Subsequently, these deposits underwent phases of intense seismic activity-induced breakage, causing a transformation of the original deposit and resulting in an assemblage primarily composed of fragmentary skeletal elements. The findings of this study align with the evidence of seismic activity recorded in geological studies conducted in the region, underscoring the site-level effects of this process. The breakages, compressions and fractures observed within the assemblages can be attributed to such seismic activities.

5.2.1. Perspectives

While this study offers valuable insights into the composition of the assemblage and the taphonomic processes at Baza-1, it should be emphasized that it provides a focused perspective on these aspects. In particular, the examination of microfauna received limited attention, and the analysis did not encompass crucial macrofauna specimens within the assemblage, including *Hipparion* sp. and *Antilop*e sp., which have been documented in Ros-Montoya et al. (2017). It is worth noting that several of these specimens are still undergoing restoration and preparation procedures.

While the primary focus in this study was to offer insights into the site's formation processes through the lens of taphonomic observations, it is important to acknowledge the significance of a holistic approach. A comprehensive understanding of site formation necessitates the integration of multiple sources of information. Such investigations can provide crucial context and corroborative evidence to enhance the overall interpretation. Future works should not only expand the sample size but also incorporate vital geological and spatial data. Such an approach would not only enhance our comprehension of the site's taphonomy and paleoecology but also contribute substantially to the broader understanding of the site's role in the relevant chronology.

The spatial data utilized in this study has certain limitations in both scope and methodology. To provide a more comprehensive understanding, it would be beneficial to expand on this research by incorporating the complete set of remains from the site and employing tools that can effectively demonstrate the associations and vertical dispersion of these remains. This expansion would assist in providing greater clarity for the conclusions drawn in this study, which primarily rely on the lateral distribution of records. Future research endeavours will involve the creation of intricate visual topographic representations depicting the site's layout, the dispersal of remains, and the spatial interconnections among various elements.

Investigating deeper into the understanding of the context surrounding the depression of surfaces and the bending observed in fossil remains necessitates a comprehensive approach. This can be accomplished through the thorough examination of detailed stratigraphic sections, which offer critical insights into the orientation and inclination of the objects that have undergone these transformative processes.

Additionally, exploring the intricate patterns of clustering and dispersion, especially when analysing elements originating from specific taxonomic groups, opens up a fascinating avenue for in-depth inquiry. This investigation offers a unique opportunity to uncover valuable insights into the site's taphonomic dynamics.

Further examination is required for specimens showing attributes that have been tentatively linked to trampling and carnivorous activities. Employing microscopic and metrical methods to analyse the configuration of these features will contribute to a more comprehensive discussion. Thorough examinations will significantly improve the interpretation of these attributes, which was initially reliant on their overall morphology and their connection to other observed features on the specimens.

The forthcoming excavations at Baza-1 could play a pivotal role in deepening our understanding of the complex site formation processes that have shaped the site. Additionally, they hold the promise of providing valuable insights that can enhance and refine the results obtained in the course of this study. These future endeavours in the field of excavation are poised to contribute significantly to the thorough understanding of the site's history and the factors that have influenced its formation.

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Annexes

Taxa	Element	Left	Right	Indet.	Age	MNE	MNI
Alephis sp.	Maxillary		1		YA	1	2
	Mandibular	2	2	1	A, YA	2	
	Scaphoid	1			A	1	
	Unciform	1	2		A	3	
	Pisiform		1		A	1	
	Sesamoid			2	A	2	
	Teeth frag.			1			
Stephanorhinus cf. *S. jeanvireti*	Maxillary			2	A, I	2	3
	Mandibular	1	1		J	1	
	Teeth frag.			10			
	Metatarsal			1		1	
	Scaphoid		1			1	
	3rd Phalanx			1		1	
Anancus arvernensis	Mandibular	2	1		A	2	1
	Teeth frag.			6		1	
	Tusk			2			
	Pelvis			5		1	
Mamuth borsoni	Maxillary	1				1	1
	Mandibular	2	2			2	
	Teeth frag.			1			
Chelonia sp.	Carapace			44			
Bovidae indet.	Metacarpal			1	A	1	
	Astragalus			1	A	1	
	Metatarsal			1		1	
	Teeth frag.			1			
Cervidae indet.	Maxillary			1		1	
	Tibia	1					
Suidae (*Sus* sp.)	Maxillary		1				

	2nd phalanx			1			
Cyprinidae indet.	Vertebra			1			
Proboscidea indet.	Tusk			24			
	Rib			3			
	Humerus			1			
	Femur			1			
	Carpal/tarsal			2			
	Metatarsal			1			
	Phalange			2		2	
	Sesamoid			1		1	
	Bone frags.			2			
Artiodactyla indet.	1st phalanx			1		1	
	Teeth frag.			1			
Carnivora indet.	Metatarsal			1	A	1	
	3rd phalanx			1	A	1	
Mammal indet.	Skull			2			
	Vertebra			3		3	
	Rib			32			
	Femoral			2			
	Astragalus			1		1	
	Carpal/tarsal			4			
	Flat bone			5			
	Long bone			21			
	Bone fragment			26			
Microfauna	Long bone			1			
Indet.	Vertebra			1		1	
	Long bone frag.			1			
	Bone fragment			22			
Total		11	12	245		38	7

Table A- 1: Distribution of sampled remains across taxa and anatomical elements

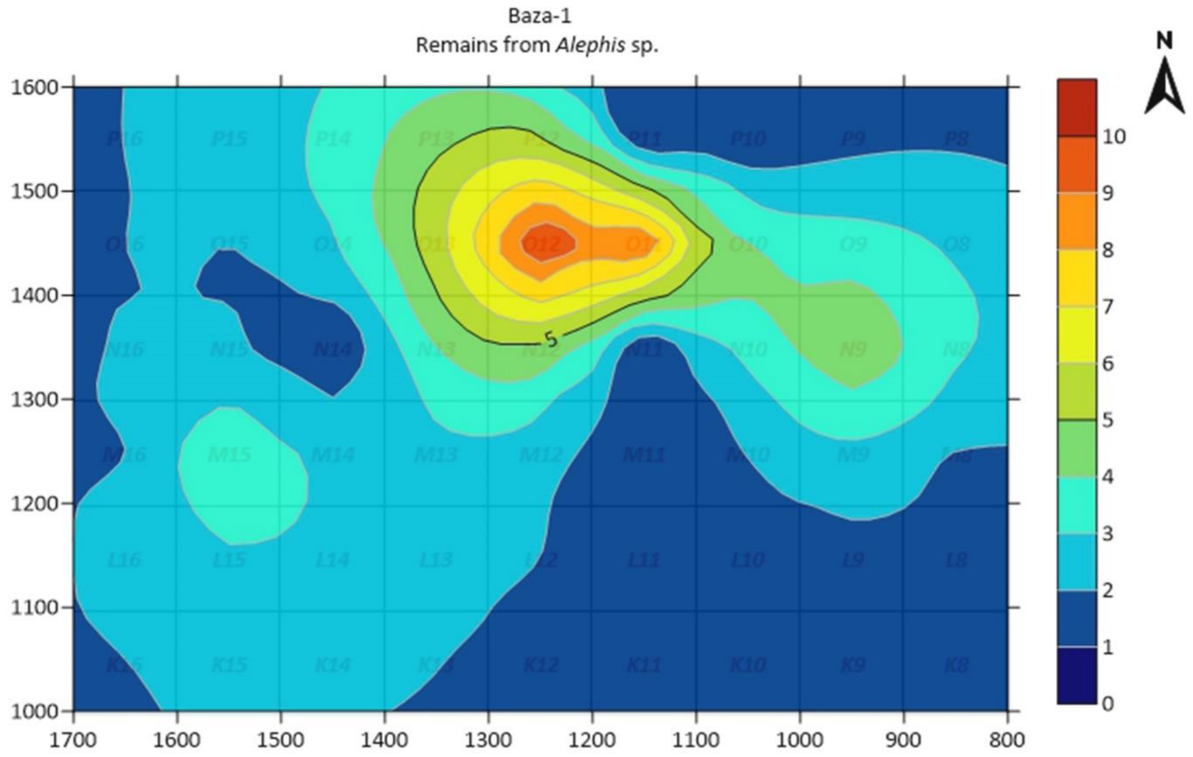

Figure A - 1: Dispersal of specimens tentatively assigned to Alephis *sp.*

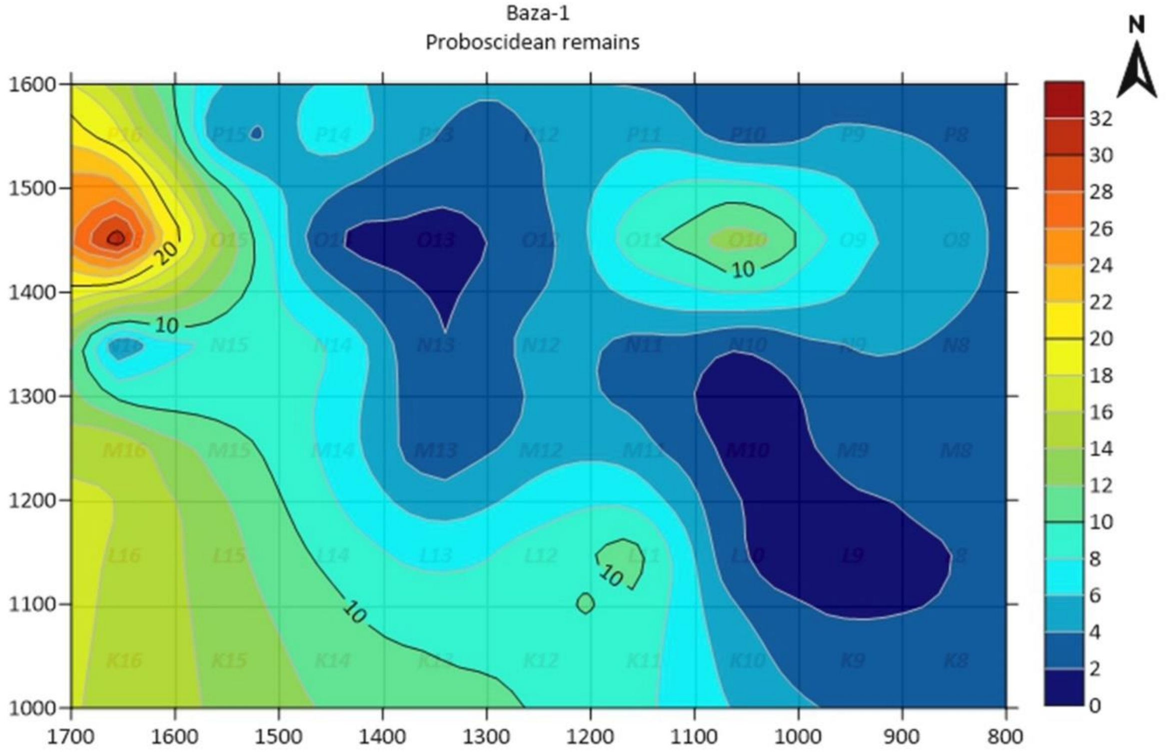

Figure A - 2: Showing the distribution of unidentified proboscidean remains with lateral dispersion emanating from tusk fragments.