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TAPHOS

2025

Comacchio (Ferrara)

10th International Meeting on Taphonomy and Fossilization Comacchio (Ferrara), June 17th-19th, 2025

ABSTRACT BOOK

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Volume 2 (2025)

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EDITED BY DAVIDE BASSI AND ORNELLA DE CURTIS

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Previous International Meetings on Taphonomy and Fossilization TAPHOS

Madrid (1990), Zaragoza (1995), Valencia (2002), Barcelona (2005), Granada (2008), Tübingen (2011), Ferrara (2014), Vienna (2017), Madrid (2022).

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Taphos 2025 logo, project design by Davide Bassi (Ferrara)

TAPHOS 2025

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Wednesday, June 18th	Scientific sessions (talks and posters). Sala polivalente San Pietro, Palazzo Bellini, via Agatopisto, 7 (point 3, see Map).
Thursday, June 19th	Post-meeting field trip: Parco del Delta del Po. Meeting time: 7:00. Departure: 7:30; meeting point number 6, via Fattibello, supermercato Coop (see Map). After lunch, return to Comacchio. *c.* 16:00: visit to the Museo del Delta Antico.

bold: presenter

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11:45–12:00	**Julio Aguirre**, Isabel M. Sánchez-Almazo, Josep M. Salvany Pyrite, gypsum, potassium-iron sulfates, and carbonate dissolution: all in once in foraminifera steinkerns.
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15:15–15:30	**Haruka Katada**, Hidekazu Yoshida, Yoshihiro Asahara, Masayo Minami, Nagayoshi Katsuta, Yui Kouketsu, Atsushi Ujihara, Shunta Ichimura, Tatsuo Oji Elemental transfer and fixation in the fossilization of turbidite-buried deep-sea fish.
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16:30–16:45	**Daniel Falk**, Aaron Quigley, Beatriz Carazo del Hoyo, Valentina Rossi, Samuel M. Webb, Oliver Wings, Maria McNamara No change in 45 million years: evolutionary conserved melanosome geometries in anurans.
16:45–17:00	**Giulia Bosio**, Eli Amson, Giovanni Bianucci, Olivier Lambert, Francesco Nobile, Marco Merella, Rafael Varas-Malca, Giorgio Carnevale, Maria Elena Gastaldello, Giovanni Coletti, Orla Bath Enright, Eudald Mujal, Mario Urbina, Anna Gioncada, Elisa Malinverno, Claudio Di Celma, Alberto Collareta Taphonomic and paleoecological insights from the type locality of *Perucetus colossus*, an oversized whale from the Eocene of Peru.
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	The taphonomic analysis of the Late Pleistocene reindeer antlers from reindeer cave (NW Scotland).
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Colecchia C., Bianucci G., Pandolfi L.: *Hippopotamus* fossil remains from the Pleistocene of Maglianella (Rome, Italy): new evidence and interpretations.

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Schneider C., Nebelsick J.H.: Brachiopods and their encrusting friends from the Late Jurassic of Southern Germany.

Vamsi Madireddi S.K., Ferreira G., Grun T., Nebelsick J.H.: Taphonomic and ecological interactions of recent clypeasteroid echinoids from San Salvador Island, Bahamas, using micro-computed tomography.

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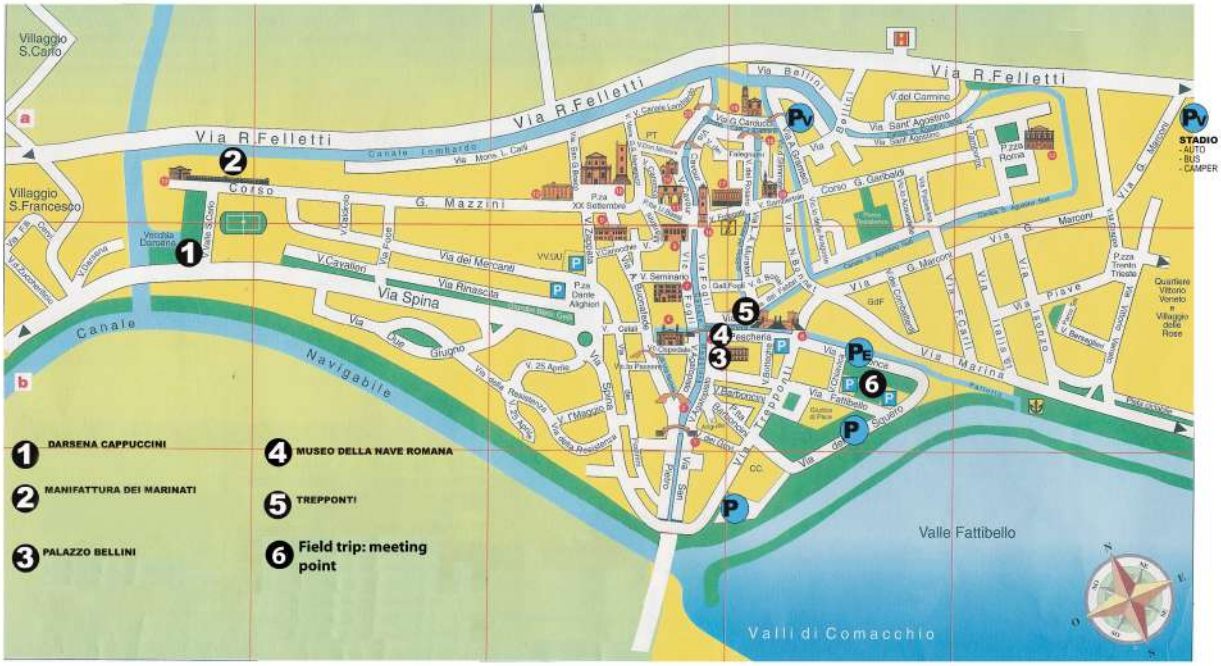

2. Aperitivo, 17 June, 2025; Manifattura dei Marinati, Corso Mazzini, 200.
3. Taphos 2025, venue; Sala polivalente, via Agatopisto, 7.

6. Meeting point for the post-meeting field trip; 19 June, 2025; via Fattibello, supermercato Coop.

ABSTRACTS

FOSSILDIAGENETIC PATHWAY OF FORAMINIFERA TESTS IN A TECTONICALLY ACTIVE REGION (MIDDLE MIOCENE DEPOSITS, BETIC CORDILLERA, S SPAIN)

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Fossil foraminifera are very abundant in marine deposits, particularly in deep-water sedimentary settings. They are abundant and widespread in the oceanic water column (planktonic foraminifera) and sea bottom (benthic foraminifera). Due to the calcitic nature of their tests, their preservation is favored. Nonetheless, their potential preservation is species-dependent (e.g., degree of calcification, shell density, or preferred habitat of species), and it also depends on bottom conditions (e.g., deposition below the lysocline or the CCD, sea bottom temperature and oxygenation, or chemistry of bottom waters). These taphonomic modifications have been largely investigated, particularly the effects of the water chemistry on foraminifera test preservation.

Once the foraminifera are definitively buried, they are exposed to diagenetic processes. Deep water sediments are mostly represented by clays and marls. These sediments are impermeable, limiting the free movement of chemically reactive pore waters and, consequently, largely preventing fossildiagenetic alterations of buried foraminifera. Therefore, foraminifera use to be pristinely preserved in quiet, deep oceanic settings; for instance, those found in oceanic cores. However, in tectonically active regions, taphonomic processes affecting microfossils during late diagenesis can be important. These late fossildiagenetic processes are less known.

The Betic Cordillera (S Spain) is a collision Alpine orogen formed during the Miocene. Several basins developed in the frontal part of the orogen and they were uplifted as the collision progressed. Deep water marls deposited in the basin depocenters contain rich and abundant foraminifera assemblages, which allow inferring the paleowater depth (middle platform to basin settings based on benthic foraminifera assemblages) and dating the sediments (Middle Miocene - Langhian-Serravallian- based on planktonics). However, in some cases, foraminifera tests are significantly modified due to late fossildiagenesis linked to the orogeny. Here, we describe some of the most significant taphonomic signatures affecting these microfossils and discuss their implications. We have focused on Middle Miocene basin deposits from several localities of the central Betic Cordillera that were involved in the orogeny.

Dissolution, inner cast formation, deformation and recrystallization are the most significant taphonomic signatures affecting the study foraminifera assemblages. Dissolution acted differently in planktonic and benthonic foraminifera. The former are dissolved and they are preserved as inner casts made up of calcite fillings. In the cases of benthonic foraminifera, they occur as inner casts but also preserving their original tests. In the planktonic foraminifera, the inner molds often replicate the complete shell morphology, reproducing even the wall pores and the wall ornamentation. Very often, the inner casts show an external crust of rhombohedral calcite crystals concealing the wall features. Finally, deformation also affected foraminifera casts. They occur as fractured and collapsed molds or as ductile deformed casts.

All these taphonomic signatures were produced during the late diagenesis, most likely during the thrusting and folding of sediments in the orogen front, allowing inferring the following late fossildiagenetic pathway. The generally well replication of the foraminifera morphology and shell wall features in the inner casts suggests that dissolution of the tests should occur after compaction and cementation of the sediment. This process commonly starts in the taphonomic active zone or immediately below it. However, due to the tectonic context of the study area, dissolution most likely occurred well after burial and cementation of the sediment due to circulation of chemically reactive pore fluids during the orogeny. However, dissolution preferentially affected to delicate planktonic foraminifera test walls, which are more vulnerable to dissolution than the benthonic ones, which are thicker and show less pores. Afterwards, saturation of calcium carbonate of the pore waters led to the precipitation of thick calcite crystals in the voids left by the dissolved foraminifera tests.

Reproduction of shell pores and external ornamentations in some study cases suggests that crystal precipitation took place slowly, replicating delicate features of the test walls. This process is critical to preserve shell characters essential to identify foraminifera at the species level, even although they have been preserved as inner casts. Fragmentation and plastic deformation were related to tectonic stress during orogeny. In the study cases, fragmentation is mostly due to collapse of incompletely filled foraminifera casts, while ductile deformation is observed in both partially and completely infilled foraminifera tests. Finally, the formation of external calcitic crusts on both inner casts and shell walls is difficult to accommodate in the described fossildiagenetic pathway. It could be a consequence of the pore water dynamics during deformation or it could be a relatively recent process linked with meteoric waters once the deposits were uplifted and definitively exposed.

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PYRITE, GYPSUM, POTASSIUM-IRON SULFATES, AND CARBONATE DISSOLUTION: ALL IN ONCE IN FORAMINIFERA STEINKERNS

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Pyritization is a well-known fossilization process to preserve 3D non-mineralized tissues of different organisms. Further, pyrite can precipitate later during diagenesis generating molds and steinkerns of buried organisms reproducing, in some cases, very delicate anatomical features. In this contribution, we describe pyrite casts of Pliocene planktonic and benthonic foraminifera from Barcelona (NE Spain). The samples were collected in several cores made for the construction of the high-speed (AVE) railroad through the Barcelona city. The Pliocene deposits, up to 100 m in thickness, consist of three units: a) a basal unit of sandy gravels and sands with some marine bivalves interpreted as high-energy lag deposits linked to the initial stages of the Early Pliocene transgression; b) a middle unit of grey marls rich in bivalves and foraminifera deposited in a sheltered, very shallow setting; and, c) an upper unit consisting of fine to coarse sands formed in shallow coastal environments (beach and foreshore deposits).

Pyritized foraminifera occur in the middle unit. They are preserved as: a) foraminifera filled up with pyrite and preserving their original calcitic tests; b) pyritized steinkerns with the original tests partially dissolved; and, c) pyritized steinkerns with the original tests completely dissolved. Elemental maps of the steinkerns indicate that the outer surface of the pyrite is slightly oxidized and transformed into iron hydroxides. Pyrite occurs as framboids, ranging from 8 μm to 16 μm (eventually, reaching up to 35 μm), as octahedral and dodecahedral (pyritohedral) crystals, and as plate-like crystals. The latter morphology is observed in the contact with the inner surface of the foraminiferal tests, while the other two growth forms fill up the foraminiferal chambers.

Together with the pyrite, there are also gypsum, which occurs as tabular crystals, and rosette-like crystal aggregates of K-Fe sulfate (jarosite?). The gypsum is found as scattered tabular crystals in the chamber cavities and replacing the calcite of the chamber walls roughly preserving the original microstructure. The K-Fe sulfate rosettes occur dispersed, but always associated with pyrite framboids, filling the foraminifera chambers.

Pyrite can precipitate in the interior of living benthic foraminifera inhabiting polluted, very restricted bays. In our study case, the pyrite fills up both planktonic and benthonic foraminifera. This suggests that pyritization took place inside the sediment after the death of the microorganisms. Although pyrite precipitation can locally occur in oxygenated settings due to the presence of heavy metal contaminants, pyritization is mostly related with the activity of microbial sulfate-reduction and iron-reduction in the first few centimeters of the sedimentary column, close to the redox interface, with Fe-rich anaerobic pore-waters. Therefore, we interpret that pyritization in the study foraminiferal casts did occur early after shallow burial of the foraminiferal tests in depleted-oxygen paleoenvironments. The morphology of the pyrite crystals is related with the precipitation conditions. The smooth tabular pyrite developed in the contact with the inner foraminiferal tests most likely replicates the inner foraminiferal membrane. In this case, pyritization could be triggered by the initial decay of the organic carbon of the tissue. The rest of the chambers were filled up with framboids and euhedral crystals due to bacterial activity.

Pyritization produced slightly acid conditions inside the foraminiferal tests, thus promoting the beginning of carbonate dissolution. In addition, oxidation of the pyrite delivers sulfate ions. The combination of these two processes lead to the precipitation of gypsum. This accounts for the transformation of the calcite of the chamber walls into gypsum roughly preserving the original

microstructure and the beginning of gypsum precipitation close to the inner parts of the foraminiferal tests. Finally, the formation of the K-Fe sulfate rosettes is very unusual and remains uncertain. It is also related with the oxidation of the pyrite. Nonetheless, the formation of this mineral occurs in very acid conditions (pH below 6, sometimes even around 2). This acidic microenvironment is incompatible with the preservation of the foraminiferal calcitic tests. Therefore, we need further analyses to account for the presence of these crystal aggregates in the observed mineral association forming the foraminiferal steinkerns.

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GETTING TO THE BONE OF TOOLMAKING: CRAFTING PRACTICES AT THE EARLY BRONZE AGE PILE-DWELLING OF VALLESE DI OPPEANO 4C

Lucilla Angeletti, Ursula Thun Hohenstein

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The Early Bronze Age pile-dwelling settlement of Vallese di Oppeano 4C, located in the Valli Grandi Veronesi near Verona, provides valuable insights into the material culture and daily practices in northeastern Italy during this period. The site stands out as one of the few currently known Early Bronze Age settlements in the Veneto region, dating back to the transitional period between EBA1 (2,300–1,900 BCE) and EBA2 (1,900–1,650 BCE).

The exceptional preservation of organic materials, granted by the waterlogged depositional conditions, has enabled detailed taphonomic analysis. Zooarchaeological analysis reveals that subsistence strategies were centred on the husbandry of sheep-goats and pigs (targeted for high-quality meat, reproduction, and secondary products) alongside the continued exploitation of wild fauna, including large and small ungulates, carnivores, birds, fish, and pond tortoises (for both meat and the recovery of raw materials such as bone, antler, and fur). These materials were likely essential for manufacturing tools, ornaments, and possibly trade goods.

Taphonomic analysis indicates specific wet post-depositional conditions, with minimal biostratinomic modification. Almost all the skeletal elements were recovered and show evidence of carcass processing within the settlement. The spatial distribution, composition of the assemblage and taphonomic modifications (such as cut marks, limited carnivore gnawing, and low degree of weathering) suggest it may represent a waste accumulation area situated at the edge of the settlement, where refuse was rapidly buried under stable, waterlogged conditions.

The presence of an on-site craft production centre is indicated by a diverse assemblage of finished and semi-finished artefacts, crafted from ungulate long bones and red deer antlers. The selection of raw materials appears both opportunistic and strategic, reflecting intimate environmental knowledge and resource management. Through detailed morphological and microscopic analyses, this study identifies various tool categories and, where possible, reconstructs the *chaîne opératoire* behind their manufacture.

The presence of crafted items, alongside evidence of both domesticated animal husbandry and wild fauna exploitation, highlights the community's adaptive strategies in resource utilisation, shedding light on early subsistence systems, technological practices and craftsmanship in the wetland landscapes of Early Bronze Age north-eastern Italy.

FOSSIL ACCUMULATION AND TAPHONOMIC PROCESSES AT GEOLOCALITY 83: A CASE STUDY FROM OLDUPAI GORGE (TANZANIA)

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Oldupai Gorge (historically referred to as Olduvai), located in northern Tanzania within the Ngorongoro Conservation Area, is among the world's most significant archaeological and palaeontological sites, offering unparalleled insights into human evolution and environmental change over the past 2 million years (Ma). The Gorge, characterised by its distinctive Y-shaped morphology formed by the Main and Side Gorges, is shaped by the seasonal Oldupai River and fluvial inputs from Mount Lemagrut, creating a complex hydrological system. The stratigraphic sequence at Oldupai spans nearly 235 metres, encompassing from bottom to top, the Ngorongoro and Naibor Soit Formations, Beds I–IV, Masek Beds, Ndutu Beds, and Naisiusiu Beds.

The Middle to Late Pleistocene units, particularly the Ndutu and Naisiusiu Beds, are much poorly known compared to the older ones, due to discontinuous exposures, pervasive sedimentary reworking, and dating challenges. Their sedimentary architecture is marked by river deposits, one or two pyroclastic units (historically identified as "yellow marker tuff"), and cyclic volcaniclastic sandstones deposited by hyperconcentrated flows. These cyclic events are frequently interrupted by episodes of pedogenesis especially in the Naisiusiu Beds, resulting in calcrete horizons indicative of depositional hiatuses. Distinguishing between the Ndutu and Naisiusiu Beds remains problematic, given their overlapping lithological and palaeontological characteristics and the lack of consistent chronostratigraphic markers.

Within this complex framework, the Tanzania Human Origins Research (THOR) team presents new findings from Geolocality 83 (~35 ka), a site of notable palaeontological significance, located near one of the Gorge's major faults. The site occupies a stratigraphic interval presumed to bridge the Ndutu and Naisiusiu Beds and hosts the one of the richest fossil assemblages documented in this section of the Gorge's stratigraphy to date. Integrated sedimentological and palaeontological analyses from Geolocality 83 provide new insights into the basin's late depositional history and support an in-depth taphonomic reconstruction.

Taphonomic analysis reveals that the fossil accumulation at Geolocality 83 do not result from a single depositional event, but rather from a complex interplay of post-mortem processes including scavenging, hydraulic transport, and localised sedimentation. The main assemblage is dominated by disarticulated and fragmentary remains of medium-sized ungulates (Size 2), which comprise 35% of the total Number of Identified Specimens (NISP) and 47% of the Minimum Number of Individuals (MNI). Taphonomic evidence (including bone surface modifications, coprolites, and juvenile hyena remains) indicates that hyenas were the principal accumulating agents, rather than large felids or canids, consistent with a scavenging-dominated assemblage and mirroring the composition of the local faunal community. Among the assemblage, articulated or associated specimens of *Pedetes* sp., *Damaliscus* sp., *Equus quagga*, and *Syncerus antiquus* were found within hyperconcentrated flow deposits, typical of a savannah thanatocoenosis involving short-distance transport of partially decomposed carcasses. The lack of fully articulated skeletons implies that these flows did not cause death but instead contributed to burial.

On the contrary, the discovery of three nearly complete skeletons of *Canis lupaster* (African golden wolf, ex. *Canis anthus*) located in a shallow, channel-shaped niche into the hyperconcentrated deposit differs sedimentologically and taphonomically from the surrounding hyperconcentrated flow facies (Fig. 1). This deposit formed by unconsolidated sand with parallel bedding lamination, may represent the remnants of either an animal-dug burrow or naturally

formed erosional niches commonly associated with hyperconcentrated flow deposits. The anatomical integrity of the *C. lupaster* specimens, absence of significant gnawing, and the presence of cranial puncture marks consistent with predation (likely by hyena), suggest that these individuals were killed and subsequently buried *in situ*. Radiocarbon dating of material from this deposit suggests a slightly younger age than the surrounding hyperconcentrated flow accumulation, adding further complexity to the stratigraphic framework of the site.

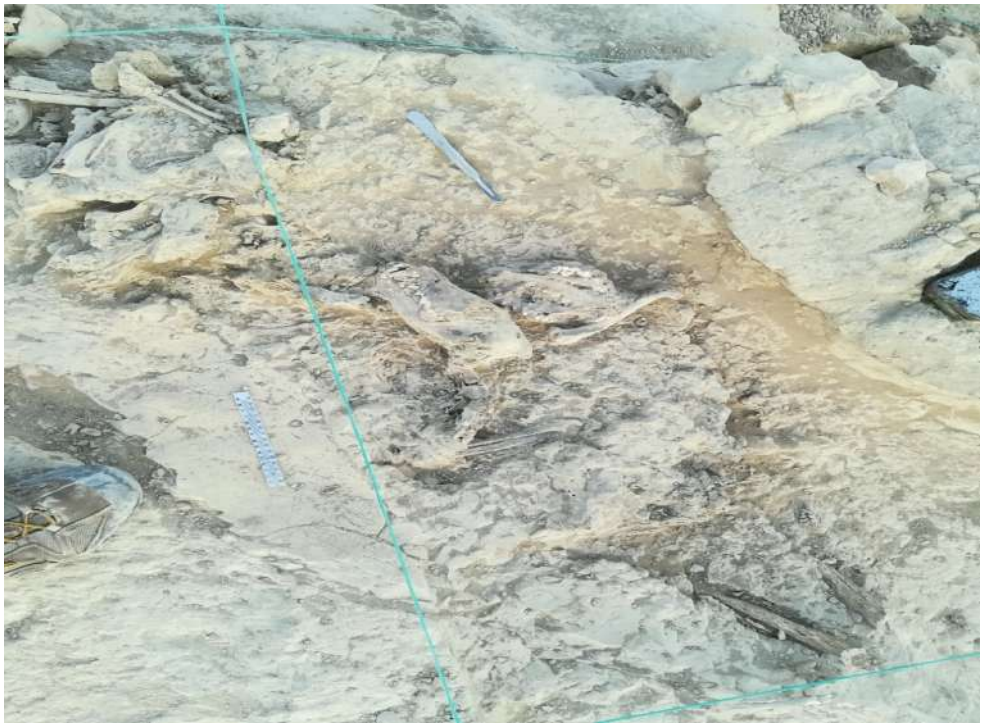

Figure 1. Excavation of *Canis lupaster* skeletons.

MICRO CT-SCAN ANALYSIS OF SHELL STRUCTURES IN UPPER OLIGOCENE *MIOGYPSINELLA* HANZAWA, 1940 (LARGER BENTHIC FORAMINIFER)

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Miogypsinids (Miogypsinidae Vaughan, 1928) constitute a group of orbitoidal larger benthic foraminifera (LBF) with hyaline-lamellar perforated shell, spiral-arranged nepionic chambers with later equatorial chambers, and spiral and intraseptal canals. This group differs from other orbitoidal forms by having an excentric position of the nepionic stage, located near the apex of the shell, and by the development of equatorial chambers in one sector only. Miogypsinids have been used in biostratigraphy of Oligocene–Middle Miocene deposits both in the Western Tethyan and in Indo-Pacific areas. The distinctive characters at genus level are based on shell structures shown by modern *Neorotalia mexicana* (Nuttall, 1928), a possible descendant of the fossil miogypsinids.

The shell architecture and systematic position of *Miogypsinella borodinensis* Hanzawa, 1940, type species of the genus and occasionally considered as the possible ancestor of the family, have been repeatedly discussed in literature. This species has been from time to time placed in the genus *Miogypsinoides* Yabe and Hanzawa. The frequently changing species names and concepts and the lack of morphometric and morphological details make difficult to evaluate the reliability of reports from the Western Tethyan and Indo-Pacific areas.

Hanzawa (1940) studied Late Oligocene (Chattian) material collected from drill cores in Kita-daito-jima (Japan). The type collection is preserved as thin sections and isolated specimens, housed at the Department of Earth Science, Graduate School of Science, Tohoku University, Sendai (Japan). The isolated specimens were micro-CT scanned at the Universidad de Granada, Spain. Although Late Oligocene in age, the specimens are very well preserved allowing direct observations on structural and architectural shell characters. The apertural lip, septal flap, intraseptal interlocular space around each embryonic, nepionic, and equatorial chamber were distinguished for the first time. Consecutive tooth plates are interconnected in adaxial position producing a primary spiral canal. Intraseptal canal system with vertical branches which issue from spiral canal and extend to ventral side only. Subsutural canals are exceptionally well preserved and illustrated.

WHO PREYED ON OUR ANCESTORS AND NEIGHBORHOOD? AN UNSOLVED PUZZLE FOR THE SOUTHERN BRAZILIAN TRIASSIC

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The *Riograndia* Assemblage Zone (Early Norian) is the youngest vertebrate fauna of the Brazilian Triassic, being the Linha São Luiz outcrop (LSLO), in Faxinal do Soturno municipality, Rio Grande do Sul state, one of the more emblematic sites. At LSLO is present a high incidence of microvertebrates (all around 10 cm in length), including procolophonids, non-rhynchocephalian lepidosauromorphs, sphenodontians, lagerpetids and probainognathian cynodonts (including *Brasilodon quadrangularis*, considered the sister-group of mammals). The fossils come from a massive sandstone facies, interpreted as an ephemeral fluvial system subject to seasonal catastrophic flooding with high sediment input related to deconfinement or avulsion of hyperconcentrated flows. Based on 160 specimens (samples) of microvertebrates from the LSLO deposited in the collection of the Universidade Federal do Rio Grande do Sul (Porto Alegre, Brazil), the following percentage of representation of bone elements was obtained: 39%, lower jaws; 17.5%, skulls plus lower jaws; 11.25%, skulls; 14.4%, post-cranial bones; 4.37%, lower jaws plus post-cranial bones; 3.12%, skulls plus post-cranial bones. Furthermore, 6.87% of the specimens are composed by groupings of partially articulated bones (skull, lower jaws and post-cranial bones), in a way that resembles an owl pellet. There is no signs of crushing or bite marks in the bones, as well as noteworthy corrosion of the bone surfaces. It has been preliminarily proposed that the concentration of small vertebrates in fossil sites is mainly controlled by predation. Unlike mammalian predators, whose chewing and digestion results in heavily damaged remains, birds can regurgitate skeletons with virtually no breakage and no apparent signs of corrosion. Furthermore, the larger the size of the bird predator compared to the size of the prey, the lower the degree of bone fragmentation inside the pellet. This set of evidence suggests for the taphocenosis of the LSLO selection (by size) and accumulation of carcasses by a carnivore medium to large size that regurgitate its food, similar to a modern owl. Actualistic experiments showed that the taphonomic history of a regurgitated pellet involves processes of weathering, disintegration, fragmentation, dispersion and transport, until final burial. Besides, the observed trend is that small/fragile bones are lost, whereas larger/more robust elements, as skull and lower jaws, are preserved. In the analyzed taphocenosis from the LSLO skull and lower jaw elements make up 67% of the sample, meeting this premise. Putative small- to middle-sized carnivores in the *Riograndia* AZ include a phytosaur, a stereospondyl amphibian and a basal saurischian dinosaur (*Guaibasaurus candelariensis*). Among these, *G. candelariensis* (c. 2 m in length) is the only who was found associated to these microvertebrates. Besides, considering its phylogenetic position, and the shared habit of regurgitation between crocodiles and birds, *G. candelariensis* is a plausible candidate for the role of producing agent of taphocenosis. Nevertheles, the microvertebrate fauna includes also an early diverging pterosauromorph (*Faxinalipterus minimus*) and a gracilisuchid

archosauromorph (*Maehary bonapartei*), both with skull lengths estimated between 3 and 5 cm long. These could represent two other alternatives of potential predators, assuming that the specimens that were found could be juvenile forms that would have been preyed upon (and regurgitated) by an adult of the same species. Moreover, several little (1 to 2 cm) cylindrical structures containing fragments of bones were also found from the same layers, and interpreted as coprolites of a carnivorous/scavenger member of the microvertebrate fauna. In this sense, the small-sized prozostodontian cynodont *Irajatherium hernandezi* (skull length estimated 4 cm), also recovered at LSLO, would be a suitable candidate. Indeed, because of its dentition and morphology (e.g., canine and post-canine teeth), a high bite forces and a tough food-based diet were already proposed for *I. hernandezi*. The LSLO represents an incredible window on the Brazilian early Norian, also including the first record of terrestrial vertebrates regurgitalites for the Triassic period in Gondwana. Further findings of known and new faunal components, as well as more in-depth analysis of already known fossil remains, can provide new keys to understand and solve these 225 Ma-old cold cases.

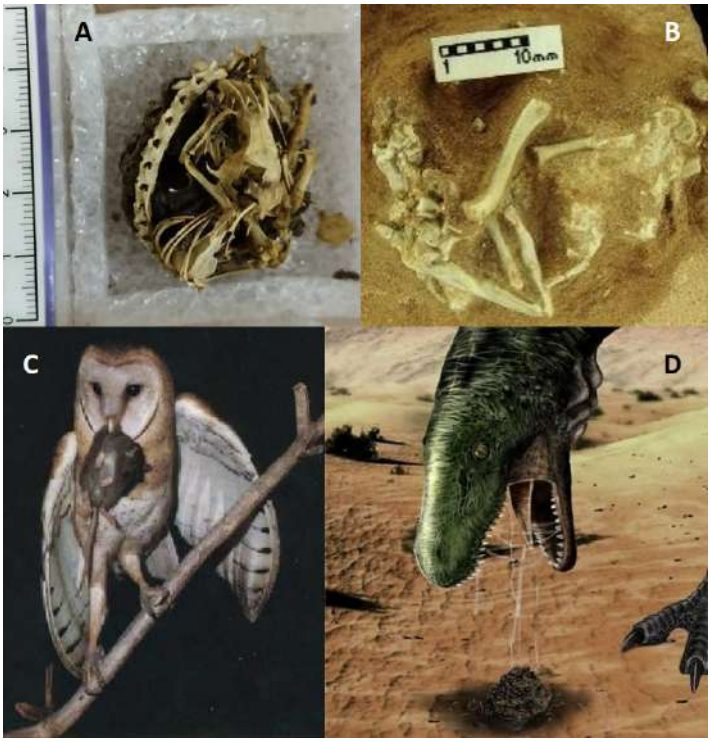

Figure 1. Recent pellet (A) produced by a nocturnal bird of prey (*Titus furcata*, in C) compared with a possible pellet from Late Triassic Linha São Luiz outcrop (B) and representation of a basal dinosaur producing it (D). Art reproduced in D is by Adolfo Bittencourt (adapted).

LITHIC TAPHONOMY: WELCOME TO THE DAMAGE

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Lithic taphonomy, as a specific field within archaeological research, has gained increasing attention in recent years as a means to understand the formation, transformation, and preservation of lithic assemblages. While the term “taphonomy” was originally coined by Efremov to describe the transition of biological remains from the biosphere into the lithosphere, its conceptual expansion has enabled archaeologists to apply similar reasoning to inorganic artefacts, particularly flaked stone tools. Unlike faunal remains, whose taphonomic trajectory begins unequivocally at the moment of death, lithic artefacts do not possess a biologically determined origin, and their post-depositional trajectory is instead linked to a complex interplay of environmental, sedimentary, mechanical, and chemical factors acting upon their surfaces after their cultural life has ended. The study of post-depositional surface modifications (PdAs) on lithics has traditionally been considered a challenge for functional analysis, as such modifications can obscure or mimic use-wear traces. Nevertheless, a growing body of research has demonstrated that these same surface alterations—ranging from edge rounding and polishing to patinas, fractures, and concretions—are valuable indicators of the environmental conditions and site formation processes that affected the assemblage after deposition. Despite this, the field of lithic taphonomy has suffered from a lack of standardized methods for recording and interpreting the sequence of such transformations. In response to this gap, we present and apply the Overlapping Method for the Taphonomy of Lithic Artefacts, a protocol developed to organize and interpret PdAs through the study of their superimposition. Drawing conceptually from analytical frameworks used in the study of rock art, this method proposes that the spatial relationships between different PdAs observed on lithic surfaces can be used to infer the relative chronology of post-depositional processes. Each PdA is defined as the result of a distinct environmental phase, and the method records their relationships as either consequential or contingent. Through the systematic analysis of these relationships across multiple artefacts, it becomes possible to reconstruct the overall sequence of taphonomic events that affected an assemblage. Originally developed through the analysis of the lithic assemblage from Pirro Nord 13 in southern Italy, the method has since been successfully applied in a range of archaeological contexts, including the Mousterian site of Ciota Ciara (northwestern Italy), the late Lower Palaeolithic open-air locality of Guado San Nicola (Molise, central Italy), and the Middle Palaeolithic site of Uzun Mera (North Macedonia). These applications have confirmed the effectiveness of the method in identifying environmental dynamics and differentiating assemblages that underwent distinct taphonomic histories. Rather than limiting itself to descriptive taxonomy, the Overlapping Method offers a processual framework in which the temporal order of alterations informs broader interpretations about site taphonomy. It enables the assessment of assemblage coherence, the identification of palimpsests, and the distinction between primary deposition and secondary reworking. Importantly, it also encourages a reconsideration of the role of damage itself: not as a hindrance to analysis, but as a valuable source of information. In conclusion, the study of PdAs through the Overlapping Method contributes to a paradigm shift in lithic analysis, positioning surface alterations as diagnostic tools for the reconstruction of archaeological and sedimentary histories.

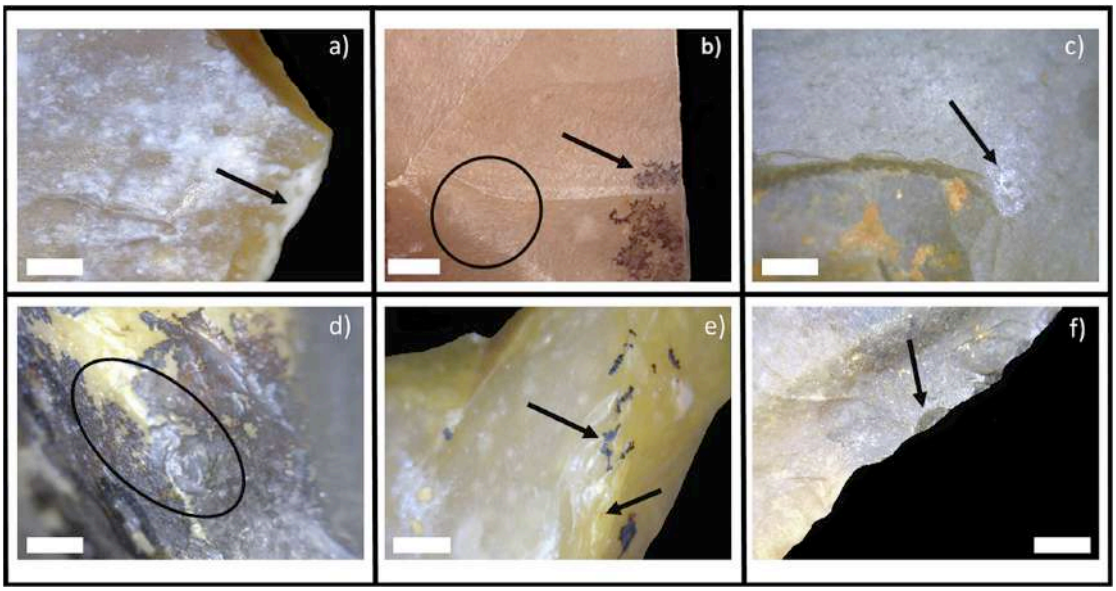

Figure 1. Examples of PdA overlap from PN13. a) white patina over rounding; b) Fe-Mn patina overlapping rounding; c) polishing over edge crumbling; d) Fe-Mn patina over rounding over edge crumbling; e) Fe-Mn patina over edge crumbling; f) Fe-Mn patina over edge crumbling. Scale bars: 1.5 mm.

IDENTIFYING FOSSIL FORMATION EVENTS THROUGH SPATIAL ANALYSIS: THE CASE OF LEVEL TE9D FROM SIMA DEL ELEFANTE SITE (SIERRA DE ATAPUERCA, SPAIN)

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The fossil record recovered from cave contexts typically reflects the influence of multiple agents (both biostratinomic and fossildiagenetic) acting over different time periods. However, these distinctions are often not appreciated during the excavation process, as post-depositional processes can displace materials and lead to the mixing of remains from different temporal and depositional contexts, resulting in a palimpsest. Recognizing this complexity is essential to avoid misinterpretations of the assemblage under study.

Sima del Elefante is a cave site with a visible sedimentary sequence approximately 25 m-thick, containing one of the longest Lower Pleistocene sequences (1.1–1.4 Ma) in Europe, as well as the earliest evidence of human activity on the continent. The fossil record recovered from the various stratigraphic levels is relatively scarce and exhibits unequal preservation. Bird remains are the most abundant, followed by those of ungulates and carnivores.

Previous studies on the faunal assemblage from the lower levels (TE14–TE9c) suggest distinct accumulation processes for the remains of birds, ungulates, and carnivores. These studies indicate that bird remains likely represent a primary accumulation, whereas the remains of ungulates and carnivores are interpreted as resulting from secondary or derived accumulations. This hypothesis is based on the identified taxa and the degree of preservation of the faunal remains. However, to date, no spatial analyses have been conducted to substantiate this interpretation.

Building on the hypothesis regarding the accumulation of fossil remains, we have initiated a line of research focused on the spatial analysis of the taphonomic properties of the faunal assemblages from of the Lower Pleistocene sequence at the Sima del Elefante site.

The first assemblage we analysed corresponds to level TE9d. We have conducted a comprehensive zooarchaeological and taphonomic analysis of all recovered faunal remains from this level. Subsequently, we performed a spatial analysis of the data using ArcMap and the *spatstat* library in R.

A total of 2,728 faunal remains has been recovered from level TE9d. Consistent with the general pattern of the site, bird remains are the most abundant, while macromammals are less represented. Evidence of anthropic activity is limited, with only four bone fragments bearing cut marks and four lithic artefacts identified.

Preliminary results indicate that the spatial distribution of the fossil remains varies by taxonomic group (birds, ungulates, and carnivores). Nevertheless, we have identified an area in which all groups are present.

The factors behind the observed differences in spatial distribution among taxonomic groups at level TE9d are unclear. In this study, we propose several hypotheses to be further investigated, including the possibility of multiple entry points for material into the cave, differences in the primary or secondary origin of the remains, and the impact of post-depositional processes within the cave environment.

TAPHONOMIC OBSERVATION OF BENTHIC FORAMINIFERA IN THE ARTIC REGION

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This study applies a taphonomic approach to investigate the impact of methane seepage on the preservation of calcareous benthic foraminiferal assemblages from sediment core HH1141, collected in the Barents Sea (Arctic region) and spanning the last 200 years. The 33 cm core was sampled at 0.5 cm intervals, and foraminiferal specimens were quantitatively and qualitatively examined in the >63 μm sediment fraction. Based on visual inspection and test microstructure of the most abundant taxa—using stereomicroscopy and Environmental Scanning Electron Microscopy (ESEM) coupled with Energy-Dispersive Spectroscopy (EDS)—five groups (A–E) were proposed to classify different degrees of diagenetic alteration.

In addition, geochemical and GDGT analyses of the sediments were conducted to interpret the environmental conditions throughout the core. The distribution of each foraminiferal group over the investigated time interval documents that the varying degrees of taphonomic alteration are linked to fluctuations in methane emission intensity. These results highlight the usefulness of foraminiferal test preservation as a proxy for reconstructing seepage dynamics in Arctic marine settings and demonstrate the value of taphonomic analysis in characterizing extreme environmental conditions.

TAPHONOMIC AND PALEOECOLOGICAL INSIGHTS FROM THE TYPE LOCALITY OF *PERUCETUS COLOSSUS*, AN OVERSIZED WHALE FROM THE EOCENE OF PERU

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The recent discovery of *Perucetus colossus*, an extremely pachyosteosclerotic heavyweight basilosaurid from the Upper Eocene Paracas Formation of Southern Peru, provides a unique opportunity to investigate the taphonomic processes affecting the preservation of massive, dense skeletons in coastal marine environments. This study presents a preliminary taphonomic assessment of the *P. colossus* holotype specimen integrating field observations with microanalytical data.

The skeletal remains, including 13 vertebrae, four ribs, and the right innominate (Fig. 1), were found disarticulated but still associated. They were recovered from fine-grained, slightly bioturbated siltstones that reflect a low-energy, open shelf depositional setting. Field observations revealed a rich associated flora and fauna, offering further paleoenvironmental insights into the depositional environment. Bony fish remains, including both scales and endoskeletal elements, belong to the families Clupeidae, Scombridae and Carangidae. They include juvenile carangids, which might suggest a nursery-like setting, possibly associated with seagrass meadows. This interpretation is broadly consistent with the common occurrence of plant remains as well as of abundant, delicate tests of possibly epiphytic benthic foraminifera. The associated macrofauna further includes small bivalves (e.g., oysters and pectinids), gastropods, bryozoans, echinoderms, epiphytic barnacles, and the costal plate of a marine turtle, which overall depicts a relatively nearshore paleoenvironment. Shark remains are rare and mostly consist of isolated *Galeocerdo* teeth. A large tooth of *Otodus (Carcharocles) auriculatus* was found contacting a *P. colossus* bone fragment, thus supporting a scavenging scenario in which the shark foraged on the carrion of the much larger whale.

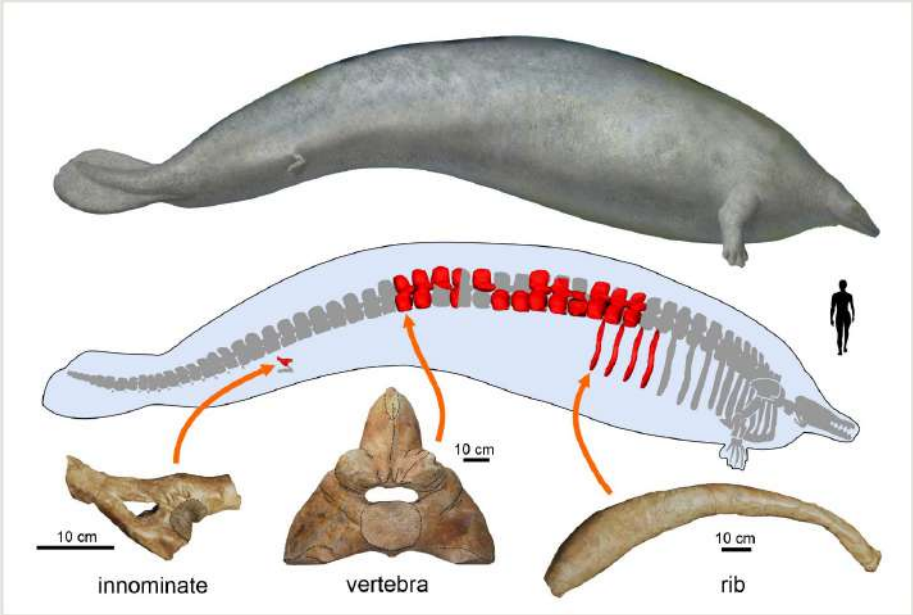

Figure 1. Schematic body and skeletal reconstruction reporting the preserved bones (red coloring) of *Perucetus colossus* (body reconstruction by Alberto Gennari).

To assess bone compactness and preservation, four core drill samples were extracted from different parts of the vertebrae, and one rib was sectioned. Thin sections were analyzed via optical and scanning electron microscopy, and in-situ chemical analyses were conducted using EPMA and LA-ICP-MS. Histological analysis revealed excellent preservation of key features such as osteons, osteocyte lacunae, and lamellae. All bones show pervasive osteosclerosis and generalized pachyostosis, with exceptional compact bone tissue resulting from both increased cortical thickness (pachyostosis) and extensive infilling of internal cavities (osteosclerosis *sensu stricto*). Taphonomic features include large bioerosional borings excavated through the bone tissue, some of which are filled with phosphatic microcoprolites. These borings locally cause the thinning of the trabeculae of the spongy bone, thus enlarging the intertrabecular cavities. These are often filled with sediment, or rimmed by silica and infilled with calcite crystals, suggesting two distinct phases of diagenetic mineral precipitation. Barite crystals are also present. Silica cement also fills microborings, Haversian canals and osteocyte lacunae, suggesting conditions favorable to silica precipitation during early diagenesis. The latter did also affect the hydroxyapatite composition of the bone tissue, which appears to be enriched in silicon.

The extraordinary skeletal density of *P. colossus* likely facilitated the rapid sinking and *in situ* stabilization of the carcass, thus minimizing the bone displacement. Disarticulation of skeletal elements, and the occurrence of invertebrate traces and microborings suggest a prolonged decay phase during which the bones remained exposed on the seafloor, allowing bone-eating microorganisms to modify the bone tissues before the final burial under low-energy conditions. In conclusion, these taphonomic and paleoecological observations shed light on the depositional history, biotic interactions, and diagenetic pathways that contributed to the exceptional preservation of one of the heaviest vertebrate skeletons ever discovered.

ESTIMATING PRE-BURIAL RESIDENCE TIME FROM THE INTERNAL STRUCTURE OF BRANCHING RHODOLITHS

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The residence time on the sea floor of rhodoliths (nodules mostly built by coralline algae) in modern rhodolith beds can be determined by radiocarbon dating of the initial growth stages. The time involved in growth of coralline algal nodules older than the application limits of this method (50–60 ka) has been estimated from the growth rates of their components. However, detailed analyses of growth patterns have shown that rhodoliths can develop in multiple phases with prolonged periods of interruption. The internal structure of nodules can help to qualitatively estimate the residence time of rhodoliths on the sea floor/taphonomically active zone before definitive burial.

In large, nucleated nodules it has been shown that long residence times (hundreds to thousands of years) lead to destruction of the original internal structure by repeated boring by invertebrates and infilling of bioperforations. In non-nucleated branching rhodoliths, the internal architecture of branches implies that their central part, composed by longer cells with walls thinner and richer in Mg, is more vulnerable to dissolution than their sides.

Low-sedimentation rates common in shallow-water rhodalgal carbonates imply long residence times of branching rhodoliths in the taphonomically active zone and, consequently, both modern and fossil branches occur with an empty or vuggy central part and well-preserved sides (macaroni corallines). This kind of preservation is common coralline algae in Middle to Upper Miocene shallow-water heterozoan carbonates in the Betic Cordillera in southern Spain. In contrast, macaroni corallines are rare in coeval redeposited carbonates, in which branching nodules and branch fragments show homogeneous preservation with no differential dissolution of central parts. These taphonomic features in coralline algae in sediment gravity flow deposits indicate rapid removal of the algae from the taphonomically active zone in shallower areas of the shelf and definitive burial before early-diagenetic dissolution.

CHARACTERISATION OF CALCAREOUS CONCRETIONS ON FAUNAL REMAINS FROM VAJO SALSONE SITE (MONTI LESSINI, NE ITALY): PRELIMINARY OBSERVATIONS AND TAPHONOMIC POTENTIAL

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The Middle Palaeolithic site of Vajo Salsone (Monti Lessini, northeastern Italy) has yielded a rich faunal assemblage associated with lithic remains, both of which are affected by calcareous post-depositional concretions. While these processes have been investigated on lithic artefacts using X-ray fluorescence spectrometers and X–RFS analyses on thin sections, similar concretions on faunal remains have not yet been considered. This paper presents preliminary observations on the extent, morphology and composition of carbonate concretions on a selected sample of faunal bones, to assess their taphonomic implications in terms of diagenetic processes, depositional conditions and preservation of anthropogenic modifications. From an interdisciplinary perspective, this analysis aims to provide a basis for future integrated studies combining taphonomic, zooarchaeological and geoarchaeological approaches.

To further characterise the carbonate concretions and better understand the diagenetic pathways involved, a suite of analytical methods can be applied. Optical and scanning electron microscopy (SEM) enable detailed microstructural observations of bone surfaces and concretions, including the identification of microcracks, recrystallisation patterns, and the presence of secondary mineral phases. Energy-dispersive X-ray spectroscopy (EDS) coupled with SEM facilitates the elemental characterisation of concretion components.

Complementary geochemical analyses include inductively coupled plasma mass spectrometry (ICP-MS) for determining the concentration of trace elements potentially involved in fossilisation processes or originating from post-depositional fluid interactions. These data can shed light on the timing and conditions of concretion formation (e.g., early vs. late diagenesis), the presence of iron and manganese oxides, and the extent of apatite recrystallisation. In selected samples, thin-section petrography in transmitted and reflected light can reveal textures and diagenetic overprinting, particularly in cortical bone. This offers insights into the interplay between bone tissue and cementing agents.

In addition, in situ micro-Raman spectroscopy represents a powerful, non-destructive technique to investigate the mineralogical composition and crystallinity of apatite within bone and concretion matrices. This approach provides high-resolution molecular-scale insights into the preservation state of fossil bone apatite and can thus significantly refine interpretations of concretion genesis and taphonomic pathways. The integration of these analytical techniques will significantly contribute to the reconstruction of post-depositional histories of the Vajo Salsone assemblage and support the development of interpretative models linking the formation of calcareous concretions to specific environmental and geochemical settings.

NEW INSIGHTS ON PHOTOPHORE STRUCTURE AND SOFT TISSUE PRESERVATION OF YPRESIAN DEEP-SEA FISHES FROM NORTHEASTERN ITALY

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Mesopelagic fishes are some of the most abundant animals in today's oceans and stand out amongst other marine vertebrates for their bioluminescent capabilities. The first Cenozoic representatives of some of the most characteristic deep-sea fishes, such as stomiiforms and myctophiforms, date back to the early Eocene. The ichthyofaunas from the sites of Solteri and Monte Solane (Trento and Verona provinces, northeastern Italy) yielded some of the most ancient specimens of some of these mesopelagic taxa (e.g., Phosicthyidae, Gonostomatidae; order Stomiiformes) dating back to the Ypresian. Furthermore, they show exquisite preservation of their soft tissues, especially of their luminous organs, the photophores. Despite a renewed interest in soft tissue preservation from fossil fishes, photophores' anatomical structure and taphonomy have never been investigated.

We carried out Raman spectroscopy and SEM analyses on the fossil photophores of different teleost families (i.e., Gonostomatidae, Phosichthyidae, Myctophidae) to examine their structure and cellular components (i.e. melanosomes) in comparison with other soft tissues (e.g., eyespots, gut content, skin). The fossil specimens are also being directly compared to modern specimens belonging to the same families, in order to better frame their preservation and to understand the evolution of luminous organs in these deep-sea taxa.

FOSSILIZATION IN VERTEBRATES FROM VALLECILLOS, NORTHERN MEXICO: A MICROSTRUCTURAL ANALYSIS

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The Vallecillos locality from the Agua Nueva Formation in Hidalgo, Nuevo Leon, northern Mexico, is a spectacular Lagerstätten from northern Mexico with an approximate age of 94 Ma. The fossil assemblage is dominated by marine fishes, especially genera such as corresponding mainly to Tselfatiforms, Picnodontids, Ichthyodectiformids, Aulopiforms and Pachyrhyzodontids. Less frequently remains of fossil turtles and chondrichthyans have been also reported. More recently, a mosasaurs and plesiosaurs have also been reported. Bivalves and ammonites are among the most common invertebrates, and microfossils are represented by planktonic foraminifera. *Inoceramus labiatus (Mytiloides)* is the fossil guide that dated this formation since the pioneer descriptions.

The Agua Nueva formation consists of grey laminated limestones with fossils and non-laminated limestones and marlstones interbedded with thin-bedded carbonaceous shales and chert in some outcrops. The environment has been interpreted as an outer shelf environments and basin facies. Although taxonomic studies have shown exquisite preservation, there are not studies at the microstructural scale.

This work reports preliminary results on the microstructure of vertebrate fish observed by SEM using natural simples. Fossil pycnodont remains macroscopically shows the whole vertebral column with more than 15 dorsal spines. These fossils exhibit a relatively good preservation in terms of the completeness as articulated organisms, color and original arrangement of the axial skeleton. The light pink sedimentary matrix has replaced the original organic material in a fashion that the original organic materials seem to be a thick outline of the axial skeleton. Microstructural observations show a tabular, rounded and rigged cavities, some of them containing individual opaque precipitates and single euhedral crystals. Other diagenetically-induced cavities show small holes inside organic fibers inserted to the caudal spinal cord. Biofilm remains were observed only in a few cases. Microstructural information obtained from direct observations of fossils is still a theoretical gap to document fossilization process.

SILENT ARCHITECTS: DECODING BIOEROSION TRACES IN MOLLUSK SHELLS FROM THE SOUTHWEST ATLANTIC

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The stratigraphy of the upper subsurface of the Argentine continental shelf comprises upper Pliocene to Holocene seismic stratigraphic sequences. In this context, marine core C19, obtained 104 km off the coast of Buenos Aires at a depth of 68 meters, offers valuable insights into benthic paleocommunities and bioerosion patterns across the Pleistocene–Holocene boundary. The aim of this study is to evaluate differences in bioerosion traces on mollusk shells within bioclastic levels and to contribute to the fossil record of soft-bodied marine organisms associated with these structures. The core measures 69.5 cm in length and consists of six sedimentary levels, five of which contain whole and fragmented shells of bivalves and gastropods. These bioclasts exhibit a variety of bioerosion traces attributed to different ichnogenera, including *Entobia* isp., *Pinaceocladichnus* isp., *Oichnus* isp., *Maendropolydora* isp., *Iramena* isp., *Finichnus* isp., and *Semidendrina* isp. These traces result from the activity of boring sponges, polychaetes, bryozoans, carnivorous gastropods, algae, and fungi. The ichnological evidence suggests the coexistence of these bioeroders within marine sublittoral environments characterized by varying energy conditions and sediment types. Levels N1 through N4 are dominated by *Entobia* isp. and *Pinaceocladichnus* isp., indicating well-oxygenated, sandy sublittoral settings. Predatory borings such as *Oichnus simplex* and *Oichnus paraboloides* were observed on live mollusks, reflecting trophic interactions within these communities. In contrast, level N5 displays increased diversity and abundance of ichnogenera, indicative of more energetic hydrodynamic conditions and greater plankton availability. The uppermost level (N6) lacks bioerosion traces, possibly due to taphonomic or environmental changes. This study highlights the significance of bioerosion traces in reconstructing ancient marine ecosystems and provides new paleobiological data on soft-bodied benthic organisms, which are otherwise absent from the fossil record. It also contributes to understanding the environmental evolution of the Argentine continental shelf during the late Quaternary.

TAPHONOMIC PROCESSES ON THE TIDAL SEDIMENTS OF THE RIVER THAMES FORESHORE, CENTRAL LONDON

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This preliminary study investigates the taphonomic processes acting on the intertidal sediments of the River Thames in central London.

The Thames foreshore, often referred to as the longest open-air archaeological site in the UK, is unique depositional environment shaped by the river's pronounced tidal regime, which exposes its foreshore twice daily due to a tidal range of over 7 meters. Unlike other major European urban rivers such as the Seine or Tiber, the Thames offers a dynamic, open-air context for observing sedimentary and taphonomic activity related to not only to organisms but also to artefacts (para-taphonomy).

This research documents both natural and anthropogenic taphonomic influences on organic (e.g., wood, leather, bone, wool) and inorganic (e.g., ceramic, metal) artefacts found along the riverbanks. By extending the concepts of autochthony and allochthony to include human-induced processes (such as trade, industry, and urban waste disposal) the study highlights the complex interactions between cultural and environmental factors in shaping the Thames paleontological and archaeological record.

The foreshore of the Thames presents a valuable archive for reconstructing historical fluvial regimes, depositional phases and patterns of urban development. Understanding these processes contributes to a more accurate interpretation of the occurrences and preservation of fossils and artefacts, and offers insight into how environmental variation (such as changes in flow rate, vegetation, pollution) has influenced the long-term survival of both organic and inorganic materials in an urban river system.

BIOTIC AND ABIOTIC PROCESSES OF BONE ACCUMULATION AT PANTALLA (ITALY), WITH A FOCUS ON INTRAGUILD PREDATION EVIDENCE

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Natural populations and the structure of biological communities are influenced by both direct interactions (such as predation) and indirect ones (like exploitative competition) among different species. One notable aspect that affects carnivore dynamics is the phenomenon of interspecific killing, where one carnivore species kills another. Although such intraguild interactions are frequently observed in natural ecosystems, the ecological and behavioral factors driving them remain largely unclear. This topic is often overlooked in paleontological analyses of ancient terrestrial ecosystems, primarily due to the lack of direct fossil evidence demonstrating these interactions.

The fossil collection from Pantalla (Perugia; central Italy) provides a unique chance to explore this subject. Excavations conducted at the site in the 1990s unearthed approximately one hundred exceptionally preserved terrestrial mammal fossils. These include eight nearly complete crania of carnivorans and three of artiodactyls, in addition to various mandibles, teeth, and postcranials. At least 11 mammal species have been identified at Pantalla: *Apodemus dominans*, *Canis etruscus*, *Vulpes* sp., *Lynx issiodorensis*, *Acinonyx pardinensis*, *Lutraeximia umbra*, *Sus strozzii*, *Pseudodama nestii*, *Leptobos merlai*, *Equus stenonis*, and *Mammuthus* cf. *meridionalis* (Fig. 1).

Approximately half of the fossil specimens were recovered from a single bone concentration ca. 2 m^2 wide located within a fine-grained sandy layer. In this deposit, cranial elements are particularly notable due to their high completeness, excellent preservation, and relative abundance. The lack of signs typically associated with post-mortem transport (such as breakage or surface wear) as well as the remarkable preservation of even the most fragile anatomical features (like the braincase and tips of antlers), combined with the absence of coarse fragments in the sandy matrix, all point toward a rapid burial event. The remaining fossils in the collection were found about 2 m above the previous bone concentration, embedded in a grayish sandy-mud layer. These specimens were more scattered along the outcrop and displayed clear signs of weathering, such as a characteristic "mosaic" cracking of the bone surfaces. Such traits are consistent with a pedogenetic accumulation.

Both fossiliferous layers are referred to the Santa Maria di Ciciliano Formation, which was deposited mainly in a fluvial context. The unit is characterized by interbedding sand and mud beds, as confirmed by the recent study of a 40 m core drilled in the paleontological site and a reassessment of numerous natural outcrops in the area. The depositional environment has been interpreted as a riverine system characterized by an expansive floodplain that was regularly inundated. The water level in the river channel likely fluctuated significantly, probably in response to seasonal changes. During periods when the floodplain was dry, paleosols began to form. However, the limited development of these paleosols, along with the considerable thickness of floodplain deposits, indicates a high sedimentation rate. This reconstruction is supported by the composition of the ostracod assemblage analyzed in the Pantalla core. Further paleoenvironmental information is provided by the Pantalla palynological record, according to which the depositional system was surrounded by a conifer-dominated forest suggestive of a

glacial phase. Geochronological and biochronological data point toward a dating of the paleontological site at c. 2.2 Ma, that is, at the Middle-Late Villafranchian transition.

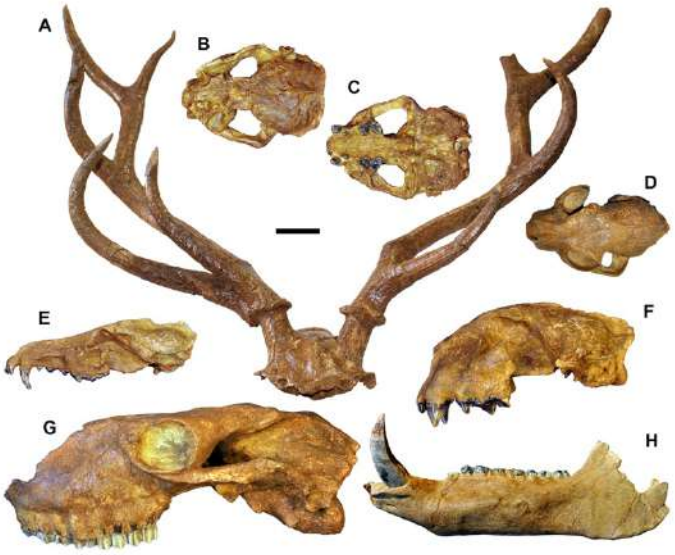

Figure 1. Fossil mammals from Pantalla. A, *Pseudodama nestii*; B-C, *Lutraeximia umbra*; D, *Lynx issiodorensis*; E, *Canis etruscus*; F, *Acinonyx pardinensis*; G, *Leptobos merlai*; H, *Sus strozzii*. Scale bar: 5 cm.

Detailed morphological examination of the fossils from the lower bone concentration revealed distinct tooth marks on at least three carnivoran crania—two of *C. etruscus* and one of *L. issiodorensis*. Additional, less distinct marks were found on two other *C. etruscus* crania, though their interpretation is more uncertain. Measurements of the spacing and size of these marks suggest that they were inflicted by the "giant cheetah" *A. pardinensis*. This conclusion is further supported by digital reconstructions and simulations using CT-based 3D models of the skulls. Studies focusing on the remarkably preserved skulls of *A. pardinensis* from Pantalla have shown that this species likely hunted differently from its alleged extant relative, the cheetah *A. jubatus*. The craniodental morphology, as well as the reconstructed jaw musculature, indicate that *A. pardinensis* employed a predation strategy more akin to that of large pantherine cats: a conclusion that aligns with the evidence from bite mark analysis. For this reason, at Pantalla we find the unusual case in paleontology of the coexistence of prey and their predator in the same bone concentration. The taphonomic features of the fossil assemblage suggest that its formation and burial resulted from a combination of biological and environmental factors, pointing to a complex formation history. This scenario appears to be unique within the context of the European record of terrestrial mammals.

HIPPOPOTAMUS FOSSIL REMAINS FROM THE PLEISTOCENE OF MAGLIANELLA (ROME, ITALY): NEW EVIDENCE AND INTERPRETATIONS

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Abundant fossil hippopotamus skeletal remains have been recovered during the first half of the 20th century, along the Via Aurelia, in the locality of Maglianella (Rome, Italy). Despite the abundance of material, only a small portion was previously described and assigned to the now-debated species *Hippopotamus tiberinus*. The entire collection is currently housed at the Natural History Museum of the University of Pisa (Calci, Italy), where a composite skeleton is also displayed. The bone assemblage is represented by approximately 530 specimens, including 19 cranial elements, numerous isolated teeth, postcranial bones and bone fragments.

These remains are attributable to a minimum of six individuals, represented by five left scapulae and a mandible with deciduous dentition. The postcranial remains can be attributable to individuals at different ontogenetic stage, as testified by several molars at different stage of wear, as well as scapulae displaying variation in the development of the root of the scapular spine (Fig. 1A). Basing on the age-classes reported for the extant *Hippopotamus amphibius*, we identified individuals belonging to classes II (estimated age less than 6 months), VIII (estimated age c. 11 years), XIV (estimated age c. 27 years), XV (estimated age c. 30 years), XVII (estimated age c. 35 years), XVIII (estimated age c. 38 years). Among the studied specimens, an individual shows evidences of malocclusion, with the third molar anomalously worn on the mesial side.

The state of preservation of the specimens is extremely variable. Nonetheless, several taphonomic features are observable. Bite marks and gnawing marks are evident on pelvis (Fig. 1B), primarily on ilia, suggesting scavenging activity by large-sized animals, probably hyenas or lions. A noteworthy pattern is that carnivores consume hippopotamus carcasses, beginning at the backside of the deceased animal.

Striations and shallow grooves (Fig. 1C) on long bone surfaces indicate brief fluvial transport or their deposition in shallow waters with moderate energy. This hypothesis is in agreement with microscopic observations of a few sediment samples collected from the bone surfaces and characterized by small granules of quartz.

These features provide valuable insights into the depositional and post-depositional processes that led to the formation of this remarkable hippopotamus bone assemblage.

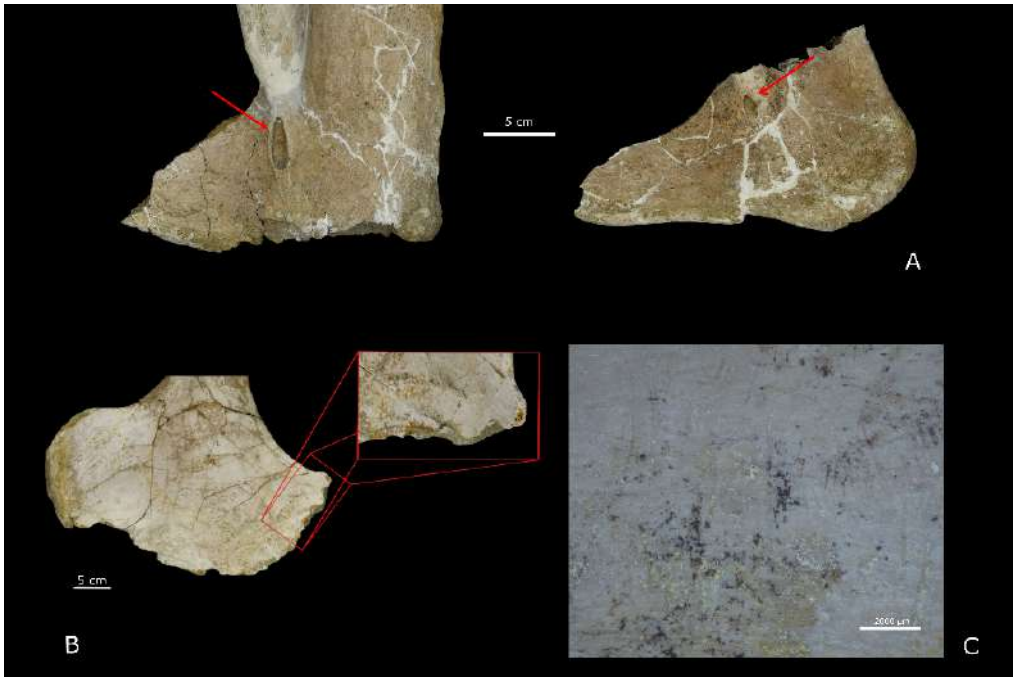

Figure. 1. Remains of *H. tiberinus* from Maglianella (Roma; Pleistocene). (A) Left scapulae showing variation in the development of the root of the scapular spine (indicated by red arrows), dorsal view. (B) Ilium with traces of bite marks and gnawings probably caused by large-size carnivores, dorsal view. (C) Striae and grooves on the dorsal surface of a costa (photo acquired with ZEISS SYCOP 3).

TRACE FOSSIL EVIDENCE FOR *OSEDAX* EXPLOITING SHARK TOOTH DENTINE ON A PLIOCENE MEDITERRANEAN SEAFLOOR

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The bone-eating worm, Osedax, is part of a peculiar group of deep-sea organisms that thrive at whale fall localities on the ocean bottoms. In addition to whale bones, extant Osedax spp. have been shown to be able to feed on the bones of other marine and terrestrial mammals, birds and reptiles, and lately also on shark teeth, exploiting the latter's dentine under experimental conditions. In the palaeontological record, the osteophagous activity of Osedax is evidenced by traces of the ichnogenus Osspecus, which have been found on a variety of vertebrate fossils, but not on fossil shark teeth.

Here, we report on the occurrence of Osspecus borings on shark teeth from Lower Pliocene offshore deposits of Tuscany, central Italy. Micro-CT investigations reveal that the traces in question excavate the dentine of the tooth roots, leaving the enameloid-coated crowns seemingly unaltered. Although many such borings have turned into poorly defined pockmarks due to the collapse of the delicate trace "roof", some of them preserve a pristine 3D morphology, thus allowing for an unambiguous ichnotaxonomic identification.

This ichnological record provides the first fossil evidence for Osedax exploiting shark tooth dentine. Furthermore, it serves as a powerful demonstration that such a behaviour can and does occur in the wild (i.e., outside experimental conditions). Root exploitation by bone-eating worms may explain the high frequency of rootless teeth in some shark tooth accumulations from modern deep-sea floors and time-averaged bonebeds.

“LOCALITY 84”: A WINDOW INTO LATE CRETACEOUS LIFE —-A NEW KONSERVAT-LAGERSTÄTTE FROM THE JULIAN PREALPS (NE ITALY)

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“Locality 84” is a newly identified *Konservat-Lagerstätte* from the Friuli Carbonate Platform in northeastern Italy, notable for its relatively well-preserved, articulated fish skeletons and a diverse assemblage of plant fossils. These remains were recovered from a carbonate olistolith embedded within one of the megabeds that characterize the late Palaeocene–early Eocene Grivò Flysch Formation in the Julian Prealps. The assemblage is dominated by fish fossils, though plant material accounts for approximately one-third of the recovered specimens. A Cretaceous age for the olistolith is supported by the presence of the conifer *Frenelopsis* and the ichthyofauna dominated by pycnodontiforms and basal non-acanthomorph teleosts. A Late Cretaceous age is indicated by a fossil flora dominated by angiosperm leaves, and the presence of rare primitive acanthomorph teleosts and of pycnodontine pycnodontiforms. Additional paleontological evidence constraining the assemblage to a more specific time interval is also considered. Taphonomic features, such as articulation of skeletal elements, limited evidence of transport or scavenging, overall completeness, dark colour of the rock and thin undisturbed lamination, suggest low-energy depositional conditions favorable to fossil preservation. Compared to other Cretaceous fossil sites on the Friuli Carbonate Platform, "Locality 84" stands out due to the absence of both shelled and soft-bodied invertebrates, the rarity of conifer shoots, and a fish assemblage dominated by pycnodontiforms and basal non-acanthomorph teleosts (e.g., elopiforms, albuliforms, gonorhynchiforms, and crossognathiforms). Acanthomorphs are scarce, while clupeomorphs, needlefish-like aulopiforms, and chondrichthyans are not represented. The depositional setting is interpreted as a restricted, low-energy water body or tidal flat within the inner Friuli Carbonate Platform, with only occasional influence from open marine conditions. These environmental factors likely played a key role in the degree of fossil preservation observed at the site.

WHO BROUGHT WHAT? NEED FOR A TAPHONOMIC APPROACH ON BONE REMAINS FROM A ROOST OF LARGE RAPTORS: POSSIBLE IMPLICATIONS FOR CURRENT PROTECTED SPECIES

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We present the results of the taxonomic analysis, and preliminary taphonomic aspects of non-fossil bone remains from a ledge on the southern slope of Colle Tordina (823 m a.s.l.), located in the Gola della Rossa e di Frasassi Regional Natural Park. The ledge, which opens onto a vertical rock wall, is connected by a short tunnel to a sub-horizontal cave. The assemblage was collected on the ledge in the early 1990s to investigate the diet of the Golden Eagle (*Aquila chrysaetos*), a species historically present in the area. However, the surveys were carried out without a taphonomic approach at the time, which means that we cannot know the distribution of in situ remains today. A first group of 54 unarticulated, unfragmented *Vulpes vulpes* bone remains, covered by a dark organic patina, was recovered inside the cave, near the tunnel's opening. We hypothesised that these remains are of an individual that died within the cavity. A second assemblage, consisting of 387 identified remains of mammals (76.74% NISP; 69.23% NMI) and birds (23.26% NISP; 30.77% NMI), was recovered from the ledge and the adjoining tunnel. These finds are loose, lack organic parts, are mostly fragmented, and often encrusted with calcareous concretions. Four vertebrae, likely originating from an open-air dump, present clear signs of butchery. Most of the finds belong to domestic fauna (73.90% NISP; 65.38% NMI), including domestic *Felis catus*, *Canis familiaris*, *Capra* vel *Ovis*, *Equus* sp., *Sus domesticus*, *Oryctolagus cuniculus* var. domestica, *Gallus domesticus*, and *Columba livia*. Among the wild species present are remains of *Martes* sp., *Sus scrofa*, L*epus europaeus*, *Gyps fulvus*, *Bubo bubo*, *Tyto alba,* and *Pyrrhocorax graculus*. Among mammals, the domestic rabbit is the most represented animal, followed equally by domestic cat and caprids, and then by the common hare. Among birds, the domestic chicken is the most abundant. At least 8 young individuals were identified among the domestic mammals, except for the dog, present with two small adults. Wild fauna, both mammals and birds, is exclusively represented by adult individuals.

A preliminary visual examination of the material, which showed no signs of carnivore chewing, led to the hypothesis that the bone accumulation was created over time by raptors that frequented the site in different historical periods. Among these, the main suspects, due to the size of the potential prey discovered, are *Gyps fulvus* and *Bubo bubo*, of which bone remains were found, and *Aquila chrysaetos*, which was observed using the ledge as a *roost* at the time of collection. The results of the taxonomic study are consistent with the known diets of all three raptor species, despite significant differences in their specific feeding behaviour. The griffon vulture is a non-hunting scavenger that feeds on the soft tissues of animal carcasses; likely, bone remains in the nest are ingested during the consumption. The golden eagle is an active diurnal hunter that brings its prey to the nest. The eagle owl is a nocturnal predator that regurgitates undigested bones as pellets. But, which of them brought which bones to the nest, when, and why? Our analyses are still in progress and the data do not allow us to distinguish the specific role played by each species in this bone accumulation, which is highly heterogeneous considering the taxa represented and the bone surface characteristics.

With this contribution we wish to underline the importance that a taphonomic approach could have given in ecological studies to recognize the agents of accumulation through the discrimination of traces detectable on the bone surfaces.

A more in-depth analysis of these bone remains, conducted with a taphonomic approach normally applied in archaeozoological research, could perhaps provide new keys to understanding and solving this case. Integrating biological and ecological studies with taphonomic analysis could

provide valuable information for the conservation of protected species, such as the large birds of prey covered by this study, which are all protected under the Birds Directive 2009/147/EC. In particular, the discovery of bones of *Gyps fulvus* is of exceptional relevance in the context of biological conservation. Clarifying the presence and role of this species in bone accumulation, together with other biological analyses (dating, DNA, etc.) could help us better understand its recent history and perhaps provide clues to the first evidence of historical nesting in peninsular Italy. Currently, the species breeds in the central Apennines only thanks to the results of reintroduction programs conducted in recent decades, but the historical breeding in peninsular Italy, although hypothesized, has never been demonstrated. Such data would be very important for future conservation efforts of this species.

MORPHOLOGY AND TAPHONOMY OF THE GASTROPOD *TEREBRALIA PALUSTRIS* FROM AN IRON AGE SITE IN THE ARABIAN PENINSULA

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Muweilah is an Iron Age II site (1000–600 BC) near the City of Sharjah, United Arab Emirates, located in an aeolian sand dune belt 15 km away from the coast. The position enabled trade between coastal and inland systems, made possible by the domestication of the camel and improved herd management. Excavations from 1994 to 2006 under the supervision of Peter Magee, Bryn Mawr College (USA) uncovered over 40.000 mollusk remains, which were lent to the University of Tübingen for detailed study. Among these, the large, edible mangrove gastropod *Terebralia palustris* dominates. This species, in the past and present widespread in the Indo-Pacific, is now extirpated in the northern Arabian Peninsula except for last occurrences in Khor Kalba (Sharjah, UAE). The aim of the research was to correlate the shell structure of *Terebralia palustris* with fragmentation, to analyze taphonomic differences between archaeological and natural settings, and to link specific preservation patterns with handling as well as consumption techniques.

Methods include morphometry, thin sectioning and scanning electron microscopy of recent *T. palustris* specimens from Khor Kalba. Remains from the Iron Age site of Muweilah were subjected to a semi-quantitative analysis including various taphonomic processes affecting preservation.

T. palustris shows a complex internal structure with a thick cross lamellar layer (Fig. 1A), which consists of alternating sublayers of densely packed fibrous elements (≤30 μm diameter) oriented obliquely to one another, and which is surrounded by a thin, homogeneous outer and inner surface layer. Both the archaeological and the recent shells show ablation (Fig. 1B) on exterior surfaces as well as small oval to round holes near the Apex (Fig. 1C). The archaeological material stands out due to high fragmentation and surface abrasion on external surfaces (Fig. 1D), which can lead to the complete removal of the outer surface layer and can reach into the crossed lamellar layers. Edge abrasion occurs on a few specimens (Fig. 1E). Internal surfaces of the shell are in a better state of preservation regarding shininess and ablation than the exterior surfaces. The internal surfaces are affected by cracks, which are mostly restricted to the surface layer and overlap leading to a reticulated pattern (Fig. 1F). Color alterations appear along the entire shell (Fig. 1G), reflected by color changes of ablated surfaces from white to beige. In addition, 6 % of the specimens show a grey to black color (Fig. 1H).

Fragmentation, surface abrasion and cracking do not occur on the recent *T. palustris* shells and reflect consumption related processing methods, predominantly shell breakage to extract the flesh. Cooking processes cause color alterations through temperature dependent microstructural changes at 200°C—300°C and a grey coloration at 400—500°C, indicating roasting in addition to boiling as primary preparation methods. Finally, ablation and holes on the exterior surfaces near the apex are caused by natural processes.

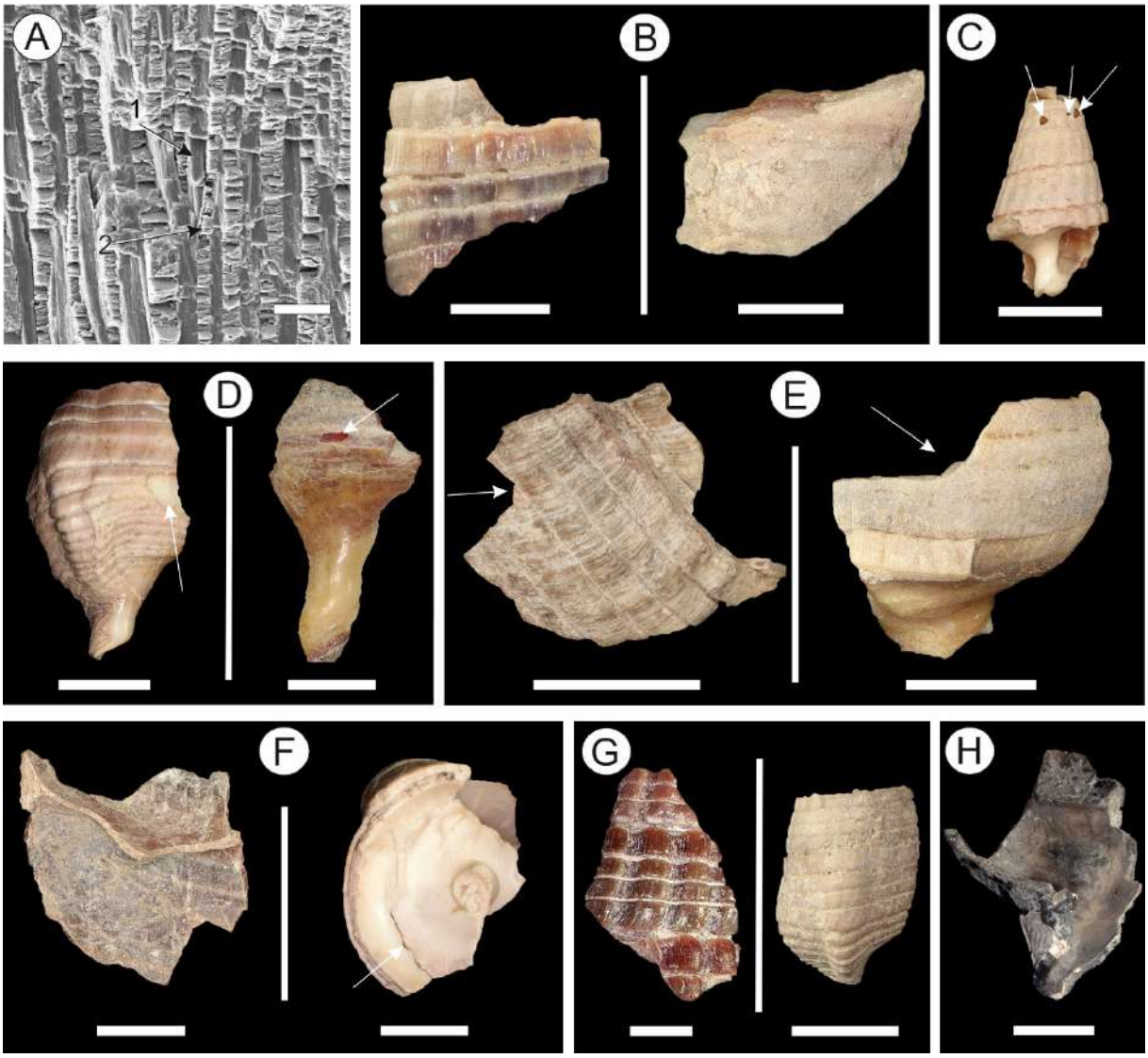

Figure 1. *Terebralia palustris* (Linnaeus, 1767). A) SEM micrograph of cross lamellar layer (Scale: 0.1 mm). B) Ablation (Scale: 10 mm). C) Apex holes (Scale: 10 mm). D) Surface abrasion (Scale: 10 mm). E) Edge abrasion (Scale: 10 mm). F) Crack presence (Scale: 10 mm). G) Color alteration (Scale: 10 mm). H) Burned specimen (Scale: 10 mm).

BIOSTRATINOMY, NECESSARY OR JUST A WHIM OF GEOLOGISTS?

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For decades, palaeontologists have studied various aspects of the paleobiology of ancient organisms, many of which are housed in museum collections, often without considering the burial conditions that led to their fossilization. Trilobites are undoubtedly among the most iconic and abundant fossils in our museum collections, prized for both their abundance and beauty. As arthropods, trilobites grew through moulting and had the ability to enclose their bodies (i.e. enrolment) as a defensive strategy to protect their ventral side from predators or adverse environmental conditions. In this abstract, I explore these two features to emphasize the relevance of biostratinomy in palaeobiological and ecological research.

Development: The moulting process through the fossil record is important to investigate since the way trilobites moulted constrained their morphology throughout the evolution of this group. Moreover, studying moults provides valuable biological information about growth and development during the early Palaeozoic, which can help resolve the affinities of enigmatic taxa from the early stages of animal evolution. Trilobites were one of the dominant groups of arthropods during the Palaeozoic. However, despite extensive studies on their moulting processes, there remains uncertainty about whether certain fossils represent actual moults or simply disarticulated exoskeletons. One possible reason for this uncertainty is that many studies have focused on isolated and disarticulated specimens from museum collections, often lacking sedimentological and taphonomic context. In this study, I present abundant, well-preserved trilobite moults from the lower Cambrian Balang Formation in southern China, with a high degree of confidence in their identification as true moults. The results reveal a distinct moulting configuration across the ontogeny of these taxa, allowing us to propose different ontogenetic moulting patterns. This research contributes to the development of a working protocol and enables us to extrapolate our findings over a broader temporal framework, demonstrating that these moulting patterns were already established in different trilobite clades during the Cambrian and Ordovician periods. Our findings show that moulting patterns-imposed constraints on morphological (disparity) and therefore taxonomic diversity in trilobites during and after the Cambrian and Ordovician.

Enrolment. For decades, it was believed that Cambrian trilobites either could not enrol or did so ineffectively, without fully encapsulating their bodies. As segmented arthropods, trilobites require articulations that allow each segment to flex, as well as structures known as coaptative (i.e. interlocking) devices to close the body when enrolled. However, the apparent absence of many of these structures led to the assumption that Cambrian trilobites were incapable of enrolling. Nevertheless, the locality of Purujosa in northeastern Spain revealed a one-meter-thick layer of red shales containing a large number of trilobites preserved in an enrolled position. Why, then, do we find such a high diversity of enrolled trilobites in Purujosa, but not in other sites? The Purujosa trilobite assemblage (PTA) is also accompanied by articulated calcitic and phosphatic brachiopods, sponges, and a wide variety of articulated Cambrian echinoderms. These features, along with the absence of bioturbation, suggest rapid burial conditions, such as an obrution event, that quickly entombed the entire benthic community. A detailed microstratigraphic and taphonomic analysis reveals that this was not the result of a single obrution event, but rather of multiple catastrophic events, all originating from the southern part of the basin, where the more proximal facies were located. The comparison of the PTA with trilobites from other sites throughout the Palaeozoic revealed a significant difference in the number of interlocking devices in those from Purujosa and elsewhere in the Cambrian. Therefore, the PTA demonstrates that Cambrian trilobites were indeed capable of enrolling their bodies, but that the burial conditions required for their preservation in this state are rare and specific to a few localities such as Purujosa. It is the presence of more

interlocking structures that enhances preservation in the fossil record, but the ability to enrol was already present very early in trilobite evolution.

As final remark the study of biostratinomy processes is a necessity for understanding how an organism transitioned from a living palaeobiological entity to a buried fossil, and it helps us to improve our comprehension of key ecological aspects in the evolution of the biosphere. Otherwise, the lack of a biostratinomy and sedimentological framework can bring misinterpretation of the fossil record.

Acknowledgements

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TAPHONOMIC AND ZOOARCHAEOLOGICAL INSIGHTS INTO NEANDERTHAL BUTCHERY TRADITIONS AT FUMANE CAVE

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Thanks to the exponential growth of taphonomic and zooarchaeological studies in recent years, the central role of taphonomy has become increasingly evident not only in understanding the processes of accumulation and preservation of bone remains in archaeological contexts, but also in reconstructing past ecologies and paleoenvironments. Depending on the archaeological context, the faunal assemblage under study, and the specific research question, the most appropriate analytical methods must be carefully selected.

This study focuses on the latest evidence of Neanderthal presence at Fumane Cave, one of the most significant Palaeolithic sites in Europe, characterized by a 12 m-thick stratigraphic sequence. In particular, the stratigraphic units A9 and A5-A6 highlight the potential of an integrated, interdisciplinary approach. These contexts provide an opportunity to reflect on the understanding of flaking methods that define Mousterian techno-complexes, such as Discoid and Levallois. While these lithic industries are well defined, the factors guiding the selection and use of specific tools remain unclear.

Starting from studies of these Mousterian lithic industries, we then focused on the most represented faunal species throughout the stratigraphy. A taphonomic investigation of *Cervus elaphus* bone remains accumulated in units A9 and A5-A6, was carried out along two main research directions: (1) the identification of cut mark patterns based on the frequency, distribution and orientation of the traces, aimed at assessing whether and how changes in lithic technologies corresponded to shifts in carcass butchery traditions; (2) a techno-functional analysis of Discoid and Levallois tools was conducted through an experimental collection, quantifying the micromorphometric features of the cut marks left on bone surfaces.

In this study the integration of various quantitative analyses provides valuable insights into the cultural complexity and ecology of Neanderthal groups at Fumane Cave during MIS 3, highlighting the flexibility and variability of their strategies and traditions in butchery activities.

TAPHONOMIC IMPLICATIONS OF INVERTEBRATE TRACES IN PLAYA SEDIMENTS OF THE UPPER HORNBURG FORMATION (MIDDLE PERMIAN, GERMANY)

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The outcrops of the late middle Permian Hornburg Fm (Saxony-Anhalt, Germany) unveil a complete fan- and playa-system and its biota, which is rarely preserved in present-day central Europe. Since September 2022, an ongoing excavation (c. 60 m^2) in the abandoned “Quarry Held”, Wolferode (Upper Hornburg Fm), unearths a variety of well-preserved trace fossils (c. 120 excavation boxes until now) including tetrapod up tp 5 cm large footprints and trackways (some of whom were probably produced by araeoscelid and / or bolosaurid reptiles), tetrapod scratching traces (probably swimming traces) and invertebrate traces. These invertebrate traces include jellyfish impressions, microbially induced sedimentary structures and a variety of arthropod trackways, that can be assigned to distinct morphotypes and producer groups, but also insect body imprints (resting traces) that might be referred to some of the arthropod trackmaker groups. In addition, conchostracan shell impressions were found during the excavation season 2024. The geological strata include c. 6 m of fossiliferous laminated siltstones and claystones that were investigated for fossil content and sedimentary structures in mm to cm-scale. Many surfaces of fine laminated claystones preserve arthropod trackways, but also halite crystal marks and jellyfish traces. Insect body imprints occur more rarely and show a low morphological diversity (two to three types). Most insect body imprints clearly show a tripartite body of 2 to 4 cm in total length with a big oval head, a short torso, an elongated, structured abdomen and six legs (type 1), resembling modern dragonfly larvae. This type of body imprint can occur in groups and is commonly found in silty layers with wavy bedding, indicating a lifestyle in slightly flowing waters, presumably to hunt for prey. Additional insect body imprints also show a tripartite body but with a much shorter abdomen than type 1 and an overall more compact body shape (1 to 2 cm in length, type 2). Type 2 typically occurs on mudstone surfaces, that are interpreted as small water bodies with stagnant waters (ponds). Conchostracan shell impressions are rare and so far, they are limited to the laminated silty mudstones at the top of lithological unit 8. Intercalated sandstone channel deposits don’t show fossil content, but a variety of sedimentary features including internal cross bedding structures, and on the bottom desiccation crack fillings, ice crystal casts, flute casts, and/or load casts. The almost complete absence of burrowing traces is notable. The sedimentary features of claystones, siltstones and sandstones suggest the occurrence non-perennial waterbodies, that were filled by decimetre to meter-scale streams and became hypersaline in dry periods. These factors may have produced a stressed environment for surface and especially infaunal organisms.

The trace fossil content of these dry evaporitic red beds is exceptional and potentially provides a biostratigraphic signal when other indicators are missing for one of the rare central European successions and biota of middle Permian age. Furthermore, by analysing the taphonomy of invertebrate trace fossils from the Hornburg Formation we gain detailed insights into Permian insect lifestyles and ecosystem functions.

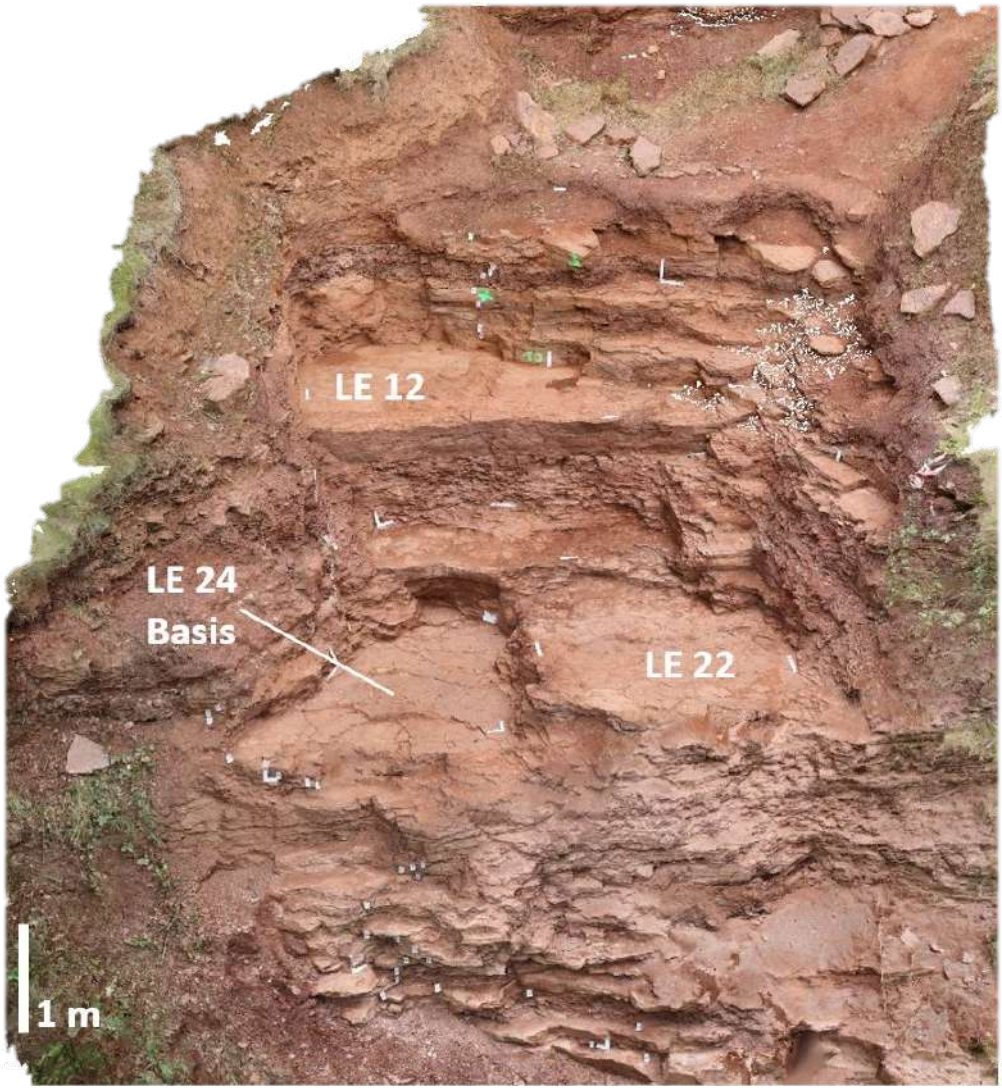

Figure 1. Photogrammetric model of the excavation site as of September 13th, 2024 (end of the excavation campaign 2024). About 43 lithological units have been documented so far, with most of them yielding trace fossils.

NO CHANGE IN 45 MILLION YEARS: EVOLUTIONARY CONSERVED MELANOSOME GEOMETRIES IN ANURANS

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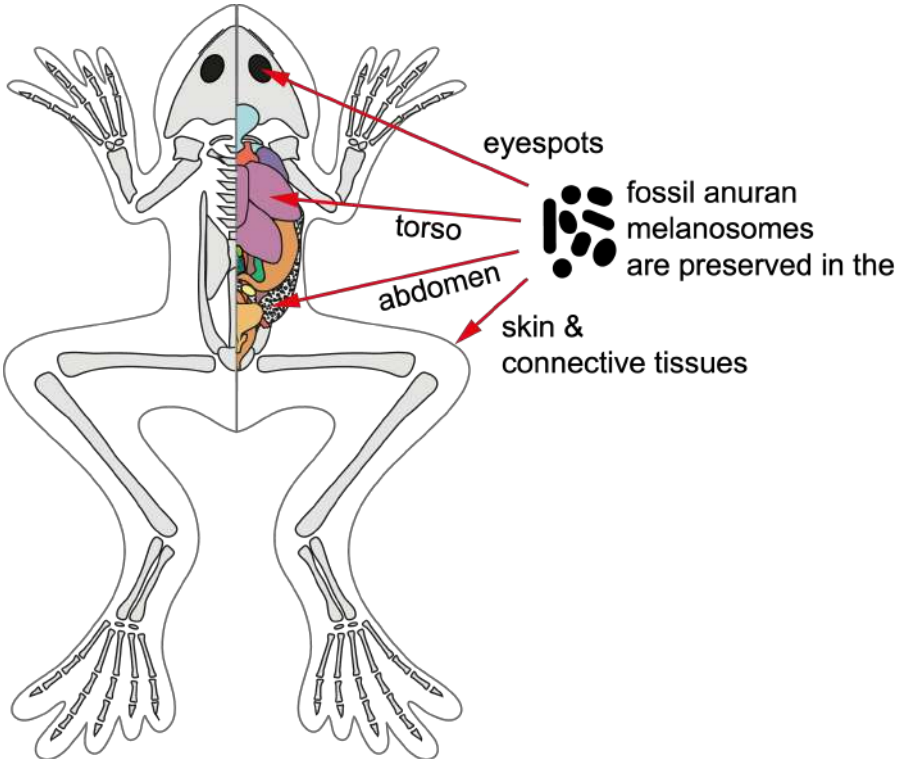
The evolution of melanin through deep time is poorly resolved. To date, few studies integrate data on melanin from fossils and their extant relatives. Here, we use data on melanosomes (micron-sized melanin-rich organelles) in four extant anuran taxa (represented by 11 specimens) and four fossil anuran taxa (represented by nine specimens) to assess the evolution of melanosome geometry in anurans for the last c. 45 Ma. The anuran fossils are from three Lagerstätten: Geiseltal (Eocene, Germany), Bechlejovice (Oligocene, Czech Republic) and Libros (Miocene, Spain). The total dataset comprises 6713 melanosomes. We measured melanosome width and length from scanning electron micrographs. Geometry data were analysed using univariate testing (i.e., significance tests) and a battery of multivariate tools including Principal Components Analysis. Synchrotron rapid scanning-X-ray fluorescence analysis (SRS-XRF) of one fossil specimen assessed the chemical variation in the metal chemistry (Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu and Zn) of melanosomes preserved in soft tissues from different body regions.

Our data show that melanosomes from the skin differ in geometry between extant and fossil species. In contrast, melanosomes from all other body regions (eyes and internal tissues) show similar geometries in fossil and extant species. These data suggest evolutionary conservatism of melanosome geometry in the eyes and internal organs, but not the skin. These trends in melanosome evolution are probably controlled by physiological constraints on melanosome function that have been in place at least since the Eocene. Our data imply that the functions of ocular melanin in the visual system of anurans has not changed over this interval. Similarly, conservation of functional roles of melanin in internal organs is not unexpected, as the fossil specimens studied are either fully aquatic or aquatic during breeding. These ecologies are ancient for anurans and thus likely impose the same functional constraints as in anurans today. Melanosome geometries from the skin may diverge from this strong trend of conservatism due to evolutionary trade-offs linked to one, or several, changes in behaviour and ecology, including diversification of integumentary coloration, activity period, the presence/absence of a lateral line system and/or habitat.



Schematic view of the anuran skeleton and soft tissues and those body areas in which fossil melanosomes were discovered.

WHEN HISTORY HELPS SOLVE TAPHONOMIC PUZZLES: A CURIOUS RIDDLE FROM ROME'S LAURENTINA DISTRICT

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Recent urban construction activities in the Laurentina district of Rome led to the accidental discovery of an underground funerary and cult complex. The structure, characterised by a cruciform plan, has been dated through architectural analysis and associated archaeological material to the Late Antique–Early Christian period (4th–5th century CE).

Within the ruins of this hypogeal complex, faunal remains were recovered in secondary depositional contexts. These remains, attributable to taxa including horse (*Equus caballus*), dog (*Canis familiaris*), cattle (*Bos taurus*), and caprines (*Ovis* vel *Capra*), were found agglomerated in localised areas of the site, in stratigraphic positions inconsistent with the primary phases of use of the complex.

The unusual distribution and condition of the remains prompted a detailed taphonomic analysis. The results suggest post-utilisation depositions that may reflect ritual or symbolic practices linked to the evolving funerary and cultic landscape of Early Christian Rome. The proposed interpretation draws on historical sources and comparative data, providing a plausible link between the faunal assemblage and the socio-religious transformations of the time.

THE ROBUSTNESS OF THE TAPHONOMIC METHOD IN MICROVERTEBRATE RESEARCH (critical view and review)

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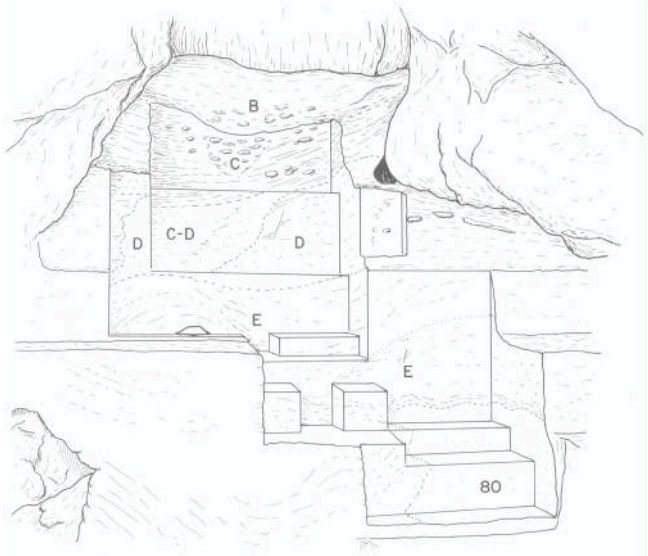
A recent article in Palaeogeography, Palaeoclimatology, Palaeoecology (https://doi.org/10.1016/j.palaeo.2024.112304) by Fried and colleagues on the taphonomy of small mammals from Tabun C (Israel) supports the need for taphonomic studies at palaeontological sites in order to obtain reliable palaeoecological interpretations. However, these authors question the robustness of the methodology used on small mammals and the preservation of taphonomic modifications in these fossil bones.

Tabun Cave (Mount Carmel, Israel) is an iconic palaeoanthropological site with fossil remains of Neanderthals (Tabun C1) and Homo sapiens (Tabun C2). Taphonomic research is essential to understand how the site was formed and to interpret the palaeoecology, palaeoenvironment and possible differences in the occupation of the cave by these two hominid species. The importance of the site and serious doubts about the soundness of the microvertebrate taphonomic methodology have led us to carry out a detailed analysis of the raw data in this article, which has allowed us to obtain new and more accurate results than those obtained by Fried and his colleagues, and to dispel their doubts.



Layer C is dated to mid- or late Marine Isotope Stage (MIS) 6 (165 ± 16 ka BP). This major stratigraphical unit, to date constitutes the only Levantine MP deposit with both *Homo Neanderthalensis* (Tabun C1, burial was found in the upper part of Layer C) and *Homo sapiens* (Tabun C2, mandible was uncovered deeper within this layer). (figure from Jelinek, et al., 1973 https://www.jstor.org/stable/41489710)

DIFFERENT PERSPECTIVES OF TAPHONOMIC STUDIES FROM SALTO DE PIEDRA FOSSIL SITE (PAMPA, ARGENTINA)

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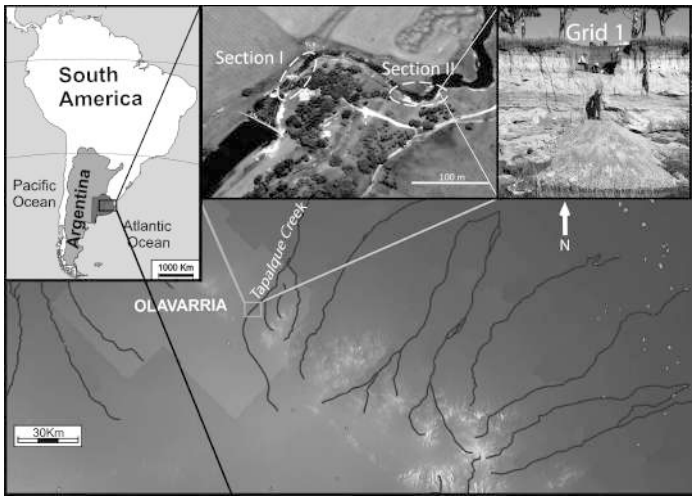
The fossil site of Salto de Piedra (in the Argentine Pampas, near the town of Olavarría) is located in the upper basin of the Tapalqué Creek, which fossil-bearing strata cover the last 150 ka BP. This period includes the Pleistocene-Holocene (glacial-interglacial) transition. Different taphonomic methods have been applied to the small mammals, macro- and megafauna, and gastropods recorded at Salto de Piedra. Systematic excavations have provided a relatively large fossil collection of the small, meso- and large mammal fossils. The different taphonomic methods, applied to different taxonomic groups, have allowed us to obtain a conclusive interpretation of the formation of the site and exclude potential reworking of these fossils recorded in a riverbank site. Re-sedimentation, however, has affected these fossil assemblages. The taphonomic results, combined with taxonomic identifications and radiometric dating, suggest that the biozones established in the Pampas region should be revised.

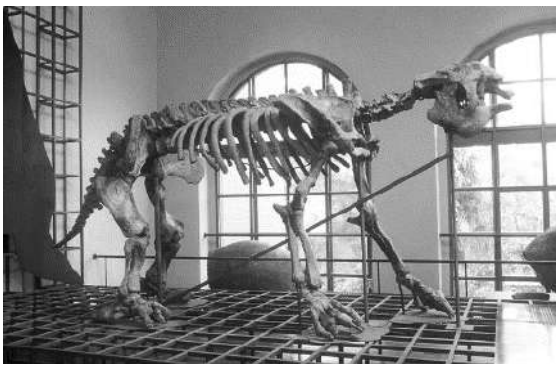
The taphonomic results obtained at the Salto de Piedra site, combined with palaeoecological analyses of small mammals and gastropods, as well as detailed radiometric dating, have also allowed us to conclude that climatic events in the Pampean region were milder than in the northern hemisphere. This evidence is currently being verified on the other side of the Atlantic, in South Africa.

Finally, the period covered by the Salto de Piedra fossils is particularly interesting in this area, since representatives of the most charismatic megafauna, such as *Megatherium* (the giant sloth), *Glyptodon* (armoured mammals) and *Smilodon* (saber-toothed cats) became extinct at the beginning of the Holocene. Salto de Piedra represents the natural context (there is no evidence of human presence), in contrast to the nearby human settlements in the area. During the Late Pleistocene (c. 13 ka BP), humans arrived in the Argentinean Pampas and various authors have suggested that they were responsible for the extinction of the megafauna. Based on the

taphonomic modifications recorded on the bone surfaces of the megafaunal fossils from Salto de Piedra, we can discuss the role of humans *versus* climate in the debate of the megafauna mass extinction.



Salto de Piedra site (Argentina).



Megatherium (left) and *Glyptodon* (right), extinct megafaunas recorded in Salto de Piedra site.

THE OTHER FACE OF METALLURGY: CUT MARKS AND MANUFACTURING TRACES ON HARD ANIMAL MATERIALS BETWEEN EXPERIMENTAL AND ARCHAEOZOOLOGICAL ANALYSES

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The analysis of human modifications on the surfaces of hard animal materials provides, in addition to insights into animal exploitation for subsistence and craft activities, a valuable mean for formulating hypotheses about the tools employed in such practices. Several papers evidence the possibility to identify traces produced by lithic implements of different morphologies and raw materials. Similarly, other researches provided promising results in distinguishing between modifications produced by stone and metal tools.

However, within the context of the Italian prehistory, the possibility of identifying the typology and composition of the metal tools employed in the past, based on the analysis of the traces observed on osseous materials is still insufficiently explored.

This contribution presents the preliminary results of an experimental study conducted with metal tools employed in butchery tasks. The primary aim is to assess the possibility of establishing diagnostic criteria (both at macroscopic and microscopic level) for distinguishing traces produced by different metal implements; the developed methodology will be then tested on archaeological specimens.

TAPHONOMY OF THE LOWER PERMIAN TORRENT DE NA NADALA SITE OF MALLORCA (WESTERN MEDITERRANEAN): A TRAMPLING CASE

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The island of Mallorca has yielded several recent discoveries of Permian vertebrates, including the oldest known gorgonopsian and the moradisaurine captorhinid *Tramuntanasaurus tiai*. However, these studies have largely focused on taxonomy, without taking into account other aspects of the remains. This work analyzes the taphonomic processes of the vertebrate remains found in two stratigraphic horizons at the Torrent de na Nadala site (Banyalbufar, Mallorca). Specifically, specimens DA21/17-01-01 (Gorgonopsia indet.) from the NA-2 horizon, and DA21/17-01-03 (holotype of *Tramuntanasaurus tiai*) from the NA-3 horizon are taphonomically analyzed. The results reveal different taphonomic biases and pathways between the two specimens. However, both specimens have something in common: they were trampled. Trampling played an important role in their preservation. In the NA-2 horizon, the remains of the indeterminate gorgonopsian DA21/17-01-01 were subaerially exposed long enough for them to disperse, this dispersal was probably due to a flash flood of short duration that transported the remains a short distance (Fig. 1).

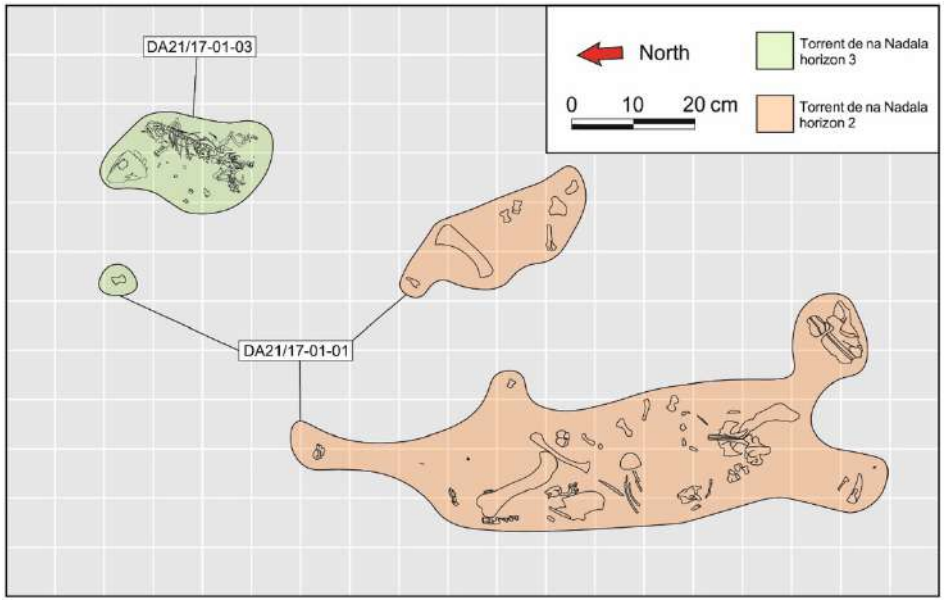

Figure 1. Torrent de na Nadala site map with all the fossils found in horizon 2 (NA-2) and horizon 3 (NA-3).

Although scavengers may also have contributed to the dispersal of these remains. After this dispersion, these remains were trampled. In the NA-3 horizon, the holotype of *Tramuntanasaurus tiai* DA21/17-01-03 shows no signs of long subaerial exposure, but rather that it has been

preserved at the place where the animal died (Fig. 1), and both the skull and part of the torso of the animal have been trampled. This indicates several trampling events, which also partially buried part of the remains of this moradisaurine captorhinid. These new taphonomic data provide paleoecological information about the formation environment of this site. These taphonomic results are similar to those present in other Permian fluvial deposits from other regions corresponding to equatorial zones during this period of Pangea, which reinforces the theory of the equatorial position of the Balearic Islands during the early Permian stage.

PUT THE SEA URCHINS IN THE AMMONITE: AN UNUSUAL AMMONITE-ECHINOIDS ASSOCIATION FROM THE UPPER CRETACEOUS OF NORTHEASTERN ITALY

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The lastame, a distinctive lithofacies of the Scaglia Rossa Veneta dating back to the Turonian (Late Cretaceous), is a nodular-subnodular limestone with a long history as building stone in the Lessinian region (northeastern Italy). Since the 19th century, extraction activities in the lastame have unearthed remains of large marine vertebrates. In recent years, these findings, sometimes spectacular, have been the focus of detailed studies, gaining international recognition. In contrast, the invertebrate fauna of the lastame, despite being relatively abundant, remains insufficiently studied, largely due to its suboptimal state of preservation. This is particularly true for ammonites, which are usually poorly preserved and, for this reason, have been largely overlooked by researchers.

Seven years ago, however, a noteworthy specimen was discovered in a quarry at San Giovanni in Loffa (Sant'Anna d'Alfaedo, Verona). The fossil is a large ammonite associated with dozens of irregular echinoids, predominantly concentrated in what was its original body chamber. The only similar finding so far reported in the literature pertains to a large *Pachydiscus* from the upper Campanian of northern Germany, whose body chamber preserved three dozen specimens of *Echinocorys*. The ammonite from the lastame deposits raises some questions about the significance and origin of this association. Is it simply a taphonomic artifact (i.e., an arrangement resulting from biostratinomic processes) or does it represent a genuine coenosis?

FOODS FOR THE GODS: WHAT BURNT BONES CAN TELL US ABOUT RITUAL PRACTICES AT THE SAMNITE SANCTUARY OF CAMPOCHIARO (CAMPOBASSO, MOLISE, ITALY)?

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A taphonomic analysis of the faunal remains recovered at the Samnite sanctuary of Campochiaro (CB; 5th century BCE – 1st-2nd century CE) revealed abundant traces of burning on the animal bones, providing valuable insights into the Samnites' ritual and religious traditions. Based on a sample of approximately 1,594 specimens, the analysis showed a significant presence of thermal alterations, ranging from superficial discolouration to complete calcination, which is consistent with direct exposure to fire. According to well-established guidelines in taphonomic literature, these remains were interpreted to reconstruct not only ritual practices but also the dynamics involved in man ageing the sanctuary and disposing of animal remains. Overall, the data greatly enrich the interpretive framework of the site, shedding new light on the cultic practices and settlement dynamics of the Samnite communities.

UNDERWATER DISARTICULATION: THE CASE OF CAMP DELS NINOTS FOSSIL-LAGERSTÄTTE

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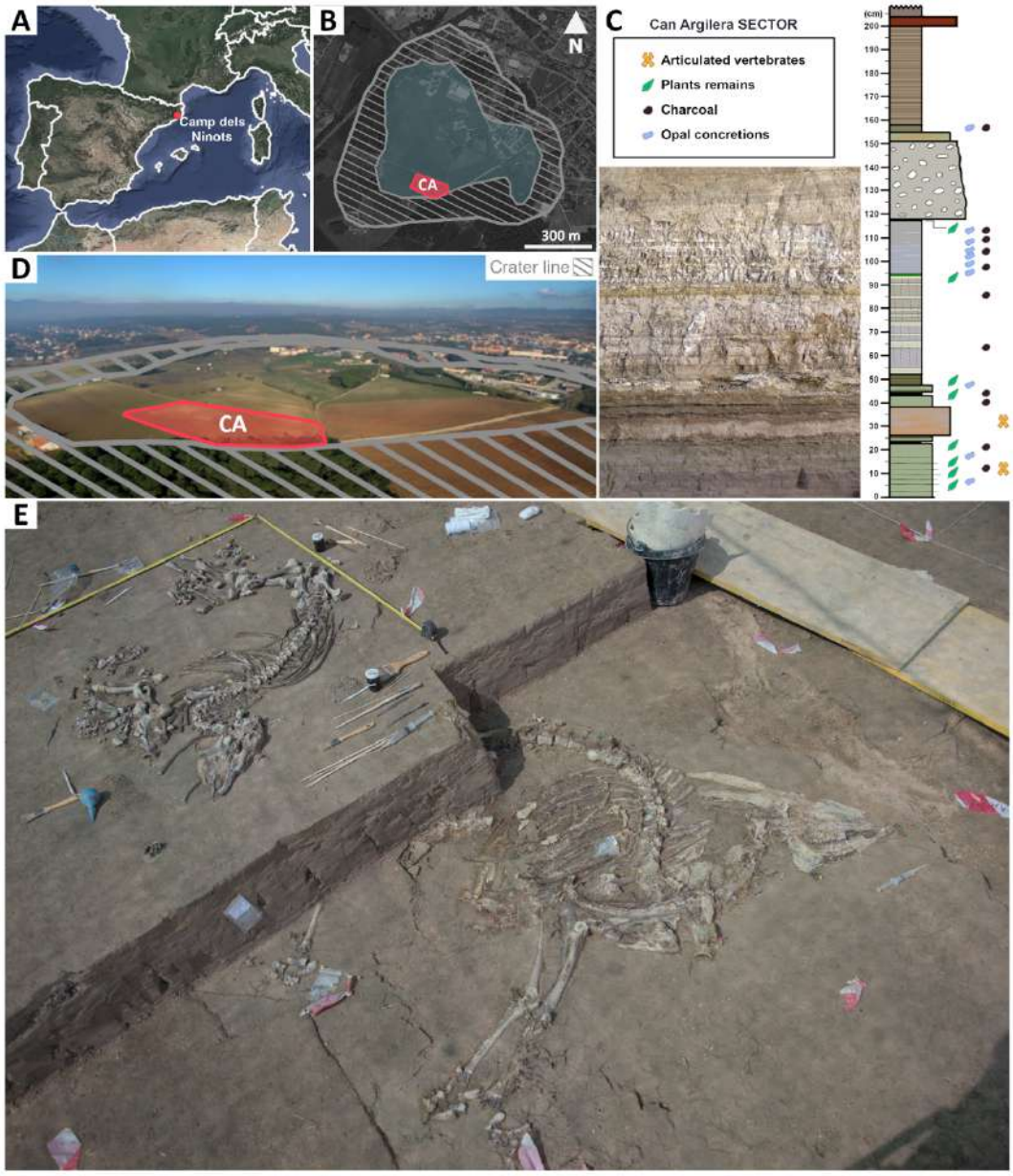
Disarticulation and dispersal of skeletal elements during post-burial processes are well known and extensively studied in terrestrial contexts but remain less understood in aquatic environments. Recent studies both in taphonomic and forensic fields indicate that underwater disarticulation can be significantly influenced by refloating, which occurs as decomposition gases accumulate during the initial stages of decay. Water depth plays a critical role, and buoyancy is negated when water pressure exceeds the internal pressure generated by decomposition gases. Vertebrates possess complex anatomical structures, with differential decomposition timing for muscles, ligaments, and tendons, leading to differential disarticulation. Understanding these processes is essential for reconstructing depositional dynamics and consequent palaeoecological interpretations.

The Camp dels Ninots *Fossil-Lagerstätte* (Girona, Spain) is a Pliocene low-relief crater (maar lake) in northeastern Iberia. It formed after a phreatomagmatic eruption at the interface between local Palaeozoic granites and Pliocene pre-volcanic sands, resulting in a paleolake with a maximum depth of 72 m, fed by groundwater.

The faunal assemblage includes large vertebrates such as tapirs, rhinoceroses, and bovids; as well as hundreds of small vertebrates including turtles, frogs, newts, and fishes. Plant remains are abundant and include imprints of wood, seeds, and leaves. Most specimens are recovered from thin laminated clay layers, which show no signs of bioturbation, indicative of an anoxic depositional environment.

The studied individuals of tapirs and bovids are found at various burial depths in the same clay layer displaying no evidence of predation and exhibiting minimal bone surface modifications. The bones also exhibit a good anatomical connection, with only the extremities more dispersed but still associated (i.e., autopodium). Isolated remains recovered were successfully reattributed to the original individuals based on the anatomical compatibility of articular surfaces. All skeletal elements were mapped, and their spatial dispersal was analysed. The observed articulation and distribution patterns suggest that these specimens sank rapidly after death at the lakebed and post-mortem displacement of the carcasses was limited and influenced by water depth, currents, and putrefaction gases.



Overview of Camp dels Ninots *Fossil-Lagerstätte.* A, location in Western Europe (NE Iberian Peninsula). B–D, view of the Can Argilera sector (CA) in the paleolake and stratigraphic section. E, excavated surface from 2018 field work with a specimen of *Tapirus arvernensis* (left) and *Alephis tigneresi* (right) from layer 11.

TAPHONOMIC ASSESSMENT OF ~2 MY OLD IVORY AND BONE TOOLS FROM KROMDRAAI, SOUTH AFRICA

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Tools made of hard animal tissues (i.e., dental, keratin or bone tissues) are well known during the Eurasian Upper Palaeolithic and African Later Stone Age. Evidence for the existence of such tools has also been found at Middle Stone Age African sites, but more rarely. The use of hard animal tissues that are minimally modified as tools during the Early Stone Age is much more debated.

Here, we report the presence of both bone and tooth tools from the Pliocene–Pleistocene deposits of Kromdraai Unit P and O. Since 2014, more than 10,000 bone specimens have been found at Kromdraai, mainly from Unit P, including at least 51 cranial and postcranial hominin remains, most of them attributed to *P. robustus*.

Of these specimens, thirty have been identified as potential bone tools, meaning that they exhibit the typical shape of a long bone splinter associated with a polished point. Of the 30 original potential bone tools, only 12 present the criteria to identify them as definitive bone tools. Ten of them are bone flakes with abraded tips, on which the presence of the micro-striation pattern can be observed.

Based on CT-scan analyses, however, two of these specimens have been confirmed as teeth, probably large suid tusks. The application of confocal microscopy will allow exploring their potential use as digging sticks or fruit peelers. Our results indicate that hominins were already exploiting a diversity of raw material as tools by at least 2 Ma in South Africa. This allows discussing the relevance of the osteodontokeratic hypothesis as well as the diversity of early Pleistocene hominin subsistence behaviors.

COMPLEXITY OF PRESERVATION AND MINERALOGY OF FOSSIL CORAL SKELETONS – NEW INSIGHTS

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Traditionally, it has been assumed that the major groups of skeletonized hexacorallian anthozoans differ in original mineralogy of their carbonate skeletons: Paleozoic rugose corals were thought to form calcitic skeletons, whereas the skeletons of Mesozoic and Cenozoic scleractinian corals were considered to be invariably aragonitic. This assumption, that the skeletons of these two coral groups consistently differ in mineralogy, has had fundamental implications for phylogenetic interpretations, for understanding the taphonomic potential of each group, and for the reliable use of coral skeletons as (paleo)environmental proxies. However, new data suggest that the original skeletal mineralogy and preservation states of corals are far more complex than previously thought.

Ordovician sediments at Kilbucho (Scotland) preserve molds of solitary coral fossils (kilbuchophyllids) interpreted as scleractinian corals based on their hexameral septal arrangement and micromorphological features. The moldic preservation of kilbuchophyllids is consistent with an originally aragonitic skeleton, as is typically inferred for scleractinians. These corals, however, co-occur with unequivocally identified rugose corals whose skeletons are likewise entirely dissolved. Thus, the moldic preservation cannot unambiguously indicate the original mineralogy. However, calcitic skeletons of rugose corals are occasionally preserved within the same deposits, whereas no aragonitic or diagenetically altered skeletons of kilbuchophyllids have yet been identified. This preservational pattern suggests that kilbuchophyllids may indeed have originally formed aragonitic skeletons, while rugosans were calcitic, but both were susceptible to dissolution under certain diagenetic conditions.

In Mesozoic sediments of Poland (e.g., Mielnik), scleractinian corals with structural and geochemical features indicative of an original calcitic mineralogy (*Coelosmilia*) co-occur with micrabaciid corals whose skeletons are also calcitic but exhibit clear signs of recrystallization. These features are characteristic of diagenetically altered aragonitic skeletons and are consistent with the preservation of well-documented aragonitic micrabaciid skeletons from other localities. The mineralogical heterogeneity of coral skeletons is further complicated by the skeletal structure of the extant scleractinian coral *Paraconotrochus*, which forms original, bi-mineralic skeleton composed of both calcite and aragonite. The presence of calcite in fossil scleractinian skeletons has traditionally been interpreted as the result of diagenetic transformation and is often used as a basis for dismissing such specimens as unreliable (paleo)environmental proxies. However, as the above examples suggest that occurrence of calcite (and potentially other polymorphs) may in some cases reflect a primary biomineralogical feature rather than diagenetic overprinting.

A largely overlooked factor contributing to the variability of coral diagenetic pathways may be the distinct microstructural features of their skeletons. Fine-scale skeletal organization (such as $CaCO_3$ fiber size and orientation, organic matrix distribution, and trace element concentrations; e.g., Mg) can influence susceptibility to diagenetic alteration. To elucidate the mechanisms underlying the preservation of fossil corals, we are conducting diagenetic experiments on modern corals with pure aragonitic skeletons but significantly different microstructures.

ELEMENTAL TRANSFER AND FIXATION IN THE FOSSILIZATION OF TURBIDITE-BURIED DEEP-SEA FISH

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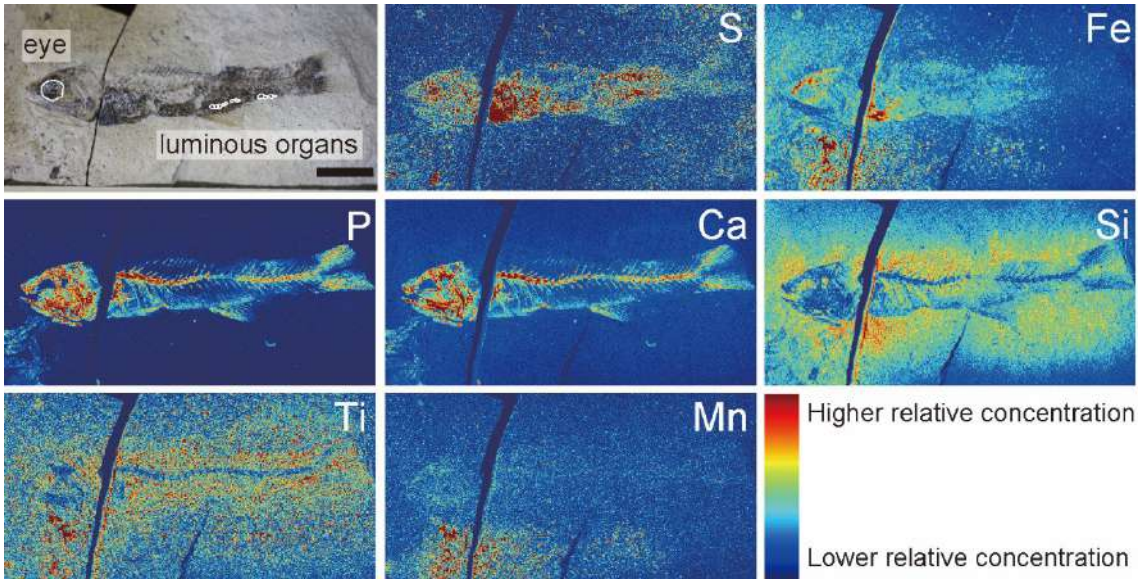
Sedimentary rocks containing fossils undergo a sequence of stages in the sedimentary cycle characterized by burial, diagenesis, and exposure. In this cycle, elements related to fossilization are transferred and fixed in and around the fossils through the stages. However, few studies have shown the link between the elemental transfer and fossilization in the entire sedimentary cycle.

In this study, well-preserved deep-sea fish fossils from the Miocene Morozaki Group, central Japan was used to investigate element transfer processes during fossilization. We investigated the changes in chemical composition during the fossilization process of lanternfish (deep-sea fish), compared to modern lanternfish. This comprised chemical mapping using X-ray microscopic analysis, mineral identification using Raman spectroscopy, and chemical analysis using inductively coupled plasma mass spectrometry and elemental analysis.

We found that carbon and nitrogen were significantly depleted during fossilization, whereas slight changes were observed in phosphorus and calcium concentrations, which are major elements of hard tissues. In contrast, iron and sulfur concentrations were elevated in fossil fish compared to living fish due to pyrite formation during fossilization.

The large amount of plant fragments surrounding the fossils promoted oxygen consumption and made the surrounding area reductive to provide a suitable environment for formation and preservation of framboidal pyrite. The iron and sulfur mobilization and fixation during the early diagenesis plays an important role in fossilization, particularly in preserving the detailed texture even in the part of soft tissue, and protecting the fossils from later diagenetic process carried out by deep burial and post-exposure oxidation.



Successive photographs and elemental maps of fish fossils. Relative abundances of elements are represented by pseudo-colors.

DEATH BECOMES THEM: UNDERSTANDING THE EXCEPTIONAL

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Konservat-Lagerstätten, geologic deposits containing exceptionally preserved fossils (e.g., complete fossils, soft-tissues, etc.), are some of the most important windows into the history of life. They are the reason that we know as much as we do about the early evolution of multicellular life, how Cambrian arthropod nervous systems looked like, what the body shape of ichthyosaurs was, and what soft-bodied animals lived throughout geologic history. The term, introduced by Seilacher in 1970, has drawn contentious debate into not only the classification of Konservat-Lagerstätten, but also comparison of Lagerstätten in geologic time and space. Debatable topics include the nature of the fossil record, as deposits from different geologic settings or different time periods will contain a wide variety of taxa; others are related to the historical and current classification of Konservat-Lagerstätten. While Seilacher emphasized the importance of fossilization processes (rapid burial, redox conditions, microbial mats) as the key to exceptional preservation, as well as sedimentary facies in the classification of Konservat-Lagerstätten, these factors alone do not yield easy evaluation. Following the wider acceptance of the Konservat-Lagerstätten term in the paleontological community, several attempts were made to classify them in a way that allows for comparison of deposits.

In 1988, Allison proposed a mineralogy-based classification, which has since been fleshed out with sedimentary geochemistry and microbial metabolic pathways by Muscente and colleagues in 2017. However, the most common classification followed today is the site-based nomenclature introduced by Allison and Biggs in 1991, and further popularized by Butterfield in 2003. This classification refers to localities with a typical style of fossil preservation (e.g., Ediacara-type, Orsten-type, Burgess Shale-type, Mazon Creek-type, etc.) and assigns a type to localities bearing the same style of preservation. While in concept a good idea, this has led to ambiguity in assigning sites to certain locality types, as there are no true boundaries in how far depositional environment can stray from the type locality, or how diagenetically overprinted fossil deposits should be treated when the original mineralogy was the same. Another chief concern in the comparison of Konservat-Lagerstätten is the shift of exceptional preservation from open marine settings to transitional and non-marine settings in the Phanerozoic.

Kimmig and Schiffbauer have promoted the application of mineralogy as a primary classification in 2024, as it not only permits better comparison of Konservat-Lagerstätten, but also removes a much ambiguity that is introduced by other classification systems. They also showed how future efforts at recording mineralogy for newly described deposits, as well as improving our mineralogical knowledge of already described ones, can significantly improve our understanding of exceptional preservation and the geological, evolutionary, and ecological processes behind it.

THE "CRUZEIRO DO OESTE" KONZENTRAT-LAGERSTÄTTEN, EARLY CRETACEOUS OF SOUTH BRAZIL: A PRELIMINARY TAPHONOMIC INVESTIGATION

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Until recently, the Caiuá Group (Bauru Basin) was considered devoid of body fossils, reflecting its deposition under the harsh, Early Cretaceous desert settings of what is now south-central Brazil. Yet, the discovery of the "Cruzeiro do Oeste Paleontological Site" near the eponymous town not only revealed an unpredicted paleontological potential but confirmed that prolific vertebrate communities could settle in specific sites, as the humid areas between eolian dunes. The local fauna is dominated by the pterosaur *Caiuajara dobruskii* but also includes dinosaurs (*Vespersaurus paranaensis*, *Berthasaura leopoldinae*), other pterosaurs (*Keresdrakon vilsoni*, *Torukjara bandeirae*), and a lizard (*Gueragama sulamericana*). Although this assemblage has been thoroughly studied from a taxonomic perspective, less attention was given to the taphonomic processes enrolled in the genesis of fossil accumulation. Here, we tackle some of these issues based on the results of several fieldworks conducted since 2021. The stratigraphic section of the site is 5.5 meters-thick (Fig. 1A), extending for about 40 meters alongside an old unpaved road, which is now roofed and isolated for fossil digging. It corresponds to sandy paleosols of the Rio Paraná Formation, with parent material composed of (from base to top): (i) cross-bedded sandstones, (ii) even-parallel laminated sandstones, and (iii) massive sandstones. Fossils are frequent in the intermediate laminated sandstones, which correspond to interdune deposits, concentrated in five bonebeds (numbered 0-4). These are all composed of mainly disarticulated elements (Fig. 1B), which indicates that the carcasses were exposed subaerially for enough time for intense decay. Yet, this exposure was probably not long, considering the absence of substantial weathering traces and the preservation of some articulated remains. The incompleteness of the skeletons suggests some level of carcass remobilization. In the uppermost bonebed (#4), trend directions identified for long bones indicate preferential orientation and the influence of water flows during the deposition. The remobilization of skeletal elements under the flows was probably not prolonged, considering the lack of abrasion, the relatively high concentration of fossils, and the presence of elements resistant to transport (Voorhies Groups II and III) in all bonebeds. This suggests that the individuals died not far from their burial site. The high fossil concentration and uniformity of taphonomic signatures indicate that the bonebeds were formed during mass-death events. We confirm previous observations that the lower bonebeds (#0-3) generally include larger fossils, with pterosaur and dinosaur remains often found associated, sometimes articulated, seldomly as nearly complete skeletons. The uppermost bonebed comprises smaller disarticulated bones, usually attributed to juveniles of *C. dobruskii*. Their abundance and dominance have been linked to the possible behavior of nesting in colonies, as common to birds nowadays, including some that inhabit arid environments. In fact, the circumstances of death and factors that led to the

accumulation of numerous individuals in a restricted area are challenging to define. These might have been connected (or not) to one another and varied among the different bonebeds. As for the diagenetic processes enrolled in the fossil preservation, micro-Raman spectroscopy revealed the typical v1 (PO_4), v2 (PO_4), and v3 (PO_4) vibrational modes of phosphate in apatite (Fig. 1C). A distinct peak corresponding to v1 (CO_3) mode of carbonate ions, typically incorporated into phosphate sites (B-type substitution), was also observed. Organic bands associated with proline and phenylalanine were detected only in the modern samples (crocodilian bones) used for comparison. In fact, the v1 (PO_4) bands in the fossil samples are narrower and shifted to higher frequencies (Fig. 1D), consistent with the trend towards fluoridation and increased crystallinity during fossilization. The transformation of the original bioapatite into a more thermodynamically stable mineral, as the carbonated fluorapatite observed here, is a common diagenetic process that helps the long-term preservation of skeletal remains.

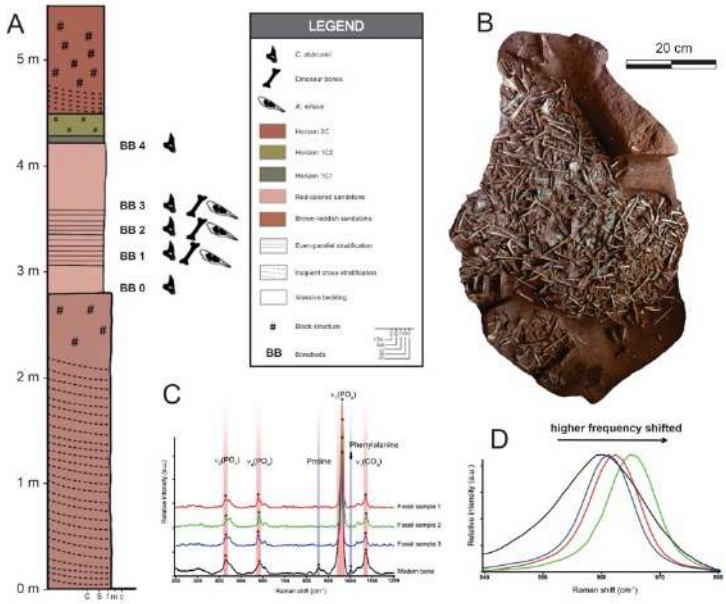

Figure 1. A, Stratigraphic section of the site. B, Example of pterosaur bone-bed (photo by P. Manzig); C, Raman spectra of modern and fossil samples showing the main inorganic (red) and organic (blue) bands in a 200–1800 cm^{-1} range. D, Comparison of v1 (PO_4) band parameters of modern (black line) and fossil (colored lines) samples; note that v1 (PO_4) bands in fossils are blue-shifted and narrower.

TAPHONOMIC AND ECOLOGICAL INTERACTIONS OF RECENT CLYPEASTEROID ECHINOIDS FROM SAN SALVADOR ISLAND, BAHAMAS USING MICRO-COMPUTED TOMOGRAPHY

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Clypeasteroid echinoids are irregular echinoids with distinct test morphologies which often function as biogenic hard substrates after death. They are useful objects for palaeoecological and taphonomic research due to their robust tests and interactions with post-mortem encrusting communities. Eight freshly acquired specimens from contemporary shallow-water carbonate environments on San Salvador Island, Bahamas, are the subject of the current study. X-ray micro computed tomography (micro-CT) is used to analyse general test preservation as well as explore patterns of encrustation and bioerosion.

The study uses AVIZO 3D software on images derived from micro-CT allowing for the examination of both the interior and exterior of the test. Interior skeletal structures, the degree of sediment infilling as well as potential bioerosion into the test can be readily seen using this non-destructive imaging technique. Morphological features including internal buttressing and remnants of the jaw apparatus can be readily observed. The degree of bioinfestation and sediment infilling can furthermore be related to the extent of exposure and fragmentation.

The analysed tests show a variety of preservation states. Two specimens show little post-mortem change and show well preserved surface features including partial spine coverage. The remaining specimens exhibit various levels of surface abrasion, fragmentation, and widespread colonization by encrusting species including bivalves, filamentous brown algae, coralline algae, foraminifera (*Homotrema rubrum*, *Planorbulina* sp.) serpulid polychaetes and bivalves.

The presence of a taxonomically varied encrusting fauna suggests that microbial films most likely represent the first colonization stage, followed by more competitive sessile species such coralline algae, bryozoans, encrusting foraminifera and serpulid worms. The interior of the tests also show encrustation as it represents a protected micro-habitat surrounded by a relative thick shell which is initially connected to the ambient sea- water by various test openings. Further exposure of the interior is then facilitated by increasing degradation and fragmentation of the test. Bioerosion into the test include shallow surface etchings and microboring, indicative of microbial activity as well as larger boreholes which can indicate boring sponges, polychaetes or bivalves. It is important to note that biotic interactions thus include both soft-bodied and calcifying benthic epi- and endobionts.

The echinoid tests thus represent "benthic islands," with their skeletal substrates serving as focal areas for sessile organisms and is compatible with the utilization of echinoid tests as stable mesoscale habitats on the seabed. When hard substrates are scarce in soft-bottom marine environments, the presence skeletal substrates is important for encrusting and bio-eroding organisms thus leading to increase in biodiversity. The preservation potentials of these echinoids are also influenced by these interactions which both promote preservation by encrustation and destroy the test by bioerosion. As shown in this study, both these tendencies and their taphonomic

implications can be analysed by utilizing the high-resolution data acquired using 3D imaging techniques.

HISTOTAPHONOMY OF NOTOSUCHIAN BONES (CROCODYLIFORMES, MESOEUCROCODYLIA) FROM THE ADAMANTINA FORMATION, BAURU GROUP, LATE CRETACEOUS, BRAZIL

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In recent decades, numerous fossils of crocodyliforms belonging to the Notosuchia group have been discovered in the Bauru Group, especially within the Adamantina Formation. It is estimated that the abundance of these fossils is related to paleoecological factors, such as the proximity of their habitat to depositional environments or behaviors that facilitated carcass burial. However, the scarcity of detailed studies on fossil diagenesis within the Bauru Group limits the understanding of these hypotheses. In this context, the present study aimed to identify the taphonomic processes involved in the preservation of a partial postcranial skeleton of a crocodyliform. Morphological and paleohistological analyses were conducted, as well as the taphonomic characterization of the specimen, collected from an outcrop of the Adamantina Formation in the municipality of General Salgado, São Paulo state, Brazil. Through standard paleohistological techniques, thin sections of a long bone fragment, carpal bone, left metacarpals, and coracoid were prepared, complemented by elemental analysis using scanning electron microscopy to identify mineral composition. The morphological results identified the specimen as an indeterminate notosuchian. In paleohistology, parallel-fibered bone tissue was observed, along with lines of arrested growth and a growth ring, indicating a slow growth rate. The presence of an internal fundamental system in the diaphysis of the long bone suggests a subadult stage. The taphonomic characteristics indicate a sequence of events that contributed to the fossil's preservation. The fractures and types of bones found suggest low bone weathering due to subaerial exposure, with limited hydraulic transport. The lithofacies observed in the outcrop indicate the burial of the specimen in a floodplain environment. During early diagenesis, fluctuations in the water table favored the filling of bone pores with manganese and cerium oxides, also promoting calcrete pedodiagenesis. In late diagenesis, weathering and leaching due to rainfall facilitated the deposition of opaque minerals on grains and fossils.

Taphonomic similarities with other studies support the hypothesis that alkaline conditions associated with groundwater-influenced environments were critical for fossil bone preservation in the Adamantina Formation.

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TAPHONOMIC DATA FROM LATNIJA AND THEIR BEARING ON THE EARLIEST MESOLITHIC OCCUPATIONS OF MALTA (SOUTHERN–CENTRAL MEDITERRANEAN)

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Archaeologists have traditionally considered that the first inhabitants of the Maltese archipelago were Neolithic farmers, ~7.5 thousand years ago (ka), based on the recovery of domestic animals, pottery, and imported chert and obsidian from excavations. According to this view, hunter-gatherer groups did not live in the Maltese islands during the Late Pleistocene-Early Holocene because either these islands either had a low carrying capacity due to their small size or navigating long distances using, for instance, dug-out canoes offered many social/technological challenges. Since 2021, researchers from the University of Malta and the Max Planck Institute of Geoanthropology (Jena, Germany) have conducted excavations at Latnija, a large doline in Mellieħa (northern Malta). These excavations have yielded archaeological, radiometric, faunal, and botanical evidence that confirm that Mesolithic hunter-gatherers inhabited Malta from at least 8.5 ka until 7.5 ka, beginning around 1,000 years prior to the arrival of the Neolithic communities. Zooarchaeological data indicate that the site's occupants hunted endemic deer (a dwarfed form of *Cervus elaphus*) and birds, but they also exploited numerous marine resources, such as fish, sea snails, limpets, crustaceans, and even seals. The human diet and subsistence practices observed at Latnija are consistent with what many scholars have documented at other Mesolithic sites located across the Mediterranean Basin. In contrast, they differ considerably from the stricter terrestrial diets of the people who inhabited Malta during the later prehistoric periods.

Here, we present new taphonomic data from the analysis of long bone breakages, skeletal element representation in relation to mineral density, and surface modifications to evaluate the post-depositional processes that may have shaped the zooarchaeological assemblage recovered from the oldest Mesolithic deposits at Latnija. Dry fractures are abundant at the site, which suggests that rock falls and sediment compaction have increased the fragmentation of our assemblage. Our analysis of skeletal element representation also indicates some degree of density-mediated attrition or bone loss. Additionally, we have documented a large number of faunal remains displaying chemical weathering or whose cortical surfaces are partly or completely obscured due to the sediment concretions. Both sediment crusts and chemical weathering seem to have been caused by the percolation of rich-carbonate water through the deposits of the open doline, while the bones were also in contact with biotic acids. As a result, bone surface modifications caused by the main agents of accumulation at Latnija are most probably underrepresented. Yet, alongside the fact that the faunal remains were found associated with lithic artifacts and combustion features, we have recorded green fractures, percussion impacts, cut marks, and burning damage, which further support the exploitation of wild faunas in Malta by Holocene hunter-gatherers.

Although the Mesolithic faunal assemblage from Latnija has been affected by post-depositional processes, it can still offer new insights regarding human hunting strategies, site use, and long-term anthropogenic effects on the local ecosystems of Mediterranean islands during the early Holocene. Our zooarchaeological study points to the transport of complete deer carcasses to the site, and hunting activities most likely took place nearby. There is no evidence for resource intensification or depletion of endemic animals. Taking everything together, hunter-gatherers used

Latnija repeatedly over a millennium but in a transient manner, without significantly impacting the availability of local resources in Malta. We propose that the Mesolithic occupation of Malta reflects low population densities and that the following extirpation of the last endemic herbivores of the island occurred much later, after the settlement of agrarian Neolithic societies, who exploited the terrestrial resources and modified the landscape much more intensively. Thus, our study illustrates how new archaeological research in small and remote Mediterranean islands can transform and refine our current understanding of the nature and timing of the human colonization of pristine island environments and its long-term ecological consequences.

SAMPLING PROTOCOLS IN CHONDRICHTHYAN TAPHONOMY: INFLUENCE OF METHOD AND COLLECTOR EXPERIENCE ON FOSSIL REPRESENTATIVENESS

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Shark fossils can undergo taphonomic processes that mix spatial and temporal information, impacting the interpretation of the data. Additionally, sampling selection bias represents another challenge, related to the non-random collection, affecting the representativeness of results. The present study aims to evaluate the effect of sampling bias in the collection of ichthyodurites in the "*Concheiros do Albardão*" region, on the southernmost coast of Southern Brazil, where biodetritic gravel deposits extend along hundreds of meters. There, shark fossils are found as ex situ vertebrae and, especially, teeth. To evaluate and quantify potential collection biases affecting shark fossils sampling, a protocol with two distinct sampling approaches was tested. "Sampling 1" consisted of a random and unrestricted collection conducted simultaneously by all collectors within a defined area of 80 x 20 m, over a 30-minute period. "Sampling 2" was also performed over 30 minutes but followed a more controlled structure: the 80-meter-long area was subdivided into four parallel strips of 80 x 5 m, with each collector restricted to their assigned strip, ensuring no overlap between collection zones (Fig. 1). Four collectors with varying levels of experience (high, medium, low, and none) participated in the experiment, performing both sampling methods randomly and under time-controlled conditions. Thus, for both sampling methods, four samples were taken during each season, between 2023 and 2024, totalizing an amount of 32 samples. As a result, 596 isolated shark ichthyodurites were collected, with 167 (28,02%) by the highly experienced collector and 92 (15,44%) by the moderately experienced one, while the collectors with low and none experience collected 197 (33,05%) and 140 (23,49%) ichthyodurites, respectively (Fig. 1B). The study reveals a non-linear relationship between the prior experience of the collectors and their success in fossil recovery. It is interesting to note that participants without prior experience demonstrated a remarkable performance on several occasions, especially in the random sampling method, sometimes surpassing the more experienced collectors in terms of quantity. This dynamic suggests that, in less structured sampling scenarios, the lack of experience may lead to a more exploratory and less selective approach, which can result in a wider area coverage and, consequently, in a larger number of discoveries. On the other hand, the strip-based sampling method appeared to have a standardizing effect by delimiting the activity area of each collector and reducing the variability of results among individuals with different levels of experience. This methodological structuring can be crucial in minimizing sampling biases associated with individual skill levels. Furthermore, this strip-based approach allows us to spatially define the distribution of these fossils from the dunes towards the sea, where it becomes evident that collectors with different levels of experience found fewer fossils in the strip close to the dunes, while collectors who stayed in the central and sea strips found more fossils. Additionally, these results may indicate

the influence of external factors, such as climatic and physical conditions (for example, fatigue, excessive sunlight, and sand in the eyes). This corroborates the hypothesis that uncontrolled environmental variables, such as climatic conditions or changes in fossil exposure, can significantly affect the results, reinforcing the importance of considering the environmental context in the analysis and interpretation of field data. These are preliminary results, and further tests are needed to better assess the influence of collector experience and different sampling methods on the recovery of shark fossils.

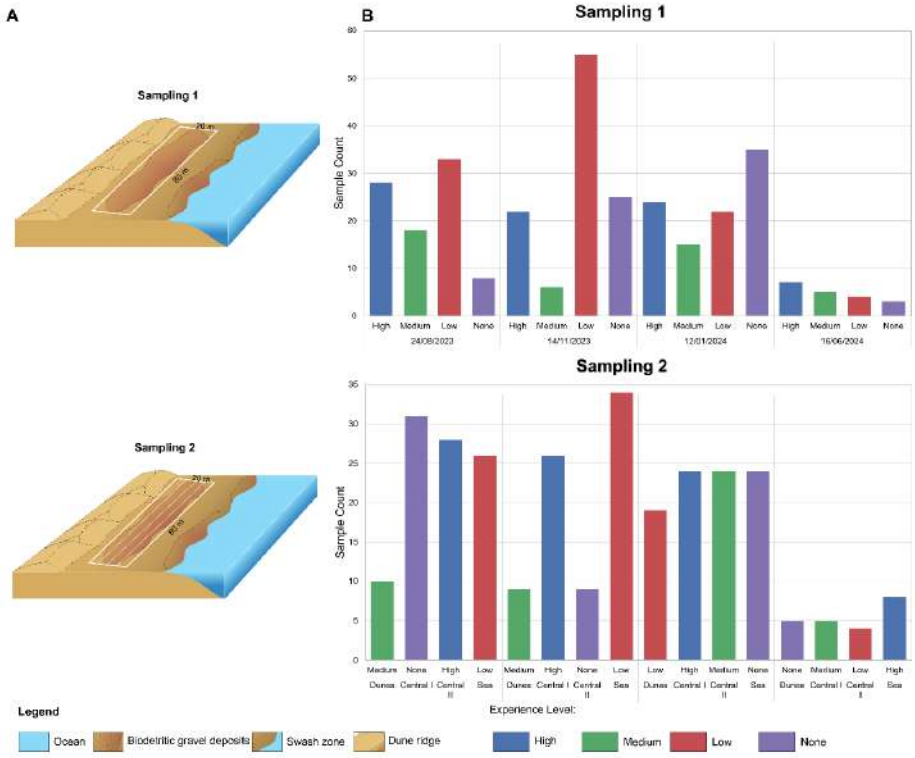

Figure 1. A, Schematic block diagram showing the delimited areas within biodetrital gravel deposits in which sampling methods were tested. B, The bar chart illustrates how sampling efforts varied among high (blue), medium (green), low (red), and no experience (purple) collectors over four time periods (August 2023–June 2024). In sampling 1 results collector are ordered in accordance to experience level, while in sampling 2 are ordered according to their position in relation to the sea, from the furthest to the closest.

MINERALS, BONES, AND TIME: DECODING EARLY DIAGENESIS THROUGH MULTISCALE ANALYSIS OF BONE CONCRETIONS AT LEVEL 19 FROM SIMA DEL ELEFANTE SITE (ATAPUERCA, SPAIN)

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In fossil assemblages, mineral concretions are often underestimated and described in a general way, without detailed investigation into their origins, compositions, or implications for taphonomic interpretation. However, these formations are of great relevance for understanding diagenetic alterations and their effects on bone integrity. This study focuses on the detailed characterization of concretions affecting the bone assemblage from Level 19 of Sima del Elefante (Atapuerca, Spain), through a multiscale taphonomic and mineralogical approach to investigate their role in site formation and remains preservation.

Concretions are defined as mineral aggregates formed through post-depositional chemical processes in the sediment, often nucleating around bone fragments or other organic/inorganic materials. These processes are closely linked to environmental factors such as pH, ion saturation, microbial activity, and sedimentary water content. Consequently, they serve not only as diagenetic features but also as paleoenvironmental indicators. In Level 19, preliminary observations reveal a wide diversity of concretion types across stratigraphic sublevels, suggesting variable sedimentary and post-depositional conditions. However, a systematic characterization of these features has not yet been carried out.

This abstract presents the objectives and methodology of an ongoing doctoral project; results are still in preparation and will be made available in future stages of the study.

The primary objective of this project is to analyse how concretions influence fossil bone preservation and to relate these effects to sedimentary dynamics and paleoenvironmental conditions. To this end, we integrate macro-, micro- and nanoscale analyses to characterize how these mineral formations influence bone preservation. At the macroscopic level, the macrofaunal remains (n= 2153) are examined for the presence, structure, and effects of concretions on cortical surfaces, including alterations such as fracturing, or mineral replacement. Based on the taphonomic alterations identified, a subset of 30 bone fragments was selected for further analysis. Each specimen underwent three complementary analytical procedures.

At the microscopic level, thin sections are examined using polarized light microscopy to assess microstructural alterations in the bone, such as recrystallization and porosity changes. Energy-Dispersive Spectroscopy (EDS) is employed to analyse the chemical composition of the concretion and relationships at the bone-concretion interface.

At the nanoscale, X-ray Diffraction (XRD) provides detailed mineralogical characterization of the concretion matrix and reveals the dissolution-reprecipitation and replacement processes that affect the bone. Additionally, Fourier Transform Infrared Spectroscopy (FTIR) is applied to detect molecular-level changes in the mineral and organic components of the bone, enhancing our understanding of diagenetic transformation.

The integration of these analyses aims to clarify the impact of concretions on the integrity and preservation of fossil bones, while also providing insights into the palaeoenvironmental conditions and sedimentary history of Level 19 at Sima del Elefante. The originality of this project lies in its interdisciplinary and multi-scale methodology, which we hope can offer a transferable framework for addressing similar taphonomic challenges at other archaeological and palaeontological sites.

TAPHONOMIC CONTRIBUTIONS FOR UNDERSTANDING MAMMOTH EXTINCTION DYNAMICS

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When and why did mammoths go extinct? Did their populations fail catastrophically, or languish over time before finally disappearing? Did mammoth extinctions around the world follow the same trajectories, or were there regional differences? While these are basic questions, answering them with any degree of certainty has proven challenging. The late Pleistocene fossil record is an unusually rich resource for studying extinction dynamics because individual specimens can often be directly radiocarbon dated. While this provides opportunities for pinpointing extinction timing with high precision, such high-resolution time series data may also be sensitive to a variety of geological, taphonomic, and biological factors, such as changes in preservation potential due to shifts in climate, depositional setting, and/or population size. While such factors may be particularly challenging to differentiate using regional- to continental-scale data, highly fossiliferous late Pleistocene records can provide relatively geographically (and thus climatically and environmentally) constrained fossil time series. Using published time-series of radiocarbon dated mammoth specimens within regions across North America and Eurasia, we combine the temporal distribution of specimen ages with the distribution and sizes of temporal gaps between dated specimens to test for shifts in population trajectories through time consistent with (1) protracted population decline, or (2) abrupt loss. We do this separately for mainland populations and Arctic island populations (where mammoths persisted for millennia following mainland extinctions and where there are no indications of human co-occurrence). We find that sampling can be excellent during mammoth extinction intervals. For example, in northern North America, gap sizes during extinction are consistent with average gap sizes across the time-series, which is inconsistent with mammoth populations dwindling slowly over millennia. However, elsewhere (e.g., St. Paul Island) gap size apparently increased during the extinction period. In the absence of a sedimentological explanation for expanding gap sizes between specimens, this record is more consistent with that of a dwindling island mammoth population. The late Pleistocene fossil record offers important opportunities for evaluating drivers of extinction. While the fossils themselves tell much of the story, gaps in the fossil record can be equally revealing for evaluating species' demographic histories.

‘EPIBIONT SHADOWING’ ON MAMMAL FOSSIL BONES: AN AS-YET UNNOTICED PATH TO THE PRESERVATION OF BARNACLE ENCRUSTERS

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‘Epibiont shadows’ are (micro)reliefs previously described only on invertebrate fossils and interpreted as areas protected by soft-bodied epibionts from erosive processes that affected the surrounding shell surface. These modifications provide insight into how much the substrate was chemically, biologically and/or mechanically eroded before burial. Here, for the first time, epibiont shadows are recognised on vertebrate fossils as centimeter-sized, subcircular, uplifted, pedestal-like areas. A proboscidean postcranial skeleton from the Pliocene deposits of Tuscany (central Italy) features numerous pedestals of (largely) unworn bone, both isolated and in clusters, superimposed on each other and on *Anellusichnus*, *Thatchtelithichnus*-like fossil traces. The pedestal-like structures are still topped by barnacle (*Amphibalanus*) shells, or by remnants of the basal plate thereof. A similar suite of bone modifications and *Amphibalanus* shells are found on the holotype skull of the Tuscan Pliocene bowhead whale relative, *Balaena montalionis*. Large, raised pedestals are also present on a Miocene whale bone fragment from the Calvert Cliffs (Maryland, USA).

These unusual modifications came to be as the bone underlying an encrusting barnacle shell was sheltered from erosion by the presence of the shell itself, thus resulting in the creation of a pedestal of (largely) unworn bone. A new terminology for these structures on bone is here proposed (‘episkeletozoan shadows’).

In conclusion, the bones of the three studied specimens remained exposed at the seafloor in shallow, coastal-marine waters for fairly a long time, which allowed for several generations of barnacles to settle and grow on the eroding bone.

TAPHONOMIC FILTERS AND THE ECONOMICS OF THE CAMBRIAN EXPLOSION

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Exceptional fossil deposits (Konservat-Lagerstätten), epitomised by the Burgess Shale of British Columbia (Canada), have opened uniquely direct windows on the rise of the animal-dominated biosphere during the Cambrian Explosion. However, taphonomic and biostratinomic constraints impose strong trade-offs between the likelihood of exceptional preservation and the palaeoenvironmental spread of Konservat-Lagerstätten. Most Burgess Shale-type deposits record deeper-water, oxygen-poor, or high-energy sedimentation settings, safe from intense scavenging, bioturbation, and decomposer activity. As a consequence, our understanding of the Cambrian biosphere is mostly based on disturbed, resource-limited, or otherwise ecologically marginal environments.

Here we show that the new taphonomic window opened by small carbonaceous fossils (SCFs) is disclosing exceptionally preserved Cambrian faunas far beyond the confines of traditional Konservat-Lagerstätten. Due to their permissive biostratinomic and taphonomic requirements, the submillimetric, cuticularised SCFs are revealing Cambrian faunas from well-oxygenated, resource-rich, and highly habitable epeiric seas. New SCFs from the middle Cambrian Bright Angel Formation of Arizona (USA), the Pika Formation of Alberta (Canada), and the Hess River Formation of the Northern Territories (Canada) indicate that these largely cryptic shelf environments hosted a range of metazoan taxa more functionally sophisticated and phylogenetically modern than their counterparts from coeval Burgess Shale-type macrofossil deposits.

This overrepresentation of comparatively derived taxa in stable, metabolically permissive shallow water settings singles out largely cryptic Cambrian environments as hotspots of early animal adaptive novelty. As such, SCFs can overcome major preservational biases to map how, and where, early animals overcame limiting physiological trade-offs on key innovations, initiating the coevolutionary feedbacks that built the Phanerozoic biosphere.

THE TAPHONOMY OF BIOLOGICAL INTERACTIONS AFFECTING SKELETAL PRESERVATION DURING LIFE AND AFTER DEATH

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Biological interactions among organisms belong to the most important ecological processes. Both lethal and non-lethal predator-prey relationships can be recognized in the fossil record of marine invertebrates. In some cases, distinct predation marks on the skeleton remain allowing for the closer identification and details of interactions involved. Predation can range from discrete boreholes (gastropods and cephalopods) to partial and wholesale destruction of skeleton by durophagous predators. Further processes, such as encrustation and bioerosion by a variety of organisms can also affect both living organisms as well as their remains after death. All these interactions have profound impacts on skeletal representations in the fossil record. In some cases, these have positive effects with for example encrustation promoting preservation while others have negative effects, such as bioerosion weakening skeletons and thus enhancing destructions. This presentation will show examples illustrating the influence of biological interaction on preservation based on common echinoids from both recent shallow water environments using an actualistic approach, as well as from the fossil record. Preservation ultimately depends on the skeletal architecture of these multi-plated skeletons which are studied in detail with respect to morphological and biomechanical aspects. Biological interactions incurred both during life and after death as well as general environmental factors such as exposure and water movement are shown to influence preservation potentials.

This study shows that there are multiple paths toward preservation leading to a wide variation of skeletal remains ranging from articulated test to highly fragmented material.

FROM THE LAST MARTIANS TO THE FIRST AMERICANS: INTEGRATING TAPHONOMY AND SPECTROSCOPY AT THE FRONTIER OF KNOWLEDGE

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Mars missions have invested in high-resolution equipment, as Raman and X-ray fluorescence (XRF) due to their excellent performance in identifying chemicals of biogenic importance (fossil and recent). Those techniques have also been applied in the studies of fossils on Earth, underscoring the methodological and conceptual convergence between paleontology and astrobiology. Our group has been working on chemical characterization and the spectroscopic detection limits of (bio)minerals such as apatites, sulfates, and oxides. Here we present data obtained from fossil analyses experiments that may contribute to understand the preservation and credibility of information in the fossil record, and to identify and validate biosignatures in Martian contexts:

(I) *Identifying (bio)minerals in oxidizing environments*. We prepared six binary mixtures of fine-grained apatite and a calcite–dolomite with 5%, 50%, and 95% goethite, and tested the effects of two micro-Raman excitations (532 and 785 nm) and mineralogical compositions on the spectral response. The results show that goethite significantly obscures peaks of apatite and carbonate as the concentration of iron increases. Furthermore, the presence in apatites of luminescence related to rare earth elements in the 785 nm laser may at the same time interfere with the identification of organics and help in the detection of trace apatites, presenting a challenge for the recognition of biosignatures. None of these luminescent bands were observed with the 532 nm laser, but it revealed distinct goethite peaks that were not visible under 785 nm. The 785 nm laser provided clearer detection of the double band of calcite-dolomite (~1087 and ~1098 cm^{-1}). Our observations highlight the complementary nature of both lasers, emphasizing the importance of tailoring analytical strategies to investigate oxidizing environments. These findings also support improved detection of weathered fossil shells, bones, and teeth, informing the choice of better-preserved mineral phases for radiometric dating and isotopic studies, enhancing accuracy of paleoenvironmental reconstructions. (II) *Dealing with fossilization and weathering biases in bones and teeth.* Skeletal fossilization involved significant changes, such as the loss of organics, permineralization of voids, adsorption or substitution of foreign ions, and recrystallization. **(A)** We recently described *Peltocephalus maturin* (Late Pleistocene, Rio Madeira Formation), the last of known giant freshwater turtles. We performed micro-Raman spectroscopy and energy-dispersive X-ray fluorescence (EDXRF) analysis to investigate carbonates and sulfates that may interfere with the reliability of dating on this fossil. Collagen was not detected, preventing nitrogen isotope analysis. Radiocarbon dating was performed on bioapatite (ages around 14,000 and 9,000 BP). Raman revealed a ~1351 cm^{-1} band in the bone, often linked to iron oxidation (hematite). No organic bands were detected in the fossil. Calcite peaks were found, supported by EDXRF, which

indicated elevated calcium but no phosphorus. Sediments associated with the bone showed gypsum/anhydrite peaks, some also of carbonates and apatite, confirmed by EDXRF. Phosphorus was more abundant in sediments, and sulfur levels reinforced the presence of calcium sulfates. Fossil and sediment contained iron and manganese, with high counts, possibly due to prolonged weathering, showing high probability of apatite reprecipitation, challenging the obtained ages. **(B)** We also applied EDXRF to study bones, teeth, and osteoderms from two ground sloths (dated to c. 13,000 and 27,000 BP, respectively) found at Santa Elina archaeological site (Mato Grosso, Brazil). We found that, regardless of the specimen's antiquity, teeth and osteoderms exhibit Fe/P count ratios lower than 0.2, whereas bones can reach values as high as 0.7. In the case of associated sediments, both sulfur and iron showed much higher counts in the oldest fossil (c. 4,000 and 50,000, respectively) compared to the youngest (c. 900 and 30,000, respectively). This suggests greater influence of weathering minerals, such as sulfates and iron oxyhydroxides, in sediments associated with the older sloth. Conversely, the low Fe/P ratios in osteoderms and teeth of both individuals may indicate the higher reliability of these specimens for isotope analyses and radiocarbon dating, compared to bones (but see Pansani et al “Elucidating possible anthropogenic burning of Pleistocene megafauna bones in Santa Elina, Brazil through taphonomy and paleometric approaches” at this meeting for further results). **(C)** In fossil specimens from older deposits, such crocodyliforms from the Adamantina Formation (Late Cretaceous, Brazil), we identified a weathering response pattern that is broadly comparable to that observed in skeletal elements of the giant sloths, this time revealed through micro-Raman. Some crocodyliform teeth display Raman peaks (around ~960–962 cm^{-1}) that closely match those of recent bioapatite. These findings underscore the utility of spectroscopy in enhancing sample selection criteria for isotopic analyses and radiometric dating.

(III) *Mars in a sand grain and experimental fossilization*. We analyzed cycad leaflet fragments and sand grains on long-term incubation iron media, with and without inoculation of microaerophiles (*Gallionella*). Over two years, we monitored the effects of iron and microbial activity on samples using micro-Raman (lasers 532 and 785 nm), scanning electron microscopy (SEM), and EDXRF. Control leaflets (iron-only) showed more conspicuous epidermal injuries. Fragments exposed to bacteria exhibited iron replication and infilling of tissues. A slight shift was observed in the lignin Raman peak, from 1604 cm^{-1} (fresh leaflet) to 1606 cm^{-1} in leaflets subjected to the experimental conditions. The band corresponding to the leaflet inoculated with bacteria exhibited a broader full width at half maximum (FWHM), suggesting a more advanced stage of lignin decay. EDXRF results demonstrated a significant increase in iron accumulation in the bacterial system (c. 240,000 counts) compared to iron-only treatments (ca. 20,000 counts). This shows that the bacteria activity may promote a more efficient mineralization of organic tissues. We also assessed mineral synthesis mediated by bacterial on sand. Raman bands characteristic of iron oxyhydroxides, including goethite, hematite, and lepidocrocite (~218–225; ~240–250; ~290–300 cm^{-1}), were detected almost exclusively in grains from the bacterially inoculated environment. EDXRF revealed iron counts below 2,000 in sand from the abiotic control, whereas values exceeded 17,000 in grains from the bacteria system. SEM imaging indicated pronounced surface corrosion in grains from both conditions; however, those exposed to bacteria displayed a distinct and specific corrosion pattern, potentially associated with biogenic processes. These results suggest that, apart from specific signatures left in the substrate, mineralogical and quantitative differences in iron oxyhydroxides may be produced by life, assisting the elaboration of specific criteria and analytical protocols to investigate return Mars samples.

ELUCIDATING POSSIBLE ANTHROPOGENIC BURNING OF PLEISTOCENE MEGAFAUNA BONES IN SANTA ELINA, BRAZIL, THROUGH TAPHONOMY AND PALEOMETRIC APPROCHES

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The Santa Elina rock shelter, in Central Brazil, is a key archaeological site in South America for discussing the early peopling of the New World. Its late Pleistocene layers (Unit III; ~27,000 and Unit II; ~13,000 c. yr BP) show evidence of human occupation (lithic culture and fire structures) in association with megafauna (giant ground sloths) bones and artifacts. We are currently engaged in a taphonomic investigation of possible anthropogenic burning of megafauna bones using a range of interdisciplinary approaches, including experimental taphonomy and the use of advanced imaging and analytical techniques. Here we present some preliminary results of scanning electron microscopy (SEM), energy-dispersive spectroscopy (EDS), and powder X-ray diffraction (pXRD) analyses of i) Santa Elina's Pleistocene fossil bones (which have a predominantly brown coloration across the whole assemblage), ii) potentially burned fossil bones from the site (black colored), and iii) reference samples (dry and experimentally burned armadillo bones). EDS data show that the black-colored fossil bones from Santa Elina are not oxide-stained. Iron and manganese are only significant in one fossil osteoderm with macroscopic "ring-like" features of oxide contamination. The comparison of 7 reference armadillo bone samples (total of 15 EDS data) and 7 fossil samples (total of 31 EDS data) shows similar patterns, such as a decrease of carbon and oxygen, relative increase of phosphorus and calcium, and lower weights of aluminum and silica in burned rather than dry/weathered bones. Combined, these data suggest likely burning of the fossil osteoderms rather than organic contamination (*e.g.*, humic acids). Future synchrotron-based X-ray fluorescence (XRF) analysis could be used to corroborate this conclusion. Quantitative pXRD data show that the crystal structure of burned reference osteoderms is more shrunken than the fresh ones, and suggest that black colored fossils have similar volume reduction in comparison with controlled brown fossil samples. SEM data images of a partially black-colored fossil rib (Unit II) and black osteoderms (Units II and III) show bone microstructure features characteristic of burned bones, such as internal microcracking, polygonal microcracking, melted-like crystals, a variety of glassy, granular, and pitted surfaces, and neo-formed crystals. However, the EDS results of the fossil rib are noteworthy for their comparatively higher amounts of carbon and oxygen relative to the fossil osteoderms, which warrants further investigation. This highlights the need for a broader and multi-technique approach in this study. Additional analyses, such as Fourier-transform infrared spectroscopy (FTIR), are under development and will complement our preliminary results by providing information on molecular-scale changes in the mineral and organic components of the fossil bones. Efforts using multiple paleometric approaches are fundamental for high-quality data that are essential for controversial topics such as the early peopling of the Americas and these people's interactions with extinct megafauna in South America.

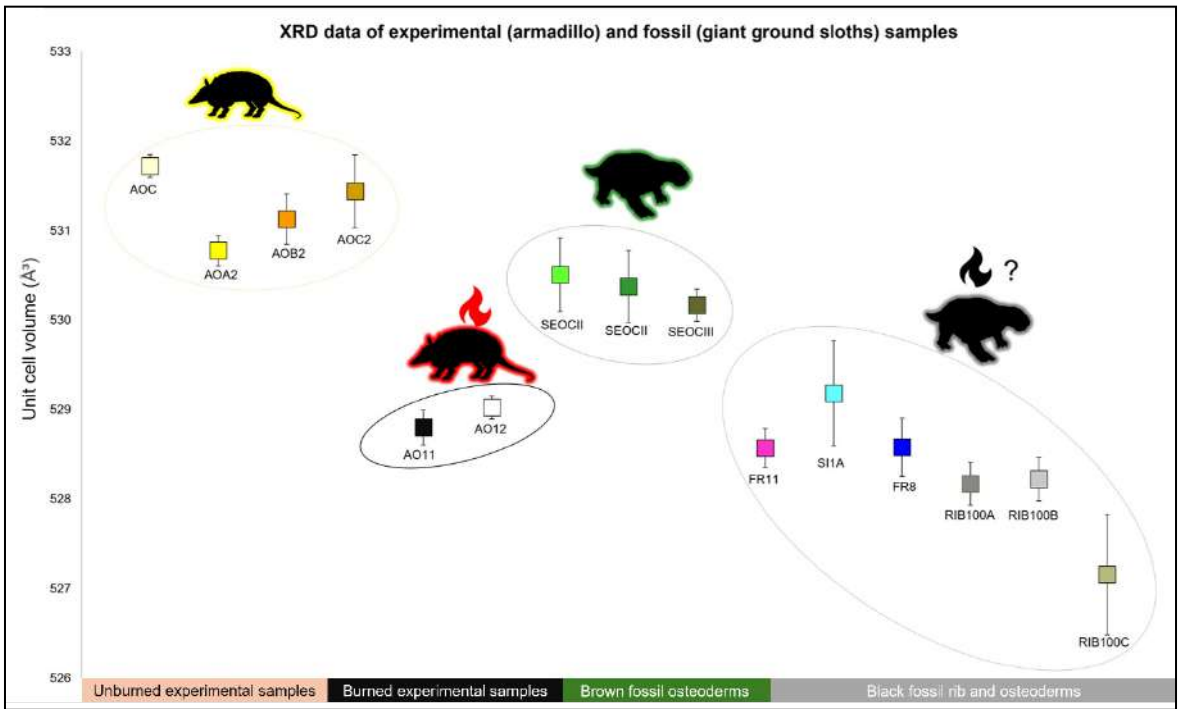

Figure 1. Unit-cell parameters of experimental samples (armadillo unburned and burned osteoderms) and brown (control) and black fossil osteoderms (giant ground sloths from Santa Elina, Brazil), acquired from X-ray diffraction (XRD) quantitative analysis. Error bars represent estimated standard deviations. Notice that burned armadillo osteoderms (AO11, black/carbonized, and AO12, white/calcified) have reduced volumes compared to unburned samples. A similar pattern is found in black osteoderms and rib compared to control osteoderms with no signs of burning.

EXPLOITATION OF HARD ANIMAL MATERIAL FROM THE TERRAMARA OF PILASTRI DI BONDENO (FERRARA): TAPHONOMIC ANALYSES OF THE FAUNAL ASSEMBLAGE

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The Pilastri di Bondeno (Ferrara) site dates back to the Terramare culture between the Middle and Recent Bronze Ages. It is located on a fluvial levee relative to the palaeochannel of Dragoncello-Pilastri. Excavations carried out between 2013 and 2018 uncovered numerous bone remains, primarly from trench B, revealing the presence of a productive structure (a hut-laboratory) containing a pyrotechnological installation. The most abundant remains identified belong to domestic taxa, mainly sheep/goats, pigs, cattle, and dogs. Horses, which are often present in contemporary sites in north-eastern Italy, were completely absent. Wild taxa are not very abundant but there is great variability, including red deer, wild boar, wolf, birds, and pond tortoises. Analyses indicate an economy based on pastoralism, on the exploitation of pigs for meat and of cattle as beasts of burden, as well as an interest in dogs, fowling, fishing, and collecting tortoises.

Taphonomic analysis of the assemblage identified numerous traces of both natural and anthropogenic modifications, which contributed to the high degree of fragmentation. The NISP covers only 30% of the total sample. Edaphic processes are present and rather abundant, such as root etching and manganese oxide deposition, which are typical of burial in wet environments. There is also evidence of gnawing by carnivores and rodents. Many remains show traces of combustion and calcination, particularly those found in the hut-laboratory, where the degree of fragmentation was more extensive than in the outer layers. Numerous butchery traces were also observed, such as striae, chop marks left by blades and metal tools, mainly on the long bone surfaces of domestic animals. Traces of thermal alteration to varying degrees are abundant and can be interpreted in relation to the presence of a pottery furnace in the hut-laboratory and waste disposal.

The bone and antler industries were widespread in the Po plain during the Bronze Age, and the artefacts from Pilastri fit well within this general context. A sample of bones was selected for taphonomic trace observation using both optical and scanning electron microscopies. The artefacts include both finished objects and waste products relating to the débitage and façonnage phases of the chaîne opératoire. The raw materials used were mostly deer antler, as well as bone elements such as long bone diaphyses and ribs. The observed processing traces are varied and attributable to three techniques: indirect fracturing, grooving using flint or metal tools, and abrasion. The artefacts are mainly of two types: bevelled tools (i.e., biseaux, likely used in ceramic production), and pointed and piercing tools such as needles and points made from bone splinters e.g. fibulae, ulnae, or metapodials, which are already morphologically thin and elongated, and then modelled by scraping and abrasion.

COMPOSITIONAL FIDELITY GRADIENT OF GASTROPODS IN UBATUBA BAY (SP, BRAZIL): TAPHONOMIC AND CONSERVATION IMPLICATIONS

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Compositional fidelity analyses are essential tools for assessing the concordance between living and dead biological communities, enabling robust inferences about environmental disturbances, whether natural or anthropogenic. This study evaluated the compositional fidelity of gastropods at four sites in Ubatuba Bay, Brazil (P1, P2, P3, and P4 – bathymetric data to be included), based on monthly trawl surveys conducted between July 2021 and June 2022. A total of 741 specimens were analyzed (548 live and 193 dead), encompassing 11 species. The dominant species were *Olivancillaria urceus* (291 live, 70 dead), *Buccinanops cochlidium* (137 live, 11 dead), and *Strombus pugilis* (1 live, 83 dead). The latter was the only herbivore and the only species to show an inverse pattern of dominance between live and dead assemblages. The overall distribution of live and dead specimens was atypical for marine environments, where a higher abundance of dead shells is generally expected due to time-averaging effects. Compositional fidelity was assessed using the following metrics: Jaccard-Chao index (J-C, taxonomic similarity), Spearman's rank correlation (ρ, abundance ordering), ΔS (difference in richness), and ΔPIE (difference in evenness), along with rarefaction curves and richness estimates using the Chao1 index. Results revealed a clear fidelity gradient among the sites. Site P4 showed high taxonomic similarity (J-C = 0.993) and a significant abundance correlation (ρ = 0.642; p = 0.033), indicating stable preservation conditions. In contrast, P2 exhibited the lowest fidelity values (J-C = 0.175; ρ = 0.219), possibly due to selective transport, accelerated degradation, or environmental disturbance. P1 showed intermediate values (J-C = 0.500; ρ = 0.230), while P3 (J-C = 0.426; ρ = 0.148) displayed metrics consistent with environments affected by eutrophication (as reported in the literature: J-C < 0.7 and ρ < 0.2). The richness analysis (ΔS) initially indicated higher richness in the dead assemblages at P1, P2, and P3; however, the rarefaction curves did not reach asymptotes, suggesting under-sampling. The Chao1 estimator, sensitive to rare species, reversed this trend, indicating greater richness in the live assemblages at most sites, except P3. Regarding evenness (ΔPIE), P4 was the only site where the live assemblage was more evenly distributed than the dead one (ΔPIE = –0.157). In the other sites, dead assemblages exhibited greater evenness, reflecting the dominance of few species in the live communities. Taphonomic data were recorded for each specimen to identify potential preservation biases. As expected, dead shells showed higher alteration rates: 90% displayed bioencrustation, 87% bioerosion, 56% abrasion, 61% color loss, and 54% fragmentation. The low fidelity observed at P1–P3 appears to be related to the scarcity of dead shells, possibly explained by hydrodynamic transport associated with local circular currents (favoring shell accumulation at P4), taphonomic agents such as bioerosion (which accelerates dissolution), or even sampling bias related to the trawling method. The fidelity gradient observed in Ubatuba Bay highlights its potential as a model system for conservation studies. Sensitive species such as *Strombus pugilis* may serve as bioindicators of population decline in the face of increasing anthropogenic pressure. Future radiocarbon (14C) dating of *S. pugilis* dead shells will aim to estimate time-averaging and determine whether these assemblages represent a once-abundant, pristine community, as well as assess their taphonomic resilience.

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ESTABLISHING AN INTERNATIONAL TAPHONOMY REFERENCE COLLECTION (ITRC) WITH A NEW SYMBIOTA-BASED ONLINE DATA PORTAL

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Bones and bone assemblages featuring various types of modifications are sources of comparative materials to help zooarchaeologists, paleontologists, ecologists, and forensic scientists interpret evidence of taphonomic processes. Current information systems used for managing and sharing museum specimen data often lack the necessary structure for clearly documenting taphonomic information. As a consequence, important taphonomic collections may be invisible to the scientific community or underutilized in their host institutions. The vocabulary used to describe taphonomic features also can vary between reference textbooks, datasets, researchers, and institutions.

Here we describe a project that aims to address these issues, as well as increase discoverability and visibility of these collections, through the development of an International Taphonomy Reference Collection (ITRC), which utilizes a Symbiota-based online data portal. Our ITRC Symbiota portal currently includes partner collections maintained by the Smithsonian National Museum of Natural History and the National Museums of Kenya, with future plans to connect with other taphonomy collections from across the globe.

The collaborative nature of Symbiota portal communities can stimulate increased understanding of taphonomic evidence and processes by promoting standardized curation practices for taphonomy reference collections as well as providing reference materials for taphonomic research, education, and outreach.

CARBONATE CONCRETIONS IN NEOGENE MARINE MAMMALS FROM SILICICLASTIC SHALLOW MARINE ENVIRONMENTS

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Most of the marine fossil mammals recorded in the Neogene basins of South Spain (Vera Basin, Almería Basin and Guadalquivir Basin) belong to the Order Cetacea, but there are also some that belong to the Order Sirenia. These remains appear to be preserved in different siliciclastic deltaic environments from upper Tortonian to Pliocene. The aim of this work is to characterize the preservation of marine mammals in different facies with special attention to the development of carbonate concretions surrounding the fossil bones.

Most of the cetacean remains in the South Spain Neogene basins are typically recorded in (1) relatively deep-water silty marls and sandy marls representing distal facies of the fan-delta, and (2) in the shallower coarse sands and conglomerates. The more complete specimens of cetaceans are recorded in the deep-water fine sediments where fossil bones present a cemented carbonate coating, whereas in the shallower environments they are represented by isolated bones with high fragmentation. In contrast, the sirenian remains have been recorded only in coarse sand facies, locally with common charcoal vegetal remains, which were deposited in shallower water closer to the shoreline areas. The sirenian remains (exclusively *Metaxytherium*) recorded in the coarse facies (conglomerates and coarse sands) are commonly articulated and poorly dispersed.

Bone dispersal in silts and sandy marls cannot be explained by high energy currents since much of the fine sediment has been deposited from suspension and there are not sedimentary structures. Floating and progressive decay could explain the record of the aligned caudal vertebrae of whales and the record of the large hemimandibles. The floatation was due to internal gas production of deceased cetaceans and the subsequent loss of body parts from floating carcasses. Articulated parts of floating corpses becoming detached and sunk onto the sea floor. The activity of scavengers surely enhanced the disarticulation and dispersion of body parts from the corpse. The rapid burial favoured the articulation of the vertebrae when reaching the sea bottom. Actually, scattering of bones of marine vertebrates is very frequent with necrokinetic and marine circulation patterns being the most important factors in the disarticulation and dispersion of the skeletons.

The development of cemented carbonate coating around decaying carcasses from relatively deep settings is probably related to the decay of blubber and other organic matter contained within the pores of the trabecular bone tissue. Cetaceans are very good swimmers and the blubber in their lipid-rich bones makes the body density very similar to the seawater favouring the movement. In contrast, the sirenians remains are never recorded with a cemented sediment coating, probably due to the density of their heavy bones (pachyostosis) that help them to remain in the sea floor where they grazed (sirenians are partially articulated and reworking was not intense in the specimens recorded).

A rapid burial recorded for some of the cetacean remains in the bottom-set fine sediments would favour a slow anaerobic decay. But probably it is not necessary evoke a fast burial due to in modern oceans, the sediment beneath and around whale carcasses, progressively enriched with lipids and other organic components, experiment anoxic conditions due to high microbial oxygen consumption that favour anaerobic sulphate reduction and methanogenesis. The blubber inside the cetacean bones would feed anaerobic microbes and produce cemented coating surrounding the remains. This kind of concretions are related to post-burial anaerobic decay of bone lipids by sulphate reduction during the early diagenesis. The microbial degradation on whale bones is more accentuated from deep-water whale falls whereas cemented coating around fossil bones of sirenians and cetaceans is less developed or absent in shallow coarse facies.

In the shallowest environments, the sirenian remains were buried rapidly in shallow coastal environments due to the high degree of articulation and the bones were laid and collapsed almost

in the original position. The absence of encrusters on the bones confirm a short exposure in the sea bottom before burial. The presence of small selachian teeth in the sediment surrounding the sirenian remains evidence the activity of scavengers. In coarse deposits from shallow environments, the largest balaenid remains are isolated and locally encrusted by oysters and balanids, and inform us about long exposure of the remains on the sea floor before final burial. Both sirenians and cetaceans are not typically coated by carbonate concretions in shallow environments.

BONE PRESERVATION OF AN UPPER JURASSIC MARINE TURTLE

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This research is focused on the taphonomy of an Oxfordian turtle from the Upper Jurassic of the Prebetic (Betic Cordillera, South Spain). The specimen was found in a limestone bed of a marl-limestone rhythmite in the Bimammatum Zone. The aim of this work is to characterize the preservation of the turtle issue in this mid-shelf environment. The remains were cleaned using acid digestion (10% acetic acid) and mechanical preparation (using pneumatic engraving pens). Fragments of bone were used for preparing thin sections, analyses with scanning electron microscopy (SEM) and micro x-ray fluorescence (μXRF) at the University of Jaén (Spain).

The fossil turtle, corresponding to the specie *Hispaniachelys prebetica* (family Plesiochelyidae), was recorded in a marl-limestone rhythmite with wackestone to packstone microfacies rich in peloids. Trace fossils are scarce and represented by *Planolites*, *Chondrites* and secondarily *Thalassinoides*. Laterally there are siliceous sponge-microbialite buildups, dominated by hexactinellid sponges. Fossil macroinvertebrates are mainly ammonite moulds, belemnites, scarce brachiopods and infaunal articulated bivalves. The fossil turtle present a carapace with 43 cm long and 34 cm wide. The specimen is largely intact, with most of the elements of the carapace remaining fused in their original positions. The degree of fragmentation is low and appears largely to affect the distal parts of bones, which are fractured and not rounded. The outer surface of the carapace presents bioerosions by *Gnatichnus pentax*. The carapace is oriented down in the limestone bed and the plastron has collapsed into the cavity of the carapace.

In thin section, iron oxides can be observed occupying the inner surfaces of the porous bone structure in the cancellous region. Under SEM, both secondary electron and back-scattered electron images show that iron oxides have framboidal morphology resembling pyrite framboids with a diameter ranging 70–20 μm. The rest of the porosity of the cancellous tissue is infilled by microsparitic calcite.

The elemental maps of μXRF confirm the composition of bones with Ca and P mainly, as well as the presence of Fe, Co and Mn associated to the walls of the pores of the cancellous tissue. The content of Ca decreases around the Haversian canals in the compact bone tissue.

SEM images has revealed that visible and well-preserved mineralized collagen fibril bundles line the trabecular walls of the spongy bone. These collagen fibrils are pseudomorphed by francolite crystals and aligned more or less parallel to where the collagen bundles had been. Filaments (< 5 μm in diameter) and globular structures (10 μm in diameter) composed of authigenic francolite are also present in the cancellous region. Some surfaces of the bones are densely covered by microspheres (< 1 μm).

The low degree of fragmentation and the low dispersion of skeletal components suggest a low-energy environment. This is congruent with the absence of sedimentary structures indicating turbulence and is also supported by the microfacies data (comprising a fine-grained wackestone with peloids). Previous paleoecological and taphonomic studies on macroinvertebrate assemblages (primarily ammonoids) have indicated a low energy and low degree of fragmentation within a softground lithological setting at a mid-shelf environment with an estimated palaeobathymetry of ~60-80 m (based on the dominance of Dictyida within hexactinellid sponges, and the low record of ammonoid of Suboder Phylloceratina).

The fragmentation of some bones could also be related to scavenging activity by larger organisms, since the water energy was likely too low to attribute the breakage of bones to (supported by the very low fragmentation present in ammonoids of the bed and of the sediment infilling of the carapace). Other components display probable fragmentation by sedimentary load, the plastron having likely collapsed via this mechanism. The distribution of bioerosion by *Gnatichnus pentax* indicates preferential colonization of the carapace, primarily by grazers. The external surface of the carapace was oriented downwards in the bed, and so pascichnia activity

probably occurred prior to the carapace being overturned. The burial orientation of the specimen is possibly due to the post-mortem activity of scavengers.

In reference to the filaments, globular structures and microspheres observed under SEM analysis, these probably represent by-products of microbial activity associated with the decay of the organic matter of the cancellous bone tissue. The decaying of organic matter from pores in bone tissue during burial favoured the oxygen consumption and the development of anaerobic conditions as confirmed by the record of pyrite framboids. Co, Mn and other trace elements appear associated to pyrite framboids located in the walls of pores of cancellous bone tissue.

EVIDENCE OF ORNAMENTAL SHELL USE IN THE EPIGRAVETTIAN LEVELS OF SAN TEODORO CAVE (ACQUEDOLCI, MESSINA)

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San Teodoro Cave, located in Acquedolci in the northeastern part of Sicily, is a key archaeological site that offers valuable insights into human activities in the Central Mediterranean during the Upper Palaeolithic. The site features a complex stratigraphic sequence, with Epigravettian layers yielding a rich assemblage of archaeological materials, such as lithic tools, faunal remains, and marine shells.

Notably, the presence of marine shells in these layers provides evidence of the long-distance exploitation of coastal resources by hunter-gatherer groups, suggesting their integration into both subsistence strategies and symbolic practices. Some of the recovered shells display clear signs of human modification, suggesting that they were not just collected for consumption. In several cases, natural perforations appear to have been modified intentionally to facilitate stringing or attachment to other materials (Fig. 1).

Microscopic analysis revealed surface traces on the modified shells, including wear patterns and micro-abrasions, consistent with prolonged handling or use as ornaments. This evidence strongly supports their interpretation as items of personal adornment or decorative use. Notably, red ochre residues were identified on several modified shells. These residues were characterised by Scanning Electron Microscopy (SEM), which confirmed their chemical composition and provided strong evidence of their intentional application.

The integration of microscopic and chemical analyses strengthens the interpretation of these artefacts as elements of symbolic behaviour, shedding light on the cultural complexity of Epigravettian communities. Further, the findings from San Teodoro Cave offer broader implications for our understanding of how coastal resources were integrated into both daily life and symbolic practices in prehistoric Mediterranean societies, while also contributing new data to the ongoing research at the archaeological investigation of the site.

Figure 1. Magnified view of a Columbella rustica shell displaying a human-made perforation.

TISSUE-SPECIFIC CHEMISTRY IN EARLY CAMBRIAN MEDUSOID FOSSILS (QINGJIANG, CHINA) REVEALED BY SYNCHROTRON-X-RAY FLUORESCENCE

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One of the most important biotic events in Earth's history was the Cambrian Radiation, which occurred approximately 540 million years ago. This evolutionary milestone revolutionized marine ecosystems and was characterised by rapid transformations of anatomy and physiology in early metazoans. Research into this event is often hindered, however, by the poor preservation of organic matter in important soft-bodied fossil assemblages. The Early Cambrian Qingjiang biota from South China provides an exceptional opportunity to advance our knowledge of early animal evolution. Unlike other biotas of similar age, this Konservat-Lagerstätte preserves soft-tissue anatomy of diverse Cambrian organisms as carbonaceous remains. Crucially, these specimens have avoided extensive alteration via thermal maturation, oxidation and/or mineral replacement, which characterise other Cambrian biotas such as the Burgess Shale and Chengjiang. The mode of preservation of the Qingjiang fossils therefore offers the potential to recover unprecedented insights into the origin of complex animals. The fossil medusoids from Qingjiang are particularly noteworthy as medusoids are extremely rare in the fossil record and usually preserve only impressions of soft tissues. Here, we present the first taphonomic study of two medusoid fossils from the Qingjiang biota.

We analysed both the part and counterpart of specimen CY711, along with one part of a second specimen (JY0377), using synchrotron-X-ray fluorescence (XRF) analysis followed by multivariate statistical analysis. We quantified the concentrations of 12 elements (P, S, Cl, K, Ca, Ti, Cr, Mn, Fe, Cu, Zn and As) in specific regions of each specimen and processed these elemental data using R. A cluster analysis was performed on pixel-level compositional data in order to identify spatial patterns in chemistry. The chemical data in each region of interest were analysed using PERMANOVA and post-hoc pairwise tests.

Our results reveal strong geochemical patterns in both specimens. Cluster analysis shows distinct clusters (regions with similar chemistry) that define the fossil soft tissues and the surrounding sediment, indicating ion exchange during early diagenesis. In both the part and counterpart of specimen CY711, the fossil is surrounded by a zoned geochemical halo whereby a Cu-rich zone immediately adjacent to the soft tissues is surrounded by successive zones rich in (1) Mn, (2) Ca and P, and (3) Ti and Cr. This last zone, in turn, transitions into Fe-rich background matrix. No such halo is evident in specimen JY0377, suggesting differences in diagenetic ion exchange between fossil and host sediment. Critically, our analysis reveals distinct chemical signatures associated with specific soft tissue features. The tentacles are enriched in Fe and S; the epidermis and gastrodermis are enriched in Ca, and the mesoglea and stomach cavity are enriched in Ca and depleted in Fe. Notably, the chemical maps define additional soft tissue features that are not evident in hand specimen: features interpreted as the ocelli and gonads are enriched in Fe and S.

Our findings demonstrate that tissue-specific chemistry can be preserved in Early Cambrian carbonaceous fossils. This offers unprecedented insight into the anatomy of the earliest large

animal fossils and confirms the potential to recover further insight into the evolution of fine-scale anatomy and physiology during the Cambrian Radiation.

TESTING THE PHYLOGENETIC AFFINITY OF FOSSILS FROM THE MAZON CREEK LAGERSTÄTTE (CARBONIFEROUS, USA) USING MELANIN CHEMISTRY

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Melanins are black to orange pigments that are widespread across extant organisms and play important roles in coloration and physiology. Fossil evidence of melanin and melanosomes (melanin-bearing organelles) has been reported from fossils dating back to the Carboniferous. Recent advancements in our understanding of melanosome attributes, including distribution, abundance, morphology and chemistry highlighted strong tissue- and taxon-specific signals in extant and fossil vertebrates, prompting the use of those melanosome attributes to investigate phylogenetic affinities in enigmatic fossil taxa. Raman spectroscopy is an emerging tool in palaeontology to investigate the chemistry of organically preserved fossils. We have recently demonstrated that quantitative analysis of Raman signatures can discriminate between melanin-rich tissues and other biological materials following thermal maturation.

Here, we test the capacity of this approach to discriminate different taxa, using Palaeozoic fossils. We analysed 21 specimens from the Mazon Creek Lagerstätte, including vertebrates, invertebrates and the enigmatic *Tullimonstrum gregarium*. We analysed the chemistry of the melanosome film preserved in the eyespots using a Renishaw inVia Qontor Raman Microscope System using a 532 nm 50 mW laser. All samples are dominated by melanin characteristic Raman peaks. Linear Discriminant Analysis (LDA) of the Raman data reveals differences in the Raman signal between invertebrates and vertebrates. Critically, our analysis suggests that *Tullimonstrum* has a vertebrate affinity. Our findings on the affinity of *Tullimonstrum* align with phylogenetic interpretations based on the morphologies of ocular melanosomes but differ from interpretations based on melanosome metal chemistry, which instead suggested an invertebrate affinity. This highlights the challenges of the application of taphonomic information to phylogenetic interpretations when our understanding of the taphonomic history of fossils, especially at the molecular level, is incomplete.

PATHOGENIC LEAF DAMAGE INSIDE A BRAIDED-RIVER REGIME DURING THE MIOCENE CLIMATE OPTIMUM FROM THE NORTH ALPINE FORELAND BASIN.

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Numerous sand and gravel pits provide insight into the Miocene vegetation history of the Upper Freshwater Molasse, which was deposited by dynamic Braided River systems. Two almost contemporaneous floras from the end of the Miocene Climatic Optimum (MCO) about 15 Ma reveal different site conditions with regard to groundwater availability, which may also be due to climatic fluctuations. Accordingly, both are characterized by different alluvial forest communities.

Unterwohlbach is dominated by the poplar *Populus balsamoides* and cinnamon-related *Daphnogene polymorpha*, with large leaved willows (*Salix* spp.), elms (*Ulmus pyramidalis)*, and *Platanus leucophylla* to a lesser extent. Entrischenbrunn, on the other hand, is characterized by leather-leaved poplar *Populus mutabilis*, which is apparently adapted to drier conditions, and the clearly narrow-leaved sun leaves of *D. polymorpha*. Other elements are characteristic for seasonal drought, such as small-leaved elms. This might indicate temporarily dried-up channels, as can be today observed in one of the few largely untamed European braided rivers, the Tagliamento in Northern Italy. However, the influx of species typical for Unterwohlbach also indicates the simultaneous presence of neighboring moist sites in Entrischenbrunn. This suggests possible relief-related differences, which are also plausible due to coarse gravel deposits and the associated stronger erosive forces. However, large-leaved specimens of *P. leucophylla* and *P. balsamoides*, which were concentrated in a certain layer, prove the simultaneous presence of adjacent wet sites.

The evaluation of intensity of hygric seasonality in alluvial forest patches is thus not only difficult because of the influence of groundwater possibly overprinting the quantities of water added by local precipitation. Also, a mixing of signals may have occurred due to the plant remains from different locations. Besides, taphonomically caused processes in the leaf litter and the sediment have to be considered.

A particular feature of this, as well as other Molasse floras of this epoch, is the infestation by pathogenic agents (mainly by foliar fungi) which affects almost all leaves and has not been documented elsewhere in this quantity. The rapid hygrometric changes between dried-out channels and high-energy flooding, leading to dynamically changing site conditions, could be responsible for this. As a consequence, plants may become weakened and susceptible to a variety of pathogens. Since such pathogens can still be active on the tree, in the leaf litter, and also in the sediment, it would be worth investigating to what extent differentiation is possible here. Another difficulty lies in the fact that current identifications are limited to purely morphological comparisons with present-day plants. However, initial studies already show striking parallels. For instance, the infestation traces on the veins of the fossil *Pueraria maxima* resemble the vein necrosis virus of the closely related modern crop soybean (*Glycine max*). However, no recent equivalent has yet been found for a scab-like infestation trace that is widespread in most Middle Miocene Molasse floras on the cinnamon-related *Daphnogene* leaves.

The importance of this previously neglected area of research is therefore already evident. Current climate scenarios suggest that as temperatures rise, there will be a shift between periods of drought and periods of heavy rainfall, as assumed for the MCO. This will undoubtedly lead to an increased occurrence of damage symptoms in naturally growing and planted plant populations. The strongly fluctuating hygrometric conditions that may be comparable to this would be characteristic of our braided river system, but are not known from other documented MCO sites

outside the Molasse zone.

Investigating how plants interact with their environment through insect tracks and pathogens on leaves will hopefully allow further conclusions to be drawn about the respective ecological conditions, e.g., degree of humidity, flooding or drought periods. Systematic classifications and statistical evaluations are still pending, but some observations and in part previously unrecorded phenomena can already be presented here, which may serve to expand the knowledge about damage typification.

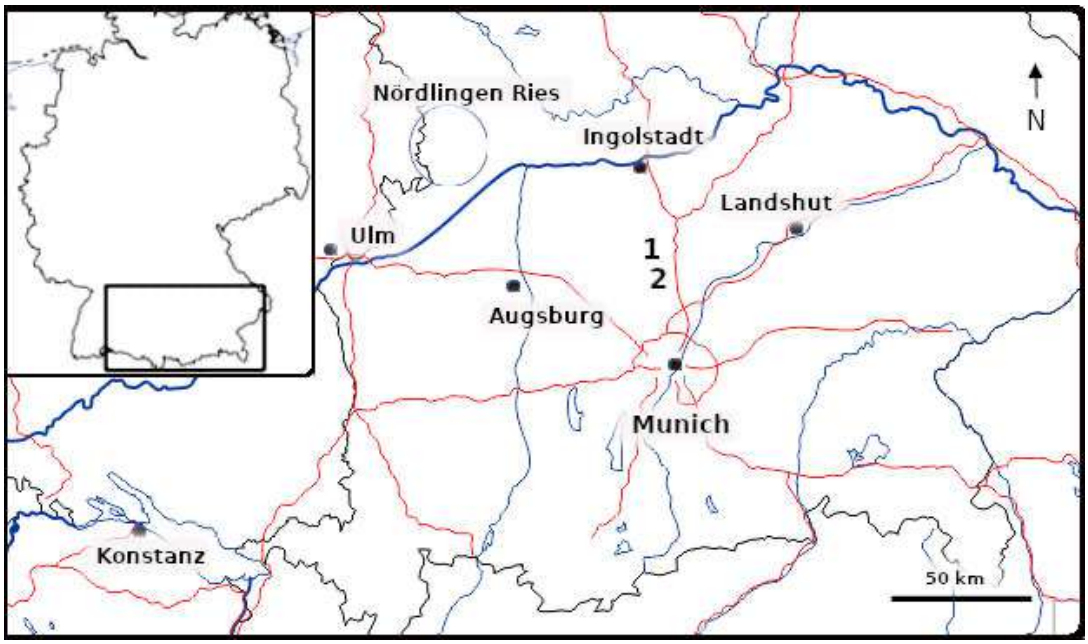

Figure 1. Position of the mentioned localities in the Bavarian North Alpine Foreland Basin 1, Entrischenbrunn; 2, Unterwohlbach. Base map is taken from https://d-maps.com/. Country borders (black), highways (red), water bodies (blue).

THE TAPHONOMIC ANALYSIS OF THE LATE PLEISTOCENE REINDEER ANTLERS FROM REINDEER CAVE (NW SCOTLAND)

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The Scottish Late Pleistocene archaeological and palaeontological records are limited, an absence that has traditionally been interpreted as either non-human or ephemeral occupations due to environmental hostility persisting until the early Holocene, and/or ephemeral or exclusively non-human occupations in this period. However, it may also reflect the limitations of the nature of the record itself: Scottish landscapes are the product of complex glacial (and therefore complex taphonomic) histories, where total ice coverage during the Last Glacial Maximum would have all but eliminated any earlier evidence for animal (or even human) life. Furthermore, there is also a lack of karstic cave systems of the type where Late Pleistocene sequences are often found. The ERC-selected/UKRI-funded PALaEoScot project is currently addressing this research gap through the multidisciplinary study of key Late Pleistocene sites in Scotland, both anthropogenic and natural, with the goal of better understanding palaeoenvironmental and palaeoecological conditions and the potential reasons for the presence/absence of faunal species and, therefore, Late Palaeolithic human groups in the region.

In this context, the Creag nan Uamh 'Bone Caves' in Assynt (NW Scotland), are of considerable interest for Quaternary research because they form part of one of the few cave systems where a large amount of faunal remains has been discovered. The Creag nan Uamh caves are a series of natural caves and rock-shelters located at the base of a high limestone cliff in the Allt nan Uamh valley, in NW Scotland. Reindeer Cave was the focus of extensive excavation in the 1920s, where different stratigraphic layers were identified, some of them very rich in Late Pleistocene sub-Arctic fauna. Specifically, in the upper gravels (composed of subangular dolomite clasts from the cave roof collapse and other glacially-derived lithologies) in the Shaft, more than a thousand reindeer antler fragments, as well as some postcranial bones, have been recovered. Previous hypotheses proposed to explain the large number of antlers inside the cave have been: 1) they were shed by reindeers in areas upslope from the caves and subsequently introduced later into the cave through fluvio-glacial and colluvial action; 2) they were introduced into the cave by animals or humans, the latter of which would represent the oldest evidence of human activity in Scotland. Nevertheless, despite several studies conducted on the site, the faunal remains have not been subject to a systematic taphonomic analysis. Furthermore, new radiocarbon dates on selected faunal remains have yielded Late Pleistocene dates ranging from ~47 ka to ~15 ka years ago and suggest a stratification of deposits that may shed light on the depositional processes within the cave.

Within the scope of the PALaEoScot project, this work is focused, for the first time, on an exhaustive taphonomic analysis of the antler remains recovered from deposits from the rear of Reindeer Cave outer chamber (known as 'the Shaft'). The main goal was to identify the agents involved in the accumulation and post-depositional alterations of the antler remains, as well as to clarify the chronology of these deposits.

Our results are consistent with the previous studies on the antlers, confirming that they belong to the species *Rangifer tarandus*, represent largely shed antlers, mainly from adult females, although young males are also present. No evidence of human activity (such as bone tools, cut marks, percussion marks, scraping marks, or intentional polishing) has been identified, nor has any evidence for carnivore action. The main modifications observed correspond to post-depositional processes, mainly dry fractures and manganese staining (in low grade), followed by water dissolution, trampling, and rodent gnawing marks. These data, together with the absence of associated cultural materials, indicate that the antler accumulation was produced by natural processes and further reject the human and carnivore origin hypothesis. New radiocarbon dates

from materials at depth-intervals down the Shaft suggest a stratified sequence with several phases of deposition beginning in the period prior to ~47 ka BP, and at least two further phases of deposition before the last British-Irish ice sheet covered the site ~32 ka BP. Further deposits in the outer chamber were dated to ~15 ka BP, suggesting deposition (along with the activity of denning species, such as bears) recommenced shortly after glacial retreat. We agree that the surrounding area of Reindeer Cave may have been used for thousands of years as a calving ground by female reindeers, who shed their antlers in spring within days of calving. After that, the antlers in the Shaft were most likely introduced inside the cave by slow mass movement processes, with the taphonomic assessment now strongly supporting this hypothesis.

In conclusion, this work presents the first complete taphonomic analysis of the reindeer antler assemblage from Reindeer Cave. Our results reinforced the previous suggestion that the area served as a calving ground by reindeer, particularly during Marine Isotope Stage 3, and that the shed antlers accumulated inside the cave via natural processes. However, it remains likely that the remains of denning animals, such as bears, represent *in situ* deposition and further study is required to understand the relationship between the remains of animals that likely inhabited the cave itself and the exogenous fossil material that was subsequently (or coevally) deposited in the caves. This research also confirms that there is no evidence of human collection and modification of antler remains at this site so far. We highlight the importance of taphonomic analysis to elucidate the processes involved in the accumulation of the faunal assemblages in archaeo-palaeontological sites, and especially in the contexts of Scottish Quaternary caves, which offer rare insights into mammalian life in Scotland before and after the Last Glacial Maximum.

TAPHONOMY OF TEETH: A NEW WORKING GROUP INITIATIVE

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Teeth differ significantly from other hard materials of animal origin, such as bones and antlers, because they are composed of distinct mineralized tissues arranged in layers: enamel, dentine, and cementum. This complex structure contributes to their exceptional durability and preservation in both archaeological and palaeontological records. As a result, different methods and techniques applied to teeth can yield ecological (e.g., microwear, isotopes, cementochronology), biological (e.g., DNA), chronological (e.g., ESR/U-Th), and cultural (e.g., tools, ornaments) information. However, teeth are often overlooked in taphonomic analysis because they lack nutritional value, meaning anthropic activity rarely reflects on them. In addition, their high structural resistance makes them less likely to show visible traces of carnivore and anthropic modifications.

In recent years, numerous works and the development of new scientific techniques have revealed the unsuspected recurrences of taphonomic alterations on teeth. Their study tackles a high diversity of topics and have implication for different lines of research within human evolution studies, including dietary reconstructions, subsistence strategies or the analysis of post-depositional processes. These findings show the necessity to develop a new line of research that investigates the unique response of the enamel to different taphonomic agents. Indeed, due to their distinct chemical composition, teeth may respond differently than bones to factors such as diet and taphonomic processes, which makes it necessary to apply specific analytical approaches adapted to their unique properties.

In September 2023, we organized a roundtable to bring together specialists working on teeth. We aimed to gain a clearer understanding of the diverse analytical methods, assess their impact on teeth, and identify common challenges encountered in the study of archaeological and palaeontological dental remains. Building on the success of this meeting, we have continued our work establishing an official Working Group (WG) called "Taphonomy of Teeth Working Group" (TaphoTeeth), supported by the IRN TaphEn. This group includes a core organization team (D.V., A.U., A.S-R., and C.M.) together with several colleagues, as well as different international institutions that collaborated with us since the first roundtable was held.

Our research focuses on the study of non-human mammal teeth, including large mammals and micromammals. The main objective of TaphoTeeth is to build a network of both specialists and early-career researchers interested in the taphonomy of teeth. We aim to encourage knowledge transfer and facilitate the identification of taphonomic agents on dental remains (*e.g.*, anthropogenic modifications, carnivore activities, natural post-depositional alterations) through

different analytical approaches and multidisciplinarity. Our research is structured around three main axes:

1. Teeth as indicators of cultural expressions of Neanderthals and *Homo sapiens*.
2. Teeth as a proxy for palaeobiological information.
3. Teeth as records for taphonomic interpretations.

In this poster, we aim to introduce, for the first time, the TaphoTeeth GW and outline our ongoing and future actions. These involve new meetings to discuss emerging questions, such as the identification of teeth as retouchers. TaphoTeeth aims also to design experiments to investigate the impact of specific agents on enamel. Our first experiment will investigate gastric digestion with specific pH level solutions on teeth to assess acid-induced alterations on dental surfaces, as well as neotaphonomic studies involving controlled interactions between wolves and dental remains, to examine the types of modifications they produce. Lastly, we want to enhance the visibility of the research fields proposed through the creation of a Hypotheses blog (https://taphoteeth.hypotheses.org/), which includes news, short articles, an online taphothèque (a digital reference collection of taphonomic alterations), and outreach through social media (i.e., Twitter).

In conclusion, TaphoTeeth aims to emphasize the importance of dental remains in taphonomic studies and the need to develop controlled experiments to better interpret modifications produced by carnivores, humans, and natural agents on teeth. This WG will consolidate a dynamic and collaborative research network, contributing to the advancement and visibility of dental taphonomy research. We invite the scientific community and all interested specialists to join us. Stay tuned for upcoming activities and news!

BRACHIOPODS AND THEIR ENCRUSTING FRIENDS FROM THE LATE JURASSIC OF SOUTHERN GERMANY

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Epibionts are important indicator for biological interactions including symbiotic or parasitic relationships between different organisms within marine ecosystems. They are also important taphonomic processes which can influence preservation potentials. Epibionts of brachiopods from the Paleozoic have been well studied in detail. Furthermore, some papers have examined encrustation patterns on recent brachiopods in both temperate and polar environments. The effects of flow patterns around brachiopods and their influence in recruiting processes of epibionts have also been researched. In comparison to examples from the Paleozoic and recent, however, only a small amount of research has been performed on encrustation patterns on Mesozoic brachiopods.

An attempt to close this gap in knowledge is made by studying the incrustation and bioerosion of the rich brachiopod fauna from the Upper Jurassic rocks of southern Germany. Previous collected material from the collections of the University of Tübingen are examined. This includes a total of 200 specimens of the Rhynchonelliformean brachiopod *Lacunosella* sp. from two areas containing Late Jurassic limestones. 60 examples originate from the Swabian Alb near Balingen, between Weilstetten and Tieringen more precisely at the Lochengründle and Bittenhalde. A further collection with 140 specimens originates from the Black Forest north of Basel. The condition under which the two limestone rocks where formed consist of a tropical warm, shallow sea with water depths up to 200 m with some sponge reef environments.

The examined brachiopods show well preserved shells, with all except one in an articulated state. The pedicle valve is slightly better preserved than the brachial valve, which is in some cases is only preserved as a steinkern. The articulated preservation indicates an autochthonous fossilization process, which is supported by the fact that in the field the genus *Lacunosella* is found in close proximity to sponges preserved in situ. In all, 133 of the 200 brachiopods showing one or more encrusting organisms on the valve surfaces. These encrusters belong to several different serpulid taxa, one bivalve, some bryozoans and some barnacles. In total there are 345 serpulids, with 229 growing on the pedicle valve and 116 on the brachial valve. On both valves, the serpulids prefer to colonize the anterior half, with the edges less crowded than the more central parts. The barnacles show no preferences in their position of the shell and are present on both valves with 11 on the pedicle valve and 8 on the brachial valve. The slight preference in all encrusters for the pedicle valve could indicate a colonization during the lifetime of the brachiopods. This is also supported by the fact that some of the encrusters are embedded in the shell and some follow the perpendicular direction of the growth lines.

Furthermore, bioerosion is present in variously shaped furrows, branched tubes and boreholes. The furrows are only found on the pedicle valve and not on the brachial valve. Some branched tubes are carved into the shell. Overall the brachiopods provide a habitat for a various epibionts and bioeroding organisms. This encrustation and bioerosion of brachiopods during life and after death lead to an increase of biodiversity.

LIFE AND DEATH IN MESOZOIC OPEN SEAS: BIOSTRATINOMY AND DEADFALL ECOLOGY OF PELAGIC REPTILES FROM DEEP-WATER SETTINGS

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Mesozoic marine reptiles are an informal group of unrelated diapsid sauropsids that underwent profound morphological adaptations for life in the sea. These secondarily aquatic amniotes shows a remarkable degree of evolutionary convergence with modern cetaceans, with anatomical and histological features that enabled the more derived forms to acquire a completely pelagic lifestyle. Modern cetaceans have long been considered the best analogue for Mesozoic marine reptiles, with morphological similarities leading to shared biostratinomic patterns. In modern oceans, sunken carcasses of large pelagic vertebrates (deadfalls) play an essential role in flux of nutrients in deep oligotrophic settings, with the development of specialized ecological successions around the remains. While most studies on Mesozoic deadfalls have been limited to shallow-water settings, the taphonomy of vertebrate remains from deep-water deposits is still largely unexplored. Here are presented the results of a detailed, large-scale taphonomic survey of ichthyosaurs, pliosaurs, metriorhynchoids and mosasaurs from the offshore pelagic units from the Middle Jurassic to the Upper Cretaceous of northeastern Italy. The taphonomic revision of the Jurassic Rosso Ammonitico Veronese dataset highlights a common poor state of histological preservation of the bones, relatively good articulation of the preserved units and common associate fossil fauna; these features are consistent with a prolonged exposure of carcasses on a little-disturbed and well-oxygenated seafloor. For the first time we confirm the role of nautiloids as active mobile scavengers by means of tens of beak elements (rhyncholites) found closely associated with, or even piercing, the bones. Hexanchiform shark teeth are also found associated with the carcasses, supporting a distinctive deep-water mobile scavenging community. Echinoids, sponges and other bioeroders are identified as representative of the enrichment-opportunist stage, and a high concentration of belemnites is believed to be indicative of mass-spawning deaths in the surroundings of the carcasses. Abundant crinoids are recognized as part of the reef stage by colonization of the eroded bones, in some cases being found growing inside the spongiosa itself. The Cretaceous dataset (Maiolica, Scaglia Rossa), follows similar preservation patterns of the skeletal remains, but stages of ecological succession are recognized solely by bioerosions on the bone tissue. While some of the new data deviate from previous Mesozoic reptile-falls from shallow-waters, they are consistent with findings at Recent whale-falls in bathyal zones, and overall represent a precious window into the complex ecology of Mesozoic open seas.

PRELIMINARY TAPHONOMIC ANALYSIS OF DIGESTED BONES IN SUBLEVELS TD10.3 & TD10.4 AT GRAN DOLINA, ATAPUERCA (SPAIN)

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Carnivore remains and their taphonomic signatures are commonly documented at Plio-Pleistocene archaeopaleontological sites, where interactions between carnivores and hominins were frequent. In such contexts, the role of carnivores as bone modifiers and accumulators varies considerably (ranging from marginal and occasional involvement, often indicative of independent or commensal relationships with other carnivores and/or hominins) to dominant roles in which certain carnivoran taxa serve as primary agents of bone modification and accumulation.

The Middle Pleistocene subunits TD10.3 and TD10.4 of the Gran Dolina site (Atapuerca, Spain), contain Acheulean lithic assemblages dated to approximately 400,000 years ago. Subunit TD10.3 yielded a total of 24,076 faunal remains and 1,236 lithic artifacts, while TD10.4 produced 742 faunal remains and 247 lithic artifacts. Both assemblages exhibit substantial evidence of carnivore activity, whereas anthropogenic modifications are sparse in TD10.3 and entirely absent in TD10.4. This preliminary study focuses on digested bones as an indicator of carnivore activity and their usefulness in identifying the carnivore taxa responsible for these modifications.

To date, over 50% of the total assemblage has been analyzed. Butchering marks are present on only 0.4% of the assemblage, whereas 7.1% of the remains exhibit modifications attributable to carnivores. Nine carnivore species have been identified, with the most represented being *Canis mosbachensis*/*Cuon alpinus* (NISP = 83), *Vulpes vulpes* (NISP = 58), and *Panthera leo* (NISP = 52). Notably, two large felids (*P. leo* and *Homotherium latidens*) are present. Documented carnivore modifications include pits, scores, punctures, furrowing, crenulated edges, licking, pitting, crushing, scooping out, mid-shaft cylinders and digestion traces. Digested bones constitute 1% of the total assemblage and 13.7% of all carnivore-modified remains. Medium-sized taxa are most frequently represented among digested remains (35.5%), followed by large-sized taxa (21.8%). Additionally, 82.5% of the digested remains correspond to non-juvenile individuals. Bone digestion has been classified into five categories (from 0 to V), with the majority (78.5%) corresponding to stages I–II. Of the digested bones, 42.5% exceed 30 mm in length.

The characteristics of the digested bones suggest the involvement of large carnivores. Three hypotheses are considered: (1) the digested bones were generated by one of the large carnivores represented in the assemblage (large felid), (2) the digested bones were deposited by a large carnivore not represented in the assemblage, and (3) the digested bones were deposited by various large carnivores including both those represented in the assemblage and those absent. Although felids are typically not considered efficient bone crackers, existing evidence indicates they can ingest bone, especially when dealing with suitably size prey. The large felids present in the assemblage, particularly *Homotherium latidens* and *Panthera leo*, cannot be excluded as potential bone modifiers. Another possible agent is *Panthera gombaszoegensis*, whose remains have been identified in nearby chronologically comparable sites such as Sima de los Huesos.

No hyaena remains or indirect evidence such as coprolites have been identified within the TD10.3 or TD10.4 assemblages. Similarly, other Middle Pleistocene in the Sierra de Atapuerca, such as Galería and Sima de los Huesos, lack hyena fossils. However, the possibility of hyena involvement cannot be fully dismissed, as the dimensions and degree of bone digestion are

consistent with modifications attributable to hyenid activity. Conversely, canids are tentatively ruled out as agents responsible for the digested remains, since *Canis mosbachensis*/*Cuon alpinus* likely lacked the digestive capacity to process large bones, according to neotaphonomic studies.

Overall, these findings underscore the complexity of carnivore involvement in the formation of the TD10.3 and TD10.4 assemblages and highlight the potential role of large felids, as significant bone-modifying agents.

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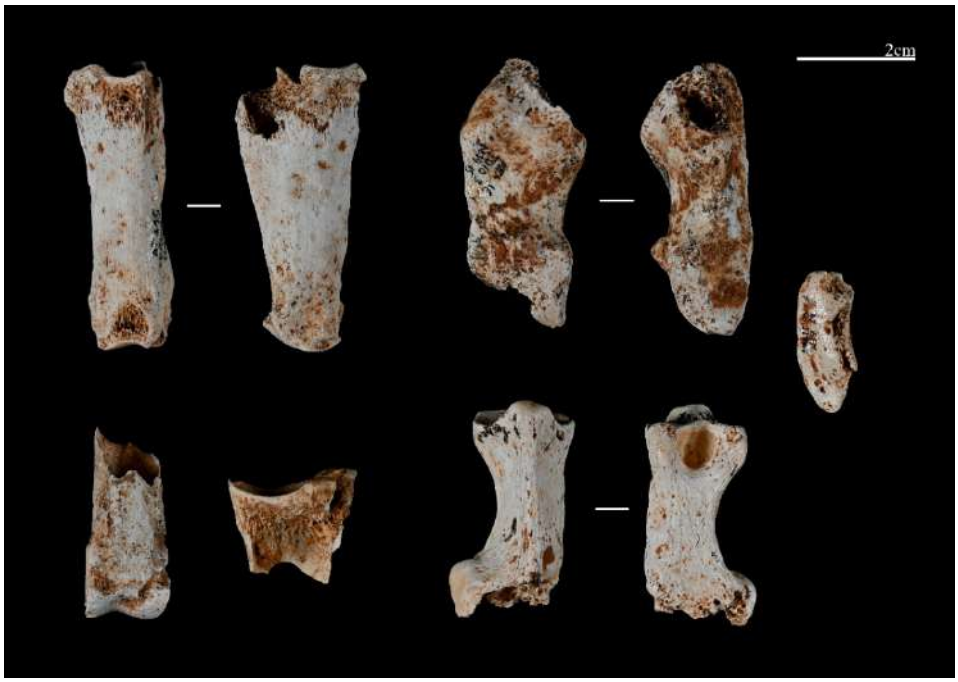

Figure 1. Examples of digested bones from sublevel TD10.3 (left: *Cervus*/*Dama* remains; right: *Panthera leo* remains).

NEW TAPHONOMIC DATA ON MEGA AND MESOFAUNAL SPECIES AT THE UNDERWATER GNLQ1 SITE (CHILE), WETLAND TAPHOCOENOSES AND SUBMARINE LANDSCAPES

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The underwater site GNLQ1 in Quintero, Chile is a rare bonebed of extinct megafaunal species from the Late Pleistocene on what was a former wetland landscape at the South American Pacific coastline. Preserved 13 m under the sea level in what is now known as the Quintero bay. This study updates the taxonomic and taphonomic information available for this site and offers new data into elucidating its depositional history.

The assemblage, dominated by megafauna, with Pilosa being the most abundant order, is characterized mainly by mylodontine sloths, where genus such as *Mylodon* and *Glossotherium* were identified. Artiodactyls also abundant, include extinct camelids such *Lama* cf. *gracilis* and *Paleolama*, and the extinct deer *Antifer* along the extant *Hippocamelus*. Perissodactyls, with *Equus* (*Amerhippus*), and carnivores as *Lycalopex,* appear in lesser abundance.

General macroscopic taphonomic data suggest that the depositional environment of GNLQ1 was shaped mostly by abiotic agents, where low intensity weathering and associated mineralized cracking, light abrasion and staining are the most common evidence of modification. This together with moderate incidences of root etching, signal a depositional scenario, where bones experienced subaerial exposure before rapid burial in a stable, low energy and minimally abrasive environment. Evidence of biotic agents in the sample is far less common but highly diagnostic, with linear marks, gnawing, scoring and corrosion traces, that align with an attritional assemblage mostly shaped by abiotic factors where sporadic predation events took place. Skeletal representation shows patterns reflecting anatomical abundances close to their original patterning. Which coincides with bioclastic indices that suggest a preserved or minimally disturbed assemblage where hydraulic sorting was minimal despite the proximity to the extinct body of freshwater and light abrasion associated.

Multivariate analyses of the taphonomic variables suggest, at least, two primary modification patterns: a general pattern associated with slight modification by abiotic agents against cases of modification by different biotic agents. Regression analyses for these types of modification reveal that some traces such as linear marks associate positively with rodent gnawing and digestive corrosion, but negatively with carnivore activity, potentially indicating mutually exclusive modification events. This in turn is interpreted as multiple, gradual and diachronical events of primary and secondary deposition of remains rather large accumulator events. This would imply a palimpsest of different remains coexisting within the same low energy and brief subaerial exposure setting during the active phase of the extinct lagoon.

GNLQ1 offers baseline information to better understand Pleistocene wetland ecosystem bonebed formations, as it provides new evidence and strengthens the understanding of how megafaunal guilds interacted with these landscapes. Despite its current nature as a marine underwater landscape, marine modification is less common, but evident from some evidence of high abrasive damage, as cirriped attachments and pholad borings, even within the lower stratigraphic units. Continental specific taphonomic processes are apparent and the commonly

identified, offering key criteria for distinguishing non-anthropogenic patterns of deposition from culturally modified bonebeds in open-air wetland settings, one of the two most commonly described type of archaeological site for the Late Pleistocene in Chile.

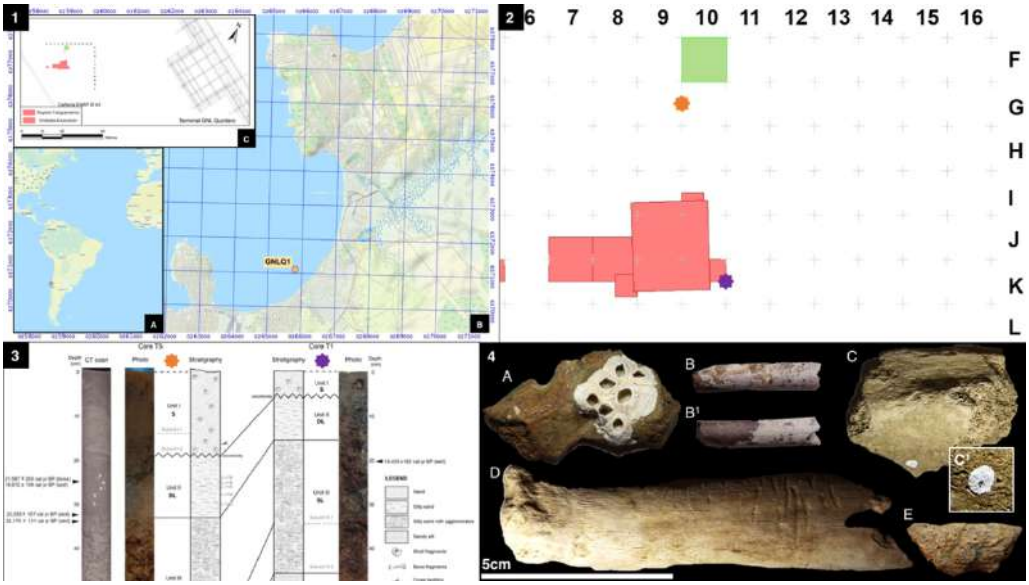

Figure 1. 1, (A) GNLQ1 position in South America, (B) GNLQ1 position in Quintero bay, (C) GNLQ1 excavation layout. 2, GNLQ1 units, red squares are units discussed in previous works, the green square represents the new data presented here, purple eight-point star is the geological core 1, orange eight-point star is the geological core 5. 3, Stratigraphic survey cores 1 (purple) closer to previous studied material and 5 (orange) closer to newly discussed material (modified from Flores-Aqueveque et al. 2021). 4, Taphonomic modification at GNLQ1, (A) Fragment with multiple cirriped attachments, (B) canine diaphysis with reddish and (B¹) black staining over intense white discoloration, (C) Fragment with a single cirriped attachment (C¹) closeup to the cirriped basal plate, (D) *Paleolama* sp. metacarpus with multiple scoring traces (E) abraded fragment with deep meandering surface borings, 5 cm scale, all specimens are in scale.

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