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RESEARCH

Inferring the role of hominids at Torralba: spatial analysis of original excavation data

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Abstract
Torralba has been a key locality for Middle Pleistocene paleoanthropology since its discovery by the Marqués de Cerralbo in the early 1900s. It yielded numerous elephant bones and lithic artifacts, leading to its first interpretation as an elephant kill site, and provoking subsequent studies and debates about that interpretation. After Cerralbo, Torralba was excavated by a multidisciplinary team led by the American paleoanthropologist F. Clark Howell between 1961 and 1963. This work generated a large body of documentation, including maps, photographs, catalogs, drawings, and notes. Here, we present previously unpublished stratigraphic sections and georeferenced and digitalized distribution maps. Combined with newly digitized archival photographs of the original excavations, these resources provide long sought and critically important spatial and stratigraphic positioning of 1,541 bones, 428 artifacts and 1,678 additional stones (among other elements). The work was carried out considering all these elements, discussing their possible stratigraphic attribution through the study of distribution and orientation patterns by applying spatial analysis methods. The results have provided important data regarding the importance of recovering documentation from old excavations and processing it with innovative analytical methods, as well as regarding the formation processes of the deposit that bear directly on previous behavioral inferences and provide valuable data for future studies.

Keywords Spatial analysis · GIS · Orientation patterns · Formation processes · Open-air · Middle Pleistocene

Introduction

The Middle Pleistocene locality of Torralba was first excavated at the beginning of the 20th Century by the Marqués de Cerralbo and has since maintained paleoanthropological prominence. Cerralbo learned about its paleontological and archaeological contents thanks to the discovery of some elephant bones unearthed by workers who were installing a pipe for a water tank at the nearby Torralba train station (Aguilera y Gamboa, 1911; Santonja et al. 2005a). Years later, Torralba was excavated by a multidisciplinary team led by F. Clark Howell. The team inferred that the locality had been an elephant kill site, but that interpretation subsequently came under scrutiny as paleoanthropology became an increasingly critical and holistic discipline.

Today Torralba continues to figure in paleoanthropological debates about Pleistocene behaviors, environments, and evolution. Several critically important data sets were missing from the ongoing debates. The most important of these were the unpublished photographic records, as well as the maps and profiles drawn during and immediately after the excavations. Here we present this previously unpublished evidence in the form of distribution maps of all the bones, stones, and lithic artifacts excavated and drawn at Torralba during the 1960s. All of the spatial information was scaled and georeferenced in a common coordinate system using Geographic Information Systems (GIS). Rather than following previously applied methods of evaluating spatial association in long lists of numbers and statistical formulas, we present below the actual spatial distribution patterns and apply statistical tests involving the physical characteristics and spatial relationships of the objects excavated at Torralba.

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None of the publications about Torralba have so far included comprehensive distribution maps of the objects excavated at Torralba. We present these here for the first time. In the case of Ambrona, the spatial distribution maps were originally selectively and incompletely published (Howell 1963, 1966; Aguirre 1989). In 2016, one of us (Sánchez-Romero et al. 2016) gathered all the partial publications of Ambrona and the unpublished distribution maps to carry out the spatial study and evaluate the processes behind the distribution and accumulation of materials in the units of Lower Stratigraphic Member of Ambrona (Sánchez-Romero et al. 2016).

For Torralba, some publications (Howell et al. 1962; Freeman and Butzer 1966; Freeman 1978; Aguirre 2005) contain pieces of what we present here, such as the description given in *Observations on the Earlier Phases of the European Lower Paleolithic* where Howell (1966) described the distribution of the Torralba artifacts and bones. This description indicated the distribution of "semiarticulated and unbroken remains of the left side of a large elephant over a 30-square-meter area without pelvis but with some vertebrae, with tusks but no skull, and with complete mandible, with transversely broken rami, displaced back of the beast's body" and where "only four flake tools/retouched flakes were associated", as well as "an area (ca. 50 sq. m) (…) showed several patches of charcoal/carbon, casts or other evidences of wood, and (two) bifaces (cleavers) and retouched flake/waste flakes." These areas were interpreted as "primary kill/dismemberment areas and secondary butchering/meat-processing areas" (Howell 1966: 122–123).

The objectives of this research are essentially three: (1) To make previously unpublished documentation of this important locality available to the scientific community; (2) To demonstrate that it is possible to give a "second life" to information generated during periods when archaeological recording methods were not as advanced as they are now, but which still allowed for adequate tracking of excavated materials and their subsequent incorporation into new investigations; and (3) To evaluate the processes and factors that may have taken part in the formation of the deposit using this "old-new data," identifying problems and inconsistencies, and the conclusions we have been able to reach by applying spatial analysis methods and integrating this data with those already published by other colleagues.

We first contextualize our results with a review of the history of discovery, excavation, and interpretation of Torralba. We then present an up-to-date geographic, geological, and geomorphological assessment of the locality, followed by a description of the materials and methods for the spatial analysis we designed to investigate the processes that could have affected the distribution and concentration of Torralba's excavated objects.

Discovery

The first publication on the Torralba locality was made by Enrique de Aguilera y Gamboa, Marqués de Cerralbo, in 1911 (Aguilera y Gamboa, 1911), who carried out numerous excavations throughout Spain. He considered Torralba "the most important of my explorations" *(translated)*. These excavations took place between 1909 and 1913 (Howell 1966; Santonja et al. 2005a), although the knowledge of the Torralba locality dates back to 1888 when, according to Cerralbo, he heard the railway workers discussing how, when opening a trench, they had encountered the bones of the head of an animal (Aguilera y Gamboa, 1911). This text (Aguilera y Gamboa, 1911) also refers to the importance of Torralba, recognized not only by Cerralbo but also by other important figures such as Émile Cartailhac, who envisioned that: "the Torralba site would be a place of pilgrimage for all paleontologists and archaeologists from all over the world" (Aguilera y Gamboa, 1911).

These early prehistorians appreciated the importance of Torralba's co-occurrence of lithic artifacts and remains of extinct large mammals long before its relative chronological placement had been established, and far in advance of the paleoanthropological datasets and intellectual debates that the site would yield later in the 20th Century. F. Clark Howell, Leslie Freeman and Emiliano Aguirre were the next to pursue these prognostications by more fully exploring Torralba and generating the data sets introduced here.

The 1960s excavations

Excavations at Torralba directed by F. Clark Howell (in the Department of Anthropology at the University of Chicago at that time) began in 1961 and continued in two subsequent field seasons (1962-63) supported by the U.S. National Science Foundation (NSF) (Howell et al. 1962; Howell 1966). Recovered faunal remains, stones, and artifacts were drawn, photographed, inventoried, and studied by many different specialists. The excavations at Torralba were resumed in the 1990s (1994–1999) by a Spanish team that first focused on digging test pits and cleaning previously excavated surfaces (Santonja et al. 2005b).

The work presented below focuses on the drawings (maps and stratigraphic sections) and photographs made during the 1960s. The first modern publication about Torralba was published in 1962 (Howell et al. 1962), comprising a preliminary assessment of the geological context and landscape, as well as a taxonomic review of the faunal assemblage. This publication included the first distribution map of some of the excavated remains alongside an artifact inventory from the 1961 excavations and Cerralbo's (Howell et al. 1962).

The first publication examining and describing the stratigraphy of the deposits at Torralba was published by Karl W. Butzer in 1965. It provided the preliminary stratigraphic correlations and inferences about the geological and geomorphological processes behind the accumulation of the Torralba deposits (Butzer 1965). Unfortunately, the geographic proximity of the Ambrona locality (only 2.5 km distant from Torralba) seems to have led Butzer to presume contemporaneity between these occurrences, a correlation subsequently disproven (Pérez-González et al. 1997, 2005; see below).

In 1966 Freeman and Butzer described the spatial distribution of some of the objects found in Torralba and made their first behavioral inferences (Freeman and Butzer 1966). They used the spatial distribution of bones and artifacts (as well as typology and raw materials) to delimit areas and infer activities performed at Pleistocene Torralba. Also in 1966, Howell (1966) published a more thorough description of both Torralba and Ambrona, establishing their geological contexts and attempting to strengthen the stratigraphic equivalence previously asserted by Butzer (1965). This publication provided a detailed description of all the units, referring to the data on fauna, sedimentology, pollen, and lithic artifacts. This was the first complete publication of Torralba and Ambrona in which the fauna, artifacts, geology of the deposits, and distributions of objects were outlined. Data from Torralba and Ambrona were compared with other localities of similar chronology and content. Howell's synthesis strengthened the misleading paleoanthropological mindset that the two occurrences were contemporary and manifestations of the same inferred hominid behaviors.

Historical interpretations and debates

Howell's influential and popular Time-Life book *Early Man* (1965) contained widely convincing illustrations of in situ bones and artifacts accompanied by evocative artistic reconstructions of human behavior (Howell 1965). By 1978, Howell's hugely successful book not only reinforced the false notion that Torralba and Ambrona could be represented as one thing, but it also served to inspire skepticism about the behavioral inferences made by the excavation team. It was widely recognized by both the excavators and their critics that the spatial and stratigraphic distributions of the bones and artifacts were keys to testing earlier interpretations of behavior at both Torralba and Ambrona.

In 1978 Freeman responded to the critics with a publication about Torralba that provided a spatial analysis of the artifacts from so-called "Occupation 7" and "Occupation 8" (Freeman 1978). He applied a series of multivariate analysis techniques to explore the spatial and stratigraphic patterning of lithics and bones, with the goal of inferring Paleolithic activities. In this publication, the existence of "ten superimposed occupation surfaces and several smaller ones" was presented (Freeman 1978:70). This publication included only two distribution maps, one for each of the "Occupations" and several tables containing a classification of the variables used in Torralba, as well as their frequencies and correlations among and within the ten "Occupations."

Employing taphonomic methods to address the controversy over the Pleistocene behavior at Torralba, Pat Shipman and Jennie Rose (1983) attempted a macroscopic and microscopic (SEM) evaluation of replicated bone surfaces. They recognized both hominid cutmarks and marks made by carnivores but highlighted the rarity of both. These studies emphasized the ubiquitous evidence of sediment abrasion on the bones from both Torralba and Ambrona. These 1980s results were judged insufficient to confirm previous inferences that the bones and artifacts represented Pleistocene butchery sites (Shipman and Rose 1983). Freeman (1994) later noted several important deficiencies in these initial taphonomic analyses, but as with many zooarchaeological assemblages, the fact that surface details had been removed by postdepositional processes had severely compromised the ability of a taphonomic approach to reveal perimortem modifications and their agencies (Haynes et al. 2021; Haynes and Wojtal 2023). A recent study by Antonio Pineda and Palmira Saladié (2019) indicated that cut marks were documented on only 0.1% of the elephant remains with evidence of anthropic alteration, and that elephant bones showed weathering due to subaerial exposure. This study concluded that the affirmation about hominids as first responsible for the accumulation of bones was, with all the available data, very risky (Pineda and Saladié 2019).

Using the published data then available, Lewis R. Binford (1987) discussed the possible role of Torralba in the global debate about hunting during the Middle Pleistocene. He concluded that most of the bones from Torralba had been heavily modified by natural agents, including trampling by elephants, and that the excavated assemblages could not be assumed as "living-floors" reflective of hominid behaviors (Binford 1987). Binford also analyzed the different lithic categories and their association with bones and activities, casting doubt on previous inferences, and thereby challenging the classic (and still-prevailing) interpretation of Torralba as an elephant kill site. Binford identified potential problems involving context and association, concluding that these assemblages were formed by a confusing and difficult to interpret constellation of natural and cultural events (Binford 1987).

Richard G. Klein (1987) extended the skeptical approach, contending that the associations made by Freeman (1978) should be considered very tentative because many bones had been incorrectly identified. Klein also doubted whether behaviorally significant patterning might have survived small-scale geological transport of sedimentary particles (and bones). His assessment continued to highlight the necessity of evaluating statistical and/or spatial associations among artifacts that seemed to the excavators to be stratigraphically associated with semi-articulated elephant bones found at Torralba (Klein 1987).

Extending these skepticisms, Paola Villa (1990) carried out a taphonomic study of bones from Middle Pleistocene localities of Áridos 1 and 2 (Madrid, Spain), comparing them with Binford's (1987) critical taphonomic approach to Torralba. She argued that Freeman's interpretations (1978) were made from a "very low number of lithic pieces" and therefore his "statistical analyses (…) can produce misleading results" (Villa 1990:307). Villa also asserted that Freeman's interpretations had based on "non-rigorous excavation procedures;" flawed assumptions about the depositional conditions at Torralba ("a belief in the pristine conditions of the site"); and "a priori assumptions about hominid hunting" (Villa 1990:307).

In 1994, Freeman contributed a volume dedicated to F. Clark Howell (*Integrative Paths to the Past*) with a chapter dedicated to Torralba and Ambrona (Freeman 1994; reprinted 2009). Here, Freeman reviewed the Howell excavations of the 1960s and 1980s; the works published by that team; his own observations in the field and laboratory; and his publications (particularly the one published in 1978) and the ongoing controversies involving behavioral inferences made from data acquired at both Torralba and Ambrona. Freeman acknowledged some mistakes and admitted that his interpretations may have gone too far. Continuing to recognize the crucial importance of the positional data recorded during the excavations, Freeman clarified, revised and re-evaluated the spatial associations he had published in 1978 (based entirely on statistical tests). Freeman also referred to a forthcoming (but today still unpublished) monograph about Torralba, intended to provide much more information and context about this locality. Freeman's 1994 chapter in the F. Clark Howell tribute volume stands today as the most comprehensive published work reviewing the debates that Torralba inspired since the 1960s.

F. Clark Howell passed away in 2007, and among his wishes was the repatriation of all documentation of his work developed in Spain. In that context, the data presented below were accessed and evaluated in the framework of the University of California at Berkeley Glynn Isaac Postdoctoral Fellowship awarded to Laura Sánchez-Romero. All relevant archival materials in the Human Evolution Research Center (HERC) at University of California in Berkeley were inventoried, classified, ordered, scanned, and shipped to Spain, and are currently archived in the National Research Center on Human Evolution (CENIEH) in Burgos (Spain). Among these materials is a large amount of unpublished information bearing directly on the debates introduced above. We first contextualize these new data, and then employ them to test former and current behavioral and depositional inferences.

Geographical, geological, and geomorphological contexts

The Middle Pleistocene open-air site of Torralba (1,115 m a.s.l.) is located in the south of Soria province, in the northern half of the Castilian Branch of the Iberian Range, coinciding with the watershed area separating the drainage basins of Duero, Tajo and Ebro rivers (Pérez-González et al. 1997, 2005; Sánchez-Romero et al. 2016). This is a strategic corridor between the Meseta highlands and the Jalón valley, which probably would have witnessed herds seasonally migrating herbivores (Butzer 1971). Ambrona, is located 2.5 km from Torralba. These locations lie at a crossing point of structures from the eastern end of the Central System and the Tertiary continental basin of Almazán, in a polje-type karst landscape (Pérez-González et al. 1997) called the Polje de Conquezuela.

This large, flat, originally closed basin is 1 km wide and 12–13 km long (Fig. 1). It developed in an anticlinal structure partially faulted to the northeast (Pérez-González et al. 2005). Several Neogene corrosion-erosion surfaces and Pleistocene rocky terraces of fluvial origin have been identified on its margins. These represent the morphogenesis subsequent to the opening of the polje by fluvial erosion. The outcropping basement deposits are Triassic (Pérez-González et al. 2005) and include the raw materials used by hominids for lithic artifacts (Sánchez-Romero et al. 2016). The Pleistocene evolution of the Polje de Conquezuela and the stratigraphic and geomorphological positions of Torralba and Ambrona have been shown to be in different geomorphological positions, and the age and stratigraphic formations for both localities are therefore demonstrably different (Pérez-González et al. 1997, 2005).

The chronologies of Torralba and Ambrona were refined using numerical dating methods consistent with the geomorphological positions of both sites. For the middle stratigraphic unit of Ambrona (AS6), an ESR/U-series date of approximately 350 ka (Falguères et al. 2006) was obtained, allowing for an estimated age of around 400 ka for the lower unit (AS1). At Torralba, OSL dating results indicate dates of 209 ± 22 ka and 174 ± 19 ka (Santonja et al. 2014a). These dates are similar to those obtained using U-series dating (Howell et al. 1995) on a terrace 20–25 m above the adjacent Alto Henares, in a comparable morphological position (Sánchez-Cervera et al. 2015). Torralba is located at

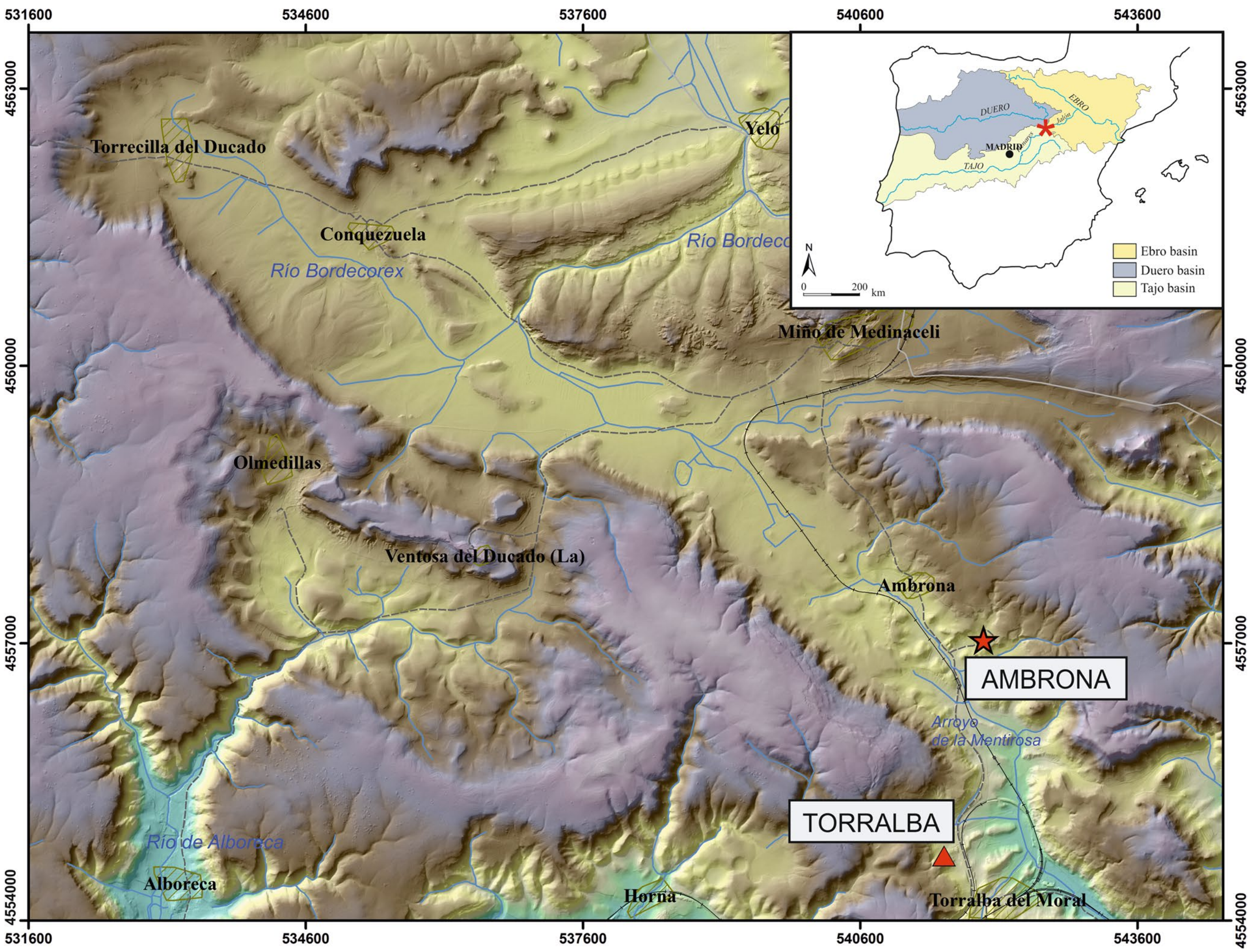


Fig. 1 Location of the Middle Pleistocene locality of Torralba (modified from Sánchez-Romero et al. 2016)

the bottom of the Bordecorex river valley, so it is estimated to correspond to MIS7. For its part, the lower and middle units of Ambrona, in a different geomorphological position than Torralba, would correspond to MIS 11 and MIS 10 or 9 respectively, in positions related to the drainage network of the Polje de Conquezuela (Sánchez-Cervera et al. 2015).

The estimated total area of the Torralba Pleistocene deposits is about 5,000 m^2 (Santonja et al. 2005a), although others estimated it at 3,000 m^2 (Freeman 1994). During 1961–1963 the excavations here covered an estimated area of about 1,026 m^2 (González Echegaray and Freeman 1998; Santonja et al. 2014b) and the limits of the Cerralbo excavation, an estimated area of about 2,000 m^2, were recognizable (Santonja et al. 2005a; Sánchez-Cervera et al. 2015). The 1960s methodology consisted of digging 3mx3m squares down to the base of the Pleistocene sequence, where the excavators reached the Keuper local bedrock. Bones, stones, and artifacts encountered were left in situ and stratigraphic profiles exposed were retained between squares. The photographs and drawings of the exposed objects provided an overview of the spatial distributions that Freeman frequently referred to (Freeman 1978, 1994).

Torralba stratigraphy was clearly visible on the walls of the 3mx3m squares (Fig. 2), and changes of levels, facies, morphologies and geometries were noted, as well as the stratigraphic positioning of the bones, stones, and artifacts exposed during excavation. However, even with this spatial and stratigraphic control, original positioning of the objects had often been obscured by intense microfaulting of the sediments.

The only detailed stratigraphy published thus far for Torralba is by Butzer (Butzer 1965) (Fig. 3). Here the composite stratigraphic profile, from bottom to the top, begins with a red colluvium (Member I), defined as "sandy silt or silty sand derived from the red Keuper clays" (Butzer 1965). The sequence continues with gray sands interspersed with facies of angular and subangular gravels that reach maximum thickness at mid-profile (Unit IIa, A-gravel) (Butzer 1965). Here, Butzer shows how the Pleistocene levels were affected by reverse faults with displacements greater than 1 m

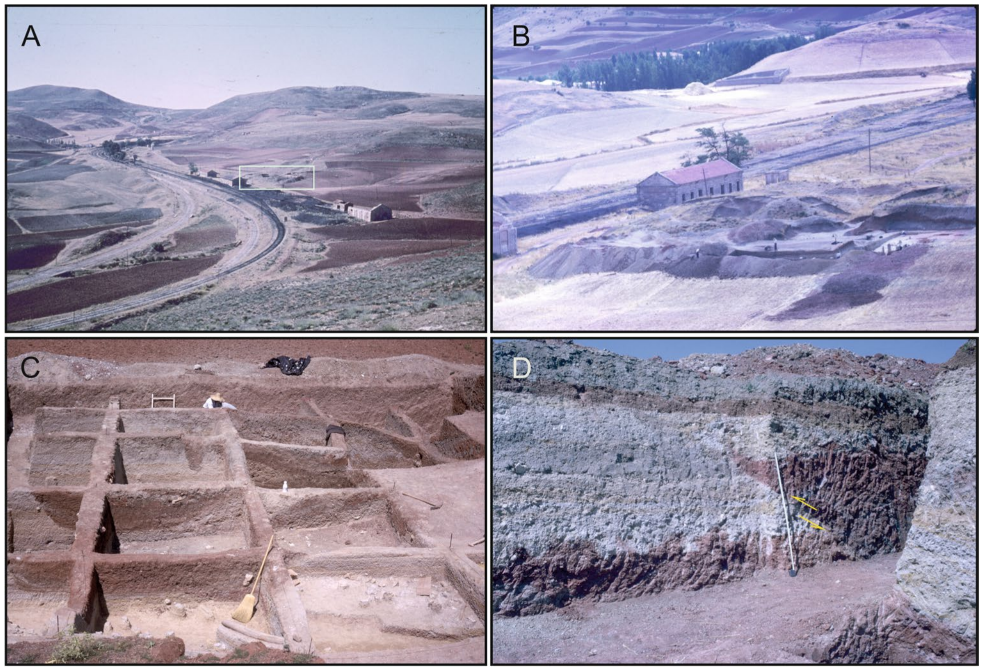


Fig. 2 **A** View of the Polje de Conquezuela from the north. The green box indicates the position of Torralba on the landscape; **B** Overall view of the excavation at Torralba in 1962; **C** View of the northern walls of the excavation at Torralba in 1963; **D** One of the reverse faults affecting the Torralba deposits is seen in the profile behind the vertical white measuring stick (see below Fig. 8 for more details of these faults)

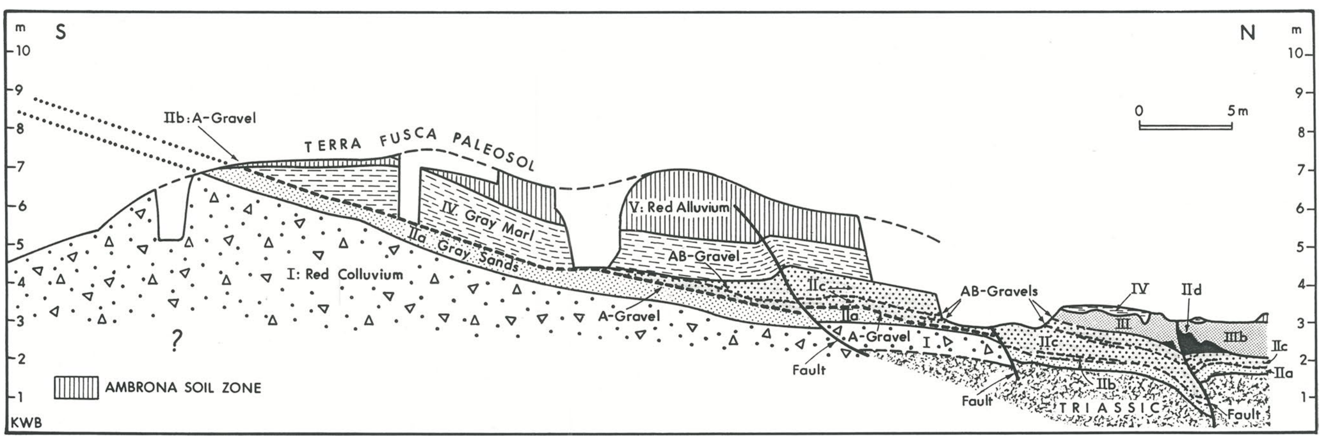


Fig. 3 The stratigraphic profile of Torralba published by Butzer (1965)

(Sánchez-Cervera et al. 2015). At the top of the sequence are gray-green marls (Unit IV) on which a red alluvial-colluvial deposit rests (Unit V, *red alluvium*) (Butzer 1965; Sánchez-Cervera et al. 2015). The stratigraphic sequence of Torralba was then interpreted as a succession of alluvial-colluvial deposits emplaced atop lacustrine facies of gray marls and fluvial facies of gray marls with fine gravels. The clayey layers identified and associated with the fluvial facies were interpreted as related to alluvial plains (Sánchez-Cervera et al. 2015).

According to Butzer (1965), the bones and artifacts ("human habitation") are found in Unit IIb, with stone rings attributable to cryoclastic processes in the A-gravels (Fig. 3). He also refers to these assemblages as "cultural horizons" and their stratigraphic association preserved "atop or among the A-gravels." Butzer indicates that there are more artifacts and "articulated bones" on top of both of the intergrading lenses of AB-gravels, which are described as "(…) one or two 10-cm intercalated bands of heterogeneous, non-cryoclastic detritus, lacking soil-frost structures, indicate water-laid screes" (Butzer 1965:1719).

A year after Butzer's publication, he and Freeman described the stratigraphy of Torralba indicating that the objects were located in Unit IIb (A-gravel), mostly concentrated on top or among the pebbles, and that there was evidence of "some downslope sliding." They also refer to the "nearly articulated position of some bones of single animals" and the "lack of size sorting of bones and artifacts" (Freeman and Butzer 1966:12). More artifacts and articulated bones were found in Unit IIc, "on top of some of the intergrading gravel lenses and within one sandy zone. Scattered water-worn bone found at some points within the gritty sands."

The next unit where some objects were found is Unit IV, where archaeological materials seem to be "scattered within the lowest marls" (Freeman and Butzer 1966:13). This publication states that most of the objects occur "in horizons within deposition Unit IIc", which are described as: "(…) several levels distinguishable on cultural grounds, most of which are occupation surfaces atop gravels. Two such horizons (levels B2 and B4a) have been analyzed sufficiently to permit inferences concerning cultural activities" (Freeman and Butzer 1966:14). According to the conclusions of that publication, levels B2 and B4a: "(…) are not the products of continual, long-term, random accumulation; rather they seem to have been produced in each level by a single short-term occupation of the site for very limited periods of time" (Freeman and Butzer 1966:18). As will be seen in the following sections, the maps of the "Occupations" do not indicate which Unit or Level they belong to, nor their association with the stratigraphic sections.

During the 1960s, concentrations of bones, stones and lithic artifacts encountered during excavation were classified as "occupations", in the sense of "spatial associations" (Freeman 1978, 1994). The "Occupations" were considered as fixed individual designations, but field designations of "levels" (that were themselves sometimes subdivided) were also used without clear definition. The criteria used to define an "Occupation" were never made explicit. Accordingly, we interpret them here to have been based on Freeman's field observations that combined both spatial and stratigraphic considerations. The archival maps that we utilize below do not indicate the stratigraphic positions for any of the mapped objects (this information did not accompany the maps). Thus, and in light of the ambiguity surrounding so-called "living-floors" and other such terms (Malinsky-Buller et al. 2011), here we refer to Freeman's "Occupations" as "Assemblages", while maintaining the original numbering system of the sake of clarity (prefixing them with the letter "A," e.g. A-I, A-II, A-III, etc.).

This constellation of "units", "levels" and "occupations" has proven to be massively confusing, as Freeman himself later admitted (Freeman 1994). Methodologically, designations of "Occupations" served as the excavator's final classification of the observed spatial concentrations of the excavated objects. The final designation and correlation of Torralba "Units" was apparently made in the laboratory as attempt to integrate the information of all maps and sections (Freeman 1994). This approach was taken due to the difficulties imposed by the ubiquitous microfaulting that even today constitutes a serious barrier to understanding Torralba.

Materials and methods

Digitization and georeferencing of maps and stratigraphic sections

We archivally recovered, digitized, cleaned, and positioned four Torralba stratigraphic sections. These sections show four key elements: (1) the texture of the deposit represented with different symbology, (2) the geometry and morphology of the different levels/facies of the deposit, (3) the original designating capital letters and Roman numerals, and (4) the limits of the squares. None of the available sections indicate the meaning of these numbers, letters or symbols, but at least the position of part of an iron pipe that is still on site is indicated. The meaning of the symbology used for the lithostratigraphy of every level or facies can be estimated according to the previous studies carried out in Ambrona (Sánchez-Romero et al. 2016). However, even though we observe some similarities between the symbology used at Ambrona and the one used for Torralba, we cannot be certain whether they refer to the same types of sediment. Given the longstanding arguments about the spatial disposition of Torralba bones, stones, and lithic artifacts, we integrated all available data of sufficient resolution to bear on the inference of Pleistocene hominid behavior. This effort represents a test of earlier hypotheses reviewed above.

The effectiveness and usefulness of reviewing archival data from old excavations to conduct new studies and interpretations has been demonstrated (Benito-Calvo and De la Torre 2011; De la Torre and Benito-Calvo 2013; Sánchez-Romero et al. 2016). In the case of Torralba, ten maps were scaled and georeferenced in a common coordinate system corresponding to the distribution of elements named by Howell's team as "Occupations" (I to VIII). The digitization of these maps involves a total of 4,065 items: 1,541 bones and 1,678 stones (this is the term the excavators used in their maps; they did not make any distinction between blocks, pebbles, cobbles, etc., at least in the georeferenced maps), among many other elements such as lithic artifacts (n=428), charcoal (n=10), wood (n=86), and indeterminate objects (n=322). Elements that could not be identified as stones or bones during the georeferencing process are "indeterminate." Some patches of what the excavators identified as ashes were also drawn as "burnt patches" (n=2). Additionally, the four stratigraphic sections were included in the map along with all the georeferenced materials (Fig. 7, see below). These Sections have been named 1, 2a, 2b (Sect. 2 is divided into two separate drawings), 3 and 4 (Fig. 4).

The georeferencing was carried out following the original Torralba excavation grid indicated on each drawn map, and where the name and number of each square was specified (SI1). The coordinate system had to be superimposed

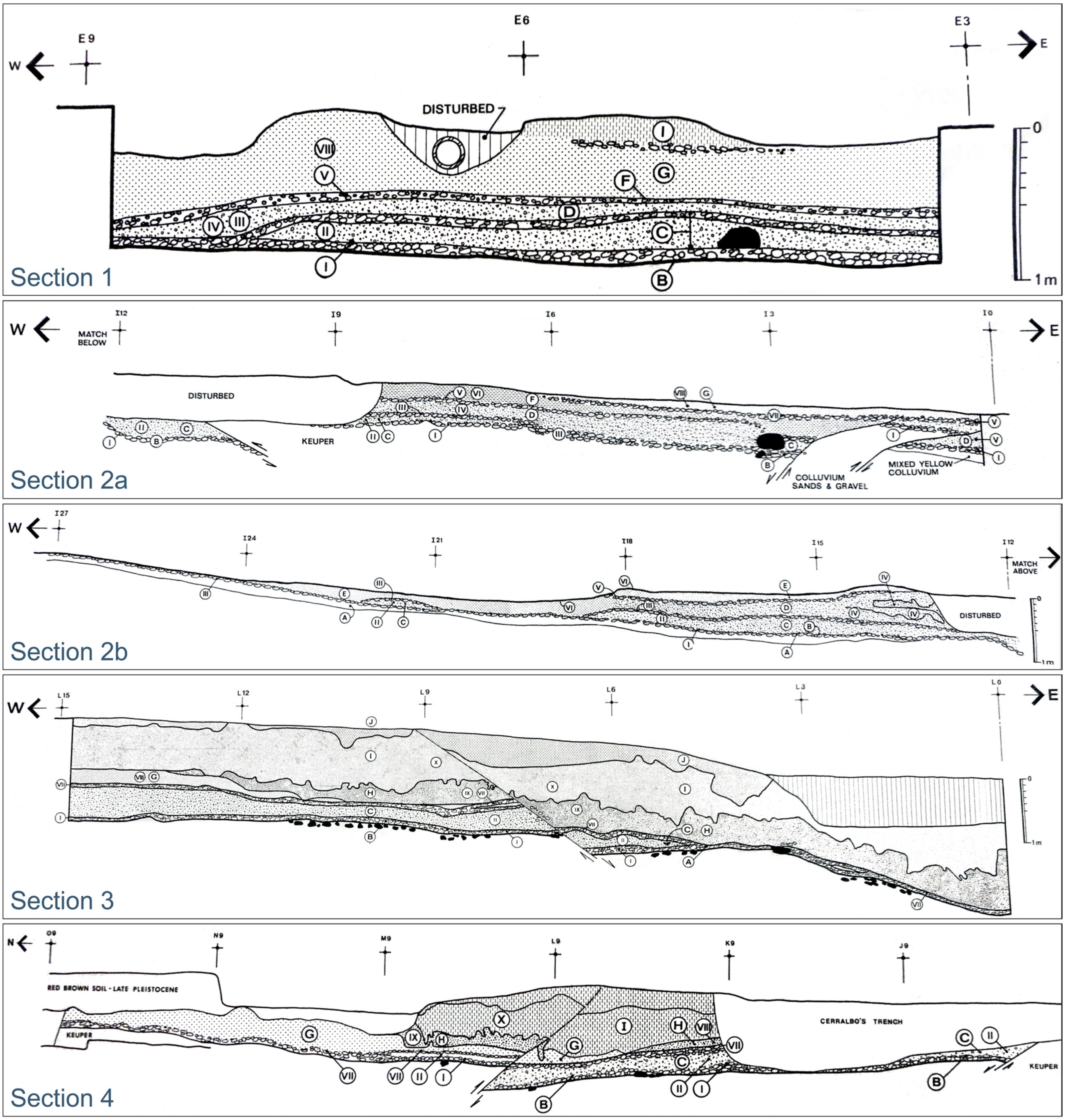


Fig. 4 Unpublished Torralba sections (HERC)

anew because there was no information available about the coordinates used for the registration of materials during the years of excavation at Torralba. However, the scale of the elements and their spatial relationships were maintained throughout.

The main constraint in our spatial analysis is the lack of information on elevation (Z coordinate; depth). The stratigraphic sections contain letters that were used to name the different stratigraphic layers, as well as Roman numerals that might be related to the "Occupations" because the latter are also designated with Roman numerals. However, we have not been able to know what the Roman numerals may correspond to, since they go up to X in the stratigraphic sections and up to VIII in the maps ("Occupations"). Therefore, we do not see the relationship that the Roman numerals could be indicating the stratigraphic position of the "Occupations."

We were not able to ascertain more about the meaning of these terminologies. For this reason, it is not possible to establish from which stratigraphic level the excavated elements from each "Occupation" were recovered. The georeferenced maps did not provide information about the level of the excavated elements, so it was not possible to assign the stratigraphic level(s) to which these objects belonged. We also have no evidence regarding the existence of refits.

For Torralba we cannot further verify the extension, development and position of the stratigraphic levels encountered by the excavators because the site was practically dismantled but not fully detailed in published accounts (Butzer 1965; Freeman and Butzer 1966; Howell 1966; Freeman 1978). The analogous information for Ambrona is similar in composition, with good drawings and maps of the distribution of artifacts and stratigraphic trenches, but with the important difference that some of the original trenches remained at the Ambrona excavation, so that the stratigraphy could be re-evaluated (Pérez-González et al. 1997, 2005; Sánchez-Romero et al. 2016).

For Torralba, we scanned a total of 604 original 35-mm color transparencies (slides) of the Torralba's 1960s excavations in the HERC archives at high resolution. These correspond to the excavations carried out at Torralba between 1961 and 1963 (Fig. 5). Thanks to this invaluable archival photographic record, it is possible to understand the excavation progress, as well as the bone accumulations and associations on the excavated surfaces and in the stratigraphic trenches. These photographs allow identification and placement of the excavated elements. Integrating this previously untapped information with the georeferenced maps and stratigraphic sections allows deeper appreciation of the excavation methods and results. We are currently working to make this important archive permanently and widely available online via CENIEH.

The georeferencing and scaling of ten hand-drawn maps found in the HERC archives were performed using ArcGIS 10.7 (also used for geoprocessing and the statistical tests employed to calculate the distribution and orientation patterns). These maps correspond to the eight assemblages named by the excavators as "Occupations I, II, III, IV, V, VI, VII and VIII" (Fig. 6). To maintain order and coherence in the naming of the different maps of these assemblages, we will use the A-I, A-II, A-III, etc. system to refer to the different "Assemblages" comprising each georeferenced map. We use these Assemblages below as our analytical "sets" in order to examine the behavioral inferences made about them by the excavators.

The georeferencing workflow was the same as that used for Ambrona (Sánchez-Romero et al. 2016), using unpublished documents from Howell's excavations (Howell 1963, 1966; Aguirre 1989). In this way, it was possible to vectorize and spatially locate all the elements related to the excavation carried out during the 1960s at Torralba.

Fig. 5 Some of the photographs from Torralba: **A** General view of Torralba to the Northeast; **B** and **C** Some of the "stone rings" identified during the excavation at Torralba; **D** Bos basicranium and horn core

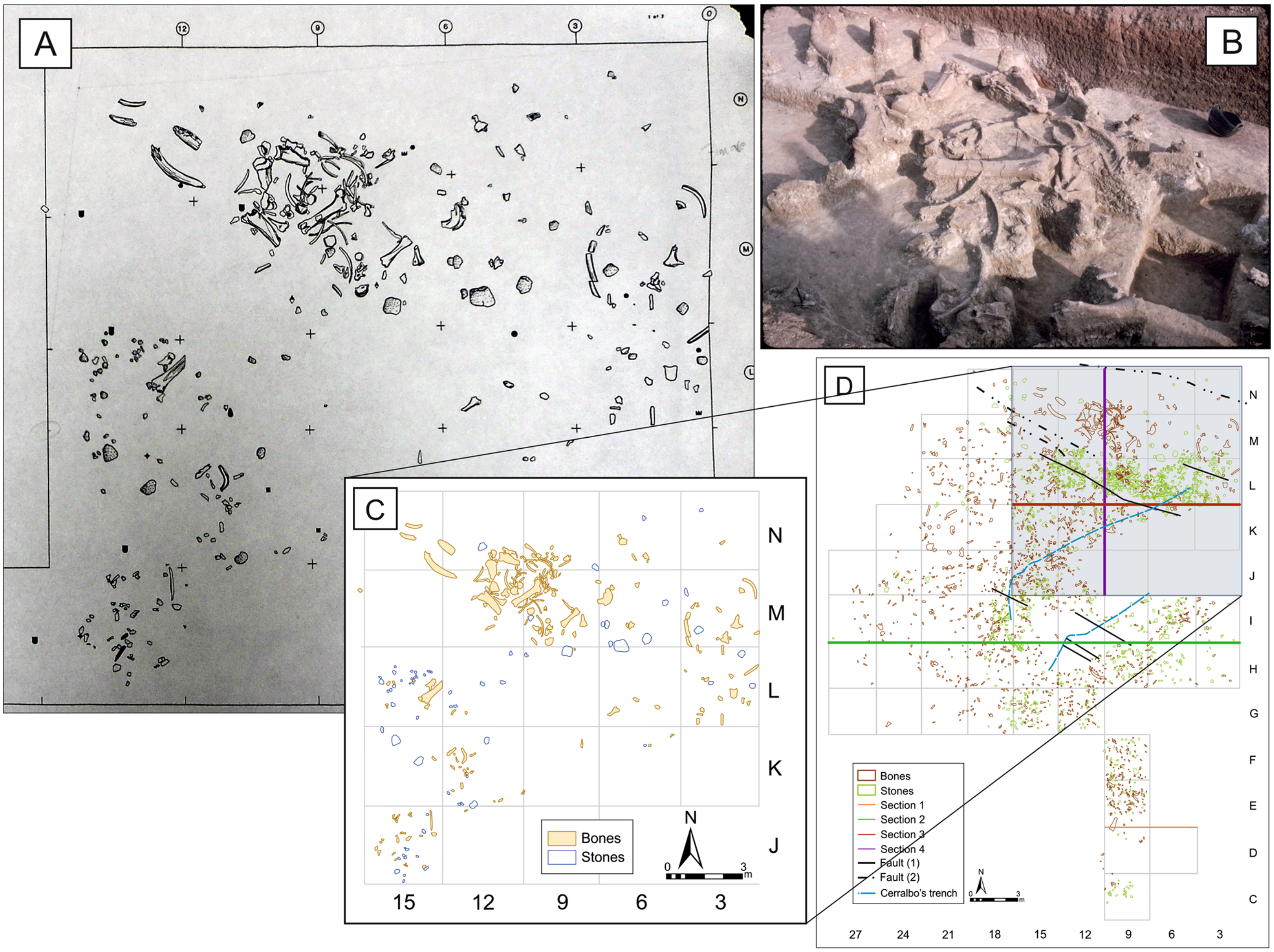


Fig. 6 **A** The distribution map recovered at HERC (ink atop pencil, on drawing paper), corresponding to "Assemblage-VII" (A-VII). **B** One of the archival photos recovered at HERC, illustrating part of the in situ assemblage (set of items) designated by the excavators as "Occupation VII." **C** Digitization and georeferencing of Assemblage A-VII. **D** Placement of the georeferenced Assemblage A-VII atop the overall digitized and georeferenced layout of the Torralba excavation (see Fig. 7 for an expanded view)

Distribution patterns and fabric analysis

Regarding the methods used in this study, we applied Kernel Density Estimation analyses (KDE) to some of Torralba's archaeological Assemblages, using different parameters of search radius depending on the characteristics and distribution of objects. This method calculates the magnitude per unit area applying a kernel function after an input value (search value) that varies depending on the analyzed area and the number of objects under study (Sánchez-Romero et al. 2022a). A search radius of 100 cm was applied to the Torralba bones and stones, except in the case of bones in A-III and stones in A-VIII (whose search radius was 150 cm). For lithic artifacts and indeterminate objects, a search radius of 200 cm was applied to A-VII and 150 cm to A-VIII. This method has been applied multiple times in spatial archaeology, particularly in recent years (Sañudo et al. 2012; Sánchez-Romero et al. 2016, 2017; Blasco et al. 2016; Pop et al. 2016; Spagnolo et al. 2016, 2020; Alperson-Afil 2017; Villaverde et al. 2017; Coil et al. 2020; *inter alia*), and is now considered to be an important step in understanding the relative concentrations of objects.

Three different methods were applied to calculate the orientation patterns of excavated Torralba bones and stones (Boschian and Saccà 2010; Benito-Calvo and De la Torre 2011; De la Torre and Benito-Calvo 2013). We followed the same protocols used for Ambrona (Sánchez-Romero et al. 2016): Minimum Bounding Geometry by width (MBR), Convex Hull (CVX) and Polygon Main Angle (PMA). MBR encloses each group of features (in this case, polygons) in a rectangle and calculates the longest axis of that rectangle. CVX calculates the longest and shortest distance between two vertices, which allows obtaining two main axes for each polygon: length and width. We also used this method to obtain the longest axis of each polygon (bones and stones) to calculate the mean, minimum and maximum length for each item. PMA calculates the dominant angles of the polygon features. In this case, we considered not only the sample size for statistical confidence of the data, but also the elongation index. Since fabrics are very dependent on the elongation index (Drake 1974), we examined all sizes (dark blue histograms in SI4) and elements with an elongation index greater than 1.6 (Ie => 1.6) and larger than 2 cm (light blue histograms in SI4) (Betran and Lenoble, 2002Lenoble and Bertran 2004; Sánchez-Romero et al. 2022b). The data obtained after the application of these methods were run in Oriana v4 to generate statistical information and histograms. Kuiper and Rayleigh tests were calculated to distributions from unimodal, bimodal or multimodal patterns (Fisher 1995; Benito-Calvo and De la Torre 2011; Walter and Trauth 2013; García-Moreno et al. 2016; Sánchez-Romero et al. 2016).

With the aim of verifying the distribution patterns on quantitative data, we calculated the Average Nearest Neighbor index (Getis 1964). In this way, it is possible to know whether the materials are clustered, dispersed, or randomly distributed, and thereafter choose the next steps for the spatial analysis. This is an essential step before applying any type of hotspot analysis (Sánchez-Romero et al. 2022a). From this information, Getis-Ord Gi* (Getis and Ord 1992) was applied to the variable *length* obtained after applying CVX. This method identifies statistically significant spatial clusters, both high (hotspots) and low (coldspots) values (Getis and Ord 1992; Siabato and Guzmán-Manrique 2019; Sánchez-Romero et al. 2022a), with the aim to find statistically significant accumulations of materials with a similar size. In this way, it is possible to observe, for example, whether the artifacts were sorted by postdepositional processes that could have removed the smaller remains and left the larger ones. This method of cluster classification has not been applied to all the Torralba Assemblages, because some were not clustered enough, or the sample size was too small to obtain relevant information or meaningful results.

Results

The results presented here are complemented with all the information provided in the SI, which details the description of the stratigraphic sections and the results obtained from the application of KDE and Getis-Ord Gi* in each of the Assemblages. SI1 is entirely dedicated to explaining the problems surrounding the assignment of letters or numbers to designate the units of Torralba and the description of the stratigraphic sections. SI2 contains the table with the results of the application of Average Nearest Neighbour (ANN) and its description. SI3 shows the distribution and KDE analysis of each of the Assemblages, describing the number of bones, stones, etc. and the ratios of each of them with respect to the assemblages excavated in Torralba. Finally, SI4 describes the results of the application of Getis-Ord Gi* (hotspots analysis) and the orientation patterns of each of the Assemblages, both for bones and stones. Due to the constraint of Torralba's excavator-classified assemblages ("Occupations") being separated from their stratigraphic placements, our spatial study was necessary limited to what each Assemblage might reveal about the agents of accumulation and modification, and the temporal resolution of each.

Georeferencing and digitizing of detailed original archival drawings have provided a high number of elements and included many of the clearly distinguishable skeletal elements: tusks, ribs, vertebrae, horns, mandibles, etc. This helped us to perform an accurate analysis of their composition, size, and orientations. Table 1 shows the number of elements georeferenced in each Assemblage ("Occupations").

The size distribution pattern indicates that most of the bones are in a range of up to 40 cm, with some exceptions exceeding 100 cm (Table S3, Fig. S2). However, in the case of the stones, we find that most of them are up to 20 cm, especially in A-I (Table S4, Fig. S3).

Assemblage A-I comprises most of the objects, followed by Assemblages A-VII and A-VIII, with A-VII containing the main accumulation of bones. A-I is characterized by containing the main concentration of stones ($n = 950$), located in Squares L3 to L12, which comprises 75.45%

Table 1 Number of elements georeferenced and digitized in each of the Torralba maps

Assemblage	Bones	Stones	Lithics	Indet	Charcoal	Wood	TOTAL
A-I	652	1259	83	107	7	60	2168
A-II	118	29	44	-	-	-	191
A-III	178	140	67	-	-	-	385
A-IV	93	17	40	30	-	-	180
A-V	66	79	23	11	-	5	184
A-VI	45	14	11	11	-	4	85
A-VII	219	70	60	84	-	11	444
A-VIII	170	70	100	79	3	6	428
TOTAL	1541	1678	428	322	10	86	4065

of the total stones of this assemblage (A-I) and 56.61% of all the stones in the 10 georeferenced maps (Fig. S5). The distribution and clustering patterns showed by stones is the most interesting pattern found with this variable at Torralba. Getis-Ord Gi* detects several hotspot and coldspot clusters, the most remarkable one being the coldspot that comprises the main accumulation of stones. This cluster contains 630 stones with an average size of 9.73 cm, which contrasts with the main cluster of bones in Square L9, made up of 97 bones and with an average size of 13.88 cm with bones that reach up to 77.73 cm (SI4). Despite of these differences, the orientation patterns show similar directions for both variables, with a clear NE-SW orientation preference.

In the case of Assemblage A-VII, although second in number of elements, comprises what Freeman and Butzer (1966:15) identified as "the half skeleton of a straight-tusked elephant" and that was at the center of their interpretations about Torralba. The bones are mainly located in the northern part of the excavated area and are detected as a hotspot cluster. This cluster is the main concentration of bones in Torralba, and it contains 94 bones of an average length of 40 cm, but with bones that range from 6 cm to up 155 cm. In contrast with the accumulation of A-I, which is a less than 0.5 m apart, the bone accumulation of A-VII barely contains stones (SI4). The orientation patterns indicate a clearly preferred orientation of the bones, in a bimodal pattern that indicates directions towards NNW-SSE and NE-SW. The sample size of stones is too small to take this variable into account.

Assemblage A-VIII is the third in number of objects, characterized by a high number of small remains concentrated in the same square (E9), and where a *burnt patch* was identified (SI3 and SI4). Getis-Ord Gi* identifies this bone accumulation as a coldspot, indicating a significant concentration of small objects in Square E9. The orientation patterns can be only considered for bones, because of the small sample size of stones. In this case, bones indicate a predominantly random orientation (SI4).

Regarding the rest of Assemblages, the absence of significant accumulations and/or orientation patterns of objects is mainly due to the small sample size of the assemblages, especially when the elongation index (Ie=>1.6) is applied (Bertran and Lenoble 2002; Lenoble and Bertran 2004). For example, Assemblage A-II contains 118 bones very scattered insufficient for further analyses, such as Getis-Ord Gi*. The orientation pattern indicates a preferred orientation towards NE-SW, similar to the pattern detected in Assemblage A-I. Assemblage A-III, with a high number of bones, shows a main accumulation of lithics in Square G15, which coincides with the main concentration of bones. An artifact identified as a *biface trimming flake* is associated with a big bone, probably elephant. In this case, both bones and stones show the same orientation pattern, a preferred orientation towards NW-SE, different to the orientation pattern showed by any other Assemblage.

Discussion

The results above can be compared with interpretations made by the 1960s excavators. The geologist Butzer (1965) described the geological context of Ambrona and Torralba for the first time, although the first publication with a preliminary report based on the 1961 excavations of Torralba was published by Howell et al. in 1962. In this work, Butzer indicated that "human habitation is first evident in Unit IIb" (Table 2), referring to the orientation and distribution of bones and the absence of rolling or wear of artifacts. His next mention of "cultural horizons" was

Table 2 Summary of interpretations about Torralba's "cultural horizons" published by Butzer (1965) and Freeman and Butzer (1966)

SUMMARY OF INTERPRETATIONS ABOUT TORRALBA'S "CULTURAL HORIZONS"	
Unit IV	"Archaeological materials scattered within lowest marls" (Freeman and Butzer 1966).
Unit IIIb	Next cultural horizon, identified as "well-defined gravel pavement" and described as "subrounded to rounded, medium-grade pebbles mildly cryoclastic, but otherwise of fluvial type" (Butzer 1965). Unit IIIb was defined as Member III of the Torralba formation but Butzer (1965) refers to Ambrona to describe it.
Unit IIc	Presence of "cultural horizons" in Unit IIc with a high number of "articulated bones on top of some of the intergrading gravel lenses and within one sandy zone" (Freeman and Butzer 1966). Publication by Freeman and Butzer (1966) approached the first spatial analysis of Unit IIc, specifically on two horizons: Levels B2 and B4a (referred to them as "cultural horizons"). Publication by Pineda and Saladié (2019) showed that the largest number of bones were labeled as B1 and B2, with only a few in B3 and B7. The analysis (Freeman and Butzer 1966) distinguished four sub-areas in Level B4a: Area 1, 2, 3 and 4. Area 1 as the main area.
Unit IIb	First evidence of human habitation (Butzer 1965) in a context of coarse, subangular to subrounded gravel. Reference to the orientation and distribution of bones: "Although some downslope sliding took place, cultural associations, independent of orientation, have been preserved atop or among the A-gravels" (Butzer 1965). The validity of "cultural associations" regardless the orientation caused by the sliding identified in Unit IIb was later emphasized by Freeman and Butzer (1966), underlining the absence of size sorting of bones or artifacts, and the "nearly articulated position of some bones." Stratigraphic association of "cultural horizons" to AB-gravels: "cultural horizons with articulated bones occur on top of both these intergrading lenses."

made regarding the AB-gravels (Butzer 1965), indicating the presence of "cultural horizons with articulated bones" (Table 2). Later, Freeman and Butzer (1966) emphasized the absence of size sorting of bones or artifacts and the presence of articulated bones. This affirmation of the existence of articulated bones is also mentioned regarding the "cultural horizons" of Unit IIc" (Freeman and Butzer 1966). These statements about "articulated bones" are very unclear, since in all the photographs and maps georeferenced and studied, we did not identify any articulated bone, as can be seen in Fig. 7 and in sections SI3 and SI4 of the Supplementary Information.

The next "cultural horizon" is identified in Unit IIIb, which was defined as Member III of the Torralba Formation, but Butzer refers to Ambrona to describe it, in a confusing mixture of localities, Units, horizons, and pavements. Ambrona and Torralba were considered "twins" (Butzer 1965), and that therefore the imagined stratigraphic parity between the sites was emphasized. Later studies have demonstrated that Ambrona and Torralba were not twins (Pérez-González et al. 1997, 2005), Torralba being slightly younger than Ambrona (Falguères et al. 2006).

The first spatial analysis approached in Torralba was focused on the Unit IIc (Freeman and Butzer 1966), on

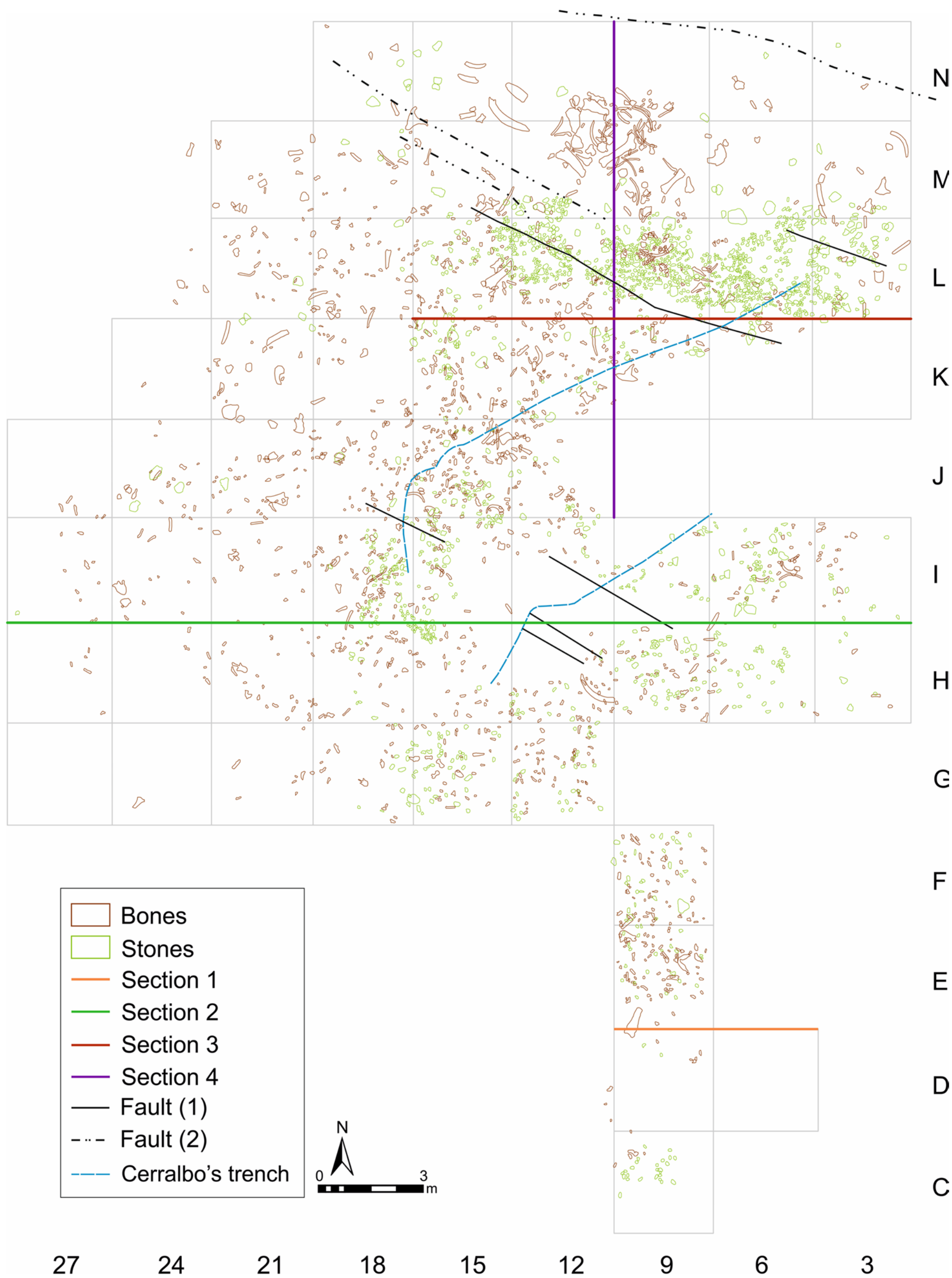


Fig. 7 Composite distribution map (plan view) of the excavated elements and position of the Torralba stratigraphic sections compiled from the HERC archives, georeferenced, digitized and spatially positioned. Information about the positions of the faults was obtained from a map found among the HERC photo archives (1) and from the partial map published by Freeman and Butzer in 1966 (2) (Freeman and Butzer, 1966)

levels B2 and B4a. Although they indicated these two levels as the "cultural horizons", the publication by Pineda and Saladié (2019) showed that the largest number of bones were labeled as B1 and B2 (with only a few bones in B3 and B7), showing once again the enormous confusion of levels, units, sublevels and "Occupations", which have significantly complicated the stratigraphic assignment of objects, and therefore the comprehension of Torralba.

That analysis (Freeman and Butzer 1966) distinguished four sub-areas, whose classification seems to have been based on observations of spatial disposition, although the contents of each sub-area differ in artifacts and bone elements of the animals represented in the maps (Fig. 8, but also Fig. 7 and SI3). Area 1, Area 2, and Area 4 include bones from map A-VII, while Area 3 includes some of the bones from map A-I (more specifically the bones of square L9 of A-I -see SI3, Fig. S2-) but without the remarkable accumulation of stones, which also show a specific pattern of accumulation and they are all almost the same size. Within these four sub-areas, Area 1 was identified as the main concentration of bones and which could indicate marrow extraction activities (Freeman and Butzer 1966). The absence of lithic materials was explained because "tools were removed from Area 1 for use in continued processing of materials in other areas nearby" (Freeman and Butzer 1966).

The investigators suggested that the presence of cores could indicate that some tools were manufactured during butchering activities. Areas 2, 3 and 4 were interpreted as spots for a secondary manipulation of the materials gathered in Area 1 (although we found that Area 3 belongs to a different "Occupation"). In addition, the use of fire was interpreted as related to the activities performed in Areas 3 and

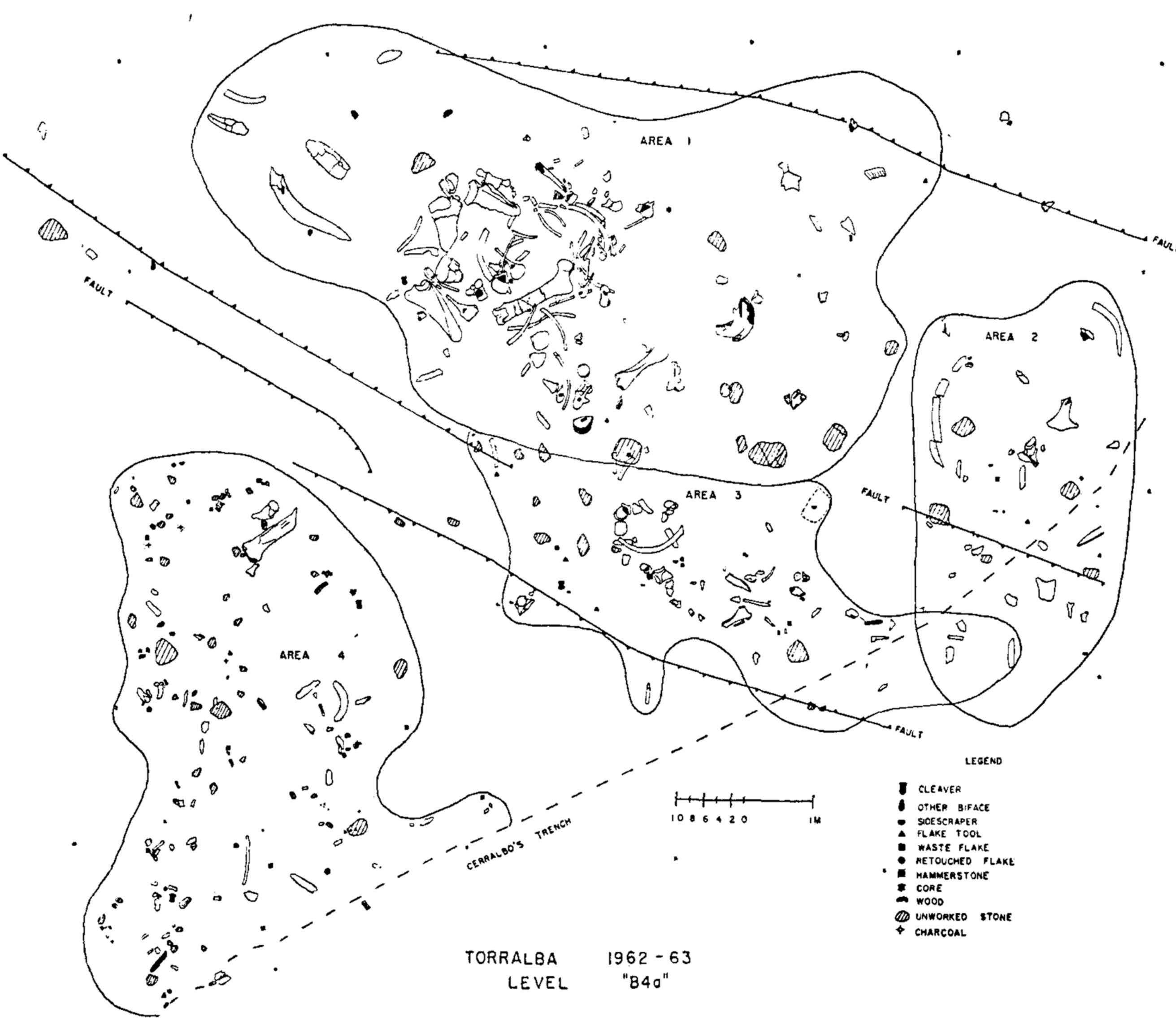


Fig. 8 Sub-areas Torralba identified and defined by Freeman and Butzer (1966)

4 (Freeman and Butzer 1966). This statement about the use of fire was based on interpretations about the distribution of bones and lithics and their classification by zones. However, on the recovered maps, the element identified as "burnt patch" is indicated in map A-VIII (see SI3), more specifically in Square E9 (quite far from these zones or areas), and it is based on a darker color of the sediment (Fig. S20). It is not difficult to understand how such inferences would be turned into artist's reconstructions of Pleistocene Torralba.

This mixture of maps and the non-incorporation of elements (in this case, stones) leads us to two possible conclusions. First, that these interpretations were made a priori and the final maps of Occupations/Assemblages we found were perhaps ready to be published in the monograph that was not published. The second possibility is that these differences from their 1960s publications were due to additional studies and interpretative changes. Whatever the case, it is impossible to determine which of these maps or distributions is correct, since the artifacts –although very accurate in their drawings when we compared with the photographs (see Fig. 6 for an example)– lack information about their stratigraphic assignments.

To pursue these issues, we have cross-referenced the unpublished data from the distribution maps and the stratigraphic sections. We observe that when we project the objects together with the stratigraphic sections, particularly in the clearest crossing point between Sects. 3 and 4, the faults seem to play a role that may be more relevant than expected in the interpretation of the deposits and Units assignations. Figure 9 shows how a lag deposit (limestone gravels) seems to be clearly linked to the concentration of stones that we see in the maps, but with a very clear separation between these stones and the "half-elephant" accumulation.

Figures 7 and 8 show the faults affecting the excavated area at Torralba. There is a fault that crosses between the accumulation of bones and stones of Assemblage A-I. It is clearly indicated in Sect. 4 (Figs. 9 and 4). This fault seems to separate both accumulations, the one in Assemblage A-I and the concentration of bones of Assemblage A-VII.

In Sect. 4, we clearly see that the gravels underneath are affected by this fault and appear closer together (probably the AB-gravels that Butzer refers to) and then as a lag. On top of these gravels, the unit or layer labeled as "G" might correspond to Unit IIc (atop of and intercalated with the AB-gravels, according to Butzer 1965) and grows in thickness towards the north of the excavated area. We do not see "G" gaining thickness laterally (E-W) in Sect. 3 (Fig. 9), but it persists as small pockets or lenses towards west (maybe this corresponds to the so-called Unit IIb). The bones of the "half-elephant" concentration are beyond the limits of the massive accumulation of stones (in green), in a spot of the deposit where hardly any stones were recorded. This may be due to a recording issue, i.e., stones were not registered here, and therefore the recorded data would be biased. It could be that there were actually no stones in this part of the site, which is hard to believe when we observe the presence of lags in the stratigraphic sections. And there is a third option: the bones are associated with the "G" deposits, where there are no stones and therefore have not been recorded. The distribution maps show that there are hardly any stones in this part of the excavated area (northern part, square lines M and N) (Fig. 7).

Bones and stones of Assemblage A-I show similar orientation patterns, with a clear preferred NE-SW orientation for both assemblages (Fig. 10, SI4). However, in the case of A-VII, the orientation patterns of bones indicate a preferred orientation NNW-SSE with some vectors NW-SE, in a multimodal pattern that points to a non-random orientation (Fig. 10, SI4). Thus, we not only observe different orientation patterns in both Assemblages, which would support

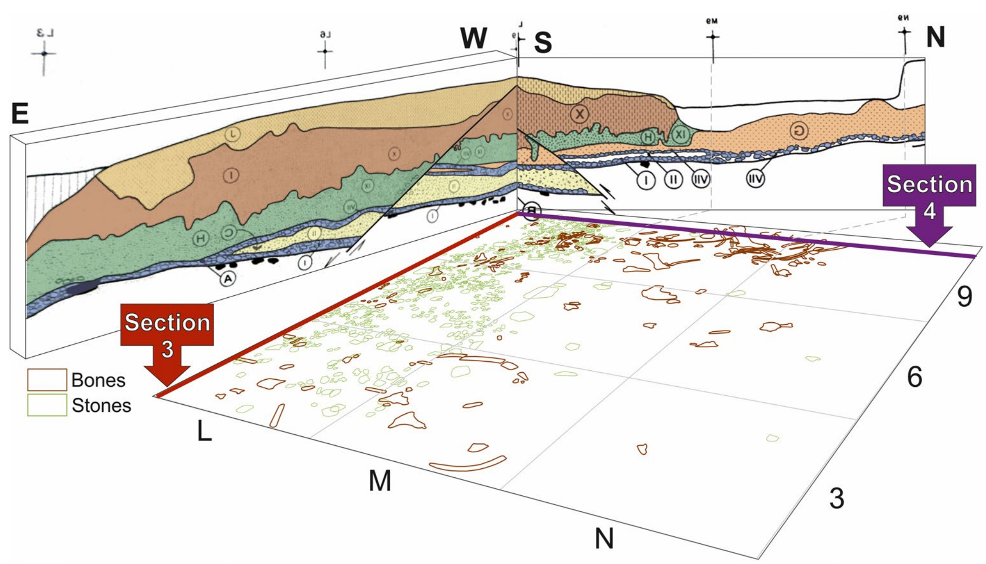
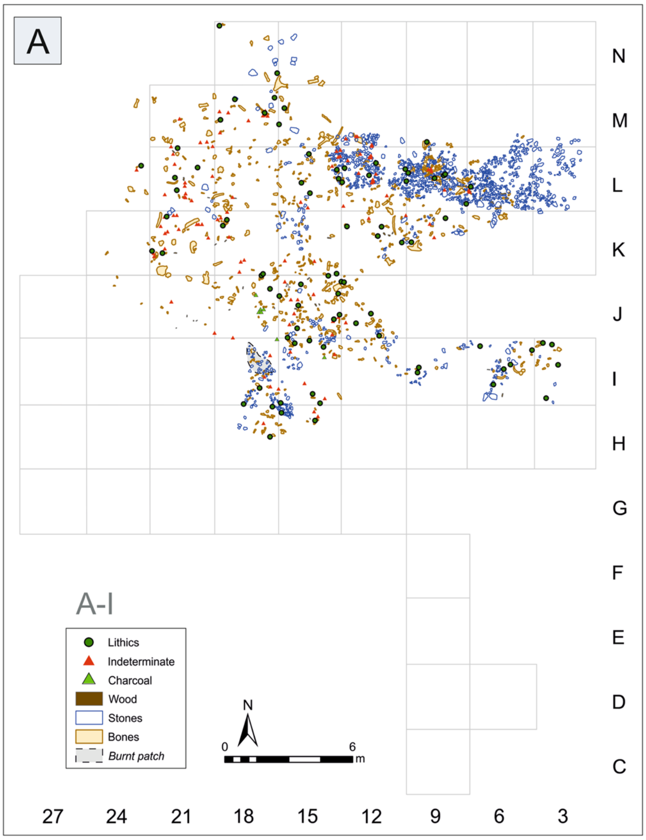
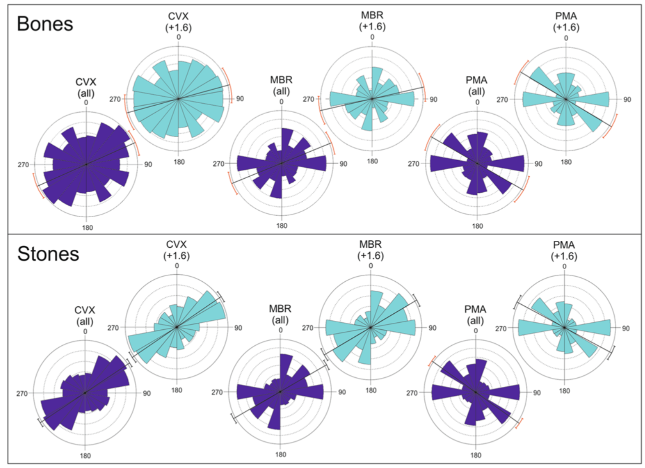
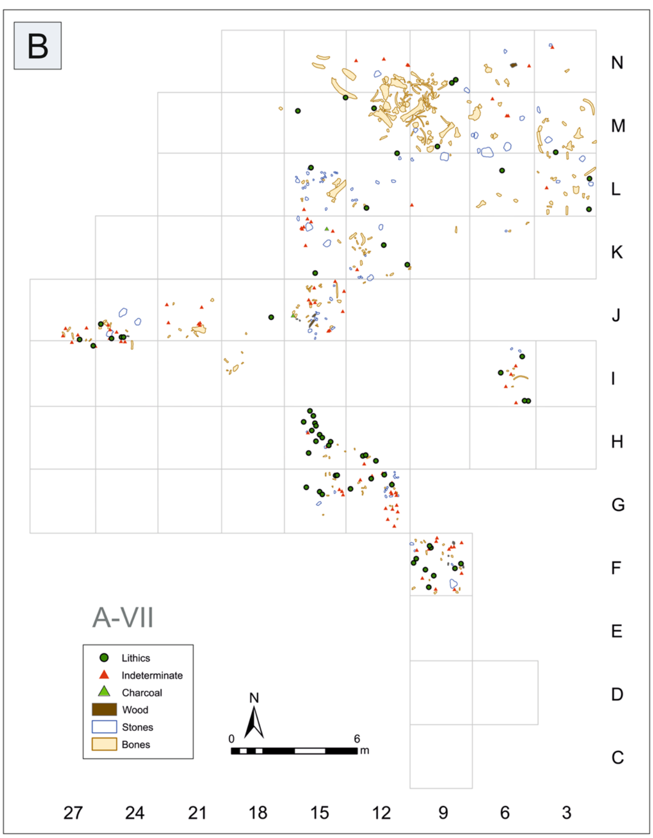


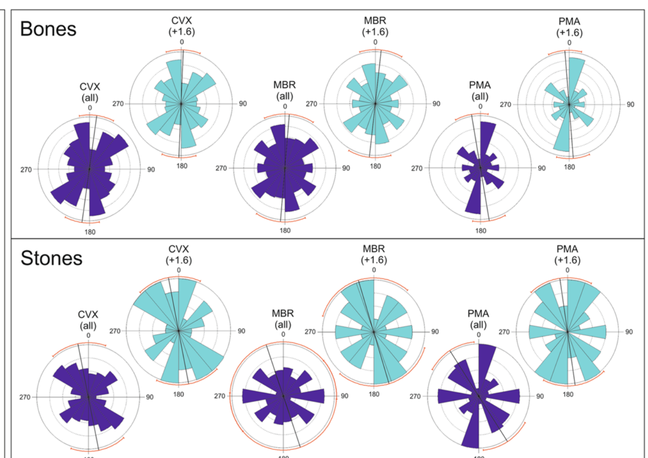
Fig. 9 Intersection of Sections 3 and 4 with the distribution map of bones and stones





Bones		le +1.6			All		
Method		CVX	MBR	PMA	CVX	MBR	PMA
Sample size		413	413	413	652	652	652
Mean Vector (°)	μ	75.008°	77.44°	120.84°	66.4°	68.049°	119.774°
Length of Mean Vector	r	0.101	0.128	0.133	0.111	0.125	0.098
Concentration	k	0.204	0.258	0.269	0.223	0.252	0.198
Circular Standard Deviation (°)	v	61.313°	58.091°	57.519°	60.076°	58.445°	61.697°
Rayleigh test	Z	4.233	6.764	7.332	8.024	10.155	6.309
	p	0.015	0.001	6.54E-04	3.27E-04	3.89E-05	0.002
Kuiper's test	V	2.034	2.854	4.219	2.501	3.719	4.88
	p	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Stones		le +1.6			All		
Sample size		474	474	474	1259	1259	1259
Mean Vector (°)	μ	56.156°	59.978°	117.836°	56.612°	60.538°	124.96°
Length of Mean Vector	r	0.284	0.251	0.228	0.235	0.198	0.185
Concentration	k	0.593	0.519	0.469	0.483	0.404	0.377
Circular Standard Deviation (°)	v	45.448°	47.623°	49.249°	48.769°	51.568°	52.61°
Rayleigh test	Z	38.259	29.896	24.677	69.414	49.299	43.187
	p	< 1E-12	< 1E-12	1.92E-11	< 1E-12	< 1E-12	< 1E-12
Kuiper's test	V	4.551	4.518	5.104	6.437	7.006	7.646
	p	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01





Bones		le +1.6			All		
Method		CVX	MBR	PMA	CVX	MBR	PMA
Sample size		192	192	192	266	266	266
Mean Vector (°)	μ	2.365°	6.441°	175.474°	8.081°	4.86°	170.295°
Length of Mean Vector	r	0.154	0.121	0.157	0.128	0.089	0.134
Concentration	k	0.311	0.244	0.318	0.258	0.179	0.269
Circular Standard Deviation (°)	v	55.438°	58.845°	55.108°	58.081°	63.019°	57.49°
Rayleigh test	Z	4.539	2.824	4.745	4.363	2.105	4.742
	p	0.011	0.059	0.009	0.013	0.122	0.009
Kuiper's test	V	2.188	1.833	2.725	2.363	1.755	2.87
	p	< 0.01	< 0.05	< 0.01	< 0.01	< 0.05	< 0.01
Stones		le +1.6			All		
Sample size		23	23	23	91	91	91
Mean Vector (°)	μ	169.332°	163.326°	171.786°	168.749°	161.306°	147.174°
Length of Mean Vector	r	0.238	0.147	0.234	0.138	0.037	0.148
Concentration	k	0.49	0.296	0.481	0.278	0.074	0.3
Circular Standard Deviation (°)	v	48.561°	56.148°	48.847°	57.034°	73.522°	55.97°
Rayleigh test	Z	1.3	0.494	1.256	1.729	0.125	2.001
	p	0.275	0.615	0.288	0.178	0.882	0.135
Kuiper's test	V	1.392	0.991	1.287	1.625	1.119	2.137
	p	> 0.15	> 0.15	> 0.15	0.10 > p > 0.05	> 0.15	< 0.01

Fig. 10 Distribution maps and orientation patterns (circular histograms, dispersion parameters, and statistics) of A-I (**A**) and A-VII (**B**). These and the rest of the Assemblages are described in detail in SI3 and SI4

the idea that they belong to different levels, but we also can confirm that bone assemblages are affected by agents that have altered their original position, arranging them to preferred orientations. In this case, and considering what Butzer stated about the sliding identified in Unit IIb (Butzer 1965), we cannot confirm if these preferred orientations are due to the slope of the deposit or the action of water as a post-depositional agent.

In the case of the main accumulation of bones from Torralba (in A-VII), although it was identified as "half-elephant" (Freeman and Butzer 1966) and the patterns of accumulation and orientation appear to be similar, we observe that the process behind of the formation and preservation of the assemblage was different from that identified in Ambrona (Villa et al. 2005; Sánchez-Romero et al. 2016). In Torralba, no anatomical connections are observed to suggest rapid sedimentation, and therefore preservation of the spatial arrangement as seen at Ambrona. Additionally, the information provided by recent taphonomic studies (even though we do not know if they correspond to these specific bones) reveal serious problems of the conservation of bone surface, highlighting elephant bones as the taxon with most poorly preserved surfaces (Pineda and Saladié 2019). Weathering is documented in 70–80% of the remains and evidence of abrasion is identified in each level, especially in Howell collection, where rounding and polishing is identified in 70% of the remains.

Regarding the main accumulation of stones of map A-I, the coldspot cluster is clear in terms of accumulation by size (see SI4, Fig. S22). The shapes are mostly regular in all stones, which suggests that they are mainly gravels or pebbles, similar to the ones we can find in the lags of Ambrona. In this case, the orientation pattern showed by this coldspot cluster (n=950) indicates a clear unimodal NE-SW orientated histogram (see SI4), with very low p-values in Rayleigh and Kuiper tests that strongly reject the uniformity of this accumulation. The orientation patterns of Assemblage A-I are very similar between bones and stones, which seems to indicate that the depositional processes could have been the same or very similar in both cases. However, we can observe that, at certain points, bones seem to have served as a *parapet* or are surrounded by seeming alignments of stones (Fig. 11). This could indicate different moments of deposition, a different behavior of the elements during motion forces and/or that the already deposited assemblage was affected *a posteriori* by post-depositional processes, as the presence of stone circles also seems to suggest.

The question about the circular spatial arrangement of stones ("stone rings") has been related to cryoclastic events (Butzer 1965; Freeman and Butzer 1966). Indeed, a certain circular or semi-circular organization of stones is observed, mainly in map A-I (Figs. 5 and 11). However, with current

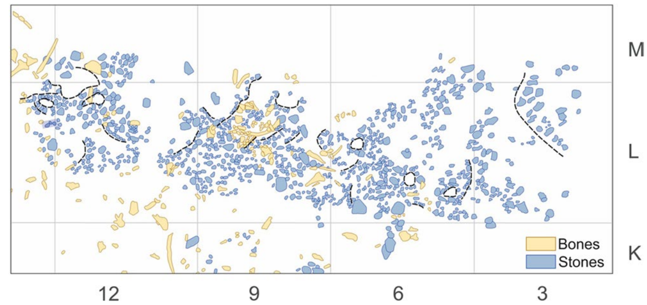


Fig. 11 Close-up of the accumulation of bones and stones at A-I. See the arrangement of some of the stones, lined up and surrounding some of the bones

data, we cannot confirm whether this is due to thermal episodes. It may be more related to the formation processes rather than to cold events affecting the deposit.

Besides bones and stones, the spatial pattern of lithic artifacts seems to clearly follow the same patterning as bones. Even among the isolated bones we found identifiable elements of lithic materials, as can be seen in Assemblages A-III, A-IV, A-V, A-VI and A-VII, where endscrapers, bifaces, sidescrapers or "biface trimming flakes" are identified alongside isolated bones outside the main distribution of elements. In Assemblage A-VII, the main concentration of lithics is clearly where one of these secondary clusters is located, with much smaller bones, while in the main cluster of bones hardly any lithic material is found. This pattern of lithic artifacts concentrated in an area away from the area where the main concentration of bones is located, and in clear association with smaller remains, could invite us to think about differentiated areas of activity, and therefore help to infer modes of hominid behavior. However, considering the nature of the assemblage and the lack of resolution to contextualize these assemblages, it is extremely risky to reach any conclusion in this regard prior to more excavation.

This study has explored many of the issues still under debate at Torralba, presenting all the unpublished information about the stratigraphy and distribution maps of bones, stones, and lithic artifacts, and allowing us to analyze the role played by natural and anthropic agents in its formation. It has been seen that the publications related to this site are sometimes contradictory and/or inconsistence with the spatial data, and therefore difficult to interpret. The published spatial analysis showing the sub-areas has been refuted and the bone and stone accumulations show to belong to different units, with different accumulation and orientation patterns that suggest that they belong to different events. The main Assemblages (A-I and A-VII) on which Torralba's main interpretations were based are reoriented and show different patterns of accumulation and composition. The published maps do not show all the elements (as in the case of the stones), critical to understanding the processes involved in the concentration and stratigraphic assignments of the lithics and bones.

Torralba shows a succession of events that have resulted in a palimpsest very difficult to unravel without an appropriate stratigraphy and control over the excavation. The locality was clearly affected by faults that most likely have influenced the first interpretations of the stratigraphy, giving rise to a confusing description of Units and sublevels that we were only partially able to unravel as we exerted spatial control based on the original data sets.

Conclusions

The presence of hominids in Torralba was long ago demonstrated by the presence of lithic artifacts and then by a few cut marks identified on some bones (Shipman and Rose 1983; Pineda and Saladié 2019). Historically hominids were seen as the main agents of bone and stone accumulation and modification, and this led to Torralba's prominence, seemingly proving Cerralbo and Cartailhac's optimism that it would become iconic in paleoanthropology. However, as paleoanthropology became a multidisciplinary endeavor, earlier interpretations were increasingly tested by new insights and methods. The introduction of actualistic studies, notably by Charles K. Brain and Lewis R. Binford in the 1980s (Binford 1981; Brain 1983) played an important role in this evolution, as did the hypothesis put forward so dramatically and popularly by Aguirre, Howell and Freeman.

Indeed, it was excavation team's work that made possible the spatial assessments presented here. Contrary to what some authors have written about the excavation at Torralba and Ambrona, the great detail observed in the drawings and photographs, and the precise match between such drawings and the photographs taken on the in situ materials, indicate rigorous attention to documentation of the excavations. Recording was not made to the millimeter, or even centimeter, but such precision would have had no effect on analytical detection of groups of objects and spatial distributions outlined here. A main interpretive problem at Torralba was then –and remains today– control of the stratigraphy in which the bones and artifacts were embedded. We trust that the work presented here on previously unpublished data will not only deliver archive the antiquities recovered in the 1960s, but also deliver cautionary tales about recording stratigraphic and sedimentological data associated with Paleolithic bones and stones.

Today, the results obtained by different analyses indicate that hominids did not play the role of the lead actor on Pleistocene Torralba's stage. In general, the accumulation of bones and stones seems to respond to natural agents, and the anthropic action seems to have been more opportunistic at most.

The discovery of multiple additional Middle Pleistocene occurrences around the world has sharpened the focus on what Binford (1981) perceptively identified as "integrity" and "resolution" in the assessment of Paleolithic stone and bone assemblages. Our study has demonstrated that Torralba occupies the low end of archaeological integrity and resolution scales compared to other open-air localities. These localities, where the presence of fossils of proboscidean and lithic artifacts has also been documented, and where in some cases spatial studies have also been carried out, although in varied depositional contexts, provide a data record that allows for more accurate inferences about site formation processes and the role of hominids in that formation. Examples of this include the localities of Schöningen (Thieme 1997; Böhner et al. 2015; Serangeli et al. 2015; Hutson et al. 2020; García-Moreno et al. 2021; Urban et al. 2023; Leder et al. 2024), La Polledrara di Cecanibbio (Anzidei et al. 2012; Santucci et al. 2016; Cerilli et al. 2023), Neumark-Nord (Mania 1990; Fischer 2010; García-Moreno et al. 2016; Gaudzinski-Windheuser et al. 2023a), the recent published evidence of cutmarks on elephant bones in the two German open-air localities of Gröbern and Taubach (Gaudzinski-Windheuser et al. 2023b), Castel di Guido (Radmilli and Boschian 1996; Boschian and Saccà 2010, 2015), Notarchirico (Moncel et al. 2023; Pineda et al. 2024), Marathousa 1 (Giusti et al. 2018; Panagopoulou et al. 2018; Milks et al. 2026) or Boxgrove (Roberts et al. 1986; Roberts and Parfitt 1999; Pope et al. 2020; Sánchez-Romero et al. 2023). Nevertheless, Torralba's historical precedence and international prominence played an important role in global paleoanthropology, particularly in stimulating crucial improvements in archaeological method and theory.

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Declarations

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