Assessment of accumulation processes at the Middle Pleistocene site of Ambrona (Soria, Spain). Density and orientation patterns in spatial datasets derived from the excavations from the 1960s to the present.

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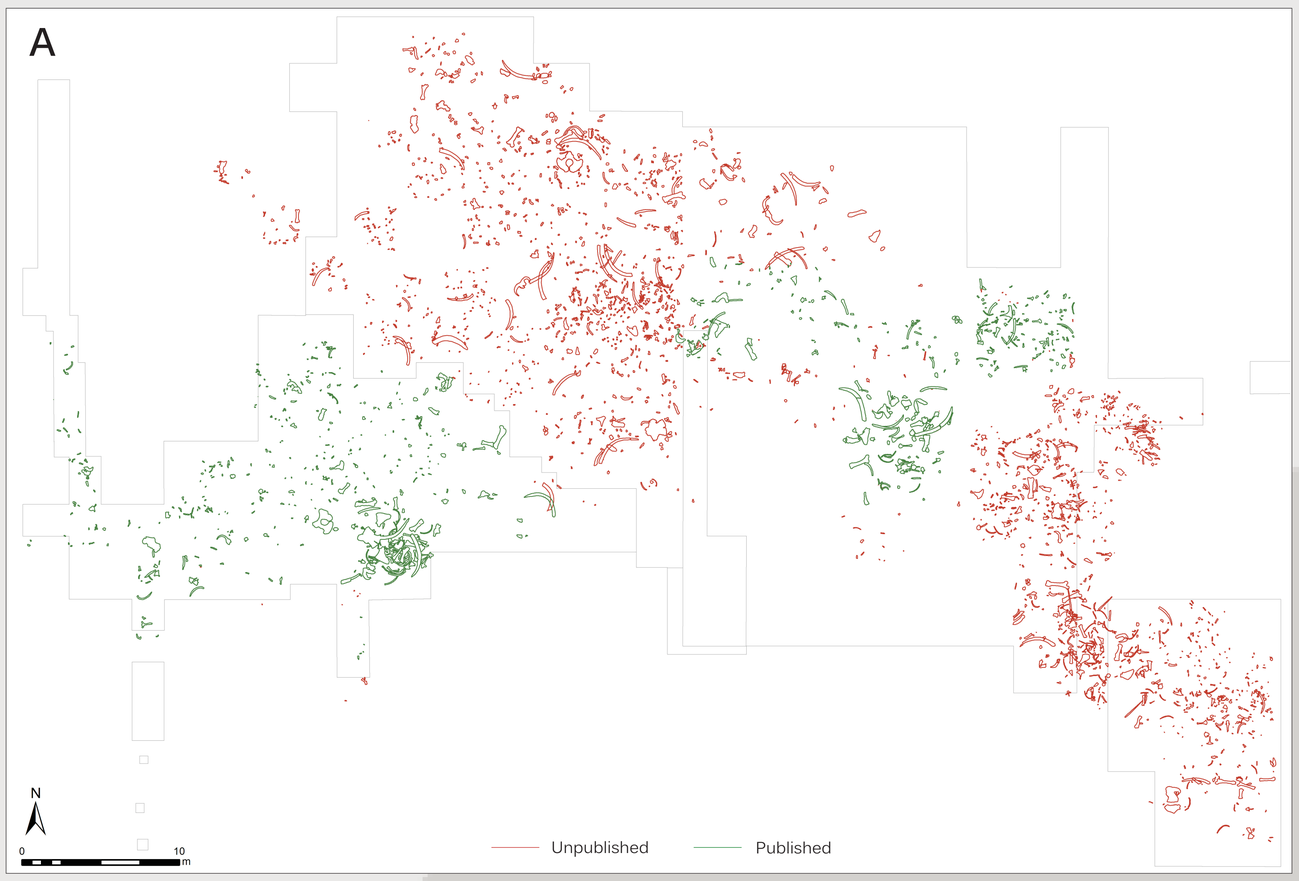
A BIT OF HISTORY...

The Middle Pleistocene site of Ambrona (Soria, Spain) is a major reference for European Acheulean studies. The origin of the lithic and fauna accumulations at this site was first thought to be anthropogenic (Howell, 1965; Freeman, 1994; Howell et al., 1995), but later studies demonstrated that it was mainly natural (Pérez-González et al., 1997; Villa et al., 2005).

Ambrona site was excavated in 1914 by the Marquis of Cerralbo; other research groups followed in more recent times (the Howell & Freeman team and the Santonja & Pérez-González team). The digs yielded a great amount of information, but until now it had never been unified. Here, we compile all the available published and unpublished excavation documentation from the 1960s to the present. Using these maps and sections, we present the spatial study of the LSM (Lower Stratigraphic Member) at the Ambrona site, combining stratigraphic criteria with GIS density and orientation analysis. This study enabled us to define the main concentrations of the LSM, providing an initial contribution to an assessment of their accumulation processes.



METHODS

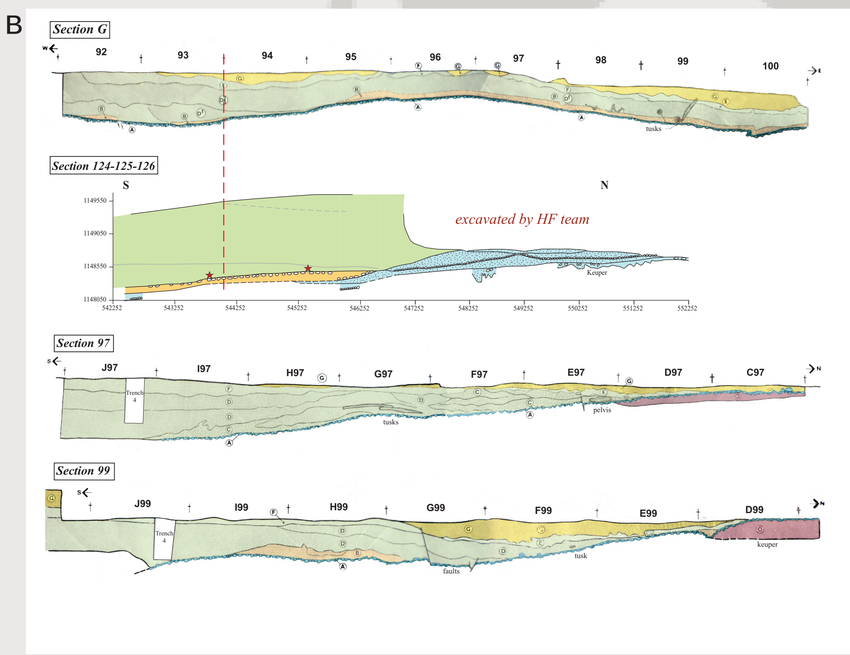
For Ambrona, we processed two types of spatial datasets: data collected by total station by the Santonja and Pérez-González team (hereinafter S&PG) from 1993 to 2000, and data collected by the Howell and Freeman team (hereinafter H&F), available through a few published maps and stratigraphic sections. However, there is a little published material from the H&F digs, despite the large area that the team excavated during this long period. We were able to fill in this thanks to Tim D. White, director of the F. Clark Howell Library at the Human Evolution Research Center (HERC), who gave us access to all unpublished information generated by the H&F team's work at Ambrona. We scanned 35 dispersion maps and stratigraphic sections into raster files, which enabled us to fill in the puzzle of the Ambrona site.

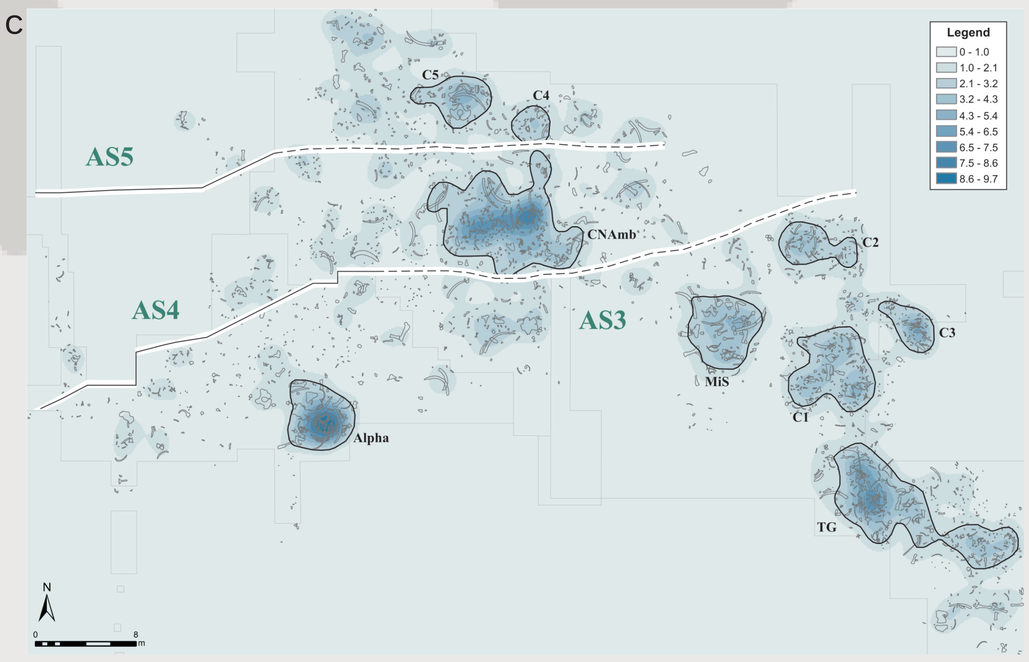
All the raster maps and stratigraphic sections retrieved from the H&F team's documentation were georeferenced, using the coordinate system generated by S&PG team with total station. We did this using common points recorded in both datasets, including excavation boundaries, the grid set up for the local coordinate system, and physical reference point left at the site by H&F dig (trenches, museum buildings, etc.). Thanks to these references in the maps, we were able to georeference and record the position of the concentrations of bone remains and lithic artifacts. In this stage, all the archaeological remains appearing in the raster plans and stratigraphic sections were vectorised in ArcGIS 10.3. Raster maps were automatically transformed into polygons (Benito-Calvo and de la Torre, 2011). The final result was GIS vector files in which each archaeological item was represented by a polygon. A total of 3,019 faunal remains were vectorised from H&F maps; counting in those already available from the S&PG team's excavations, we have a total of 4,417 faunal remains from the whole excavated portion of the site (Fig. A). Moreover, 3,577 lithic items were likewise vectorised and incorporated in the database.

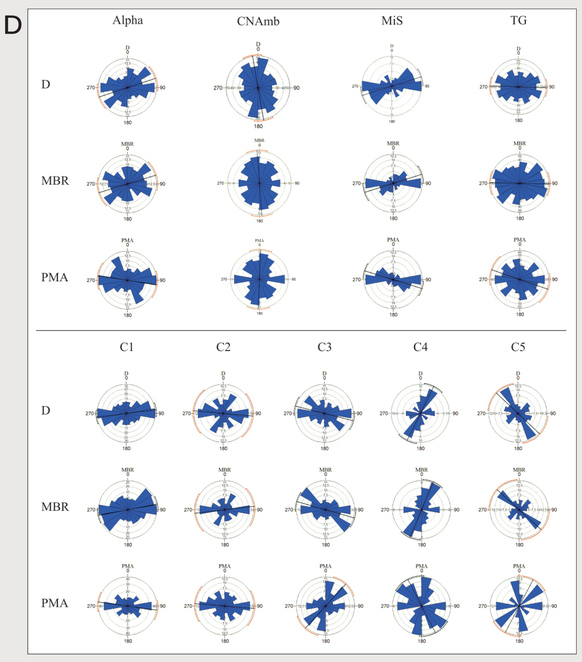
RESULTS

The stratigraphic sections made by the H&F team were studied in detail and compared with those made during the S&PG's team fieldworks. The correlation was based on control points common to stratigraphic sections made in different excavation periods. The control points were checked with direct field observations in places where the section was still preserved. Using these control points, the stratigraphic sections and the sedimentological characteristics of the facies were interpolated with the distribution of the stratigraphic units in the area being studied (Fig. B). The stratigraphic sections surveyed by the HF team were studied in detail, georeferencing in its position taking into account the current coordinate system and the spatial references indicated in the sections. The H&F's team stratigraphic sections in the 1960s and 1980s were made according to lithostratigraphic criteria (Butzer, 1965), whereas the S&PG team's sections were made according to allostratigraphic criteria (Pérez-González et al., 2005). Lithostratigraphic, sedimentological and thickness parameters were used to compare the two kinds of sections, as well as the presence or absence of faunal remains. The units where we found coinciding control points were AS1 (sands and gravels, fluvial environment), AS3 (clay, lacustrine environment), AS4 (sandy-clay and pebbles, fluvial-lacustrine environment), AS5 (sandy-clay and pebbles, fluvial-lacustrine environment) and AS6 (silty-clay with sands, fluvial-lacustrine environment). Fig. C shows the boundaries and extension of the deposits: AS3 is limited to the central and NE part of the site, whereas units AS4 and AS5 widen towards the edges of the site. The expansion of units AS4 and AS5 was probably due to the increase in river discharge from the NE basin, which caused progradation of the lake shores.

Based on this approach, we suggest that there are three main concentrations of faunal remains in the excavated area: one in the south (Alpha), in the central-northern part (CNAmb) and in the west (TG). CNAmb concentration displays a wider dispersion, and includes several tusks around 3 m long and large amount of small-sized remains. The overlapping geometry observed when we performed the stratigraphic correlation suggests that this concentration could belong to the AS4 unit. TG concentration was excavated in 1962 and without any stratigraphic reference. The stratigraphic correlation performed in this study suggests that this concentration might belong to AS3, since in this area this unit is dominant for its position and thickness. Moreover, the dispersion and size of the remains are very similar to those of the other accumulations we found in AS3. As the density map shows, the bones are less concentrated in TG than in Alpha. There is also a prevalence of long and large bones in TG, unlike the situation in the CNAmb concentration. The characteristics of C1, C2 and C3 are more similar to those of TG, where there are smaller remains and the assemblage does not consist solely of large bones. In the northern part of the site, we found other two concentrations -C4 and C5- likewise ascribed to AS5. The boundary of AS5 is very clear, which is why we could correlate these concentrations to this unit. Most of the concentrations described are defined by a very clear preferred orientation pattern. CNAmb, TG, MiS, C1, C3 and C4 display preferred orientations, which are statistically very significant and are dominated mostly by unimodal distributions; this suggests that natural processes oriented the items. Conversely, uniformity distribution cannot be reject for the C5, C2 and Alpha concentrations, hence we suggest that they are random accumulations resulting from non-orientation natural processes. The orientation distribution shows a spatial pattern that depend on the site zone. Orientation patterns with a predominant E-W trend are located in the eastern part of the site and pertain to the AS3 unit (MiS, C1, C3 and TG concentrations). Circular histograms for Alpha and C2 (southern part of the site) are similar to this first group, although statistical tests do not confirm preferred orientation. On the other hand, a third group of orientation patterns is located toward to the northern part of the site, displaying NNE-SSW, NW-SE, and minor E-W directions (C4 and C5 concentrations developed in AS5). The CNAmb concentration would belong to this third group, which occurs in a different stratigraphic unit (AS4) and it is characterized by a N-S pattern. This latter pattern differs from those in the other histograms, but may resemble those in the C5 and C4 concentrations in unit AS5. The association between orientation patterns and stratigraphic units points to a correlation between the accumulation processes that produced the concentrations and the sedimentological characteristics of the units.







Method		Alpha			CNAmb			MiS			TG			C1			C2			C3			C4			C5		
		D	MBR	PMA	D	MBR	PMA	D	MBR	PMA	D	MBR	PMA	D	MBR	PMA	D	MBR	PMA	D	MBR	PMA	D	MBR	PMA	D	MBR	PMA
Size sample	*n*	83	83	83	290	290	290	42	42	42	332	332	332	143	143	143	55	55	55	67	67	67	33	33	33	46	46	46
Mean Vector (°)	*μ*	71,57°	72,847°	98,78°	169,988°	175,527°	2,495°	72,315°	72,576°	107,226°	92,057°	91,127°	109,27°	83,093°	78,845°	97,883°	95,104°	83,253°	94,784°	104,251°	105,845°	42,538°	26,619°	22,92°	152,766°	133,33°	132,1°	27,798°
Length of Mean Vector	*r*	0,173	0,149	0,165	0,139	0,126	0,108	0,377	0,344	0,41	0,128	0,097	0,072	0,25	0,232	0,18	0,117	0,14	0,152	0,268	0,25	0,175	0,35	0,334	0,216	0,156	0,133	0,187
Concentration	*k*	0,351	0,302	0,335	0,28	0,253	0,217	0,814	0,732	0,898	0,258	0,194	0,144	0,517	0,476	0,367	0,235	0,282	0,307	0,557	0,517	0,357	0,748	0,708	0,442	0,315	0,269	0,38
Circular Standard Deviation (°)	*v*	53,676°	55,874°	54,378°	56,955°	58,362°	60,45°	40,019°	41,867°	38,262°	58,101°	61,922°	65,766°	47,679°	49,002°	53,032°	59,401°	56,859°	55,633°	46,484°	47,678°	53,445°	41,483°	42,437°	50,174°	55,252°	57,519°	52,482°
Rayleigh test	*Z*	2,48	1,849	2,261	5,57	4,57	3,378	5,967	4,963	7,056	5,43	3,105	1,708	8,962	7,668	4,646	0,747	1,07	1,266	4,815	4,199	2,063	4,054	3,677	1,536	1,115	0,817	1,604
	p	0,084	0,157	0,104	0,004	0,01	0,034	0,002	0,006	6,83E-04	4,00E-03	4,50E-02	1,81E-01	1,28E-04	4,68E-04	0,01	0,474	0,343	0,282	0,008	0,015	0,127	0,016	0,024	0,216	0,33	0,444	0,202
Kuiper's test	*V*	1,47	1,292	1,562	2,386	2,018	1,954	2,4	2,122	2,276	2,132	1,778	1,613	2,497	2,498	2,113	1,169	1,365	1,32	1,955	1,959	1,797	1,761	1,782	1,636	1,399	1,559	2,49
	p	> 0.15	> 0.15	0.15 > p > 0.10	< 0.01	< 0.01	< 0.025	< 0.01	< 0.01	< 0.01	< 0.01	< 0.05	0.15 > p > 0.10	< 0.01	< 0.01	< 0.01	> 0.15	> 0.15	> 0.15	< 0.025	< 0.025	< 0.05	< 0.05	< 0.05	0.10 > p > 0.05	> 0.15	0.15 > p > 0.10	< 0.01

CONCLUSIONS

Our density and orientation analyses of these maps constitute an initial contribution to the study of the accumulation processes that affected the concentrations of large mammal remains that characterize the Ambrona site. We are now able to define the main concentrations present at Ambrona, which display different orientation patterns, depending on stratigraphic unit they are in. This circumstance suggests that accumulation patterns are closely linked to the stratigraphic units. Orientation analyses show that most of the concentrations display preferred orientation patterns. Exposure to and orientation by natural processes may have been more intense for concentrations located in shore areas of the wetland (CNAmb, TG, MiS, C1, C3, C4). One concentration was also identified in a more central part of this wetland; its random orientation pattern indicated that it did not undergo any orientation process during its accumulation. The Alpha assemblage consists of a nearly whole elephant skeleton. As it was located in the deeper part of the pond, the bones were quickly buried and preserved by rapid sedimentation. This is consistent with the data obtained by available taphonomic studies, which show that oriented accumulations had been more subjected to post-depositional processes than those with random orientation patterns.

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