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Not only domestic spaces: dismantling short-term occupations in Level 497D of Cova Gran de Santa Linya (Pre-Pyrenees, Spain)

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ABSTRACT: The Early Upper Paleolithic Level 497D of Cova Gran (Pre-Pyrenees, Spain) comprises large assemblages of lithics, fauna, hearths, ash accumulations and well-preserved refitting sequences. This provides exceptional information to analyze spatial patterns and deepen our understanding of the socio-economic behavior of these human groups. This large interdisciplinary dataset has allowed us to carry out a detailed spatial study based on density analysis, geostatistics, fabric analysis and orientation techniques, revealing a structuring of the activities performed within the rock shelter. The distribution and accumulation of lithic artifacts, fauna and refits, and their association with the 10 hearths and ash accumulations, show that different types of activities were developed at the site, as well as showing the different uses of the hearths. 497D is a palimpsest where several short-term occupations and/or activities could have occurred in a relatively short period of time, avoiding prolonged exposure to biotic and abiotic post-depositional factors that could have significantly disturbed this well-preserved assemblage. This level shows a place visited several times in relation to the development of specific activities, with movements throughout the landscape for the exploitation of local and regional resources, and less so its use as a domestic space. This implies that the central settlement, or dwelling space, would have been located somewhere other than Cova Gran.

KEYWORDS: Early Upper Paleolithic; geostatistics; GIS; refitting analysis; spatial analysis

Introduction

The Middle to Upper Paleolithic transition is probably one of the most widely discussed topics from many disciplines. In Europe, the encounters between anatomically modern humans and contemporary Neanderthals have been actively explored for more than a century. Recent advances in understanding include better chronometric control, better excavation practices and the application of spatial archaeological techniques.

Recent studies of environmental and climate changes, and their link with the distribution of hunter-gatherer groups and the disappearance and appearance of certain technocomplexes, have provided this debate with a significant amount of information (Higham et al., 2014; Marín-Arroyo et al., 2018; Devièse et al., 2021; Finlayson et al., 2023). In this context, research on settlement patterns of hunter-gatherer groups in different regions (Wadley, 2001; Conard et al., 2004; Munro, 2004; Henshilwood, 2005; Conard, 2011; Rios-Garaizar et al., 2022; Peresani, 2023) helps to define and specify the concepts of occupational intensity and suggest the population size (Varien and Mills, 1997, Henshilwood et al., 2001, Wurz, 2002; Munro, 2004; Conard, 2011; Will et al., 2014; Reynard et al., 2016; Marcazzan et al., 2022a). These investigations are mostly centered on the analysis of fauna, taxonomic variations, the presence/absence of certain species and variations in the lithic industry, including changes in technological variability, access to raw materials, etc. Interesting work on spatial analysis has recently been published that bring together all these elements to understand the intra- and inter-site spatial patterns. This work considers all the elements that played a role in the formation of the site and show how these elements together provide remarkable results, allowing an understanding of which, how and to what extent these factors were involved in the formation of the deposit (Carbonell, 2012; Chacón et al., 2015; Bargalló et al., 2016; Vaquero et al., 2017; Bertran et al., 2019; Arteaga-Brieba et al., 2023; Gabucio et al., 2023; Spagnolo et al., 2024). These elements include the formation of the cave, rock shelter or open-air site to the internal organization of the site, accumulation of artifacts, intensity of occupation and presence of carnivores that could have also intervened in the formation of the assemblage.

Spatial studies focused on occupational intensity other than artifact densities have a strong dependence on ethnography to make inferences based on behavioral elements, such as the division of activities, waste areas, hearths as central elements around which all activities were articulated, activities developed at the site (e.g. knapping and tool configuration, prey processing and even social activities), etc. (Yellen, 1977a, 1977b; Binford, 1978, 1983; Brooks and Yellen, 1987; O'Connell, 1987; O'Connell et al.,1988, 1990; Kelly, 1992; Enloe et al., 1994). These studies have been, and continue to be, of great interest and help to characterize what hunter-gatherer societies were like. However, recent advances made

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in the fields of micromorphology (Goldberg et al., 2009; Aldeias et al., 2012, 2023; Miller et al., 2013; Miller, 2015; Leierer et al., 2019; Haaland et al., 2021; Marcazzan et al., 2022a, 2022b), spatial analysis and Geographic Information Systems applied to archaeology (McPherron et al., 2005; McPherron, 2005, 2018; Benito-Calvo & Martínez-Moreno, Mora, et al., 2009, 2011; Benito-Calvo and De la Torre, 2011; De la Torre and Benito-Calvo, 2013; Sánchez-Romero et al., 2016, 2020, 2021, 2022, 2023; Spagnolo et al., 2020a, 2020b; García-Moreno et al., 2016, 2021; Zilio et al., 2021, *inter alia*) have greatly contributed to obtaining a high-resolution picture of these contexts, approaching them from a perspective that has allowed us to obtain a more approximate understanding of these time periods while avoiding falling into actualism.

The Cova Gran rock shelter allows us to evaluate and understand the patterns of occupation and use of space, because it not only comprises an extensive record of lithic and bone assemblages, but also an impressive record of well-preserved hearths, ash accumulations and refitting sequences (Martínez-Moreno et al., 2010, 2019; Mora et al., 2020; Samper Carro et al., 2020). The present study presents an integrative spatial analysis of the Early Upper Paleolithic (EUP) Level 497D of Cova Gran, with the aim of understanding the type of occupations that were carried out on this site by the human groups that inhabited the region during this period.

The context of Cova Gran

Cova Gran de Santa Linya is a large rockshelter located at 385 m a.s.l., in the lower foothills of the Serres Marginals Exteriors of the Pre-Pyrenees (northeast Iberia) (Fig. 1), at the bottom of the Sant Miquel ravine, a tributary of the Noguera–Pallaresa river on the western side of the Segre main watercourse (Benito-Calvo et al., 2009; Polo-Díaz et al., 2016; Martínez-Moreno et al., 2019). The Sant Miquel ravine forms a small V-shaped valley, incised more than 250 m, that developed between the Late Cretaceous Bona Formation and the clays and gypsums of the Upper Triassic. This E–W contact is displaced by transverse faults that cause minor variation in the valley direction, forming incised meanders (Benito-Calvo et al., 2009; Polo-Díaz et al., 2016). Cova Gran is situated in one of these incised meanders, coinciding with a limestone area that was weakened by faulting (Benito-Calvo et al., 2009).

The Pleistocene stratigraphic sequence of Cova Gran (CG) was mainly described in the west side of the rock shelter. In this sector, the deposits reach a relative elevation of +9 m above the stream (Benito-Calvo et al., 2009), where most of the archaeological and sedimentological studies have taken place (Mora et al., 2011). The sequence comprises two main stratigraphic units, the lower (S1) and the upper (497) (Fig. 1). S1 comprises nine levels, including Middle Paleolithic levels (S1B–S1I), and the Early Upper Paleolithic level of 497D, all with archaeological material and where the bedrock has not yet been reached (Benito-Calvo et al., 2009; Mora et al., 2011).

The work presented here focuses on the spatial analysis of the 497D archaeological level, located in the western part of the rock shelter, in the sector known as Ramp (R), on top of the unit S1 (Martínez-Moreno et al., 2019). 497D, with a variable thickness of 5–10 cm and excavated over an area of about 40 m^2 (Benito-Calvo et al., 2009; Mora et al., 2020), is developed in the stratigraphic boundary between two stratigraphic layers (S1-10 and S1-05) (Fig. 1). S1-10 (base) is poorly sorted, massive and heterometric, and mainly clast-supported. S1-05 (top) is a similar breccia layer but includes meter-sized boulders, interpreted as a breakdown facies from the partial collapse of the rock shelter ceiling. Micromorphology analyses of S1-10 matrix revealed light brown and blackish sediment aggregates, and scattered remains of reworked burnt plants and bone tissues (Polo-Díaz et al., 2016; Mora et al., 2020). These aggregates indicate surface exposure, but with distinctive features suggesting an anthropogenic origin and very little evidence of syn-/post-depositional processes (Polo-Díaz et al., 2016; Mora et al., 2020). For the EUP level of 497D, four dates have been obtained from charcoal via ^{14}C accelerator mass spectrometry (AMS)-ABA (acid-base-acid), which provided a range of 38–36 ka cal BP; with ^{14}C AMS-ABOx (acid-base-oxidation), the same sample was dated to 39–38 ka cal BP (Martínez-Moreno et al., 2019) (Table 1). This sample was treated with several protocols and older dates were obtained when more aggressive purification methods were applied. These differences highlight the need to note variables such as the protocol used for sample purification, especially in such limited chronological ranges, because they directly affect discussions of the chronometry of the Middle to Upper Paleolithic transition (Higham et al., 2014; Marín-Arroyo et al., 2018; Fewlass et al., 2020; Devièse et al., 2021).

Level 497D contains a large assemblage of lithics, bones and ornaments, as well as 10 combustion structures and three ash accumulations that have been interpreted as reflecting hearth waste management (Mora et al., 2020). The lithic assemblage is composed of cores, flakes, blades, bladelets and retouched pieces. The use of hard hammer percussion and the low occurrence of core management actions have been interpreted as technical decisions that created accidents and the abandonment of the core (Martínez-Moreno et al., 2019). Furthermore, these characteristics and the low quality of the raw material may be related to the abundance of transverse broken blanks in the lithic assemblage (Martínez-Moreno et al., 2019). The retouched pieces include backed points, apical fragments of laminar blanks, backed bladelets, points, sidescrapers, burins, retouched blades, denticulate tools and notches in flakes. It is important to highlight that there is a disproportionate number of bladelets compared to the low number of bladelet cores, which has been interpreted as indicating that bladelets were obtained from the same cores as other blanks (Martínez-Moreno et al., 2019). The production of blades and bladelets in Cova Gran appears to be interspersed with the production of regular flakes, as has been observed in the refitting sequences (Martínez-Moreno et al., 2019). However, this could also align with the fact that the bladelets had been configured elsewhere and imported to the site for specific tasks, as confirmed by the raw material (Mora et al., 2020). The lithic assemblage documented in 497D of Cova Gran has characteristics that do not allow it to be placed within the main technical traditions attributed to the Early Upper Paleolithic. The number of blade/bladelets is low, while there is a predominance of flakes. Among the retouched tools, end scrapers, burins and retouched blades are identified. Some straight bladelets and retouched points are also identified, but not specific cores to obtain Dufour bladelets characteristic of the Protoaurignacian, nor carinated scrapers to obtain Roc de Combe bladelets characteristic of the Early Aurignacian. The most common retouched tool types are side scrapers and denticulates. On the other hand, the reduction system does not follow the technical parameters described for blade production systems defined for the Protoaurignacian and Early Aurignacian technocomplexes (Bon, 2002; Zilhão, 2009). Technology and refitting analyses (Martínez-Moreno et al., 2019) have allowed the identification of some technical features similar to those observed in the Châtelperronian (Roussel et al., 2016). However, the lack of specific diagnostic elements, such as Châtelperronian points, prevents us from assigning this

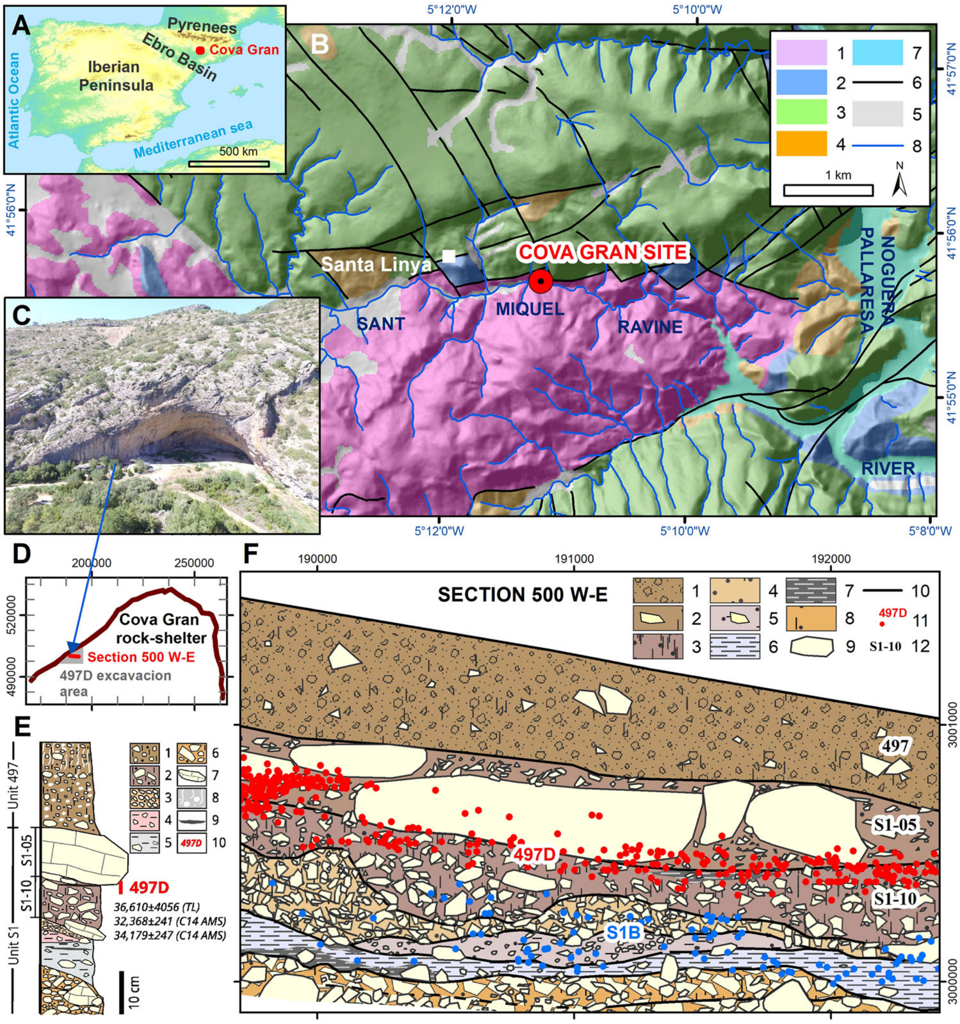

Figure 1. Location and stratigraphy of the Cova Gran 497D archaeological level (after Benito-Calvo et al., 2009, Mora et al., 2011 and Polo-Díaz et al., 2016). (A) General location. (B) Geological situation. Legend: 1: Triassic; 2: Jurassic; 3: Cretaceous; 4: Tertiary; 5: Quaternary; 6: faults; 7: reservoir; 8: drainage network. (C) Aerial view Cova Gran rock-shelter. (D) Rock shelter plan view and position of section 500 W–E in the 497D excavation area of the Cova Gran site (grid in mm). (E) Stratigraphic section 500 W–E showing the distribution of the 497D archaeological remains (grid in mm). Legend: 1: breccia-conglomerate with abundant matrix; 2: breakdown breccia; 3: heterometric clast-supported breccia; 4: breccia with scarce matrix and subrounded clasts; 5: reworked ashes and clasts; 6: ash accumulation; 7: sediments rich in charred remains; 8: clast-supported breccias with scarce matrix; 9: limestone boulders and clasts; 10: bedding; 11: archaeological artifacts; 12: stratigraphic layers. (F) General stratigraphic column of the Ramp area showing the chronology of Level 497D (a BP). Legend: 1: breccia-conglomerate with abundant matrix; 2: heterometric clast-supported breccia; 3: breccia including scarce matrix and subrounded clasts; 4: reworked ashes; 5: ash accumulation; 6: clast-supported breccias with scarce matrix; 7: limestone boulders and clasts; 8: pedogenic carbonates; 9: sediments rich in charred remains; 10: archaeological artifacts of 497D. [Color figure can be viewed at wileyonlinelibrary.com]

Table 1. ^{14}C AMS results of the dated charcoal samples from Level 497D of Cova Gran.

Sample	Protocol purification*	Lab. ID	Age, BP	σ	Age, cal a BP 2σ
497D-50	AAA	Beta-207578	32 630	450	38 155–35 784
497D-49	A	AA 68834	32 368	241	36 891–35 685
497D-49	ABA	AA 68834	33 068	261	38 167–36 431
497D-49	ABOx	AA 68834	34 179	247	39 337–38 134

*A, acid only; AAA, acid-alkaline-acid; ABA, acid-base-acid; ABOx, acid-base-oxidation.

lithic assemblage to the Châtelperronian. These attributes make it difficult to ascribe Cova Gran to a specific technocomplex described for the beginning of the Early Upper Paleolithic in Western Europe (Martínez-Moreno et al., 2010, 2019).

Regarding the bone assemblage, the preservation of bones is poor and only a small number of identifiable bones have been recovered, but it was possible to determine the presence of *Cervus elaphus*, *Bos/Bison*, *Capra pyrenaica*, *Stephanorhinus hemitoechus*, *Equus ferus*, *Vulpes vulpes*, *Oryctolagus cuniculus* and *Aves* sp. (Mora et al., 2020; Samper Carro et al., 2020).

Materials and methods

The CG database, and specifically Level 497D, is large. All objects larger than 1 cm have been recorded by total station with respect to a local coordinate system (Mora et al., 2014;

Roy Sunyer et al., 2014, 2015; Sánchez-Martínez et al., 2021). The smallest pieces were recovered in a variable circular area of about 0.25 m. In this case, we have generated randomly estimated coordinates for each of these pieces considering a circular area with a radius of 0.25 m. The central point is that of the excavated area where these objects were collected and was registered by total station. This method has proved useful and has been tested on several sites with good results (Rios-Garaizar 2012; Blasco et al., 2016; Sánchez-Romero et al., 2020, 2022). Thus, the number of objects has increased considerably (see Supplementary Information section SI1). In the case of lithic artifacts, the number of recorded objects (*XYZ*) was 5107, while the number of artifacts with random *XY* coordinates was 3892. In total, we worked with a total record of 8999 lithic artifacts. For fauna, only 738 items with *XYZ* coordinates were recorded, due to the poor preservation of these materials, although the number of bones smaller than 1 cm amounted to 5220. The high fragmentation of bones means that these data are considered but treated with caution, so this variable has only been studied for kernel density estimation (KDE) and always with reference to the coordinated and non-coordinated elements in each of the cluster analyses. Due to the high fragmentation and poor preservation of bones, the small sample size with anthropogenic modifications (Samper Carro et al., 2020) has not been considered for spatial analysis, since it would not have provided any relevant information. In addition to lithic industry and fauna, we studied other variables, such as ornaments ($n = 42$), charcoal ($n = 135$), ash accumulations ($n = 3$) and 10 hearths identified in 497D (Mora et al., 2020).

Identification and analysis of the distribution patterns was conducted by different methods. First, we analyzed the general distribution of the main variables (lithics and fauna) using the average nearest neighborhood (ANN) and Global Moran's *I*, which was only applied to lithic artifacts to infer its distribution according to the length variable. ANN statistics test whether the materials are dispersed, clustered or randomly distributed, while Global Moran's *I* measures the spatial correlation by considering the location of the features (objects) and their values (Sánchez-Romero et al., 2021). With both tests we can understand the distribution pattern and, from that information, consider the rest of the analysis. In both cases, we obtained a clustered distribution. We then applied KDE (Silverman, 1986) to estimate the maximum and minimum areas of the concentration of objects. In the case of 497D, we performed KDE to lithics, fauna and charcoal remains with a search radius of 0.5 m due to the characteristics of the area, type of distribution and number of objects. We also applied the Jenks method (Jenks, 1967) to maximize the differences between the classes previously identified by KDE and therefore evaluate the differences between the data and the accumulations (Sánchez-Romero et al., 2016, 2020, 2021; De la Torre and Wehr, 2018). In addition to ANN and Global Moran's *I*, we applied the two-tailed *t* test to evaluate the differences and statistical significance detected in the groups identified and classified by Getis–Ord Gi*, as well as the chi-square statistical test (Pearson, 1900; Simek and Leslie, 1983) and standardized Pearson residual (Montgomery et al., 2012) to examine whether these size differences were related or conditioned by the typology of the lithics in each group. We evaluated the fabric shape of the recorded lithic artifacts, with the aim of evaluating any anthropogenic or natural selection processes during the formation of the accumulations. For that, we applied ternary diagrams of the representation of fabric shape data (Sneed and Folk, 1958; Benn and Ballantyne, 1993; Benn, 1994; Bertran and Texier, 1995; Ringrose and Benn, 1997) using length, width and thickness data of the lithics. Additionally, we analyzed the possible disturbance of the assemblage by calculating the size-class distribution of the lithic artifacts (Bertran et al., 2012; De la Torre et al., 2017; Jia et al., 2019).

Once KDE was performed, detailed analyses of the accumulation patterns using inferential statistics were carried out by applying the Getis–Ord Gi* test (Getis and Ord, 1992). This enabled us to identify statistically significant accumulations of high (hotspots) or low (coldspots) values of the chosen quantitative variable (Getis and Ord, 1992; Siabato and Guzmán-Manrique, 2019; Mora et al., 2020; Sánchez-Romero et al., 2021, 2023). In this case, we applied Getis–Ord Gi* according to two variables. The first was the number of items in each quadrant. We created a grid or fishnet considering the number of objects and the area of the site, based on the Quadrat Method proposed by Getis (1964). In this way, accumulations can be identified in a more precise and delimited way, especially in areas with a higher concentration of materials. These results were then crossed with the results obtained with KDE. By combining the two methods, the areas of greatest concentration can be analyzed and correlated with other variables and features, such as hearths. The distance band parameter was 153 mm, the same as that calculated for the length of the sides of each quadrat. Second, Getis–Ord Gi* was applied to the length variable of the lithic artifacts to evaluate the possible sorting of pieces by size and to interpret the anthropogenic or natural processes involved in their accumulation. It was only possible to perform this analysis on lithics, because the fauna sample size containing this information was too small. The distance band applied in this case was 973.78 mm.

Finally, we have included refits in the spatial analysis. Plotting of all the refitted artifacts and connection lines was performed using the Refits extension for ArcMap developed by CEPAP-UAB. This generates a graph which was then converted into a shapefile. This gave us 3D information about the distribution of the refits (Fig. 2), considering the extent and characteristics of the deposit, as well as the position of the limestone boulders. The assemblage of refitted artifacts comprises 538 refitted pieces (12.08% of artifacts with *XYZ* data and without considering the smallest flakes or debris) and 269 connection lines, which were measured. Orientation patterns were then able to be calculated (De la Torre et al., 2019; Sánchez-Romero et al., 2023). Several types of refits were identified, with the most common being transverse fractures ($n = 232$), followed by dorsal–ventral and core-product refitting sequences (see section SI7; Table S8, Figs. S18–S24).

Results

KDE analysis shows greater accumulations of lithic objects towards the west and center of the excavated area. On the one hand, the main lithic accumulation detected by KDE is located between hearths H4 and H2 (Fig. 3) and comprises a total of 2422 lithic artifacts (see Supplementary Information section SI3). On the other, there is another concentration located near the main one, but around hearths H4 and H10; another concentration coinciding with H14, H13 and the ashes of H16; and an additional concentration between H7 and the large limestone block located at the outer part of the excavated area (Fig. 3; Fig. S11).

It is remarkable that most of the fauna remains are found on the opposite side, where the main lithic accumulation is identified (Fig. 3; section SI4). In some areas, lithic and fauna concentrations coincide, such as at the north of the site, but the faunal remains are mainly distributed in the center and east of the excavated area. The main concentrations (considering

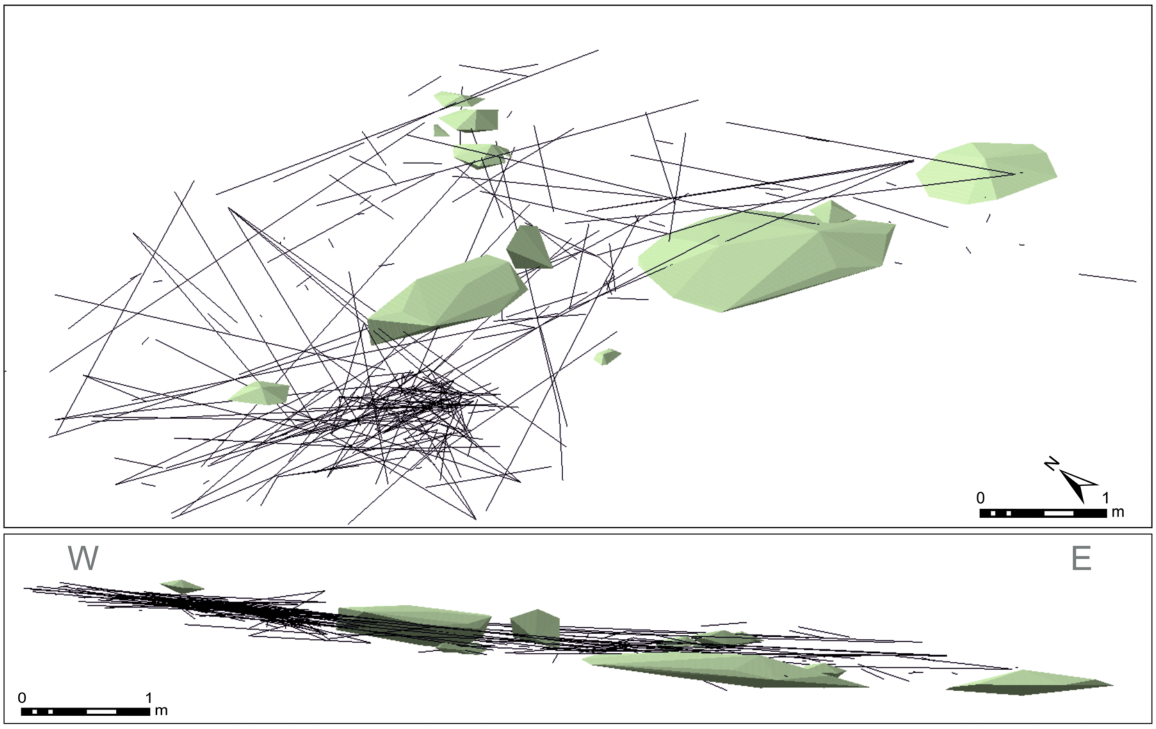

Figure 2. 3D plots of the refitting sequences of the lithic assemblage of Level 497D of Cova Gran. In green: limestone boulders. [Color figure can be viewed at wileyonlinelibrary.com]

the same values as those considered for lithics) are one very large and two smaller concentrations (Fig. 3; Fig. S12). However, the largest contains several accumulations that are worth highlighting. One is located to the NW of the site, between a large limestone block and the wall of the rock shelter; another between H14 and H19; one coincides with H13 and the ashes of H16 and H11; and another is located further to the east of the study area and in clear relation to the hearth H8 (Fig. 3; Fig. S12). The smaller concentrations of fauna identified by KDE are found near hearth H10 and in the outer area, very close to the large limestone block (Fig. 3). A detailed description of these clusters and the composition of each of them can be found in Supplementary Information section SI4.

Density analysis of the recorded charcoal remains (Fig. 3) did not reach solid conclusions regarding the spatial distribution due to the small sample size ($n = 135$). However, the main concentrations of charcoal do not coincide with the position of hearths. The only possible relationship is with H2, where the spatial distribution seems to suggest that charcoal may have been displaced from that hearth due to small inputs of water (such as rain, as these remains are small and light), the slope of the deposit or trampling. Regarding the other concentrations of charcoal, they could be caused by natural agents or by very ephemeral combustion or accumulations of burnt material, but no evidence of burnt sediment has been found in the substrate. However, the sample size of the charcoal is still too small to reach any conclusions.

Regarding the ornaments ($n = 42$), the distribution is well delimited towards the half-west zone of the excavated area (section SI2), clearly associated with the hearths, especially between H10 and H17, and the wall, partially coinciding with the concentration of fauna identified by KDE.

In addition to the KDE analysis, and according to the results obtained with ANN and Global Moran's *I* (Table S5) that indicate a clearly clustered pattern, Getis–Ord Gi* analysis applied to the number of items in each quadrat provided detailed and accurate information about the identification of accumulations (Fig. 4). This type of analysis is based on inferential statistics, so its combination with the data provided by KDE resulted in a useful, precise method to identify and analyze the main concentrations of lithics and bones. In the case of lithics, the objects were mainly concentrated where hearth H4 is located, between hearths H4 and H2, but also with hotspots with 99% confidence from H4 towards hearth H10. Another statistically significant hotspot cluster, where H14, H13, part of H9 and the ashes of H16 are located, was also identified by KDE. Getis–Ord Gi* also detected the hotspot cluster between H7 and the large limestone block identified by KDE, but with greater precision in its delimitation. A detailed description of and a table detailing the clusters identified by KDE in the lithic assemblage can be found in Supplementary Information section SI3.

In the case of fauna, Getis–Ord Gi* is more precise, although all objects are clearly distributed and accumulated towards the center and east of the site. The hotspots of bone accumulation detected by KDE are identified as clusters with 99% confidence by Getis–Ord Gi* (Fig. 4). All were found near a hearth or an ash accumulation, except in the case of the hotspot cluster attached to the large limestone block, which is clearly associated with the block.

The application of Getis–Ord Gi* to the length variable (lithics) shows several cluster hotspots (high values) and coldspots (low values). Some of the identified accumulations comprise just a few objects, so were not considered statistically significant and hence excluded from the study. The main clusters are three hotspots (HL1 with 99% statistical confidence, and HL1A and HL1B with 95% statistical confidence) and two coldspots (CL1 and CL2, both with 99% statistical confidence) (Fig. 5). All are clearly associated with hearths, except for one of the coldspots (CL2), which is clearly related to the large limestone block located in the outer part of the rock shelter (Fig. 5 and section SI5). A detailed description of and tables (Tables S6 and S7) detailing the clusters identified by Getis–Ord Gi* according to the length variable can be found in Supplementary Information section SI5.

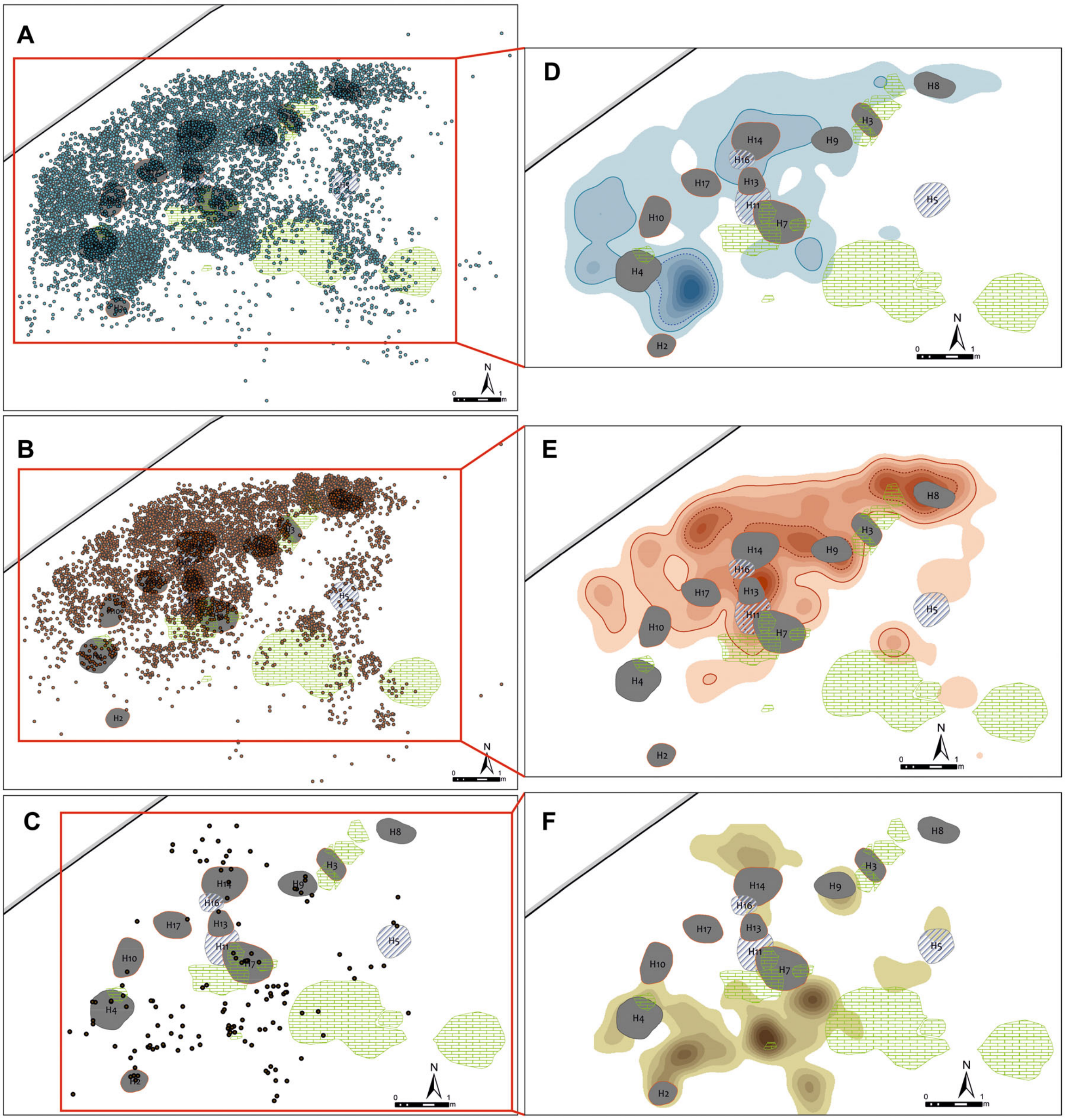

Figure 3. Distribution of all lithics (A), all bones (B) and charcoal (C). Kernel density estimation (KDE) of lithics (D), bones (E) and charcoal (F). The pit-hearths are outlined with orange lines and ash accumulations are marked with a striped pattern. [Color figure can be viewed at wileyonlinelibrary.com]

These clusters were analyzed to determine their statistical significance, in both the size and composition of the clusters (see section SI5). The reason behind analyzing the statistical significance, based not only on the results obtained by the Getis–Ord Gi* statistic, is that the differences detected by the statistics may be less significant from the point of view of data interpretation, so the data must be analyzed more thoroughly. In the case of the length variable, a two-tailed *t* test was carried out to determine if there was significant evidence between the sizes detected by the Getis–Ord Gi* statistics. In all cases, the results showed that the *p*-value was less than 0.05 (95% statistical confidence) and therefore the null hypothesis was rejected. Getis–Ord Gi* detected differences that allowed for the detection of statistically significant sets of data according to their length, and the results were confirmed by this. Additionally, a chi-square test was applied to check whether these size differences detected were related or conditioned by the type of lithic artifact in each group. In all cases it responded to random patterns and no significant differences were noted that would indicate a dependence on the data. Therefore, although size differences were detected, located and analyzed, they did not respond to factors that might indicate artifact selection or significant groupings of certain tools, but rather responded to random patterns.

The analysis of refits indicates that most are in the area where the main concentration of lithic remains was detected, both by KDE and Getis–Ord Gi* – an approximate area of 3.21 m^2 between hearths H4 and H2 (Fig. 6). Of the 269 connection lines of the 538 refitted pieces, 195 are less than 1 m in length (72.5%) (and therefore less than 1 m distance between the refitted pieces) (Fig. 6; Table 2). The minimum distance between refits is 0.012 m, while the maximum distance reaches almost 5 m. The average distance of all the refitting lines is less than 1 m (0.855 m). Of the 72.5% of connections of less than 1 m, 42.75% ($n = 115$) are located in the area of maximum concentration of lithic industry (Fig. 6; Table 3). This zone comprises 63.2% ($n = 170$) of the refitting sequences with a maximum distance of 2 m, with 21.56% less than 0.5 m and 42.38% less than 1 m (Table 3).

Analysis of the orientation patterns of the refitting sequences shows no clear preferred orientations (Fig. 7; see also

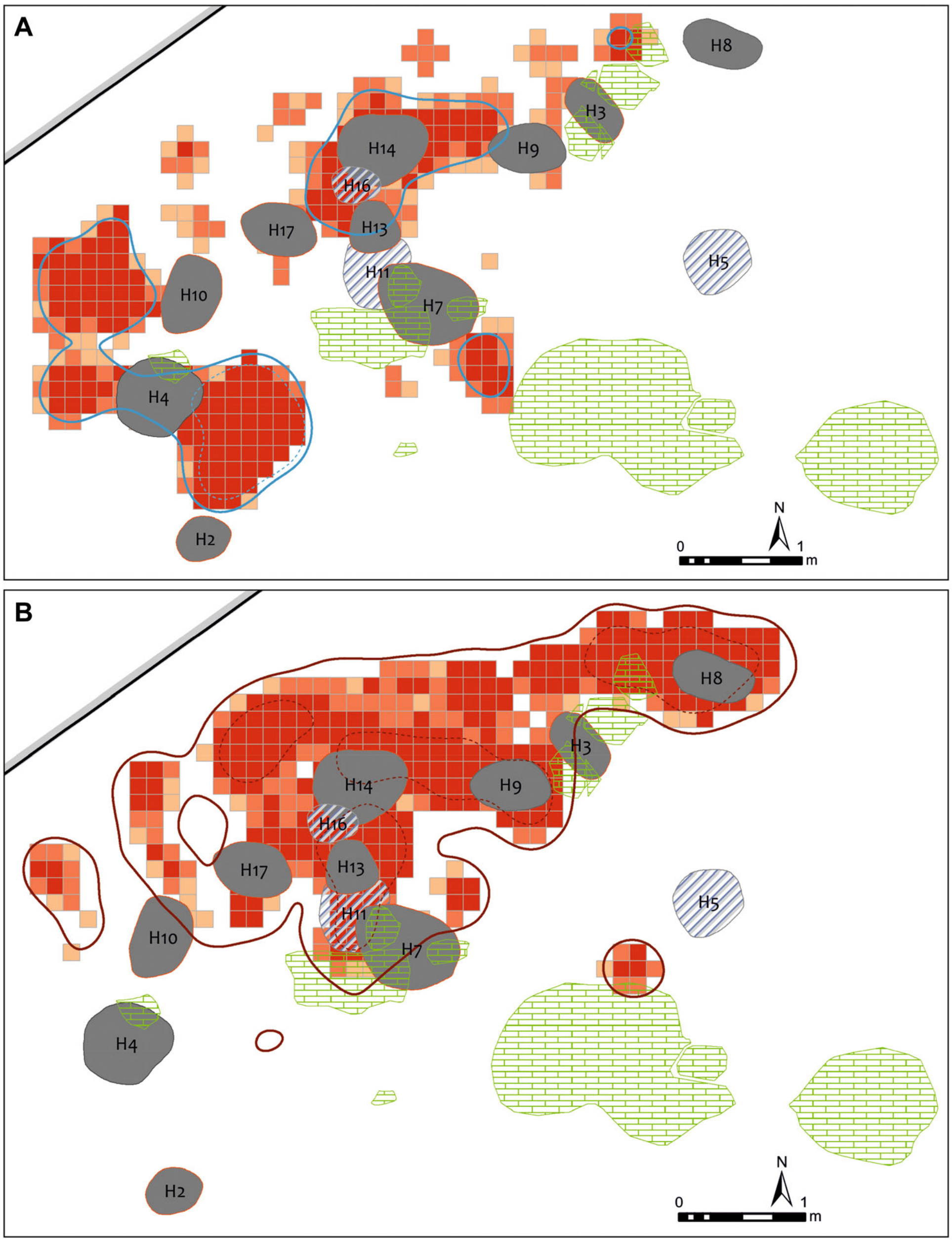

Figure 4. (A) Hotspot clusters identified by Getis–Ord Gi* in the lithic assemblage of Level 497D according to the number of objects included in each square (quadrat method). KDE lines are superimposed on the Getis–Ord Gi* analysis. (B) Hotspot clusters identified by Getis–Ord Gi* in the bone assemblage of Level 497D according to the number of objects included in each square (quadrat method). KDE lines are superimposed on the Getis–Ord Gi* analysis. The pit-hearths are outlined with orange lines and ash accumulations with a striped pattern. [Color figure can be viewed at wileyonlinelibrary.com]

section SI7), with histograms and statistical analysis indicating a clearly random pattern. Most of the refitting lines go from the main lithic concentration area towards different directions, especially to the areas where the maximum concentration of fauna is observed. The mean vector of all refitting lines points to 35.69° (Fig. 7; Table 4), indicating a dominant trend towards the area where the main accumulations of fauna are located; this is similar to the main vector obtained for the refitting lines of less than 0.5 m. In general, as can be seen in the histograms and statistical values (Fig. 7; Table 4), the orientation pattern shown by lines up to 1 m is predominantly random. However, a change in trend is observed with the longer refitting lines, indicating a predominant trend towards the west and east. In the case of the lines between 1 and 2 m, they are directed mainly towards the area of main accumulation of lithics and refitting sequences, while the refitting lines longer than 2 m clearly point to the SSE, towards the area where concentrations RMU-B and RMU-SLL3 were identified (Mora et al., 2020). These lines seem to correspond to different patterns, in which the movements appear to be more limited to this specific area of the site, connecting the areas of fauna accumulation located around the large limestone block. Some of these lines connect with the main areas of fauna concentration, while very few refitting lines connect with the main area of lithic accumulation.

Discussion

Level 497D of Cova Gran is mainly formed by the accumulation of gravitational debris coming from the spalling and rockfall of the wall and ceiling of the rock shelter (Benito-Calvo et al., 2009, Mora et al., 2011). In this area, vertical movements related to gravitational processes dominated the sedimentation, but 497D was preserved from fluvial erosion of

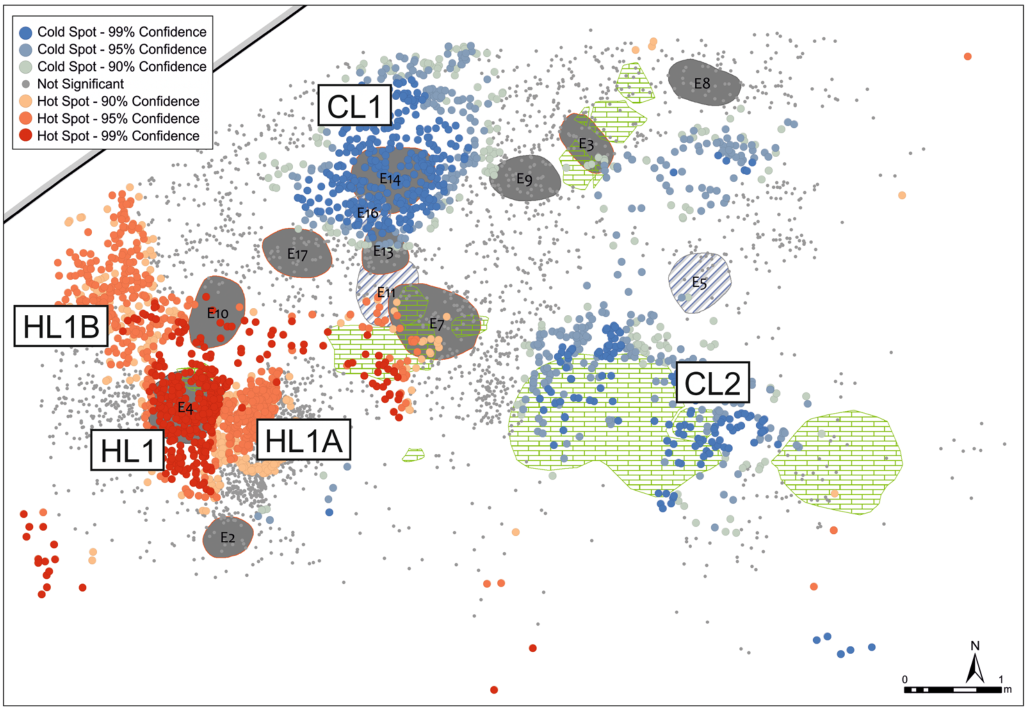

Figure 5. Map of the hotspot and coldspot clusters identified by Getis–Ord Gi* according to the length variable for lithic artifacts. [Color figure can be viewed at wileyonlinelibrary.com]

the Sant Miquel stream by two large limestone boulders (Benito-Calvo et al., 2009) (Fig. 1). Level 497D was documented between two clast-supported breccia layers (Polo-Díaz et al., 2016; Fig. 1E and F), the upper containing boulders related to breakdown of the rock shelter ceiling and therefore sealing and protecting the integrity of the level from lateral processes due to water flow. Previous orientation and dip analysis of lithics defined a planar fabric with no preferred orientation, but with a higher degree of isotropy than the natural sedimentary subangular clasts contained in the breccia layers (Benito-Calvo et al., 2009; Roy Sunyer et al., 2014). The higher degree of isotropy could be due to human activities in rough ground during accumulation of Level 497D, although some activities such as trampling could not replicate that fabric through experimentation (Benito-Calvo & Martínez-Moreno, Mora, et al., 2011). The integrity of this level has been shown by micromorphological analysis that revealed anthropogenic aggregates and *in situ* combustion residues associated with the Early Upper Paleolithic artefacts (Polo-Díaz et al., 2016), indicating that human activity was not subject to relevant post-depositional disturbance. Additionally, the presence of small–very small objects, both lithic artifacts and fauna, and the results obtained in the ternary diagram (see section SI6), show that there was no selection of items by size, shape and/or volume. These results were confirmed by analysis of lithic size-classes, as no evidence of particle size sorting was detected, but there was strong evidence of a well-preserved assemblage supported by other features, such as sedimentary features, fabric shape, spatial distribution or refitting analysis (Bertran et al., 2012). We detected no spatial patterns explained by post-depositional processes affecting the assemblage, because: (i) there is no disappearance of smaller objects, and/or (ii) there is no disappearance of compacted remains that may have rolled away from the assemblage and/or accumulated elsewhere, as favored by the slope and characteristics of the deposit. Furthermore, although the archaeological characteristics of the 497D assemblage indicate that it was formed during repeated visits to the site (Mora et al., 2020), the assemblage was not exposed for a long period of time, it was buried relatively quickly. Otherwise, these spatial relationships and its integrity would not have been preserved with this resolution, because it would have been affected by post-depositional natural or anthropogenic processes that would have displaced the artifacts away and 'broken' the spatial pattern schemes observed throughout the level. We discuss this further below.

The excavation and documentation of this level with a rigorous data recording system has allowed us to obtain significant information from all the excavated objects. We were therefore able to work with detailed information on lithic artifacts, hearths, refitting sequences and fauna, although with less resolution in the fauna due to preservation problems. The spatial analysis of 497D shows that there are several differentiated areas of accumulation of lithic artifacts and bones. The main KDE lithic accumulation (L1A) contains barely any faunal remains and non-identifiable lithics (non-coordinated), but there are many medium–small flakes and identifiable objects larger than 1 cm (section SI3). Also, this spot is where most of the refits are concentrated. All the identified lithic clusters are associated with hearths, with some of them overlapping. In all lithic concentrations, there is a predominance of coordinated objects, except in KDE cluster L2 where there are more small remains (coinciding with the coldspot cluster CL1) and fauna predominates the lithics (see section SI3, Fig. S11, Table S1). This cluster is located at the fauna concentration, clearly differentiated and on the opposite side of the site where the main accumulation of lithic artifacts was noted. The fauna accumulation indicates a clear predominance of small–very small remains, with 4398 of non-coordinated compared to 443 coordinated remains (larger than 2 cm). Except for the KDE F1B cluster (see section SI4, Fig. S12), all clusters are associated with hearths.

KDE lithic clusters L1, L1A and L2 are located in relation to hearths and ash accumulations (see section SI3 and Fig. S11). In the case of bones, except in the case of KDE bone cluster F1B (see section SI4 and Fig. S12), all clusters are also associated with hearths, especially between H4 and H10, with a distance of 0.25 m between them. The distance between H4

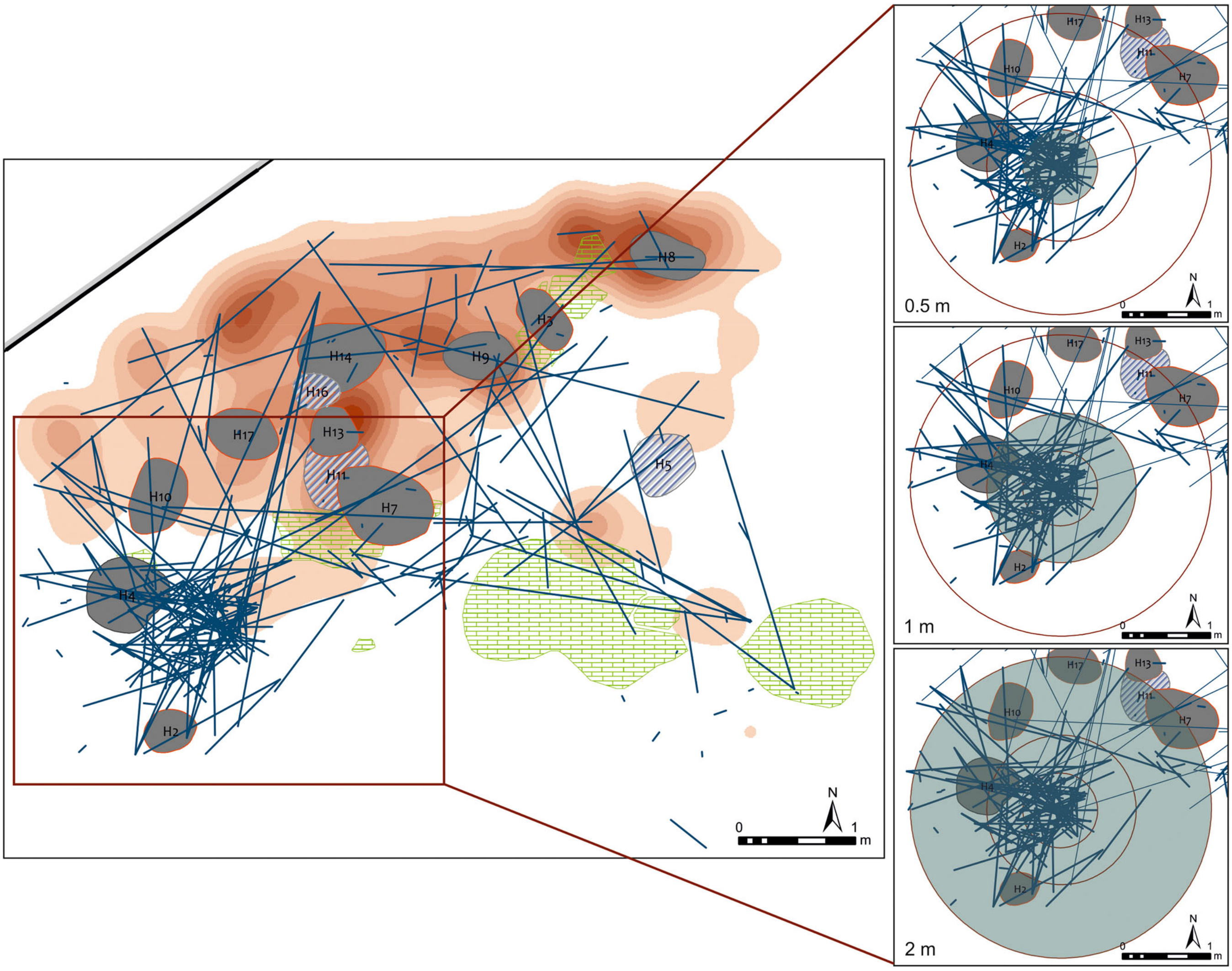

Figure 6. All 497D refitting lines and the different radii (0.5, 1 and 2 m) used to calculate the number of refits within the maximum area of accumulation of refits and lithic artifacts. [Color figure can be viewed at wileyonlinelibrary.com]

Table 2. Number of refitting lines for each distance section (from 0.5 m to more than 3 m) and the percentage they represent in the entire set of refits identified in Level 497D of Cova Gran.

	n	%
<0.5	134	49.81
0.5–1	61	22.68
1–2	46	17.10
2–3	12	4.46
>3	16	5.95
Total	269	100.00
Min.	0.012	
Max.	4.811	

Table 3. Number of refits for each distance section of the marked radius (from 0.5 m to 2 m) in the area with the highest concentration of refits and lithic artifacts, and the percentage they represent in the total of the assemblage.

Radius	*n*	%
<0.5	58	21.56
< 1	114	42.38
<2	170	63.20
Total refitting lines Level 497D	269	100

and H2 is less than 1 m. Two of these features are pit-hearths and only one is flat (H4), being aligned and in clear relation to the large accumulation of lithics and refits. This small distance between hearths and its possible implication was addressed at the Castanet site (France), where three rock-cut hearths were identified (White et al., 2017), which, according to the studies carried out, were interpreted as having been used simultaneously. Magnetic susceptibility analysis showed the function of each: one was used as a central hearth, another as an area of potential ash dump and the last as a special-purpose area where hot embers were moved, probably to control the heat (White et al., 2017; Clark and Ranlett, 2022). The site of Hohle-Fels (Germany) also contained several features in the transitional levels from Middle to Upper Paleolithic. Studies of micromorphology and fabric analysis on thin section slides allowed the identification and discrimination between dumped features and controlled hearths where bones were used as fuel (Schiegl et al., 2003; Gabucio et al., 2014; Marcazzan et al., 2022a). In Grotta di Fumane (Italy), Late Mousterian (A11–A4), Uluzzian (A3) and Early Aurignacian (A2) levels also contain several flat and pit-hearths for each level, some in clear relation to large limestone blocks (Peresani et al., 2016; Marcazzan et al., 2022b), and where the diverse functionality of these hearths was identified (Marcazzan et al., 2022b).

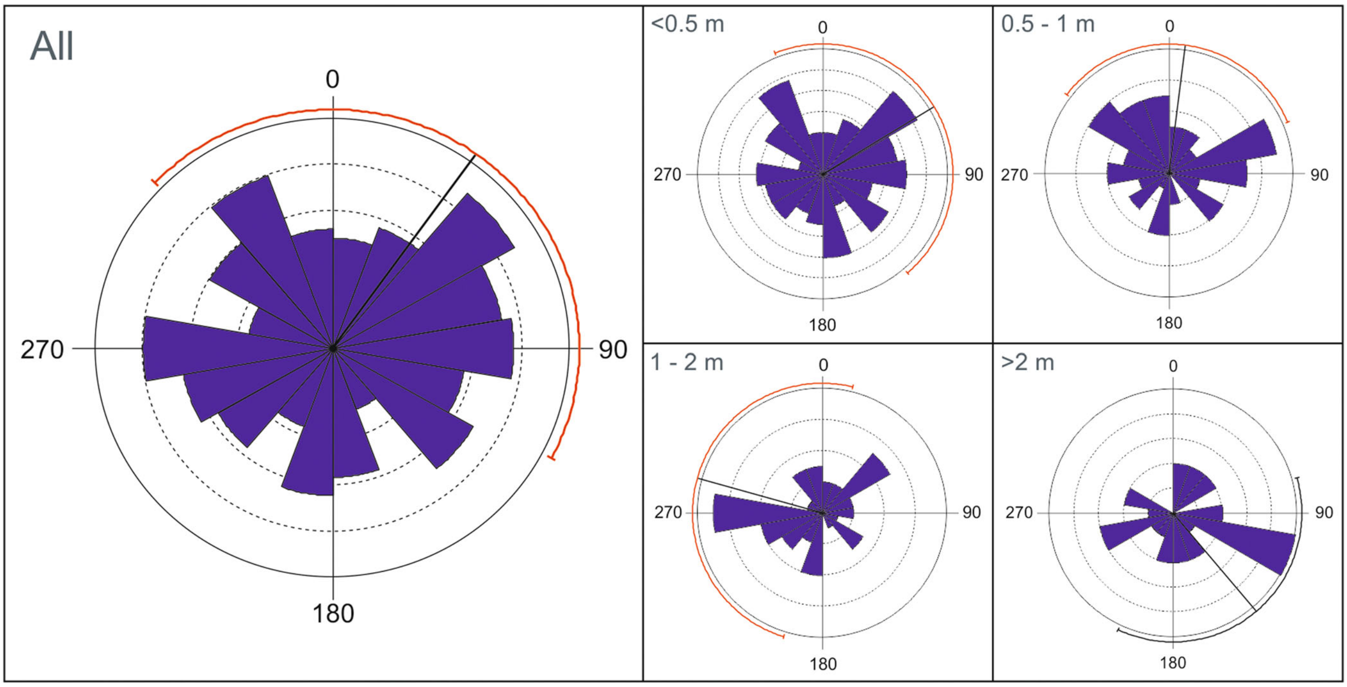

Figure 7. Circular histograms of all refitting sequences and those classified according to the distance separating each of the refitted items (length of the refitting lines): less than 0.5 m, between 0.5 and 1 m, between 1 and 2 m, and more than 2 m. [Color figure can be viewed at wileyonlinelibrary.com]

Table 4. Dispersion parameters and circular statistics of the orientation of the refitting sequences according to the length of the refitting lines (all, less than 0.5 m, between 0.5 and 1 m, between 1 and 2 m, and more than 2 m).

	All	<0.5 m	0.5–1 m	1–2 m	>2 m
Number of observations	269	134	61	46	28
Group width (and number of groups)					
Mean vector (μ)	35.693°	58.908°	7.088°	285.504°	139.722°
Length of mean vector (*r*)	0.059	0.085	0.169	0.132	0.226
Concentration	0.119	0.171	0.343	0.267	0.464
Circular variance	0.941	0.915	0.831	0.868	0.774
Circular standard deviation	136.251°	127.161°	108.025°	115.271°	98.793°
One sample tests					
Rayleigh test (*Z*)	0.941	0.973	1.744	0.803	1.432
Rayleigh test (*p*)	0.39	0.378	0.175	0.45	0.241
Kuiper's test (uniform, *V*)	1.231	1.15	1.379	1.32	1.311
Kuiper's test (*p*)	>0.15	>0.15	>0.15	>0.15	>0.15

Ethnographic and archaeological studies (Gamble, 1986) noted a regular distance of 3 m between hearths, although other studies showed a regular pattern in hearth spacing (Henry, 2012). For example, in the Aurignacian site of Regismont-le-Haut (Bon, 2002), nine hearths were found, with a distance between them that allows us to consider the models observed in ethnographic examples. Most of these features are separated by several meters and distributed throughout the site, each a regular size. As has been observed in several sites with combustion features, the distances, size and location of hearths depend on the related activities; small hearths would emit small amounts of smoke and their proximity to the back wall would force the smoke to ascend and flow out (Kedar and Barkai, 2019). However, this applies mostly to caves because, in the case of open rock shelters, smoke from hearths close to the entrance would probably flow out due to the wide opening (Kedar and Barkai, 2019). Archaeological evidence seems to suggest that ethnographic rules do not always apply, and some features can be used at the same time for different purposes. They can also be difficult to distinguish when there were several occupations and some of the features overlap. This is the case with Cova Gran, where 10 hearths and three ash accumulations have been identified; some of these hearths are located very close to each other (as in the case of H14, H13, H17 and H7, H9 and H3, or H4 and H10). However, this proximity between features has not been linked to contemporary or simultaneous use, but rather to several episodes of occupation of the rock shelter (Mora et al., 2020) that have resulted in a distribution pattern of hearths very close to each other. These human groups occupied the available space offered by the rock shelter and that is protected from climatic inferences, resulting in the repeated occupation of the same area. Nevertheless, the idea of structures closer together due to simultaneous use cannot be ruled out, as ash accumulations or smaller pit-hearths may reflect maintenance activities to control heat or ash dumping.

In this way, not only in the KDE lithic accumulations of L1, L1A and L2 is the pattern of aligned hearths found in relation to clusters of lithics (Fig. S11), but also in other parts of the site. Hearths H14, H13 and H7, together with the associated ash accumulations, are related to accumulations of small lithic remains and evident faunal accumulations, as can be seen in

KDE clusters F1C and F1A (Fig. S12). In the latter, bone accumulation is associated with pit-hearth H14 and the flat hearth H9. In this way, as that the lithic artifacts are associated with H14 and there is also an accumulation of fauna related to both features, it is possible that we are looking at two features that could have been used simultaneously, while KDE accumulation F1C could have been more related to hearth H14 and ash accumulations H16 and H11. Therefore, these accumulations and features may be more closely related to ash dump processes and cleaning (Schiffer, 1972, 1976; Schiegl et al., 2003; Miller et al., 2010; Mallol et al., 2013; Mentzer, 2014; Marcazzan et al., 2022a), with a mixture of ashes and bones separated and accumulated between the limestone blocks. On the other hand, feature H8 is flat and relates to an accumulation of fauna, located in a more separate area of the site. This dynamic of accumulations in clear association with flat and pit-hearths, and ash accumulations in different areas of the site, some more separated than others and some others in relation to limestone blocks, seems to indicate a wide variety of activities, the result of several occupations that established main hearths for the centralization of activities (Binford, 1983; Stevenson, 1991; Vaquero and Pastó, 2001; Vallverdú et al., 2010). Other features could have acted, as in the case of Castanet, as multi-purpose areas for the maintenance and control of the fire and ash dump. This variety of functions between the features would match the variety and mixture of flat and pit-hearths, ash accumulations and accumulations of objects that we find throughout the site. Magnetic susceptibility studies, such as those carried out at Castanet (White et al., 2017), or fabric analysis on thin-section slides in hearths (Mallol et al., 2013; Mentzer, 2014; Marcazzan et al., 2022a, 2022b) would shed more light on the functions and purposes of the different hearths found in Cova Gran.

Sleeping zones (e.g. Abric Romaní, Oscurusciuto or Abri Pataud) (Binford, 1983; Chiotti et al., 2003; Alperson-Afil et al., 2009; Marquer et al., 2010; Vallverdú et al., 2010; Higham et al., 2011; Hayden, 2012; Gabucio et al., 2017; Spagnolo et al., 2019; Bargalló et al., 2020) and the use of bones as fuel (e.g. Abri Pataud or Grotta di Fumane) (Théry-Parisot, 2002; Théry-Parisot et al., 2005; Villa et al., 2002; Cain, 2005; Marcazzan et al., 2022b) are aspects that have been widely discussed when considering the lifestyles and organization patterns during the Middle and Upper Paleolithic. In the case of bones used as fuel in 497D, we cannot separate which accumulations could respond to the bone exploitation activities themselves and which to the use of bones as fuel – many burned remains have been found, and they are so fragmented that making inferences between what is the product of a specific activity or its use as fuel is impossible. The high fragmentation and number of bones indicate abundant fauna at the site. However, the causes of the high fragmentation cannot be isolated or distinguished from an anthropogenic origin (i.e. specific activities, use of bones as fuel, exploitation of fauna) or the preservation of bones due to the characteristics of the deposit. It is probably due to a combination of both factors – human and natural – as the high number of fragments, their characteristic spatial distribution and their association with hearths seem to indicate. In relation to sleeping areas, we did not find sufficient evidence to indicate areas with such characteristics. Although there are hearths closer to the shelter wall, such as H17, H14 and H10, we do not see an absence of remains that point to a cleaner area with fewer remains that could suggest a resting area. The areas with a less significant number of artifacts are not close to the wall, but towards the outer part (such as between the large limestone block and hearth H2) (Fig. 8).

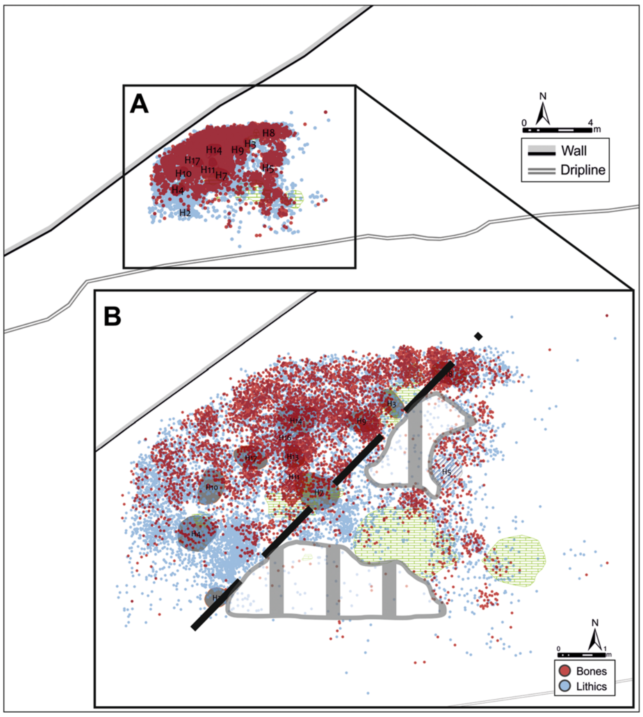

Figure 8. (A) General view of the bones and lithics of Level 497D of Cova Gran with the position of the wall and dripline of the rock shelter. (B) Map of the distribution of bones and lithics in 497D of Cova Gran where the emptier areas are observed (striped areas marked in gray), as well as the (dashed) line that seems to separate these outer areas from the rest of the site (inner) with a greater concentration of objects. [Color figure can be viewed at wileyonlinelibrary.com]

The empty space delimited between the limestone blocks and hearths H8, H3, H9 and H7, and the large limestone block located at the outer part of the rock shelter (Fig. 8) is ~3 m long and 1 m wide and contains very few artifacts (especially evident when only the bones are plotted). The same occurs with the clear delimitation of the main lithic accumulation to the east, on the opposite side to where hearth H4 is located (Fig. 8). The difference in density between these areas emptier of objects and the remaining areas with objects is clear, and the arrangement of blocks and hearths seems to mark a line of separation between the two areas. This was tested by applying Jenks' method to maximize the difference between them (Fig. 9). This difference between densities became even more evident and allowed us to verify the very straight line that delimited the two areas.

Level O of Abric Romaní provides an example where some hearths are outside of the dripline and others located at the entrance, near and between limestone blocks (Vallverdú et al., 2012). In Cova Gran, hearths H7, H9, H3 and H8 are clearly aligned with and between limestone blocks, but away from the dripline and, together with hearth H2, parallel to the wall of the rock shelter (Figs. 8 and 9). It is possible that the emptier zone identified in Level 497D of Cova Gran, being in an area further outside the rock shelter, is an area of passage from the activity zones to the outside of the rock shelter, and that this constant passage would have separated the remains that could have fallen to the sides.

The dripline is too far away (Fig. 8) to have affected this distribution of objects, so it does not seem to be related to these emptier spaces. Another possibility is that this is an area where no activities have taken place and that these activities occurred in the areas where the highest density of materials is observed. A combination of both options seems most plausible, because passing through this area would have

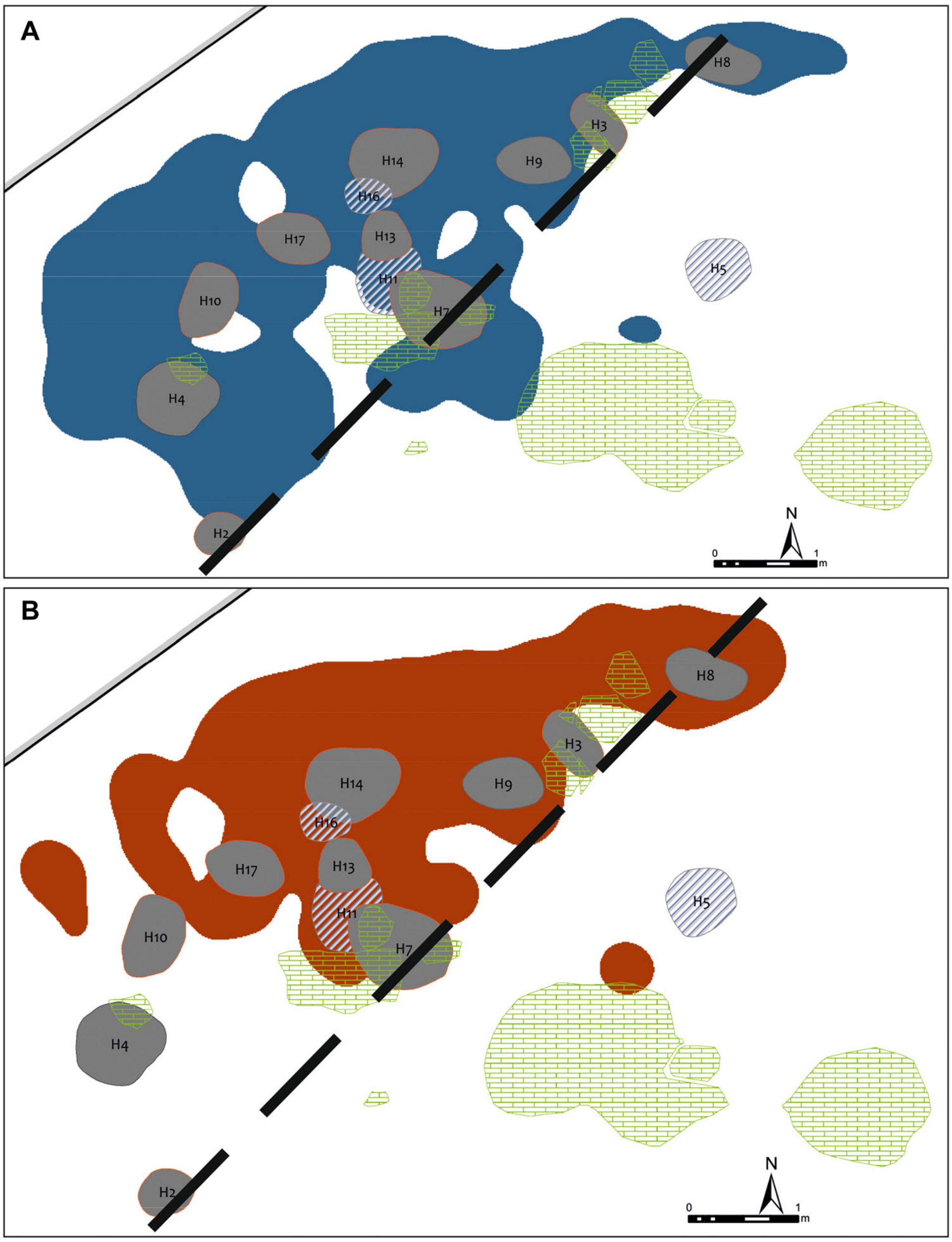

Figure 9. Jenks' method applied to KDE to verify the observations on the clear difference between densities between the outer and the inner part of the rock shelter. [Color figure can be viewed at wileyonlinelibrary.com]

moved the remains to the sides in a completely involuntary action, but would have generated this empty area pattern. Being a transit area, few activities would have been developed and they would have remained outside the main occupation zone. On the other hand, how would it be possible to distinguish one option from another in the data record if what defines one option from the other is intentionality? Sites such as Buhlen (Germany) show the presence of large rocks to secure the edges of a tent-like structure set up against the wall of the rock shelter and 'wall effect' (Hilbert and Fiedler, 1990; Stapert, 1990), observations mainly based on the distribution (and voids) of artifacts (Stapert, 1990; Bourguignon et al., 2002; Jaubert and Delagnes, 2007; Kuhn et al., 2009; Clark, 2023). The abrupt variations in densities have been explained by the so-called *structures latentes* (Leroi-Gourhan, 1950; Leroi-Gourhan and Brezillon, 1972), which define archaeological characteristics that can be inferred from the study of observable spatial distribution patterns (Sánchez-Romero et al., 2020). In the case of 497D, the distance between the line of blocks and hearths to the wall is about 3.5 m, and it is possible to observe a clear change in densities that could indicate the presence of some type of windbreak or hut in this precise location. However, we do not have sufficient evidence to confirm the presence of this type of structure beyond the arrangement of the blocks (which could have naturally acted as structuring elements of the space), hearths and the sharp change in densities between one area and another. Geology has not detected anything that indicates that it could be an alteration by the action of dripping from the roof of the shelter (the dripline is quite far from this area) or the effect of flowstones that could have cleared this area.

The concentration and pattern shown by the refitting sets point to a single major episode of knapping that generated such a well-defined concentration. The knapping process generates considerable waste and, if several episodes of knapping had occurred at this point of the site because of different groups or during different visits, it would be a great coincidence if this had occurred at exactly the same point, without, for example, each group having cleared the area of sharp flint from previous knapping activities. Spatial variations of the refitting sets are not seen in the surrounding area, but at exactly the same point. If time had passed between one episode and another, and if there had been several knapping episodes, we would not see such a fixed pattern and more dispersed patterns would be observed. The passage of other humans and animals, especially as this is an area with several hearths (elements that attract the attention of some animals, as studies carried out by Camarós et al., 2013 have shown), would have largely scattered these artifacts and the refitting aggregates. This is something we do not find in Level 497D of Cova Gran. The longest lines of refits clearly connect the main area of lithics with the area of fauna concentration, mostly associated with the hearths of this area. It is possible that there has been reuse of lithic artifacts from that main accumulation area of lithics, as we can see in more discrete groups of refits further from the main area (Fig. 10). One of the groups occurs in the area of the large limestone block located in the outermost area of the shelter (Fig. 10), where the main concentrations of raw materials RMU-B and RMU-SLL3 were identified (Mora et al., 2020), and where a concentration of fauna has also been highlighted by KDE and Getis–Ord Gi*; in this area, no other remarkable lithic concentrations have been identified. This seems to indicate a single event of exploitation of specific resources, where certain raw materials, including some bones, were knapped. This may correspond to another of the episodes of occupation of 497D CG that can be inferred from this high-resolution palimpsest.

The longer and more repeatedly a site is occupied, the greater the degree of outward movement, or 'centrifugal dispersion' (Kolen, 1999; Clark, 2017). Level 497D of Cova Gran shows evidence of having been repeatedly occupied and the movement of the objects is clearly of anthropogenic origin. The patterns of accumulation and distribution are always associated with the presence of hearths and discrete events, such as the reduction sequences observed in the main accumulation of lithics (and refits) within a radius of up to 1 m or the concentration of specific raw materials and bones on the outer part of the excavation area near the large limestone block. Another question involved in the 'centrifugal dispersion' relates to the fact that lithics can be picked up from knapping accumulations and moved around the site and reused (Kolen, 1999; Clark, 2017). This idea of reusing previously discarded artifacts or recycling is not ruled out (Mora et al., 2020). The definition of recycling implies the criteria of reusing or resharpening (functional change) but also the use of previously discarded artifacts (Vaquero et al., 2015). For example, Level M of Abric Romaní shows high concentrations of raw material units (RMUs) with long-distance connections of single artifacts separated from the rest of the objects that compose the RMUs (Vaquero et al., 2015), indicating that these long-distance connections are not random but the result of intentional displacements of these artifacts to other parts of the site. These long-distance refitting connection lines are also observed in some of the cases studied in France by Clark (2016, 2017), but all are open-air sites, and some are affected by geological processes, such as at Bossuet. In level 497D of Cova Gran, long-distance refitting connections are present and some of them, such as some of the core-product (S17) or dorsal–ventral (S18) refitting sequences, connect the main lithic accumulation to the bone accumulation area. According to Clark's definition, it is possible that recycling occurred in 497D CG, although with the current data we could not identify the surface alteration that would suggest two different temporal events (i.e. patinated or thermally altered surfaces, retouched or reduced after surface damage) (Galili and Weinstein-Evron, 1985; Nishiaki, 1985;

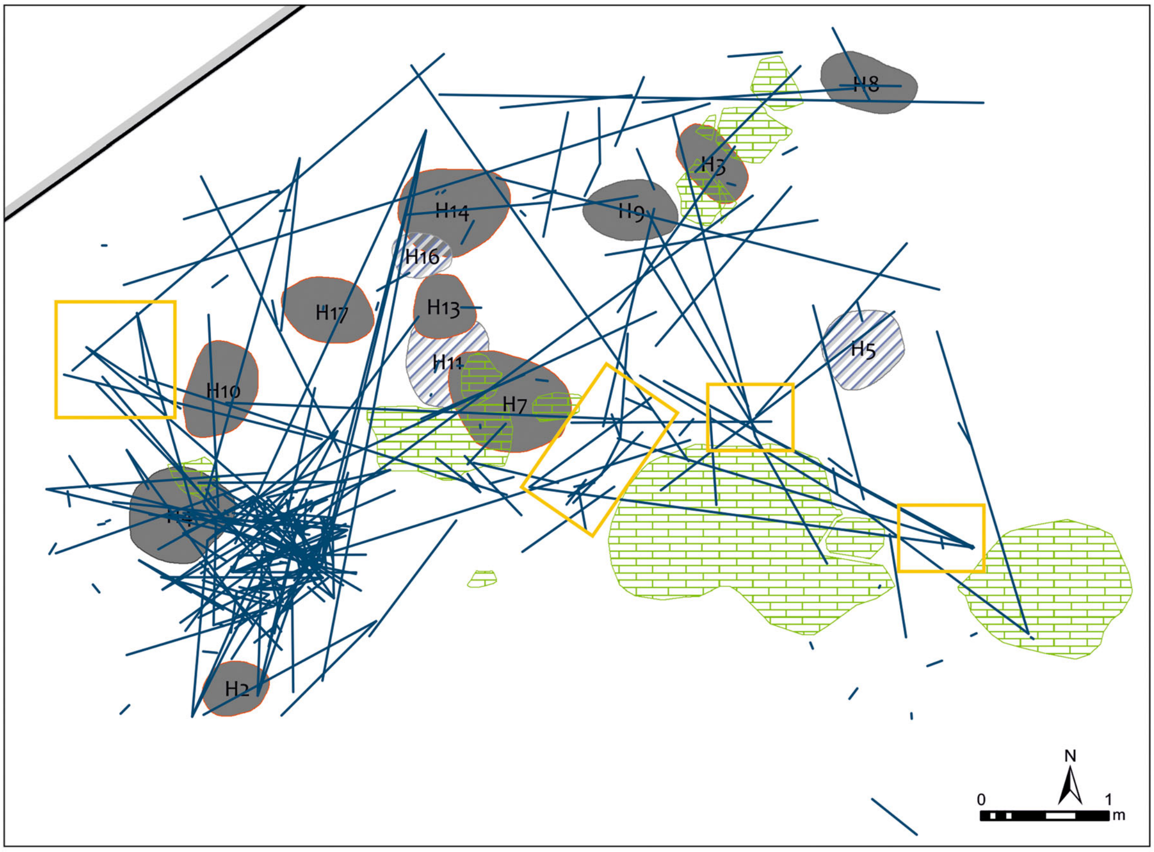

Figure 10. Estimation of the discrete groups of refits that might indicate a reuse of lithic artifacts beyond the main accumulation, and therefore indicate other episodes of activities within the formation of 497D by human groups. [Color figure can be viewed at wileyonlinelibrary.com]

Debenath, 1992; Mora et al., 2004; Navazo and Díez, 2008; Barkai et al., 2009; Vaquero et al., 2015). Therefore, although the 'centrifugal dispersion' pattern (Clark, 2016, 2017) seems to fit the scheme found in 497D CG, we cannot confirm whether this is exclusively due to recycling of lithic artifacts, or (and more probably) the repeated use of the space and development of activities related to lithic knapping and bone processing.

The idea of spatial distribution of certain lithic categories (cores, retouched tools, etc.) depending on specific zones of activity and that the organization of space became increasingly formalized into and throughout the Upper Paleolithic (Clark and Ranlett, 2022) do not apply in the case of 497D CG, where there is no such organization by lithic categories in relation to the activity carried out. Instead, the distribution responds to random patterns. Regarding the retouched tools, although there is a certain concentration in the area with the highest density of lithic industry (where there is no fauna), they are mostly distributed throughout the site, without notable concentrations in the main area of fauna exploitation. The same occurs with the remaining lithic categories, such as flakes, blades and cores. In the case of the hammerstones, they follow the distribution of lithics, mainly distributed in the middle western area of the site and with a total absence in the middle eastern area, from the line of hearths H14–H16–H13–H7 onwards. Only the ornaments show a more concentrated and localized pattern. They are distributed over an area of about 3.5 m^2 and may respond to some type of personal ornament that at some point broke and, probably due to the passage of people through the site or simply because it broke, has been distributed in this specific spot.

The study of level 497D of Cova Gran was based on a large sample size of lithic artifacts and bones, many features (hearths and ash accumulations) and a multitude of contrasted analysis methods, and considering both the field results and data from the study of other variables (sedimentology, lithic industry, fauna, etc.). A reiteration is observed within the occupations, with repeated visits that, if ideal schemes of organization of space and objects had existed, have remained completely diffuse because it represents a palimpsest. The ideal schemes of, for example, a core surrounded by flakes or debris, are erased: (i) when there are several occupations, because there are many cores, many flakes and even more debris distributed throughout the site, so it is not possible to distinguish some sets from others; (ii) if there are several occupations, then ideal schemes can be displaced by the passage and activity of humans (and animals that have visited the site), as well as recycling of the lithic elements (Galili and Weinstein-Evron, 1985; Nishiaki, 1985; Debenath, 1992; Mora et al., 2004; Navazo and Díez, 2008; Barkai et al., 2009; Vaquero et al., 2015); and (iii) when we are not looking at an activity from a few days, weeks or months ago, but rather occupations and activities from several thousand years ago, with all that entails (passage of animals, other humans, deposition of sediment, falling blocks, possible post-depositional alterations such as water, roots, gravity, burrows, etc., that have clearly altered the initial ideal position we expect to find in pristine locations). The ideal patterns of identifying neat activity areas may not be detectable in archaeological records, as other researchers have noted (O'Connell, 1987; Fisher and Strickland, 1989; Simms and Heath, 1990; Fisher et al., 1991), especially when several visits were made, and the use of space was not punctual or sporadic. Although recent studies seem to demonstrate that, under certain characteristics of the preservation of the deposit and its features (e.g. good preservation of hearths), a higher resolution in the identification of activities and events of occupation can be obtained (Machado et al., 2013, 2019; Machado and Pérez, 2016; Mallol and Hernández, 2016; Mallol et al., 2019; Mayor et al., 2020; Sossa-Ríos et al., 2022). Furthermore, it is important to consider that the spatial organization that we find at a site (excluding possible post-depositional alterations) will depend largely on the type of occupation and the duration of the occupations (Kent et al., 1989; Galanidou, 1997; Marcazzan et al., 2022b), and perhaps less so on cognitive modernity (Clark, 2023).

Conclusions

Spatial studies have proved to be a great tool for site analysis, as they bring all the data from different disciplines together and analyze them together. In this way, the agents that may have participated in the formation of the site can be inferred, either biotic or abiotic, as can the degree of resolution of the data. Thus, we can infer the type of activities that were carried out on the site. We can better understand their intensity, organization of the space and the dynamics of the occupations, and therefore the type of occupation and behavior of the human groups.

With this spatial analysis study, we observe that repeated occupation events occurred, and that the disposition and distance of hearths may respond to different activities, social interactions or privacy, as has been stated by ethnographic studies carried out by different researchers (Nicholson and Cane, 1991, Galanidou, 2000, Henry, 2012). The data indicate that Level 497D of Cova Gran is a palimpsest where several visits and activities would have been carried out in a period short enough not to have been exposed to post-depositional factors for a prolonged period, which maintained the differentiated distribution patterns, as well as the spatial relationships and schemes. It is possible that these visits were more related to specific activities carried out in this part of the valley, with movements around the site for the exploitation of local resources, and less so for use as a domestic space. These movements throughout the territory, with temporary short-term occupations, would probably have been related to the migration of prey, such as deer and horses, which moved between the lands of the Ebro depression and the Pyrenees. This would imply that the domestic/central settlement may have been located elsewhere and not in Cova Gran. This hypothesis is also supported by the information provided by the lithics, as it appears that the already configured bladelets were imported to the site to perform specific tasks (Martínez-Moreno et al., 2019).

If the visits had occurred over longer periods of time, this level of resolution and integrity could not have been preserved, and the spatial distribution schemes would have been blurred or even have disappeared. The highly marked areas of accumulation of objects, hearths, ash accumulations and very well-defined refitting sequences would have been affected by post-depositional processes, either natural or by the action of other humans and/or animals. It is important to highlight that the archaeostratigraphic studies performed have not allowed us to differentiate between different events or deposition of materials, so these repeated visits must have occurred in periods of time that did not allow sedimentation between events.

The spatial analysis of Level 497D of Cova Gran opens new perspectives regarding the modes and dynamics of occupation of these human groups from the Early Upper Paleolithic. Until now, very few spatial studies have been carried out in the northeastern region of the Iberian Peninsula (e.g. Roca dels Bous, Abric Romaní, Teixoneres and L'Arbreda cave) (Carbonell, 2012; Martínez-Moreno et al., 2004, 2016; Bargalló et al., 2020; Zilio et al., 2021; Rufi et al., 2021) that allow comparison of the spatial organization and characteristics of occupational patterns in these chronologies. This region, although belonging to the pre-Pyrenees, has traditionally been framed within the Mediterranean margin. The area contains numerous sites of very different contexts and locations, allowing us to understand the dynamics of occupation and mobility during the Early Upper Paleolithic, such as L'Arbreda (Bischoff et al., 1989; Maroto et al., 2012; Wood et al., 2014), Cova Foradada (Calafell) (Morales et al., 2019), Abric Romaní (Bischoff et al., 1994; Camps and Higham, 2012), Cova de les Malladetes (Martínez-Alfaro et al., 2021; Villaverde et al., 2021) and Cova de les Cendres (Villaverde et al., 2019; Bel et al., 2020; Bel, 2022; Real and Villaverde, 2022), among many others. These sites extend across a region that covers more than 600 km along the entire Mediterranean basin of the Iberian Peninsula, showing the great diversity of occupation dynamics and the different modes of resource exploitation, as well as the processes of formation of caves and rock shelters, both in coastal and inland areas. All these elements make this region one of the most well-studied in Europe for these chronologies.

Future spatial studies that bring all the disciplines together in these and other sites of the Mediterranean margin will allow further exploration of the spatial organization and dynamics of occupation of these human groups, and it will be very useful to compare them with each other. This will contribute greatly to establishing similarities and differences between sites with similar chronologies in the same region and in SE France. In this way, the dynamics of occupation and mobility of these human groups throughout the territory during the transition from the Middle to Upper Paleolithic can be resolved.

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Data availability statement

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

Supporting information

Additional supporting information can be found in the online version of this article.

Figure S1: Distribution of lithics. A) Lithics recorded in the field with total station (XYZ). B) All lithics, including artifacts with random XY coordinates.

Figure S2: Distribution of bones. A) Bones recorded in the field with total station (XYZ). B) All bones, including bones with random XY coordinates.

Figure S3: Spatial distribution of cores.

Figure S4: Spatial distribution of flakes and chunks.

Figure S5: Spatial distribution of debris.

Figure S6: Spatial distribution of unmodified lithics and hammerstones.

Figure S7: Spatial distribution of retouched tools.

Figure S8: Spatial distribution of elongated flakes.

Figure S9: Spatial distribution of blades/bladelets.

Figure S10: Spatial distribution of ornaments.

Figure S11: Lithic clusters identified by KDE.

Figure S12: Bone clusters identified by KDE.

Figure S13: A) Getis-Ord Gi* according to the 'length' variable of lithic artifacts. B) Clusters identified by Getis-Ord Gi* in the lithic assemblage according to the "length" variable. The percentage indicates the confidence.

Figure S14: Ternary diagram with the classification of the shape of lithic artifacts.

Figure S15: Lithic size-classes distribution (metric data for 435 of the 5107 artifacts with XYZ coordinates are not available).

Figure S16: Circular histogram and statistics of the orientation patterns calculated for the 269 refitting lines identified in CG 497D.

Figure S17: A) Selection of the most complete refitting sequences (in black cores of the refitting sets #41, #98, #191, #102 and #120). B) All cores recorded in the site that are part of all the refitting sets identified in CG 497D. The picture of the refit set #120 is part of the article published by Martínez-Moreno et al., 2019.

Figure S18: Type of refitting sequence: core-product.

Figure S19: Type of refitting sequence: dorsal-ventral.

Figure S20: Type of refitting sequence: longitudinal fracture.

Figure S21: Type of refitting sequence: transversal fracture.

Figure S22: Type of refitting sequence: Recycling/reuse.

Figure S23: Type of refitting sequence: thermal.

Figure S24: Type of refitting sequence: natural fracture.

Table S1: Description of the number of lithic artifacts and bones in each lithic cluster identified by KDE.

Table S2: Lithic categories in each of the lithic clusters identified by KDE.

Table S3: Description of the number of bones and lithic artifacts in each bone cluster identified by KDE.

Table S4: Species and age range of each of the bone clusters identified by KDE.

Table S5: Statistical results obtained from the application of ANN, and Global Moran's I.

Table S6: Number of lithic artifacts identified in each of the clusters identified by Getis-Ord Gi* and the maximum, minimum and average sizes of each of the clusters (mm).

Table S7: Lithic categories within of each of the clusters identified by Getis-Ord Gi*.

Table S8: Types of refitting sequences identified in level 497D of Cova Gran.

Abbreviations. ANN, Average Nearest Neighborhood; CL1, CL2, lithic coldspot clusters; F1, F2, etc., fauna clusters; HL1, HL1A and HL1B, HL2, lithic hotspot clusters; KDE, Kernel Density Estimation; L1, L2, etc., lithic clusters; RMU, Raw Material Unit.

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