



Identifying activity areas in a neanderthal hunting camp (the Navalmaíllo Rock Shelter, Spain) via spatial analysis

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Abstract

Spatial analysis has been much used to examine the distribution of archaeological remains at Pleistocene sites. However, little is known about the distribution patterns at sites identified as hunting camps, i.e., places occupied over multiple short periods for the capture of animals later transported to a base camp. The present work examines a Neanderthal hunting camp (the Navalmaíllo Rock Shelter in Pinilla del Valle, Madrid, Spain) to determine whether different activities were undertaken in different areas of the site. A spatial pattern was detected with a main cluster of materials (lithic tools, faunal remains, and coprolites) clearly related to the presence of nearby hearths—the backbone of the utilised space. This main cluster appears to have been related to collaborative and repetitive activities undertaken by the hunting parties that used the site. Spatial analysis also detected a small, isolated area perhaps related to carcasses processing at some point in time and another slightly altered by water.

Keywords Middle Palaeolithic · Neanderthal · Spatial analysis · Hunting camp · Zooarchaeology · Lithic tools

Introduction

The characterisation of human occupation patterns in the Pleistocene archaeological record has been of major interest. Studies on ethnohistoric hunter-gatherer groups, such as the Hadza (Bunn et al. 1988; O'Connell et al. 1991, 1992), Nunamiut (Binford 1978a, b, 1980), ¡Kuhn (Yellen 1977),

Kua San (Bartram et al. 1991), and Efé (Fisher and Strickland 1991), have helped define different types of activity area in their camps (domestic, peripheral, and communal areas) (Yellen 1977; Binford 1978b; Bartram et al. 1991). These activity areas are defined by the activities undertaken within them, by the remains that accumulate in them, and by the structures they contain (e.g., hearths). However, the

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interpretation of occupation patterns in the archaeological record remains complex.

Hearths—such as family hearths and cooking areas—have been ethnoarchaeologically shown to form the backbone of group activities within camps (Bartram et al. 1991; Binford 1978a, 1983; Fisher and Strickland 1991; O’Connell et al. 1991; Yellen 1977), and as such are a major element in the identification of activity areas (Vaquero and Pastó 2001). However, their mere presence does not directly indicate the existence of activity areas in archaeological sites; hearths have many different uses. In this way, the identification of hearths does not mean that we can always identify activity areas in the archaeological record, and it is important to link their presence to other archaeological materials/features (Kuhn 1992; Mellars 1996; Moncel and Rivals 2011; Picin and Cascalheira 2020; Rendu et al. 2011) or even to the type of hearth (Mallol et al. 2007) in order to do a correct interpretation of the sites. One example are those activity areas identified as “sleeping areas,” where the hearths are the only elements used for heating the Neanderthals and they cannot be seen as the main structure (Vallverdú et al. 2010).

Bearing in mind that archaeological sites should be understood as palimpsests (Bailey 2007) and that their occupation was related to different events (Bargalló et al. 2016; Canals 1993; Canals et al. 2003; Sánchez-Romero et al. 2017; Vallverdú et al. 2005; Mayor et al. 2020; Gabucio et al. 2018), researchers have tried to understand the patterns associated with their use. However, these studies have focused mainly on later periods in human evolution. Sites from earlier periods have not often been the subject of modern spatial analysis. Recent work at the African Lower Pleistocene sites of FLK Zinj, DS, and PTK (Olduvai Gorge, Tanzania), where a spatial pattern quite different to that recorded for ethnohistoric hunter-gatherer groups has been recorded (Diez-Martín et al. 2021; Domínguez-Rodrigo and Cobo-Sánchez 2017), is therefore of great interest. The faunal and lithic industry distributions at these sites involve a large cluster of materials, providing evidence of communal behaviour and food-sharing and indicating the absence of different activity areas (Diez-Martín et al. 2021; Domínguez-Rodrigo and Cobo-Sánchez 2017). In contrast, Upper Pleistocene sites such as Verberie (Audouze and Enloe 1997) and Pincevent (Enloe et al. 1994), or even from the Middle Pleistocene, as Boxgrove (Pope et al. 2020), show clear evidence of distinct activity areas.

The spatial behaviour of Neanderthal groups that existed during the Middle Palaeolithic is poorly defined according to some authors (Farizy and David 1992; Stringer and Gamble 1993), who indicate that of anatomically modern humans to be far more complex. However, many authors believe the archaeological record of the spatial behaviour patterns of Neanderthals and modern humans shows common elements. Indeed, both undertook domestic activities around artificial

structures such as hearths or natural structures such as large stone blocks (Chase 1986; Henry et al. 1996, 2004; Karkanas et al. 2007; Rosell et al. 2012a; Sánchez-Romero et al. 2020; Vaquero and Pastó 2001). Certainly, at the Bruniquel Cave, circular constructions made by Neanderthals have been identified, clearly revealing their interest in control over the space they used (Jaubert et al. 2016). Similarly, level N of the Abric Romaní site has identifiable sleeping areas (Vallverdú et al. 2010).

When trying to understand the types of occupation at Neanderthal sites (or about any group of Palaeolithic hunter-gatherers), it should be remembered that these could have been short- or more long-term (Cascalheira and Picin 2020). The duration of occupation provides valuable information on the functionality of a site and the behaviour of the human group involved. Thus, it can be said that the duration and functionality of the sites are strongly interrelated, the latter depending on the former. In general, we can relate long-term occupations of hunter-gatherer groups to residential occupations, while short-term occupations tend to have a function related to extractive tasks of different types (Cascalheira and Picin 2020). For example, the activities undertaken at a kill/butchering site (Boismier et al. 2012; Yravedra et al. 2012), at a site where raw materials were collected (Baena et al. 2008; Turq 1988) or at a short-term hunting camp (Bodu et al. 2011; Costamagno et al. 2006; Daujeard and Moncel 2011; Griggo et al. 2011; Marchand et al. 2011; Marín et al. 2019; Moclán et al. 2021; Rendu et al. 2011; Simonet 2011; Valdeyron et al. 2011) would not be the same as those undertaken at a long-term residential camp (Gabucio et al. 2014; Kelly 1992; Rosell et al. 2012b); in consequence, the archaeological records at such sites would be different (e.g. different types of activity areas or *chaînes opératoires*). Theoretically, they should also show differences from a spatial point of view (Kuhn 1992; Mellars 1996; Moncel and Rivals 2011; Picin and Cascalheira 2020; Rendu et al. 2011). The spatial organisation of a resource collection or kill/butchering site would be minimal since all activity would be directly related to these functions, but at a settlement, it would be much more complex. In addition, where occupations are long-term, combustion structures are deep and have high densities of bone remains, lithic production took place inside the settlement, the toolkits are composed of products of all different phases of the *chaîne opératoire* (hammerstones, anvils, cortical and non-cortical flakes, cores, chunks, debris, and retouched tools), and the space is consequently more structured (Moncel and Rivals 2011; Picin and Cascalheira 2020). Short-term occupation sites generally show reduced spatial organisation, and little-developed knapping activities (with tools not from the immediate area constituting small toolkits [retouched tools predominate]) and animal processing (Binford 1980, 1981, 1983; Kuhn 1992; Moncel and Rivals 2011; Picin and Cascalheira 2020).

However, the dichotomy outlined above is not always so clear. Different occupations can be superimposed, which can mask their individual characteristics (Schiffer 1983, 1987; Churchill 2014). It is therefore important to clearly identify hunting camps; these are short-term occupation sites but can look like more long-term occupation sites when different occupation events are superimposed (Churchill 2014). Pleistocene hunting camps are usually characterised by the predominance of low nutritional anatomical elements (e.g. crania, mandibles) and the underrepresentation of high nutritional anatomical elements (in relation to their quantity of meat or marrow [e.g. upper and intermediate long bones]) (Thomas and Mayer 1983; Metcalfe and Jones 1988; Jones and Metcalfe 1988; Emerson 1993; Marean and Frey 1997; Friesen 2001; Morin 2007; Faith and Gordon 2007; Yravedra and Domínguez-Rodrigo 2009; Morin et al. 2016) which are mainly transported to base camps, the presence of specialised tools (in short-term occupation, final products knapped with nonlocal raw material are especially common), and a low-level presence of lithic remains and hearths (which would show little vertical development) (Bon et al. 2011; Costamagno et al. 2011; Mallol et al. 2007; Picin and Cascalheira 2020; Marín et al. 2019; Rendu et al. 2011; Moncel and Rivals 2011; Moclán et al. 2021; Griggo et al. 2011). However, if a site has been used many times, the superimposition of occupations might induce the accumulation of abundant lithic remains. Very few studies have examined such sites from a spatial point of view (Griggo et al. 2011; Marín et al. 2019). Against this background, the present work examines the use of space at a Middle Palaeolithic hunting camp—the Navalmaíllo Rock Shelter (at Pinilla del Valle, Madrid, Spain; hereinafter NV)—via an analysis of the archaeological record of its level F. This site seems to have been used repeatedly by Neanderthal groups as a hunting camp where mainly large bovids (*Bos/Bison*) and cervids (*Cervus elaphus*) were butchered (Moclán et al. 2021).

Three hypotheses were tested regarding the spatial organisation and formation processes of the layer F assemblage. The first was that the site shows a distribution of remains definable as “multi-cluster”, based on the idea that different occupations might generate different areas of use, rather like that produced by different nuclear families in a base camp (Bartram et al. 1991; Binford 1978a, b; Cascalheira and Picin 2020; Domínguez-Rodrigo and Cobo-Sánchez 2017; Mallol et al. 2007; O’Connell et al. 1991; Yellen 1977; Carrancho et al. 2016; Vallverdú et al. 2005, 2010). Hypothesis 2 states that there is but one cluster of archaeological materials, i.e., the space was used in the same way in all occupations, with no areas given over to identifiably different activities (Moncel and Rivals 2011). Such a model would be similar to that seen at the FLK Zinj, PTK, and DS sites (Diez-Martín et al. 2021; Domínguez-Rodrigo

and Cobo-Sánchez 2017). Hypothesis 3 states that there is no cluster-type distribution pattern, i.e., the distribution of archaeological remains is random or even regular (Marín et al. 2019), the product of the entire site being used indistinctly (Baddeley et al. 2016).

The spatial distribution of the site was examined via (1) the analysis of bone and lithic refittings to determine the state of alteration of the explored surface (Bleed 2002; Czesla et al. 1990; Fernández-Laso et al. 2020; Rosell et al. 2012a; Vaquero and Pastó 2001; Vaquero et al. 2017); (2) an archaeostratigraphic study to determine its degree of vertical integrity and to identify topographic features; this analysis extends upon a previous study (Sánchez-Romero et al. 2017) in which the existence of two sublevels was proposed for level F; (3) the analysis of the spatial distribution of archaeological remains—trying to explain the relationships between the materials found, and the importance of the hearths discovered at the site—using quantitative techniques recently adopted by the field of spatial archaeology (Diez-Martín et al. 2021; Domínguez-Rodrigo and Cobo-Sánchez 2017; Domínguez-Rodrigo et al. 2017, 2018; Luzón et al. 2021; Marín et al. 2019; Panera et al. 2019; Saladié et al. 2021). The overall aim was to identify different activity zones within level F of the site and test the hypothesis set above for its spatial characterisation.

The Navalmaíllo rock shelter

The NV site belongs to the collection of Calvero de la Higuera sites (all at Pinilla del Valle) (Fig. 1) in the Sierra de Guadarrama, some 55 km north of the city of Madrid (Spain) (Arsuaga et al. 2011; Baquedano et al. 2012; Pérez-González et al. 2010). These sites cover chronologies from the Middle Pleistocene to late prehistory and even the Middle Ages. The most important occupations are those of MIS5 to MIS3 represented at the Cueva del Camino, the Buena Pinta Cave, the Cueva Des-Cubierta, and the Ocelado Rock Shelter (Álvarez-Lao et al. 2013; Arsuaga et al. 2011, 2012; Baquedano et al. 2012, 2015; Galindo-Pellicena et al. 2019; Huguet et al. 2010; Laplana et al. 2015, 2016; Pérez-González et al. 2010). NV, discovered in 2002 and now the most intensely documented Neanderthal site at Pinilla del Valle (Baquedano et al. 2012), is a rock shelter produced by the action of the Valmaíllo Stream; it occupies an area of some 250 m² (Análisis y Gestión del Subsuelo S.L. [AGS] 2006; Pérez-González et al. 2010).

The stratigraphic sequence of NV from bottom to top (Arriaza et al. 2017; Pérez-González et al. 2010; Sánchez-Romero et al. 2017) starts with at least 2 m of allochthonous fluvial deposits (F1)—sands and siliceous gravel—deposited by the Valmaíllo Stream. Level F lies above these fluvial facies and is some 0.85 m thick. It has a clay-sand texture

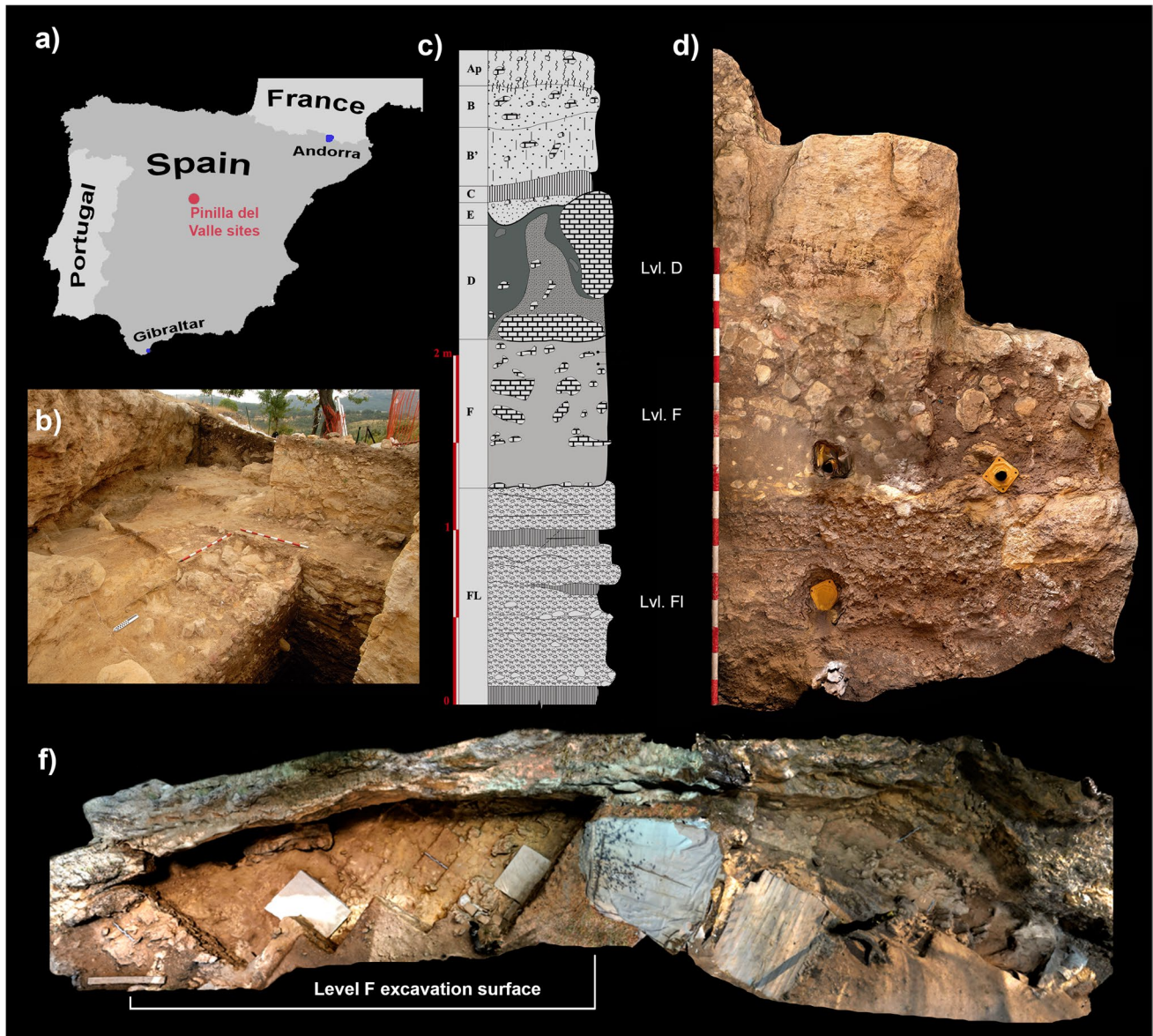


Fig. 1 **a** Location of Pinilla del Valle; **b** general view of the excavated surface of level F; **c** a stratigraphic column extracted by Arriaza et al. (2017); **d** orthophotographic model of the west wall in squares D18

and E18; **f** orthophotograph of the site showing the excavated surface of level F

(colour 10 YR 4/3) and contains carbonate clasts, with the longest axis reaching 0.35 m. Level F has been dated by thermoluminescence (at the *Universidad Autónoma de Madrid*) as $71,685 \pm 5082$ or $77,230 \pm 6016$ years old (Arsuaga et al. 2011; Pérez-González et al. 2010), placing it at the end of MIS5a. The palynological data for level F suggest an open environment (Ruiz Zapata et al. 2015). This level contains abundant archaeological remains, including hearths (Baquedano et al. 2012). About 50 m² have been excavated to a depth of ~20 cm.

Large blocks of dolomite (the longest axis of some exceeds 1 m) lie at the top of level F and are related to

the collapse of the rock shelter ceiling. The fallen ceiling itself forms level D. The matrix between the blocks is, to a large extent, the sediment of level F that was hydroplastically injected into the corresponding spaces. The remainder of the infill appeared after the ceiling collapsed. In some places, the top of level D is overlain by either level α or level β , both of which show signs of anthropic activity (still under study), including lithic remains, faunal remains, and hearths (Baquedano et al. 2012). The stratigraphic sequence continues with at least two levels of colluvium of dolomitic clasts and a silt-sand matrix (7.5 YR 6/3) 1 m in thickness and a horizon Ap (10 YR 5/2) with a

depth of 0.20–0.40 m. The present work focused on level F, which contains the main archaeological assemblage of NV. This level has been recently identified as a Neanderthal hunting camp used as an intermediate locus between kill/butchering sites and a referential camp (Moclán et al. 2021). This interpretation has been proposed mainly due to the characteristics of the anatomical profiles of the ungulates (i.e. inverse utility curve), the local origin of the most part of the lithic assemblage, and the expeditious nature (i.e. thin structures) of the hearths at the site (for more details, see Moclán et al. 2021).

Over 60% of the total archaeological remains of level F correspond to lithic industry (Márquez et al. 2016). Most of the lithic remains (77.49%) (Table 1) are made from quartz collected in the surrounding area (Márquez et al. 2013); indeed, some 97% of all the lithic remains represent locally collected material (Abrunhosa et al. 2014, 2019, 2020). A tendency towards apparently intentional microlithisation has been identified, at least for tools made from quartz (Márquez et al. 2013). The presence of bipolar products indicates that the bipolar on anvil knapping technique was used in the production of small quartz tools (Márquez et al. 2013).

The simple flake is the most common technological category represented (see Table 1), although different types of retouched elements have been recovered, such as denticulates, notches, and sidescrapers (Márquez et al. 2013). Use-wear studies have revealed the versatile use of tools at the site (e.g. in butchering and woodworking) (Márquez et al. 2016, 2017).

To date, five hearths have been discovered in level F, but they show little vertical development (Baquedano et al. 2012).

A zooarchaeological and taphonomic analysis of level F was recently undertaken by combining the data for levels D and F, given the injection of the latter into the former (Moclán et al. 2021). The most common taxa were shown to be large (mainly *Bos/Bison*) and medium-sized animals (red deer). The agency of the faunal assemblage is clearly Neanderthal activity; cut marks, percussion marks, and other anthropogenic modifications, such as the presence of bone retouchers, are clearly present (Huguet et al. 2010; Moclán et al. 2018, 2020, 2021).

Lynxes and hyaenas have modified some bones at the site (Arriaza et al. 2017; Moclán et al. 2020, 2021). The lynx activity was identified via the presence of modified rabbit bones and the presence of small coprolites (Arriaza et al. 2017). Hyaena activity is visible in the ravaging of the faunal remains abandoned by the Neanderthal occupants of the site (Moclán et al. 2020, 2021). However, previous analyses of level F following use-wear (Márquez et al. 2016, 2017), technological (Márquez et al. 2013), and taphonomic (Moclán et al. 2021) techniques indicate its integrity to be well maintained.

A preliminary spatial analysis of this level, involving an exploration of its spatial point pattern and a refitting and archaeostratigraphic examination, allowed Sánchez-Romero et al. (2017) to propose the existence of two archaeostratigraphic sublevels within level F. That study contemplated the archaeological materials recovered between 2002 and 2010; in the present work, the data available for 2002–2019 is examined.

Materials and methods

The spatial analysis undertaken in the present work involved the examination of 31,678 archaeological remains (Fig. 2) (9840 faunal remains, 20,451 lithic industry remains, and 72 coprolites). The archaeostratigraphic analysis also considered the data for 397 dolomite blocks.

The examined remains were all those for which positions were recorded in NV level F between 2002 and 2019. Level D was excluded from the spatial analysis given the upward injection of level F, although it was taken into account in lithic and bone refitting studies. The latter analysis also considered remains with no recorded position. The positions of all lithic industry elements were, however, recorded, as were those of the examined coprolites, those of all animal remains over 2 cm in length (longest axis), those that were smaller but which showed anatomical or taphonomic features of zooarchaeological or palaeontological importance (e.g. isolated teeth, bone flakes), and those of all dolomite blocks over 10 cm in length (longest axis). From 2002 to 2017, positions were recorded using xyz coordinates employing flexometers and a laser level; from 2018 onwards, a total station was used. General orientation and slope were also recorded, and the positions of remains were sketched, although the precision of these data precluded certain analyses.

Three types of studies were undertaken: (1) bone and lithic refittings, (2) archaeostratigraphic profiles, and (3) a spatial analysis. The first of these is of interest in interpreting the degree of alteration and dispersion of remains, and their vertical relationships (Bleed 2002; Czesla et al. 1990; Fernández-Laso et al. 2020; Morin et al. 2005; Rosell et al. 2012a; Sumner and Kuman 2014; Vaquero et al. 2017). There are different types of refitting depending on the refitted fracture plane/structure/surface. In the case of lithic tools, refitting can be differentiated between conjoins (i.e. broken pieces that have been refitted) and “technological refittings”, which are related to different phases of the *chaîne opératoire* (e.g. cores and flakes) (Bleed 2002). Faunal refittings can be considered as intermembral, anatomical, bilateral pairs and mechanical refittings (which are the most common) (Lyman 1994, 2008; Fernández-Laso 2010). Plotting of the refittings was performed using ArcGIS Desktop 10.5 software. Figure 3 shows some examples of lithic and bone

Table 1 Characteristics of the lithic industry elements of level F recovered between 2002 and 2019. The table also shows those elements for which xyz coordinates were not recorded

	Quartz		Chert		Quartzite		Rock crystal		Sandstone		Porphyry		Limestone		Other rocks		Total	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
Tool type (<i>n</i>) by raw material at Navalmaillo rockshelter (level F)																		
Hammerstones/anvils	27	0.16	0	0	7	1.80	0	0	5	4.72	12	4.48	1	33.33	70	4.6	122	0.57
Cores on pebble	378	2.29	32	1.49	13	3.34	4	1.1	1	0.94	9	3.36	0	0	14	0.92	451	2.12
Tools on pebble	9	0.05	1	0.05	1	0.26	0	0	0	0	0	0	0	0	0	0	11	0.05
Cores on flake	150	0.91	21	0.98	7	1.80	2	0.55	0	0	3	1.12	0	0	4	0.26	187	0.88
Retouched tools	847	5.13	153	7.14	27	6.94	30	8.26	3	2.83	14	5.22	1	33.33	19	1.25	1094	5.14
Flakes	10847	65.75	1464	68.35	298	76.61	230	63.36	60	56.6	183	68.28	1	33.33	276	18.15	13,359	62.75
Fragments	4129	25.03	343	16.01	36	9.25	91	25.07	7	6.6	35	13.06	0	0	782	51.41	5423	25.47
Indeterminate	110	0.67	128	5.98	0	0	6	1.65	30	28.3	12	4.48	0	0	356	23.41	642	3.02
Total	16,497		2142		389		363		106		268		3		1521		21,289	
% total	77.49		10.06		1.83		1.71		0.50		1.26		0.01		7.14			
Stage of core abandonment (<i>n</i>)																		
Initial	11	2.26	0	0	3	15.79	0	0	0	-	3	25	0	-	5	33.33	22	3.79
Middle	143	29.42	8	18.6	6	31.58	0	0	0	-	8	66.67	0	-	5	33.33	170	29.26
Final	332	68.31	35	81.4	10	52.63	6	100	0	-	1	8.33	0	-	5	33.33	389	66.95
Total	486		43		19		6		0		12		0		15		581	
% total	83.65		7.40		3.27		1.03		0		2.07		0		2.58			
Core type (<i>n</i>)																		
Centripete/Discoidal	131	28.85	14	40	7	38.89	3	50	0	-	5	41.67	0	-	4	28.57	164	30.43
Levallois	1	0.22	0	0	1	5.56	0	0	0	-	0	0	0	-	0	0	2	0.37
Massive	26	5.73	0	0	1	5.56	0	0	0	-	1	8.33	0	-	1	7.14	29	5.38
Orthogonal	62	13.66	7	20	2	11.11	1	16.67	0	-	3	25.00	0	-	1	7.14	76	14.10
Pyramidal	12	2.64	1	2.86	0	0	0	0	0	-	0	0	0	-	1	7.14	14	2.60
Other	222	48.90	13	37.14	7	38.89	2	33.33	0	-	3	25.00	0	-	7	50	254	47.12
Total	454		35		18		6		0		12		0		14		539	
% total	78.14		6.02		3.10		1.03		0		2.07		0		2.41			
Retouched tools (<i>n</i>)																		
Denticulate	290	39.4	53	44.17	10	43.48	11	39.29	0	0	7	63.64	0	-	9	47.37	380	40.5
Notch	92	12.5	12	10	3	13.04	7	25	0	0	1	9.09	0	-	0	0	115	12.2
Retouched flake	141	19.16	18	15	3	13.04	4	14.29	2	100	1	9.09	0	-	7	36.84	176	18.74
Point	26	3.53	3	2.5	1	4.35	1	3.57	0	0	0	0	0	-	1	5.26	32	3.41
Scraper	113	15.35	29	24.17	6	26.09	4	14.29	0	0	2	18.18	0	-	2	10.53	156	16.61
Enscraper	24	3.26	0	0	0	0	1	3.57	0	0	0	0	0	-	0	0	25	2.66
Borer	23	3.13	3	2.5	0	0	0	0	0	0	0	0	0	-	0	0	26	2.77
Other	27	3.67	2	1.67	0	0	0	0	0	0	0	0	0	-	0	0	29	3.09
Total	736		120		23		28		2		11		0		19		939	

Table 1 (continued)

	Quartz		Chert		Quartzite		Rock crystal		Sandstone		Porphyry		Limestone		Other rocks		Total	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
% total	78.38		12.78		2.45		2.98		0.21		1.17		0		2.02			

refittings. The refitting analysis that we have included here can be considered preliminary due to the number of identified refits in the assemblage being too low in comparison with the total number of lithic/faunal remains. We hope that in the future we will increase the number of refits and carry out a more in-depth analysis of them. In this sense, we have only analysed in depth the distance between the different remains.

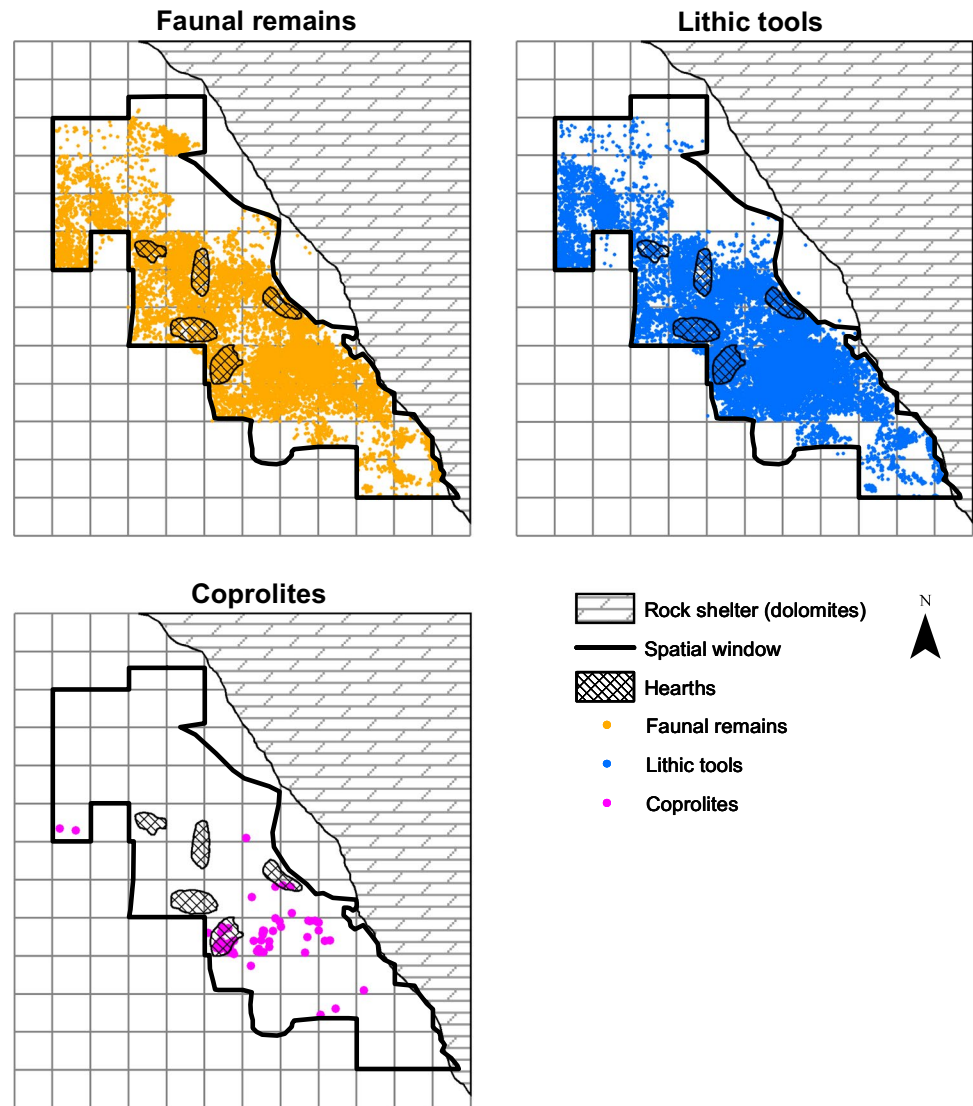
The archaeostratigraphic analysis was performed to identify the presence of temporal hiatuses in the vertical distribution of the remains. These voids imply the absence of activity in determined archaeological levels and allow different sublevels of occupation to be identified (which might otherwise remain undetectable) (Canals 1993; Canals et al. 2003; Fruitet 1991; Vaquero et al. 2012). The archaeostratigraphic examination of the dolomite blocks was important given their large volume compared to the other remains; their lower and upper z coordinates were therefore recorded (for all other elements, only the lower z coordinate was recorded). For these analyses, archaeostratigraphic sections (hereinafter “transects”) of 10 cm in width and that crossed the site were used, following the method of Sánchez-Romero et al. (2017). The latter work involved 10 transects and incorporated data for level F obtained between 2002 and 2010. The present work reproduced those 10 transects and added 10 more, some involving transversal sections running north–south and east–west (Sánchez-Romero et al. 2017) (Fig. 4). Data were examined using ArcGIS Desktop v.10.5 software.

Sánchez-Romero et al. (2017) proposed the existence of two sublevels within level F. This has important implications in the study of the archaeological record: each would require the individual examination of their archaeological material and spatial analysis. However, upon repeating the work of the latter authors and adding to it the archaeological data obtained since that study, no such sublevels were detected. Thus, the present spatial analysis contemplated the entire excavated depth (~20 cm) of level F as a whole.

All transects were subjected to a visual analysis of the remains. The remains under transect 8 (the longest), however, were also subjected to k-means analysis to confirm any archaeostratigraphic differences (Martín-Perea et al. 2020). Silhouette analysis of the transect 8 data was used to determine the number of clusters of remains; this was performed using the “factoextra” library (Kassambara and Mundt 2020) in R (R Core Team 2020). It should be noted that, for transects 7, 8, 10, 11, and 13, the recording of the positions of remains in parts of squares D18 and E18 (see squares visible in figures) was less strict due to a geological survey being undertaken. These were included in the archaeostratigraphic profiles produced but not in the spatial analysis.

The spatial analysis of the remains was performed using the “spatstat” library (Baddeley and Turner 2005) in R (R

Fig. 2 Spatial distribution of faunal remains (top left), lithic remains (top right), and coprolites (below) recovered from level F. The grid system formed units of 1 m²



Core Team 2022). This library allows a large number of statistical analyses of spatial point patterns (SPPs) represented in 2D (Baddeley et al. 2016), providing information on the intensity of the pattern, the type of pattern, and the relationships between different types of point (e.g. those representing lithic or faunal remains). The “spatstat” library has previously been used for similar site analyses and for identifying patterns in experimental settings (Diez-Martín et al. 2021; Domínguez-Rodrigo et al. 2017, 2018; Marín et al. 2019; Panera et al. 2019; Domínguez-Rodrigo and Cobo-Sánchez 2017; Luzón et al. 2021). For descriptive purposes only, the examined surface was divided into arbitrary areas (e.g. north, northwest, etc.) (Fig. 5a).

An SPP may fit the complete spatial randomness (CSR), cluster (positive relation between points, [points tend to be close together]); or regular model (negative relation between points [points tend to avoid each other]) (Baddeley et al. 2016). In the present work, the spatial analysis was

performed in two ways: contemplating SPPs with points representing a single type of element (e.g. all quartz tools taken together) and contemplating SPPs with points representing more than one type of element (e.g. taking into account identifiably different quartz tools separately). In such analyses, each type of element is known as a “mark” (Baddeley et al. 2016); when only one element is contemplated (e.g., all quartz tools together), an SPP is said to be “unmarked”. It is important to differentiate between unmarked and marked SPPs since the statistical analyses performed for each type are different. The analytical protocol for unmarked SPPs—which focuses on testing the CRS model—involves the next steps:

1. A χ^2 test to examine the homogeneity of the samples. In the present work, this was performed by dividing the analysed surface into squares of 5 × 5, 8 × 8, 10 × 10, and 12 × 12 units.

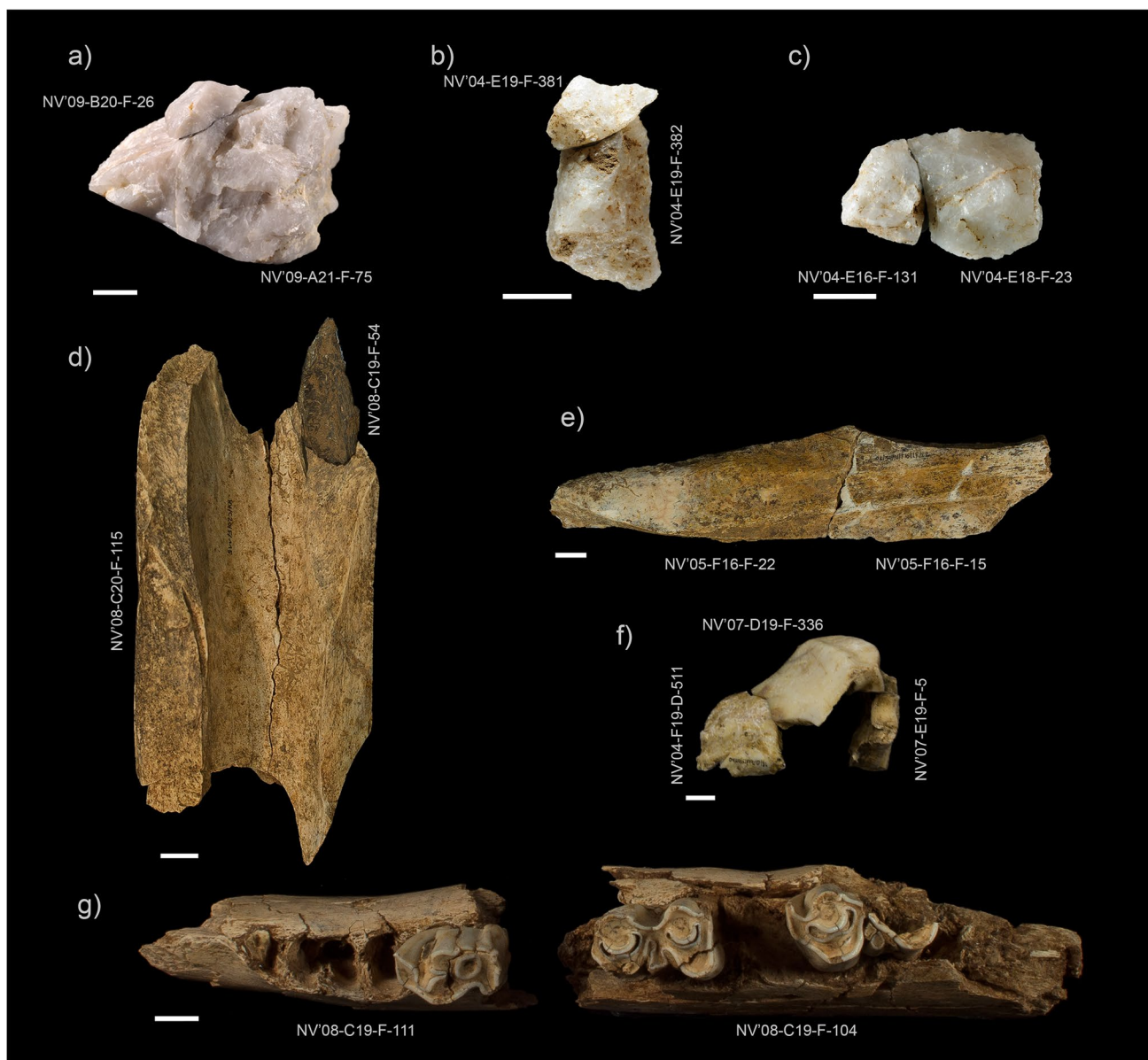


Fig. 3 Examples of lithic (a–c) and faunal refittings (d–g). **a** Refitting of a quartz core and flake; **b**, **c** refittings of quartz flakes; **d** refitting of tibia fragments from a large animal (one fragment is a piece of burnt bone that fits into the notch in the fracture plane of the other fragment; note that the bone flake is not complete); **e** refitting of two frag-

ments of tibia diaphysis from a large animal; **f** refitting of three fragments of a molar belonging to *Stephanorhinus hemitoechus*; note that one of the fragments was recovered from level D; **g** refitting of two fragments of jawbone from *Bos/Bison*

2. Since all the present samples were identified as inhomogeneous, analyses were performed to examine whether the SPPs for the faunal remains, lithic remains, and coprolites corresponded—or not—to a “correlation-stationary process (CSP)” (Baddeley et al. 2016). (This is important since the type of inhomogeneity dictates the functions to be used in later parts of the analysis; see below.) For this, the studentised permutation test was performed employing a K inhomogeneous function. This required dividing the analysed surface into different

zones (Fig. 5b). The results confirmed that the SPPs did correspond to a CSP (Table 2).

It should be noted that the coprolite sample was too small to analyse in this way.

3. Following the same methodology, tests were made to determine whether the SPPs corresponded to a locally

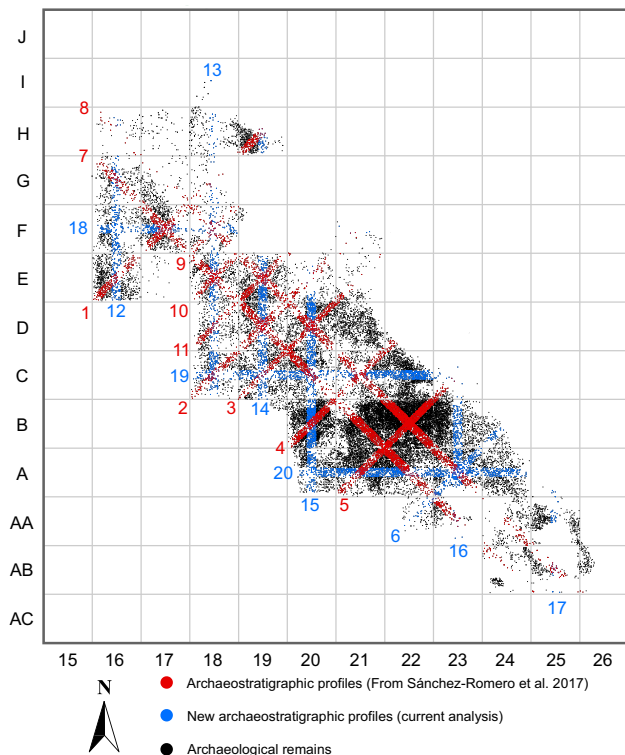


Fig. 4 The archaeostratigraphic profiles analysed

- scaled point pattern—a null hypothesis that could not be rejected. Consequently, locally scaled K and L functions were used to analyse the SPPs with respect to their faunal and lithic remains (the complete sample, pieces > 9 mm, and pieces > 19 mm) and coprolites.
- The inhomogeneous pair correlation function was then used with the same samples as for the locally scaled functions to see whether this could reject the null hypothesis for the CSR pattern.
 - The Hopkins–Skellam and Clark–Evans tests were then performed to see if the SPPs fitted the CSR, cluster, or regular model. These tests are sensitive to inhomogeneous samples and commonly return a false “cluster” result (Baddeley et al. 2016; Ebner et al. 2018). However, it is true that Hopkins–Skellam test is less sensitive to this problem (Baddeley et al. 2016), and it usually provides better results than the Clark–Evans tests. In any case, both comprise all the spatial information into a single number, and this can be a problem in relation to the interpretation of the SPPs (e.g. if a marked difference of intensity exists).
 - The SPPs were next subjected to an analysis of their intensity using the Kernel density test with likelihood cross-validation correction.

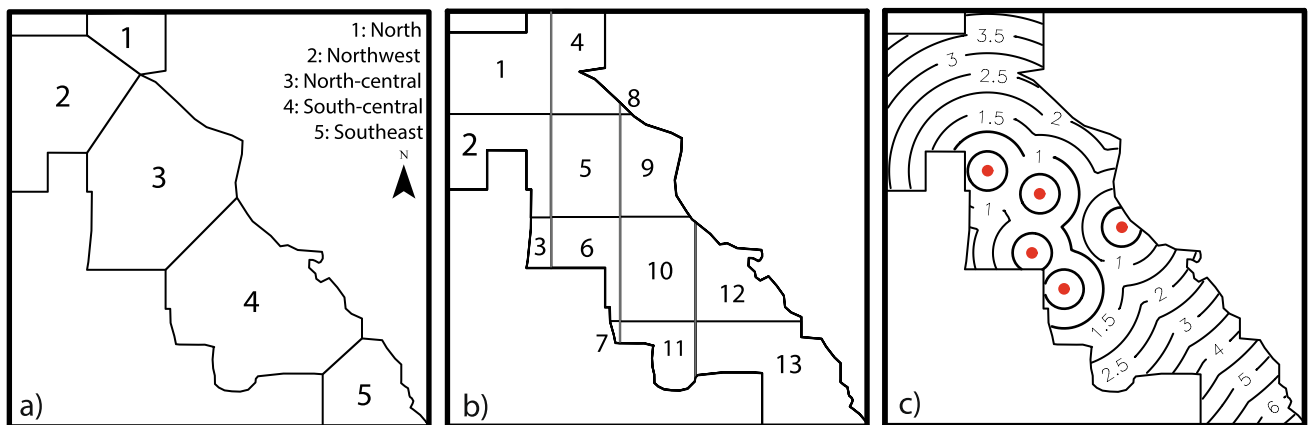


Fig. 5 **a** Different areas used in the description of the spatial analysis. **b** Tessellation map created to test the null hypothesis for the correlation-stationary process and locally scaled point distribution. **c** Distance to heaths' map

Table 2 Results provided by the studentised permutation test run with the inhomogeneous K and L functions and locally scaled K and L functions. Note that the sample composed of coprolites remains could not be analysed due to its small size

Archaeological remains	K inhom. function	K-scaled function		
	T	p -value	T	p -value
Lithic tools (≥ 1 mm)	0.45643	0.078	4.1933	0.277
Lithic tools (≥ 10 mm)	0.32262	0.179	2.9764	0.437
Lithic tools (≥ 20 mm)	0.038566	0.773	0.32533	0.757
Faunal remains	0.13287	0.172	0.5303	0.695
Coprolites	NA	NA	NA	NA

7. The presence of hotspots was then determined by calculating the likelihood ratio test value. The same analysis was performed using samples from areas where their presence was 99% significant.
8. Finally, the SPPs were examined using the inhomogeneity versions of the K , L , F , G , and J functions to determine (with 95% confidence) whether they fitted the CSR, cluster, or regular model. These functions were also used with the maximum absolute deviation (MAD) and Diggle–Cressie–Loosmore–Ford (DCLF) tests, which can identify whether an SPP corresponds to the CSR model. The MAD and DCLF tests were also run employing the locally scaled K and L functions.

Note that all these methods are extensively explained by Baddeley et al. (2016) (analyses about marked patterns are also included in Baddeley et al.'s work).

All these analyses were performed for the faunal and lithic remains and for the coprolites. For the faunal remains, the entire sample (always ≥ 20 mm) was analysed (including burnt remains, remains with green fractures, cut, percussion, tooth, or trampling marks, and signs of rounding and polishing). Given the small coprolite sample, all such elements were included, irrespective of their size. The lithic elements were at first analysed including the entire sample (all elements ≥ 1 mm in length) and then by size category (≥ 10 mm and ≥ 20 mm in length). For separate analyses of burnt lithic remains, quartz, flint, rock crystal, porphyry, granitic and gneiss remains and remains to show signs of erosion/rounding due to the action of water, only elements ≥ 20 mm were included.

For the marked SPPs, the following procedure was followed:

1. A χ^2 test was used to examine the homogeneity of the samples; as before, all SPPs were found to be inhomogeneous ($P < 0.05$). An intensity map was produced for each mark.
2. Spatially varying probabilities were determined for each mark with a relative risk test. When the number of marks was > 2 , a joint assessment was made of the probability of certain marks appearing within the same space as another.
3. Finally, the possible correlation between the analysed marks was examined via random labelling analysis using the K - and L -functions (those available in the “spatstat” library for inhomogeneous samples). The K_{cross} and L_{cross} functions for inhomogeneous samples were also used to examine the presence/absence of correlation between marks (by pairs). These analyses are useful in order to measure the degree of segregation between marks.

The above procedures were also used to compare the distributions of the faunal remains with different degrees of rounding (R0, R1, R2, or R3) and polishing (P0, P1, P2, or P3) (0 = absence of alteration; 1 = low degree; 2 = medium degree; 3 = high degree of alteration) (for specific details of the different degrees see Cáceres 2002), the lithic remains of different materials, the lithic and faunal remains, the burnt lithic and faunal remains, the faunal remains and tools with percussion marks (hammerstones and anvils), and the faunal remains with tooth marks and coprolites.

Another type of spatial variable exists, known as a covariate, which Baddeley et al. (2016, p. 8) define as “any data that we treat as explanatory, rather than as part of the “response”. In the present work, the positions of the hearths in level F were understood as covariates. The xy coordinates for the centroids of the hearths (as determined using ArcGIS Desktop v.10.5 software) were used in the latter's spatial analysis. The “distfun” function of the “spatstat” library was then used to produce a “distance from hearths” map (Fig. 5c). ANOVA was then performed to examine the fitted effect of the covariate in the SPPs, followed by the use of the ρ function (“rhotat” in “spatstat”) to examine the influence of the distance to the hearths from any other type of remain at any selected point. This test is similar to the former one but shows in greater detail the possible variations in the intensity of remains with distance from the hearths. Finally, a Z_1 and Z_2 Berman–Lawson–Waller test was performed. All these tests (which are explained in detail by Baddeley et al. 2016) were performed for the burnt faunal and lithic remains (≥ 20 mm), unburnt faunal and lithic remains (≥ 20 mm), and the coprolites.

All were undertaken using R Studio software (RStudio Team 2021), with supplementary in-house code as required (Supplementary File [SF] 1). Derived data supporting the findings of this study are available from the corresponding author (AM) on request.

Results

Refitting analysis

Seventy-two refittings were undertaken (Fig. 6)—25 with lithic remains (19 of these with remains of known position) and 47 with faunal remains (44 of these with remains of known position) (See SF 2).

The majority of refitting exercises were undertaken with material from level F; only three (all faunal refitting) involved material from level D, and six from between these levels (three faunal and three lithic refittings), a consequence of the injection of material from level F towards level D.

Ten lithic refittings were performed for remains separated by less than 10 cm and five with their various pieces

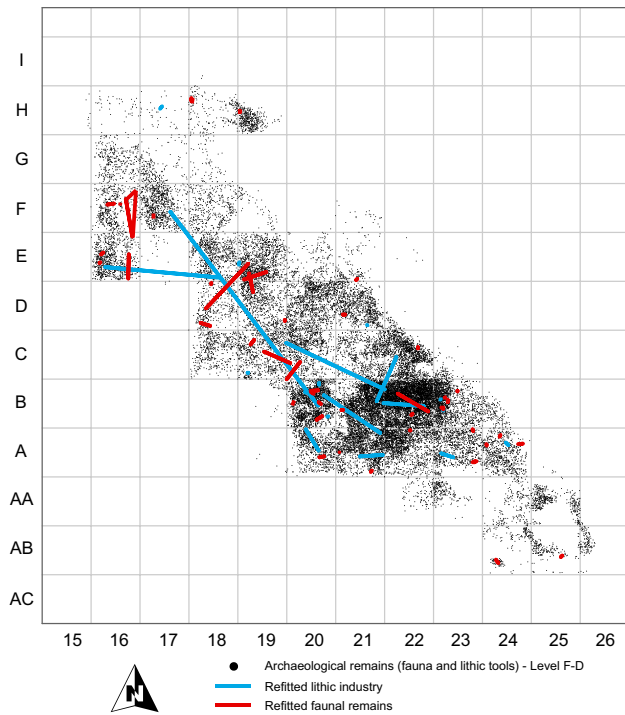


Fig. 6 Floor view of levels F and D, plus the faunal and lithic refittings

25–98 cm distant from one another. The remaining refittings involved pieces separated by over 1 m, and in one case, 4.98 m. Most of the refittings involved quartz pieces ($n = 15$) and quartzite ($n = 7$); flint, porphyry, and gneiss refittings involved just one each.

In the case of those refitting composed of not-mapped remains, the distances are similar to those provided by those mapped. The lithic tools of three refittings (L1, L2, and L4, see SF 1) are in the same excavation square, and a little distance can be considered. In other cases (L5, L6, and L7), the remains were found in different squares separated by 2–3 m.

Anatomical refittings were made, e.g., for isolated teeth of the same dental series ($n = 11$), as well as refittings for green ($n = 6$), dry ($n = 7$), or indeterminate fractures ($n = 23$). Seven faunal refittings involved more than two remains. The majority of the faunal refittings ($n = 32$) involved pieces separated by 1–10 cm. However, six involved pieces were separated by 10–20 cm, and five involved pieces were 49–72 cm apart. One faunal refitting (F10 in SF 2) involved several pieces separated by 39–139 cm. It must be noted that one faunal refitting is composed of non-mapped remains that were found in the same square (F47).

Archaeostratigraphic analysis

The examined transects can be seen in SF 3. Table 3 provides a summary of the results; Fig. 7 shows some of the most representative features revealed by their analysis,

Table 3 Results of the archaeostratigraphic analysis. Orientation refers to that of the transect; deformation refers to the presence (x) or absence of deformations at the top of level F, in contact with level D; Arch. Hiatus refers to the presence (x) or doubtful presence (?) of temporal hiatuses in the transect (note in the text that the idea of these being temporal hiatuses is rejected); cluster pattern refers to the presence (x) or absence of a possible cluster pattern; slope refers to that shown by the slope of the transect, which might be orientated towards a cardinal point (e.g., north) and may show concavities or convexities

Transect	Orientation	Deformation	Arch. hiatus	Clustered pattern	Slope
1	NE-SW	x		x	NE
2	NE-SW	x			NE
3	NE-SW		?		NE
4	NE-SW	x		x	Concavity
5	NE-SW	x		x	Flat surface
6	NE-SW	x			Flat surface
7	NW-SE	x	?	x	NW—flat surface
8	NW-SE	x		x	NW—flat surface
9	NE-SW				NE
10	NE-SW				Convexity
11	NE-SW		?		NE
12	N-S	x			Flat surface
13	N-S				N—flat surface—N
14	N-S			x	N—flat surface
15	N-S	x	?	x	N
16	N-S				Flat surface—N
17	N-S				N
18	E-W	x			Flat surface
19	E-W	x			W
20	E-W	x			W

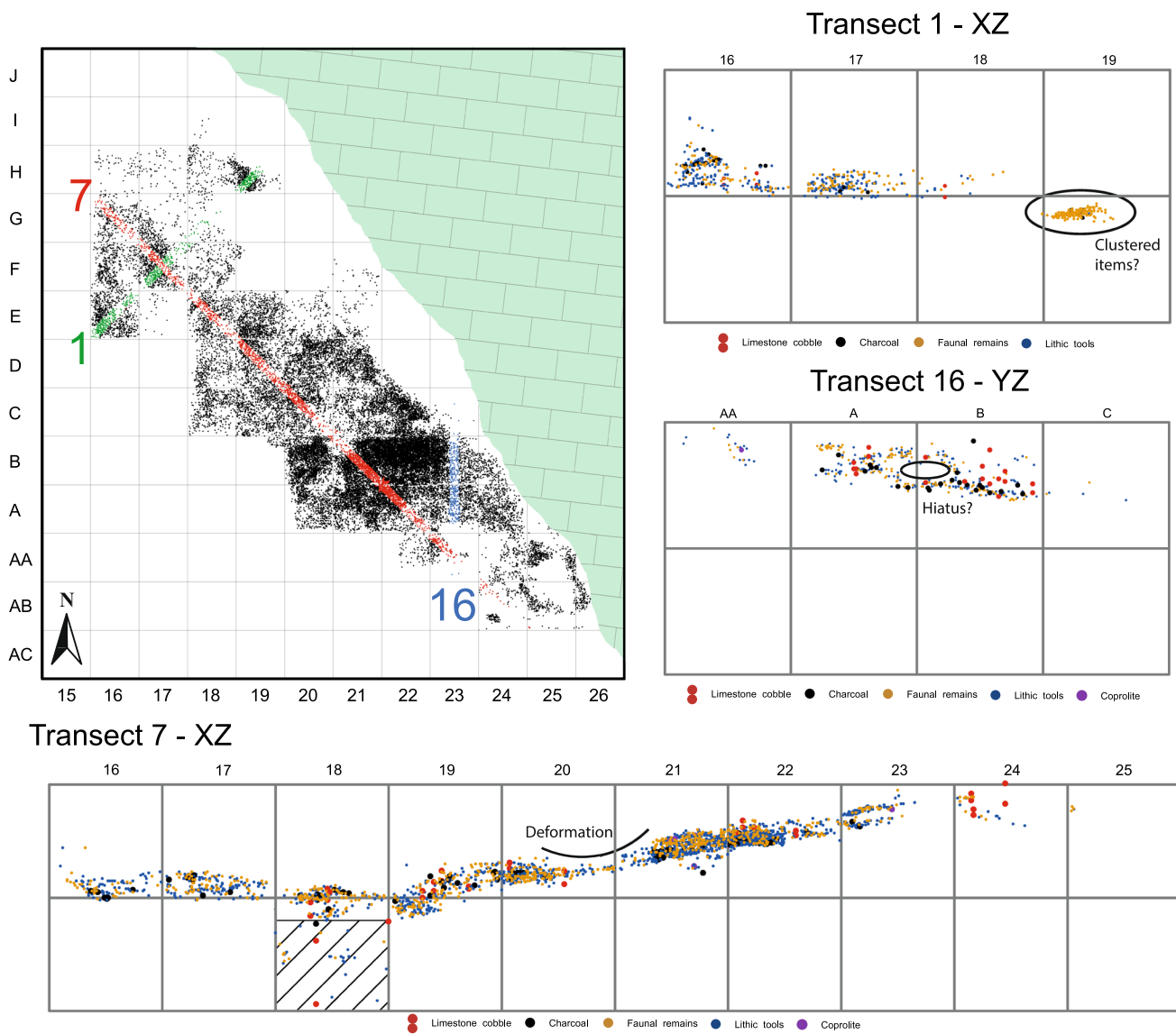


Fig. 7 Details of transects 1, 7, and 16 (floor view and profile). Note the presence of a cluster of faunal remains for transect 1, a hiatus filled by a large dolomite block for transect 16, and the clear slope of the site shown by transect 7. All squares are 1 m²

including the deformations produced when the ceiling of the rock shelter collapsed, the slope of level F, the possible existence of clusters of archaeological material, and temporal hiatuses. Firstly, visualisation of the transects revealed deformations in the ceiling at different points, clearly visible from the vertical distribution of remains along transects 1, 2, 4, 5, 6, 7, 8, 12, 15, 18, 19, and 20. In most cases, these deformations only affected small areas, although some were much larger, e.g., in the contact zone between squares E16 and F17 (transect 1), B20 and C21 (transect 4), B21 and C20 (transect 7), and C21 and B22 (transect 8).

The central/southeastern part of the site was higher than the northwestern part, as clearly illustrated by transects 7

and 8, which crossed the greater part of the excavated surface. The remaining transects reveal a slight difference in height between the parts of the rock shelter closest to its wall (which were higher) and those furthest from it (which were lower) (see transects 19 and 20). These features are quite obvious despite the deformations caused by the collapse of the ceiling.

Examination of the transects also revealed points with accumulations of archaeological material, i.e., in squares A22, B22, A21, and B21 (transects 7 and 8) in the central-south area. Here, a clear accumulation of faunal and lithic industry remains can be seen, coinciding with a topographically higher point. Another significant accumulation, mostly of

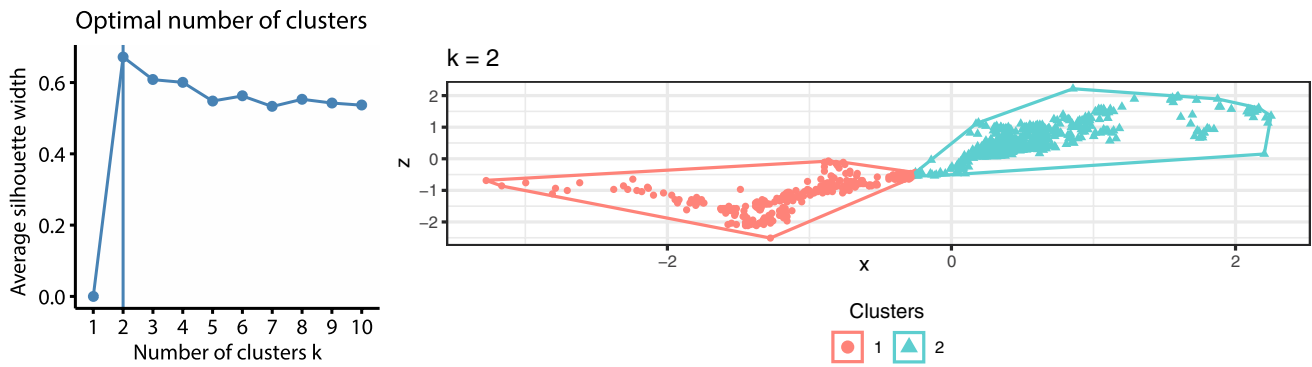


Fig. 8 Left: calculation of the optimum number of clusters for transect 8. Right: *k*-means analysis for the remains associated with transect 8

faunal remains, was noted for square H19 (transects 1 and 14). *k*-means analysis of the transect 8 remains (Fig. 8) showed that when these are divided into two clusters (i.e., the optimum number according to the average silhouette width test), one lies in the highest area of the site and one in the lowest. No archaeological sublevels of level F were seen.

Spatial analysis

For the lithic remains ≥ 1 mm and ≥ 10 mm, the faunal remains, and the coprolites, the pair correlation function showed that the null hypothesis for the CSR pattern could be rejected (Fig. 9). Indeed, part of the SPPs revealed a clear cluster-type distribution. For the lithic remains ≥ 20 mm, the same null hypothesis could not be rejected (Fig. 9c).

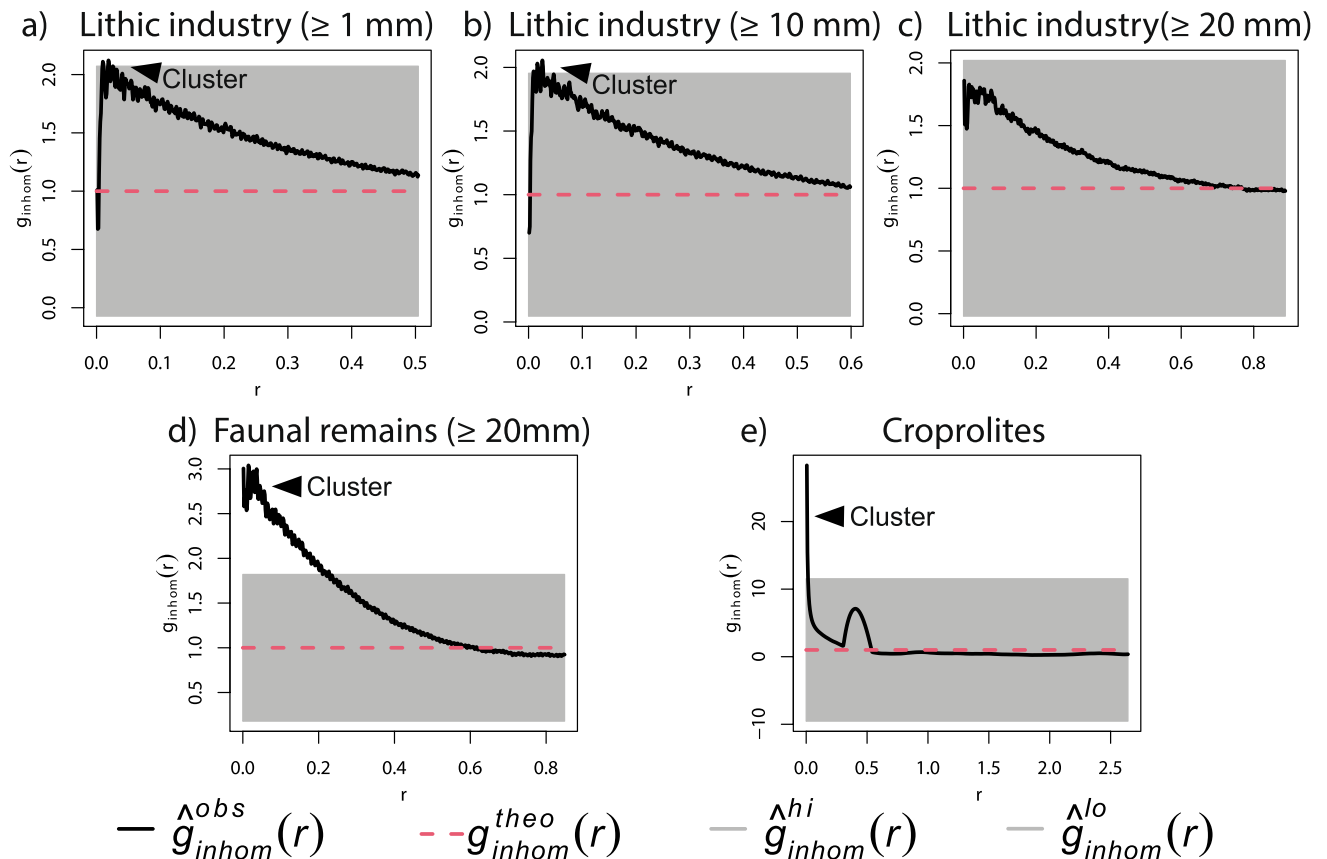


Fig. 9 Plot showing the results provided by the inhomogeneous pair correlation function. Acceptance region (shaded) for complete spatial randomness (with significance set at $P < 0.05$)

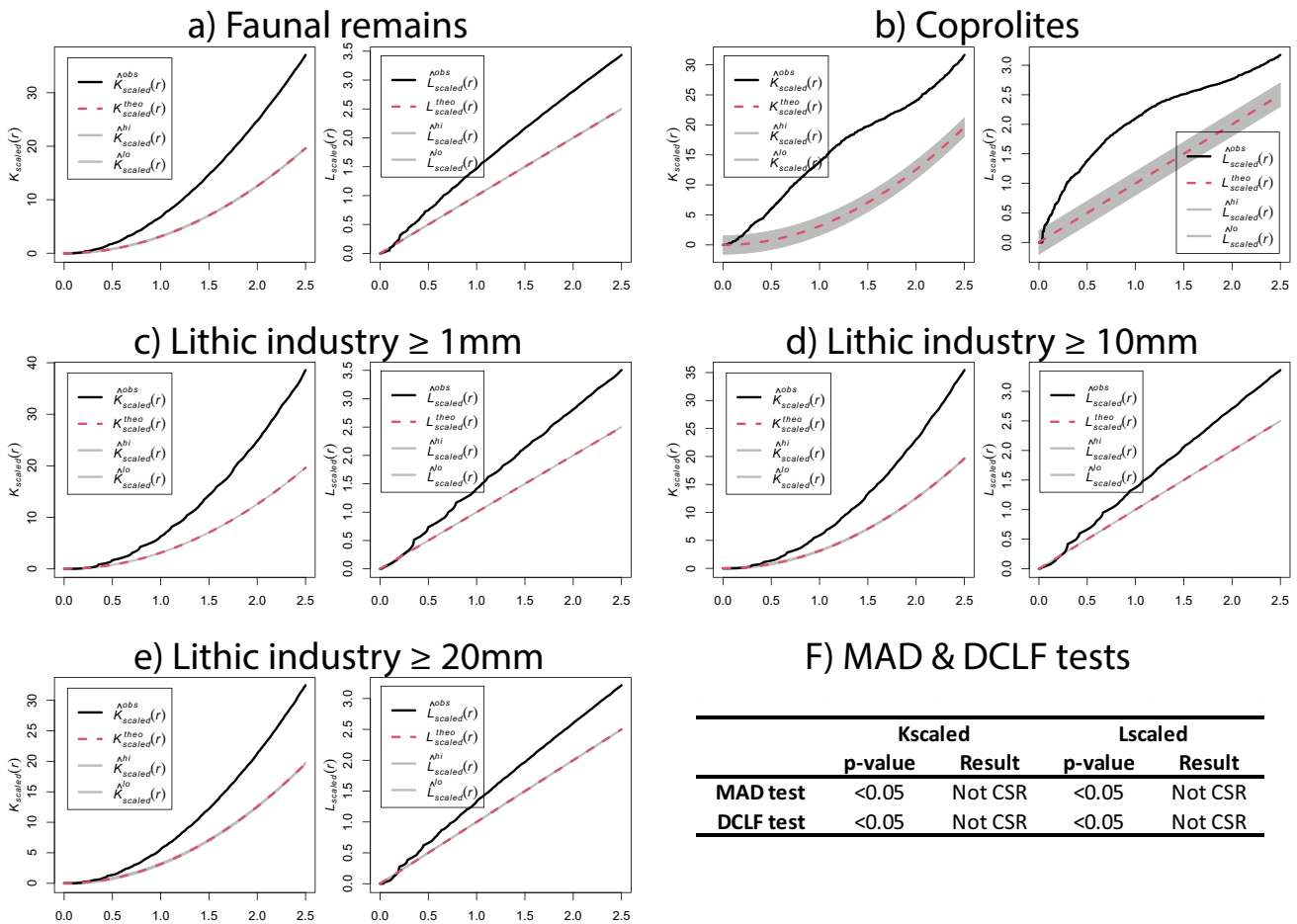


Fig. 10 Plot showing the results provided by the locally scaled K and L functions (a–e). Acceptance region (shaded) for complete spatial randomness (with significance set at $P < 0.05$). f Summary table

showing the results provided by the DCLF and MAD tests employing the locally scaled functions (note that the results are the same for all materials)

The use of the locally scaled K and L functions showed all the samples analysed to fit a cluster-type distribution (Fig. 10a–e). The use of the MAD and DCLF tests with these same functions (Fig. 10f) returned probability values of < 0.05 , ruling out that the distribution was random. All the spatial analysis results, except for those obtained using the pair correlation and locally scaled functions, are shown in SF 4.

Faunal remains

The analysis of all faunal remains together (SF 4, p. 1) revealed a large cluster in the centre-south of the site and a smaller one in the northern part. These results agree with those obtained using the K , L , G , and J functions, the DCLF test with the functions K , L , G , and J , and the MAD test with the functions G and J . This pattern is visible in the probability and intensity maps (Fig. 11a). The probability and intensity maps for the burnt bones (Fig. 11b; SF 4, p. 2)

showed a large accumulation of remains in the centre-south, although only the DCLF and MAD tests with the J function rejected the null hypothesis for the CSR pattern. The same was seen for bones with signs of trampling (SF 4, p. 7).

The bones with cut (SF 4, p. 4) and percussion marks (SF 4, p. 5), showed very clear distribution patterns with accumulations in the centre-north and centre-south of the site (Fig. 11c, d). The bones with green fractures seem to be related to the centre-south area (SF 4, p. 3).

However, it must be noted that for bones with percussion marks (SF 4, p. 5), no test rejected the null hypothesis for the CRS pattern. The same was seen for bones with tooth marks (SF 4, p. 6), although the intensity and probability maps (Fig. 11f) suggested these to be accumulated on two high-density areas at the centre-north and centre-south of the site (however, note that the sample size was small).

For the bones showing rounding (SF 4, pp. 8 and 9), and polishing (SF 4, pp. 10 and 11), the pattern of distribution was different to all those described above. When analyses

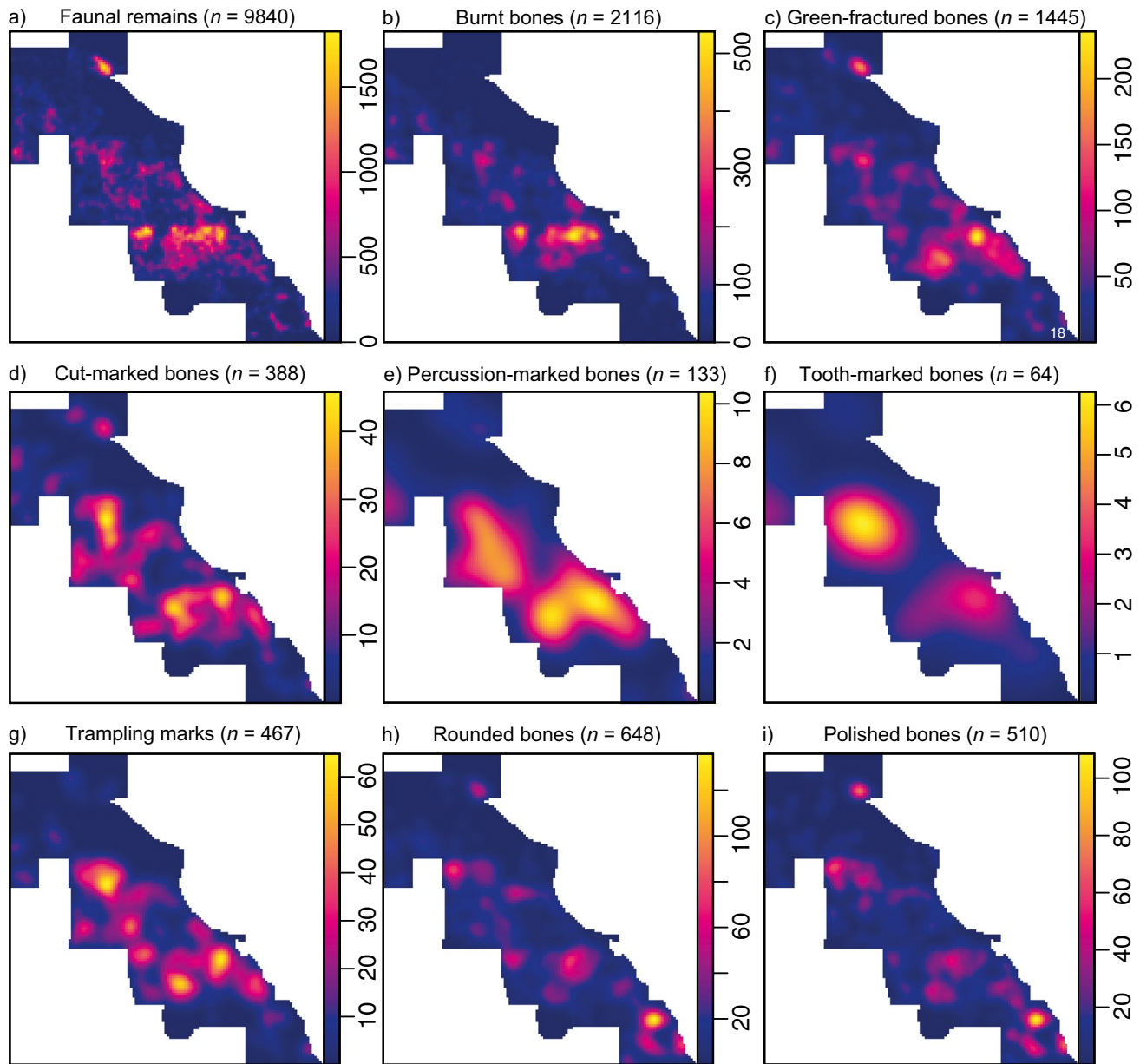


Fig. 11 Maps showing the kernel smoothed intensity for the different faunal remains examined

were performed for these types of bone affectation separately, without including degrees of intensity (SF 4, pp. 8 and 10), both returned a cluster distribution (as identified by the *J* function and the DCLF and MAD tests employing the *J* function). However, the intensity maps were not very clear (Fig. 11h, i), with the maximum for both observed in the southeast of the site. This interpretation was reinforced when an analysis for a marked SPP was run that included the different degrees of rounding (SF 4, p. 9) and polishing (SF 4, p. 11) recorded. When taking all bones together, P0 and R0 bones (i.e., with no alteration) were most likely to appear anywhere in the site (see spatially varying relative

risk; SF4 p. 9 and 11), but when analysing rounding- and polishing-affected bones separately, P1 and R1 (both little affected), P2 and R2 (medium affected), and R3 (strongly affected) bones were seen to be more frequent in the south-east. No correlation was detected between the different degrees of affectation.

Coprolites

The coprolites (SF 4, p. 12) showed a cluster distribution pattern (as determined by the *L* function and the DCLF and MAD tests with the *L* and *J* functions) over a

space-occupying part of the centre-south of the site and coinciding (for the most part) with a hearth (see Figs. 2 and 5c).

Lithic industry

The lithic industry elements showed a clear cluster pattern (Fig. 12a), mainly focused in the centre-south of the site, as determined by the K , L , and J functions and the DCLF and MAD tests employing these functions. The same patterns were seen when examining the remains ≥ 1 mm (SF 4, p. 13), ≥ 10 mm (SF 4, p. 14), and ≥ 20 mm in length (SF 4, p.

15) (although in the latter of these, the DCLF test employing the K function did not reject the null hypothesis for the CSR distribution). For the burnt lithic remains, an intensity pattern similar to that for all lithic elements was obtained, but the K and L functions also indicated a regular pattern (SF 4, p. 16) (Fig. 12b).

The analysis of the raw materials (SF 4, pp. 17–22; Fig. 12d–i) returned very similar intensity and probability patterns, with the lithic industry focused at the centre-south of the site and extending slightly towards the centre-north for quartz, flint, quartzite, and porphyric rocks. However, only the quartz (SF 4, p. 17) and gneiss (SF 4, p. 22) patterns

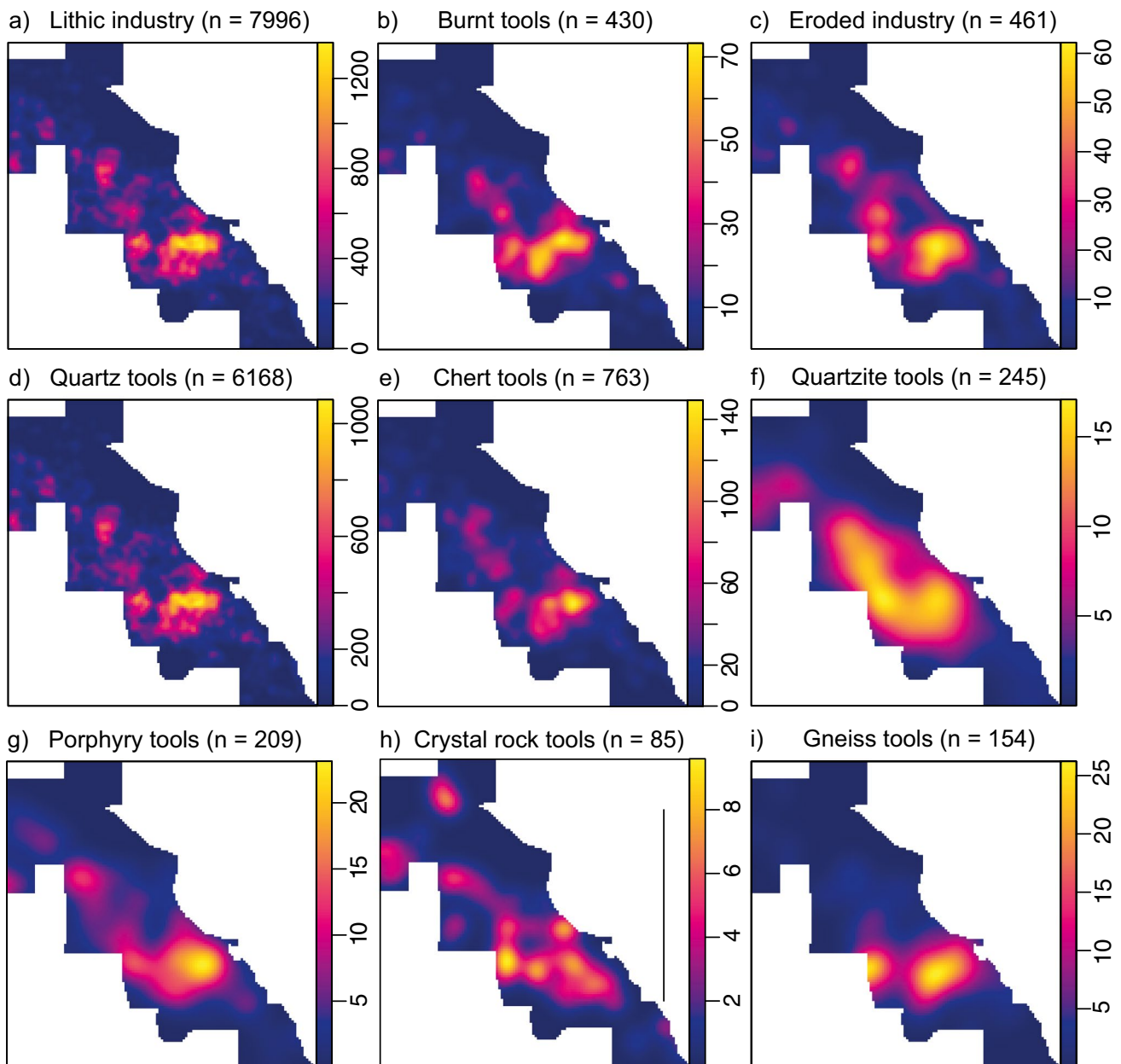


Fig. 12 Maps showing the kernel smoothed intensity for the different lithic industry remains examined

were significant. The quartz showed a cluster pattern (identified by the K and L functions and the DCLF and MAD tests employing these functions), coinciding with the general pattern for the lithic industry (quartz was the dominant raw material); in contrast, the gneiss materials appeared in greater intensity towards the centre-south and in a regular pattern, easily seen in the intensity and probability maps. The K -cross and L -cross functions (SF 4, p. 23) showed a negative correlation (i.e. segregation) between all the raw materials.

Finally, the lithic remains showing evidence of water erosion (SF 4, p. 24) fell into a CSR pattern, with the greatest intensity and probability in the centre-south of the site, coinciding with the lithic industry cluster.

Correlation analysis

The faunal and lithic industry remains (SF 4, p. 25) (Fig. 13a, b) showed positive and negative correlation, as determined by the K cross and L cross functions (K cross function only identifies negative correlation). The constructed maps show that the probability of both types of elements appearing across the site is similar, except in the north, where the lithic remains showed very low probability values. The same analysis was performed for burnt remains (SF 4, p. 26) (Fig. 13c, d) and K cross and L cross functions revealed a negative correlation. It must be noted that both types of burnt materials are located in the same locations and very close to the hearths, which can be indicative of a certain relation between the location of hearths and the accumulation process of the faunal/lithic remains.

Negative correlation was also detected between the faunal remains with percussion marks and lithic remains related to percussion (i.e., hammerstones and anvils) (SF 4, p. 27) (Fig. 13e, f). No correlation was identified between the distribution of the coprolites and faunal remains with tooth marks (SF 4, p. 28).

Hearths as covariates

Strong correlation was detected between all types of remains (faunal, lithic, burnt lithic remains, and coprolites) and the position of the hearths (the covariate) (SF 4, pp. 29–33). Fitted intensity analysis revealed the quantity of all remains to decrease with distance from the hearths (ANOVA, $p < 0.05$). In addition, the Berman–Lawson–Waller Z_1 and Z_2 analysis indicated the expected and observed distributions to be significantly different ($p < 0.05$).

The relative intensity (ρ) analysis detected the same scenario (i.e., decreasing numbers of remains with distance from hearths). For the coprolites (SF 4, p. 33), this was strongly marked in the first 50 cm of distance. The faunal (SF 4, p. 29), burnt faunal (SF 4, p. 30), and lithic industry

(SF 4, p. 31) and burnt lithic industry (SF 4, p. 32) remains showed similar behaviours (Fig. 14), with greater intensities between 0 m and 0.5 m, with a new, smaller peak at 1.5 m, and then a recovery at 4 m. ρ analysis also revealed a small increase in the number of faunal remains at a distance of 3 m from the hearths, coinciding with the small cluster identified in the north of the site (square H19) during the archaeostratigraphic and intensity analyses.

Discussion

The spatial analysis results for the refitting connections show most of the corresponding elements to be separated in most cases by short distances, especially for the faunal remains. This suggests the entire site to have been a little disturbed. For example, most of the bone refittings for fresh fractures were under 10 cm apart, indicating these bones to have likely been fractured very close to where they were found. Similarly, the short distance between the elements making up the lithic refittings suggests the possible existence of knapping areas. However, nowadays we have founded few lithic refitting to reconstruct clear knapping areas that should be logically present at the site due to the *chaîne opératoires* of some raw materials being complete (Márquez et al. 2013). This aspect must be improved in the future by trying to reconstruct complete/near-complete knapping sequences. The finding of refittings between levels D and F is to be expected given the infection of level F into level D (Pérez-González et al. 2010). The majority of the refittings were found in the centre-south of the site, the main area of concentration of remains (see below).

The archaeostratigraphic analysis performed with all available data up to 2019 suggests that the two sublevels of level F proposed by Sánchez-Romero et al. (2017) are not clear. Firstly, the k -means analysis of transect 8 suggests the remains to be separated topographically rather than archaeostratigraphically. Secondly, some transects (i.e., 3, 5, 11, 15, and 16) showed hiatuses in terms of archaeological materials—hiatuses with no archaeostratigraphic explanation. Indeed, the dolomite blocks in transects 5 and 16 clearly show higher and lower xyz coordinates than these hiatuses and must therefore fill them. Finally, Sánchez-Romero et al. (2017) only detected their sublevels in certain places; they were not appreciable in most areas of the site. Together, these arguments (specially that we cannot identify different sublevels across the entire surface of the site) suggest that nowadays we cannot differentiate different sublevels at the level F. However, their existence cannot be completely discarded due to the occupation pattern at the site. In the future, new approximations to the archaeostratigraphic analysis of the site must be done when the entire level F is fully excavated.

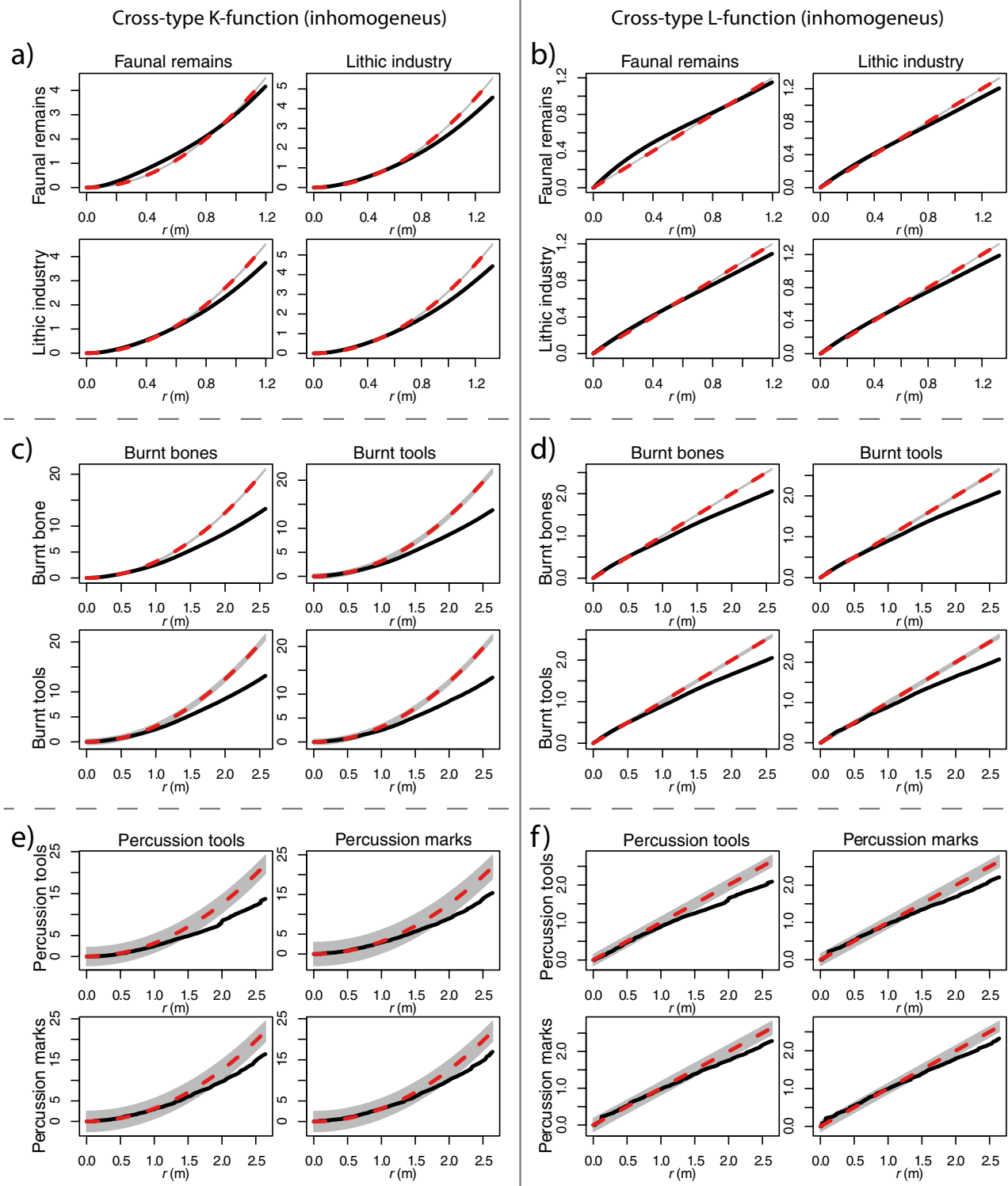


Fig. 13 Results for the *K-cross* and *L-cross* function analyses of the faunal and lithic industry remains (a, b), burnt faunal and lithic industry remain (c, d), and percussion tools and faunal remains with percussion marks (e, f)

The archaeostratigraphic results also suggest the existence of different clusters (confirmed in the spatial analysis). They also show that the slope of level F is coherent with that

expected given the direction of the Valmaíllo Stream and the formation of its terraces (i.e. the south of the site is higher than the north) (Karampaglidis 2015; Pérez-González et al.

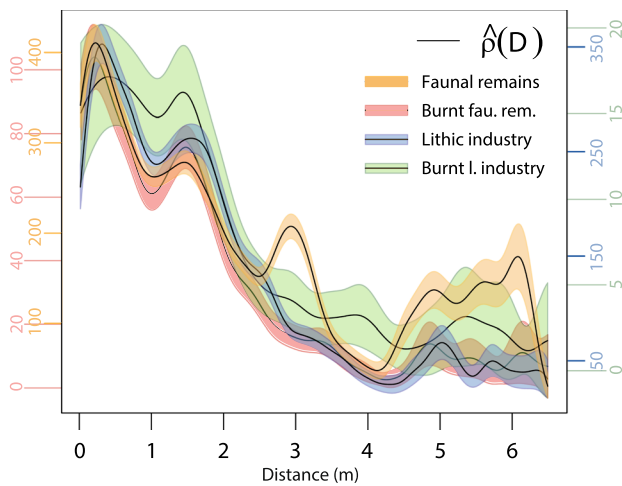


Fig. 14 Overlap of the relative intensities (ρ) of the faunal and lithic industry and burnt archaeological remains (faunal and lithic). In the construction of this figure, the x -axis was slightly modified (see SF 4 for a view without this modification). The y -axes cover the values for each of the samples (see colour legend). Note the peak at 3 m for the faunal remains

2010). An analysis of the slope of the transects confirms that the southeastern and centre-southern areas are indeed higher than the centre-north and north. The area closest to the rock shelter wall is also higher than the more external areas. These findings reveal the absence of strong stratigraphic alterations in level F (i.e., beyond the clear hydroplastic deformation of its top), such as faults or strong erosion.

The spatial analysis revealed a large cluster of archaeological material (faunal and lithic industry remains) in the centre-south of the site. This was confirmed by analyses involving different functions, especially K , L , and J (the last of which is the most sensitive, especially with small samples). The DCLF and MAD tests employing the latter functions also identified non-random patterns. The analyses involving the pair correlation function and locally scaled functions also detected cluster-type accumulations, as did the Hopkins–Skellam and Clark–Evans tests in nearly all analyses. However, the results these last tests provide should not be understood as evidence of a cluster pattern but as back-up to that provided by the χ^2 test, which suggested an inhomogeneous distribution (Baddeley et al. 2016).

The existence of a correlation between the lithic and faunal remains is of particular interest since it suggests their anthropic accumulation (the best example being the correlation between percussion tools and bones with percussion marks). It might be suggested that the accumulation has its origin in a tractive process (e.g. in water currents), but the topographic features of the site and of the cluster itself rule this out (see Fig. 7) (Domínguez-Rodrigo et al. 2018). If some phenomenon had significantly moved the materials in the cluster, they would have been concentrated at the lowest

part of the slope, i.e. the centre-north and northwest, not at its top, i.e. the centre-south. Moreover, few of the archaeological remains show any sign of having been affected by water. The anatomical representation of the accumulation also reveals it to have been little affected by water (Moclán et al. 2021).

Previous works related to the taphonomic and zooarchaeological analysis of the site have pointed out that at least three different carnivorans have accumulated/modified faunal remains at NV. Lynxes are the main accumulator of rabbits, and most parts of coprolites of the site have been identified as produced by these animals (no hyena coprolites have been identified at the site) (Arriaza et al. 2017). Other small carnivores (such as mustelid) have also modified/accumulated herpetofaunal remains at the site (Blain et al. 2022). In addition, hyena activity has also been identified at the site as a scavenger of remains accumulated by Neanderthals (Moclán et al. 2020, 2021). It must be noted that the existence of small-sized animals (10–50 kg) has also been connected with short episodes of accumulation by a large carnivore (e.g. hyenas, lions) (Moclán et al. 2021). Thus, we have tried to relate the spatial location of coprolites and tooth marks to shed more light on this topic.

The coprolites showed a slightly different distribution than the other materials. While they too were mostly found in the centre-south, they do not appear to be related to the main cluster in that area. Rather, they appear over a hearth (see Figs. 2c, 5c, and SF 4, p. 12 and 33). This distribution, plus the fact they are mainly lynx coprolites (Arriaza et al. 2017), is coherent with the tendency of carnivores to enter anthropic sites when these are not occupied and to move around the remains left in hearths (Arilla et al. 2020; Camarós et al. 2013). In this sense, it can be argued that at least during one of the lynx arrivals, they were able to use a hearth as a latrine.

There is no correlation (and the high-intensity areas of both materials are clearly different) between the carnivore tooth marks on macrofaunal remains and coprolites produced by lynxes, which can be interpreted as new evidence of at least the use of space by two different carnivorans. The distribution of the remains with tooth marks appears to be slightly different to the anthropically affected remains, appearing in greater density in the centre-north of the site and not in the main cluster. This SPP is difficult to explain if carnivores were only scavengers of the carcasses left by Neanderthals. However, it is possible that at some point when no Neanderthals were present, carnivores may have brought a small prey animal (10–15 kg) back to the rock shelter, as we previously proposed (Moclán et al. 2021), resulting in this different distribution—a phenomenon recognised at other sites (Sánchez-Romero et al. 2020; Zilio et al. 2021). In this sense, spatial analyses of the site support the previous interpretations related to the carnivore activity at the site.

The general distribution of all the remains—not just that of the coprolites—corresponds with the location of hearths (concentrated in the central area of the site). The different analyses undertaken clearly reveal the greater concentration of materials close to the hearths, their presence diminishing with distance from these structures. This agrees with the indications of other authors who have linked hearths to areas of activity (Bartram et al. 1991; Binford 1978a, 1983; Fisher and Strickland 1991; O'Connell et al. 1991; Vaquero and Pastó 2001; Yellen 1977). The same idea has been reached in a number of spatial studies involving a Neanderthal context (e.g. Enloe et al. 1994; Rosell et al. 2012a; Vaquero and Pastó 2001; Vallverdú et al. 2005, 2012; Spagnolo et al. 2019, 2020; Carbonell 2012; Romagnoli and Vaquero 2016; Vaquero et al. 2017), although the methods used in the present work confirm the statistical significance of this link.

Together, these results would appear to support the second hypothesis of this work: that there is but one main cluster of archaeological materials (i.e., the space was used in the same way in all occupations, with no areas given over to different activities), in this case at the centre-south of the site. This cluster would have formed as the same behaviour pattern was repeated during successive occupations, with hearths made and the majority of activities undertaken in this area. Similar findings have been reported for Lower Pleistocene sites in Africa, such as FLK Zinj and PTK (Domínguez-Rodrigo and Cobo-Sánchez 2017), where there is just one cluster related to communal activities. The Neanderthal hunting camp at Umm el Tlel (Syria) may show the same arrangement, with a cluster of materials in its southeast, although spatial studies are needed to confirm this (Griggo et al. 2011). Certainly, this pattern would seem reasonable for the NV site since it was a hunting camp where the members of the hunting party would have undertaken necessary tasks before returning to their base camp, where a multi-cluster pattern would be expected with areas for different activities (Gabucio et al. 2014; Kuhn 1992; Mellars 1996; Moncel and Rivals 2011; Picin and Cascalheira 2020; Rendu et al. 2011; Rosell et al. 2012b). Interestingly, the present results contrast with those obtained for levels Pa and Pb of the Abric Romaní site (Spain), a hunting camp that shows signs of different activities depending on the animal captured (the site has been interpreted as a residential site in the case of the accumulation of cervids and as a hunting camp in the case of equids). Indeed, the distribution pattern is regular for most remains (those of cervids and equines), with a cluster of cervid-only remains in one small area. This has been proposed as related to differences in the processing of cervid and equine carcasses (Marín et al. 2019).

The regular pattern of equids of the levels Pa and Pb of Abric Romaní (Marín et al. 2019) is indeed completely different to our data provided by NV, and therefore these differences could indicate the existence of differences between

both sites. In our opinion, two different explanations can be proposed (that can be interrelated between them), one related to the differences between the formation processes of the sites and other related to the areas that can be occupied at both sites.

First, in the case of the Abric Romaní, the formation processes produce a quick sealing of the different levels, which does not exist in NV. This situation can obliterate the occupation patterns. For example, if some occupation patterns occur at the site with the same scenario can create a cluster-type model such as the NV model. However, if few occupations or only one occupation is located at the site, maybe it cannot create a cluster-type model and create a more random or even regular model instead. On the other hand, the usable surface of the Abric Romaní is higher and flatter than what we have identified at NV, which can lead to the entire surface being occupied in a similar manner. However, as we have seen, in NV the topography seems to be an important variable to use the space, which may indicate that this variable is important when it comes to understanding the pattern of occupation of space by Neanderthal groups (e.g. flat surfaces provide more regular patterns?).

We consider that this second option is more likely due to the results provided by the hunting camp of Umm el Tlel, where a very short-term occupation is identified and the SPP is characterised as cluster-type (Griggo et al. 2011).

The present results do, however, provide evidence against a one-cluster model for the site. Firstly, the southeast of the camp contains significantly more rounded and polished faunal remains than any other area, revealing a cluster pattern possibly associated with an area altered by water. However, the degree of rounding and polishing of the bone remains is not very great, and the lithic industry is not affected at all, suggesting that any water action could not have been strong. Secondly, the archaeostratigraphic and spatial analysis of the faunal remains identified the presence of a secondary cluster of such remains in the north of the site (squares H19 and H18). The sketches made during excavation work show this secondary cluster to be isolated from the rest of the site by decimeter-sized dolomite blocks (Fig. 15).

To determine how the composition of the secondary cluster differs from that of the remainder of the site, a comparison of percentages and ratios chosen for their taphonomic value (e.g. percentage of remains with cut marks) or importance in the NV context (remains of large and medium-sized animals and quartz lithic industry) was made with different parts of the site (including the southeast [which shows some signs of water alteration], and parts approaching the central area) (Table 4). Visual comparisons of the various ratios revealed clear differences between the secondary cluster and the rest of the site, with the former showing higher or lower values depending on the remains in question (Table 4), although the percentages for certain types of a taphonomic

Fig. 15 Cartographic representation of the remains in squares H18 and H19, produced from sketches made during the excavation

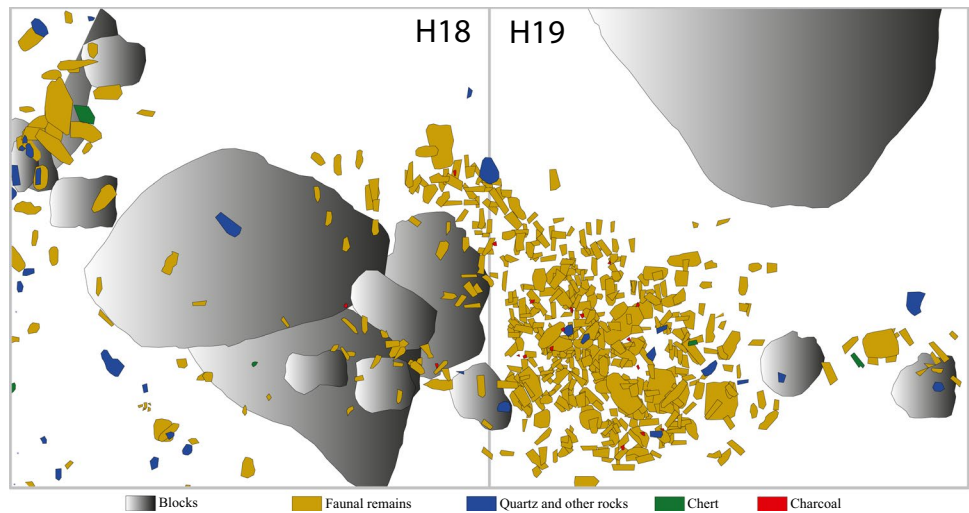


Table 4 Ratios and percentages calculated for different areas of interest. Values in bold are the highest for each row; those underlined are the lowest. Note that the secondary cluster nearly always shows the highest or lowest values *LS*, large-sized animals; *MS*, medium-sized animals

Ratios	NV sample	Main cluster	Secondary cluster	Southeast area (water affected)	Main cluster extended	NV Sample excluding the secondary cluster	NV Sample excluding the main cluster	NV Sample excluding both clusters
Bone/lithic tolos (> 2 cm)	1.48	<u>1.26</u>	38.23	2.95	1.35	1.42	1.62	1.52
Quartz/other raw materials	3.34	<u>3.18</u>	16	3.96	3.21	3.34	3.51	3.50
Quartz: cortical/non-cortical	0.13	<u>0.1</u>	0.6	<u>0.1</u>	0.13	0.13	0.17	0.17
Burned tools/non-burned	0.04	0.04	<u>0</u>	0.03	0.04	0.04	0.04	0.04
Bone/tooth	8.21	8.06	247	32.53	<u>7.4</u>	7.85	8.16	7.58
LS/MS	2.09	2.16	3.32	2.40	2.06	2.06	2.08	<u>2.04</u>
LS/other sizes	1.52	1.6	2.92	2.10	1.47	1.50	1.50	1.47
LS: long bones/flat bones	6.87	6.88	<u>2.19</u>	4.12	8.16	7.53	6.97	7.99
MS: long bones/flat bones	5.79	4.74	<u>2.17</u>	3.75	6.1	6.06	6.48	6.87
Burned bones/non-burned	0.28	0.38	<u>0.008</u>	0.090	0.32	0.3	0.23	0.3
%Cut marks	3.35%	2.48%	<u>2.41%</u>	2.46%	3.58%	3.39%	3.95%	4.06%
%Percussion marks	1.11%	0.93%	<u>0.4%</u>	0.5%	1.29%	1.14%	1.31%	1.37%
%Tooth marks	0.61%	0.4%	<u>0.2%</u>	0.53%	0.69%	0.63%	0.79%	0.83%
Green fractured bones	12.29%	<u>9.7%</u>	11.87%	17.19%	12%	12.31%	14.01%	14.16%
Green fractured long bones	52.45%	52.12%	55.56%	67.62%	<u>50.8%</u>	53.05%	52.98%	52.86%
%Bone flakes	15.54%	16.82%	13.56%	<u>9.18%</u>	17.43%	16.62%	15.05%	15.13%
Trampling	4.19%	3.62%	<u>0.8%</u>	3.86%	4.77%	4.33%	4.58%	4.85%

alteration affecting bones were only slightly lower than those recorded for the rest of the site. However, the secondary cluster showed very low percentages of remains affected by trampling (0.8%), rounding (4.43%), polishing, and very few lithic remains altered by water. This rules out that this accumulation came into being via water or any other form of transport. The small number of bones with tooth marks also rules out carnivores as the generating agent.

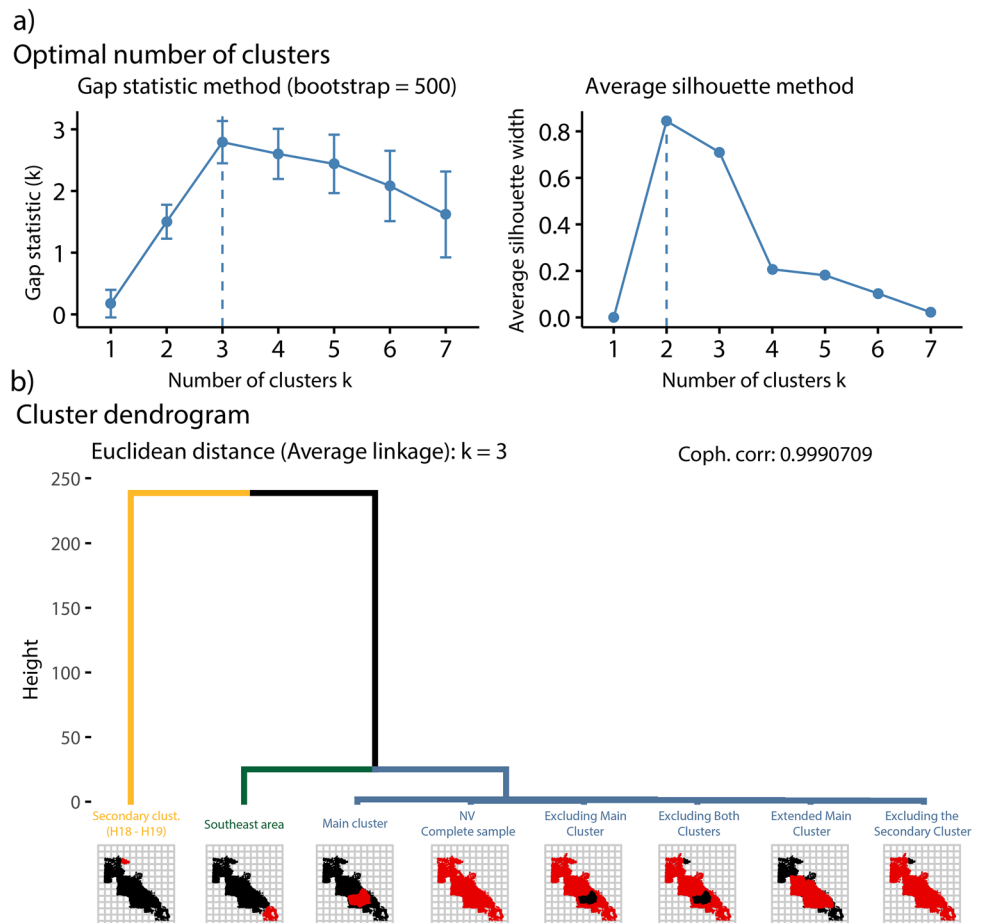
To explore the possible differences between the secondary cluster and the rest of the site in greater depth, a hierarchical clustering analysis was undertaken using the data in Table 4. This analysis was performed using the “factoextra” library (Kassambara and Mundt 2020) in R (R Core Team 2022). The cophenetic correlation indices returned by different types of hierarchical clustering dendrogram (Manhattan, Euclidean, and maximum), determined using the maximum, single, complete, average, centroid, and ward.D methods, showed the Euclidean dendrogram produced by the “average” method to be the most powerful (cophenetic correlation index = 0.99). The gap statistic (bootstrap = 500) and average silhouette methods were used to divide the Euclidean hierarchical dendrogram into “dendrological clusters”, with the former method suggesting there to be three and the

second just two (Fig. 16). Under all the conditions outlined in Fig. 16, the main (spatial) cluster groups with most of the site. The gap statistic, however, shows the southeastern area to be different. The secondary cluster also appears clearly differentiated. The high content in faunal remains and low content in lithic remains points to its use in carcass processing or perhaps a disposal area.

The site might thus be said to show a multi-cluster pattern, as contemplated by the first hypothesis. Certainly, as shown in Fig. 15, the secondary accumulation is completely isolated from the rest of the site and indeed entirely marked by the dolomite blocks. The site's Neanderthal occupants may have put these blocks in place, but it is also possible that they simply fell into their present positions when the ceiling collapsed. However, when taking all these findings together, the remains in NV level F would appear to have a cluster distribution as detailed in hypothesis 2. The evidence for accepting hypothesis 1 is not as strong.

In our opinion, what we can interpret about all these aspects related to the spatial pattern of NV level F is that a high variability can be identified at Neanderthal hunting camps from a spatial point of view. There is a few previous information that we can use to compare statistically with

Fig. 16 **a** Calculation of the optimum of clusters via the gap statistic and average silhouette width methods; **b** dendrogram showing how the different areas of level F group together according to their archaeological remains. The lower part of the dendrogram shows the planimetry of level F; the remains analysed are in red, and those in black were excluded



the SPP of NV. Note that only with the examples of Abric Romaní levels Pa, Pb, and NV can we consider two opposed models of occupation of a hunting camp in a rock shelter (regular vs. cluster-type SPPs). This situation allows us to propose by the moment that Neanderthal occupied these types of hunting camps in relation to their morphological features. In the case of NV, the main cluster is clearly related to the top area of the site, which can make it more comfortable for different reasons (e.g. less humidity, less accumulation of debris).

A question that may arise from the study presented here is: what is the real importance of the main cluster of the site (and the second one)? And what happens in other areas of the site from an archaeological point of view? We must say that during the development of this work and the specific taphonomic analysis of the site (Moclán et al. 2021), we noted that the entire surface of the site is dominated by the same types of animal and lithic remains (i.e. mainly bovinds and cervids dominate the assemblage, carnivore remains are rare, quartz tools [especially simple flakes] are common along the excavated surface). In fact, in two preliminary taphonomic works (Huguet et al. 2010; Moclán 2016; Moclán et al. 2017) focused on the centre-north area of the site, we concluded exactly the same anthropic pattern for the site as that recently provided by Moclán et al. (2021).

What does this mean? We consider that this situation can be considered evidence that the Neanderthal occupation of the shelter was carried out on the entire surface in a common way; however, the main cluster is the area where human activities (e.g. butchering, knapping) were carried out most frequently/intensely, which ends up generating the SSP identified here. In fact, the faunal remains located at the secondary cluster are extremely similar to that of other parts of the site (see Table 4), which we think is indicative that the behaviour related to the secondary cluster is similar to that performed at other parts of the site.

In summary, we can conclude that the palimpsestic nature of this hunting camp is reflected in a cluster-type model that is characterised by the repeated use of the same space during different occupation phases. This occupation pattern generates a main accumulation that can be considered small in comparison with the whole surface of the site, but that can be explained by its topography and, probably, by the small size of the groups that are normally included in hunting parties (e.g. Binford 1978a).

Conclusions

The present work shows NV level F to contain archaeological elements little altered by diagenetic or biostratinomic processes. The present spatial analysis also reveals that:

- The site was used in the same way in its different occupations, leading to the formation of the main cluster. This area is topographically higher. The activities undertaken in the area of this cluster were related to the presence of hearths.
- An area in the southeast of the site contains elements with a degree of water alteration, although this was very mild and the area maintains other properties that relate it to the rest of the site.
- A small area of activity in the north of the site is limited by dolomite blocks. This would appear to be an area associated with carcass processing or perhaps a disposal area.
- Taking all the findings together, the remains in NV level F would appear to have a cluster distribution as detailed in hypothesis 2. The evidence for accepting hypothesis 1 is not as strong. This differs from the behaviour recorded at the hunting camp of Abric Romaní level P, where a regular SPP has been identified (Marín et al. 2019).
- Carnivores entered the site, as revealed by tooth marks on some faunal remains and by the presence of coprolites (Arriaza et al. 2017; Moclán et al. 2020, 2021). Lynxes and (probably) hyaenas (Moclán et al. 2021) used different areas of the site. It would appear that, at least on one occasion, a lynx undertook activity over an abandoned hearth.

These results help us gain a better understanding of how Neanderthals used their hunting camps, and if a comparison is made between NV level F and Abric Romaní levels Pa and Pb, it allows us to identify that high variability exists among these occupations. The main cluster detected in NV level F indicates the occupants had an interest in undertaking activities together, perhaps collaboratively, including those related to carcass processing and lithic industry.

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Author contribution AM, RH, BM, and EB conceived the idea behind this work. AM wrote the manuscript and the required code, conducted the GIS and statistical analyses, and performed all faunal refitting. Lithic refitting was performed by BM and technicians at the Museo Arqueológico Regional. AM and RH conducted the taphonomic analysis. BM undertook the technological analysis of all lithic industry

elements. All authors supervised the archaeological excavations. JLA, AP-G, and EB supervised the project. All authors discussed the results and contributed to the final manuscript.

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Data availability Not applicable.

Code availability Code is included as supplementary material.

Declarations

Competing interests The authors declare no competing interests.

Ethical approval Not applicable.

Consent to participate Not applicable.

Consent for publication Not applicable.

Conflict of interest The authors declare no competing interests.

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