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RESEARCH

Homo sapiens and Neanderthal Use of Space at Riparo Bombrini (Liguria, Italy)

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Abstract

Because it is often assumed that fundamental behavioral differences distinguish Neanderthals and *Homo sapiens*, the ability to structure space within the sites they occupied into distinct activity areas is often invoked as a key distinctive trait of our species. However, this behavior has never been assessed for both groups at a single site, hindering direct comparisons to date. To help resolve this question, this study uses a single methodology to evaluate the spatial organization in the Protoaurignacian levels (A1-A2, associated with *Homo sapiens*) and the latest Mousterian levels (MS1-MS2, associated with Neanderthals) at Riparo Bombrini (Liguria, Italy) to assess the changes over these three stratigraphic units vis a vis other information about site use. Combining GIS and quantitative methods allows the study of the spatial distribution of plotted finds and features in these levels, showing that Neandertals and *Homo sapiens* organized their living spaces in accordance with the duration of occupation, the occupation intensity, the tool assemblage and the faunal exploitation. Our results indicate that there is a logic behind the distribution of plotted finds and the use of the space, suggesting comparable cognitive capacities for both anatomically modern humans and Neanderthals. This contributes further data that undermines the notion of 'behavioral modernity' as a useful heuristic in human origins research.

Keywords Middle Paleolithic · Upper Paleolithic · Spatial analysis · Neanderthal · *Homo sapiens* · Behavior

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Introduction

This paper presents the results of the spatial analysis of the Protoaurignacian and last Mousterian levels of the site of Riparo Bombrini (Liguria, Italy), a collapsed rockshelter that has yielded early modern human and Neandertal levels in very close succession thus allowing meaningful diachronic comparisons of the spatial behavior of the two populations in the same locale.

The ability to structure space within occupied sites is often considered a distinctive *Homo sapiens* behavior (Bar-Yosef, 2002; Henry *et al*., 2004; Mellars, 2005; Wynn & Coolidge, 2011). Because of the rapidity and extent of the appearance of new behaviors during the Upper Palaeolithic linked to the arrival of anatomically modern humans in Europe, as well as the almost contemporary disappearance of Neanderthals, this period has been described as also marking a "cognitive revolution" (Bar-Yosef, 1998; Mellars & Stringer, 1989). This notion has led some researchers (Mellars & Stringer, 1989; Stringer and Gamble 1993; Soffer, 1994; Klein, 1995) to suggest the appearance of "behavioral modernity" during the Upper Paleolithic. However, recent research seems to indicate that the elements of the "cognitive revolution" did not appear suddenly during the Upper Palaeolithic, but gradually, and usually earlier in Africa (McBrearty & Brooks 2000, Scerri & Will 2023), and that Neanderthals mastered most of these elements as well: complex tools, personal ornaments, use of ocher, wall engraving and above all a social and economic organization allowing planning and adaptability (Clark & Riel-Salvatore, 2006; Finlayson, 2019; Hovers *et al*., 2011; Romagnoli *et al*., 2022; Spagnolo *et al*., 2019; Vallverdú *et al*., 2010).

Spatial organization and the ability to structure one's space are elements often mentioned as an indicator of modern human behavior to distinguish our species from other representatives of the genus *Homo* (Bar-Yosef, 2002; Mellars, 2005). It is assumed that multiple concentrations of distinct activities characterized modern human's complex social structures whereas the spatial organization of Neanderthals was simple and static, composed of areas of general activity concentrated around a single hearth: "Archaic site structures are thought to display a single central hearth or, more commonly, none at all in conjunction with artifacts and bones pointing to overlapping, superimposed, diverse activities in living areas." (Henry, 2012: 263) Some even argued that, during the Middle Palaeolithic, artifacts were grouped randomly in aggregations of debris with little if any organization (Stringer and Gamble 1993; Mellars, 1996; Pettitt 1997; Kolen, 1999). This alleged lack of organization would be evidence of evolutionary and cognitive characteristics separating Neanderthals from anatomically modern humans. Alternatively, some have maintained that spatial organization in and of itself may be the result of non-intentional or even non-human processes, which requires identifying and eliminating the influence of such processes before a purposeful organization can be inferred (*e.g*., Dibble *et al*., 1997). Further, recent research has also demonstrated that although it is often assumed that modern human use of space is characterized by clearly distinct activity areas, the ethnographic record indicates that hunter-gatherers' use of space is more fluid and adaptable to social and practical factors and does not necessarily translate materially into strictly defined activity areas (Clark, 2017).

As a result, the analytical methods devised to study spatial organization have grown in sophistication over the past decades. Indeed, systematic reassessments of Middle Paleolithic sites have demonstrated that their spatial organization is much more complex than previously recognized. Recent analyses of sites attributed to Neanderthals have provided undisputable evidence of the use of space in a structured way (Alperson-Afil & Hovers, 2005; Jaubert and Delagnes, 2008). Such examples notably include the sites of Amud (Hovers *et al*., 2011) and Kebara (Speth *et al*., 2012) in Israel, La Folie (Bourguignon *et al*. 2002; Bourguignon *et al*., 2006) and Grotte du Lazaret (Mellars, 1996) in France, Grotta Fumane (Peresani, 2012), Riparo l'Oscurusciuto (Spagnolo *et al*., 2019) and Riparo del Molare (Boscato & Ronchitelli, 2008) in Italy, Kůlna in Czech Republic (Neruda, 2017), Abric Romani in Spain (Gabucio *et al*., 2018; Carbonell 2012) and Molodova I in Ukraine (Gamble, 1986; Hayden, 2012). The structures at Bruniquel, deep underground and away from the entrance further reinforce this (Jaubert *et al*. 2016). The purposeful organization of space identified even in earlier hominins is also increasingly accepted (*e.g*., Gesher Benot Ya'aqov in Alperson-Afil *et al*., 2009), although the question of the antiquity of spatial differentiation, of its practice and its variability of expression by other hominins continues to be explored (Alperson-Afil & Hovers, 2005).

In sum, there is currently little debate that, at least in some contexts, purposeful organization of space appears to have been part of the Neanderthal behavioral repertoire (see discussion in Clark *et al*., 2022). This, along with the recent 'deconstruction' of other alleged 'uniquely modern' behavioral traits, has led an increasing number of scholars to question whether 'modern human behavior' is even still a useful heuristic for paleoanthropological research (Nowell, 2010, Shea, 2011, Villa and Roebroeks 2014; Roberts, 2016; Zilhão, 2018; Romagnoli *et al*., 2022; Nowell, 2023). However, the question of whether Neanderthal behavior may have differed from that of modern humans in degree rather than kind remains an open question. As concerns spatial organization, assessing this has so far been impossible because analyses have focused on documenting the spatial organization of either one of the populations as opposed to comparatively approaching the issue. The most straightforward way of doing this would be to analyze and compare the spatial organization of the two groups using the same methods in a single site, to hold constant and rule out our site morphology as a possible confounding factor.

The present study aims to correct this by identifying the spatial organization in Protoaurignacian and Final Mousterian levels excavated in the same site, Riparo Bombrini. It builds on a preliminary study of the Mousterian spatial organization at Bombrini that suggested Neanderthals structured their use of space within the site according to different mobility strategies (Riel-Salvatore *et al*., 2013). However, it expands on this earlier study by including Protoaurignacian levels and data from 2015–2022 excavations that explored the Final Mousterian and Protoaurignacian over a larger spatial area than that reported in 2013.

The analysis of Protoaurignacian faunal and lithic remains resulted in the identification of distinct mobility strategies, which could correlate with specific spatial behaviors and organizational patterns for Levels A1 and A2 (Riel-Salvatore & Negrino, 2018a; Pothier Bouchard *et al*., 2020). Additionally, the spatial organization results agree with the overall mobility patterns observed in the Protoaurignacian, indicating a coherent relationship between spatial arrangements and the

strategies employed during that period. If the Final Mousterian exhibits comparable "modern" characteristics to the Protoaurignacian or adheres to similar behavioral principles, then its spatial organization should align with the same rationale and correspond to its mobility pattern.

We begin with a brief overview of the site of Riparo Bombrini that highlights its relevance and regional particularities for understanding Neanderthals and *Homo sapiens* behavior across the Middle to Upper Paleolithic transition. We then present the methodological framework used in this study, followed by a discussion of the results obtained with the quantitative and qualitative methods applied to the spatial distribution of the Protoaurignacian levels (A1 and A2), and so-called 'semi-sterile' Final Mousterian levels (MS1 and MS2). The paper concludes with a comparison of spatial organization across stratigraphic units and a broader discussion on the implications for debates about cognitive differences between Neanderthals and *Homo sapiens*.

Riparo Bombrini: An Overview of Prior Work

Riparo Bombrini is a collapsed rockshelter located in the Paleolithic site complex of the Balzi Rossi in Liguria (Italy), a distinctive limestone cliff formation located near the French-Italian border and abutting the Tyrrhenian Sea (Fig. 1). Before railway construction in the late nineteenth century isolated it, Riparo Bombrini probably constituted the eastern end of a large talus that sprawled towards the sea from the entrance of the Grotta del Caviglione (Villeneuve, 1906). Two previous excavation campaigns (1976; 2002–2005) revealed a stratigraphy that comprises Late Mousterian (Middle Paleolithic) and Protoaurignacian deposits (Upper Paleolithic) characterized by an abundance of lithic and faunal plotted finds, among others (Vicino

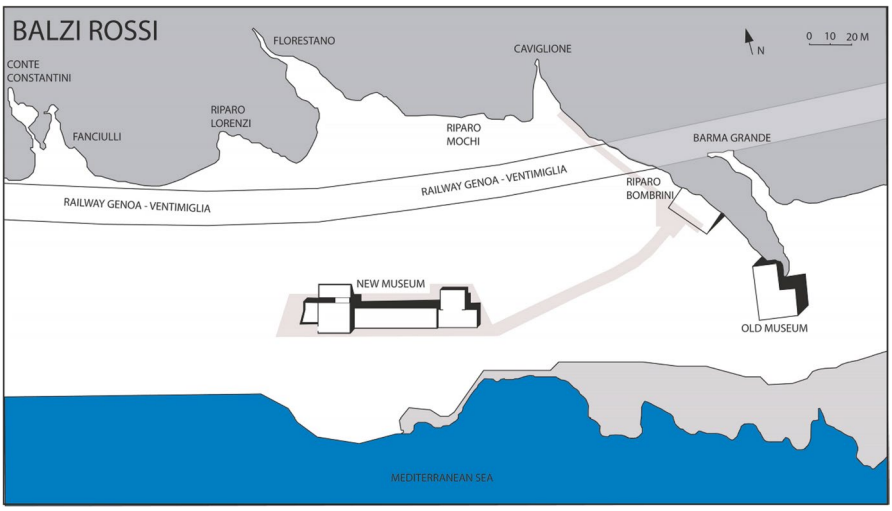


Fig. 1 Map of the Balzi Rossi cave complex (Ventimiglia, Italy) showing Riparo Bombrini, Riparo Mochi and Grotta del Caviglione (after Pothier Bouchard *et al*., 2020)

1984; Negrino & Riel-Salvatore, 2018; Holt *et al*., 2019). In the Protoaurignacian Level A2, a deciduous incisor attributed to an anatomically modern human child was discovered, representing one of the very few known diagnostic *Homo sapiens* remains from the earliest Upper Paleolithic (Benazzi *et al*., 2015; Formicola, 1989). More recently (2015–2022), a third project led by Fabio Negrino and Julien Riel-Salvatore explored the site to better document the transition from the Middle to Upper Paleolithic by increasing the excavation area and employing new analytical methods (see Pothier Bouchard *et al*., 2019, 2020; Hirniak *et al*., 2019; Riel-Salvatore *et al.* 2022).

A series of radiocarbon dates complemented by cryptotephra analysis converge to situate the Mousterian occupation between 45 to 42 ka cal. BP (Fig. 2), making it among the most recent known in Eurasia (Benazzi *et al*., 2015; Higham *et al*., 2014; Negrino & Riel-Salvatore, 2018; Riel-Salvatore & Negrino, 2018a). Levels A1 and A2 are dated between 41.5 ky and 36 ky cal BP (Higham *et al*., 2014; Benazzi *et al*., 2015; Riel-Salvatore & Negrino, 2018a; Holt *et al*., 2019). While absolute dates have yet to be obtained for the MS1 and MS2 levels, they likely accumulated starting around 42.75 ka cal. BP (Riel-Salvatore *et al*. 2022). A stratigraphic discontinuity resulting from an apparent erosional event marks the transition to the Protoaurignacian (Holt *et al*., 2019), but it is likely that the two phases of occupation were not separated by a significant hiatus, if any (Riel-Salvatore & Negrino, 2018a).

The Protoaurignacian Levels A1 and A2

The sedimentary matrix of the Protoaurignacian is a 10–20 cm thick layer of yellowish clay with small pebble inclusions, which accumulated over large blocks of roof collapse in the immediately underlying levels (see below). A third Protoaurignacian level (A3) is limited to a narrow 15 cm band of deposit along the rockshelter wall. Although largely eroded and undated, with limited finds, it represents the earliest Protoaurignacian occupation of the site (Holt *et al.*, 2019, Pothier Bouchard *et al*.,

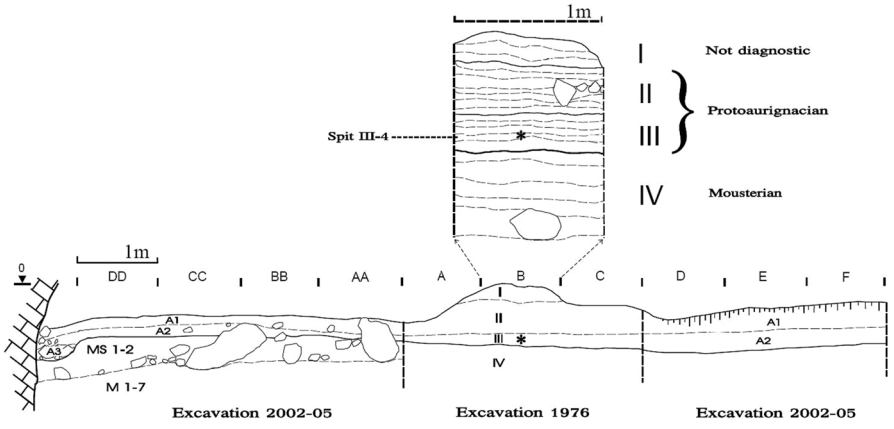


Fig. 2 Stratigraphic profile of Riparo Bombini: A: Protoaurignacian levels, MS: semi-sterile Mousterian levels, M: Mousterian levels. (Drawn by Fabio Negrino, from Riel-Salvatore & Negrino, 2018a: 166)

2020). Due to its exiguity, we exclude it from consideration here, although it is represented on the maps for Level A2 to account for a gap in artifact distribution (see below). Hearths are present in Levels A1 and A2, always located close to the wall of the rockshelter (Fig. 4), and an additional hearth is documented in Level A1 outside the shelter. A pit in the same position is also documented in both levels (Pothier Bouchard *et al*., 2020).

The Protoaurignacian, as a cultural manifestation of the initial dispersal of anatomically modern humans into Europe, is characterized by a suite of technological and symbolic innovations that easily distinguish it from the Mousterian (Kuhn, 2002; Anderson *et al*. 2015; Negrino & Riel-Salvatore, 2018; Marciani *et al*., 2020). In Italy, the Protoaurignacian is best viewed as an archaeological and behavioral adaptation rather than a precise chronological phase (Douka *et al*., 2012; Higham *et al*., 2009; Marciani *et al*., 2020; Riel-Salvatore & Negrino, 2018b). Levels A2 and A1 contain rich archaeological assemblages that include numerous retouched bladelets (including classic Dufour types), bone tools, ocher fragments and decorative objects including pierced shells, drilled soapstone beads, and incised bird bones and fossil belemnites (Holt *et al.* 2019; Arrighi *et al*., 2020). The breadth of raw materials implies a circulation or exchange network over a large territory of several hundred kilometres extending from the Rhône Valley to the Central Apennines (Negrino *et al*., 2016).

Despite the technological homogeneity of the Protoaurignacian levels, differences in mobility strategies and subsistence patterns are clearly documented (Riel-Salvatore & Negrino, 2018a, b). Level A2 displays a more expedient lithic technological organization, reflecting a logistical mobility strategy. In contrast, the lithic technological organization of Level A1 favors greater use of local raw materials and retooling activities, corresponding to a more residential mobility strategy.

These differences are also borne out by differences in the acquisition and management of animal resources in both levels (Pothier Bouchard 2022; Pothier Bouchard *et al*., 2020). Despite a rather low degree of resolution, zooarchaeological analyses show clear indications of bones having been broken by percussion to recover the marrow in both Protoaurignacian levels outside the rockshelter, specifically in squares C1 and C2 (Pothier Bouchard pers. comm.). The faunal data suggest an area of carcass processing activity linked to marrow extraction, particularly focused on red deer. However, evidence of butchery of the same taxon is documented inside the shelter, and the taphonomic resolution is not high enough for the entire site.

The Final Mousterian Levels MS1 and MS2

The sedimentary deposit corresponding to the 'semi-sterile' Mousterian levels (MS1-MS2) consist of an orange clay matrix 30–40 cm thick, incorporating numerous large limestone blocks spalled from the roof of the rockshelter as a result of intense cryoclastic activity at the time (Riel-Salvatore *et al*. 2022). A distinct concentration of charcoal inside the rockshelter signifies a discrete combustion feature. The artifacts are characteristic of the Late-Final Mousterian of the region: discoid cores, scrapers, and denticulates (Riel-Salvatore & Negrino, 2018b). The raw

material is almost exclusively local flint from the *I Ciotti* conglomerate with a handful of exceptional long-distance imports, such as quartzite from Castellane (France).

The scarcity of archaeological material and the presence of animal coprolites in these levels suggests sporadic, low-intensity human occupations. However, recent data from the 2015–22 excavations, and corresponding ones at Riparo Mochi located a few dozen meters away, challenge the characterization of this level as 'semi-sterile' (Riel-Salvatore *et al*. 2022). Notably, this Mousterian occupation is now also documented outside the rockshelter and its assemblage has grown eightfold compared to previous assessments (cf. Negrino & Riel-Salvatore, 2018; Riel-Salvatore *et al*., 2013). The most significant clarification of human activity during this period comes from the combustion zone in units DD2 and EE2 excavated from 2016 to 2018. This zone has yielded the majority of the new material, tripling the documented presence of ocher and confirming its association with the hearth at the back of the shelter. Shells are also much more abundant than previously reported (Riel-Salvatore *et al*. 2022; Gazzo, 2021).

Previous Work on Spatial Organization at Riparo Bombrini

To date, only the Mousterian and semi-sterile Mousterian levels at Riparo Bombrini have undergone a preliminary spatial analysis, revealing different forms of spatial organization in the Mousterian levels, likely reflecting different land-use strategies (Riel-Salvatore *et al*., 2013). These analyses proposed that Levels MS1-2 represented the site's use as an ephemeral extraction site (task site), while Levels M1-5 served as a logistical base camp. In contrast, Levels M6-7 corresponded to a residential base camp. Baseline information about M1-7 can be found in Riel-Salvatore *et al*. (2013).

Levels associated with residential mobility were correlated with informal combustion areas and although the spatial distribution was not well known, the authors suggested a more limited range of tasks. However, it was correlated with lower lithic densities outside the shelter. The use of the site as a logistical base camp, in contrast, was correlated with formal hearths and efforts to segregate activities associated with waste production towards the front of of the shelter. Most noisome debris was concentrated outside the dripline, as illustrated by the overwhelming frequency of animal remains outside of the shelter. The assemblage corresponding to use of the site as a task site (MS) was mostly found inside the shelter with fairly abundant ochre use, and a relatively dense fauna accumulation inside the shelter; no structure was documented. This accumulation at the back of the shelter suggests a potential animal butchering and processing zone.

The overall degree of mobility appears to have been higher in the Protoaurignacian relative to the Mousterian (Riel-Salvatore, 2010; Riel-Salvatore & Negrino, 2018b). However, despite differences between the Protoaurignacian and the Mousterian both industries indicate the ability to adapt land-use and technological organization strategies along a continuum of residential to logistical mobility (Riel-Salvatore & Negrino, 2018a).

Data

The data utilized in this study includes all piece-plotted finds constituting the assemblages from Protoaurignacian levels (A1 and A2) and the semi-sterile Mousterian levels (MS1-MS2) recovered during the 1976, 2002–2005, and 2015–2022 excavations (Table 1). Unplotted finds are excluded from this study as their analysis is pending. However, it is crucial to note that the assemblages, if incorporating these data, would be considerably larger, involving thousands of pieces, as evident from the extensive faunal and lithic material analyzed in the Protoaurignacian levels (see Riel-Salvatore & Negrino, 2018a and Pothier Bouchard *et al*., 2020). Following Riel-Salvatore *et al*. (2022), the 'semi-sterile' Mousterian levels MS1 and MS2 were combined in this analysis to create a level comparable to the Protoaurignacian. By combining these two levels, which represents two short-term palimpsests with similar spatial patterns, a better resolution of the organizational patterns is also obtained since the palimpsests are accepted as indicators of behavioral tendencies across a larger temporal horizon. The underlying Mousterian levels (M1-M7), investigated over smaller areas, are excluded in the present analysis but will be the focus of future studies.

Excavations at Riparo Bombrini since 1976 have exposed a 26 m^2 area comprising 6 m^2 from G. Vicino's initial excavation and 8 m^2 of undisturbed deposits considered as the interior of the collapsed rockshelter today (Fig. 3). Artifacts over 2 cm, shells, ochre and charcoal have been systematically piece plotted since the site's earliest work. Vicino's categorization of piece-plotted finds into five broad categories (lithics, bones, shell, ochre, charcoal) was maintained for consistency in the 2002–05 and the 2015–22 projects, facilitating integration of previous and recent data. Ongoing efforts to process the small debris into a unified database prevent holistic analysis at this stage (Fig. 4).

The excavated area at Riparo Bombrini offers a sample of the total prehistoric occupation. While the exterior deposits (Levels A1 to M5) were disturbed during the XIX^{th} century railway construction, limiting archaeology study, the dripline boulders appear to naturally segregate activities and constrain artifact dispersion. Although acknowledging information loss, it's improbable that the exterior material would have a direct connection to the inner shelter activities. Despite challenges, the excavation is considered representative of diverse activities, with the dripline's natural boundaries mitigating autocorrelation concerns and the 5 m^2 trench providing insights into potential activities. Overall, confidence exists in the sample's representativeness of various hominin activities at Riparo Bombrini.

It's essential to stress that the archaeological levels at Riparo Bombrini do not represent occupation floors, as per Dibble *et al.* (1997). Rather, the Protoaurignacian and Mousterian levels are palimpsests reflecting thousands of years of site reoccupation by different groups at varying intervals. The observed distributions are thus not the product of a single event, but rather the accumulation of recurrent events, disturbances and activities. It is these accumulations that allow archaeologists to zero in on the time-averaged expression of recurrent strategies over time and to interpret the levels as macrounits that express general and long-term behavioral tendencies (Reeves *et al*.,

Table 1 Counts of the plotted finds, broken down by types and areas of the shelter

	Lithic				Fauna				Ochre				Shell				Total			
	Outside	Dripline	Inside	Total	Outside	Dripline	Inside	Total	Outside	Dripline	Inside	Total	Outside	Dripline	Inside	Total	Outside	Dripline	Inside	Total
MS	36	30	296	362	53	26	296	375	0	3	35	38	2	1	27	30	91	60	654	805
MS Density (m^2)	4.5	3.7	29.8	38	6.7	3.2	29.8	39.7	0	0.4	3.5	3.9	0.3	0.1	2.7	3.1	11.5	7.3	65.9	84.7
A1	420	62	372	852	99	13	96	208	9	3	38	50	30	6	14	50	558	84	518	1160
A1 Density (m^2)	48.1	8.4	37.3	93.8	11.3	1.8	9.7	22.8	1	0.4	3.8	5.2	3.4	0.8	1.4	5.6	64	11.4	52.2	127.6
A2	426	22	417	865	100	17	106	223	7	4	41	52	11	0	33	44	544	43	597	1184
A2 Density (m^2)	53.3	2.7	42	98	12.5	2.1	10.7	25.3	0.8	0.5	4.1	5.4	1.4	0	3.3	4.7	68.1	5.3	60.2	133.6

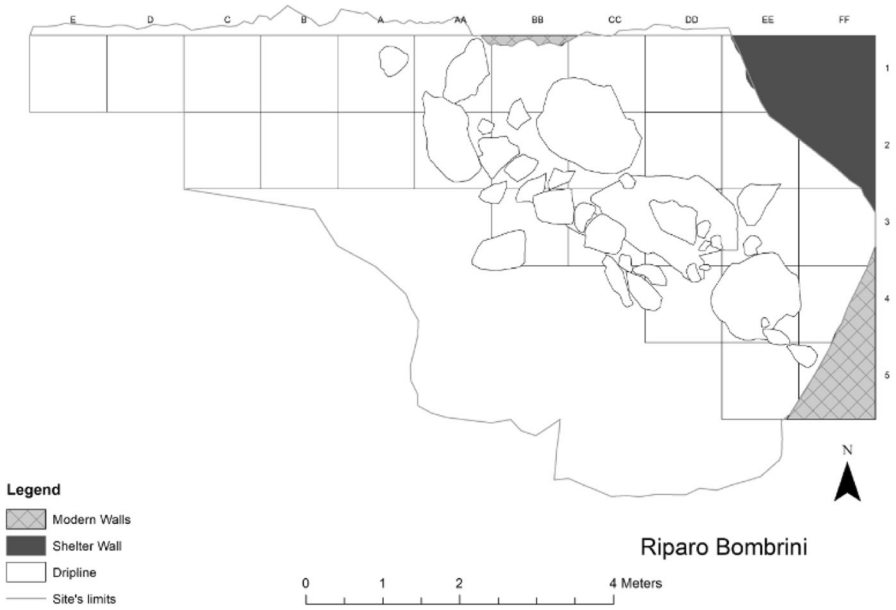


Fig. 3 General planimetry of Riparo Bombrini indicating all excavated units (from Vallerand, 2021: 32)

2019). Riparo Bombrini has been affected by several distinct post-depositional forces over the millennia, most recently the construction of the railway, the blasting of the cliff face, and the construction of the footbridge, not to mention the partial collapse of the rockshelter in the deep past. The sundry taphonomic factors, as well as the nature of the occupations of the site, clearly do not allow the study of individual occupation events, and this study does not claim to be able to reach this type of resolution, recognizing that these factors hinder the reconstruction of behavioral tendencies specific to time-averaged contexts in Pleistocene and Early Holocene deposits (Barton & Riel-Salvatore, 2014; Perreault, 2019).

Methods

As mentioned, the spatial analysis is based on the position of the following materials: lithics, bones, shell, ochre, charcoal, and structures (hearth and pit). Possible equifinality problems may arise from the coarse classification. Details such as size, macro-traces, retouch, cut marks and the state of carbonization can help identify with more certitude the nature of the activity areas. The present study thus employs this coarse classification scheme of the piece-plotted artifacts to use the largest dataset possible to develop a first comprehensive approach to Protoaurignacian and Final Mousterian spatial organizations at a single site. Our results can subsequently be tested with finer-grained classification in future studies and provide guidelines and hypotheses to test.

Fig. 4 Protoaurignacian hearth in Level A2 inside the rockshelter (by Fabio Negrino, 2003)

It is important to emphasize the preliminary nature of this work and the impact of lacking qualitative data for all types of artefacts, which limits our interpretation. For example, there is no direct correlation between a high-density area and an activity area. For instance, the qualitative distinction of lithic material is essential to understanding the different stages of activities associated with lithic production. Microdebris represent the best proxy to identify a knapping area as it could indicate an actual working zone. Large-sized production waste could indicate cleaning behavior (Spagnolo *et al*., 2019). Given the limitations related to the resolution of the data at this point in the analysis, we cannot precisely identify a de facto refuse area or a primary (or secondary) refuse area. We can, however, emphasize the importance of the lithic material at a location and suggest that some part of the lithic work took place

there. Further work involving the plotted and unplotted findings could statistically test the correlations between them.

However, some interpretations of the material remain accessible. For instance, high densities of animal remain associated with a hearth or a combustion area would suggest meat processing/consuming (Spagnolo *et al*., 2019). Moreover, the co-occurrence of lithic tools and high densities of fauna suggest a specialized area for the processing/butchering of animal remains (Bartram *et al.*, 1991; Binford, 1983; Keeley, 1991). Although shellfish were only used for dietary purposes during the semi-sterile Mousterian (Gazzo, 2021), non-dietary shells and ocher can be considered materials correlating to social or symbolic activities although their precise use is still unknown (Riel-Salvatore *et al*., 2013). However, ocher also has potentially utilitarian purposes such as the making of resin glues (*e.g*. Sano *et al.*, 2019), antiseptic properties, and the working of animal skins (Rifkin, 2011).

Hearths are often considered central elements of occupation since their versatility allows the framework of several activities and the identification of individual events during temporal resolution analysis (Conard *et al*., 1998; Henry, 2012; Henry *et al*., 2004; Speth *et al*., 2012; Vaquero & Pastó, 2001). Clusters or all types of artefacts debris would suggest some type of floor clearing, especially if concentrated in a marginal area (e. g. Bartram *et al*., 1991; Binford, 1983; Thomas *et al*., 1983; Vaquero, 2012). The distinction in the use of the inner and outer areas of the shelter is also used to discern domestic activities from accumulations of refuse away from the social and living areas (Binford, 1983; Thomas *et al*., 1983).

Moreover, while we do not have the information for the non-plotted pieces, we assume that they behave in the same general pattern as the plotted finds. Pothier Bouchard *et al.* (2020) use both plotted and unplotted finds to analyse the fauna of the Protoaurignacian levels. This study indicates similar results and interpretation of the fauna material, at the least. While this study remains preliminary, it serves as groundwork for more advanced and detailed analysis.

Forager Strategies Continuum

To build on the results of a preliminary spatial analysis of the Mousterian levels (Riel-Salvatore *et al*. in 2013) and prior lithic analyses at Riparo Bombrini (Riel-Salvatore, 2010; Riel-Salvatore and Negrino, 2018a, b) we use here, as a heuristic, the same general categorization of forager mobility strategies (see Table 2). These categories are themselves based on the mobility spectrum of hunter-gatherers defined by Binford (1980), who viewed mobility strategies as behavioral responses conditioned by the distribution of resources within a given spatial and temporal frame. 'Logistical' land-use strategies imply the occupation of sites as home bases for prolonged periods, from which task groups are sent to a range of "satellite sites" to provision them with resources from afar (Binford, 1980; Kuhn 1992, 1995; Riel-Salvatore, 2010). This strategy is better suited to environments where resources are more patchily distributed, and their availability is more difficult to predict. Residential mobility strategies imply the use of sites as home bases that are moved more frequently, where the resources are mostly procured in the site's immediate vicinity.

Table 2 Mobility Strategies: Characteristics of the logistical, residential and task site mobility strategies

	Logistical strategy	Residential strategy	Task site
Occupation length	Long-term	Short-term	Sporadic
Assemblages	Large and associated with overall low degrees of retouch frequency	Low density and associated with proportionally higher retouch frequency	Very-low density
Resources availability	Patchily distributed and more unpredictable resources	Dense, predictable, and homogeneously distributed resources	Decrease and narrowing of resource spectrum
Innovation	Technological innovation at a premium	No inducement to invest in technology	No inducement to invest in technology
Climate	Climactic instability	Climactic stability	Climactic instability
Spatial organization	Very defined organization and structures	Less defined organization and more unformal and reused structures	Targeted and limited occupation and no combustion structures

Overall, it is a strategy that aims to bring people to known and abundant resources (Binford, 1980; Kuhn 1992).

However, logistical and residential mobility represent two ends of a continuous spectrum, and Binford did not intend to create a typology of foragers (Kelly, 2013). We integrate this concept to understand the patterns related to the use of the landscape and spatial behaviors. It should also be noted that distinguishing between activities limited by frequent group movements and between activities related to special task groups from a residential base is particularly difficult, and to date, no one has resolved the specific material correlates of this.

Methodological Approach

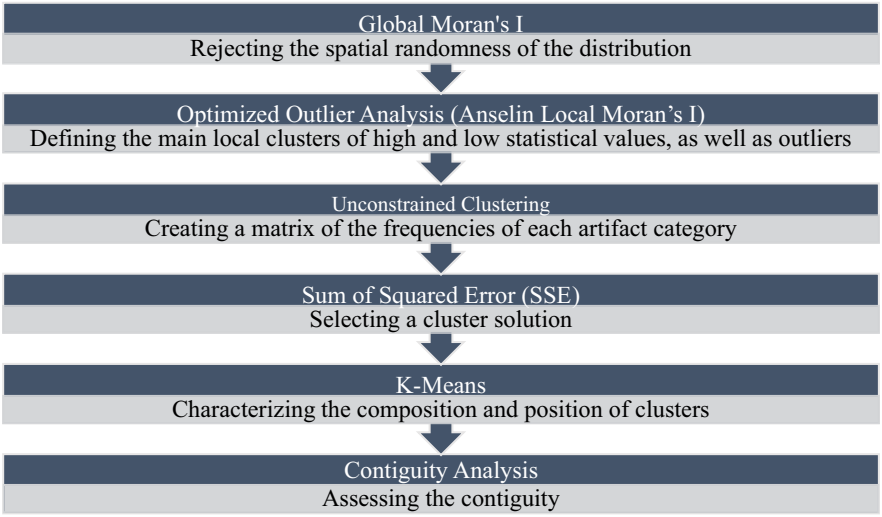
A central axiom of this analysis is the non-random position of plotted finds: because human behavior is not random in space, the material residues associated with these behaviors are distributed non-randomly (Alperson-Afil & Hovers, 2005; Binford, 1983; Newell, 1987; Schiffer, 1972, 1975). The use of space, on a landscape and in a site, is thus considered an important aspect of hominin adaptation (Reeves *et al*., 2019). The segregation of activities is a way of organizing and manipulating cultural and physical environments and codifying social relations (Alperson-Afil & Hovers, 2005). It occurs during normal activities of daily life and helps distinguish and maintain relationships in groups (Clark *et al*., 2022; Hovers *et al*., 2011). Considering the influence of mobility strategies and survival decisions on site usage, one can anticipate that these factors would similarly affect the distribution and composition of identified artifact groups at Riparo Bombrini.:

Therefore, we first sought to determine whether we can reject the spatial randomness of the distribution of plotted finds in three successive Paleolithic levels (Alperson-Afil & Hovers, 2005). Subsequently, we sought to characterize these organizational models for each level and to define the aggregates and co-occurrences of plotted finds and structures to identify the general patterns of the three levels (Table 3). Finally, we define types of organization by comparing the levels from a diachronic and cultural perspective and begin addressing the question of whether similarities in spatial organization may represent a shared evolutionary trait.

An integrated methodology combining visual and quantitative methods was developed to characterize the type of distribution and to identify statistically significant groups and their composition. The three levels are subject to the same analyses to implement a uniform methodology that can provide directly comparable results (see also Sánchez-Romero *et al*., 2021). The analyses presented in the paper were performed using R Statistical Software (v4.1.2; R Core Team, 2021) with cluster and psych packages, and ArcMap 10.8.1 (ArcGIS Desktop 10.8.1).

The first step was to create distribution maps and to delimit the dripline in each level. To facilitate inter-analysis comparisons, the definition of this area, which separates the 'inside' (dripline to back wall) and 'outside' (dripline outwards) parts of the shelter was based on the criteria outlined in Riel-Salvatore *et al*.'s (2013) preliminary analysis. A recurrent and narrow linear space runs through the site at an approximate NW–SE angle through units AA1 and BB1 more or less parallel to

Table 3 Summary of the integrated methodology



the back of the rockshelter (see also Reeves *et al*., 2019). The precise cartography undertaken since 2015 extended the dripline to the EE5 unit. The outward limit of the dripline is defined by the continuous erosion of the entrance and by the rocks deposited during its progressive collapse across time and archaeological levels. In this sense, the limit of the dripline is dynamic and differs (*i.e*., contracts) slightly from Level MS to Level A1 to account for this diachronic phenomenon.

Global Moran's I

To assess the spatial relationships, quantitative methods were used. Global Moran's I autocorrelation test assesses the level of spatial autocorrelation and the trend of the data globally for each level. Spatial autocorrelation measures the similarities between features in a spatial framework and determines the level of interdependence in a sample (see Wandsnider, 1996; Bivand *et al*., 2008; Carrer, 2017; Reeves *et al*., 2019; Sánchez-Romero *et al*., 2020; Carrer, 2022). It analyzes the organization of plotted finds along a continuum (clustered, random, or dispersed) to characterize the relationship of elements in a space.

Optimized Outlier Analysis (Anselin Local Moran's I)

Once the spatial randomness of the distribution is rejected, Optimized Outlier Analysis is used to analyze the attributes of a data set, identifying groups of high and low values as well as significant outliers according to the Anselin Local Moran's I statistical calculation (Sánchez-Romero *et al*., 2020:11). This analysis helps to indicate statistically intense (high) or diffuse (low) groups as well as outliers by evaluating apparent similarities or differences more pronounced than a random scatter. Outliers

represent results that do not correspond to the dominant relational tendencies of the surrounding plotted finds (i.e. high-value cluster in a diffuse pattern or low-values in a clustered pattern). We aim to identify the positions of statistically significant areas of interest.

Unconstrained Clustering Analysis

This intrasite analysis strategy, initially developed by Whallon (1984) and later refined by Kintigh (1990), involves partitioning the site's space based on the relative proportions of categories of plotted finds according to their specific coordinates (Peeples, 2020). Each plotted find is assigned to an individual grid unit, and the total of artefacts are then tallied by units. This results in a matrix displaying the frequencies of each plotted find category in each grid unit. Row percentages are subsequently calculated.

Whallon (1984) recommends using a square grid, creating a moving analysis window to regularize the data and produce clear and simple interpretable models. Considering the site data's nature and size, as well as following several tests, we opted for a grid composed of 50×50 cm cells to enhance representation and achieve a more nuanced interpretation. This scale also corresponds to the minimum scale used during the excavation, preventing blurring of spatial patterns.

Charcoal is excluded from this analysis as it was not systematically collected during excavation. When enough samples were gathered to potentially date a feature, additional charcoal pieces were not consistently plotted. In addition, units containing five or fewer piece-plotted finds were also excluded to avoid disproportionately influencing the dataset.

K-means Analysis

We then apply K-mean cluster analysis, drawing upon the R script developed by Matthew Peeples (2011), to the matrix of artefacts percentage by units to define the composition and infer the behavioral meaning of the groups we identified. The K-means algorithm is probably the best-known and most widely used method for cluster analysis (see Whallon, 1984; Kintigh, 1990; Rigaud & Simek, 1991; Wandsnider, 1996; Papalas *et al*., 2003). This non-hierarchical method partitions data by optimizing a set seeking to minimize differences within groups and maximize differences between groups. The analysis focuses on distribution patterns of the different materials, assigning a composition of entities to a specific group number and identifying each area of a site accordingly.

To establish the optimal number of groups for each level, we utilize the Sum of Squared Error (SSE) on the original data and 1,000 randomized versions of this data. SSE represents the sum of squared distances between each member and the centroid of a group, serving as an overall measure of error. The actual and randomized results are compared to identify inflection points and departure from random variation. The number of groups is selected by balancing the maximum possible detail and identifying the pivot point where the reduction in SSE significantly slows down, indicating statistical

significance. The minimum number of groups considered for each level is based on the four categories of plotted finds, enabling a detailed portrayal of the activities.

Contiguity Analysis

Considering that human activities extend beyond areas of $0.25m^2$, it can be argued that homogeneity, or in this analysis the presence of contiguous units assigned to the same group, is a factor underlying a spatial structure. To establish contiguity for each group, the number of squares per group and then the number of contiguous squares of the same type are tallied. Each unit sharing a side is assigned a value of 1, while each corner is assigned a value of 0.5, with complete contiguity amounting to 6. Subsequently, the data is randomized 1,000 times to create a set of random measurements for comparison with the original dataset. This procedure aids in determining whether the observation is a result of stochasticity or an underlying structure.

Results

Global Moran's I

The results of Global Moran's I analysis allow us to reject the random spatial nature of the distribution in each of the three individual levels studied at Riparo Bombrini (MS: $Z=11.29$, $p=0.00$; A2: $Z=3.36$, $p=0.00$; A1: $Z=9.60$, $p=0.00$). It suggests that the spatial patterns of the distributions were likely not the result of random processes.

Artifacts and Structures Distribution

All stratigraphic units of occupation exhibit both high and low-intensity activity areas, indicating at least occasionally conspicuous groupings of plotted finds (see below). Structures are consistently present in all levels, maintaining recurrent positions over time, relating to different types of organization. For instance, a pit is situated in the same location in both Levels A2 and A1, while the internal hearths of the Protoaurignacian levels, along with the combustion zone of the semi-sterile Mousterian, are generally positioned near the back wall of the shelter.

Table 1 illustrates that, despite its greater thickness, Level MS yielded the smallest number of plotted finds. Lithics ($n=362$) and faunal remains ($n=362$) are much less abundant than in the Protoaurignacian levels, while the quantities of ocher ($n=38$) and shell ($n=30$) are comparable to those reported for Levels A2 (ocher = 52, shell = 44) and A1 (ocher = 50, shell = 50). It is also noteworthy that Level MS has the highest proportion of plotted finds within the interior of the rockshelter (81%). Levels A1 and A2 exhibit similar total plotted finds by type, but their material distribution patterns slightly differ. While both levels contain roughly the same amount of material inside (44% and 51%, respectively) and outside of the

rockshelter (48% and 46%, respectively), A1 contains a slightly higher proportion of material at the dripline (8%).

Level MS

The distribution map indicates that the lithic and faunal plotted finds are mainly concentrated inside the rockshelter associated with the combustion zone (Fig. 5). The combustion zone serves as the focal point for all categories of plotted finds, and the degree of aggregation inside the rockshelter decreases with distance from it. Ocher and charcoal, in particular, exhibits a close association with the combustion zone and the back of the rockshelter.

The Optimized Outlier Analysis highlights statistically significant concentrations of high values within the rockshelter over a large area, and linked with the combustion zone, notably in units DD2 and EE2 (Fig. 6). This underscores that the interior of the rockshelter is the most intensely occupied zone of the site, serving as the primary area for material deposition and waste. Statistically significant concentrations of low values characterize the rest of the space of the rockshelter. However, high outliers are visible within these low areas indicating notable aggregations.

The optimal solution based on SSE is identified as five groups (Fig. 7a). Contiguity results indicate high overall adjacency ($p < 0.015$). The K-means analyses determined that Groups 1, 2 and 5 provides us with the best insights into the activities on site (Fig. 8, Table 4). Group 1 is predominantly located inside the

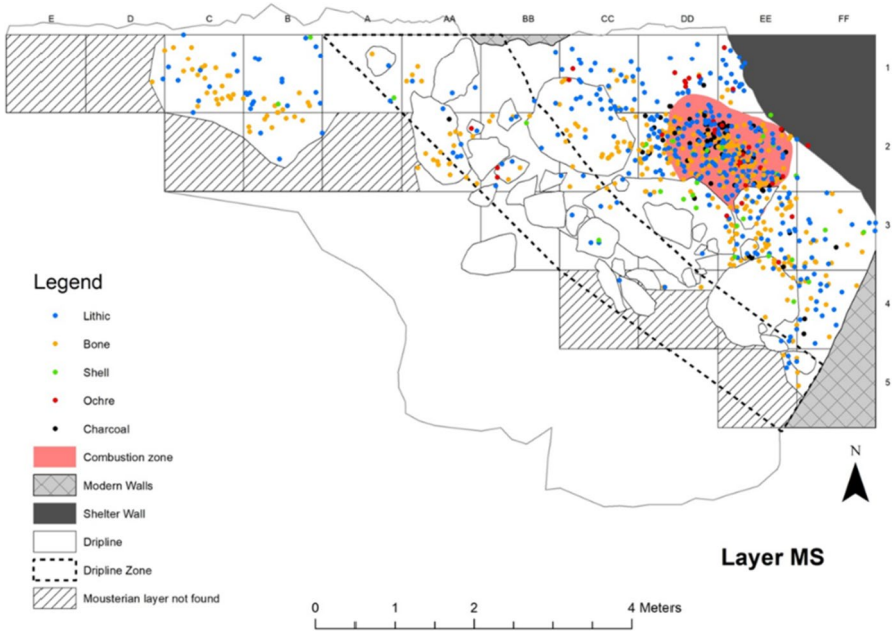


Fig. 5 Distribution map of piece-plotted finds, Level MS

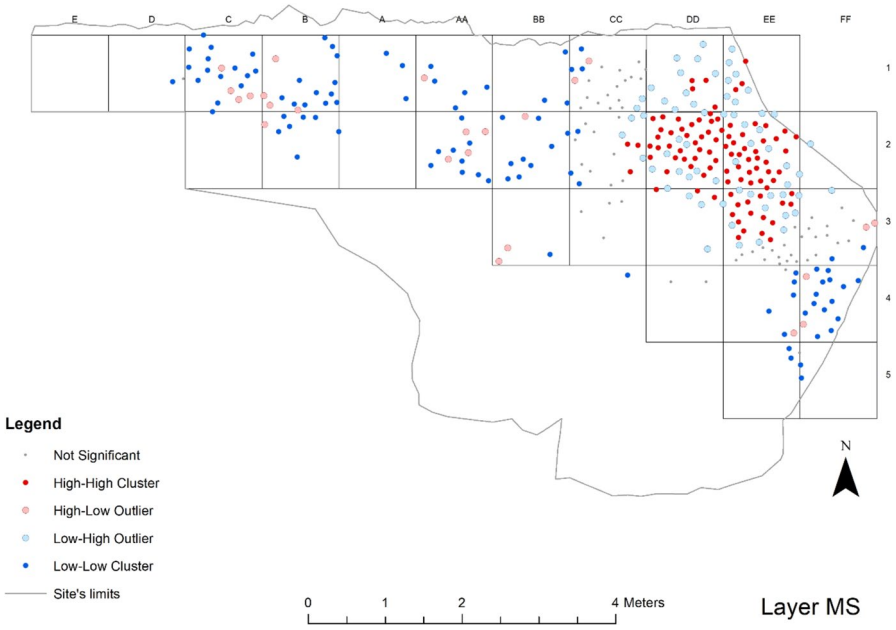


Fig. 6 Optimized Outlier Analysis map, Level MS

rockshelter and makes up a large part of the assemblage related to the combustion zone over an area of 2 m^2. Fauna frequency is greater than that of lithics. Group 2 is notable for its composition primarily comprising of fauna, representing the highest proportion of fauna among all MS groups. This composition extends outside and on the periphery of the most intense activity zone of the site. It therefore seems that the activities related to these zones were deliberately kept outside the rockshelter or at a certain distance from the area of most intense occupation.

Groups 3 and 4 are very poorly represented and are non-contiguous. They contain very few plotted finds and bear little significance. Group 5 exhibits similar proportions to Group 1, with an inverse ratio for lithics and fauna. It is often associated with Group 1, especially inside the rockshelter and in the combustion zone. The particularity of the group is that it includes the highest proportion of shells among all groups. Shells are relatively rare in Level MS (n = 32) and are also very little represented in the compositions. However, although ocher also does not constitute a large part of the assemblage (n = 38), it is more prevalent in the scattered and infrequent groups, particularly Group 4.

Level A2

The distribution map illustrates that the spatial structure is conditioned by internal structures and the dripline (Fig. 9). The interior of the rockshelter is highly structured, and space appears to be organized by these structures. The apparent gap in

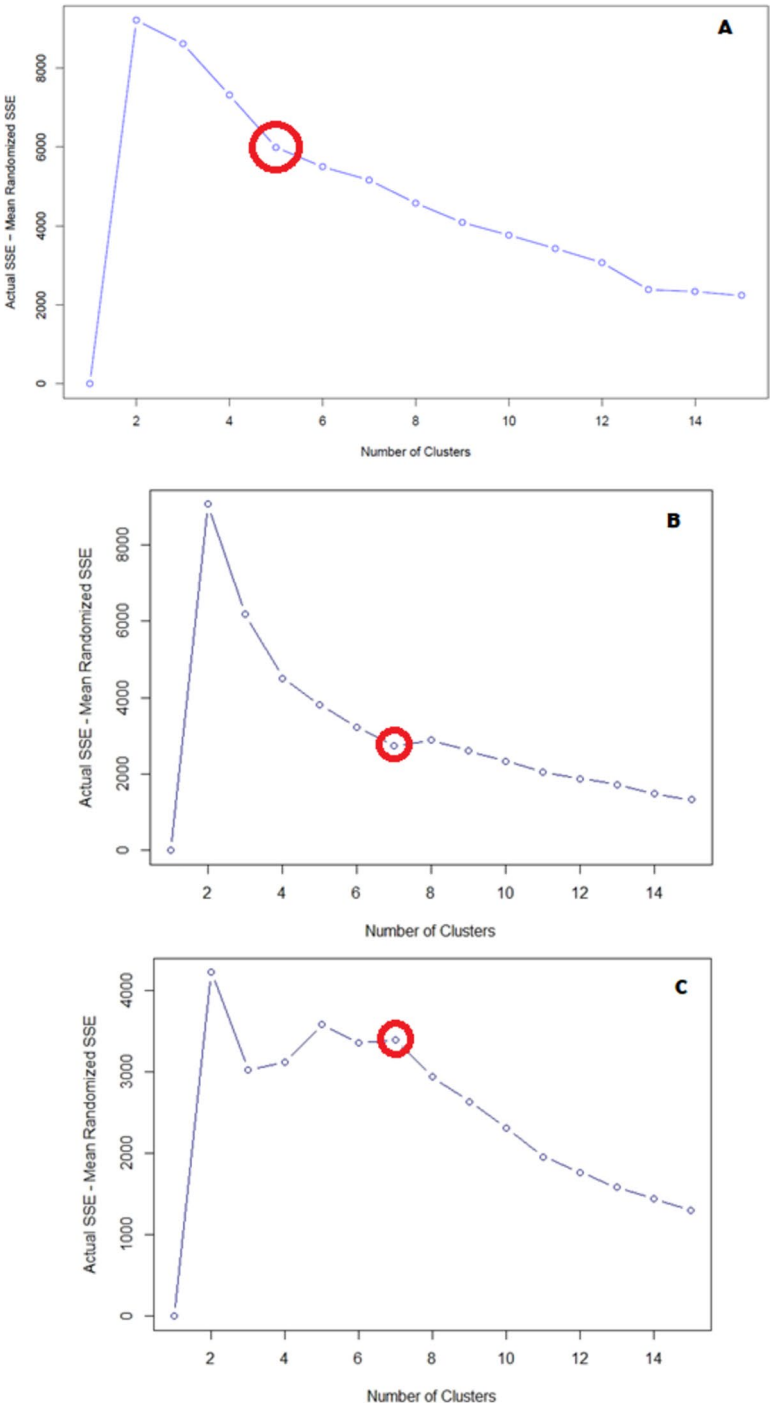


Fig. 7 SSE Solutions for the number of K-means groups for Levels MS(A), A2 (B), A1(C)

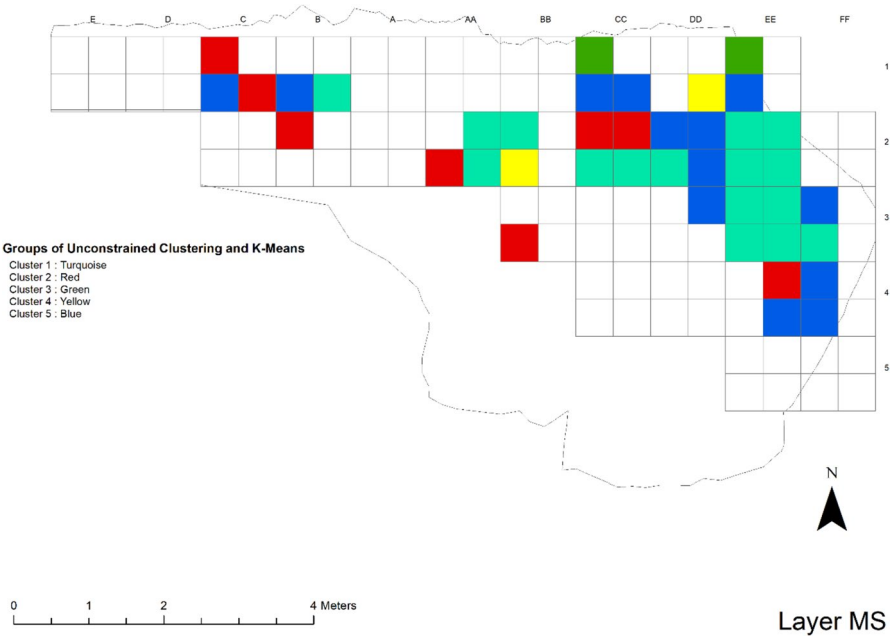


Fig. 8 Distribution of K-means Groups 1–5, Level MS

Table 4 Composition of K-means groups, Level MS

Group/Type (%)	Lithic	Fauna	Ocher	Shell
1	37.57	53.70	5.30	3.70
2	14.06	84.38	0.00	1.56
3	86.67	0.00	13.33	0.00
4	54.52	13.04	30.43	0.00
5	54.55	37.19	3.31	4.96

artifacts is due to the presence of Level A3 as a narrow berm of sediment along the backwall which is largely devoid of artifacts and remained in place as Level A2 accumulated. A clear distribution gap at the dripline also delineates the interior and exterior spaces. The exterior of the rockshelter is characterized by a large distribution of plotted finds, mainly lithics, but also a significant co-occurrence of fauna.

The Optimized Outlier analysis reveals the structure of A2 which presents the clearest spatial organization of the three levels (Fig. 10). Statistically significant groups of high values are closely associated with the hearth and pit, indicating intense concentrations of plotted finds. The dripline is sparsely occupied and characterized by an abnormally low distribution. The Optimized Outlier analysis reveals that the spatial distribution in units B1, C1 and D1 expresses a random or regular pattern framed by groups of low values and high values outliers.

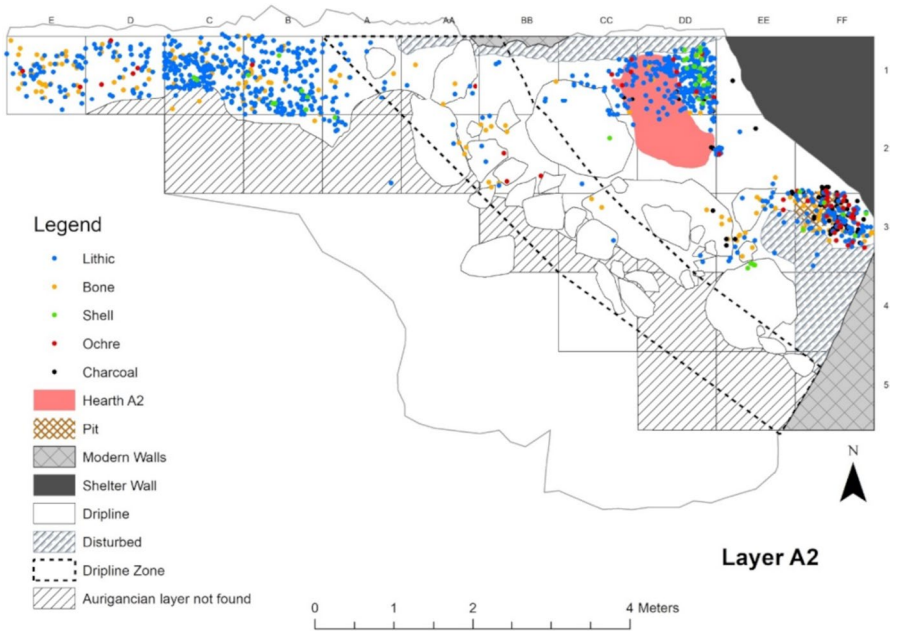


Fig. 9 Distribution map of piece-plotted finds, Level A2

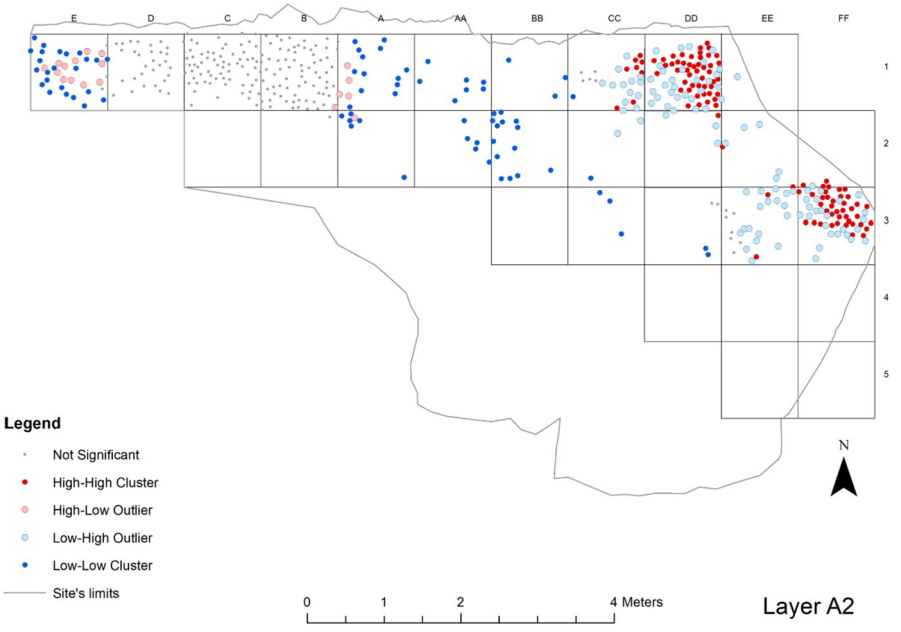


Fig. 10 Optimized Outlier Analysis map, Level A2

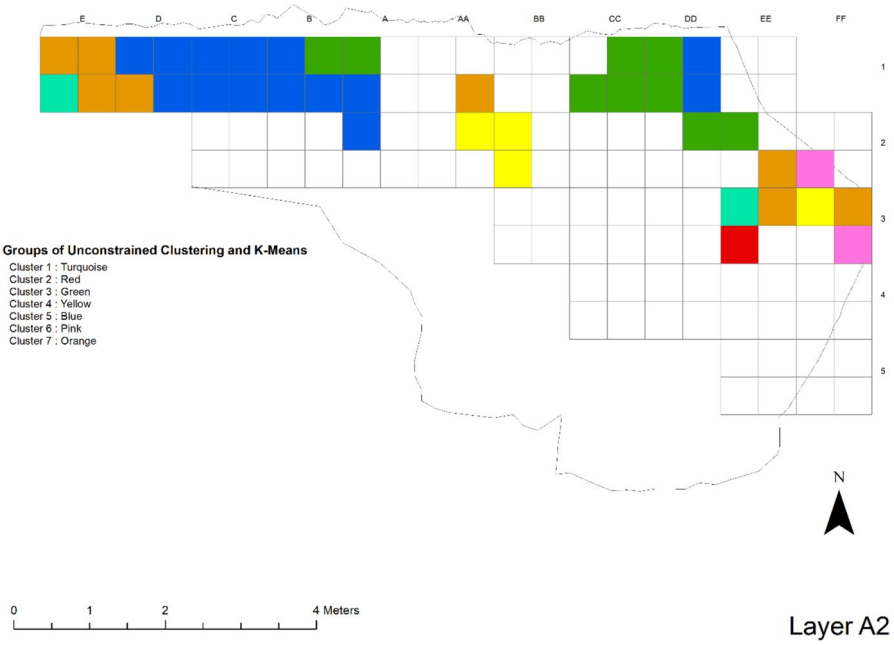


Fig. 11 Distribution of K-means Groups 1–7, Level A2

Table 5 Composition of K-means groups, Level A2

Group/Type (%)	Lithic	Fauna	Ocher	Shell
1	26.32	73.68	0.00	0.00
2	38.39	33.33	0.00	27.78
3	92.74	3.91	3.35	0.00
4	41.30	46.74	9.78	2.17
5	79.58	13.50	1.77	5.14
6	56.67	13.33	23.33	6.67
7	56.61	31.75	10.58	1.06

SSE indicates an optimal clustering of seven groups (Fig. 7b), and contiguity results indicate a very high overall contiguity ($p < 0.000$). The groups vary in contiguity, but the estimated probabilities suggest robust results reflecting structural aspects of the site. Groups 3, 4, and 5 are particularly significant and are associated with structures and areas of interest (Fig. 11, Table 5).

Lithics dominate the inner hearth at the back of the rockshelter, especially Groups 3 and 5. Group 3 is particularly well-represented in relation to the hearth, while Group 5, against the wall, contains the majority of the plotted finds related to this structure. Fauna is very poorly represented compared to lithics. Group 5 also dominates the exterior of the rockshelter, particularly in units where the distribution is more regular with a large majority of lithics (80%), and a large part

of fauna (15%). Outside outliers exhibit strong lithic components, but a greater proportion of fauna (32%) and ocher (11%).

Near the pit, several groups contribute to the area, which is expected given the eclectic nature of a waste pit. However, Groups 4 and 7 contain the greatest amount of material and are in the centre of the structure. Interestingly, the composition of groups associated with the pit differs from activities documented near the hearth with a more significant presence of fauna and ocher. We also note the significant presence of shells (Group 2), and ocher (Group 6) at the margin of the structure.

Level A1

Level A1 features three structures: a hearth and a pit inside the shelter, and an external hearth. The structures seem to condition the greatest densities of plotted finds, excluding the internal hearth (Fig. 12). The Optimized Outlier analysis indicates that the statistically significant groups of high values are associated with the pit and outer hearth, while the interior of the rockshelter exhibits distinct high-density areas scattered across a large statistically low-concentrated space (Fig. 13).

High outliers are particularly concentrated in unit DD2, linked to the inner hearth. Unlike Levels A1 and MS, the inner hearth is not a particularly dense area, but it contains sufficient material to differentiate the activities associated with it from the rest of the rockshelter space. The inside of the rockshelter appears to be exploited more diffusely, and the material shows fluidity dispersion through the rest of the

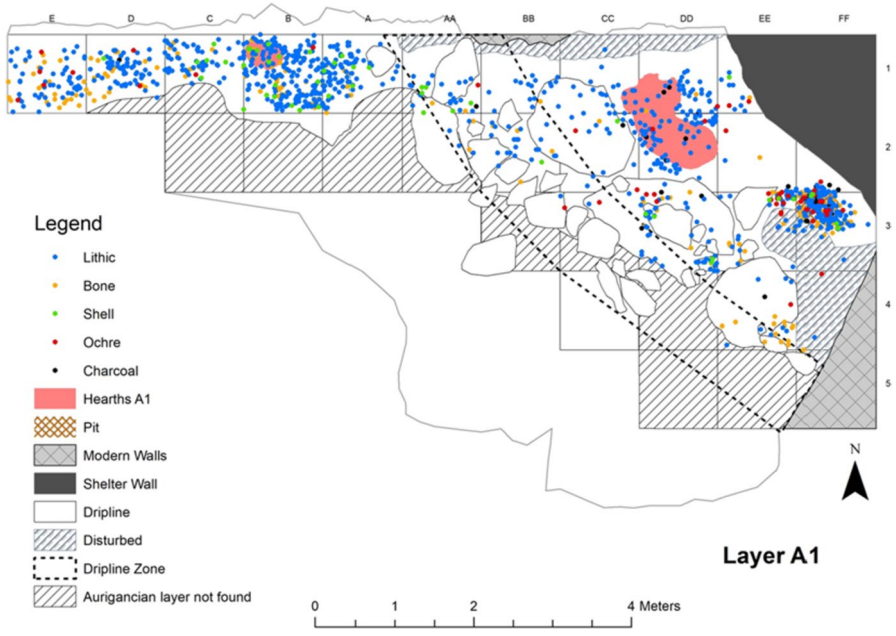


Fig. 12 Distribution map of piece-plotted finds, Level A1

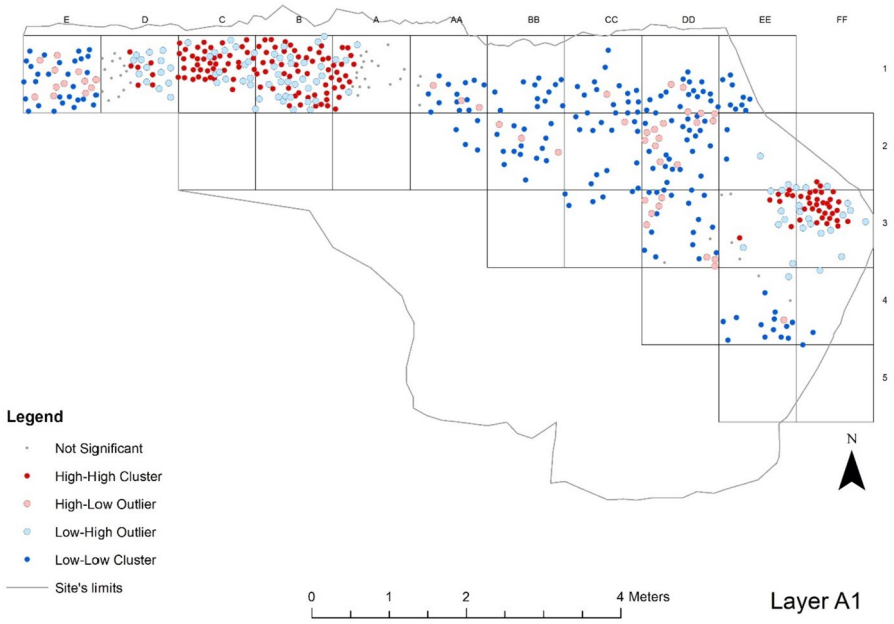


Fig. 13 Optimized Outlier Analysis map, Level A1

space. The dripline is actively used, with significantly higher material presence than in the other two levels.

SSE has established seven groups as the optimal grouping for plotted finds, with a high overall degree of contiguity ($p < 0.025$) (Fig. 7c). Groups 3 and 6 exhibit the most contiguous, with statistically very low probabilities that this is the result of random chance (Fig. 14, Table 6). However, contrary to Level A2, a clustering of units of a single group is not evident in a straightforward manner (Fig. 14). Analyzing the composition of the plotted finds is very challenging due to the very low contiguity.

Nevertheless, Group 1 primarily constitutes the pit, comprising a majority of lithic (65%), as well as a significant part of fauna (26%). Ocher and shells form a minority of the compositions. High outliers related to the inner hearth consist of Group 3, dominated by lithic plotted finds (94%). Groups 4 and 6 represent outliers at the dripline. Although these groups are mainly composed of lithic, the fauna constitutes a rather important part of them, and the shells are well represented (Group 4 = 24%). The outer hearth is made up of Groups 1, 3 and 6, with Group 6 containing the majority of the plotted finds related to this structure. Lithic pieces (79%) dominate this group, but it also contains some faunal remains.

Fig. 14 Distribution of K-means Groups 1–7, Level A1

Table 6 Composition of K-means groups, Level A1

Group/Type (%)	Lithic	Fauna	Ocher	Shell
1	65.43	25.71	5.43	3.43
2	52.73	12.73	25.45	9.09
3	93.97	3.52	1.51	1.01
4	63.64	12.12	0.00	24.24
5	56.96	39.24	3.80	0.00
6	78.91	14.06	1.04	5.99
7	29.41	70.59	0.00	0.00

An Integrated Overview of the Changes in the Use of Space: Levels MS, A2 and A1

We were able to characterize organizational models for each level and define the grouping of plotted finds, that is, their patterns of co-occurrence. The data produced for each level allowed the study of spatial organization and the identification of types of organization from both a diachronic and intercultural perspective.

Given the results of the spatial analysis (Table 7), and considering the information gathered on the types of mobility (Table 2) and the characteristics of Levels MS, A2, and A1 (Table 8), it becomes possible to offer an integrated view of the evolution of the use of space at Riparo Bombrini. We can then assess how the spatial

Table 7 Summary of the Spatial Organization of Levels A1, A2, and MS at Riparo Bombrini

	A1	A2	MS
Structures	Two hearths and one pit	One hearth and one pit	One combustion zone
Inside	- Lithic and fauna distributed relatively equally in the space (cold zones, hot outliers) - Punctual use of the space, but denser around the pit suggesting some form of maintenance (hot zone) - Lithic remains more closely associated with the inner hearth (hot outlier)	- Most of the material is concentrated around the inner hearth and the pit (hot zones) - Lithic remains suggest lithic production around the hearth - Shell remains suggest non-utilitarian uses - The pit highlights the maintenance of the inside of the rockshelter	- Co-occurrence of lithic and fauna within the combustion zone (hot zone) - Most intense use of ochre of any Mousterian level - Lithic production is documented through lithic remains
Outside	Dense faunic and lithic distribution associated with the outside hearth (hot zone)	Important lithic assemblage associated with lithic production activities (not significant zone, hot outliers)	Fauna and lithic co-occurrence suggesting butchering activities (cold zone, hot outliers)
Dripline	Majority of lithics but significant remains of fauna and shell (cold zones, hot outliers)	- Relative equal remains of lithic and fauna - Not very used (cold zone)	Few plotted finds (cold zone)
Clusters	7	7	5
Plotted finds	1160	1184	805

Table 8 Characteristics of Levels A1, A2 and MS at Riparo Bombrini

	A1	A2	MS
Occupation length	Short and infrequent	Prolonged and repetitive	Short and sporadic
Assemblages	- Great share of retooling - Discarding of broken tools - Restocking in local raw materials - Selected for their mobile toolkit cores and the tools necessary to produce bladelets	- Expeditious lithic technology - Longer and narrower medium for blade production - Replacement and discarding off-site - *In situ* lithic production activities emphasized by large numbers of cores	- Highly variable and adaptable lithic technology - Artifacts are typical Mousterian
Resources availability	- Local raw material *(I Ciotti*) - Circumlocal material - Exotic raw material from the Rhone Valley to the center of the Apennines	- Local raw material *(I Ciotti*) - Circumlocal material - Exotic raw material from the Rhone Valley to the center of the Apennines	- Local raw materials (*I Ciotti)* - Few exceptions of imported materials such as quartzite from Castellane (France)
Innovation	The Protoaurignacian assemblage is used as a way of reacting and adapting to the unexpected in part by developing very extensive exchange networks	The Protoaurignacian assemblage is used as a way of reacting and adapting to the unexpected in part by developing very extensive exchange networks	The Neanderthal technocomplex is characterized by high technological variability supported by local sourcing
Climate	Associated with the glacial interstage 8 (GI 8) which is slightly more temperate, although generally arid and cold	Corresponds to a phase of climatic degradation following the glacial interstadial 9 (GI 9) and the cold period preceding the 4 Heinrich event	Warmer and more humid than the preceding Mousterian levels
Spatial organization	- One hearth and one pit - Less rigid structuring - Less systematically cleared - Reuse of fireplaces	- Two hearths and one pit - Densest and most structured layer	- One combustion zone - Fewer artifacts in greater sedimentary deposit - Significant presence of coprolites

organization of artifacts and features changed over these three stratigraphic units vis a vis other contextual information about site occupation (climate, cultural indicators, faunal exploitation, assemblage type, *etc*.). Additionally, we aim to assess whether patterns of spatial organization align with mobility strategies in these three levels, as previously highlighted in various studies (Riel-Salvatore & Negrino, 2018a; Riel-Salvatore *et al*., 2013).

Our findings indicate distinct pattern distributions and use of space for each of the levels analyzed here. This is not unexpected as previous analyses have suggested that each of these palimpsests resulted from different types of dominant occupation modality and that the compounded accumulations resulting from the decisions behind these strategies expressed the spatial organization of space (Riel-Salvatore, 2007, 2010; Riel-Salvatore & Negrino, 2018a; Pothier Bouchard *et al*., 2020; Riel-Salvatore *et al*., 2013, 2022).

It is crucial to highlight that the number of plotted finds across all levels is significantly lower than the total number of analyzed artifacts reported in some previous studies (*e.g*., Pothier Bouchard *et al*., 2020; Riel-Salvatore & Negrino, 2018b). This discrepancy is explained by the fact that many more artifacts have been recovered at Bombrini during wet screening than pieces plotted in the field over the years. From a methodological perspective, we advise caution. The presence of high-density clusters of any type of plotted finds does not necessarily equate to a specific task, given the absence of qualitative data for plotted finds or quantitative data for unplotted finds. To understand the precise use of the identified area, finer-resolution analyses are necessary. We emphasize the preliminary nature of this study in both these regards and present probable hypotheses about the site's use based on a macro categorization of the finds.

Interpretation of the Spatial Organization of Level MS

In terms of the spatial organization of Level MS, lithic and faunal remains are primarily concentrated inside the rockshelter in association with the combustion zone, while the dripline is largely devoid of traces of discard. The dripline does not seem to have been an area chosen for sustained human activities, perhaps as a result of greater exposure to the elements or of falling vault clasts, which may partially explain why plotted finds are so scant in that part of the site. While this absence might also be due to erosion caused by dripping water at the shelter's mouth, it is worth highlighting that hydraulic disturbances are only documented at Bombrini in the form of an erosional channel along the back wall of the rockshelter between levels MS1 and A2, which is filled in by what remains of level A3, which appears to be the only level seriously affected by erosion. Currently, there is no evidence suggesting that the absence of finds at the dripline in Level MS is the result of non-human processes.

We identified repetitive patterns of organization, as indicated by the presence of a conspicuous combustion of area in a single spot inside the shelter. The use of ocher is mainly concentrated inside the rockshelter. Although the exact purpose of ocher remains elusive, its frequency suggests complexity in Neanderthal behavior,

maintaining potential non-utilitarian or complex technical aspects of their culture, even when confronted with changing contexts or faced new challenges. Shellfish were only used for dietary purposes during the semi-sterile Mousterian indicating subsistence activities.

The co-occurrence of fauna and lithics suggests the exterior of the rockshelter could have been suitable for butchery activities, or at the least, to a large quantity of undesirable waste kept far from the inner space of the shelter. It appears that despite the preferential use of part of the interior of the rockshelter, ephemeral activities were performed across the rest of the space.

Therefore, the MS level aligns with a more ephemeral human presence and a contraction in the range of exploited raw material sources. The significant presence of coprolites (Holt *et al*., 2019) suggests that large carnivores alternated with humans in occupying the site, which indicates a more sporadic occupation of the rockshelter by foragers during this period (Riel-Salvatore *et al*. 2022). The last Neanderthals of the region seem to have undergone a demographic and geographical contraction at that time, reflected by the use of lithic reduction strategies aimed at exploiting local raw materials as fully as possible.

As discussed elsewhere, the final Mousterian in Liguria represents an expression of a Neanderthal "enclave" in a region otherwise occupied by anatomically modern humans associated with the Uluzzian to the east and the Protoaurignacian to the west (Riel-Salvatore *et al*. 2022). It appears Neanderthals favored strategies to maximize the utility of their lithic assemblages while tailoring their hunting strategies in response to fluctuating conditions, which accounts for their more ephemeral nature in what was likely a contraction of ecological refugium at the time. The rarity of exotic raw materials in the lithic assemblage from Level MS, mainly brought as non-local artifacts, suggests short-term occupations of the site at that time, mainly as a hunting a retooling site (Riel-Salvatore *et al*. 2022, Pothier Bouchard 2022).

In summary, as also argued in Riel-Salvatore *et al*. (2022), Level MS represents a recurrent stopping point for hypermobile groups in a changing environment. These data are consistent with interpretations of the MS level as a hunting camp used by hunter-gatherers already provisioned with tools (Riel-Salvatore, 2007, 2010, Pothier Bouchard 2022).

Interpretation of the Spatial Organization of Level A2

The spatial organization of Level A2 represents the densest and most structured of the Protoaurignacian at Riparo Bombrini. The structural elements, the high densities of artifacts associated with them, as well as the relative absence of plotted finds beyond the structures, suggest long-term occupations combined with care in maintaining occupiable surfaces in the shelter.

Considering the importance of the lithic implements and the significant presence of shells associated with the hearth, we propose a multipurpose hearth-related activity area hypothetically related to lithic production with some economic activities. While the hypothesis of lithic production is highly probable, exact characterization of the stage of lithic production activities cannot be established definitely until a

qualitative technological study is conducted. The pit contains a mixture of lithic and faunal remains along with ochre, which likely represent the refuse of daily activities within the shelter. This pit may have served as a kind of midden used to intentionally keep the interior of the rockshelter free of debris, allowing the interior of the rockshelter to accommodate a variety of activities while maintaining a space free of activities and clutter, potentially serving as a resting or living area.

The high-density areas identified outside the shelter, along with the results of the Optimized Outlier analysis (B1, C1, D1), suggest the presence of distinct activity or at least a certain intentionality in the distribution. A regular distribution, in the context of a site repeatedly occupied by humans, may indicate anthropogenic action indicating an underlying systematic structure as it implies planning and organization of the site. The exterior of the rockshelter is mostly associated with lithic artifacts, possibly indicating the location of retooling activities as it is situated far from the inner part of the shelter. It thus appears that over the occupation of level A2, the interior and exterior of the rockshelter had different functions targeted and organized within a precise framework of lithic production and spatial separation of the different tasks to be performed on the site. The occupations seem prolonged and recurrent, as shown by the robustness of the cluster analysis and spatial results. The presence of gaps in the distribution of artifacts is also significant and may be the result of habitual clearing of the surface of refuse.

The lithic technological organization and faunal exploitation strategies of Level A2 converge to suggest it was used as a 'logistical' base camp, supplied with the necessary resources by forays to specific procurement sites, sometimes located great distances from the site. The patterns of bladelet production indicate retooling activities, which is supported by the presence of several cores that indicate in situ lithic production activities (Riel-Salvatore & Negrino, 2018a).

Interpretation of the Spatial Organization of Level A1

The spatial organization conforms to expectations from shorter-term occupations compared to those observed in Level A2. The structuring of discard patterns at the site is less rigid in this level, and the overall space appears to have been less systematically cleared, despite the reuse of fireplaces across individual occupations. Discard was more extensive inside the shelter, with the most important hot zone being related to the pit. The importance of lithic activities is evident in the distributions and concentrations analysis, where they dominate, similar to Level A2. However, despite similar assemblages, the spatial distribution differs significantly.

The inner hearth shows minimal activity apart from lithic production, while the pit confirms the use of fauna and ocher, which were subsequently cleaned from the space, as in Level A2, highlighting another recurrent structural element along with the inside hearth across the two levels. The diffuse use of the inner space, punctuated by high-density activity zones, suggests a variety of activities beyond lithic or animal tasks. It seems that the interior space was dedicated to activities other than intensive production,

allowing for potentially more individuals and avoiding the accumulations of material waste in large quantities, or demonstrating a long-term use of the rockshelter.

Although lithic and faunal artifacts are distributed relatively evenly across the interior and exterior of the site, the exterior distribution is notably denser and more closely associated with the hearth in that part of the site. This level, analyzed in this study, is the only one with a clearly defined external hearth. A potential interpretation regarding the outer hearth and its significant lithic association is that it may have been used for the initial stages of artifact production while retooling and shaping could have occurred inside the rockshelter. However, the significant co-occurrence of other types of plotted finds (shells, fauna) indicates not only lithic activities but also a greater complexity in the nature of the short-lived occupations. In addition, these activities appear intentionally kept outside the shelter.

The variable and eclectic character of activities in Level A1 supports shorter occupations than in Level A2. Despite a relatively similar plotted finds density, A1 exhibits a less structured occupation than A2, possibly influenced by less overlapping independent events or shorter and more distanced occupations over time. It is important to highlight that while the structures of the shelter were reused over an extended period, the reuse did not allow for similar patterns of organization to emerge, suggesting less frequent and shorter occupations, hindering a cohesive form of occupation. Technological and zooarchaeological analyses also support shorter and less frequent occupations.

Therefore, Level A1 is characterized as a short-term base camp within an overall 'residential' land-use strategy. Technologically, this implies a greater emphasis on retooling on site, as occupants could restock with local raw material procured from the nearby *I Ciotti* conglomerate, dispose of broken tools, and replace them with new ones made on-site. The occupants of the site likely left the site for the next with the cores and the tools necessary to produce bladelets (Riel-Salvatore & Negrino, 2018a).

Discussion

Riparo Bombrini's assemblages constitute palimpsests, with accumulations spanning thousands of years that do not represent singular occupations or activities (or even subsets of them), but rather signify the gradual accumulation of material across occupations by multiple groups. What the present study highlights is thus best comprehended as 'central tendencies' that distinguish overall adaptive strategies of forager populations over extremely long timespans marked by shifting paleoenvironmental and human conditions, among other factors. The position of the inner hearths and the pit underscores this, implying continuity in the factors shaping the layout of structures at Riparo Bombrini persisting over an extended duration across and through the levels (cf. Henry *et al*., 2004).

At first glance, our results may seem to suggest major differences between Neanderthals and *Homo sapiens*. The hearths, the pit, and the more structured use of the interior of the rockshelter suggest a greater resemblance between the Protoaurignacian occupations than to the Neanderthal one. However, it is crucial to recognize that these occupations are conditioned by land-use and mobility

strategies. In that light, Level MS emerges as a sporadically occupied task site (likely a hunting and butchering site – Pothier Bouchard 2022), while Levels A2 and A1 function as logistic and residential base camps respectively. As such, all three levels articulate around a shared degree of behavioral flexibility, encompassing variations in occupation duration, reoccupation intervals, the number of occupants, and the nature of activities undertaken. One therefore cannot expect ephemeral and sporadic occupations to result in the same general spatial signature as base camps occupations due to intrinsic differences in their characteristics and motivations for accumulation. Like archaeological structure, these strategies do not inherently signify unique cognitive abilities or qualitatively unique space management but rather reflect a degree of behavioral plasticity rooted in adaptive poses with a much deeper evolutionary history (Clark *et al*., 2022). The most parsimonious interpretation of the analyzed data in this study suggests that using a single methodology across levels within a single site occupied by both populations does not reveal incoherences in terms of how Neanderthals and *Homo sapiens* occupied the site and that, at Riparo Bombrini. Here, their distinct use of space appears to be driven by factors rooted in the same overarching adaptive strategies.

The quantitative and statistical methods employed here enable us to minimize bias by providing evidence that surpasses the simple description of structural elements and the distribution of plotted finds. Another distinctive aspect of our analysis is the direct comparison of Neanderthal and *Homo sapiens* spatial organization within the same site, thus ruling out site morphology as a confounding variable in comparing the two populations. This is significant because the structuring of occupations by modern humans in the Upper Paleolithic is often assumed rather than demonstrated, resulting in less study and scrutiny of the spatial organization of *Homo sapiens* compared to Neanderthals.

The impact of natural or animal disturbances within the Riparo Bombrini layers appears minimal (Holt *et al*., 2019), limited to the migration of a few small Protoaurignacian pieces in contact with the semi-sterile Mousterian, easily identified based on raw material (Riel-Salvatore *et al*. 2022). Thus, we can confidently assert that the spatial distribution of plotted finds in Levels MS, A2 and A1 primarily results from human activities and that the documented spatial organization reflects an intentional behavioral dimension. Additionally, the statistical tests of autocorrelation confirm the grouped and organized nature of the data, to which the analyses of the composition of the groups (Unconstrained Cluster Analysis) give meaning.

Our results also allow us to build upon the initial observations presented in Riel-Salvatore *et al*. (2013). In particular, the recent excavations at Riparo Bombrini and the implementation of new data recording protocols (*e.g*., systematic use of the total station and GIS technologies) have considerably refined our understanding of Level MS. While our results confirm that it represents a palimpsest of ephemeral occupations, statistical analyses have unveiled a coherent spatial organization associated with this kind of site-use modality, linked to the recurrent use of structures whose position remained relatively stable over time. Moreover, the abundance of plotted finds in that level and the discovery of a combustion zone also confirm that calling it ‘semi-sterile’ is a misnomer since it simply reflects a distinct way Neanderthals occupied the Balzi Rossi at that time (Riel-Salvatore *et al*. 2022).

While the breakdown of plotted finds into only four categories in our study may be criticized as presenting too coarse a behavioral record, we argue that in this specific context, it represents a strength. A greater typological refinement might hinder the comparability of our data across the Late Mousterian and Protoaurignacian by imposing *a priori* unbridgeable differences between the two periods. It would then be impossible to compare them directly, as the technological and cultural categories would be too different upstream. Specifically, this would impede the comparisons of the results of the Unconstrained Cluster and K-mean analyses undertaken for each level. Our approach enables us to look beyond the distinctive cultural characteristics of Neanderthals and *Homo sapiens*, focusing on how plotted finds and structures are distributed through space and in relationship to one another. We emphasize here the usefulness and importance of initiating spatial studies using general archaeological remains categories, especially when comparing groups of different human populations. As demonstrated by studies of lithic technology (*e.g.*, Riel-Salvatore & Negrino, 2018b), faunal analysis (Pothier Bouchard *et al.*, 2020; Pothier Bouchard, 2022), and marine shells (Gazzo, 2021), the results of detailed studies can easily be combined with the results of our spatial analyses to yield detailed views of the distinctions between – and within – the two groups.

Finally, the interpretations regarding site function and activity areas presented in this study provide working hypotheses that can serve as the foundation for future studies. These investigations should integrate non-plotted finds and more refined technological and faunal data, along with information about the small artifact fraction recovered during sieving, which is currently being compiled. It is essential to acknowledge that, as mentioned earlier, the results of Pothier Bouchard (2022), by using plotted and non-plotted findings, reached conclusions that generally align with our results. While further studies are needed for a comprehensive understanding, these concordances are promising and underscore the utility and the reliability of this analysis as groundwork for establishing the general spatial organization of a site.

Conclusion

This work contributes to highlighting the growing dissonance between the current narrative about Neanderthal spatial organization capacity and what the data indicate. By introducing the important element of directly comparing their spatial behavior to that of *Homo sapiens* in the same site according to the same parameters, our study provides one more indication that they do not seem to differ qualitatively. Indeed, our results indicate that both populations could adapt to the nature of their occupation of Riparo Bombrini according to decipherable land-use strategies (Table 2). This direct comparison reveals no fundamental difference in their understanding of space and the organization of their activities. The two species used the site according to their needs and their mobility strategies while keeping some elements constant, such as the position of combustion features/hearths and an avoidance of the dripline as a locus of activities.

In summary, Late Middle Paleolithic Neanderthals used Riparo Bombrini as a specific task site in the context of rapid climatic change that appears to have impacted their social and natural geographies, leading to a much higher degree of mobility (Riel-Salvatore *et al.* 2022). In contrast, anatomically modern humans

alternated between logistical and residential mobility strategies to adjust to the drastic climatic events that characterized their expansion into this new territory. Plotted find distributions vary across all occupations, but each fits a particular mobility strategy revealing an underlying logic to how the space was used. The differences in distribution between Levels A2 and A1 underscore this reality perfectly since the composition of the assemblages is relatively similar, but the way of exploiting the site was quite distinct (Riel-Salvatore & Negrino, 2018a, b; Pothier Bouchard *et al*., 2020). Contextual information about the occupations also indicates that the different strategies are used under different circumstances and highlights how the use of space changes through time and adaptations.

One of the corollaries of this analysis is that it highlights how necessary it remains to systematically unbiased or even decolonize our perception of archaic populations like Neanderthals since long-lasting preconceptions about their behavioral capacities impose conceptual blinders on our interpretations of their assemblages. Because they involve important cognitive processes, technological and cultural complexity are often taken as a reference (Clark & Riel-Salvatore, 2006), but the expression of characteristics is intimately linked to the ecological and social context (Ames *et al.* 2013). Archaeological finds reflect only those elements of human knowledge that are accepted and incorporated into social norms and whose repeated use has made them visible (Hovers & Belfer-Cohen, 2006). In this sense, we should not necessarily expect similar behaviors even in a single biological population whose members share equivalent cognitive abilities.

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Authors' contributions A.V. and J.R.S. designed the project. J.R.S. supervised the research. J.R.S. and F.N. directed the excavations. A.V. established the methodology, performed the spatial analysis and interpreted the results. A.V. and J.R.S. wrote the first version of the main manuscript text. A.V. prepared all figures and tables. All authors extensively discussed the results and reviewed the manuscript.

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Data Availability The data that support the findings of this study is available in the GitHub repository at https://github.com/amelievallerand/Riparo-Bombrini.git, reference number 10.5281/zenodo.10537095.

Declarations

Competing interests The authors declare no competing interests.

References

Alperson-Afil, N., & Hovers, E. (2005). Differential use of space at the Neandertal site of Amud Cave, Israel. *Eurasian Prehistory, 3*(January), 3–22.

Alperson-Afil, N., Sharon, G., Kislev, M., Melamed, Y., Zohar, I., Ashkenazi, S., Rabinovich, R., *et al*. (2009). Spatial Organization of Hominin Activities at Gesher Benot Ya'aqov, Israel. *Science, 326*(5960), 1677–1680. https://doi.org/10.1126/science.1180695

Ames, C. J. H., Riel-Salvatore, J., & Collins, B. R. (2013). Why We Need an Alternative Approach to the Study of Modern Human Behaviour. *Canadian Journal of Archaeology, 37*(1), 21–47.

Anderson, L., Bon, F., Bordes, J.-G., Pasquini, A., Slimak, L., Teyssandier, N. (2015). Relier des espaces, construire de nouveaux réseaux: aux origines du Protoaurignacien et des débuts du Paléolithique supérieur en Europe occidentale . In.

Arrighi, S., Moroni, A., Tassoni, L., Boschin, F., Badino, F., Bortolini, E., Boscato, P., *et al*. (2020). Bone Tools, Ornaments and Other Unusual Objects during the Middle to Upper Palaeolithic Transition in Italy. *Quaternary International, 551*(June), 169–87. https://doi.org/10.1016/j.quaint.2019.11.016. Peopling dynamics in the Mediterranean area between 45 and 39 ky ago: state of art and new data.

Barton, C. M., & Riel-Salvatore, J. (2014). The Formation of Lithic Assemblages. *Journal of Archaeological Science, 46*(June), 334–352. https://doi.org/10.1016/j.jas.2014.03.031

Bartram, L. E., Kroll, E. M., & Bunn, H. T. (1991). Variability in camp structure and bone food refuse patterning at kua san hunter-gatherer camps. In E. M. Kroll & T. Douglas Price (Eds.), *The Interpretation of Archaeological Spatial Patterning* (p. 77e148). Springer.

Bar-Yosef, O. (1998). On the nature of transitions: The Middle to Upper Palaeolithic and the Neolithic revolution. *Cambridge Archaeological Journal, 8*, 141–163.

Bar-Yosef, O. (2002). The Upper Paleolithic Revolution. *Annual Review of Anthropology, 31*, 363–393.

Benazzi, S., Slon, V., Talamo, S., Negrino, F., Peresani, M., Bailey, S. E., Sawyer, S., *et al*. (2015). The Makers of the Protoaurignacian and Implications for Neandertal Extinction. *Science, 348*(6236), 793–796. https://doi.org/10.1126/science.aaa2773

Binford, L. R. (1980). Willow Smoke and Dogs' Tails: Hunter-Gatherer Settlement Systems and Archaeological Site Formation. *American Antiquity, 45*(1), 4–20. https://doi.org/10.2307/279653

Binford, L. R. (1983). *Pursuit of the Past. Decoding the Archaeological Record*. Thames & Hudson Ltd.

Bivand, R. S., Pebesma, E. J.,Gómez-Rubio, V. (éd). (2008). Areal Data and Spatial Autocorrelation . In *Applied Spatial Data Analysis with R*, 237–72. Use R! New York, NY: Springer. https://doi.org/10.1007/978-0-387-78171-6_9.

Boscato, P., & Ronchitelli, A. (2008). *Strutture di combustione in depositi del Paleolitico medio del Sud Italy, Atti XVII Congr. Ass. Antrop. It.* (pp. 218–225). Springer.

Bourguignon, L., Sellami, F., Deloze, V., Sellier-Segard, N., Beyries, S., & Barbier, A. E. (2002). L'habitat moustérien de « La Folie » (Poitiers, Vienne) : synthèse des premiers résultats. *PALEO. Revue d'archéologie préhistorique, 14*, 29–48.

Bourguignon, L., Vieillevigne, E., Guibert P., Bechtel, F., Beyries, S., Emery-barbier, A., Deloze, V., Lahaye, C., Sellami, F., Sellier-segard, N. (2006). Compléments d'informations chronologiques sur le campement moustérien de tradition acheuléenne du gisement de La Folie (Poitiers, Vienne) . *PALEO. Revue d'archéologie préhistorique*, nº 18 (décembre): 37–44. https://doi.org/10.4000/paleo.126.

Carbonell, E. (2012). *High resolution archaeology and Neanderthal behavior: Time and space in level J of Abric Romaní (Capellades, Spain) (Vertebrate Paleobiology and Paleoanthropology)*. Springer Netherlands.

Carrer, F. (2017). Interpreting Intra-Site Spatial Patterns in Seasonal Contexts: An Ethnoarchaeological Case Study from the Western Alps. *Journal of Archaeological Method and Theory, 24*(2), 303–327. https://doi.org/10.1007/s10816-015-9268-5

Carrer, F. (2022). Assessing the Effects of Trampling on the Spatial Organization of Archaeological Assemblages Using Statistical Methods: An Ethnoarchaeological Case Study . In *Intrasite Spatial Analysis of Mobile and Semisedentary Peoples | The University of Utah Press*, edited by Amy E. Clark et Joseph A.M. Gingerich, 240. Salt Lake City: The University of Utah Press.

Clark, A. E. (2017). From Activity Areas to Occupational Histories: New Methods to Document the Formation of Spatial Structure in Hunter-Gatherer Sites. *Journal of Archaeological Method and Theory, 24*(4), 1300–1325. https://doi.org/10.1007/s10816-017-9313-7

Clark, G. A., Riel-Salvatore, J. (2006). Observations on Systematics in Paleolithic Archaeology . In *Transitions Before the Transition: Evolution and Stability in the Middle Paleolithic and Middle Stone*

Age, edited by Erella Hovers et Steven L. Kuhn, 29–56. Interdisciplinary Contributions to Archaeology. Boston, MA: Springer US. https://doi.org/10.1007/0-387-24661-4_3.

Clark, A.E., Ranlett, S., Stiner, M.C. (2022). Domestic spaces as crucibles of Paleolithic culture: An archaeological perspective. *Journal of Human Evolution* 172. https://doi.org/10.1016/j.jhevol.2022.103266.

Conard, N.J., Prindiville, T.J., Adler, D.S. (1998). Refitting bones and stones as a means of reconstruction middle Paleolithic subsistence in the Rhineland. In: Brugal, J.-P., Meignen, L., Patou-Mathis, M. (Eds.), Économie préhistorique: les comportaments de subsistance au Paléolithique. XVIIIe Rencontres Internationales d'Archéologie et d'Histoire d'Antibes. Sophia Antipolis. APDCA, pp. 273–590.

Dibble, H. L., Chase, P. G., McPherron, S. P., & Tuffreau, A. (1997). Testing the Reality of a "Living Floor" with Archaeological Data. *American Antiquity, 62*(4), 629–651. https://doi.org/10.2307/281882

Douka, K., Grimaldi, S., Boschian, G., del Lucchese, A., & Higham, T. F. G. (2012). A New Chronostratigraphic Framework for the Upper Palaeolithic of Riparo Mochi (Italy). *Journal of Human Evolution, 62*(2), 286–299. https://doi.org/10.1016/j.jhevol.2011.11.009

Finlayson, C. (2019). *The Smart Neanderthal*. Oxford University Press.

Formicola, V. (1989). Early Aurignacian deciduous incisor from Riparo Bombrini at Balzi Rossi (Grimaldi, Italy). *Rivista Di Antropologia, 67*, 287–292.

Gabucio, M. J., Fernández-Laso, M. C., & Rosell, J. (2018). Turning a rockshelter into a home. Neanderthal use of space in Abric Romaní levels M and O. *Historical Biology, 30*(6), 743–66. https://doi.org/10.1080/08912963.2017.1340470

Gamble, C. (1986). *The palaeolithic settlement of Europe* (Ser. Cambridge world archaeology). Cambridge University Press.

Gazzo, S. (2021). Analisi tafonomica, tracceologica, tecnologica e spaziale della malacofauna marina proveniente dai livelli protoaurignaziani del Riparo Bombrini (Ventimiglia, Imperia). Unpublished MSc thesis, Università di Ferrara.

Hayden, B. (2012). Neandertal social structure? *Oxford Journal of Archaeology, 31*(1), 1–26. https://doi.org/10.1111/j.1468-0092.2011.00376.x

Henry, D. (2012). The palimpsest problem, hearth pattern analysis, and middle paleolithic site structure. *Quaternary International, 247*(January), 246–266. https://doi.org/10.1016/j.quaint.2010.10.013. The Neanderthal Home: spatial and social behaviours.

Henry, D. O., Hietala, H. J., Rosen, A. M., Demidenko, Y. E., Usik, V. I., & Armagan, T. L. (2004). Human behavioral organization in the middle paleolithic: were neanderthals different? *American Anthropologist, 106*(1), 17–31. https://doi.org/10.1525/aa.2004.106.1.17

Higham, T., Brock, F., Peresani, M., Broglio, A., Wood, R., & Douka, K. (2009). Problems with radiocarbon dating the Middle to Upper Palaeolithic transition in Italy. *Quaternary Science Reviews - Quaternary Sci Rev, 28*(June), 1257–1267. https://doi.org/10.1016/j.quascirev.2008.12.018

Higham, T., Douka, K., Wood, R., Ramsey, C. B., Brock, F., Basell, L., Camps, M., *et al*. (2014). The timing and spatiotemporal patterning of Neanderthal Disappearance. *Nature, 512*(7514), 306–309. https://doi.org/10.1038/nature13621

Hirniak, J., Smith, E., Johnsen, R., Hodgkins, J., Orr, C., Negrino, F., Riel-Salvatore, J., *et al*. (2019). Discovery of cryptotephra at Middle–Upper Paleolithic sites Arma Veirana and Riparo Bombrini, Italy: a new link for broader geographic correlations . *Journal of Quaternary Science* 35 (November). https://doi.org/10.1002/jqs.3158.

Holt, B., Negrino, F., Riel-Salvatore, J., Formicola, V., Arellano, A., Arobba, D., Boschian, G., *et al*. (2019). The Middle-Upper Paleolithic transition in Northwest Italy: new evidence from Riparo Bombrini (Balzi Rossi, Liguria, Italy) . *Quaternary International* 508 (November). https://doi.org/10.1016/j.quaint.2018.11.032.

Hovers, E., Belfer-Cohen, A. (2006). "Now You See It, Now You Don't"—Modern Human Behavior in the Middle Paleolithic . In *Transitions Before the Transition: Evolution and Stability in the Middle Paleolithic and Middle Stone Age*, edited by Erella Hovers et Steven L. Kuhn, 295–304. Interdisciplinary Contributions to Archaeology. Boston, MA: Springer US. https://doi.org/10.1007/0-387-24661-4_16.

Hovers, E., Malinsky-Buller, A., Goder-Goldberger, M., Ekshtain, R. (2011). Capturing a moment: Identifying short-lived activity locations in Amud Cave, Israel . In *The Lower and Middle Palaeolithic in the Middle East and neighbouring regions*, Etudes et Recherches Archéologiques de l'Université de Liege 126, 101–14. Liege. https://doi.org/10.13140/2.1.2004.4809.

Jaubert, J., Delagnes, A. (2008). De l'espace parcouru à l'espace habité au Paléolithique moyen . *Biologie et cultures, Editions du CTHS*, Documents préhistoriques, n° 23: 263–81.

Jaubert, J., Verheyden, S., Genty, D., Soulier, M., Cheng, H., Blamart, D., Burlet, C., et al. (2016). Early Neanderthal constructions deep in Bruniquel cave in southwestern France. *Nature, 534*(7605), 111–114. https://doi.org/10.1038/nature18291

Keeley, L. H. (1991). Tool use and spatial patterning. Complications and solution. In E. M. Kroll & T. Douglas Price (Eds.), *The Interpretation of Archaeological Spatial Patterning* (pp. 257–268). Springer.

Kelly, R. L., (éd). (2013). Mobility . In *The Lifeways of Hunter-Gatherers: The Foraging Spectrum*, 77–113. Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9781139176132.005.

Kintigh, K. W. (1990). Intrasite Spatial Analysis: A Commentary on Major Method . In *Mathematics and Information Science in Archaeology: A Flexible Framework*, edited by Albertus Voorrip, 165–200. Studies in Modem Archaeology 3. Holos: Bonn.

Klein, R. G. (1995). Anatomy, behavior, and modern human origins. *Journal of World Prehistory, 9*(2), 167–198. https://doi.org/10.1007/BF02221838

Kolen, J. (1999). Hominids without homes, on the nature of Middle Paleolithic settlement in Europe. In W. Roebroeks & C. Gamble (Eds.), *The Middle Paleolithic Occupation of Europe* (pp. 139–175). University of Leiden.

Kuhn, S. L. (1992). On planning and curated technologies in the middle paleolithic. *Journal of Anthropological Research, 48*(3), 185–214. https://doi.org/10.1086/jar.48.3.3630634

Kuhn, S. (1995). Mousterian lithic technology. In *An ecological perspective*. Princeton University Press.

Kuhn, S. L. (2002). Pioneers of Microlithization: The "Proto-Aurignacian" of Southern Europe. *Archaeological Papers of the American Anthropological Association, 12*(1), 83–93. https://doi.org/10.1525/ap3a.2002.12.1.83

Marciani, G., Ronchitelli, A., Arrighi, S., Badino, F., Bortolini, E., Boscato, P., Boschin, F., *et al*. (2020). Lithic Techno-Complexes in Italy from 50 to 39 Thousand Years BP: An Overview of Lithic Technological Changes across the Middle-Upper Palaeolithic Boundary. *Quaternary International, 551*(June), 123–49. https://doi.org/10.1016/j.quaint.2019.11.005. Peopling dynamics in the Mediterranean area between 45 and 39 ky ago: state of art and new data.

Mcbrearty, S., & Brooks, A. (2000). The revolution that wasn't: A new interpretation of the origin of modern human behavior. *Journal of Human Evolution, 39*(Decembre), 453–563. https://doi.org/10.1006/jhev.2000.0435

Mellars, P. A., & Stringer, C. (1989). *The Human Revolution: Behavioural and Biological Perspectives on the Origins of Modern Humans*. Edinburgh University Press.

Mellars, P. (1996). *The neanderthal legacy : an archaeological perspective from Western Europe*. Princeton University Press.

Mellars, P. A. (2005). The Impossible Coincidence. A Single-Species Model for the Origins of Modern Human Behavior in Europe . *Evolutionary Anthropology: Issues, News, and Reviews*14 (1): 12–27. https://doi.org/10.1002/evan.20037.

Negrino, F., & Starnini, E. (2003). Patterns of lithic raw material exploitation in Liguria from the Palaeolithic to the copper age. *Préhistoire du Sud-Ouest,* supplément, 5, 235–243.

Negrino, F., Riel-Salvatore, J., & Bertola, S. (2016). Colonization dynamics and the diffusion of the Protoaurignacian in Italy and southern France: The Rhône-Marche corridor and its chrono-cultural implications. In *6th annual meeting of the European society for the study of human evolution*. https://doi.org/10.13140/RG.2.2.23823.18081

Negrino, F., & Riel-Salvatore, J. (2018). From Neanderthals to Anatomically Modern Humans in Liguria (Italy): The Current State of Knowledge. In V. Borgia & E. Cristiani (Eds.), *Palaeolithic Italy. Advanced Studies on Early Human Adaptations in the Apennine Peninsula* (pp. 161–82). Leiden: Sidestone Press Academics.

Neruda, P. (2017). GIS Analysis of the Spatial Distribution of Middle Palaeolithic Artifacts in Kůlna Cave (Czech Republic). *Quaternary International, 435*(April), 58–76. https://doi.org/10.1016/j.quaint.2015.10.028. Settlement Dynamics of the Middle Paleolithic and Middle Stone Age.

Newell, R. (1987). Reconstruction of the partitioning and utilization of outside space in a late prehistoric/early historic Inupiat village. In S. Kent (Ed.), *Method and theory for activity area research: An ethnoarchaeological approach* (pp. 107–175). Columbia University Press.

Nowell, A. (2010). Defining behavioral modernity in the context of Neandertal and anatomically modern human populations. *Annual Review of Anthropology, 39*, 437–452.

Nowell, A. (2023). Rethinking Neandertals. *Annual Review of Anthropology, 52*(1), 151–170. https://doi.org/10.1146/annurev-anthro-052621-024752

Papalas, C. A., Clark, G. A., & Kintigh, K. W. (2003). Liencres Revisited – the Significance of Spatial Patterning Revealed by Unconstrained Clustering. In H. Kindgren, K. Knutsson, L. Larsson, & D. Leoffler (Eds.), *Mesolithic on the Move: Papers presented at the Sixth International Conference on the Mesolithic in Europe, Stockholm 2000* (pp. 253–61). Oxbow Books.

Peeples, M. A. (2011). R Script for K-Means Cluster Analysis. Electronic document, http://www.mattpeeples.net/kmeans.html. Accessed 28 Nov 2023.

Peeples, M. (2020). Unconstrained Clustering. http://www.mattpeeples.net/modules/UnconstrainedClustering.html. Accessed 15 Feb 2021

Peresani, M. (2012). Fifty Thousand Years of Flint Knapping and Tool Shaping across the Mousterian and Uluzzian Sequence of Fumane Cave. *Quaternary International, 247*(January), 125–150. https://doi.org/10.1016/j.quaint.2011.02.006. the Neanderthal Home: Spatial and Social Behaviours.

Perreault, C. (2019). *The quality of the archaeological record*. University of Chicago Press.

Pettitt, P. B. (1997). High resolution Neanderthals? Interpreting middle palaeolithic intrasite spatial data. *World Archaeology, 29*(2), 208–224. https://doi.org/10.1080/00438243.1997.9980374

Pothier Bouchard, G., Mentzer, S., Riel-Salvatore, J., Hodgkins, J., Miller, C., Negrino, F., Wogelius, R., & Buckley, M. (2019). Portable FTIR for on-site screening of archaeological bone intended for ZooMS collagen fingerprint analysis. *Journal of Archaeological Science: Reports, 26*(August), 101862. https://doi.org/10.1016/j.jasrep.2019.05.027

Pothier Bouchard, G., Riel-Salvatore, J., Negrino, F., & Buckley, M. (2020). Archaeozoological, Taphonomic and ZooMS Insights into The Protoaurignacian Faunal Record from Riparo Bombrini. *Quaternary International, 551*(June), 243–63. https://doi.org/10.1016/j.quaint.2020.01.007. Peopling dynamics in the Mediterranean area between 45 and 39 ky ago: state of art and new data.

Pothier Bouchard, G. (2022). *A ZooMS-informed archaeozoological and taphonomic analysis comparing Neanderthal and Homo sapiens subsistence behaviors in Northwest Italy.* Unpublished PhD thesis, Université de Montréal.

R Core Team. (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria, URL https://www.R-project.org/. Accessed 1 Sept 2021.

Reeves, J. S., McPherron, S. P., Aldeias, V., Dibble, H. L., Goldberg, P., Sandgathe, D., & Turq, A. (2019). Measuring Spatial Structure in Time-Averaged Deposits Insights from Roc de Marsal, France. *Archaeological and Anthropological Sciences, 11*(10), 5743–5762. https://doi.org/10.1007/s12520-019-00871-y

Riel-Salvatore, J. (2007). The Uluzzian and the Middle-Upper Paleolithic transition in southern Italy (Order No. 3270615). Available from ProQuest Dissertations & Theses Global Closed Collection. (304896109). https://www.proquest.com/dissertations-theses/uluzzian-middle-upper-paleolithic-transition/docview/304896109/se-2. Accessed 2 Feb 2023.

Riel-Salvatore, J. (2010). A Niche Construction Perspective on the Middle-Upper Paleolithic Transition in Italy. *Journal of Archaeological Method and Theory, 17*(4), 323–355. https://doi.org/10.1007/s10816-010-9093-9

Riel-Salvatore, J., Ludeke, I. C., Negrino, F., & Holt, B. M. (2013). A Spatial Analysis of the Late Mousterian Levels of Riparo Bombrini (Balzi Rossi, Italy). *Canadian Journal of Archaeology/journal Canadien D'archéologie, 37*(1), 70–92.

Riel-Salvatore, J., Negrino, F., Pothier Bouchard, G., Vallerand, A., Costa, S., & Benazzi, S. (2022). The 'Semi-Sterile Mousterian' of Riparo Bombrini: Evidence of a Late-Lasting Neanderthal Refugium in Liguria. *Journal of Quaternary Science, 37*(2), 268–82. https://doi.org/10.1002/jqs.3411

Riel-Salvatore, J., Negrino, F. (2018a). Proto-Aurignacian Lithic Technology, Mobility, and Human Niche Construction: A Case Study from Riparo Bombrini, Italy . In *Lithic Technological Organization and Paleoenvironmental Change: Global and Diachronic Perspectives*, edited by Erick Robinson et Frédéric Sellet, 163–87. Studies in Human Ecology and Adaptation. Springer International Publishing. https://doi.org/10.1007/978-3-319-64407-3_8.

Riel-Salvatore, J., & Negrino, F. (2018b). Human Adaptations to Climatic Change in Liguria across the Middle-Upper Paleolithic Transition. *Journal of Quaternary Science, 33*(3), 313–22. https://doi.org/10.1002/jqs.3005

Rifkin, R. (2011). Assessing the Efficacy of Red Ochre as a Prehistoric Hide Tanning Ingredient. *Journal of African Archaeology, 9*(décembre), 131–58. https://doi.org/10.3213/2191-5784-10199

Rigaud, J.-P., & Simek, J. F. (1991). Interpreting spatial patterns at the Grotte XV. In E. M. Kroll & T. D. Price (Eds.), *The interpretation of archaeological spatial patterning. Interdisciplinary contributions to archaeology* (pp. 199–220). Springer US. https://doi.org/10.1007/978-1-4899-2602-9_7

Roberts, P. (2016). 'We have never been behaviourally modern': The implications of Material Engagement Theory and Metaplasticity for understanding the Late Pleistocene record of human behaviour. *Quaternary International, 405*(juin), 8–20. https://doi.org/10.1016/j.quaint.2015.03.011. The material dimensions of cognition: Reconsidering the nature and emergence of the human mind.

Romagnoli, F., Rivals, F., Benazzi, S. (2022). Chapter 1 - Updating Neanderthals: Taking stock of more than 160 years of studies . In *Updating Neanderthals*, édité par Francesca Romagnoli, Florent Rivals, et Stefano Benazzi, 1–15. Academic Press. https://doi.org/10.1016/B978-0-12-821428-2.00020-2.

Sánchez-Romero, L., Benito-Calvo, A., Marín-Arroyo, A. B., Agudo-Pérez, L., Karampaglidis, T., & Rios-Garaizar, J. (2020). New Insights for Understanding Spatial Patterning and Formation Processes of the Neanderthal Occupation in TheAmalda I Cave (Gipuzkoa, Spain). *Scientific Reports, 10*(1), 8733. https://doi.org/10.1038/s41598-020-65364-8

Sánchez-Romero, L., Calvo, A. B., & Rios-Garaizar, J. (2021). Defining and Characterising Clusters in Palaeolithic Sites: A Review of Methods and Constraints. *Journal of Archaeological Method and Theory*. https://doi.org/10.1007/s10816-021-09524-8

Sano, K., Arrighi, S., Stani, C., Aureli, D., Boschin, F., Fiore, I., Spagnolo, V., *et al*. (2019). The Earliest Evidence for Mechanically Delivered Projectile Weapons in Europe. *Nature Ecology and Evolution, 3*(10), 1409–1414. https://doi.org/10.1038/s41559-019-0990-3

Scerri, E. M. L., & Will, M. (2023). The revolution that still isn't: The origins of behavioral complexity in homo sapiens. *Journal of Human Evolution, 179*(June), 103358. https://doi.org/10.1016/j.jhevol.2023.103358

Schiffer, M. B. (1972). Archaeological context and systemic context. *American Antiquity, 37*, 156–165. https://doi.org/10.2307/278203

Schiffer, M. B. (1975). Behavioral chain analysis: activities, organization, and the use of space. *Fieldiana: Anthropology, 65*, 103–119.

Shea, J. J. (2011). Homo sapiens Is as Homo sapiens Was. *Current Anthropology, 52*(1), 1–35. https://doi.org/10.1086/658067

Soffer, O. (1994). Ancestral Lifeways in Eurasia — The Middle and Upper Paleolithic Records . In *Origins of Anatomically Modern Humans*, edited by Matthew H. Nitecki et Doris V. Nitecki, 101–19. Interdisciplinary Contributions to Archaeology. Boston, MA: Springer US. https://doi.org/10.1007/978-1-4899-1507-8_5.

Spagnolo, V., Marciani, G., Aureli, D., Berna, F., Toniello, G., Astudillo, F., Boschin, F., Boscato, P., & Ronchitelli, A. (2019). Neanderthal Activity and Resting Areas from Stratigraphic Unit 13 at the Middle Palaeolithic Site of Oscurusciuto (Ginosa - Taranto, Southern Italy). *Quaternary Science Reviews, Neanderthals: Ecology and Evolution, 217*(August), 169–193. https://doi.org/10.1016/j.quascirev.2018.06.024

Speth, J. D., Meignen, L., Bar-Yosef, O., & Goldberg, P. (2012). Spatial Organization of Middle Paleolithic Occupation X in Kebara Cave (Israel): Concentrations of Animal Bones. *Quaternary International, 247*(January), 85–102. https://doi.org/10.1016/j.quaint.2011.03.001. the Neanderthal Home: Spatial and Social Behaviours.

Stringer, C., Gamble, C. (1993). *In Search of the Neanderthals: Solving the Puzzle of Human Origins*. Thames and Hudson. https://eprints.soton.ac.uk/391482/.

Thomas, D. H., Davis, J. O., Grayson, D. K., Melhorn, W. N., Thomas, T., & Trexler, D. T. (1983). The Archaeology of Monitor Valley. 2: Gatecliff Shelter. *Anthropoogical Papers,* 59*,* NY, American Museum of Natural History*,* 1–552.

Vallerand, A. (2021). L'organisation spatiale: un comportement clé de Néandertal et d'homo sapiens: analyse spatiale des couches moustériennes (MS1-MS2) et protoaurignaciennes (A1-A2) de Riparo Bombrini (Imperia, Italie). MSc Thesis, Université de Montréal.

Vallverdú, J., Vaquero, M., Cáceres, I., Allué, E., Rosell, J., Saladié, P., Chacón, G., *et al*. (2010). Sleeping Activity Area within the Site Structure of Archaic Human Groups: Evidence from Abric Romaní Level N Combustion Activity Areas. *Current Anthropology, 51*(1), 137–145. https://doi.org/10.1086/649499

Vaquero, M., & Pastó, I. (2001). The Definition of Spatial Units in Middle Palaeolithic Sites: The Hearth-Related Assemblages. *Journal of Archaeological Science, 28*(11), 1209–1220. https://doi.org/10.1006/jasc.2001.0656

Vaquero, M. (2012). Introduction: neanderthal behavior and temporal resolution of archeological assemblages. In: Carbonell I Roura, E. (Ed.), High Resolution Archaeology and Neanderthal Behavior Time and Space in Level J of Abric Romaní (Capellades, Spain). Springer, Dordretch, pp. 1–16.

Vicino, G. (1984). Lo Scavo Paleolitico al Riparo Bombrini (Balzi Rossi Di Grimaldi, Ventimiglia). *Rivista Ingauna e Intemelia, 39*, 1–10.

Villa, P., & Roebroeks, W. (2014). Neandertal demise: An archaeological analysis of the modern human superiority complex. *PLOS One, 9*(4), e96424. https://doi.org/10.1371/journal.pone.0096424

Villeneuve, L. (1906). *Les Grottes de Grimaldi (Baoussé-Roussé)*. Monaco.

Wandsnider, LuAnn. (1996). Describing and Comparing Archaeological Spatial Structures. *Journal of Archaeological Method and Theory, 3*(4), 319–384. https://doi.org/10.1007/BF02233574

Whallon, R. (1984). Unconstrained clustering for the analysis of spatial distributions in archaeology. In H. J. Hietala (Ed.), *Intrasite Spatial Analysis in Archaeology* (pp. 242–277). Cambridge University Press.

Wynn, T., & Coolidge, F. (2011). *How to Think like a Neanderthal*. Oxford University Press.

Zilhão, J. (2018). Modernity, Behavioral . In *The International Encyclopedia of Anthropology*, 1–9. John Wiley & Sons, Ltd. https://doi.org/10.1002/9781118924396.wbiea1787.