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RESEARCH

The Time of the Stones: A Call for Palimpsest Dissection to Explore Lithic Record Formation Processes

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Abstract
The dissection of archaeological palimpsests has become a crucial process for achieving a diachronic understanding of the history of human groups. However, its widespread application to archaeological deposits has been hampered by both methodological and theoretical limitations, as well as by the inherent characteristics of the deposits. This paper explores whether overcoming these barriers, both methodological and theoretical, truly represents a significant shift in understanding past human behaviour, thereby motivating the pursuit of shorter timescales. To this end, we have analysed the lithic assemblages of Unit Xb from the Neanderthal site of El Salt (Alcoi, Iberian Peninsula) focusing on lithic attributes and raw material analyses, enabling the definition of raw material units and refitting sets. Considering these variables, we have applied archaeostratigraphic and spatial analyses in order to generate units of analysis whose content is compared to that of the entire unit. The defined archaeostratigraphic units display different spatial distributions and lithic composition. Some of them are attached to certain hearths and composed of refitted sets, while other units are related to areas without combustion evidence and integrated with bigger and heavier single products. Through this approach, here, we show that reducing the spatiotemporal scale of the record helps to unravel behavioural variability, reducing interpretative errors implicit in the assemblage-as-a-whole approach. This highlights the role of temporal resolution in reconstructing site formation processes and challenges research perspectives that assert the unnecessary or impossible nature of palimpsest dissection.

Keywords Neanderthal behaviour · Archaeological palimpsest · Lithics · Archaeostratigraphy · Spatial analysis · Middle Palaeolithic

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Introduction

The lithic record constitutes a significant component of nearly all Palaeolithic assemblages. It has been investigated through various approaches, such as technological, raw material or use-wear analyses, typically relying on the stratigraphic unit (SU) as the primary unit of analysis. However, ordering in time and space the anthropogenic activities that led to the deposition of thousands of products within a single SU remain a challenging area of research. Advancing along this trajectory promises a better understanding of the lithic assemblages formation processes and, consequently, a more comprehensive reconstruction of the history of past human groups (Stevenson, 1985; Vaquero, 2008).

Nevertheless, a significant obstacle in this endeavour is the archaeological palimpsest effect. We consider this phenomenon to be the result of the accumulation and transformation of multiple anthropogenic and natural events over time and space in archaeological deposits (Bailey, 1983; Binford, 1981; Lucas, 2008, 2012, 2021; Vaquero, 2012). Although different types of palimpsests have been proposed to explain record formation processes (*i.e.* true, cumulative, spatial or temporal cf. Bailey, 2007), our broad definition is based on the inherent spatiotemporal uncertainty that characterises the archaeological record. This uncertainty can lead to scenarios where multiple types of palimpsests coexist within the same context, irrespective of the resolution at which they are analysed.

Regardless of the definition, what seems to be agreed is that this phenomenon creates a mixture of remains that do not clearly reflect single occupations, but rather an amalgam of events that may span hundreds or thousands of years. Considering that geological time spans over centuries and millennia, defining archaeological assemblages based solely on stratigraphic criteria can be misleading. It can obscure the variability and nuance of human behaviour by averaging different events into a single unit of analysis. This makes it difficult to identify flexible responses to short-term changes and can lead to simplistic and erroneous interpretations of the past. For a more accurate understanding of lithic record formation processes in particular and past human behaviour in general, it is critical to generate and use units of analysis that more closely approximate the temporal resolution of individual events, thus overcoming the challenges posed by the palimpsest.

But is it truly possible to dissect a palimpsest? Throughout the works focused on the formation of archaeological assemblages, we find examples in which palimpsest dissection is the main objective for the reasons already mentioned (*e.g.* Malinsky-Buller *et al.*, 2011; Machado *et al.*, 2013; Bargalló *et al.*, 2016; Sánchez-Romero *et al.*, 2017; Spagnolo *et al.*, 2020a). However, this objective requires clarification. While the ultimate goal is to identify human occupation episodes, achieving such a resolution is rare. So are we actually dissecting a palimpsest? The answer is that we are indeed separating different anthropogenic formation stages, thereby reducing the scale of analysis as far as the diachrony indicators allow. Thus, in our view, palimpsest dissection should be understood as an ongoing process rather than a final outcome, without ever abandoning the idea of reaching that “illusory goal” of the human occupation episode (cf. Bailey, 2007).

This paper aims to explore the interpretative differences that arise from applying different scales of analysis to lithic record formation processes. To do so, we focus on the lithic assemblages from the El Salt SU Xb, a time-averaged deposit with an estimated minimum time span of 200–240 years (Herrejón-Lagunilla *et al*., 2024). By examining how scale influences our interpretations, we seek to shed light on the broader implications for understanding human behaviour as reflected in the archaeological record.

Although the concept of palimpsest and its consequences on the interpretation of the archaeological record have been argued, particularly among researchers working with Palaeolithic records (Mallol & Hernández, 2016; Romagnoli *et al*., 2018a; Vaquero, 2008), attempts at palimpsest dissection remain sporadic. The reasons behind this seem to be influenced by theoretical positionings and methodological constraints. In the following subsections, we delve into these issues by first addressing the theoretical obstacles that hinder the application of palimpsest dissection and then exploring the methodological challenges inherent in the Palaeolithic record when attempting to reconstruct its formation processes.

Theoretical Obstacles in Understanding Human Behaviour

The scarcity of studies of the archaeological record geared towards palimpsest dissection may be attributed to certain theoretical positions. Some researchers adhere to the statement that archaeological stratigraphic sequences/units and long-term changes observed within them reliably indicate human behavioural variability (*e.g.* Hodder, 1987; Pettitt, 1997, 2000; Barton *et al*., 2014; Reeves *et al*., 2019). This perspective is rooted in the adaptation of the Braudelian division of time, where research can be directed towards the long-term (*i.e.* geographical-geological), medium-term (*i.e.* structural history) or short-term scale (*i.e.* event) (Knapp, 1992). According to this postulate, each of these temporal compartments could offer distinct behavioural aspects. Thus, if the research questions pertained to general trends, such as human–environment interactions, delving into the event might be considered unnecessary. In this scenario, Time Perspectivism, which emerged in the 1980s and evolved during the following decades, seeks to transcend the debate over the primacy of long-term versus short-term processes by accommodating multiple temporal structures according to the scale offered by the palimpsest (*e.g.* Bailey, 2007, 2008; Murray, 1999, 2008). While this approach has fostered greater caution in interpreting the archaeological record (*e.g.* the criticism on uniformitarianism), it has also led to a certain laxity in the search for scientific advances in temporal resolution. Thus, our perspective suggests a clear avenue for research: the reconstruction of long-term scales can only be achieved through the sum of several diachronic and short-term events (Harding, 2005; Lucas, 2008, 2012; Vaquero, 2012).

Despite theoretical debates on how to approach time as a variable, there is a tendency in the aforementioned perspective to dismiss the analysis of short-term changes, interpreting them as mere "noise" in the context of human behavioural variability (Barton *et al*., 2014: 349). This reluctance appears to be primarily linked to practical aspects, reflecting a hesitation to engage with the complexity of short-term events, rather than deriving from theoretical conceptions. While constructing explanations based on behavioural averages may seem more straightforward, avoiding the event could lead to a "Frankenstein" history of ancient hunter-gatherers. This kind of fragmented reconstruction comprising different and disordered human activities has resulted in the comparison and assimilation of Neanderthal spatial behaviour with that of carnivores by Pettitt (1997:219). An assemblage-as-a-whole approach tends to focus on long-term structural factors and therefore favours a strict adaptationist and deterministic perspective of human behaviour. This reductionist perspective misses the range of behavioural variability that can be expressed in short-term scales.

In this context, short-term processes not only risk being perceived as a category without historical implications, but also face the challenge of seeming impossible when searching for an apparent contemporaneity (Bailey, 2007). Nevertheless, it is crucial to highlight that palimpsest dissection aims to explore the opposite: diachrony. The primary aim of palimpsest dissection is not to prove that some events were contemporaneous in occupational terms, but to establish the temporal order of the formation episodes identified in an archaeological unit, that is, to determine what happened before and what happened after. Therefore, the outcome of palimpsest dissection does not need to be expressed as a sequence of occupation events, but often as a sequence of formation stages. Even in contexts where "strict contemporaneity" or "occupational contemporaneity" (Adler *et al.*, 2003; Conard & Adler, 1997) might be inferred, researchers have debated the temporality imbricated within the ostensibly same event, and contemporaneity is consistently questioned (*e.g.* Vaquero *et al.*, 2019; Machado *et al.*, 2019; Mayor *et al.*, 2019, 2020; Sossa-Ríos *et al.*, 2022). Similarly, there is a risk of inherently associating the definition of short-term events with fine-grained assemblages (*sensu* Binford, 1978a) as previously warned by Bailey (2008) and taken up by Rezek *et al.* (2020). This "scepticism" (*sensu* Binford, 1981) may lead to accepting the limitations of high-density palimpsests and therefore opting for a lower resolution approach and drawing behavioural inferences from SUs.

Despite these positions, there are inherent limitations within the archaeological record itself that prevent us from achieving the desired level of resolution. These challenges prompt the question: are these limitations unequalled?

Methodological Challenges in Palimpsest Dissection

The shortage of studies can also be attributed to the methodological challenges inherent in deciphering time-averaged deposits. These issues are considered a significant impediment when establishing correlations between the temporal scale of the data provided by archaeological sites and behavioural hypotheses often based on the application of ethnographic models and concepts (Bailey, 1983; Lucas, 2012; Kuhn & Clark, 2015). This complexity becomes particularly evident in sites with high-density assemblages, where the spatiotemporal separation and characterisation of human occupations are difficult tasks. However, recent research shows a clear concern for achieving a better alignment between time resolution and research questions in Palaeolithic archaeology. Examples include the development of fire high temporal resolution sequences (Herrejón-Lagunilla *et al*., 2024; Vandevelde *et al*., 2018), the improvement of time resolution in palaeoclimate or seasonality reconstructions through faunal assemblages (Pederzani *et al*., 2021; Rivals *et al*., 2021) and the extraction of lipids or DNA from microstratigraphic units (Rodríguez de Vera *et al*., 2020; Massilani *et al*., 2022).

In the context of lithic assemblages, the palimpsest dissection approach has been applied across different Pleistocene contexts, spanning various time periods. The main goal has been to achieve a more detailed understanding of human behaviour at a higher temporal resolution by discerning the different events contributing to the formation of the lithic assemblages (Clark, 2017; de la Peña *et al*., 2022; Fraile-Márquez *et al*., 2022; Martínez-Moreno *et al*., 2016; Mayor *et al*., 2020). These advancements have been developed mainly through the application of archaeostratigraphy and spatial analysis. The archaeostratigraphic analysis has been widely used in Palaeolithic archaeology since the 1980s, gaining greater prominence in the last decade (*e.g.* Baker, 1978; Villa, 1982; Villa & Courtin, 1983; Stevenson, 1985; Canals *et al*., 2003; Martínez-Moreno *et al*., 2004; Machado *et al*., 2013; Roy *et al*., 2015; Sánchez-Romero *et al*., 2017; Spagnolo *et al*., 2020a). By focusing on the vertical point pattern as the primary object of study, archaeostratigraphy offers direct markers of diachrony through vertical material gaps. This method involves separating material layers and converting them into units of analysis (*i.e.* archaeostratigraphic unit or any of its variants: archaeo-level, sublevel), which provides a better approach to studying spatial behaviour.

In general, both techniques enable the definition of new units of analysis that serve to diminish temporal uncertainty and provide context for associated lithic materials (Bargalló *et al*., 2016; Clark, 2017; Discamps *et al*., 2023; Machado *et al*., 2013; Martínez-Moreno *et al*., 2004). Consequently, these approaches are increasing our knowledge about the sequence and processes underlying the lithic artefact discard behaviour. In sites where palimpsest deposits have been systematically analysed, the fallacies resulting from interpreting lithic assemblage-as-a-whole (*e.g.* complete operational chains) have been prominently highlighted (Dibble *et al*., 2017; Vaquero, 2008). These findings underscore the significance of the spatiotemporal resolution and emphasise the potential risks associated with interpretations based on assemblages derived from entire SUs (Sossa-Ríos *et al*., 2022; Turq *et al*., 2013; Vaquero, 2012).

However, when objects and their spatial relationships are completely illegible for defining units of analysis, alternative approaches should be considered before fully adopting the assemblage-as-a-whole approach. The analysis of activity events has demonstrated its potential in isolating specific tasks within dense palimpsests, allowing for the characterisation of certain aspects of human behaviour on a shorter timescale. For instance, the technological study of different refitted sequences provides insight into the technical processes developed within brief moments (Vaquero, 2008; López-Ortega *et al*., 2011; Clark, 2017, 2019; Machado *et al*., 2019; Cenk-Yeşilova, Ollé & Vergès, 2021). Similarly, examining recycled products can reveal information about specific selection behaviours, which can be linked to mobility dynamics and technological backgrounds among groups distanced over time (Mayor *et al.*, 2024; Vaquero *et al.*, 2012, 2015).

So far, we have reviewed different cases where lithic assemblages have been studied from the stratigraphic unit, from the archaeostratigraphic and spatial unit and from the activity event. However, in order to know the consequences of palimpsest dissection, it is key to study the same assemblage from several of these scales and compare the interpretative disparities that arise. For this purpose, the Middle Palaeolithic site of El Salt (Alcoi, eastern Iberia) has been a scenario of interdisciplinary research geared towards archaeological palimpsest dissection. Previous investigations of SU Xa have combined archaeostratigraphy with raw material, technological, use-wear and zooarchaeological analyses, enabling the separation and characterisation of the archaeological record at small timescales (Bencomo *et al.*, 2023; Machado & Pérez, 2016; Machado *et al.*, 2017; Mayor *et al.*, 2019, 2020). In addition, recent archaeostratigraphic and archaeomagnetic research into a hearth set from SU Xb has highlighted the palimpsest nature of this stratigraphic unit by quantifying the minimum time elapsed between different pairs of hearths within the sampled fires (Herrejón-Lagunilla *et al.*, 2024). These temporal intervals range from decades to centuries, with an overall minimum formation time of 200–240 years for the entire set. Knowing the minimal diachronic range between hearths makes SU Xb a perfect case to study the differences between analysing the lithic assemblage-as-a-whole and through higher-resolution units. In this paper, we present the results of raw materials, lithic attributes, refits, archaeostratigraphy and spatial patterns from SU Xb according to different temporal frameworks.

The Middle Palaeolithic Site of El Salt

El Salt (Fig. 1) is located in Alcoi, in eastern Iberia, at an elevation of 620 m.a.s.l. (Fig. 1A), beneath a 38-m-high limestone wall covered by travertine and tufa (Fig. 1B). It is situated near the headwaters of the Serpis River basin and faces its valley (Fig. S1 and Fig. S2). This is a territory characterised by the presence of numerous silicifications defined in previous works (Molina *et al.*, 2015, 2016), formed within the mountainous surroundings of the river and resedimented during Cenozoic times after erosion and transport. It has been the context of human occupation since MIS 5, as far as it is recorded (Galván et al., 2014), with Neanderthal sites such as Beneito cave (Muro d'Alcoi, Alacant; Iturbe *et al.*, 1993), Foradada cave (Oliva, València; Eixea & Sanchis, 2022), El Puntal del Gat cave (Benirredrà, València; Eixea *et al.*, 2019) and Abric del Pastor rockshelter (Alcoi, Alacant; Machado *et al.*, 2013, 2019), along with more than 70 surface sites with Middle Palaeolithic remains (Molina & Mayor, 2023; Molina *et al.*, 2015, 2016). These surface sites contain lithic records with no signs of combustion features or faunal remains. However, there have been identified two distinguishing kinds of sites: those located near raw material sources and exclusively related to flint acquisition and processing, which are the majority (*e.g.* Molina & Mayor, 2023), and those far away from deposits containing

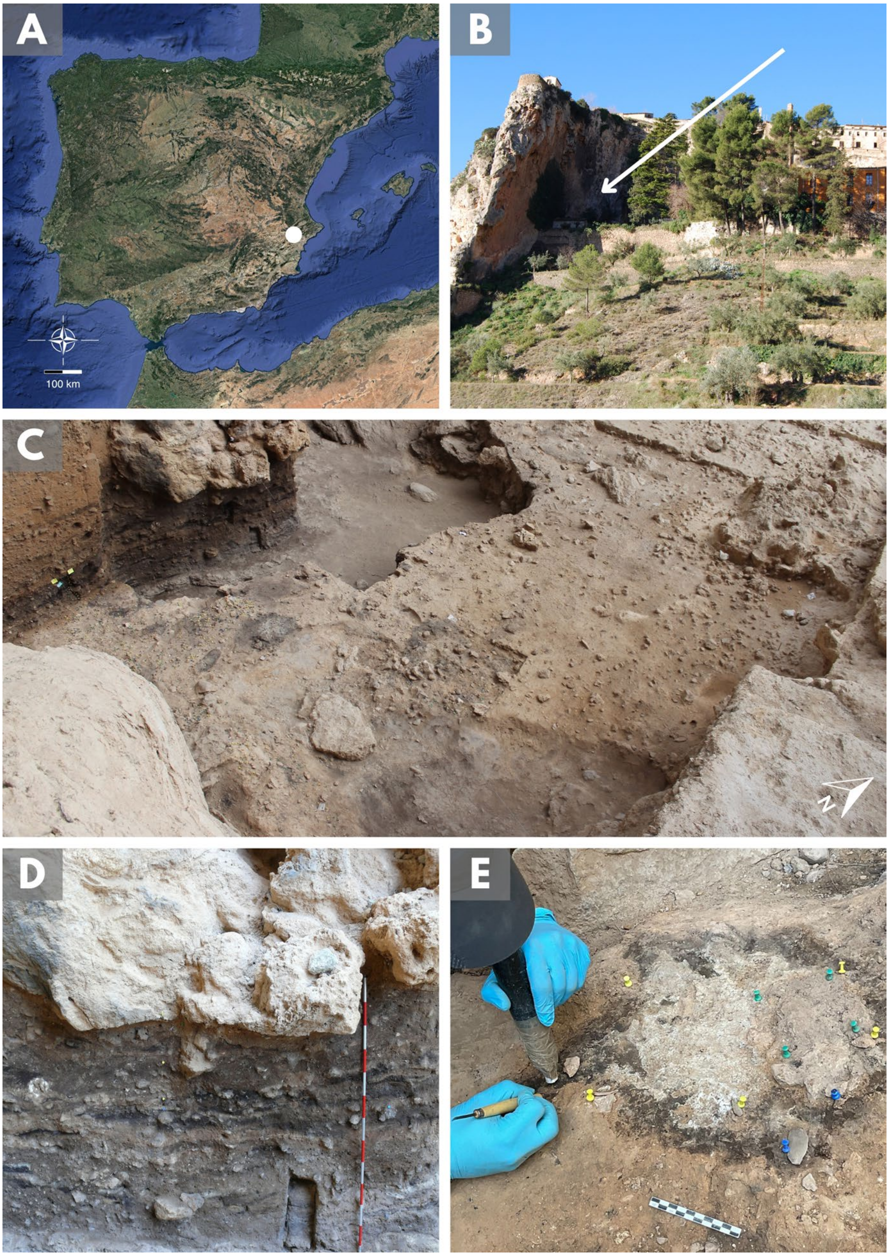

Fig. 1 Overview of El Salt. **A** Location of the site. **B** El Salt under the tufa formation. **C** Excavation surface of SU Xb . **D** Stratigraphic profile of El Salt. **E** Hearth preservation and excavation process of SU Xb

flint and associated with other activities, due to the predominant presence of retouched tools and the relative absence of knapping subproducts (Barciela & Molina, 2005). Furthermore, the mobility patterns derived from flint analysis indicate a prevalence of unidirectional itineraries focused on the upper and the middle courses of the Serpis valley throughout the river, as well as an absence of siliceous products from other valleys (Mayor *et al.*, 2022; Molina, 2015).

In the specific case of El Salt and Abric del Pastor, recent studies have corroborated the intrinsic relationship of Neanderthal groups with the Serpis River by examining flint from a postgenetic perspective (*i.e.* Molina, 2015; Mayor et al., 2022). These studies reveal cases of preferential gathering of flint nodules in fluvial contexts, highlighting the river's pivotal role in Neanderthal mobility patterns. Additionally, increasing the spatiotemporal resolution of the units of analysis in these sites has led to a more precise detection of diachronic changes in raw material selection (Machado & Pérez, 2016; Machado *et al.*, 2017, 2019). Extending this resolution may enable the association of these changes with other behaviours, such as intrasite space use or biotic resource management.

The El Salt excavation area comprises 38 m^2 within a larger archaeology-bearing area of 250 m^2 (Fig. 1C) (for 3D model see ElTossal Topografia, 2015). The excavation area has been divided into two main zones based on their macroscopic sedimentary features and archaeological content. In the field, the outer area is characterised by a homogeneous deposit of calcitic sandy clayey silt, while the inner area, which is currently slightly sheltered by the overhang of the wall, is also composed of calcitic sandy clayey silt but also contains abundant organic matter, from both anthropogenic and natural sources (Leierer *et al.*, 2019; Mallol *et al.*, 2013). The stratigraphic sequence (Fig. 1D) is around 6 m thick and has been divided into 13 SUs, with dates ranging from 81.5 ± 2.7 to 44.7 ± 3.2 ky BP (Fig. S3) (Fumanal, 1994; Galván *et al.*, 2014). Starting from the bottom, SU XIII is an archaeologically sterile calcitic tufa sequence of unknown thickness. From SU XII to the base of V, the sedimentary layers are composed of sandy clayey silt containing Middle Palaeolithic archaeological remains dated to between 60.7 ± 8.9 ky BP for SU XII and 44.7 ± 3.2 ky BP for SU V (Fig. S4). The top of SU V is an archaeologically sterile layer of sandy silt with undetermined Palaeolithic remains towards the top, and SUs IV to I are gravelly and cobble-rich layers containing reworked Holocene archaeological remains originating from undetermined sources. The erosional process responsible for this reworked deposit also eroded part of the Pleistocene deposit within the excavation area, at the southeast.

The site was discovered in 1959 by Juan Faus, who communicated its archaeological significance to Vicente Pascual, who in turn contacted Lluís Pericot of the University of Barcelona (Galván, 1992). Pericot then entrusted the initial excavation to Vicente Pascual and Ricardo Martín, which took place in 1960 and 1961 with the financial support of the Wenner-Gren Foundation. These excavations revealed several lithic and faunal remains attributed to the Middle Palaeolithic but also resulted in the creation of a substantial trench that divided the archaeological surface. The recovered lithic materials were subsequently analysed by Bertila Galván from the University of La Laguna during the early 1980s. The site has been uninterruptedly excavated from 1986 until now by an international team coordinated by the University of La Laguna.

Stratigraphic Unit X

Stratigraphic unit X has been divided in the field into two different subunits, SU Xb and SU Xa, based on a combination of colour and texture: SU Xb, at the base, is 15 cm thick and exhibits finer-grained, darker-coloured sediment, while SU Xa is 10 cm thick and rests directly above Xb with a diffuse, undulating contact, exhibiting a sandier, lighter-coloured sediment (Leierer, 2021; Leierer *et al.*, 2019). The chronometric average of the thermoluminescence dating for SU X is set at 52.3 ± 4.6 ky BP (Galván *et al.*, 2014) (Fig. S4).

Archaeological research at El Salt has focused mainly on these two subunits. Here, we summarise different studies that have been conducted in both, highlighting various aspects of palaeoenvironmental conditions and Neanderthal behaviour. The microvertebrate species present in the SU Xb, such as *Microtus arvalis*, *Apodemus sylvaticus* and *Elyomis quercinus*, as well as the anthracological taxa, including *Pinus nigra sylvestris*, *Acer* sp. and *Quercus* sp., indicate supramediterranean conditions within a landscape characterised by open forests, suggesting a colder and wetter climate than current records (−3.3 °C, + 113.3 mm) (Fagoaga *et al.*, 2018; Vidal-Matutano *et al.*, 2018). Additionally, the presence of water or wet areas in the vicinity of the site is inferred from the recovery of amphibians (*i.e. Bufo bufo*, *Epidalea calamita*, *Alytes obstetricans*), reptiles (*i.e. Chalcides bedriagai*, *Acanthodactylus erythrurus*) and snakes (*i.e. Rinechis scalaris*) from this unit (Marquina *et al.*, 2017).

Furthermore, from a behavioural perspective, anthracological analyses in SU Xb identify *Pinus nigra sylvestris* as the most frequently gathered taxon within a radius of 1 km, along with *Acer* sp., and up to 5 km for *Quercus* sp. and *Juniperus sabina* (Vidal-Matutano *et al.*, 2018). Despite the predominance of *Pinus nigra sylvestris*, other less represented taxa such as *Buxus sempervirens* have been recognised in certain hearths, as well as other taxa related to specific combustion structures (Vidal-Matutano *et al.*, 2017). Concerning the lithic and faunal assemblages, research on SU Xa points towards the existence of short-term human occupations, marked by discrete accumulations resulting from knapping, woodworking and butchery activities that display diachronic variability within this unit (Bencomo *et al.*, 2023; Machado & Pérez, 2016; Machado *et al.*, 2017; Mayor et al., 2020). Lithic assemblages in Xa also exhibit a prevalence of hierarchised knapping strategies, mainly with centripetal modalities. Flint is the dominant raw material, with the input of different flint types (*i.e.* Serreta, Mariola and Beniaia) that were procured from distances ranging from 5 to 25 km, as has been indicated by analysing signs of postgenetic alterations (Machado *et al.*, 2017; Molina, 2015). Regarding the faunal assemblage, the most notable taxa in SU Xa encompass *Capra pyrenaica*, *Cervus elaphus* and *Equus ferus* (Machado & Pérez, 2016; Pérez, 2019), with the added observation that certain bones from deer and horse were utilised as retouchers (Pérez, Hernández & Galván, 2019).

On the other hand, the archaeostratigraphic and archaeomagnetic work carried out on four hearths from SU Xb (*i.e.* H48, H50, H55 and H59) has revealed the minimum time elapsed between different pairs of fires (Herrejón-Lagunilla *et al.*, 2024). This study shows differences of a few decades between H55 and H48 (20–25 years), several decades between H48 and H59 (70–85 years) and a century between H50 and H59 (85–105 years). These temporal disparities underscore the diachronic nature of the hearth sequence within this unit. When considered alongside a hearth from the base of SU Xa, these data collectively suggest a minimum formation period of 200–240 years for the entire assemblage.

In terms of taphonomic integrity, the preservation of SU X has been evaluated through different proxies. First, soil micromorphology has been applied to both unburnt and burnt sediments, revealing a poorly sorted mix of calcitic sand, silt and clay and plant residues, excrements and archaeological remains, such as bone, flint, charcoal and char. Furthermore, numerous well-preserved, in situ combustion structures have been identified, composed of a charred organic-rich substrate (seen as black layers in the field), overlain by variably preserved wood ash containing burnt bone, charcoal, char and excrements (Fig. 1E) (Mallol *et al*., 2013; Rodríguez-Cintas & Cabanes, 2017; Leierer *et al*., 2019; 2020). Biomolecular sedimentary analyses have shown good lipid biomarker and bacterial aDNA preservation, exhibiting different compounds between black layers, ashes and control samples (Leierer *et al*., 2019; Rampelli *et al*., 2021; Sistiaga *et al*., 2014). In the case of the lithic assemblages, previous archaeostratigraphic analyses in SU Xa have shown the absence of vertical movements of elements belonging to raw material units (RMU) (Machado *et al*., 2017; Mayor *et al*., 2020). Moreover, use-wear analyses have shown the presence of different traces in good preservation states (Bencomo *et al*., 2023). Similar results have been derived for the faunal record, revealing minimal diagenetic damage and the same archaeostratigraphic context of individuals (Machado & Pérez, 2016). In addition, the taphonomic study of the micromammal assemblage has indicated a limited occurrence of weathering and abrasion processes (Marín-Monfort *et al*., 2021).

Materials and Methods

In this work, we conducted a comprehensive analysis of 1544 lithic artefacts, examining their technological attributes, raw material composition, RMU association and refits. Using these variables, we conducted archaeostratigraphic and spatial analyses, complemented by data from 14 hearths. All objects were excavated from 2013 to 2016 and three-dimensionally recorded (*i.e.* X, Y, Z) by a Sokkia iM-50 Series and a Leica Geosystems FlexLine TS02 total stations. Although we aim to coordinate every lithic remain independently of its size, there are products that have been recovered in the water screening process. In order to estimate the handicap in the sample of coordinated material, we have selected one subsquare (*i.e.* 50 × 50 cm) from the inner area and another from the outer area where most of the material was comprehended. From these, we have counted, weighed and measured the uncoordinated flint remains from the seasons involved. In the inner area, the sampled subsquare contained 46 lithic remains, weighing 2.49 g, in which only one product exceeded 1 cm (*i.e.* 14 mm). In the outer area, we report 19 lithic remains, totaling 0.99 g, of which only one surpassed 1 cm (*i.e.* 13 mm). Considering this information, we decided not to rely on this data, since this record does not provide the required petrological and technological information for this study.

Lithic Attribute Analysis

For this analysis, we first separated the complete lithic assemblage into four types of products based on their technological characteristics: flakes, retouched products, cores and fragments. Then, we studied the morphometric features of the lithic assemblage. In this way, the overall lithic record was measured in millimetres and weighed in grammes. For size class analysis, the length and width of each product were multiplied and classified following the size groups proposed by Vaquero (2008): very small (*i.e.* < 500 mm^2), small (*i.e.* ≥ 500 to < 1000 mm^2), medium (*i.e.* ≥ 1000 to < 1500 mm^2), large (*i.e.* ≥ 1500 to < 2000 mm^2) and very large (*i.e.* < 2000 mm^2). The weight of each product was considered a variable to detect potential variations among assemblages and in particular with those with similar sizes (Shott, 1994; Mears *et al.*, 2022). Furthermore, we have examined whether the products were thermally altered or not by observing colour changes, the presence of heat-induced domes, glossy shining or the occurrence of reticular fissures and fractures. These alterations resulting from thermal alteration were also specifically studied for the flint types found in the Serpis basin and surroundings (Dorta *et al.*, 2010), allowing for their comparison in this paper.

In the specific case of flakes, we have measured their percentage of cortex to spatially identify areas of knapping activity. A higher presence of cortical surface could indicate a higher likelihood of complete knapping actions and/or initial knapping stages taking place in these areas (Vaquero, 2008). For this purpose, we have categorised the flakes into six groups based on the proportion of cortex: 0%, 0–25%, 25–50%, 50–75%, 75–100% and 100%. In addition, two indexes were calculated to gather additional information regarding the morphometric features of flakes, specifically in terms of volumetric shape (Díez-Martín *et al.*, 2009): Elongation Index (*i.e.* length/width) and Thickness Index (*i.e.* the minimum value between length and width/thickness).

Raw Material Analysis

Raw materials can provide valuable insights into past human mobility dynamics (Gómez *et al.*, 2020; Tarriño & Terradas, 2013). In the context of El Salt, the studies conducted in the Serpis Valley and surroundings by Molina *et al.*, (2010; Molina, 2015) and Mayor *et al.*, (2022; Mayor, 2023) have established the groundwork for a comprehensive characterisation of the flint types and the procurement sources in the basin, following the flint itinerant history proposed by Fernandes and Raynal (2006). However, our work will be solely on the examination of raw material and flint types, with the aim of shedding light on interassemblage variability, and compositional differences among archaeostratigraphic and spatial units. In this approach, the whole lithic assemblage was examined, considering the following variables: grain size, translucence degree, inclusions (*e.g.* fossils, carbonate features, recrystallisations, detrital quartz, megaquartz geodes) and colour spectrum. The analysis was conducted macroscopically, and in cases in which this characterisation was not possible, a Euromex Novex AR-Zoom microscope was employed. The variables listed before were compared to the reference collection developed by Molina *et al.*, (2015, 2016).

Raw Material Units and Refitting Analysis

The raw material analysis enables us to define raw material units (RMUs). This concept, initially introduced by Roebroeks (1988) and widely adopted by other researchers (*e.g.* Conard & Adler, 1997; Dietl *et al.*, 2005; Vaquero, 2008; Mora *et al.*, 2020), refers to groups of artefacts that exhibit similar genetic and postgenetic features. Consequently, these products can be interpreted as deriving from the same raw material nodule, allowing us to identify potential areas of knapping activity and understand the input and output of lithic materials (Mora *et al.*, 2020; Turq *et al.*, 2013). In this study, building upon our previous research (Sossa-Ríos *et al.*, 2022), we will distinguish between two types of RMUs: set-RMUs (*i.e.* S-RMU), which comprise two or more products sharing similar characteristics, and single-element RMUs (*i.e.* SE-RMU), which are all the artefacts that have not been associated with a S-RMU, and therefore, each of them constitutes the result of potential exploitation of an original raw material nodule. The only difference between this and the former is that SE-RMUs comprise a single artefact instead of several, which provides critical information regarding its management.

Lithic refits are S-RMUs that provide one or more physical connections (*i.e.* R-RMU). They have been extensively used in technological, archaeostratigraphic and spatial analyses with the same objectives as S-RMUs, but with the added assurance offered by the material linkage (Machado *et al.*, 2019; Romagnoli & Vaquero, 2019; Vaquero *et al.*, 2019). In our methodological approach, we conducted two refitting trials for each lithic product over a span of 2 months, ensuring a comprehensive exploration of potential connections.

Archaeostratigraphic Analysis

Archaeostratigraphic analysis was performed once the lithic assemblage was studied following the steps described above. This analysis aims to obtain archaeostratigraphic units (AUs), which offer a higher spatiotemporal resolution compared to the SU (Machado *et al.*, 2013; Martínez-Moreno *et al.*, 2016; Sañudo, Blasco & Fernández-Peris, 2016; Bargalló *et al.*, 2016; Mora *et al.*, 2020; Spagnolo *et al.*, 2020a). The analysis was performed using Environmental Systems Research Institute (*i.e.* ESRI) ArcGIS Desktop software, version 10.5.

In this process, the initial step was plotting the lithic and hearth assemblages in three dimensions using the ArcScene tool. This process aimed to visualise the overall point distribution from various angles and thus mitigate the lack of perspective inherent in the second step (*i.e.* two-dimensional cross-sections) (Arteaga-Brieba *et al.*, 2023; Roy-Sunyer, 2015; Sánchez-Romero *et al.*, 2017). Second, we used the ArcMap tool to generate 38 cross-sections, each 25 cm wide, that spanned the entire surface. After reviewing the general spatial distribution, the cross-sections containing the greatest accumulation of archaeological material were selected for display. These cross-sections allowed analysis of the vertical distribution of objects and facilitated the identification of gaps in the archaeological material and correlations within the record. This process is particularly focused on examining the vertical distribution of S-RMUs and R-RMUs and the connections of black and white layers with different assemblages, since both layers represent, at least, two different moments in time; the black layer represents human activity on the hearth substrate prior to the combustion event, and the white layer represents the combustion event (Mallol *et al*., 2013; Mayor *et al*., 2020).

Spatial Analyses

Spatial analyses were carried out using the software ESRI ArcGIS Desktop, specifically ArcMap, version 10.5. Kernel density estimation (KDE) analysis was applied to examine the spatial distribution patterns within each AU. This method allowed us to identify zones with higher concentrations (*i.e.* clusters) or lower concentrations of artefacts (Sánchez-Romero *et al*., 2016, 2020; Spagnolo *et al*., 2019, 2020b; Zilio *et al*., 2021). As both high and low concentrations of artefacts offer valuable insights, we considered the two categories in the analysis of lithic assemblages. For this examination, different search radii were applied to each area of the site depending on the generated density raster with the aim of obtaining detailed results. Thus, a radius of 0.4 m was applied for the inner area and a radius of 0.5 m for the outer area. The selection of resulting spatial concentrations is in line with the method proposed by Clark (2017), although our criteria focused on the range of values and the record itself rather than the contours. Additionally, we conducted the average nearest neighbour (ANN) statistical analysis to assess whether the tested AUs exhibited clustering, randomness or dispersion in their spatial arrangement (Romagnoli & Vaquero, 2016; Sánchez-Romero *et al*.,2021, 2022). Furthermore, the chi-square test was employed using the PAST software, version 4.0.3, to examine the hypothesis that relates time, space and lithic variables, assessing their interdependence. To investigate potential spatial variations in the formation of the lithic assemblages within each AU, we considered the following variables: product type, flint type, size class, weight, amount of cortex and thermal alteration.

Results

Given the restricted spatial relationship between the inner and outer zones of the site (ref. "The Middle Palaeolithic Site of El Salt" section), we present the results of each zone separately, with the aim of establishing possible connections in the discussion section. These results are structured in four subsections, in which the first one corresponds to the analysis of the assemblage-as-a-whole and the other three to the analysis of the same assemblage by means of higher-resolution units of analysis: the overall content of the SU ("The Assemblage-As-A-Whole" section), temporal units (“Archaeostratigraphic Units” section), spatial patterns (“Spatial Result” section) and lithic content within defined units (“Lithic Assemblages in Higher-Resolution Units” section). However, it is important to highlight that each subsection incorporates data from the others, as the spatiotemporal dissection and characterisation are interrelated tasks, providing mutual feedback.

The Assemblage-As-A-Whole

The lithic assemblage from the outer area ($n=678$) (Table 1) is characterised by the predominance of Serreta flint type (50%), followed by Mariola (17%) and Beniaia (16%). The remaining 17% of the assemblage remains indeterminate. The total weight is 4794 g in which the small-sized products dominate (61%), followed by small- (17%), medium- (12%), large- (6%) and very large–sized elements (4%). Flakes are the most abundant product type (66%), followed by fragments (23%), cores (6%) and retouched products (5%). Cortex is primarily represented in the 0% group (53%), followed by 0–25 (24%), 25–50 (11%), 50–75 (4%), 75–100 (4%) and the 100% group (4%). Regarding thermal alteration, 23% of the products exhibit some signs of burning, while 77% show no alteration. In this area, we recognised 2 R-RMUs both in Serreta flint type, encompassing 2 and 3 products.

The lithic record from the inner area ($n=866$) (Table 1) exhibits a predominant presence of Serreta flint type (45%,) followed by Mariola (23%), Beniaia (11%), Font Roja (3%) and Catamarruc (1%). The 16% of the assemblage remain indeterminate. The total weight is 2402 g, with small-sized products dominating (73%), followed by small- (18%), medium- (7%), large- (2%) and very large–sized products (1%). Flakes constitute the majority of the assemblage (72%), followed by fragments (22%), retouched products (4%) and cores (2%). The amount of cortex is predominantly represented in the 0% group (56%), followed by 0–25 (23%), 25–50 (7%), 75–100 (5%), 50–75 (4%) and the 100% group (4%). Concerning thermal alteration, 24% of the products exhibit signs of burning, while 76% do not show any alteration. In this area, we identified 9 R-RMUs, comprehending 31 products produced in different flint types: Serreta (5 R-RMUs, $n=10$ products), Mariola (2 R-RMUs, $n=6$), Font Roja (1 R-RMU, $n=12$) and Catamarruc (1 R-RMU, $n=2$).

Spatially (Fig. 2), the outer area shows high concentrations notably positioned in front of the H46, H50, H52, H53 and H54 hearths, coinciding with the presence of the two R-RMUs. A parallel pattern is evident in the inner area, where most of the highest concentrations are surrounded by hearths (*i.e.* H55, H57, H61 and H66), including the R-RMUs in this space as well.

Archaeostratigraphic Units

We have identified 2 AUs in the outer area and 2 in the inner area (Fig. 3). The material density and topographic characteristics of these two areas have shown distinct vertical point patterns. Generally, in the outer zone, material hiatuses are well observed, but few R-RMUs are detected, while in the inner zone, the gaps are less developed, but R-RMUS are more frequent, and hearths with black and white layers

Table 1 Main lithic results of the SU Xb, differentiating between outer and inner areas

	Flint type		Size			Type of product			Amount of cortex		Thermoalteration	
Outer area	Serreta	339 (50%)	Very small	413 (61%)		Flakes	448 (66%)		0%	359 (53%)	Yes	157 (23%)
	Mariola	118 (17%)	Small	115 (17%)		Fragments	157 (23%)		0–25%	160 (24%)	No	521 (77%)
	Beniaia	105 (16%)	Medium	84 (12%)		Cores	40 (6%)		25–50%	73 (11%)		
	Font Roja		Large	39 (6%)		Retouched	33 (5%)		50–75%	25 (4%)		
	Catamarruc		Very large	27 (4%)					75–100%	31 (4%)		
	Indet	116 (17%)							100%	30 (4%)		
	Total	678 (100%)			678 (100%)			678 (100%)		678 (100%)		678 (100%)
Inner area	Serreta	391 (45%)	Very small	634 (73%)		Flakes	627 (72%)		0%	459 (56%)	Yes	205 (24%)
	Mariola	203 (23%)	Small	152 (18%)		Fragments	189 (22%)		0–25%	202 (23%)	No	661 (76%)
	Beniaia	102 (11%)	Medium	58 (7%)		Cores	19 (2%)		25–50%	64 (7%)		
	Font Roja	22 (3%)	Large	17 (2%)		Retouched	31 (4%)		50–75%	35 (4%)		
	Catamarruc	7 (1%)	Very large	5 (1%)					75–100%	41 (5%)		
	Indet	142 (16%)							100%	38 (4%)		
	Total	866 (100%)			866 (100%)			866 (100%)		866 (100%)		866 (100%)

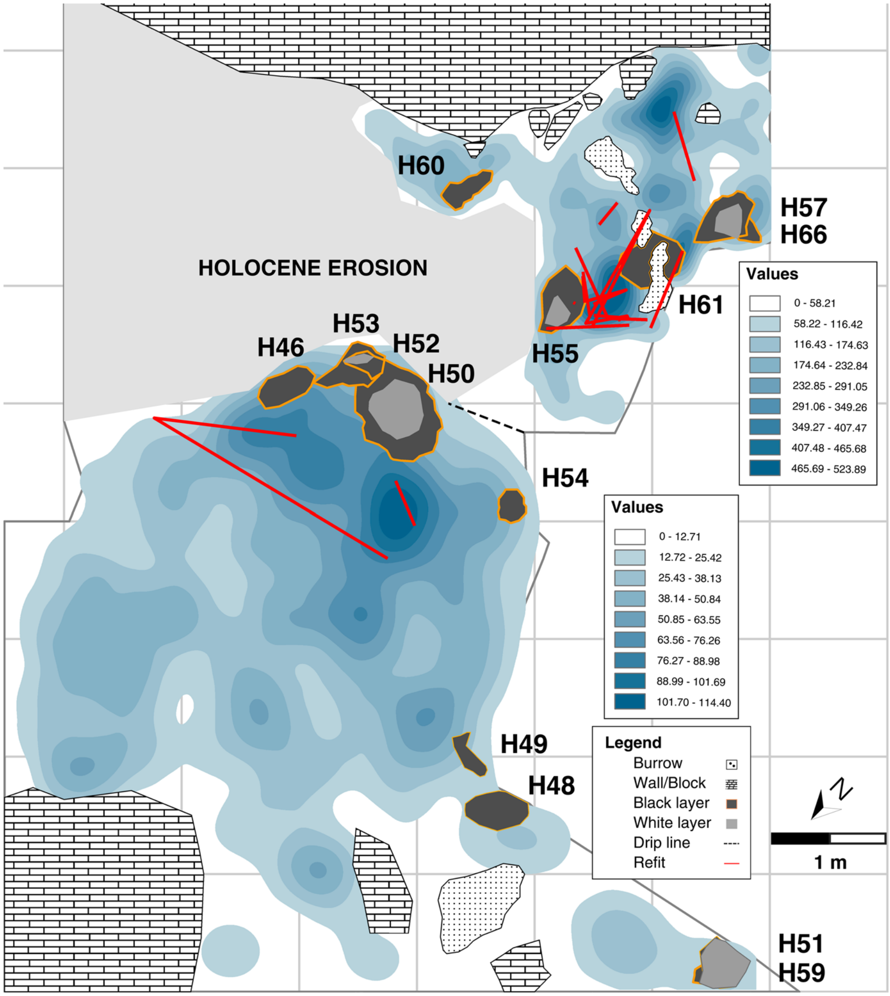

Fig. 2 General plan of El Salt displaying Kernel Density results for the SU Xb lithic record, refits and hearths

are better preserved. Below, we provide a comprehensive description of each AU and its content (Table 2), along with visual representations of the vertical cross-sections containing the greatest amount of material (Figs. 3, 4 and 5).

Outer Area

Archaeostratigraphic units Xb1out and Xb2out are distributed across the entire excavation surface of the outer area (ca. 30 m^2) with a southeastern slope (Fig. 4B). These units were defined following material superposition criteria, material hiatuses between beds and vertical connections with hearths (Fig. 4d–g). Most lithic remains were

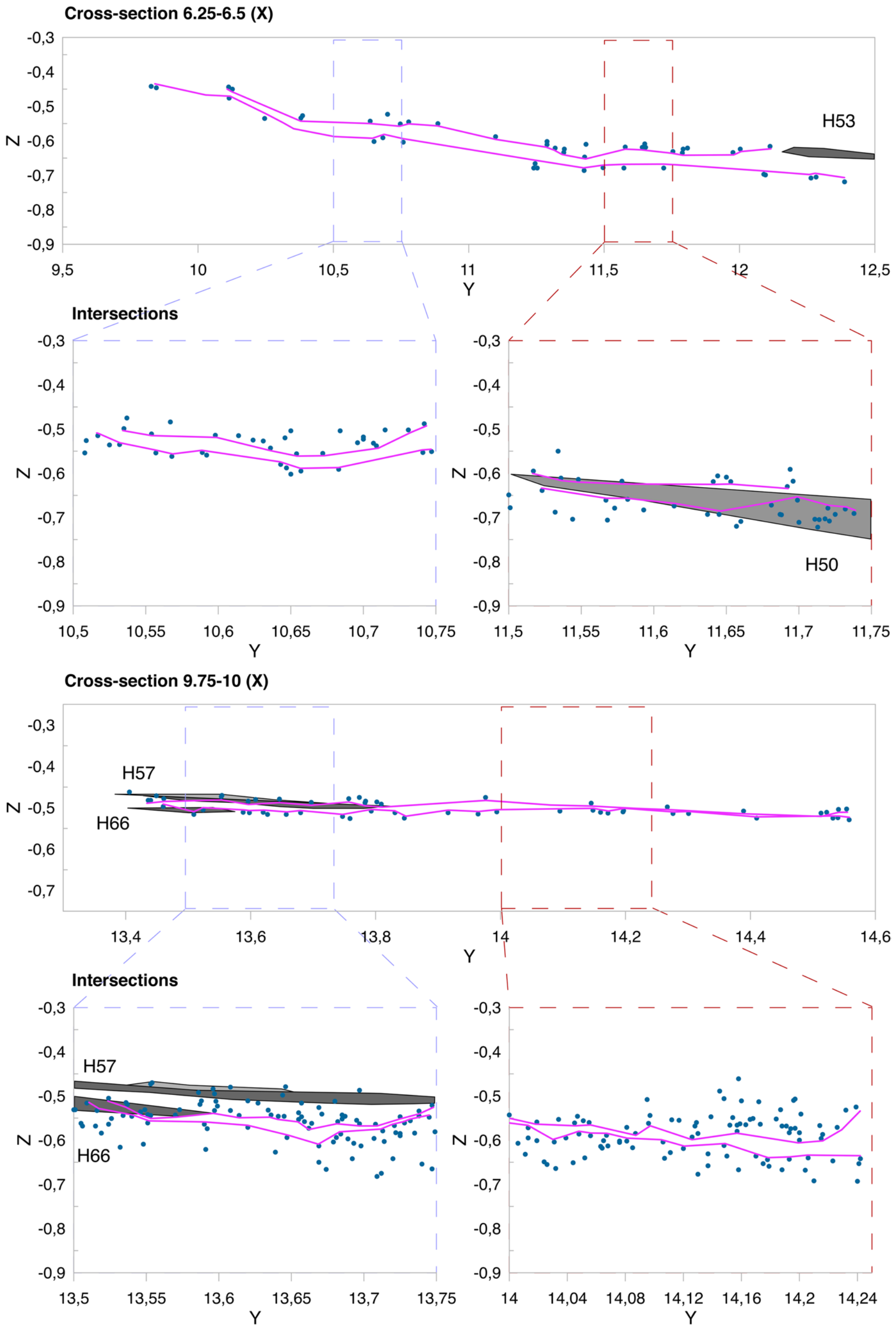

Fig. 3 Archaeostratigraphic sections and intersections showing the identified material gap: outer area (top), inner area (bottom)

Table 2 Material record associated with archaeostratigraphic units

AU	Lithic remains	Hearths	R-RMU
Xb1out	304	4	1
Xb2out	371	2	1
Indet. out	3	3	–
Total	**678**	**9**	**2**
Xb1in	195	3	–
Xb2in	530	1	12
Indet. in	141	1	–
Total	**866**	**5**	**14**

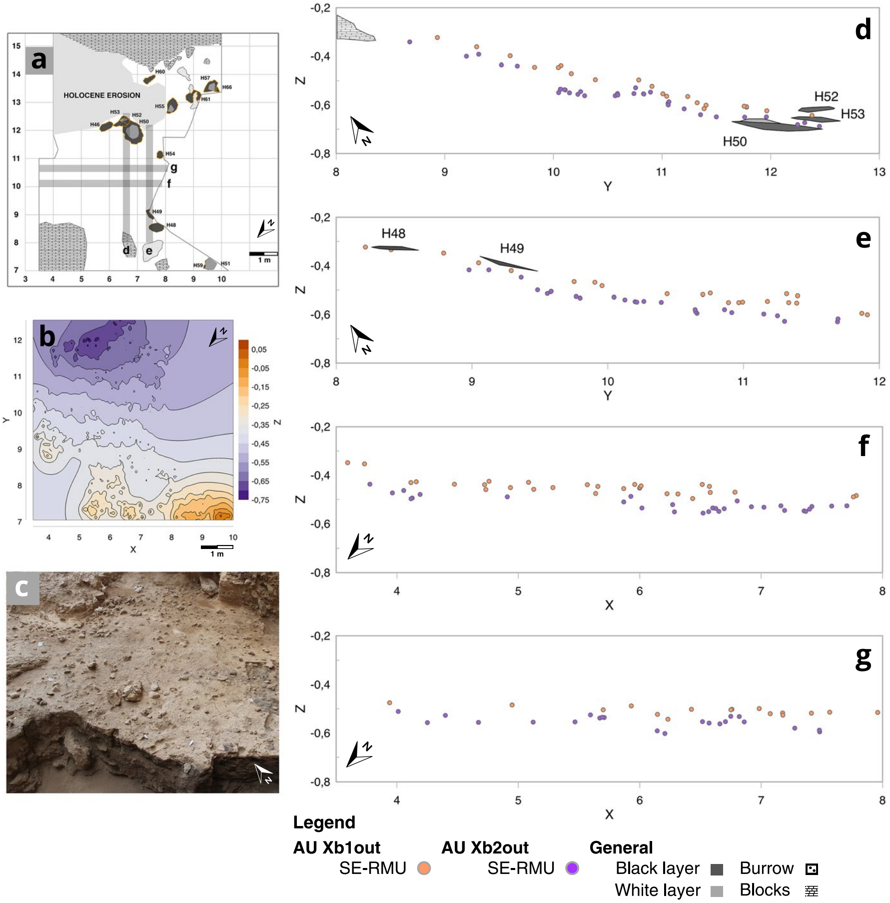

Fig. 4 Archaeostratigraphic profiles of the outer area: **a** plan of the El Salt Xb excavation surface highlighting the cross-sections of the outer area, **b** contour map of the excavation surface created to depict the topographical variations in the outer area, **c** photo of the excavation surface of the outer area, **d** D-cross-section, **e** E-cross-section, **f** F-cross-section, **g** G-cross-section

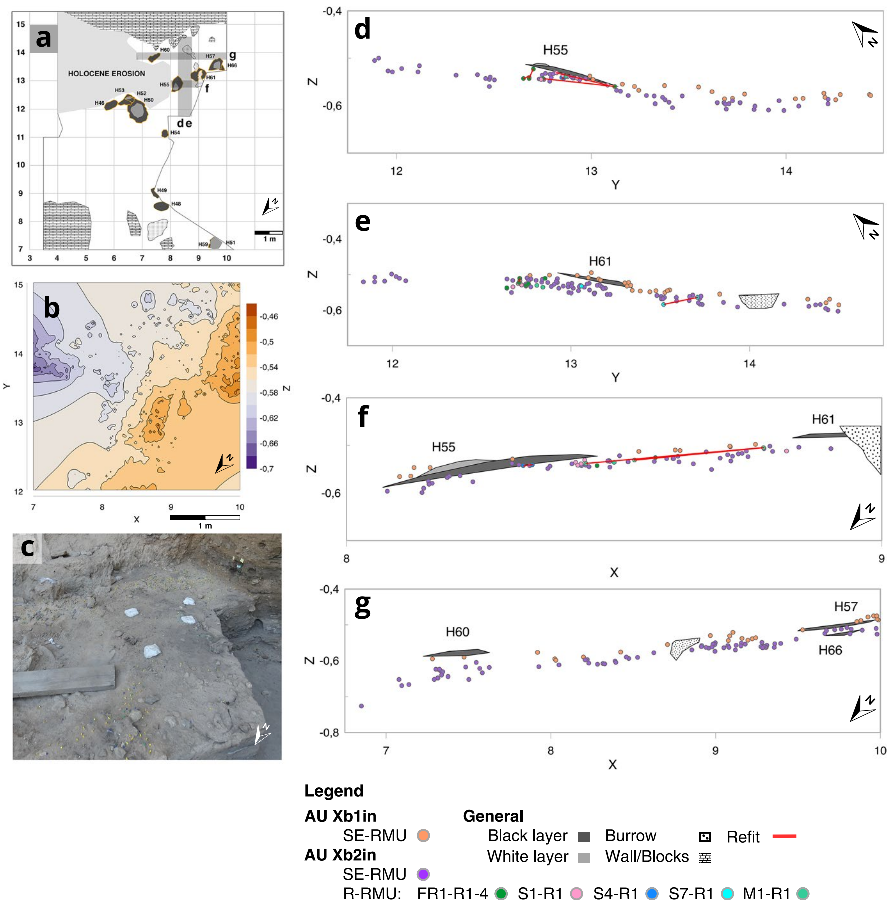

Fig. 5 Archaeostratigraphic profiles of the inner area: **a** plan of the El Salt Xb excavation surface highlighting the cross-sections of the inner area, **b** contour map of the excavation surface created to depict the topographical variations in the inner area, **c** photo of the excavation surface of the inner area, **d** D-cross-section, **e** E-cross-section, **f** F-cross-section, **g** G-cross-section

included in the two units, given a continuous 1–5 cm-thick hiatus observed among the two beds (Fig. 3). Nevertheless, three remains were considered indeterminate.

– Xb1out comprises 304 lithic products including 4 S-RMUs and 1 R-RMU, as well as four hearths (*i.e.* H48, H51, H53, H54). This unit exhibits a higher density of points in the southwestern part, while in the east, only a few remains are present. It is connected to the tops of the H53 and H48 black layers, with H49 and H52 positioned above them (Fig. 4d–e). The position of these two latter hearths makes us consider them as indeterminate, without association with any AU. A similar situation is observed with H46, located even above H52. Regarding H51 and H54, they were associated with the upper unit, particularly H51, whose white layer contains Xb1out material. This hearth lies directly atop H59 (Fig. S5).

– Xb2out comprises 371 lithic products with 7 S-RMUs and 1 R-RMU and two hearths (H50, H59). This AU shows a more homogeneous distribution across the surface, including the eastern area where AU Xb1out is less prevalent. In terms of hearth association, AU Xb2out underlies the H53 black layer, connecting with the H50 white layer (Fig. 4d). In the case of H59, this unit links with the top of its black layer, and it is situated beneath the H51 black layer (Fig. S5).

Inner Area

Archaeostratigraphic units Xb1in and Xb2in are distributed across the whole excavation surface of the inner area (ca. 6 m^2) with an eastern downward slope (Fig. 5b). These units were defined using the same criteria as the outer AUs but were further reinforced by R-RMUs and their connections. In this case, although material gaps were also identified (Fig. 3), we considered 141 lithic products as indeterminate, most of which were in close proximity to the travertine wall (ca. 50 cm), showing an irregular point pattern (Fig. S5).

– Xb1in contains 195 lithic products including 3 S-RMUs, as well as 3 hearths (*i.e.* H55, H57, H61). This unit was fundamentally defined by the link between the uppermost materials to the 3 mentioned hearths. In the case of H55 and H61, the AU Xb1in connects with both black layer top, with materials immersed in the H55 white layer (Fig. 5d and Fig. 5f). The same occurs with H57, in which points are just on top of its black layer (Fig. 5g). H60 is the only combustion structure from the inner area that was considered indeterminate, since the Xb1in unit underlies its black layer (Fig. 5g). Despite being present throughout the entire inner area, this AU exhibited a low vertical density and lacked R-RMUs, which made difficult archaeostratigraphic correlation. Furthermore, it displayed occasional lithic gaps as observed on the left side of H61 (Fig. 5e). This empty space is filled with faunal points that show a concave morphology (Fig. S5).
– Xb2in comprises 530 lithic products with 5 S-RMUs and 9 R-RMUs and 1 hearth (*i.e.* H66). This unit was established based on three criteria: the presence of points within and/or below the black layers of hearths from AU Xb1in (*i.e.* H55, H57, H61) (*e.g.* Figure 5d), the link between this assemblage with H66 black layer top (Fig. 5g) and the 9 R-RMU connections (Fig. 5d–f). Most of the R-RMUs are located below the H55 and H61 black layers. They exhibit horizontal connections, displaying subtle slopes ranging from 5 to 20°. The only exception is observed in the case of 2 products from the Xb-FR1-R1-4, where a more vertical connection is detected (Fig. 5d).

Spatial Results

In the next paragraphs, we describe spatial patterns observed for each AU, including clusters and their location, morphology, size, width and general content, as well as descriptions of material scatters. This information is supported by visual representations of the KDE results (Figs. 6 and 7) and by ANN results (Table S1).

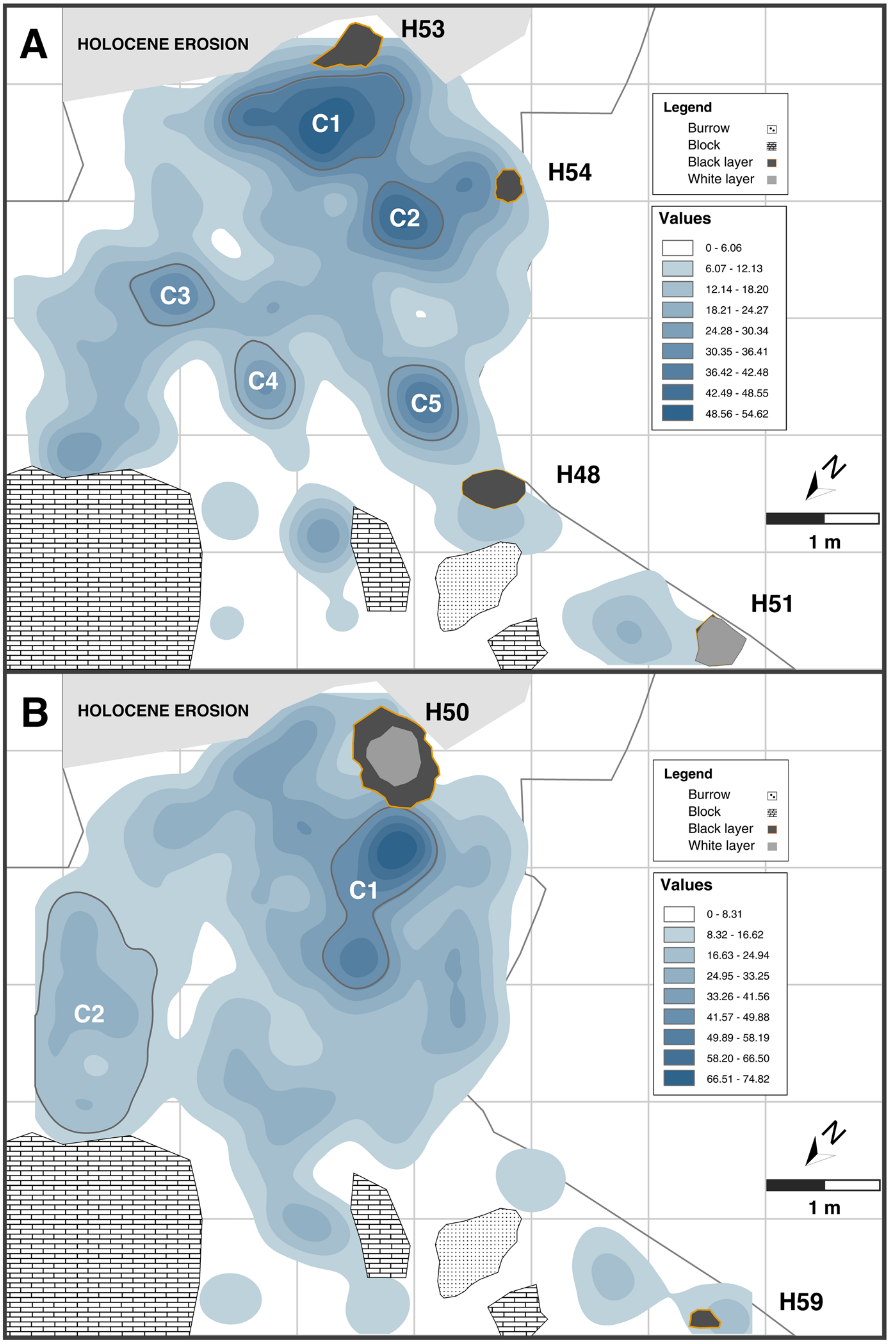

Fig. 6 Kernel density analysis results for the outer area divided into **A** lithic assemblage from the AU Xb1out and **B** lithic assemblage from the AU Xb2out

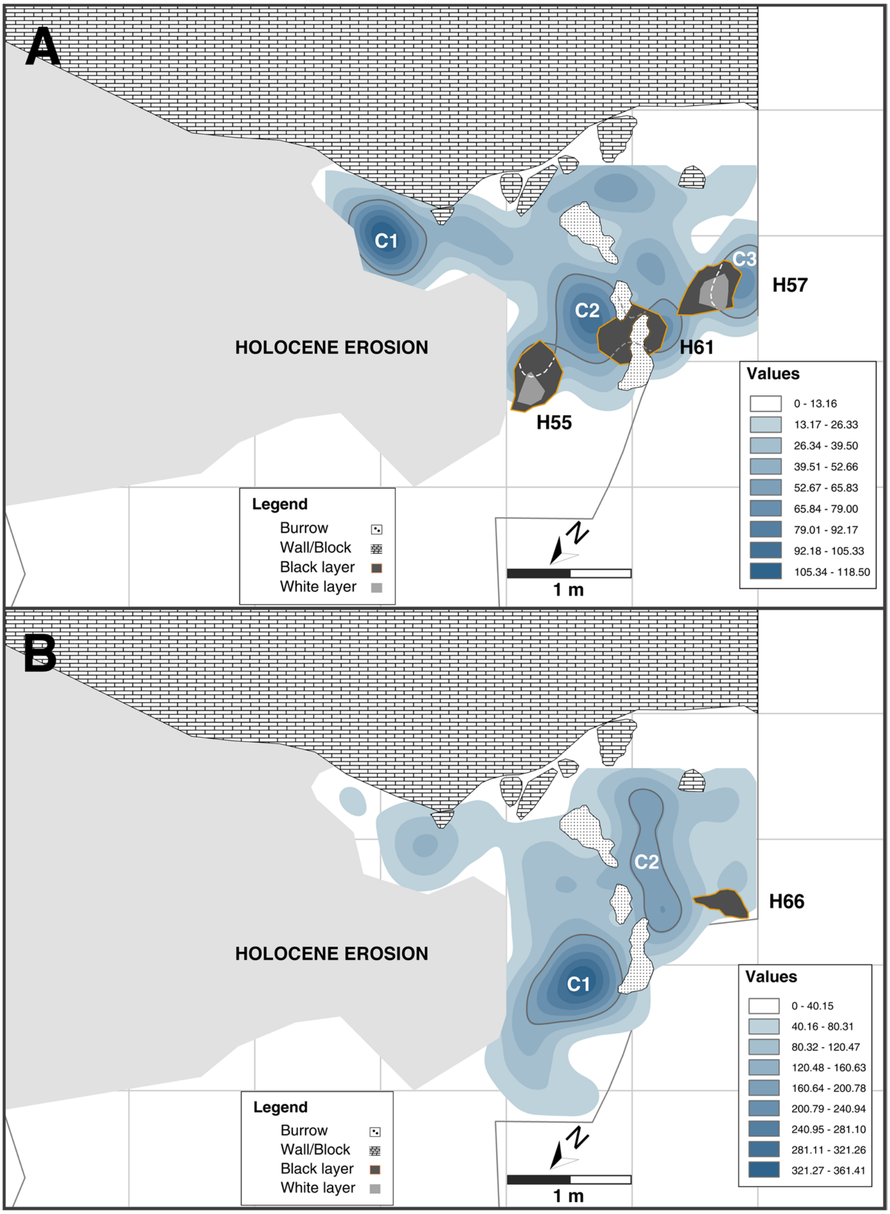

Fig. 7 Kernel density analysis results for the inner area divided into **A** lithic assemblage from the AU Xb1in and **B** lithic assemblage from the AU Xb2in

Outer Area

Within this area, 2 AUs were determined (Xb1out and Xb2out). These units are distributed across the whole outer area (ca. 30 m^2), with a relatively lower representation in the northwest, and both exhibit clustering patterns (Table S1). Furthermore, Xb1out shows a clustering tendency towards the southwest, while Xb2out displays a more southeastern distribution (Fig. 6).

The AU Xb1out comprises 5 clusters (Fig. 6A). C1 is situated in the southeast, close to H53. It has an irregular morphology, measuring 1.50 × 0.80 m, and contains 43 lithic products. C2 is positioned in the south, near H54, and has a circular morphology with dimensions of 0.60 × 0.57 m, containing 15 lithic products. C3 is located in the northeast and exhibits an elliptical morphology measuring 0.72 × 0.55 m, with 12 lithic products. C4 is found in the north and features an elliptical morphology measuring 0.68 × 0.50 m, comprising 10 lithic products. C5 is situated in the northwest, adjacent to H48, and has a circular morphology, with dimensions of 0.64 × 0.59 m, containing 13 lithic products. The remaining materials ($n = 211$) that fall outside of these 5 clusters have been classified as dispersed.

The AU Xb2out comprises 2 clusters (Fig. 6B). C1 is located in the south, near H50, and has an eight-like morphology, measuring 1.57 × 0.92 m. It contains 55 lithic products. C2 is positioned in the northeast and has an elliptical morphology, with dimensions of 2.03 × 0.98 m, containing 48 lithic products. Within this AU, 268 lithic products have been considered dispersed.

Inner Area

In this zone, we have identified 2 archaeostratigraphic units (Xb1in and Xb2in) that are regularly distributed across most of the surface (ca. 8 m^2), with clustering patterns (Table S1). The area covered ca. 50 cm near the travertine wall in the southwest was excluded from the spatial analyses due to its distinct vertical point pattern (ref. "Archaeostratigraphic Units" section).

In the AU Xb1in, we have identified 3 clusters (Fig. 7A). C1 displays an elliptical morphology and is situated in the southeast, spanning an area of 0.65 × 0.52 m and containing 31 lithic products. C2, with an irregular shape, is positioned at the centre of the inner area, between H55 and H61, with two smaller concentrations adjacent to each of them. It covers an area of 1.34 × 0.72 m and consists of 53 lithic products. C3, exhibiting an elliptical form, is located in the southwest, coinciding with the position of H57, and has an extension of 0.58 × 0.36 m, integrating 18 lithic products. The remaining materials ($n = 93$) have been categorised as dispersed.

In the case of AU Xb2in, we have identified 2 clusters (Fig. 7B). C1 is positioned at the centre of the inner area, showing an elliptical morphology spanning 0.87 × 0.57 m, and containing 117 lithic products. C2 is situated in the same central zone of the inner area, with a southwestern orientation closer to H66. It exhibits an irregular shape measuring 1.14 × 0.26 m, and comprises 64 lithic products. The remaining materials ($n = 349$) are classified as dispersed.

Lithic Assemblages in Higher-Resolution Units

Once we have established and presented our units of analysis, this section focuses on describing the lithic content of each cluster within the four defined AUs.

Additionally, we describe the dispersed material, as these scattered assemblages also provide valuable behavioural observations.

Before detailing the aforementioned data, we show the results offered by chi-square, obtained through a comparison of AUs and lithic variables (Fig. S6). In this sense, we distinguish three interdependence patterns: first, instances of complete dependence such as the case of weight, in which all results show p-values below 0.01. Secondly, scenarios of complete independence are evident in variables like cortex on flakes and thermal alteration. Lastly, there are cases of intermediate dependence observed in variables such as size, flint type and product, mainly exhibiting interdependence between upper or lower AUs from both outer and inner areas (*e.g.* size or flint type variables between Xb1out and Xb1in and between Xb2out and Xb2in). Nevertheless, some dependent cases are also identified between AUs within the same zone (*e.g.* product variable between Xb1out and Xb2out).

Having elucidated this, we can now proceed to the content of each cluster. Our subsequent analysis will focus on six variables: size class, weight, type of product, flint type, cortical percentage on flakes and thermal alteration. Here, we exhibit the most remarkable data supported by Tables 3, 4, 5, 6, 7 and 8 and Figs. 8, 9 and 10, but a comprehensive description can be found in the Supplementary material (Table S2 to Table S41).

AU Xb1out

In this AU, we recognised 5 clusters (Fig. 8). C1 comprises 43 lithic products, weighing 147 g, with a prevalence of Serreta flint type (53%), followed by Mariola (33%) and Beniaia (14%). The three types are mainly composed of very small and small flakes. C2 includes 15 lithic remains (*i.e.* 17 g), dominated by Serreta (71%), Mariola (21%) and Beniaia (7%). Notably, there are no cores or retouched products in this cluster, which is dominated by very small and small flakes. C3 consists of 12 lithic products (*i.e.* 87 g), characterised by Mariola (50%), Serreta (38%)

Table 3 Flint type distribution and total weight of the concentrations and dispersed materials within the outer AUs

AU	Serreta	Mariola	Beniaia	Indet	Total weight (g)
Xb1out					
C1	19	12	5	7	147.10
C2	10	3	1	1	17.01
C3	3	4	1	4	86.69
C4	5	2	3		18.34
C5	7		3	3	29.15
Dispersed	106	31	28	46	1479.42
Xb2out					
C1	36	7	8	4	261.83
C2	24	12	9	3	1084.35
Dispersed	128	47	47	46	1657.25

Table 4 Flint type distribution and total weight of the concentrations and dispersed materials within the inner AUs

AU	Serreta	Mariola	Beniaia	Font Roja	Catamarruc	Indet	Total weight (g)
Xb1in							
C1	11	9	3			8	63.25
C2	21	10	5	2		15	63.88
C3	11	5				2	46.24
Dispersed	40	28	8	2		15	290.29
Xb2in							
C1	44	27	17	14	2	13	338.58
C2	30	14	11		1	8	110.67
Dispersed	156	88	42	3	4	56	1038.13

Table 5 Size class distribution and total weight of the concentrations and dispersed materials within the outer AUs

AU	Very small	Small	Medium	Large	Very large	Total weight (g)
Xb1out						
C1	28	9	5		1	147.10
C2	11	3	1			17.01
C3	8	1	1	1	1	86.69
C4	8	2				18.34
C5	10	1	1		1	29.15
Dispersed	134	37	23	11	6	1479.42
Xb2out						
C1	36	4	9	2		261.83
C2	16	9	7	9	7	1084.35
Dispersed	160	44	37	16	11	1657.25

Table 6 Size class distribution and total weight of the concentrations and dispersed materials within the inner AUs

AU	Very small	Small	Medium	Large	Very large	Total weight (g)
Xb1in						
C1	24	4	2	1		63.25
C2	46	6	1			63.88
C3	12	5	1			46.24
Dispersed	64	17	7	5		290.29
Xb2in						
C1	86	22	4	5		338.58
C2	53	8	3			110.67
Dispersed	251	64	25	5	4	1038.13

Table 7 Product type distribution and total weight of the concentrations and dispersed materials within the outer AUs

AU	Flakes	Cores	Fragments	Retouched products	Total weight (g)
Xb1out					
C1	29	1	12	1	147.10
C2	14		1		17.01
C3	6	1	4	1	86.69
C4	9		1		18.34
C5	11		2		29.15
Dispersed	135	16	55	5	1479.42
Xb2out					
C1	39	2	11	3	261.83
C2	28	9	8	3	1084.35
Dispersed	176	10	62	20	1657.25

Table 8 Product type distribution and total weight of the concentrations and dispersed materials within the inner AUs

AU	Flakes	Cores	Fragments	Retouched products	Total weight (g)
Xb1in					
C1	21		8	2	63.25
C2	31	1	21		63.88
C3	14		3	1	46.24
Dispersed	68	3	17	5	290.29
Xb2in					
C1	89	2	20	6	338.58
C2	46	1	16	1	110.67
Dispersed	250	10	78	11	1038.13

and Beniaia (12%). Apart from very small and small flakes, Mariola large cores and retouched products are present in this cluster. C4 comprises 10 lithic remains, weighing 18 g, with a representation of the three flint types, Serreta (50%), Beniaia (30%) and Mariola (20%) in very small and small flakes. C5 contains 13 lithic products (*i.e.* 29 g), all flakes, mainly Serreta (70%) with Beniaia (30%) but not Mariola. Apart from the absence of the latter, it is worth noting that these percentages shift when the weight is considered: Serreta (36%) and Beniaia (64%).

The dispersed materials in this AU encompass 211 lithic products, totaling 1479 g, primarily composed of Serreta (64%), Mariola (19%) and Beniaia (17%). However, the weight distribution tells a different story. In this case, Beniaia is the most prominent (*i.e.* 591 g), followed by Serreta (*i.e.* 452 g) and Mariola (*i.e.* 336 g). This variance can be attributed to the weight of Beniaia cores. A major part of each

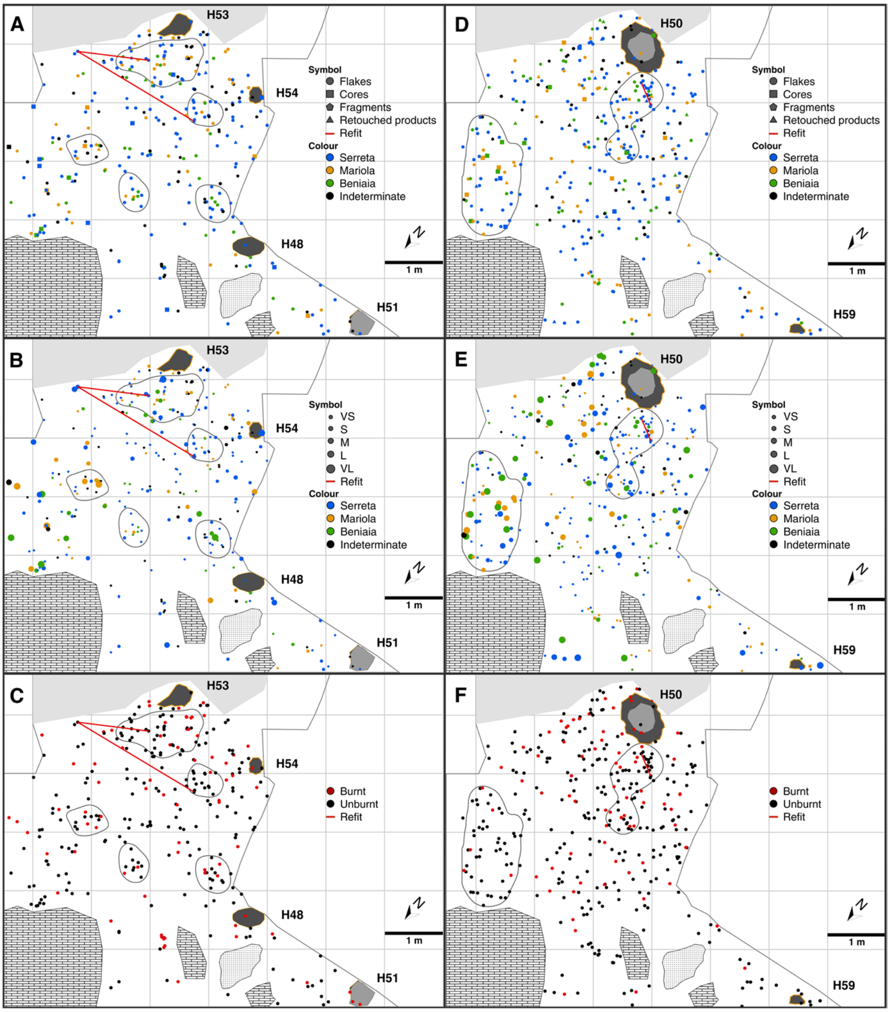

Fig. 8 Spatial distribution of the lithic assemblages based on flint type (colours), type of product, size class, thermoalteration and refits. **A–C** AU Xb1out, **D–F** AU Xb2out

assemblage consists mainly of very small and small flakes, followed by small and medium fragments, as well as medium, large and very large cores and retouched products, except for the Mariola flint type, which lacks retouched elements.

AU Xb2out

We identified 2 clusters in this AU (Fig. 8). C1 includes 55 lithic remains, weighing 262 g, with a dominance of Serreta (70%), followed by Mariola (14%) and Beniaia (16%) flint types. Very small and small flakes are present in all three flint types. C2 comprises 48 lithic products (*i.e.* 1,084 g), predominantly Serreta (53%), Mariola

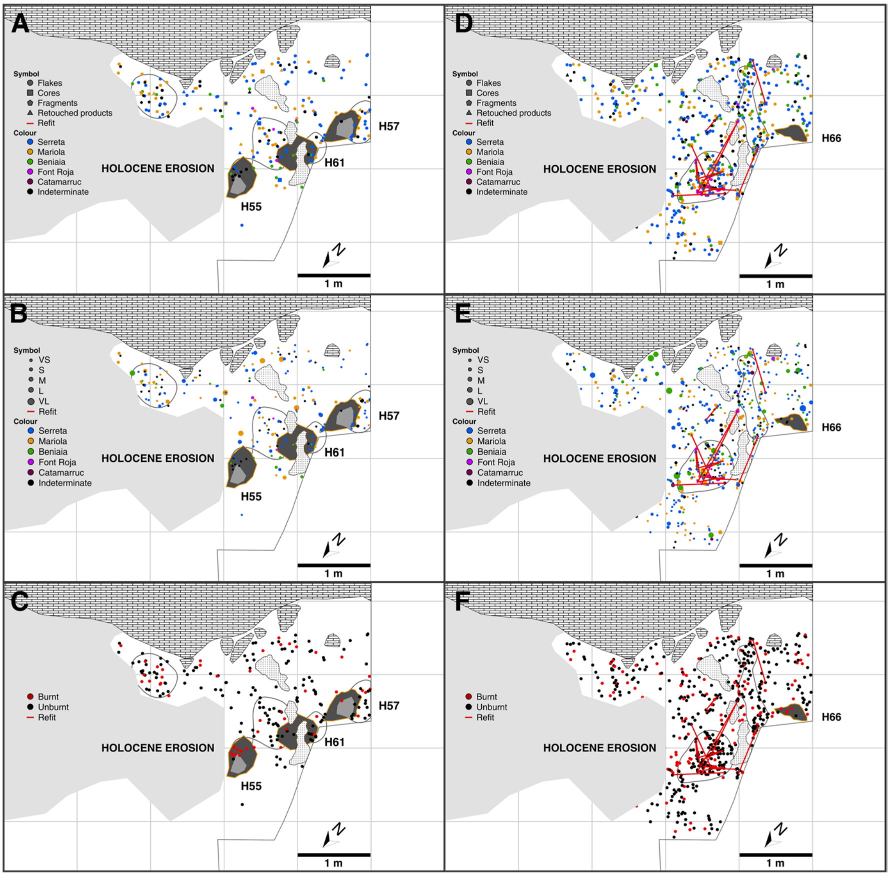

Fig. 9 Spatial distribution of the lithic assemblages based on flint type (colours), type of product, size class, thermoalteration and refits. **A–C** AU Xb1in, **D–F** AU Xb2in

(27%) and Beniaia (20%). In contrast, the distribution of weights takes a different trajectory. In this cluster, Beniaia holds the highest weight (*i.e.* 701 g), followed by Mariola (*i.e.* 185 g) and Serreta (*i.e.* 160 g). This variation can be attributed once again to the weight of Beniaia cores (*i.e.* large and very large), as well as flakes (*i.e.* mostly very small in Serreta and small to very large in Beniaia). The Mariola flint type, on the other hand, also presents cores, but they are smaller and lighter compared to Beniaia. Figure 10 illustrates this composition within C2 of this AU, showcasing a uniform distribution of sizes across all classes, which stands in contrast to any other example in this study.

Dispersed materials in this AU consist of 268 lithic products, totaling 1657 g, with a prevailing presence of Serreta (58%), Mariola (21%) and Beniaia (21%). In this case, the weight distribution alters the sequence again, though the differences are less pronounced than in the case of C2: Beniaia (*i.e.* 692 g), Serreta (*i.e.* 543 g) and Mariola (*i.e.* 330 g). Within products, all three flint types present flakes,

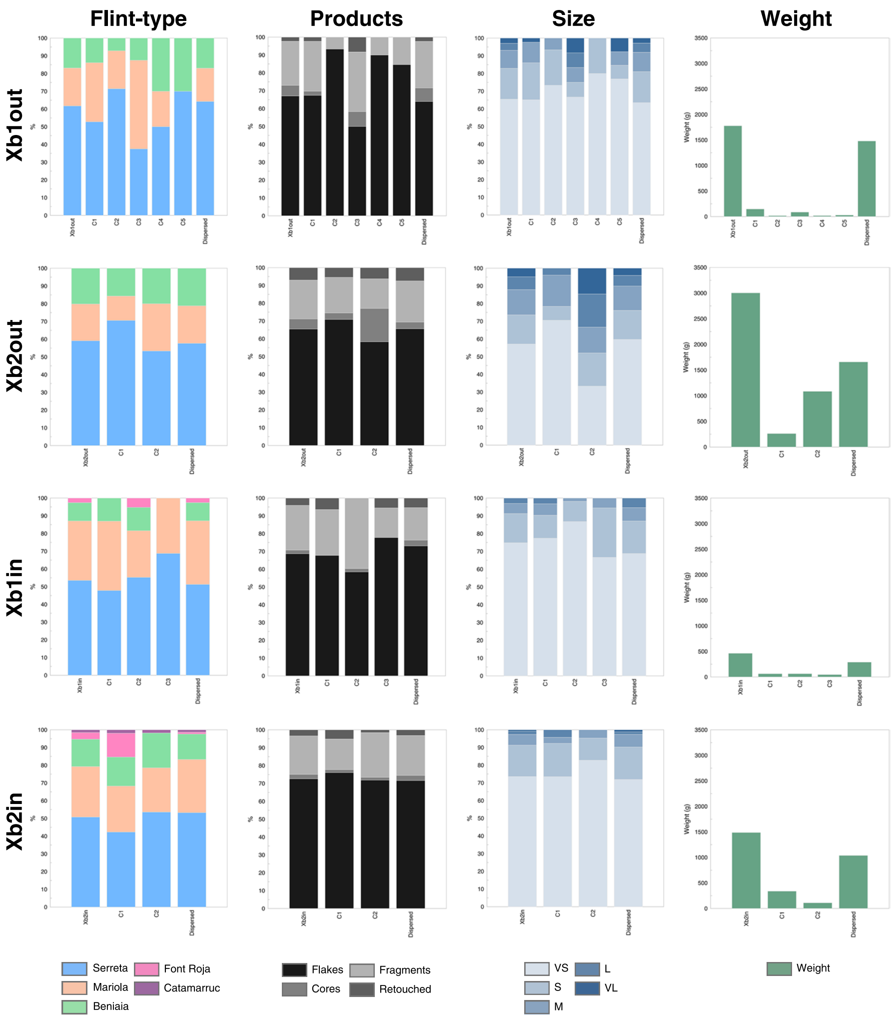

Fig. 10 Bar charts comparing the content of the defined AUs, based on flint type, type of product, size class and weight

retouched products, fragments and cores. The two latter are especially weighty and very large products in the case of Beniaia, which could account for the observed reordering of flint proportions.

AU Xb1in

In this AU, we recognised 3 clusters (Fig. 9). C1 contains 31 lithic remains (*i.e.* 63 g), dominated by Serreta (47%), Mariola (39%) and Beniaia (13%). Notably, no cores are identified in this cluster. C2 comprises 38 lithic products (*i.e.* 56 g). In this cluster, the sequence of flint types follows the same path, with Serreta (55%), Mariola (26%) and Beniaia (13%) at the forefront, and a new inclusion of the Font Roja flint type (5%). These flint types share common characteristics, featuring predominantly very small and small flakes and fragments. Remarkably, large and very large products are notably absent. Only one core, crafted from the Serreta type, has been identified in this cluster, while no retouched products have been observed. C3 includes 16 lithic products (19 g), exclusively composed of Serreta (69%) and Mariola (31%), with a notable prevalence of very small and small flakes, particularly evident in the Serreta type. We identified a retouched element produced from the Mariola flint type, while no cores have been recognised.

In this AU, dispersed materials consist of 93 lithic products, totaling 290 g, primarily composed of Serreta (51%), Mariola (36%) and Beniaia (10%). However, the weight alters this sequence, elevating the Mariola flint type to a predominant position (58%), followed by Serreta (33%), Beniaia (19%) and Font Roja (3%). Flakes, fragments, cores and retouched elements are present in the Serreta and Mariola assemblages, including large cores and retouched products observed in the Mariola type. Conversely, Beniaia and Font Roja flint types only exhibit very small and small flakes.

AU Xb2in

We identified 2 clusters in this AU (Fig. 9). C1 encompasses 117 lithic products, weighing 339 g. Within this cluster, the Serreta flint type is prevalent (42%), followed by Mariola (26%), Beniaia (16%), Font Roja (13%) and the appearance of Catamarruc at 2%. Yet again, the weight generates changes in this ranking, placing Mariola (*i.e.* 117 g) at the forefront, followed by Beniaia (*i.e.* 109 g) and Serreta (*i.e.* 67 g). These three groups predominantly exhibit very small and small flakes, along with small and medium retouched products in the case of Serreta and Mariola. Cores, exclusive to the Mariola and Beniaia flint types, assume a large size, while the Font Roja and Catamarruc flint types are limited to very small and small flakes. C2 consists of 64 lithic products, weighing 111 g. In this cluster, the flint assemblage is composed of Serreta (54%), Mariola (25%), Beniaia (19%) and Catamarruc (2%). The weight generates slight differences in this case, placing the Beniaia flint type at the forefront (*i.e.* 36 g), followed by Serreta (*i.e.* 25 g), Mariola (*i.e.* 24 g) and Catamarruc (*i.e.* 10 g). An important point is that the Font Roja flint type is notably absent from this cluster. The products in this cluster are characterised by very small and small flakes in all the flint types.

Dispersed materials in this AU consist of 349 lithic products, totaling 1038 g, mainly composed of Serreta (53%), Mariola (30%), Beniaia (14%) Catamarruc (1%) and Font Roja (1%). Across the three main flint types, these present the complete range of products including flakes, retouched products, fragments and cores. However, some differences are noted: Beniaia stands out with its large and very large cores and retouched products, while Serreta and Mariola show these products in small and medium sizes. In the case of Font Roja and Catamarruc flint types, they are restricted to very small and small flakes.

S-RMUs and Lithic Refits

In the entire assemblage, 18 S-RMUs and 14 R-RMUs have been recognised (Table 9 and Fig. 11). Focusing on refits, they involve 35 lithic products representing 2.25% of the overall assemblage. From the 14 refits, 4 are included in a R-RMU

Table 9 Set-RMUs and refitted-RMUs by AUs and flint types

	Serreta		Mariola		Beniaia		Font Roja		Catamarruc
AU	S-RMU	R-RMU	S-RMU	R-RMU	S-RMU	R-RMU	S-RMU	R-RMU	R-RMU
Xb1out	2	1	2						
Xb2out	1	1	2		3				
Xb1in	1		1				1		
Xb2in	2	5		2	2			1	1
Xb2in-out					1				
Total	6	7	5	2	6		1	1	1

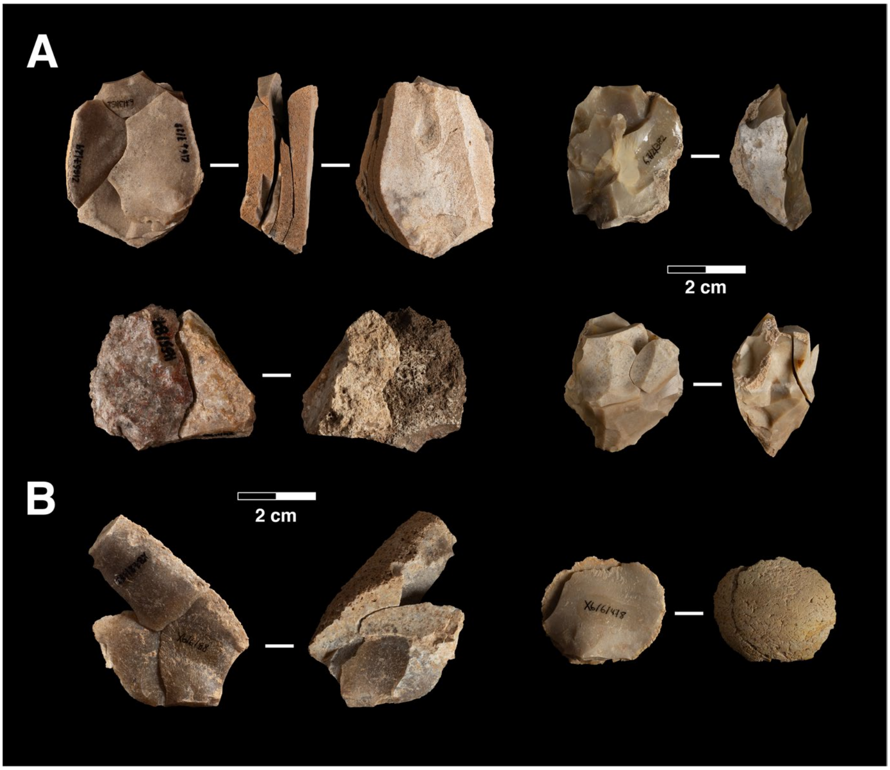

Fig. 11 Refitted sequences from El Salt SU Xb. **A** Some examples of R-RMUs from the inner area and **B** R-RMUs from the outer area. Photography: Maria Guillén (IPHES)

(Font Roja), while the remaining 10 R-RMUs are distributed among Serreta ($n=7$), Mariola ($n=2$) and Catamarruc ($n=1$) flint types. From these, two are a result of fracture, while the other 12 are technical. These refits show 21 connection lines with an average distance of 0.41 m in the inner area and 1.31 m in the outer area (Table S42).

In AU Xb1out, we have identified one Serreta R-RMU. This refit consists of three flakes: comprising one small and two medium-sized ones. These flakes are distributed across C1 and C2, as well as within the dispersed materials. The distance between the closest pieces is 1.21 m, while the farthest spans 2.31 m. Turning to AU Xb2out, we encountered one Serreta R-RMU composed of two small flakes, both located within the C1 cluster, with a distance of 0.41 m.

Regarding AU Xb2in, it is crucial to highlight the significant presence of refits in this AU ($n=12$). Among these, the Serreta flint type exhibits 5 refits. Each of these refits consists of 2 products, but they display differences in composition and distances. The intricate net of connections includes a linkage between small flakes positioned in C1 (*i.e.* 0.22 m); a connection that bridges a medium-sized core and a small flake, positioned in C2 and the dispersed material (*i.e.* 0.71 m); another similar association involving a very small core and small flake, both located within the dispersed material (*i.e.* 0.62 m); another refit ties together fragments immersed within the dispersed materials (*i.e.* 0.24 m) and finally, conjoined materials, as evidenced by one medium-sized retouched element and a small fragment within C1, that appeared together (*i.e.* <0.01 m) inside the black layer of H55.

In this same AU, the Mariola flint type displays two refits. In one case, we identify one R-RMU composed of two small flakes and one very small flake, all included in C1 with similar distances (*i.e.* 0.31–0.34 m). The second refit comprises one medium-sized core, a very small flake and a small fragment. These elements are immersed not only within C1 but also in the dispersed materials, with distances that exhibit variations between 0.66 and 0.33 m. On the other hand, the Catamarruc flint type presents one refit in this AU that is characterised by the linkage of two flakes, small and medium-sized, between C1 and the dispersed materials (*i.e.* 0.70 m). In this case, one of these flakes appears inside the H55 black layer, exhibiting signs of thermal alteration.

At last, the Font Roja flint type immersed in the same AU shows four refits, but represents a single S-RMU. The first refit ($n=6$) is composed of 5 small and very small flakes positioned within C1, along with a medium-sized flake in the dispersed material. The distances span a spectrum from 0.10 to 1.10 m. The second refit showcases the connection of two very small flakes within C1 (*i.e.* 0.04 m), as well as the third one, which is characterised by the linkage of two small flakes within C1 (*i.e.* 0.37 m). Finally, the fourth refit is composed of a small and very small flake in C1 (*i.e.* 0.02 m).

To sum up, it is worth highlighting that no refits were detected within AU Xb1in, and equally significant is the absence of Beniaia refits throughout the entire assemblage. Furthermore, only one S-RMU presents pieces in two AUs, as in the case of one Beniaia unit composed of one large core in Xb2in and one small flake in Xb2out, separated by 1.88 m.

Discussion

After conducting a comprehensive analysis of lithic assemblages from El Salt SU Xb, we have defined and characterised four AUs along with their respective spatial units and lithic content. How does the spatial and lithic information from AUs differ when compared to the SU? Which aspects remain static and which show variability? These fundamental questions will be explored in the following sections, with the overall objective of evaluating the impact of palimpsest dissection.

Taphonomic and Methodological Insights

Regarding the defined AUs, it is crucial to make some taphonomic observations before delving into behavioural interpretations (Schiffer, 1983), especially in the inner zone, where AUs Xb1in and Xb2in are situated. The area near the tufa wall exhibits a scattered point pattern, potentially attributed to vertical water flows or falling blocks, phenomena commonly observed in caves and rockshelters (Goldberg & Macphail, 2005; Mentzer, 2017). The absence of S-RMUs connecting this affected area with other zones hinders our ability to evaluate the extent of the damage (Conard & Adler, 1997; López-Ortega *et al.*, 2019; Vermeersch, 2001). Nevertheless, due to the irregular point pattern and the absence of combustion structures, we approach this zone cautiously and exclude it from behavioural interpretations. Although ongoing research into site formation processes at El Salt may provide further insights into this area (Mallol *et al.*, in prep), our taphonomic observations are essential as they prevent spatial or lithic analyses of potential disturbances, a scenario that could arise in an approach solely based on the SU.

Furthermore, it is important to highlight that AUs from the inner area present a high level of complexity. They reveal a more irregular distribution compared to outer AUs, featuring topographic variations within a confined space and intersecting burrows that disrupt the point clouds. The introduction of hearth sections and refits has played a critical role in detecting postdepositional issues (Martínez-Moreno *et al.*, 2004; Mora *et al.*, 2020). In this sense, the previously analysed hearths within the inner area (*i.e.* H55, H61, H57) show no signs of postdepositional reworking, trampling or diagenetic alteration (Leierer *et al.*, 2019). Moreover, although refits are scarce, they do not exhibit straight-trend slopes that could suggest vertical movements, except for a singular case (*i.e.* Xb-FR1), in which one of the four refits within this R-RMU displays a more pronounced slope.

Coupling hearths and refits were also pivotal in addressing the complexity of the lithic record formation processes. They enabled us to discern two distinct accumulations in the inner area when the point pattern alone was insufficient for separating assemblages. In fact, they allow us to uncover a fallacy derived from the assemblage-as-a-whole approach: if we had analysed the SU spatial distribution from a behavioural perspective (Fig. 2), most of the refits would have been associated with H55 and H61, aligning with hearth-related activities. However, vertical projections have demonstrated the diachrony between refits as older events and these hearths as more recent events. In contrast to the inner area, outer AUs display clearer and more regular gaps between them, facilitating their vertical definition despite having fewer R-RMUs. Even here, where we have a more defined picture, the archaeostratigraphic analysis proved crucial for separating events, as illustrated by the case of H52 or H60. They were initially considered part of the general set of hearths from SU Xb but subsequently repositioned, leading to their exclusion from the study.

On the other hand, the geological and archaeological history of the site prompted us to segregate two areas and subsequently attempt to establish potential connections between them. In this work, we possess only one evidence that can play this role. RMU Xb-B4 comprises one core and one flake made up of Beniaia flint type (Fig. 12), contained in the oldest AUs (Xb2out and Xb2in) and separated by 1.88 m. The Beniaia flint type has been characterised by a relatively high degree of both internodular and intranodular variability (Mayor *et al.*, 2022; Molina, 2015). These distinctive lithological features, common to both artefacts, serve as coincident markers indicating their provenance from the same nodule. This fact, along with their positioning within the lowest AUs, could give us the confidence to establish a stratigraphic correlation between AU Xb2in and AU Xb2out. However, we consider this evidence to be limited, as the rest of the record does not provide additional data indicating a link between these AUs. Therefore, we are inclined to maintain and discuss them separately. Under this assumption, we identify at least four formation stages coinciding with each of the archaeostratigraphic units defined.

Time and Space: Static vs. Dynamic Behaviours

After examining the taphonomic and compositional aspects related to AUs, it becomes pertinent to inquire about their implications in terms of time. Regarding the abundance of remains in each AU, including numerous RMUs and hearths, we consider that each unit comprises multiple human events, thereby encompassing an indeterminate amount of time. However, there are data that can help us to refine the temporal uncertainty surrounding the formation of the studied record. The recent

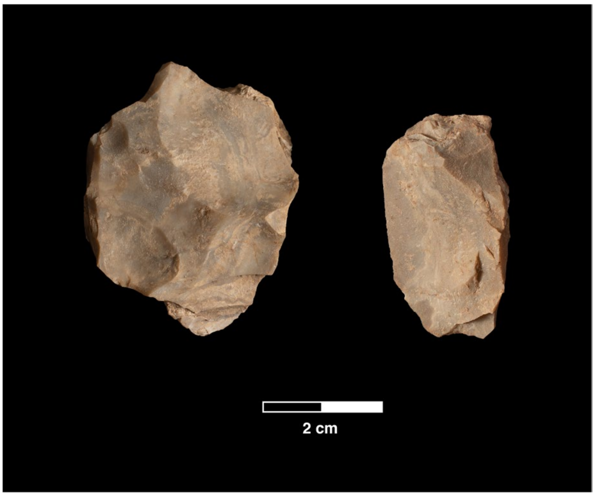

Fig. 12 The S-RMU Xb_B4 that could link the oldest AUs (Xb2out and Xb2in). Photography: Maria Guillén (IPHES)

archaeostratigraphic and archaeomagnetic analyses of four hearths within this unit have allowed us to further separate the formation stages (Herrejón-Lagunilla *et al.*, in press). This refinement is key when the lithic record no longer provides diachrony in its spatiotemporal dimension. Such is the case with unit Xb2out, where H50 and H59 are temporally indistinguishable based on our current data, suggesting a minimum of one occupation. However, archaeomagnetic data reveal a minimum time difference of 85–105 years between these fires. This increases the minimum number of occupations within this AU to two, with a temporal difference longer than that of a human lifespan. Considering this information, the AUs presented here can be interpreted as formation stages spanning along a minimum of 200–240 years, rather than single occupations occurring over an undetermined period. Consequently, we expect to be faced with two scenarios: general patterns arising from the persistent palimpsest effect and aspects that reflect variability.

In this context, we observe broad trends within the AUs. Notably, there is a differential spatial distribution between areas, with high concentrations in the inner area and less developed accumulations in the outer. This pattern is consistent in caves and rockshelters, suggesting a preference for occupying the covered spaces from the Pleistocene to modern hunter-gatherers (Bailey & Galanidou, 2009; Clark *et al.*, 2022; Galanidou, 2000; Spagnolo *et al.*, 2019; Vaquero *et al.*, 2012). Additionally, the Serreta flint type predominates in all AUs, as well as in most clusters and dispersed materials. A similar scenario is observed in SU Xa with Serreta type (Machado *et al.*, 2017) and in SU VIII with Beniaia type (Mayor *et al.*, 2022). While this may reflect a common procurement and introduction model, it also acts as an indeterminate average. A massive input of a specific flint type in certain episodes could mask numerous events with fewer materials of other types. This view of apparent homogeneity is also present in the dispersed material, whose content within the four AUs represents all elements in each of the variables. This difference with respect to some clusters which, for example, fail to show certain variables (*i.e.* C3 and C4 in Xb1out or C3 in Xb1in), may reflect a greater severity of the palimpsest effect in the case of the scattered lithic remains. If we assume that events earlier in time suffer more dispersion and therefore have a greater temporal range (Stevenson, 1985), we would expect them to represent all variables in the record. Likewise, this challenge extends to particular variables such as the amount of cortex and thermal alteration, as they are homogeneously distributed across all times and spaces. Beyond lithics, other elements act as temporal screens. For instance, *Pinus nigra* is the most represented taxon in SU Xb, both temporally and spatially (Vidal-Matutano *et al.*, 2017). The constant presence of these variables suggests a presumed behavioural continuity, which would also be maintained for at least 200–240 years (Herrejón-Lagunilla *et al.*, 2024). While the hypothesis of recurring behaviours can not be disregarded, the apparent static nature may also stem from the palimpsest effect. This is where temporal resolution becomes an obstacle, hindering our ability to discern between variability patterns and recurrency.

However, with the identification of four AUs, along with their respective clusters, we were also able to discern dynamic behaviours. First, the AUs show spatial distributions different from those shown by the unit-as-a-whole. This is the case of C1 in Xb1in which is noticeable in the AU, while it hardly shows high values in the SU.

Another example is the concentration observed in the SU to the right of H57 and H66 which after dissection actually corresponds to H57. Conversely, there may be cases where the concentration is observed both in the SU and in the two AUs, such as that located between hearths H55 and H57. However, their vertical separation allowed us to observe that they exhibit different lithic contents. Based on the refitted sequences, it becomes apparent that knapping activity is more concentrated in the inner area. However, we have shown that this activity was not continuous but rather confined to the oldest AU (*i.e.* Xb2in) and specifically attributed to C1, being the only concentration that includes almost complete core reduction activities. Notably, we have observed distinct contributions from Mariola and Beniaia flint types, revealing an intriguing trend upon palimpsest dissection: these flints undergo changes concurrently with other variables. For instance, when product type or size displays indicators of variability, the flints exhibit similar variations (*e.g.* C3 in Xb1out or C2 in Xb2out). Mariola appears to be associated with the presence of specific products, such as fragments, while Benaia changes coincide with variations in weight or size. These subtle pulses of change among homogeneity potentially reinforce the hypothesis that the prevalence of the Serreta type may obscure other aspects of the record. On the other hand, we recognised one cluster (*i.e.* C2 from Xb2) characterised by larger and heavier materials than any other unit in this study. Beyond its content or possible interpretations (ref. "Bigger and Heavier" section), separating and analysing the spatial distribution and lithic content of each AU have revealed that, as in the case of this cluster, certain behaviours are not consistently present. Likewise, it is also evident after dissection that a greater number of hearths does not necessarily imply a higher concentration of materials. The upper units, despite having the largest pyrotechnological record ($n = 8$), are surpassed in materials by the oldest unit with just three hearths.

These time clues extend beyond the lithic record, as evidenced by similar findings in other studies within SU Xb. While *Pinus nigra* prevails as the dominant taxon in the unit, distinct fuel resources are evident in specific hearths. For instance, H48, H53 and H57 exhibit discrete accumulations of *Buxus sempervirens*, *Quercus* sp., and a combination of *Acer* sp. seeds and *Pinus nigra* decayed wood, respectively (Vidal-Matutano *et al.*, 2017). Moreover, the development of use-wear analyses within SU Xa has revealed that activities conducted in a single area vary over time (Bencomo *et al.*, 2023). If all of these details were solely examined at the assemblage-as-a-whole level, the nuances of temporal variation would have been ignored, leading to potentially incorrect interpretations.

Searching for Variability

While the defined AUs serve as a valuable starting point for preliminary behavioural investigations, the temporal resolution achieved in El Salt SU Xb seems to be far from that observed in Palaeolithic examples such as AU IVfH17 from Abric del Pastor (Sossa-Ríos *et al.*, 2022). The hearth-related assemblage characterised at Abric del Pastor recorded a temporal scale remarkably close to the ethnographic scale. This leads to two hypothetical scenarios: (1) El Salt SU Xb represents a sum of multiple and recurrent "Abric del Pastor-type" occupations or (2) we are dealing with a different model. Given that vertical resolution did not yield additional details, the answer to this question must be explored within the spatial, lithic and other contextual records.

The AUs defined within SU Xb could indeed support the first scenario to a certain extent. Spatially, we have recognised clusters near hearths that align with the hearth-related assemblage model (Stevenson, 1991; Vaquero & Pastó, 2001). For example, the assemblages located in proximity to H50, H53, H55 or H57, primarily comprising very small to small flakes and fragments, could indicate knapping activities near combustion structures. In the cases of H50 and H53, short-distance refits have also been identified, connecting clusters in the latter case. This model, where humans act and interact around the fire (Binford, 1978b), has been diachronically identified in most of the Neanderthal sites, constituting a prevalent spatial manifestation of hunter-gatherer behaviours (Vaquero *et al.*, 2004). While these occupation patterns are typically short-term (Picin & Caschalheira, 2020), the question remains: do we have any indicators of variability?

H50 might offer insights into a different scene. Its related cluster (C1 from Xb2out) is characterised by the prevalence of Serreta flint type, mainly comprising very small- and medium-sized flakes, two of which are refitted. This overall picture is completed by the minor presence of Beniaia and Mariola flint types, with few examples of retouched elements and cores. Except for the refit, this hearth-related assemblage does not allow for further dissection and may represent multiple activity events. Given the absence of apparent signs of diachrony within this cluster, we must explore other aspects of the record, such as the hearth itself. H50 is a hearth that comprises 88 × 66 cm in the black layer and 71 × 45 cm in the white layer, with a maximum depth of 13 cm in the centre of the black layer. It is linked to *Pinus nigra* and *Acer* sp. fueling (Vidal-Matutano *et al.*, 2017), with a common procurement distance of 1 km (Vidal-Matutano *et al.*, 2018). In terms of charcoal distribution, *Pinus nigra* dominates both the white layer (53%) and the perimeter (71%) with larger charcoals found in the latter, while *Acer* sp. is close in percentage in the white layer (40%), but it is less represented in the adjacent area (19%). In addition, the micromorphological analysis showed no more than one combustion episode, with evidence of reworking the white layer while preserving its structure (Leierer *et al.*, 2019). Additionally, the archaeomagnetic signal indicates a stable direction, suggesting that reworking did not impact the black layer (Herrejón-Lagunilla-Lagunilla, 2020). Considering this information, we propose the following three times ordered from the oldest to most recent:

- Time 1: H50 fueled with *Pinus nigra*, present in the white layer
- Time 2: H50 white layer reworked, which may have led to the dispersion of *Pinus nigra* to the adjacent area
- Time 3: H50 fueled with *Acer* sp., present in the white layer but scarce in the perimeter

Suggesting an order in the sequence of activities observed in H50 raises a significant question: is the described scenario the result of interoccupational or intraoccupational diachrony? If the combustion activity resulted from different groups using two different firewood, the time involved in the two episodes might have been too short to leave any temporal microstratigraphic evidence. This could suggest that these are two different episodes in the same space, but close in time (*i.e.* interoccupational diachrony). Alternatively, we could propose a single event with different pyrotechnological activities, indicative of more investment and, thus, longer duration (*i.e.* intraoccupational diachrony). The morphology of the hearth provides clues and intriguing questions. While hearths excavated in El Salt typically do not exceed 50 cm in diameter, with black layers penetrating no more than 2 cm (Mallol *et al.*, 2013), H50 surpasses these dimensions, particularly in depth (*i.e.* 13 cm). Although experiments conducted with the El Salt matrix did not record black layers greater than 2 cm in depth (Mallol *et al.*, 2013), the experimental programme by Aldeias *et al.* (2016) showed that extended burning times (*i.e.* 19 h) accompanied by moisture, which sustains temperatures for longer durations, result in the greatest heat penetration and rubefaction (*i.e.* 8–10 cm). This data might indicate another difference, suggesting a longer formation time for H50.

If we were to assume a contemporaneous relationship between C1 and H50, then the input of different flint types and the abundance of SE-RMUs could be explained in terms of intraoccupational diachrony. However, there is no evidence in the record to support the contemporaneity of the accumulation. In this sense, other clusters could provide clues to this scenario.

Bigger and Heavier

This brings us to C2 from AU Xb2out. This cluster is located 1.87 m from C1 and 2.39 m from H50. Here, we report the significant presence of large and heavy Beniaia flint cores with minimal technical intervention, as well as small- and medium-sized exhausted cores from the Mariola flint type (Fig. 13). Notably, no S-RMUs are identified within C2, and it is not linked to other accumulations or dispersed material. The clustered nature of these two types of materials has been observed separately in other Neanderthal contexts, often interpreted as areas for refuse disposal.

With similar characteristics to those observed in the Beniaia assemblage, the Molare rockshelter (Italy) layer 56 exhibits large cores accumulated within a 2 m^2 area (Spagnolo *et al.*, 2020b). A similar pattern is observed in the Abri du Maras (France) level 4.1, where peripheral areas containing large products without recognised refits have been identified (Guillemot *et al.*, 2023). The Oscurusciuto SU 13 (Italy) presents a distinct scenario, with exhausted cores among the discarded materials (Spagnolo *et al.*, 2019), aligning with the observed Mariola assemblage. In the case of the Abric Romaní (Spain) level Ja, peripheral zones 1, 5 and 7 have shown a high abundance of large products, some of which were not technically intervened (Vaquero, 1999; Vaquero *et al.*, 2001). However, the review of this level proposed an alternative explanation to refuse disposal areas, as refit connections are scarce and unidirectional, hindering the possibility of contemporaneity. The introduction of these large products as SE-RMUs of different flint types during several events and their diachronic integration with hearth-related assemblages could

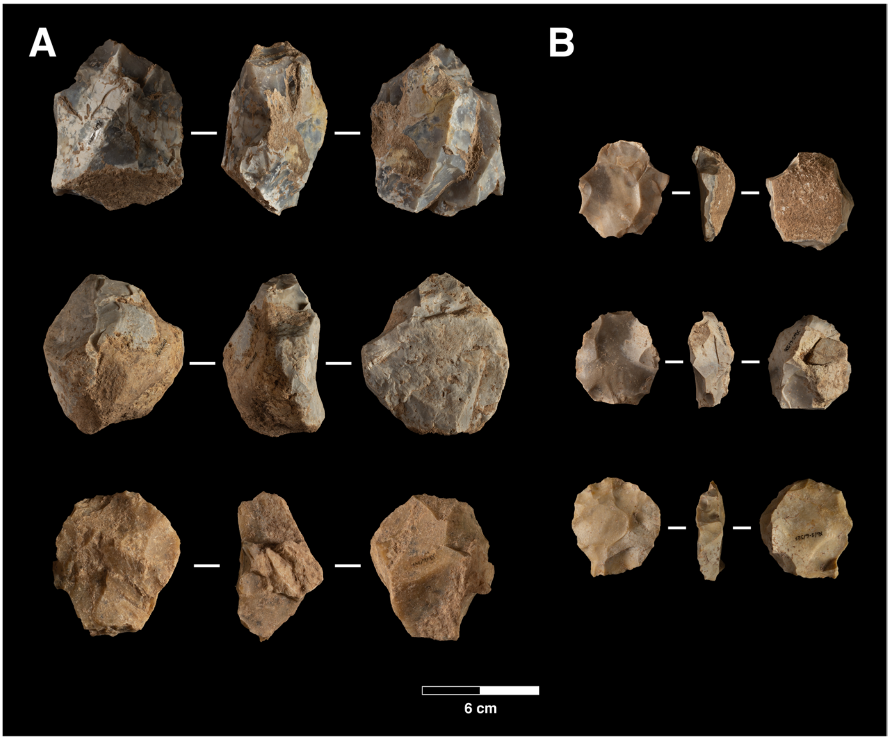

Fig. 13 Representation of the lithic assemblage contained in C2 from Xb2out. **A** Beniaia large cores and **B** Mariola exhausted cores. Photography: Maria Guillén (IPHES)

create a misleading picture of contemporaneous refuse disposal activity (Vaquero *et al*., 2012). A similar case is also reported in one cluster of the Abric Romaní level M, where large artefacts are found (Vaquero *et al*., 2015, 2019). This cluster is located in the outermost part of the rockshelter and contains several cores and large flakes. Five artefacts (three cores, one flake and one flake fragment) were refitted with reduction sequences carried out in the innermost part of the rockshelter, suggesting that they were moved to the outside and accumulated in the same area. However, none of them were modified or reduced after this transport. Finally, similar behaviours are also identified in Late Pleistocene contexts, with different spatial concentrations of cores and tested nodules in the gravettian level 497C of Cova Gran (Sánchez-Martínez *et al*., 2022).

Is the disposal of refuse related to differences in occupation duration, intensity or group size? According to Yellen (1977), the appearance of secondary refuse areas depends on occupation length. This is why they are not documented in !Kung short-term camps. The study of O'Connell (1987) focused on Alyawara groups that documented refuse disposal areas or middens on the periphery of households. The formation of these areas is highly dependent on occupation length or duration, increasing in items when more people and activities are involved (Stevenson, 1985). Furthermore, large products (*i.e.* > 5 cm) are more likely to be discarded, while small elements tend to persist in the activity areas. Binford (1978a, b) also identifies this kind of behaviour as "cleaning up/dumping" activities, referred to as "secondary refuse" by Schiffer (1972). This phenomenon is different from tossing activity, since dumps typically occur before or after hearth-related activity and far from it, whereas tossing happens during the combustion, generating a belt around hearths. Concerning time, length or investment, while this cleaning behaviour is clearly present in residential contexts (Galanidou, 2000), it is absent in hunting camps where people normally do not spend much time and/or engage in fewer activities. In the case of toss action, it is common in all contexts where a fire is placed.

While we could use ethnoarchaeological examples to interpret cluster C2 as a pristine picture of cleaning performance in the context of H50, the temporal resolution of the lithic record must be discussed, as emphasised by Vaquero *et al.* (2012). In our case, the absence of S-RMUs between the hearth perimeter and C2 hinders potential temporal associations. Furthermore, although postgenetic processes were not recorded, and only flint types were considered for this work, Beniaia and Mariola flint types are generally associated with different procurement contexts. In the context of El Salt, Mariola has been observed to be gathered more prevalently in the upper course of the Serpis River, whereas Beniaia frequently appears to have been collected predominantly from the middle course (Mayor *et al.*, 2022; Molina, 2015). Even if different gathering contexts may be visited in a single movement or various flint types may be procured at the same location, distinct types tend to reveal several moments. Moreover, although Beniaia and Mariola exhibit significant size-sorting, the presence of Serreta flint type in this cluster introduces additional spatiotemporal uncertainty. Although the mixed presence of flint types could theoretically result from a single refusal event of previously existing materials from different moments, diachrony must be assumed when studying the technological and provisioning-related features of these assemblages.

If we entertain this perspective, the alternative explanation for these materials is related to their diachronic introduction as SE-RMUs. In this sense, the preference for the large size has been interpreted as an advantage for mobility patterns, reducing costs and gaining exploitable mass (Morrow, 1996a). However, in the case of Beniaia, where cores show minimal technical intervention and originate from the most distant location, this behaviour appears to incur a high cost (Vaquero and Romagnoli, 2017), unless there is a different utilisation pattern. The use of cores as tools has been demonstrated in Neanderthal contexts (Navazo *et al.*, 2023), and there is evidence of frequently knapped raw materials being used as hammerstones (Pop *et al.*, 2018). In this regard, zooarchaeological and use-wear analyses are needed to assess the possible association of C2 with carcass processing or woodworking, allowing to test differences between this concentration and hearth-related assemblages (*e.g.* Rosell *et al.*, 2012; Speth *et al.*, 2012; Blasco *et al.*, 2016; Bencomo *et al.*, 2020).

After analysing the aforementioned information, we propose that, even though several events could occur during the formation of the H50-related assemblage and cluster C2, they represent an avenue for exploring behavioural variability. Are some of the events representing inter or intraoccupational diachrony? Why are these large material units not found in every Neanderthal site/analytical unit? Further zooarchaeological, taphonomic, technological and use-wear analyses can shed light on this problem. However, what can be asserted is that all these questions might have been ignored by the SU approach. C2 would have been mixed with more recent materials, diluting its composition.

Why Are You Single?

Beyond the H50-related assemblage and cluster C2, the AUs reveal another condition differing from high-resolution examples, such as the one observed at Abric del Pastor. They manifest a notable presence of SE-RMUs, not only within the defined AUs, but also extending to AUs within SU Xa (Machado & Pérez, 2016; Machado *et al*., 2017). This situation stands in contrast to other sites, including Abric del Pastor, Abric Romaní, Cova Gran or Oscurusciutto (Machado *et al*., 2019; Mora *et al*., 2020; Spagnolo *et al*., 2019; Vaquero *et al*., 2012). These examples exhibit more complete knapping sequences, longer connection distances between different areas (*i.e.* > 5 m) and, in some cases, bidirectional movements of elements (Vaquero *et al*., 2017, 2019). The distinctive scenario at El Salt may suggest a higher fragmentation of operational chains (Turq *et al*., 2013), indicative of discrete activity events with low development and the introduction of single products, resulting in a high number of existing "orphans" (Morrow, 1996b). This is evident not only in the scarcity of refits and the short distance of connections, but also in the few S-RMUs that link inner and outer areas. Similar to SU Xb, in Xa, only one S-RMU, composed of two pieces, was involved between both zones (Machado & Pérez, 2016). Furthermore, the use-wear data obtained from AUs in Xa (Bencomo *et al*., 2023) and level M at Abric Romaní (Martín-Viveros *et al*., 2020) indicate that even small-sized products are susceptible to use, reinforcing the possibility of a single introduction of these elements as part of toolkits (Romagnoli *et al*., 2018b).

The challenge of associating products in this assemblage, evident due to the abundance of singular elements and numerous recognised hearths, may be linked to a sequential pattern of many short events occurring over a minimum of 200–240 years, some of which may not be related to combustion activities. This episodic character of the record, within the context of a long-term formation process, leads us to propose that the hearth-related assemblage model represents just one of the ways in which Neanderthals occupied El Salt.

Conclusions

After analysing and discussing our data, it is time to reconsider whether palimpsest dissection still matters. Throughout this paper, we have consistently observed that time-averaged affected deposits pose a persistent challenge. Despite methodological application, the resolution achieved is insufficient to reach the human occupation episode, which is the unit of analysis to be pursued. However, this approach has revealed various aspects where variability can be observed. Regardless of the perceived relevance of these aspects, our aim was to illustrate that avoiding palimpsest dissection not only prevents the observation of certain facets of human behaviour but may also lead to wrong interpretations derived from mixing events. Studying an assemblage-as-a-whole not only fails to add but subtracts from and blurs our understanding of the site, the factors and the temporality that have combined to form the assemblage. Moreover, an approach focused on palimpsest dissection allows us to distinguish between the long-term structural constraints and those behaviours related to the specific circumstances of each formation stage. However, further long-term, regional-scale interpretations require more teams provide data from dissected assemblages.

With the obtained information, we have gained insights into the temporal and spatial variability of certain activities such as knapping or the introduction of different flint types within the defined units. However, categorising our units into specific types proves to be both inadequate and unnecessary. Statements like “this hunting/residential camp is conformed as a palimpsest” represent a serious mistake, since the interpretation is assimilated before the problem is considered. In contexts where an unknown number of events have occurred, some of which may have played completely different roles but left limited evidence, assigning a definitive site function and typological categorisation becoming unrealistic. Attempting to understand the long-term history without accounting for the shorter processes that shape it is like building the wall without the bricks. Regardless of their grain size, whether coarse or fine, each brick must be characterised and ordered for the establishment of a solid structure of Neanderthal history.

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Data Availability The authors have confirmed that the data supporting the results of this study are available within the Supplementary material file.

Declarations

Competing Interests The authors declare no competing interests.

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